LEARNING MATERIAL OF

WATER SUPPLY & WASTE WATER ENGINEERING

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SECTION – A : WATER SUPPLY ENGINEERING

CHAPTER-1

Introduction to Water Supply, Quantity and Quality of water

INTRODUCTION

The branch of civil engineering which deals with the supply of water for various purposes e.g. domestic, industrial, commercial & public is called **Water Supply Engineering.**

Necessity: Water is the most essential commodity for the continuation of life. An adequate & clean water supply is the basic requirement for domestic use for various purposes like:

(i) for drinking & cooking

(ii) for bathing & washing

(iii) for watering of lawns & gardens

(iv) for air-conditioning system

(v) for street washing etc.

Water is also required for various types of industrial & commercial purposes.

During planning a water supply scheme, it is the duty of the engineer to carefully examine the various types of water demand of the town & then to find out the suitable water sources from where the demand can be met. The various types of water demand of a city or town are:-

(i) Domestic Water Demand

(ii) Commercial & Industrial Demand

(iii) Demand for public uses

(iv) Fire Demand

Domestic Water Demand:-This demand includes the quantity of water required in the houses for drinking, cooking, bathing, washing, gardening, sanitary purposes etc. It mainly depends upon the living conditions of the consumer. As per IS: 1172-1963 water required for domestic purposes for average Indian condition per head per day may be taken as 135 litres. In developed countries this may be as high as 350 litres. The total domestic water consumption may amount to 50 to 60% of the total water consumption.

DETAILS OF WATER REQUIREMENTS FOR DOMESTIC PURPOSES

Sl.No.	Description	Consumption of water per head per day in litres
1	Drinking	5
2	Cooking	5
3	Bathing	55
4	Washing of clothes	20
5	Washing of utensils	10
6	Washing of houses	10
7	Flushing of Latrines etc.	30
	Total	135

Commercial & Industrial Water Demand: This includes offices, hotels, hospitals, schools, stores, Shopping centres etc. This demand depends upon the nature of the city, number and types of industries. On an average, 20 to 25% of the total water demand may be allowed for this type of demand in the design.

Demand for public uses: Public demand includes the quantity of water required for public utility purposes such as watering of public parks, gardening, sprinkling on roads, use in public fountains etc. In many water supply schemes these demands are not believed as essential and a nominal amount not exceeding 5% of the total demand is kept on arbitrary basis.

Fire Demand: It is the quantity of water required for fighting a fire outbreak. For high value cities, water requirement for this purpose is particularly essential. The quantity of water required for this purpose can be found out by applying certain empirical formula. These are:

(i) National Board of Fire Underwriters Formula:

$$Q = 4640P^{1/2}(1 - 0.01P^{1/2})$$

Where Q = Quantity of water required in litres per minute. P = Population of the town in thousands

(ii) Freeman formula:

$$Q = 1135.5\left\{\left(\frac{P}{10}\right) + 10\right\}$$

(iii) Kuichling's Formula :

$$Q = 3182P^{1/2}$$

Per capita Demand:- It is the annual average amount of daily water required by one person and includes the domestic, industrial , and public use.

If Q = total quantity of water required by a city per year in litres & P = Population of the city

Then Per Capita Demand in litre per day = $\frac{Q}{P \times 365}$

Variation in Demand:-

It has been seen that the demand does not remain uniform throughout the year, but it varies from season to season, even from hour to hour. So variation in rate of demand may be termed as :

(i) Seasonal variation.

(ii) Daily variation.

(iii) Hourly variation.

Seasonal Variation:- In Summer the water demand is maximum, because people will use more water in bathing , cooling, lawn watering, street sprinkling etc. This demand goes on reducing & in winter it becomes minimum, because less water will be used in bathing & there will be no lawn watering.

Daily Variation: The rate of demand may vary from day to day also. This is due to habits of the consumer, climatic conditions, holidays etc. On hot and dry day water requirements will be more as compared to a rainy day.

Hourly Variation: The rate of demand during 24 hours does not remain uniform & it varies according to hours of the day. On Sundays & other holidays the peak hours may be about 8 A.M due to last awakening whereas it may be 6 A.M. on the other working days. Certain industries may be working in day & night shifts & consuming more water.

Factors affecting Per Capita Demand: The various factors which affect the per capita demand are

1. Climatic condition: Water requirements during summer are more than winter. During summer more water is used for bathing, drinking & also more water is consumed in running coolers etc. Hence water consumption is much more in summer than that in winter.

2. Size of city: Generally the demand of water per head will be more in big cities than that in small cities. In big cities lot of water is required for maintaining clean & healthy environments while in small towns it is not required.

3. Habits of people: High class community uses more water due to their better standard of living & higher economic status. Middle class people use water at average rate and for poor people ,a single water tap may be sufficient for several families.

4. Industries: More water will be required in highly industrialised city.

5. Cost of water: More costly is the water less will be rate of demand. Hence the cost at which water is supplied to the consumer may also affect the rate of demand.

6. Quality of water: A water works system having a protected & good quality of water supply would always be more popular with consumers. Hence more quantity of water will be consumed if the quality is good.

7. Pressure in the distribution system: These would be of great importance in the case of localities having a number of two or three storied buildings. Adequate pressure would mean an uninterrupted and constant supply of water.

8. **System of supply:** The system of supply may be continuous or intermittent. In continuous system water is supplied all the 24 hours while in case of intermittent system, water is supplied for certain fixed hours of the day only, result in some reduction in the consumption. This may be due to decrease in losses & other wasteful use.

Methods of forecasting population:- The following are the methods used for forecasting population :

(i) Arithmetical Increase Method :- In this method, the increase in population is assumed to be constant and an average increase of the last 4 to 5 decades is calculated and added in the present population to determine population of the next future decade. The population can be found out at the end of “n” year or “n” decades.

$$Pn = P + n * i$$

(where P = Present population , i = Yearly or per decade increase in population)

(ii) Geometrical Increase Method:- In this method the average %age of growth of last few decades is determined. The population forecasting is done on the basis that % age increase per decade will be the same. Thus population at the end of “n” years or decades is given by**:**

$$Pn = P\,(1 + (i/100))^{n}$$

Where i = % age rate of increase per decade

(iii) Incremental Increase Method: This method is improvement over the above two methods . The average increase in the population is determined by the arithmetical method and to this is added the average of the net incremental increase once for each future decade.

Thus population at the end of “n” years or decades is given by:

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

Where I_a = Average Arithmetical Increase &

I_c = Average incremental Increase

(iv) Decreasing Rate Method: In this method the average decrease in the %age increase is worked out and is then subtracted from the latest %age increase for each successive decade.

Problem: The following data have been noted from the census department.

Year	Population
1940	8,000
1950	12,000
1960	17,000
1970	22,500

Calculate the probable population in the year 1980, 1990 & 2000.

By using Arithmetical Increase method:

Answer by using Geometrical Increase Method:

Year	Population	Increase in population	Percentage increase in population
1940	8,000	---------	-----------
1950	12,000	4000	(4000/8000) *100 = 50.0%
1960	17,000	5000	(5000/12000)*100 = 41.7%
1970	22,500	5500	(5500/17000) *100 = 32.4%
	Total	14,500	124.1
	Average per decade	4,833	41.37

The population at the end of various decade will be as follows :

Year	Expected population
1980	22,500 + (41.37 / 100) × 22,500= 31,808
1990	31,808 + (41.37 / 100) × 31,808= 44,967
2000	44,967 + (41.37 / 100) ×44,967= 63,570

Impurities in water : For the purpose of classification the impurities present in water may be divided in to the following three categories.

1. Physical impurities
2. Chemical impurities
3. Bacteriological impurities

1. Physical impurities:

(i) Colour: The water bodies may be receiving colour from natural and artificial sources. The discharge from many industries may be coloured and such discharge in to natural water bodies imparts colour to the water of such water bodies.

It may be noted that pollution of water due to colour is mainly an aesthetic one and in many cases, it does not de4velop any thread to the public health. The measurement of colour in water is carried out by means of a fintometer. For public water supply the number on cobalt scale should not exceed 20 and should be preferably less than 10.

(ii) Taste and odour: The eater possesses taste and odours due to various causes and they make the water unpleasant for drinking. The industrial wastes contain many strong smelling chemical compounds and when such trade wastes are discharged in to rivers or streams, the water of such rivers or streams gets unpleasant taste and odours. The taste and odour in water in general have no real public health significance. But the pollution of water by taste and odour has the following effects.

- Such waters may prove detrimental to fish life and may damage the value of fisheries.
- Such waters are not liked by public and they are rejected even in preference to tasteless and odourless waters of poor quality.
- if taste and odour in water are due to certain toxic chemical gases, the use of such water may seriously injure the public health.

The test is carried out by in having through tests of an osmoscope. The taste and odour of water may also be tasted by Thresholds number. For public water supply the threshold number should not be more that.

(iii) Temperature: If the temperature of trade wastes which are discharged in to rivers or streams is high, their bodies. For instance, the cooling water from thermal and nuclear power statuses is considerably warm and if such warm water is discharged in to natural water bodies, it will result in the rise of temperature of water of such natural bodies.

The test for temperature of water has no practical meaning in the sense that it is not possible to give any treatment to control the temperature in any water supply project. The temperature of water to be supplied from storage reservoir depends on the depth from which it is drawn. The desirable temperature of potable water is 10°c while temperature of 25°c is considered to be objectionable. The measurement of temperature of water is done with the help of ordinary the temperature. From the study of temperature the characteristics of water such as density, viscosity vapour pressure and surface tension can be determined. It also helps in determining the saturation values of solids and gases which can be dissolved in water and also the rates of chemical, biochemical and biological activity.

(iv) Turbidity: The colloidal matter present in water interferes with passage of light and thus imparts turbidity to the water. The turbidity in water may also be due to clay and silt practices, discharges of sewage or industrial wastes, presence of large numbers of nitro organisms etc. And the cloudy appearance developed in water due to turbidity is aesthetically unattractive and it may also be harmful to the consumers. Turbidity disturbs the disinfection process because the solids may practically shield the organics from the disinfectant.

The turbidity is expressed in terms of parts of suspended matter per million parts of water or shortly written as P.P.M. It is to be noted that the expression p.p.m is also equivalent to mg per liter or mg/ltr. The standard units of turbidity are the turbidity produced by one part of filters earth which is in the form of finely divided silica in a million parts of distilled water. The permissible turbidity for drinking water is 5 to 10 p.p.m.

The measurement of turbidity in the field is done by means of turbidity rod and it is referred to as the visual method of turbidity measurement for lab, turbidity meters are used for to measure the turbidity of water. The data obtained from turbidity measurements are helpful in the following ways.

- It assists in deciding whether turbidity interferes with the photosynthesis reaction in streams and lakes.
- It gives indicator of the quantity of chemicals required for day to day operators of water treatment works. The excess turbidity may seriously affect the functioning of slow sand filters.

Chemical impurities and chemical tests:

(i) **Chlorides:** The chloride contains especially of sodium chloride or salt, are workout for a sample of water. The excess presence of sodium chloride in natural water indicate pollution of water due to sewage, minerals, edible oil, mill separators, ice-cream plant effluents, chemical industries, sea water intrusion in coastal regions etc. For portable water, the highest desirable level of chloride content is 25mg/ltr. And its maximum permissible limit is 600mg/ltr.

The presence of chlorides can corrode and such water cannot be used for boilers because of formation HCl due to presence of magnesium chloride in water.

(ii) **Dissolved gasses:** The water contains various gasses from its contact with the atmosphere and ground surfaces. The usual gasses are nitrogen, methyl hydrogen sulphide, CO_2 and oxygen. The contents of these dissolved gasses in a sample of water are suitably worked out.

The Nitrogen is not very important the methane concentration is to be studied for its explosive property. The hydrogen sulphide gives disagreeable odour to the water even if its amount is very small. The carbon dioxide content indicates biological activities causes corrosion, increases the solubility of many minerals in water and gives taste to the water.

The oxygen in the dissolved state is obtained from atmosphere and pure natural surface water is usually saturated with it. The simple test to determine the amount of dissolved oxygen present in a sample of water is to expose water for 4 hours at a temperature of 27°C with 10% acid solution of potassium permanganate.

The quantity of oxygen observed can then be calculated. This amount for portable water should be about 5 to 10 p.p.m.

(iii) **Hardness:** The term hardness is defined as the ability of the water to cause precipitation of insoluble calcium and magnesium salts Of higher fatty acids from soap.

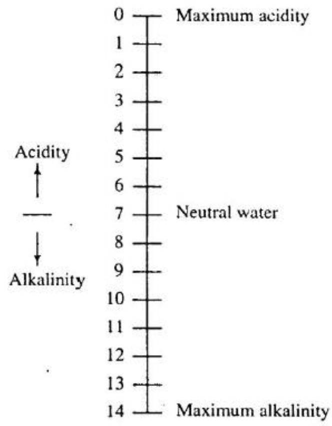
The hardness or soap destroying power of water is of two types - Temporary hardness and permanent hardness. The temporary hardness is also known as the carbonate hardness and it is mainly due to the pressure of bicarbonate of calcium and magnesium. It can be removed of boiling or by adding line to the water. The permanent hardness is also known as the non-carbonate hardness and it is due to the presence of sulphates, chlorides and nitrates of calcium and magnesium.

It cannot be removed by simply boiling the water. It requires special treatment of water softening. The excess hardness of water is undesirable because of various reasons such as it causes more consumption of soap, affects the working of dyeing system, provides scales on boilers, causes corrosion and inner station of pipes, makes food tasteless etc. The hardness is expressed as per

Clark's scale in terms of degree of hardness. Thus one grain of $CaCO3$ dissolved in one gallons of water will produce one degree of hardness. The expression p.p.m. is used to mean mg per liter and in that case, one degree of hardness will be equal to 14.5 p.p.m. It is found that each degree of hardness causes wastage of about 0.60 gram of soap. The water having hardness of about 5 degrees is reasonably soft water and a very soft water is tasteless. Hence for portable water, the hardness should preferably be more than 5 degrees and less than 8 degrees or so.

(iv) Hydrogen-ion concentration(pH value) :

The acidity or alkalinity of water is measured in terms of its pH value or H-ion concentration. The pure water ($H2O$) consists of positively charged hydrogen or H-ions combined with negatively charged hydroxyl or OH-ions. But the process of dissociation takes place in pure water and hence it contains some uncombined positively charged H-ions and some uncombined negatively charged OH-ions. The water becomes acidic when positively charged H-ions are in excess then negatively charged OH-ions and it becomes alkaline when reverse is the case.



pH-scale

Neutral water has pH value of 7. As pH value becomes less, the water becomes acidic and when pH value is zero it indicates maximum acidity similarly the water becomes alkaline as pH values at increase and maximum alkalinity is indicated when pH value is equal to 14.

- It is desirable to maintain pH value of water very close to 7. The acidic water causes tuberculation and the alkaline water causes incrustation.
- For portable water, the pH value should be between 6.5 and 8.5.

(v) Alkalinity:-The term alkalinity with reference to the water and waste water is defined as the capacity of substance contained in the water to take up hydronium (H_3O^+)to reach a defined pH value 4.3 to 14.

- The alkalinity is due to the presence of bicarbonate (HCO^3-), carbonate (CO_3^{--}) or hydroxide (OH^-).
- The alkalinity is usually divided into the following two parts.
- Total alkalinity i.e., above pH 4.5
- Caustic alkalinity i.e. above pH 8.2

The alkalinity is measured by the volumetric analysis. The various types of indicators are available for this purpose the commonly adopted two indicators are as follows.

- Phenolphthalein pink above pH 8.2 and colorless below pH 8.2.
- Methyl orange: Red below pH 4.5 and yellow orange above pH 4.5
- The excess alkalinity is harmful for irrigation which leads to the soil damage and reduce crop yields.
- The highly alkaline water is usually unpalatable.
- The large amount of alkalinity imparts a bitter taste to the water.
- The water having alkalinity less than 250 mg/ltr is desirable for domestic consumption and for R.C.C construction.

(vi) **Acidity:** The term acidity with reference to the water and waste water is defined as the capacity of substance contained in water to take up Hydroxyl ions ($OH-$) to reach a defined pH value (0 to 8.2).

The acidity are of the following two types.

- **Carbon dioxide acidity:** This acidity is due to the presence of CO_2 in ground water and surface water.
- **Mineral acidity:** The mineral acidity is due to the presence of HCl, H_2SO_4, HNO_3 and strong organic acids.
- Total acidity (as $CaCO_3$) = Mineral acidity + CO_2 acidity.
- The determination of acidity of water has got significance because of the following reasons.
- It affects the aquatic life.
- It affects the biological treatment of sewage.
- It corrodes pipes.
- The water having acidity more than 50mg/ ltr. Cannot be used for R.C.C construction.

(vii) **Metal and other chemical substances:** Various tests are made to detect the presence of different metals and other chemical substance in a sample of water.

Name of metal	Maximum permissible concentration in mg/ ltr
Arsenic (As)	0.05
Copper (Cu)	1.00
Fluoride(F)	1.70
Iron (Fe)	0.30
Zinc(Zn)	5.00

(viii) Nitrogen and its compounds: The nitrogen is present in water in the following four forms

- Free ammonia
- Albuminoid ammonia
- Nitrites
- Nitrates

→ The amount of free ammonia in portable water should not be exceeded 0.15 p.p.m. and that of albuminoid ammonia should not exceed 0.3 p.p.m.

→ The term albuminoid ammonia is used to represent the quantity of nitrogen present in water before the decomposition of organic matter has started.

→ The presence of nitrides indicates that the organic matter present in water is not fully oxidized or in other words, it indicates an intermediate oxidation stage. The amount of nitrites in portable water should be nil.

→ The presence of nitrated indicates that the organic matter present in water is fully oxidized and the water is no longer harmful. For portable water, the highest desirable level of nitrates is 45mg/ltr.

(ix) Total solids: The term solids with reference to the environmental engineering is defined as the residue in water left after evaporation and drying in oven at 703°c. The total solids consist of dissolved and suspended matter.

1. **Dissolved solids:-** In natural water the dissolved solids mainly consists of inorganic salts like carbonates, bicarbonates, chlorides, sulphates, etc. together with small amounts of organic matter and dissolved gases.
   - For measuring the total dissolved solids, the sample of water is placed in a clean porcelain dish and it is ignited in muffle furnace. After partial cooling in the air, it is cooled in a dedicator and is weighed.

     Then, total dissolved solids in mg/ltr = $\frac{A-B}{V}$ x 1000

     Where A= Final weights of the dish

     1. B= Initial in mg weight of the dish in mg.

     V= volume of sample in ml.

Many dissolved substances are undesirable in water and they impart displeasing color, taste and odour.

- The water with higher content of the dissolved solids has laxative or sometimes reverse effect or the human body and it takes time for poodle to adjust with such water.

- In a similar way the high concentration of dissolved solids say 3000 P.P.M may also produce distance in livestock and many lead to sealing boilers corrosion, etc.
- The estimation of total dissolved solids is useful in determining the suitability of water for drinking purpose as well as for agriculture and industrial processes.
- The permissible total dissolved solids for drinking water according to BIS is 500 mg/ltr with tolerable limit as 1500 mg/ltr.

2. **Suspended solids: -** In surface water the suspended solids consists of inorganic matter like silt and organic matter like algae. These materials are generally carried by erosive action of the following water over land.
    - For measuring suspended solids the water is filtered through a fine filter and dry material retained on the filter is weight. The drying is carried out for the hour in an oven at 105°C.
    - Then total suspended solids in mg/ltr = $\left(\frac{W_2 - W_1}{V}\right)$ x 1000

    Where W_1 = Initial weight in mg.

    W_2 = Weight of dry material retained on filter in mg.

    V = Volume of sample in ml.

The suspended matter is objectionable in water for following reasons

i. It is aesthetically displeasing
ii. It may include disease causing organisms.
iii. It may release obnoxious odours.
iv. It provides absorption sites for chemical and biological aquents.
v. The estimation of total suspended solids in extremely useful in the analysis of polluted water and for evaluating the efficiency of treatment units.

BACTERIOLOGICAL TESTS: -

- The examination of water for the presence of bacteria is very important. The bacteria are very small organism and it is not possible to detect them by microscope. Hence they are detected by circumstantial evidence or chemical reactions.
- The bacteria may be harmless to mankind or harmful to mankind. The former category is known as the non-pathogenic bacteria and the latter category is known as pathogenic bacteria.
- The combined group of pathogenic and non-pathogenic bacteria is designated by bacillus coli (bacillus- bacterium coli = intestine) or B-coli group. This group of bacteria is present in intestines of living warm-blooded animals.

Following are the two standard bacteriological tests for the bacteriological examination of water:

1. Total count or agar plate count test.
2. B-coli test.

1. **Total count or agar plate count test:** In this test, the bacteria are cultivated on specially prepared medium of agar for different dilution of sample of water with sterilized water. *The diluted sample is placed in an incubator for 24 hours at 37˚ c (i.e. blood heat) or 48hours at 20˚c.These represent the so called hot count and clod counts respectively .The bacterial colonies which are formed, are then counted and the4 results are computed for i.e. For potable water, the total count should not exceed 100 per c.c.
2. **B-coil test:** This test is divided into the following three parts:
   (i) Presumptive test.
   (ii) Confirmed test.
   (iii) Completed test

(i) Presumptive test: Following procedure is adopted in this test:

(a) The definite amount of diluted sample of waters are taken in multiples often, such as 0.1c.c, 1.0 c.c., 10 c.c. etc.

(b) The water placed in standard fermentation tubes containing lactose broth. The tube is maintained at a temperature of 37˚c for a period of 48hr.

(c) If gas is seen in the tube after this period is over, it indicates presence of B - coil group and the result of the test is treated as +ve. If reverses is the case, it indicate absence of B - coil group and the result of the test is treated as negative.

(d) A negative result of presumptive test indicates that water is fit for drinking.

(ii) Confirmed test: This test is carried out in the following ways:

(a) A small portion of lactose both showing positive presumptive test is carefully transferred to another formation tube containing brilliant green Lactose bile ,if gas is seen in the completed test become essential.

(b) A small portion of material showing positive presumptive test is make on the plates containing Endo or eosin-methylene- blue agar. the plates are kept at 37˚C for 24 hrs. if colonies of bacteria are seen after this period ,it indicates positive result and the competitive test becomes essential. The colonies are prominent by metalize brightness and dark spots.

(iii) Completed test: This test is made by into dicing or inculcating bacteria colonies into lactose broth fermentation tube s and agar tubes. The incubation is carried out at 37˚c for 24 to 48 hours .if gas is seen after this period, it indicates positive result and further detailed test are carried out to detect the particular type of bacteria present in water. The abusers of gas indicates negative result and the water is considered sate for drinking.

Standards of Water Quality:

The following are the standards of water to be used for domestic purposes:

Physical

Temperature	-	10℃ to 15.6℃
Odour	-	0 to 4 p.p.m
Colour	-	10 to 20 p.p.m
Turbidity		5 to 10 p.p.m
Taste	-	No objectionable Taste

Chemical

Total Solids	-	upto 500 p.p.m
Hardness	-	75 p.p.m to 115 p.p.m
Chlorides	-	upto 250 p.p.m
Iron & Manganese	-	upto 0.3 p.p.m
pH value	-	6.5 to 8
Lead	-	0.1 p.p.m
Sulphate	-	upto 250 p.p.m
Arsenic	-	0.05 p.p.m
Carbonate alkalinity	-	upto 120 p.p.m
Dissolve oxygen	-	5 to 6 p.p.m
B.O.D	-	Nil

Biological

B- Coli	-	No B-coli in 100 ml

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CHAPTER – 2

Sources and Conveyance of water

Surface sources: The sources of water in which the water flows over the earth surface are called surface sources. The surface sources are mainly classified as: River, Stream & Lakes, Impounding reservoir.

Rivers, Stream & Lakes: They are formed by rainfall runoff i.e. rain water flowing along the ground into these natural drainage depressions. Quantity varies depending on the catchment.

Rivers: Rivers are born in the hills, when the discharge of large number of springs and streams combine together. Rivers are the only surface sources of water which have maximum quantity of water which can be easily taken. Streams. In mountainous regions streams are formed by the run off. The discharge in streams is much in rainy season than other seasons. The quality of water in streams is normally good except the water of first run-off.

Lakes: In mountains at some places natural basins are formed with impervious beds. Water from springs & streams generally flows towards these basins and Lakes are formed. The quantity of water in the lakes depends on its basin capacity, catchment area, annual rainfall & porosity of the ground etc.

Impounded Reservoirs: It may be defined as an artificial lake created by the construction of a dam across a valley containing a water course. The object is to store a portion of the stream flow so that it may be used for water supply.

The reservoir consists of three parts:

(i) A dam to hold back water

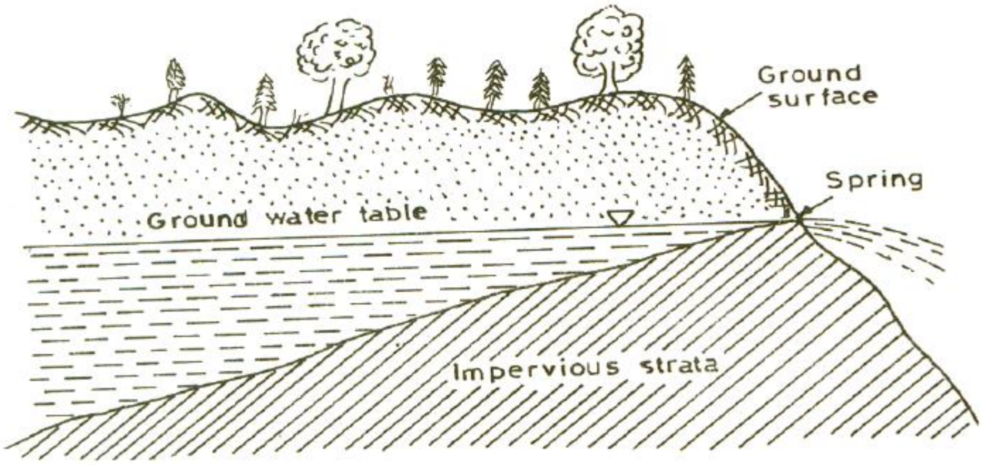
(ii) A spillway through which excess stream flow may discharge

(iii) A gate chamber containing the necessary valves for regulating the flow of water from the reservoir.

Underground Sources: These are the sources of water which supply water from below the earth surface. They include Springs, wells & galleries.

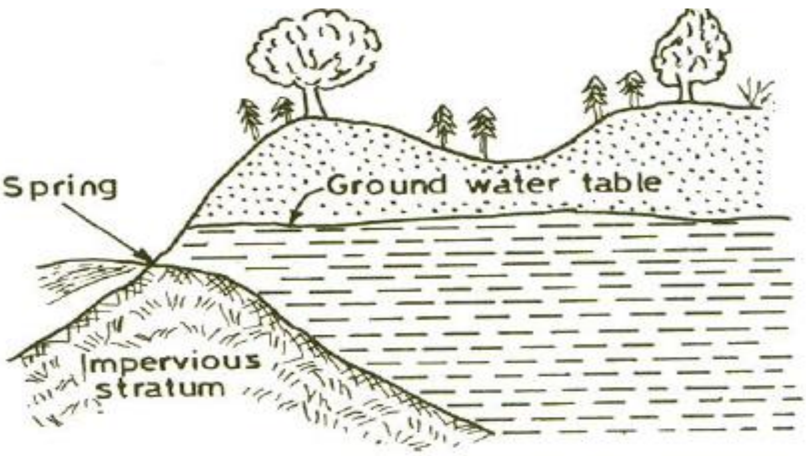
Springs: Ground water reappears at the ground in the form of springs. Springs are brought about under the following conditions:

1. When the surface of earth drops sharply below the normal ground water table, the water bearing stratum is exposed to the atmosphere and the springs are created. The formation of such springs results from an overflow of the ground water table. This type of spring is also called as **Gravity** or **Shallow springs** and the water table in such springs varies with the rainfall.



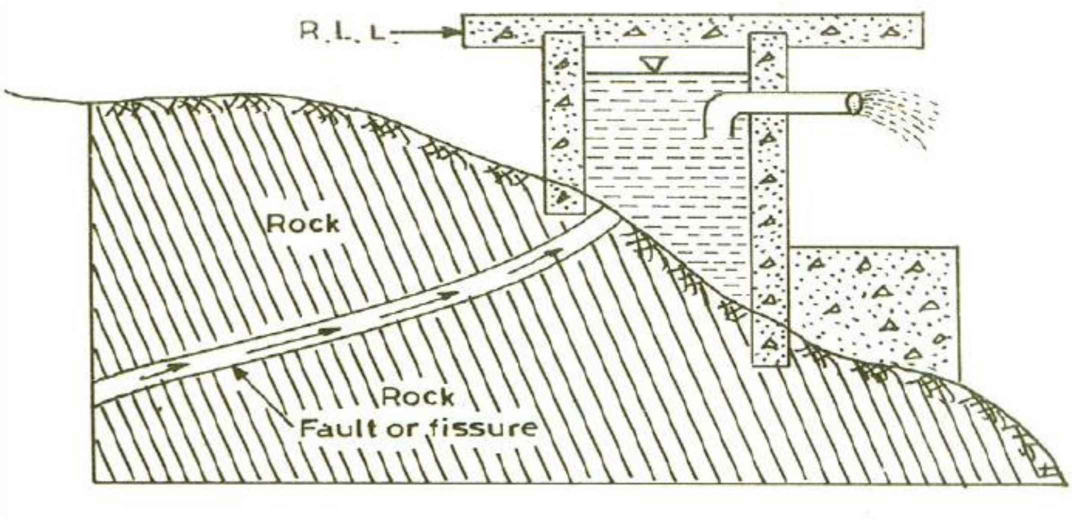
(Shallow Spring)

2. When due to an obstruction ground water is stored in the form of a reservoir, & this water is forced to overflow at the surface. Springs of this type are the most common. These are formed when an impervious stratum, which is supporting the ground water reservoir becomes outcrops.



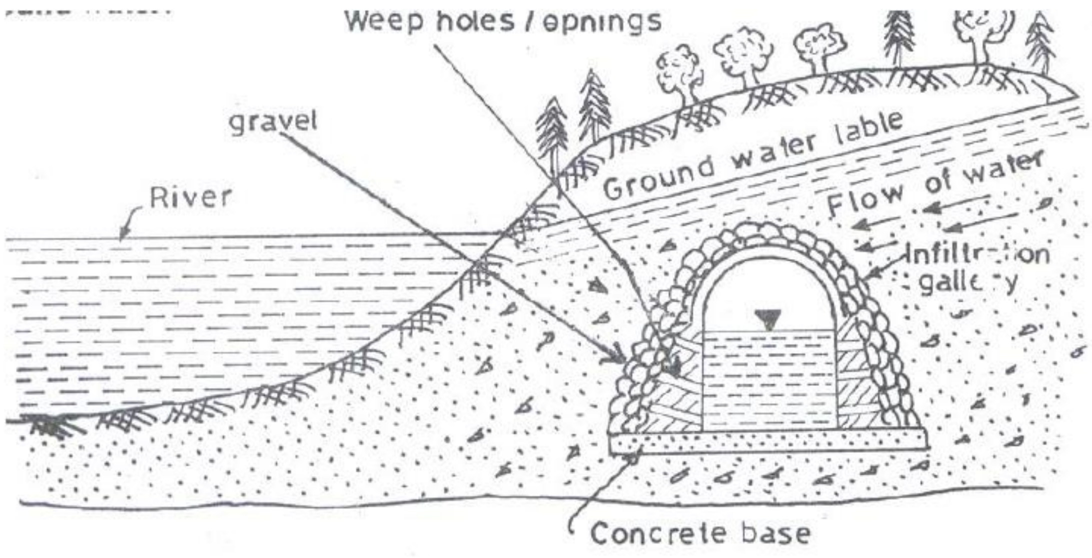
(Springs)

3. When the fissure in an impervious stratum allows artesian water to flow in the form of springs. Such types of springs come across when the ground water rises through a fissure in the upper impervious stratum. These are also known as **Artesian Springs.** The amount of water available is large & the rate of flow of water is constant because water comes out by a constant pressure.



(Formation of spring due to a fault in a rock)

4. **Infiltration Galleries:** A gallery is a horizontal or approximately horizontal tunnel constructed through water bearing material in a direction approximately normal to the direction of flow of the underground water. As we know that sub-surface water always tries to travel towards lakes, rivers or streams. This travelling water can be intercepted by digging a trench or by constructing a tunnel with holes on sides at right angle to the direction of flow of underground water. These underground tunnels used for tapping underground water near lakes, rivers etc are called Infiltration Galleries.

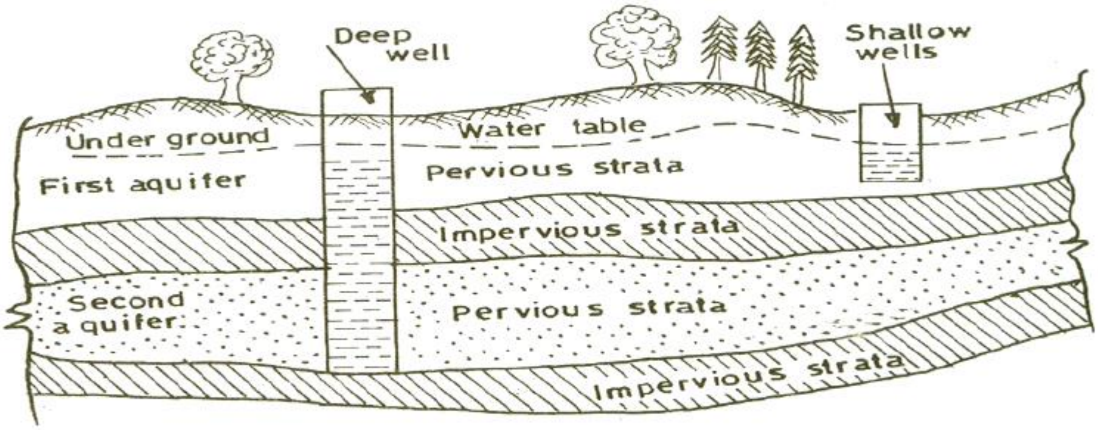


(Infiltration Gallery)

5. **Infiltration Well:** An infiltration gallery may be a line of wells closely spaced & placed across a normal to the direction of underground flow in an aquifer. These are commonly placed close to the

bank of a river or a lake to intercept the underground flow towards the body of surface water. Wells so placed are called Infiltration Wells. It may be more economical to draw potable water from beneath a river by such means than to purify the surface water taken directly from the river.

6. **Well:** The vertical hole dug into the ground to get sub- surface water is called a well. Wells are generally classified as: Shallow well & Deep Well.
    - A shallow well is that well in which the water is obtained from the upper most water bearing stratum without encountering any impervious stratum. The yield of the shallow well is uncertain due to large variation in the ground water level throughout the year.
    - A deep well is that well in which the water is obtained from the underneath of an impervious layer. The yield of a deep well is greater & constant as there is no quick fluctuation of the water level.



(Shallow & deep well)

Types of Well:-

According to condition of flow , wells may be classified as : Gravity wells & Pressure wells.

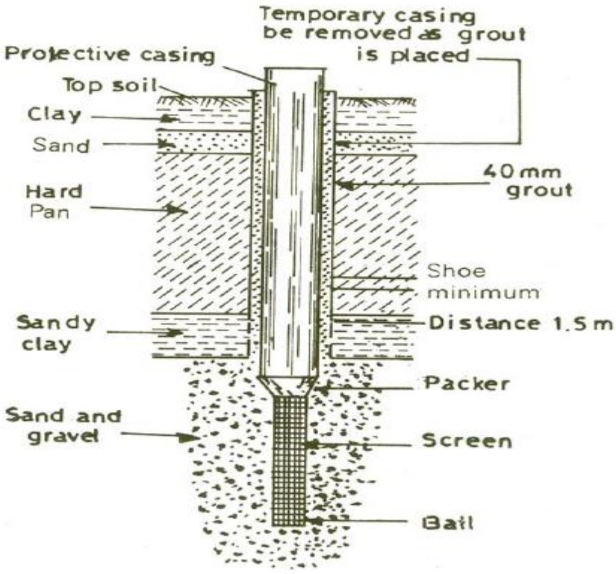
When the surface of the water in the water bearing stratum surrounding the well is at atmospheric pressure, the well is called **gravity well**.

When the aquifer is confined between two impervious layers, one above & other below, & the water in this aquifer is at a pressure greater than atmospheric, the well is called **pressure well**.

According to the type of construction, wells may be classified as**:** Dug Wells, Bored Wells or Tube Wells & Driven Wells.

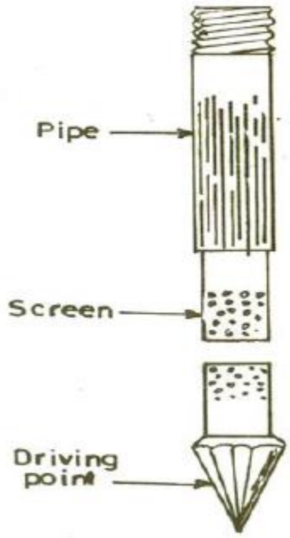
1. **Dug Wells :** Small dug wells are generally excavated by hand. In loose soils, they are lined with brick, rubble or concrete. In rock, they are commonly left unlined. This lining is termed as **"Curb"**. In the case of a well used for domestic purposes, the upper portion of the curb is made impervious for a depth of 1.80m to 2.40m .Dug wells should be completed when the water table is at its lowest level.
2. **Bored Wells or Tube Wells:** This type of well can be bored by using hand or power augers into cohesive soils. Above the water table, the excavated soil is collected in the auger, which is raised

time to time to remove the collected soil . When the boring is done below the water table, sand may wash out of the auger and have to be removed from the bore hole by hand auger. The holes varying from 5 to 75 cm in diameter & 9 to 12m depth can be bored by hand auger , whereas power augers will drill holes of diameters ranging from 20 to 75 cm and depth 7.5 to 90m.



(Bored or Tube well)

Driven Wells (Percussion Wells): For domestic use, percussion type or driven wells develop smaller water supplies. The reason for this is that driven wells are shallow and of smaller diameter. This is because of the difficulty in driving a large pipe to greater depths. All such wells will be located round a collecting well with a suction pump at a distance not exceeding 9m. Driven wells are adopted to soft, granular formation. Percussion well consists of a drive point & a pipe as shown in Fig. 3.7. A piece of pipe pointed at one end & perforated for remaining length is driven into a water-bearing formation by a wooden hammer or hydraulic ram. The diameter of the casing varies from 2.5 cm to 15cm. The whole pipe should be driven perfectly vertical as far as possible.



(Percussion Well)

Yield from Well: Yield has been defined as the amount of water flowing into the well per unit time. It is expressed in litres per second or sometimes in cubic meter per day.

Methods of determination of Yield of the well:-

If D = the vertical distance from the water table to the bottom of the well.

d = the depth of water in the well

R = the radius of the circle of influence

r = the radius of the well

p = porosity ratio

k = constant, then

Yield of the well Q = Km (D^2 – d^2)/ log10 (R/r) litre per minute.

Where Transmissibility constant Km = 3.143pk × $\frac{1000}{(24 \times 60 \times 2.303)}$

Measurement of an open yield:- The yield can be determined by the following two methods:

(i) Actual Pumping Method

(ii) Theoretical Method

Actual Pumping Method: The specific yield of a well can be determined by the following formula **–**

$$\frac{C}{A} = (2.303/ T) \log10 \left(\frac{S_1}{S_2}\right)$$

Where $\frac{C}{A}$ = Specific yield.

S_1 = Depression head in the well at the time immediately after the pumping was stopped

S_2 = Depression head in the well at time "t" after the pumping was stopped.

T = Time after pumping when measurement S_2 was taken. Knowing the value of $\frac{C}{A}$, the discharge "Q" of the well can be determined by :

$$Q = \frac{C}{A} \times A \times S$$

Where A = Cross sectional area of the well

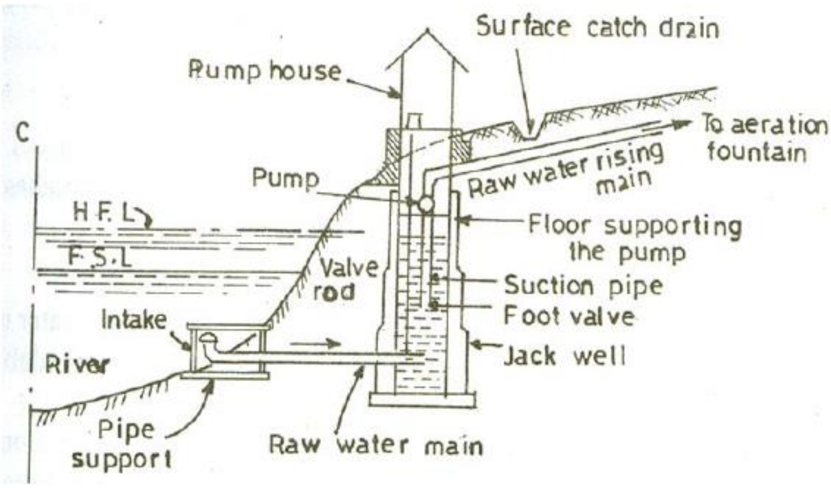
Theoretical Method: The approximate quantity of water entering or percolating in the wall can be calculated as:

Q = A × V × B

Where A = cross sectional area of the well opening

V = Velocity of water percolating in the well & B = Permeability constant.

Intake: A device placed in a surface water source to draw water from this source & then discharge into a conduit through which it will flow into the water work system , is called intake. It consists of a conduit with protective work, screen at both ends, gates and valves to regulate the flow as shown in fig.

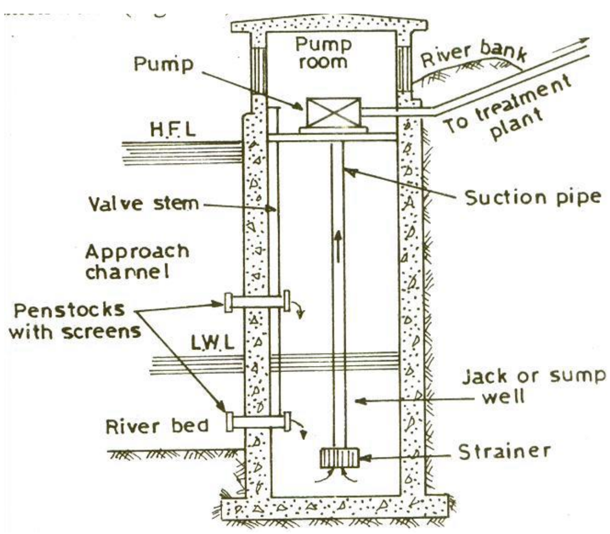


Types of Intakes:- Intakes are used to collect water for water works from various sources. The sources may be rivers, reservoirs, canals. Common type of intakes are:

(i) River Intake

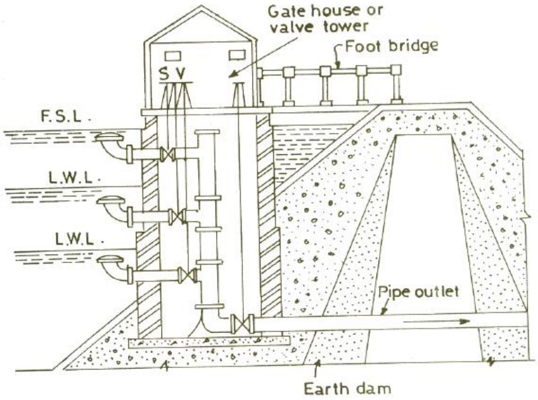
(ii) Reservoir Intakes

River Intake: It is a circular masonry tower constructed along the bank of river at such place from where required quantity of water can be obtained in the dry period. The water enters in the lower portion of the intake is known as the sump well from penstock. The penstocks are fitted with screens to check the entry of solid and are placed on the downstream side. The opening & closing of penstock valves is done with the help of wheels provided at the pump house floor.



(River Intake)

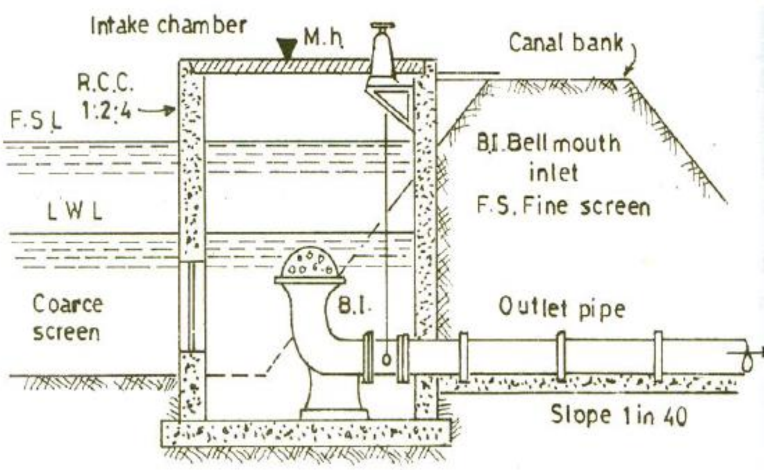
Reservoir Intakes: These consists of intake towers having no water inside other than in the intake pipes. The interior of the tower is thus made available for inspection & operation. Fig. shows a reservoir intake which is usually located either along the upstream of an earthen dam or within the body of a masonry dam. There are number of inlets protected by screen at different levels to draw in clear water from near the sources.



(Reservoir Intake)

When the discharge of some river in summer remains sufficient to meet up the demand, but some rivers dry up partly or fully & can't meet the hot weather demand. In such cases reservoirs are constructed by constructing weirs or dams across the river.

Canal Intake: Canal Intake is a very simple structure constructed on the bank of a canal & consists of a RCC or brick masonry chamber built partially in the canal bank. It has a side opening fitted with course screen which excludes heavier matter from entering the conduit. The end of pipe inside chamber is provided with a bell mouth fitted with a hemispherical fine screen. The outlet pipe carries the water to the other side of the canal bank from where it is taken to the treatment plant.



(Canal Intake)

PIPES: These are circular conduits in which water flows under pressure. Now a days the following types of pipes are available:-

(i) Cast Iron Pipe

(ii) Steel Pipe & Wrought Iron Pipe

(iii) RCC Pipe

(iv) Asbestos Cement Pipe

(v) Polyvinyl Chloride Pipes

Cast Iron Pipes: These are most commonly used in water supply scheme due to their durability, strength, resistance to corrosion, easy of laying etc. But the disadvantages of this type of pipes are:-

(i) Due to its heavy weight, large diameter pipes are difficult to transport in hilly & difficult terrain.

(ii) Coating inside and outside of the pipe is required for carrying corrosive water.

Steel & Wrought Iron Pipes: These pipes are stronger than cast iron pipes. They are however less durable having life up to 50 years, more liable to corrosion. To increase the life of wrought iron pipes sometimes these are galvanized with zinc. These pipes can withstand much higher pressure but are of lighter section & hence easy to transport to site.

Advantages of Steel Pipes:

i. Steel Pipes are cheap.
ii. These pipes are more durable.
iii. These pipes are light in weight, hence easy to transport.
iv. These pipes are available in large lengths which decreases the number of joints.
v. Steel pipes can resist high internal pressure.

Disadvantages:-

i. Steel pipes are likely to be rusted which reduces their life.
ii. These pipes require more time for repair.
iii. The maintenance cost is more.

Reinforced Cement Concrete Pipes: These are very durable , heavier & can be used up to 1.8m diameter. Transportation costs are much reduced if the pipes are cast- in –situ. These pipes are resistant to corrosion & specially suitable for soft & acidic water. The concrete mix normally used is 1:2:2.

Advantages:

i. These pipes have low maintenance cost.
ii. The pipes are not corroded from inside by normal drinkable water.
iii. These are very durable**.**

Disadvantages:

i. These pipes are difficult to repair & join.
ii. The pipes have tendency to leak due to shrinkage cracks & porosity.
iii. The pipes are difficult to transport.

Asbestos Cement Pipe: These are manufactured from a mixture of port land cement & asbestos fibre combined under pressure into a dense homogeneous structure. These pipes are very light in weight, can be easily cut, joined & handled. They resist corrosion & are very smooth. Use of these pipes are restricted to minor works of distribution system, because of poor structural resistance to bending stresses caused during transportation.

Advantages:

i. The pipes are very light in weight.

ii. The pipes are smooth & their carrying capacities do not reduce with time.

iii. The pipes are very suitable as small distribution pipes.

iv. The pipes are flexible as such the joints are easily formed.

Disadvantages:

i. The pipes are costly & less durable.

ii. The pipes are soft & brittle & do not have much strength.

iii. The pipes are likely to be damaged during transportation.

PVC Pipes :- These pipes are widely used for cold water services, rain water system etc. These are strong & can withstand much high pressure for a given wall thickness. It is quite resistance to salt water, corrosive fumes , corrosive soil etc.

Selection of Pipe Material: The factors which affect the selection of pipe materials are :

(i) Internal pressure & external loads to which the pipe is subjected.

(ii) Type of water to be conveyed & it‘s resistance to corrosion.

(iii) Maintenance cost.

(iv) Availability of fund.

(v) Expected life & repair & replacement.

PIPE JOINTS: The common types of pipe joints are as follows :-

(i) Spigot & socket Joint

(ii) Flanged Joint

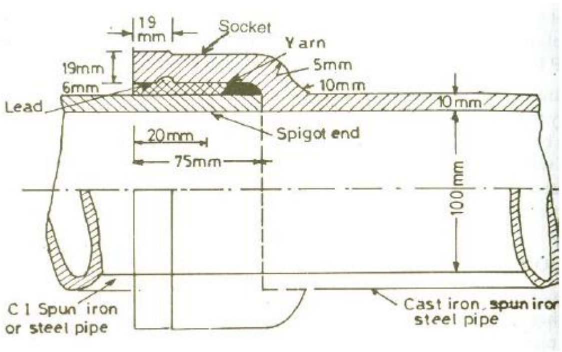
(iii) Expansion Joint.

(iv) Flexible Joint

(v) Collar Joint

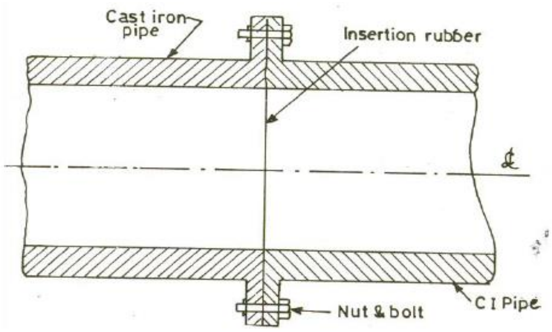
(vi) Screwed & socket Joint

(i) Spigot & Socket joint: This type of joint is commonly used in case of cast-iron-pipes. For the construction of this joint the spigot or normal end of one pipe is centred into the socket of the other pipe. Hemp yarn is then wrapped around the spigot, leaving unfilled the required depth of socket for lead. A kneeled clay ring is then placed around the barrel & against the face of the socket. After this molten pig lead is poured into fill the remainder of the socket.



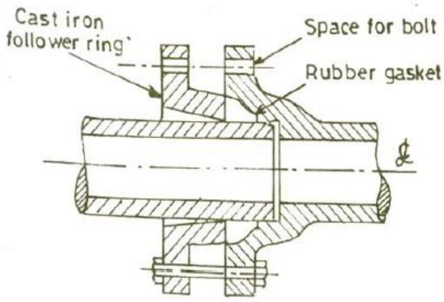
(Spigot & Socket Joint)

(ii) Flanged Joint: These joints are rigid & are easy to disjoint, as such used where pipe joints have to occasionally opened out for carrying out repair work as in pumping chamber. The pipe in this case has flanges on its both ends, casted, welded or screwed with the pipe. A gasket of rubber, canvass or lead is introduced between the two flange of cast iron pipes, which are then tightened with bolts & nuts.



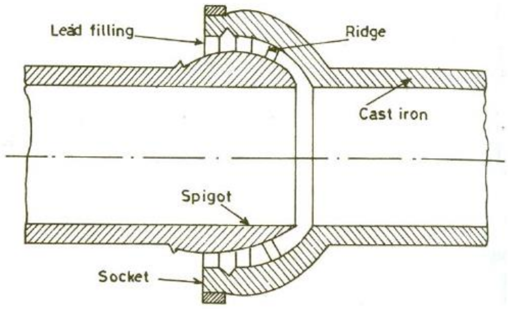
(Flanged Joint)

(iii) Expansion Joint: These joints are used on pipes exposed to considerable differences of temperature allowing for free expansion or contraction without setting up thermal stresses in the pipes. Here when the pipe expands, the socket end moves forward & when pipe contracts , it moves back word in the space provided for it & the elastic rubber gasket in every position keeps the joint water tight.



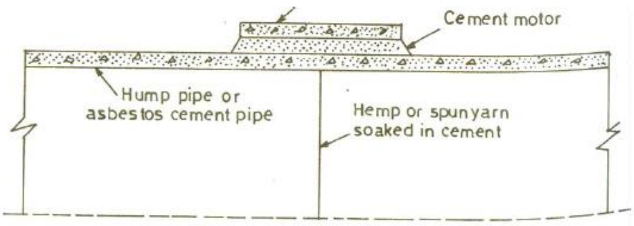
(Expansion Joint)

(iv) Flexible Joints: These joints are used for pipes to be laid submerged under water, where the bottom of the river is uneven with the possibility of settlement & consequent damage. If one pipe is given any defection, the ball shaped portion will move inside the socket, & the joint will remain water proof in all the position.



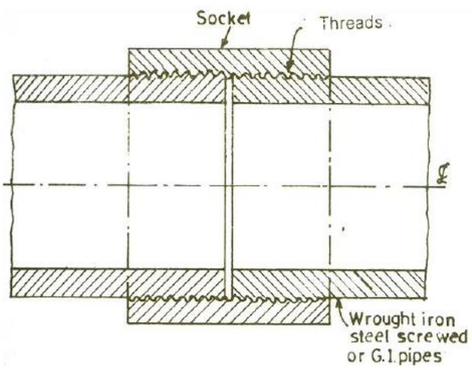
(Flexible joint)

(v) Collar Joint: This joint is mostly used for joining concrete & Asbestos cement pipe having bigger diameter. A rubber gasket is placed between steel rings in the groove after bringing the ends of the two pipes in one level. Then the collar is placed at the joint so that it should have the same lap on both the pipes. After this cement mortar (1:1) is filled in the gap between the pipes & the collar.



(Collar Joint)

(vi) Screwed & Socket Joints: This is a simple type of joint commonly used for jointing screwed wrought iron or Galvanised iron pipes. In this joint, two ends of the pipes are threaded on the outside and on them a suitable jointing compound should be used before screwing socket over it having corresponding threads from inside.



(Screwed & Socket Joint)

Laying of Pipes: Pipes are generally laid with a flat slope parallel to the hydraulic gradient to avoid any air locking trouble. Where there is slope, pipe laying should be done in an uphill direction to facilitate joint making.

Testing of Pipe Lines: After a new pipe line has been laid & jointed, it shall be subjected to the following two tests:

(i) Pressure Test

(ii) Leakage Test

Pressure Test at a Pressure at least double the maximum working Pressure: The procedure adopted for pressure testing of pipes is as follows:

(i) The pipe line is tested from section to section. At a time only one section lying between two sluice valves is taken up for testing.

(ii) First the downstream sluice valve of the section is closed & water is admitted in the section through the upstream sluice valve. During filling air valve is properly operated to remove all air from the pipe.

(iii) Then the upstream valve is close to completely isolate the section from the rest of the pipe line.

(iv) Pressure gauges are then fitted along the pipe length of the section at suitable interval (generally 100 mm or so) on the crown through holes left for this purpose.

(v) The pipe section is then connected to the delivery side of a pump through a small by-pass valve & the pump is started to increase the pressure in the pipe. The operation is continued till the pressure inside the pipe reaches a pressure at least double of the maximum working pressure.

(vi) The by-pass valve is then closed & the pump is discontinued.

(vii) The pipe is kept as it is for 24 hours & inspected for any fall of pressure. This completes the pressure testing of pipes.

Leakage Test at a Pressure to be specified by the authority: After successfully completing The pressure test , the leakage test is carried out. Leakage Test is to test maximum allowable leakage which is determined by the formula:

$$Q = (NDP^{1/2}) / 3.3$$

Where Q = allowable leakage in cm^3/hr

N = number of joints in the length of pipe line

D = diameter in mm

P = the average test pressure during the leakage test in kg / cm^2

Causes of corrosion in water system pipes

Pipes used to distribute drinking water are made of plastic, concrete, or metal (e.g., steel, galvanized steel, ductile iron, copper, or aluminium). Plastic and concrete pipes tend to be resistant to corrosion.

Metal pipe corrosion is a continuous and variable process of ion release from the pipe into the water. Under certain environmental conditions, metal pipes can become corroded based on the properties of the pipe, the soil surrounding the pipe, the water properties, and stray electric currents. When metal pipe corrosion occurs, it is a result of the electrochemical electron exchange resulting from the differential galvanic properties between metals, the ionic influences of solutions, aquatic buffering, or the solution pH.

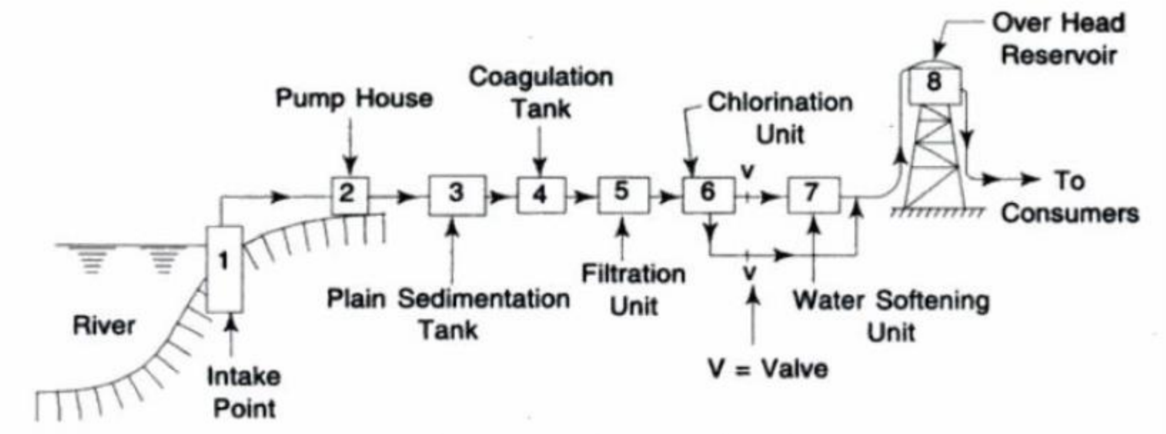
Remedies:-

- Avoid placing of old pipes.
- Avoid placing of rust pipes.
- Control dissolved gases from water which flows through the pipes.
- Rust preventives like lubricants, greases, oils are used to form a protective film to prevent corrosion.

▪▪▪

CHAPTER – 3

Treatment of water



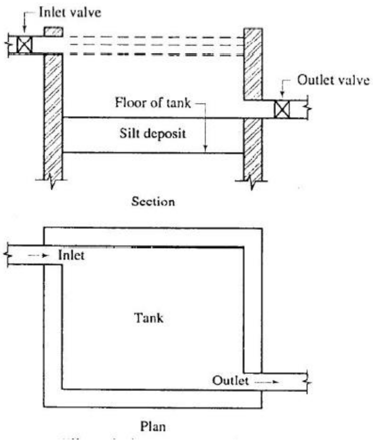
(Flow diagram of treatment plant)

TYPES OF SEDIMENTATION TANKS (CLARIFIERS) Depending upon the nature of working, clarifiers are of the following two types: **(1) Fill and draws type clarifies. (2) Continuous flow type clarifies.**

(1) Fill & draw a type clarifies:

- **(i) Working:** These are also knows also the quiescent type or intermittent type clarifiers .The working of tanks is simple .the water is filled in the tank and it is then allowed to test for a certain time. During the period of rest the particles in suspensions will settle down at the bottom of the tank .the clear waters then drawn off and the tank is cleared of silt and filled again. The usual period of rest to cause settlement of particles is about 24 hours or so .if time is required for inlet, outlet, emptying and clearing portion is added a period about 30 to 36 hours is required to put the tank again in working condition. This means that the least two tanks will be required if an additional unit is to be provided as stand by, the minimum number of tanks required under this type of working will not be less than three.
- **(ii) Design consideration:** The cubical contents of the tanks will represent the storage capacity of the tank. the provision is made at the bottom for accumulation of still .The outlet value is provide at the top of still deposit zone .the inlet and outlet for water are arranged at opposite ends as seen in plan of the tank fig.1 shows the plan section of a typically fill and draw type of clarifier.

USE: These tanks are mostly out of the use at present as they process many disadvantages.



(Fill and Draw type tank)

(i) If velocity of the flow is reduced a large amount of suspended impurities from water can be easily removed. This is the principle on which continuous flow type of sedimentation tanks is working. *The working operation of the tank is very simple. The water enter the tank from one end as it travels towards the out let at the other end, its velocity is broken and radiuses by means of bottle walls. The walls contain opening at di8ffriencer level. The velocity of the flow is so adjusted that the time taken by a particle of the water to move from one end to other is slightly move then that require d for the settlement of suspended impurities in water. The entry of impure water from one end the exit of clear water from the other end are continuous .The flows of water is designed to meet the following two requirement .

(a) The velocity of flows is such that suspend impurities of require size settle down at the bottom clarifier.

(b) The total amount of flow from the tank within 24 hours equals to the daily demand of the water. The silt is deposited at the bottom of clarifies and when it is accumulated in sufficient quantity, the flush valve is opened and the clarifier is cleaned.

(ii) **USE:** These clarifiers are widely used in the modern times as they possess many advantages

(a) Less labor & supervision: The action of the sedimentation tank is continuous and hence, no manual labour is required expect at the time of cleaning or washing the clarifier, also only general supervision is required during the working of the clarifier.

(b) LITTLE LOSS OF HEAD: The out let is situated near top of clarifier; there is practically very little loss of head .Also the pure water is drawn from the top level.

(c) TANKS IN SERIES: The continuous tanks are arranged in series and hence any one of them may be isolated for Cleary or washing purpose. Thus the provision of area for stand by units works out to be comparatively less.

(d) TIME OF OPERATION: As the flow of water is continuous, there is no wastage of time, once the tank is put into commission further, no clean water storage tanks will be required and this will be required and this will result in reduction in cost.

DISADVANTAGE: There is an only one mirror disadvantage of continuous flows type of clarifiers when the cleaned the water in the tanks is to be taken out. Thus there is considerable wastage of water. But cleaning operation are not carried out frequently. Hence such wastage of water can be to legated.

SEDIMENTATION WITH COAGULATON: The turbidity is mainly due to the presence of very fine particle of clay still and organic matter.

- All these impurities are in a finely divided state & it is not possible to detain them in plain sedimentation tanks unless such tanks are designed longer detention period.
- The other alternative to remove such particles is to increase their size so that they become settleable. The purpose of coagulation is thus to make particles of bigger size by adding certain chemicals known as coagulants to the water. The coagulants react with the impurities in water and convert them in settleable size.
- The coagulation is to be adopted when turbidity of water exceeds about 40ppm.

PRINCIPLES OF COAGULATION: The principle of coagulation can be explained from following two considerations.

(1) Floc formation: When coagulants are dissolved in water and thoroughly mixed with it. They produced a thick gelatinous precipitate. This precipitate is known as the floc and thus floc has got property of arresting the suspended impurities in water during its drowned travels towards the bottom of the tank.

(2) Electric charges: The ions of floc are found to possess positive electric charge .Hence they will attract the negatively charged colloidal particles of clay and thus they caused the removal of such particle from the water. *The surface of floc is sufficiently wide to arrest colloid and organic matter present in water. The term flocculation is used to denoted the process of flock formation and thus the formation and thus the flocculation flows the addition follows the addition of coagulants and its efficiency depends on the usual coagulants**.**

Following six are the usual coagulants which are adopted as coagulants:

(1) Aluminum sulphate.
(2) Chlorinated coppers.
(3) Ferrous sulphate & Lime.
(4) Magnesium carbonate.
(5) Polyelectrolyte
(6) Sodium aluminate.

1. **ALUMINIUM SULPHATE:**
    - This is knows the filter alum or alum only. Its chemical composition is $Al_2(so_4)_3$ $18H_2O$.
    - The alum in water treatment practice is commonly supplied and used in the form of flawless or solids lumps and then applied in a solution from.
    - The advantages of using alum as a coagulant are as follows.

→ It also reduces taste and odour in water.

→ It is cheap.

→ It produces crystal clear water

Generally the bicarbonate alkalinity is present in water and the chemical reaction involved between bicarbonate alkalinity and alum is as follows:

$$Al_2(So_4)_3\ 18H_2O + 3Ca(HCO_3)_2 = 2Al(OH)_3 + 3CaSO_4 + 18H_2O + 6CO_2$$

- The aluminum hydroxide formed is insoluble in water and it behaves as folic.
- If water possesses a little or no alkalinity, the lime is added to water.

The chemical reaction is as follows.

$$Al_2(So_4)_3 18H_2O + 3Ca(OH)_2 = 2Al(OH)_3 + 3CaSO_4 + 18H_2O$$

This coagulant is found to be effective between pH range of 6.5 to 8.5. In practices the dosage of alum varies from 5 to 30 milligrams per litre for normal water the usual being 14 milligrams per lit.

The disadvantages of using alum as a coagulant are mainly two.

→ It is different to dewater the sludge formal and further, it is not easy to distance it off also as it is found unsuitable for filling of lying lands.

→ The effective PH range for coagulation with alum is found to be too small and in some cases, the lime or caustic soda will have to be added to adjust the PH value at a proper level. This will increase the cost of treatment of water.

2. **CHLORINATED COPPERAS:**

- When chorine and solution of ferrous sulphate are fixed, the following chemical reaction takes place.

$$6FeSO_4.7H_2O+3Cl_2 = 2Fe_2(SO_4)_3 + 2FeCl_3 +42H_2O$$

- The combination of ferric sulphate $Fe_2(SO_4)_3$ and Ferric chloride is known as the chlorinated coppers, each one of the compound is effective as a flock and the combination is also quite effective.
- The ferric sulphate and ferric chloride $FeCl_3$ both can be used independently with lime to act as coagulant and the chemical reactions involved would be as follows.

$$Fe_2(SO_4)_3 + 3Ca\ (OH)_2 = 3CaSo_4+2Fe\ (OH)_3 2Fecl_3+3Ca\ (OH)2 = 3CaCl_2 + 2Fe\ (OH)_3$$

- The ferric hydroxide Fe $(OH)_3$ forms the floc. For ferric sulphate, the effective pH change is 4 to 7 and above 9. For Ferric chloride, the effective pH range is 3.50 to 6.50.

3. **FERROUS SULPHATE AND LIME:**

- When ferrous sulphate and lime are added to the water, the following chemical reaction takes place.

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

- The ferrous hydroxide $Fe(OH)_2$ thus oxygen in water and ferric hydroxide is formed as per the following chemical reaction.

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

- The ferric hydroxide $Fe(OH)_3$ forms the flock. For ferrous sulphate, the effective PH range is 8.50 and above.

4. MAGNESSIUM CARBONATE:

- When magnesium carbonate is dissolved and is mixed with water along with lime the following reaction takes place.

$$Mg\,Co_3 + Ca(OH)_2 = Mg(OH)_2 + Ca\,Co_3.$$

- The compounds magnesium hydroxide $Mg(OH)_2$ and calcium carbonate are insoluble in water and the sludge formed in this process contains a sludge of $Mg(OH)_2$and $Ca\,Co_3$. This coagulant is not at present flavored.

5. POLYELECTROLYTES:

- These are special types of polymers and depending upon the charge the carry, they are classified as anionic, cationic and nonionic only cationic polyelectrolyte's can be used effectively as independent coagulants. The others varieties can be used along with alum or other conventional coagulants.
- The use of polyelectrolytes is still in pilot stage and they may prove to be an alternative to the alum in future.

6. SODIUM ALUMINATE:

- The chemical composition of this coagulant is

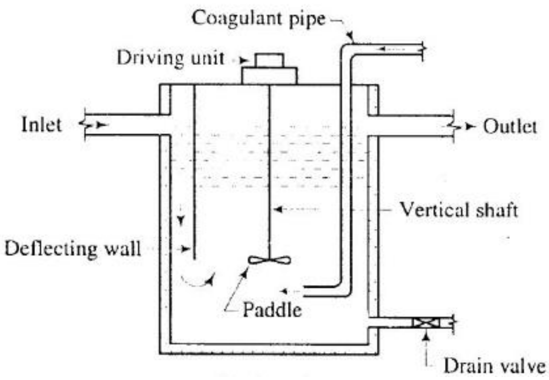
$$Na_2Al_2O_4+Ca(HCO_3)_2 = Ca\,Na_2Al_2\,O_4+Na_2CO_3+CO_2+H_2O \rightarrow (1)$$

$$Na\,Al_2\,O_4+ Ca\,Cl_2 = Ca\,Al_2\,O+2NaCl\ldots\ldots\ldots(2)$$

$$Na\,Al_2\,O_4 = Ca\,Al_2\,O_4 + Na_2So_4\ldots\ldots\ldots\ldots(3)$$

This coagulant removes carbonate or tempers or hardness as seen from equation (1) and it also removes non-carbonate or permanent hardness as seen from equation (2) and (3). The effective range of PH value for this coagulant is 6 to 8.5. This coagulant is costly and hence it cannot be adopted for treating water on a large scale.

FLASH MIXERS: Flash mixture are used to achieve quickly mixing and then the transfer water from the flash mixture to the slow mixture known as floc water.



(Flash Mixer)

The mixing is achieved by a rotating paddle situated at the lower end of the vertical shaft. The incoming water is defected toward the moving paddle by deflecting wall.

- The coagulants are brought by coagulant pipe and also discharge just near the rotating fan.
- Adriane value is providing to remove sludge from the bottom of flash mixture.
- The slow mixing is achieved by rotating paddles. The paddles usually make about 2 to 3 revolted per minute.

FILTRATION

NECESSITY:

- The sedimentation tanks remove a large perce4ntage of the suspended solids and the organic matter present in raw water.
- The process of coagulation further assists in the removal of impurities present in the water .But even then; the resultant water is not pure and may contain some very fine suspended particles, bacteria etc.
- In order to remove or to reduce the content of impurities still further, the water is filtered through the beds of fine granular material like sand .The process of passing though the bed such granular material is known as filtration

PRINCIPLES OF FILTERATIONS:

Process of filtration consists of the allowing water to pass through a thick layer of sand.

Principles of filtration are:

1. **Mechanical straining:** The suspended participles which are unable to pass through the voids of sand grains are arrested and are removed by mechanical straining.
2. **Sedimentation:** The voids between sands grains of filter act more or less like small sedimentation tanks .The particle of impurities arrested in these voids, at here to the participles of sand grains and are the removed by the action of sedimentation.
3. **Biological metabolism:** The growth and silt process of the living cells is known as the biological metabolism. When the bacteria are caught in the voids of sand grains, a zoological jelly or film is formed around the sand grains. This film contains large colonies of living bacteria.

The bacteria feeds on the organic impurities contained in water. They convert such impurities in to harm less compounds by the complex biochemical reaction.

4. **Electrolytic changes:** According to this theory when two substances with opposite electric charges are brought in to contact with each other, the electric charges are neutralized and in doing so, new chemical substances are formed.
    - It is observed that some of the sand grains of filter are charged with electricity of some polarity. Hence, when particle of suspended and dissolved matter contain electricity of opposite polarity come into contact with such sand grains they neutral each other and neutralize result in the alteration of chemical characteristics of water.

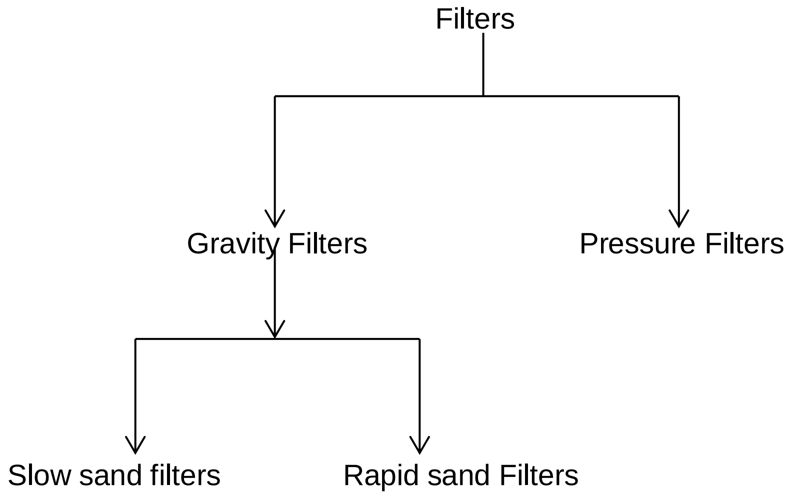
CLASSIFICATION OF FILTERS: The filters are classified in to the following

1. Slow sand filter
2. Rapid sand flitter.

The rapid sand filters are further subdivided into the following two categories.

1. Gravity types rapid sand filter.
2. Pressure type rapid sand filter.

The above classification is based on the rate of filtration .On the consideration of the gravity and pressure the filters may be classified as follows.



Combining the above two classification, there are following three types of filters.

1. Slow sand filter
2. Rapid sand filter
3. Pressure filter

SLOW SAND FILTERS:

PURPOSE: In case of slow sand filtration, the water is allowed to pass slowly through a layer of sand placed above the base of the, material and thus the purification process are at simultaneously improving the biological chemical and physical characteristic of water.

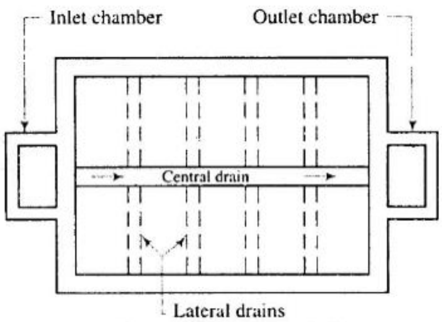
The slow sand filtration is very well suited for rural are as in developing countries because of its simple operation and maintains procedure s. It thus provides safe drinking water at low recurrent cost.

ESSENTIAL PARTS: A slows sand filter consist of the following five parts.

1. Enclosure tank
2. Under drainage system
3. Base material
4. Filter media or sand
5. Appurtenances.

(1) ENCLOSURE TANK: A water tight tank is constructed either in stone masonry or brick masonry. The sides & floor are also coated with water proof material. The bed slope is about b1 in 100 to 1 in 200 towards the central drain The depth of tank is about 2.50m to 3.50m .The surface area of a slow sand filter may vary from 30m to 2000m or even more.

(2) UNDER DRAINAGE SYSTEM: The under drainage system consists of a central drain and lateral drain. The lateral drain is placed at a distance of about 2.5 m to 3.5m and they are stopped at a distance of about b500mm to 800mm from the walls of the tanks. The drains may be pipes which are laid with open joint.



(Plan of slow sand Filter)

(3) BASE MATERIAL: The base material is gravels &it is placed on the top of under drainage system. Its depth varies from 300mm to 750mm. It is usually graded and laid in layers of 150mm. The topmost layer should be small size gravel and the lowest layer should be of bigger size gravel. Followings is a typical section of base material.

Top most layer 150mm depth – size 3mmto 6mm 150mm

150mm depth - size 6mm to 20mm

150mm depth –size 20mm to 40mm

150mm depth – size 40mm to 65mm

Total 600mm depth.

4. **FILTER MEDIA OF SAND:**
    - A layer of sand placed above the gravels.
    - The depth of sand layer varies from 600mmto 900mm.
    - The effective size of sand varies from 0.20 mm to 0.30mm & the uniformity co-efficient about 2 to 3.
    - The finer the sand, the better will be the efficiency of filter regarding the removal of bacteria but in that case, the output from the flitter is lowered.
5. **APPURTENANCE:** The various appurtenances are to be installed for the efficient working of slow sand filter. The devices for measuring loss of head for controlling depth of water above sand layer and for minting rate of flows through filter are to be suitably installed. The vertical air pipe passing through layer of sand help in proper function of filtering layer.
6. **WORKING & CLEANING:** The water allowed to enter the filter through the inlet chamber. It descends through the filter media and during this process it gets purified. Water is then collected in the outlet chamber and taken to the clear water storage tank. The depth of water filter is to be carefully decided. It should neither be too small nor too high. Generally it is kept as equal to the light of filter media of sand.

    For the purpose of cleaning the top layer of sand is scrapped or removed through a depth of about 15mm to 25mm. The water is then admitted to the filter. But the purified water is not taken into use until the formation film around sand grain occurs.
7. **RATE OF FILTERATION:** The rate of filtration of a normal slow sand filter varies from 100 to 200 liters/ hours/ m^2 of filter area.

<u>RAPID SAND FILTERS (GRAVITY TYPE):</u>

1. **Purpose:** The great disadvantages of a slow sand filter are that it requires considerable space for its installation. This requirement makes it uneconomical for places where land values are high.

    The difficulty of requiring moves space for slow sand filters can be obviated by increasing the rate of filtration which is accomplished in rapid sand filter by increasing the size of sand.
2. **Essential parts**: - Fig shows the layout of a typical rapid sand filter (gravity type) . It consists of the following five parts.
    (i) Enclosure tank
    (ii) Under drainage system
    (iii) Base material
    (iv) Filter media
    (v) Appurtenances

(i) **Enclosure Tank:** A watertight tank is constructed either of masonry or concrete. The side and floor are also coated with waterproof material. The depth of tank is about 2.5m to 3.5m. The surface area of a exit of rapid sand filter varies from $10m^2$ to $30m^2$.

(ii) **Under drainage system:** There are various forms of under drainage system of a rapid sand filter and most of them are patented by the manufacturers. Following are two common types of under drainage system

(a) perforated pipe system

(b) pipe and strainer system

(a) Perforated pipe system: In this system there is a central drain or manifold and to this manifold the various lateral drains are attached. The drains are usually made of cast-iron. The lateral drains are placed at a distance of about 150mm to 300mm.

The lateral drains are provided with holes at the bottom side and such holes make an angle of 20° with the vertical. The perforated pipe system is economical and simple in operation.

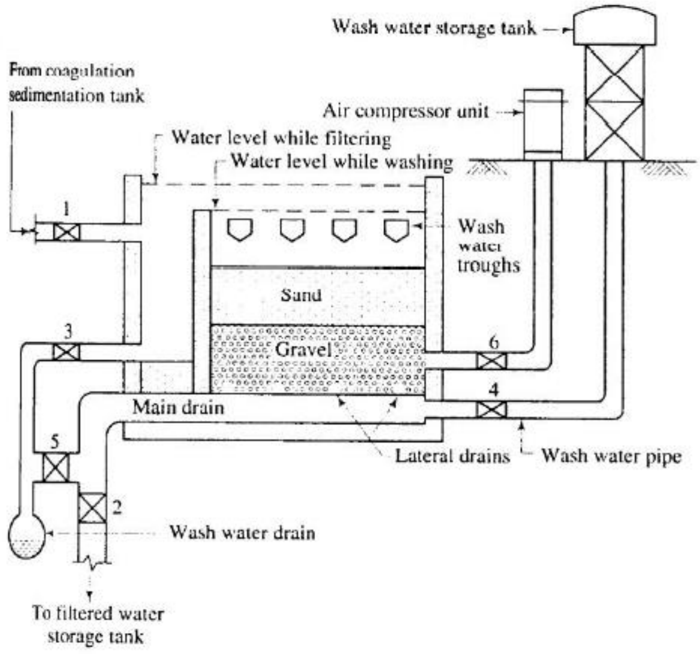
(b) Pipe and strainer system: In this system also there is a central drain or manifold with lateral drains attached on either side as shown in the fig. But in this system the strainers are placed on lateral drains instead of drilling holes.

- A strainer is a small pipe of brass. It is closed at top and contains holes on its surface.
- The strainers are either screwed or fixed on the top of lateral drains.
- When pipe and strainer system is adopted the compressed air is used for the purpose of washing the filter. This results in saving of wash water.

Following general rules should be observed in designing the under drainage system:

i. The ratio of length of lateral drain to its diameter should not exceed 20.
ii. The cross sectional area of central drain should be about twice the cross sectional area of lateral drain.
iii. The total cross sectional area of perforations should be about 0.20% of the total filter area.
iv. The cross sectional area of lateral should be about two to four times the total cross sectional area of perforations in it.
v. The perforations in the lateral drain should be of diameter 6mm to 12mm.
vi. The spacing of perforation in the lateral drain should vary from 75mm to 200mm center to center.

(iii) **BASE MATERAIL:** The base material is gravel and it is faced on the top .of under drainage system. The gravel to be used for best material should be clean and free from clay, dust, silt and vegetable matter.



(Layout of Rapid sand filter (gravity type))

The gravel particle should be durable, hard, round and strong. The depth of base material varies from 450mmto 600mmgravel .It is usually graded and laid in layers of 150mm. The topmost layer should be of small seize of gravel and the lower layer should be of big size gravel.

Following is a typical section of base material:

Top most layer 150mmdepth – size3mm to 6 mm

Intermediate layer {150mm depth-size 6mm to 12mm

{150mm depth -size 12mm to 20mm

Lower layer 150mm depth - size 20 mm to 40mm

Total 600mm depth

(iv) **FILTER MEDIA OF SAND:** A layer of sand is placed above gravel. The depth of sand layer varies from 600mm t0 900mm. The coarse sand is used as filter media. The effective size of sand varies from 0.35mm to 0.60 mm and the uniformity coefficient of sand is between 1.20 to 1.70. Thus the space of voids between sand particles is increased and it result in the increase rate filtration.

(v) **APPURTENANCES:**

a) **AIR COMPRESSORS:** The agitation of sand grains during washing of filter is carried out either by compressed air or by water jet or by mechanical rakes. When air is to be used an air compressor of required capacity should be installed.

b) **WASH- WATER THROUGHS:** The dirty water after washing of filter is collected in wash water through or gutter which is placed above sand bed level.

c) **RATE CONTROL:** There are various devices which may be fitted at the outlet end of the filter to control the rate of flow.

3. **Working and cleaning:** Valve 1 – Inlet valve.

    Valve 2 – Filtered water storage tank valve.

    Valve 3 – Waste water Valve to drain water from inlet chamber

    Valve 4 – Wash water storage tank Valve

    Valve 5 – Waste water Valve to drain water from main drain

    Valve 6 – Compressed air Valve

- The Valve 1 is opened and the water from coagulated sedimentation tank is allowed to enter the filter.
- The Valve 2 is opened to carry filtered water to the filter water storage tank. All other Valves are kept in closed position. Thus when filter is in working condition only Valves 1 and 2 are in open position.
- When the filter requires cleaning or washing it is carried out follows.
    - → The Valves 1 and 2 are closed.
    - → The Valves 4 and 6 are opened out. The wash water is then forced in the upward direction through the under drainage system, base material and filter media of sand. The compressed air assists the cleaning process of filters.
    - → The Valve 6 is closed and the Valve 3 is opened out to carry dirty water through the inlet chamber to the wash water drain.
    - → When washing of filter is over, the Valves 3 and 4 closed and Valve 1 and 5 are opened out. Thus, when filter is put into use after washing, the filtered water in the beginning is led to the wash water drain through main drain. This is continued for few minutes to condition the filter.
    - → The Valve 5 is closed and the valve 2 is opened ou6t to put the filter in the normal working condition.

4. **Loss of head and negative head: -**When water passes through the filter it has to resist the frictional resistance. It therefore losses some of its head. The loss of head can easily be computed by knowing the water level in the filter and pressure of water in the outlet pipe. The difference between the two head s indicates the loss of head in filter. In the beginning when the

filter is cleaned the loss of head is very small about 150mm. `to 300mm. the loss of head then gradually goes on increasing. The loss of head can be measured by inserting piezometers in filter as shown in fig. The difference of water level in two tubes indicates the loss of head.

→ A stage then comes when frictional resistance offered by filter media exceeds the static head above sand bed. This is developed due to the deposit of suspended matter in top layer of about 100mm to 150mm. thickness. The lower portion then act more or less like a vacuum and the water is succeed through the filter media rather than flittered through it. The fall of liquid level in the piezometer tube below the center line of under drainage system indicates the negative head.

→ The negative head thus formed tense to release dissolved air and other gasses present in water. The bubbles stick to the sand grains and the working of filter is seriously disturbed. This phenomenon is known as air binding as air binds filter and stops its working. The rate of filtration is consequently greatly reduced.

→ In case of rapid sand filter the allowable loss of head is about 3m. To 3.5m. and the allowable negative head is about 1200mm. The filter is to be washed when this limit of the allowable loss of head has been reached it is usually cleaned after 2 to 3 days.

5. **Troubles in operation:** Following two troubles are generally encountered in operating rapid sand filter.

(i) Mud balls: The mud ball are generally formed near the top of filter media. They may even be formed and distributed throughout the filter. The mud balls are formed or caused due to insufficient washing of sand grains. The gelatinous film formed during filtration is not separated out from sand grains during washing. The mud balls interfere with the normal working of the filter and their size is about 25mm to 50mm.

(ii) Cracking of filters: The fine material contained in the top layer of filter shrinks and this shrinkage leads to form cracks in the filter. These cracks are prominent near wall junctions.

To remove these troubles, the following remedies are adopted.

i. The mud balls are broken with the help of rakes or some such equipment.

ii. The working of filters is carried out with high velocity of water.

iii. The damaged portion of filter media is replaced.

6. **Rate of filtration:** The chief advantage of a rapid sand filter is that its rate of filtration is very high. It is about 3000 to 6000 liters/ hour/cm^2 the high rate of filtration results in considerable saving of space for the installation of filter.

7. **Efficiency of rapid sand filter:** The efficiency of rapid sand filter is as follows.

   (i) Bacterial load: The rapid sand filters are less effective in the removal of bacterial load. It is expected that they remove about 80 to 90 percent of bacterial impurity present in water.

(ii) The rapid sand filters are highly efficient in colour removal and the intensity of colour can be brought down below 10 on cobalt scale.

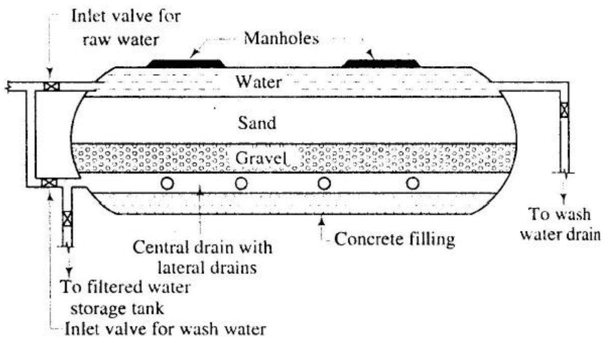
(iii) Turbidity: The rapid sand filter can remove turbidity to the extent of 35 to 45 p.p.m. As water entering rapid sand filter is invariably given the treatment in coagulation sedimentation tank, it possesses less turbidity. This turbidity is brought down easily to the permissible limits by rapid sand filters.

PRESSURE FILTERS:

These filters are more or less similar to the rapid sand filters (gravity type) except with the following differences.

1) Pressure filter: The pressure filter does not indicate that the water is pumped through the filter under a high pressure loss. But it indicates that a filter is enclosed in space and the water passes under pressure greater than atmospheric pressure. This pressure can be developed by pumping and it may vary from 0.3 to 0.7 N/mm^2.

2) Construction: The pressure filters are closed cylinders either riveted or welded. They may be of horizontal or vertical type. The diameters of pressure filters vary from 1.50m to 3.00m. and their lengths or height varies from 3.50m. to 8.00m. the manholes are provided at top for inspection.



(Pressure Filter – Horizontal type)

3) Working: The water mixed with coagulant is directly admitted to the pressure filter. Thus the flocculation takes place inside the pressure filter itself. In normal working condition, all valves are closed except those for raw water and filtered water. The water is admitted through inlet and after it is filtered, it is collected in the central drain and converged to the filtered water storage tank.

4) Cleaning: The compressed air may be used to agitate sand grains. The values for raw water and filtered water are in closed position and those for wash water and wash water drain are in open position during the operation of washing of filter. The cleaning of pressure filters may be required more be frequently. The automatic pressure filters are available in which washing of filter is done automatically at a predetermined interval of time or loss of head.

5) Rate of filtration: The rate of filtration of pressure filters is high as compare to that of rapid sand filters. It is about 6000 to 15000 liters/hour/m^2 of filter area as compared to that of 3000 to 6000 liters/hour/m^2 of rapid sand filters.

6) Efficiency: The pressure filters are found to be less efficient than the rapid sand filters in terms of bacterial loads, colour and turbidity.

7) Suitability: The pressure filters are more suitable for public water supply projects. But they can be installed for small water supply projects such as colonies of few houses, industrial plants, private estates, swimming pools etc.

DISINFECTION

Water disinfection means the removal, deactivation or killing of pathogenic micro-organisms. Microorganisms are destroyed or deactivated, resulting in termination of growth and reproduction. When micro-organisms are not removed from drinking water, drinking water usage will cause people to fall ill.

Sterilization is a process related to disinfection. However, during the sterilization process all present micro-organisms are killed, both harmful and harmless micro-organisms.

Necessity:

- They should destroy all the harmful pathogenic organisms from the water and make it perfectly safe for use.
- They should not take more time in killing pathogens, but do their task within the required time at normal temperature.
- They should be economical and easily available.
- They should not require high skill and costly requirement for their application.
- After their treatment the water should not become toxic and objectionable to the user.
- They should be of such a nature that their strength or concentration in the treated water can be quickly determined.
- Their dose should be such that it leaves some residual concentration for protection against contamination in the water during its conveyance and retention.

Methods of disinfection:

Disinfection can be attained by means of physical or chemical disinfectants. The agents also remove organic contaminants from water, which serve as nutrients or shelters for microorganisms. Disinfectants should not only kill microorganisms. Disinfectants must also have a residual effect, which means that they remain active in the water after disinfection. A disinfectant should prevent pathogenic micro-organisms from growing in the plumbing after disinfection, causing the water t0 be re-contaminated.

(a) By the boiling of water
(b) By ultra-violet rays
(c) By the use of Iodine and bromine.
(d) By the use of Ozone.
(e) By the use of excess lime.
(f) By using Potassium Permanganate

(a) By the boiling of water: The water can be disinfected by boiling for 15 to 20 minutes. By boiling water all the disease causing bacteria are killed and the water becomes safe for use. This process can only kill the existing germs but does not provide any protection against future possible contamination. This method is very costly and can be used only individually in emergency cases during the break up of epidemics in the town or city.

(b) By ultra-violet rays: Ultra - violet rays are invisible light rays having wave lengths of 1000 to 4000m. Sun rays also have ulta–violet rays which can also be utilized in the disinfection of water. In the laboratory they can be obtained by the ultra violet ray equipment, which consists of mercury vapours enclosed in quartz bulb and passing current in it.

Ultra - violet rays are highly disinfectants and kill the disease bacteria. After removing the turbidity and the colour of water, its disinfection by ultra – violet rays can be done.

The water is allowed to pass in thickness not exceeding 10cm before ultra violet rays. These rays penetrate in water and kill the bacteria

This process is very costly and requires technical skill and costly equipments.

(c) By the use of Iodine and bromine: Addition of Iodine and Bromine in the water, kills all the pathogenic bacteria. The quantity of Iodine & Bromine should not exceed 8 p.p.m and they can kill bacteria in minimum contact period of 5 minutes. These disinfectants are easily available in the form of pills and very handy. These are also used in treating water works at individual estate or industry.

(d) By the use of Ozone: ozone is an excellent disinfectant. It is used in gaseous form, which is faintly blue in colour of pungent odour. Ozone is an unstable allotropic form of oxygen, with its every molecule containing three oxygen atoms.

Ozone is produced by passing a high tension electric current through a stream of air in a closed chamber. The production of ozone can be shown

$$3O_2 \longrightarrow 2O_3$$

But as the ozone is highly unstable, it breaks down in the ordinary oxygen and liberate nascent oxygen.

$$O_3 \longrightarrow O_3 + O$$

(Nascent oxygen)

The nascent oxygen is very powerful oxidizing agent and it kills all the bacteria as well as oxidises the organic matter present in the water. For obtaining a residual of 0.1 p.p.m after a contact period of about 13 minutes, the dose of ozone to be added in water is about 2 - 3 p.p.m. the quantity of residual ozone is measured by Orthotolidine test.

(e) By the use of excess lime: lime is usually used at the water works for reducing the hardness of water. It has been noted practically that if some additional quantity of lime is added than what it actually requires for removal of hardness, it will also disinfect the water while removing the hardness.

The addition of excess of lime in the water increases the pH – value of the water. When the pH value is more than 9.5, all the bacteria are killed.

(f) By using Potassium Permanganate: This is the most common disinfectant used in the village for disinfection of dug well water, pond water or private source of water. In addition to the killing of bacteria it also reduces the organic matters by oxidising them.

Due to its good oxidizing quality, it is sometimes added in small dose 0.05 to 0.10 mg/litre in the chlorinated water also. In the rural areas it is common practice to dissolve a small amount of potassium permanganate in a bucket of water and mix it with the water of the well frequently, to kill the bacteria.

The usual dose of KMnO_4 is 1- 2 mg/lit of water with contact period of 4 - 6 hours. Its efficiency is only 98%.

CHLORINATION

Water chlorination is the process of adding chlorine or chlorine compounds such as sodium hypochlorite to water. This method is used to kill bacteria, viruses and other microbes in water. In particular, chlorination is used to prevent the spread of waterborne diseases such as cholera, dysentery, and typhoid.

Various Chlorine compounds which are used as disinfectants are Hypochlorites of calcium and sodium, The Chloramines, Chlorine and complex chlorine compounds such as $(CH_2CO)_2NCl\ etc.$

Chlorination has several advantages over other methods:

- The process is economical and cheap.
- It is harmless to human beings.
- It is reliable and effective.

- Residual Cl_2 can be maintained in the water.

Free available Chlorine:

Chlorine in its various forms is most widely and universally adopted product for disinfecting water. It is reliable, cheap and not very difficult to handle. The chlorine reacts with water and forms hydrochloric acid and hypochlorous acid.

$$Cl_2 + H_2O \rightarrow HCl + HOCl$$

$$HOCl \rightarrow H^+ + OCl^-$$

The $HOCl$ ionizes into hydrogen ions (H^+) and Hypochlorite ions (OCl^-). Thus the hypochlorous acid and the hypochlorite ion also known as Free available Chlorine.

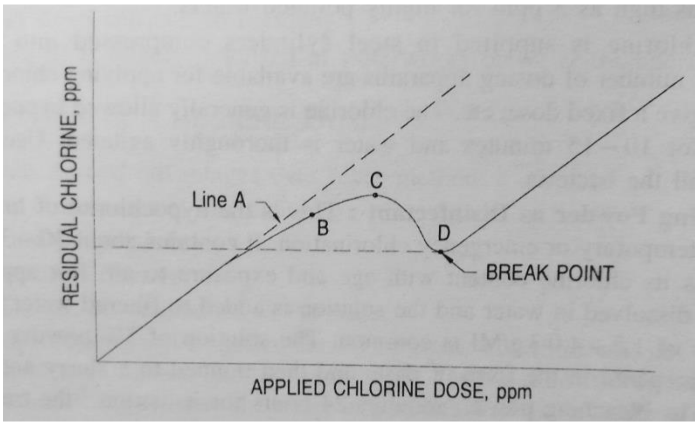
Chlorine Demand:

Chlorine demand is defined as the difference between the amount of chlorine added to water and the amount of chlorine (free available and combined available) remaining at the end of a specified contact period.

Residual Chlorine and Break point Chlorination:

The chlorine is first used for disinfection. During the disinfection process, the amount of residual chlorine will be less in the beginning and will gradually increase as the demand for disinfection is satisfied. After sometime, the oxidation of organic matter starts and the chlorine again starts to be used up and water contains less and less amount of residual chlorine as the process continues. When this demand is also satisfied the amount of residual chlorine again build up. The stage at which both these demands are satisfied and residual chlorine just tends to increase is called “Break point” i.e. any further dose of chlorine re-appears as free chlorine. The chlorine is added in such amounts, which gives the residual chlorine as 0.1 – 0.2 ppm.

From figure it is clear that the applied chlorine will be equal to residual chlorine if there are no organic impurities and bacteria, which is not possible, and hence line A is imaginary. First at point B, the residual chlorine gradually increases but soon after it again decreases to oxidize the organic matter till the residual chlorine at D is available after which there is marked increase in residual chlorine. The taste and odour disappear at this point. The break – point can be detected by instantaneous yellow colur if the orthotolidine solution test is applied.



(Break-point Chlorination)

Types of Chlorination:

Plain Chlorination: where good surface water is available, it is used with no other treatment except chlorination. In hilly areas, only chlorination is done and the water is safeguarded against disease. Such type of chlorination is known as plain chlorination.

The water of lakes and springs is pure and can be used after plain chlorination. If the water contains organic matters more dose of chlorine should be added and the contact period should be increased. The chlorine is added in the water in the pipe leading from an impounding reservoir to the city

Pre – chlorination: when chlorine is added to raw water before any treatment it is known as pre-chlorination. Thus chlorine is added in small dosage before raw water enters sedimentation tanks. The dosage should be so adjusted that about 0.10 to 0.50 ppm of chlorine comes to the filter plant.

Post – chlorination: when the chlorine is added in the water after all treatment, it is known as post – chlorination. Generally this is done after filtration process. The chlorine may be added in the suction pipe, but it is more suitable to add it in the clear water well. The minimum contact period should be 30 minutes, before the use of water.

Double – Chlorination: when chlorine is added to raw water at more than one point, it is known as double – chlorination. When raw water is highly contaminated and contains large amount of bacterial life, it becomes necessary to adopt pre – chlorination and post – chlorination for such water.

Super – chlorination: it is defined as the administration of a dose of chlorine considerable in excess of that necessary for the adequate bacterial purification of water. Under certain circumstances such as during epidemics of water borne diseases, as a precautionary measure, high dose of chlorine is given to the water, generally 2 to 3 ppm beyond the break point. The contact period is generally 10 – 30 minutes.

It is also used before filtration if the water contains a large amount of organic matter or turbidity (i.e. highly polluted) it is also practiced in waters where the water is coloured or iron and manganese have to be oxidized. The adding of chlorine in excess is called “super – chlorination” and gives a strong odour and the taste of chlorine in the treated water, which can be removed by de-chlorination.

De-chlorination: De-chlorination is the process of removing chlorine from water (e.g, disinfected wastewater) before discharging the water into the environment. De-chlorination is performed because chlorine can form deposits on the internal edges of industrial equipment, cause health issues (e.g., choking) or lead to corrosion.

Softening of water

Water softening is an important process, because the hardness of water in households and companies is reduced during this process. When water is hard, it can clog pipes and soap will dissolve in it less easily. Water softening can prevent these negative effects.

Necessity of water softening:

The raw water specially from the ground sources may contain large quantity of bicarbonates, sulphates, carbonates and chlorides of calcium and magnesium as dissolved impurities. The dissolved impurities of salts usually make the water hard due to which its removal from the water becomes essential.

- More quantity of soap is consumed at home and in laundries for washing of clothes. This is due to the reason that about 25 ppm additional soap quantity is required for every 1.0 ppm of hardness in the water.
- The fabric of clothes gets spoiled while washing it to remove precipitate formed by soap in hard water.
- In industries hard water forms scales in the boilers, due to which more fuel is wasted and boiler metals are overheated causing danger to the boiler plant.
- Hard water creates serious troubles in the manufacturing process of textile, finishing, paper making, dyeing, rayon industry, canning, ice making etc.
- Hard waters choke and clog plumbing due to precipitation of salts in them.

METHODS OF WATER SOFTENING:

1. Removal of temporary hardness
2. Removal of permanent hardness

1. **Removal Of Temporary Hardness:** if the water contains temporary hardness, it can be removed by the following methods:

a) By boiling
b) By addition of lime water

a) By Boiling: The presence of magnesium and calcium carbonates in water makes it temporarily hard. In this case, the hardness in water can be removed by boiling the water.

- When we boil water the soluble salts of $Mg(HCO_3)_2$ is converted to $Mg(OH)_2$ which is insoluble and hence gets precipitated and is removed. After filtration, the water we get is soft water.
- Soluble bicarbonates are converted into insoluble carbonates which are removed by filtration.

$$Ca(HCO_3)_2 \rightarrow \Delta CaCO_3\downarrow + H_2O + CO_2\uparrow$$

$$Mg(HCO_3)_2 \rightarrow \Delta MgCO_3\downarrow + H_2O + CO_2\uparrow$$

- But this is very costly process and it is not possible to use it in the water works . however, it can be adopted as individual basis

b) By addition of lime water: if the water of lime is added in the water containing temporary hardness, it can be removed by adding the lime water. The following chemical reactions takes place, when the water of lime is added in the water.

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

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

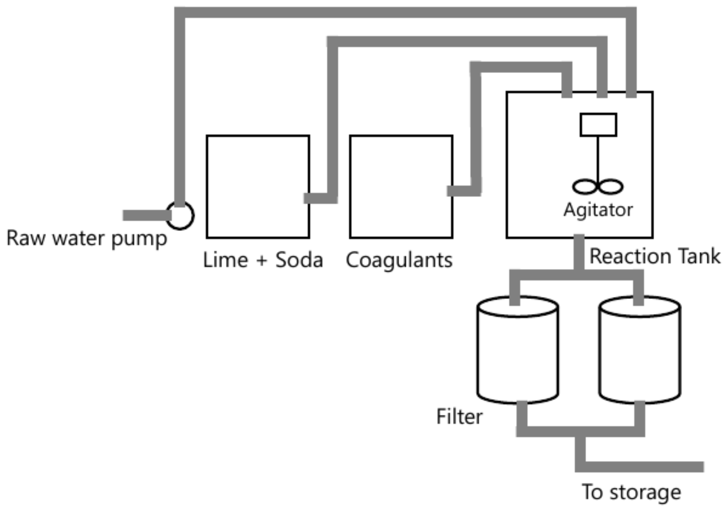
- The calcium carbonate and magnesium hydroxide are insoluble in water and get precipitated and can be removed by sedimentation tanks.
- This method is used in softening water which contains only temporary hardness. If the water contains temporary as well as permanent hardness, its softening is done only by permanent softening methods.

2. Removal Of Permanent Hardness:

Removal of permanent hardness from the water is difficult and requires special methods and equipment for its removal. The methods employed for the removal of permanent hardness from the water are known as water softening methods. Followings are the various methods which are commonly adopted for the removal of permanent hardness from the water.

a) Lime soda process
b) Base exchange process
c) Demineralization process

a) Lime soda Process: Soda lime is a process used in water treatment to remove Hardness from water. This process is now obsolete but was very useful for the treatment of large volumes of hard water. Addition of lime (CaO) and soda (Na_2CO_3) to the hard water precipitates calcium as the carbonate, and magnesium as its hydroxide. The amounts of the two chemicals required are easily calculated from the analysis of the water and stoichiometry of the reactions. The lime-soda uses lime, $Ca(OH)_2$ and soda ash, Na_2CO_3, to precipitate hardness from solution.



Soda Lime water softening process

Carbon dioxide and carbonate hardness (calcium and Magnesium bicarbonate) are complexed by lime. In this process Calcium and Magnesium ions are precipitated by the addition of lime ($Ca(OH)_2$) and soda ash (Na_2CO_3).

Following are the reactions that takes place in this process:

As slacked lime is added to a water, it will react with any carbon dioxide present as follows:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O....(1)$$

The lime will react with carbonate hardness as follows:

$$Ca(OH)_2+Ca(HCO_3)_2 \rightarrow 2CaCO_3\downarrow+2H_2O.....(2)$$
$$Ca(OH)_2+Mg(HCO_3)_2 \rightarrow MgCO_3+CaCO_3\downarrow+2H_2O.....(3)$$

The product magnesium carbonate in equation (3) is soluble. To remove it, more lime is added:

$$Ca(OH)_2MgCO_3 \rightarrow CaCO_3\downarrow+Mg(OH)_2\downarrow.....(4)$$

Also, magnesium non-carbonate hardness, such as magnesium sulfate, is removed:

$$Ca(OH)_2+MgSO_4 \rightarrow CaSO_4+Mg(OH)_2\downarrow.....(5)$$

Lime addition removes only magnesium hardness and calcium carbonate hardness. In equation (5) magnesium is precipitated, however, an equivalent amount of calcium is added. The water now contains the original calcium non-carbonate hardness and the calcium non- carbonate hardness produced in equation 5. Soda ash is added to remove calcium non-carbonate hardness:

$$Na2CO3+CaSO4 \rightarrow Na2SO+CaCO3\downarrow.....(6)$$

To precipitate CaCO3 requires a pH of about 9.5; and to precipitate Mg(OH)2 requires a pH of about 10.8, therefore, an excess lime of about 1.25 meq/l is required to raise the pH.

The amount of lime required:

Llime (meq / l) = carbon dioxide (meq / l) + carbonate hardness (meq / l) + magnesium ion (meq / l) + 1.25 (meq / l)

The amount of soda ash required:

Soda ash (meq / l) = non-carbonate hardness (meq / l)

After softening, the water will have high pH and contain the excess lime and the magnesium hydroxide and the calcium carbonate that did not precipitate.

Recarbonation (adding carbon dioxide) is used to stabilize the water. The excess lime and magnesium hydroxide are stabilized by adding carbon dioxide, which also reduces pH from 10.8 to 9.5 as the following:

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + H_2O \quad CO_2 + Mg(OH)_2 \rightarrow MgCO_3 + H_2O$$

Further re-carbonation, will bring the pH to about 8.5 and stabilize the calcium carbonate as the following:

$CO_2 + CaCO_3 + H_2O \rightarrow Ca(HCO_3)_2$

It is not possible to remove all of the hardness from water. In actual practice, about 50 to 80 mg / l will remain as a residual hardness.

b) Base exchange process: This process also known as Zeolite or Cation Exchange Process. The process depends on the ability of certain insoluble substances mainly silicates to exchange cation with other substances dissolved in water.

- The hard water is passed through a bed of Zeolite sand (complex silicates of aluminium and sodium), while passing through it the *Ca* and *Mg* cation get replaced by sodium from the exchanger and the water becomes soft.
- The sodium from the zeolite sand goes on getting exhausted and after some time it can not remove the hardness of water.
- But the reactions are reversible and the zeolite can be recharged by passing through it in a solution of common salt.

CHAPTER – 4

Distribution system And Appurtenance in distribution system

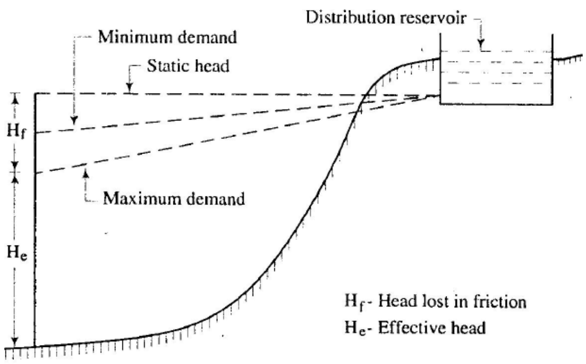
After complete treatment of water, it becomes necessary to distribute it to a number of houses, estates, industries and public places by means of a network of distribution system. The distribution system consists of pipes of various sizes, valves, meters, pumps, distribution reservoirs, hydrants, stand posts etc. The pipe lines carry the water to each and every street, road. Valves control the flow of water through the pipes. Meters are provided to measure the quantity of water consumed by individual as well as by the town. Hydrants are provided to connect the water to the fire fighting equipments during fire. Service connections are done to connect the individual building with the water line passing through the streets. Pumps are provided to pump the water to the elevated service reservoirs or directly in the water mains to obtain the required pressure in the pipe lines.

Requirements of Good distribution system:

(i) It should convey the treated water up to the consumers with the same degree of purity.
(ii) The water should reach to every consumer with the required pressure head.
(iii) Sufficient quantity of treated water should reach for the domestic and industrial use.
(iv) The distribution system should be economical and easy to maintain arid operate.
(v) It should be able to transport sufficient quantity of water during emergency such as fire-fighting.
(vi) It should be reliable so that even during breakdown or repairs of one line water should reach that locality from other line.
(vii) During repair work, it should not cause obstruction to the traffic.
(viii) It should be safe against any future pollution. The pipe lines as far as possible should not be laid below the sewer lines.
(ix) The quantity of the pipes laid should be good and it should not burst.
(x) It should be water-tight and the water losses due to leakage should be minimum as far as possible.

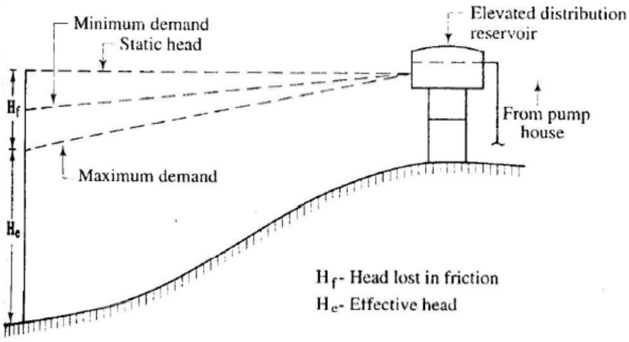
METHOD OF DISTRIBUTION Depending upon the topography of the country, any one of the following three methods may be adopted for the distribution of water.

1. **Gravity system:** In this system the water is conveyed through pipes by gravity only. The gravity system is the most reliable methods of distribution. But it is useful only when the source of water supply is situated at a higher level than that of distribution area. Fig. below shows the gravity system with hydraulic gradients during maximum and minimum demands. In case of a fire, the motor pumps may be used to develop high pressure for fire fighting purpose.



(Gravity System)

2. **Combined Gravity and pumping system:** In this system, the treated water is pumped and stored in an elevated distribution reservoir. The excess water during low consumption remains in the elevated reservoir and it is supplied during the peak period. The pumps are generally worked at constant rate and this rate of pumping is so adjusted that the excess quantity of water stored in reservoir during low consumption is nearly equal to the extra demand of water during peak period. Fig. below shows the combined gravity and pumping system with hydraulic gradients during maximum and minimum demand.



(Combined Gravity and pumping system)

This method of distribution is usually applicable in most of the cases and it has the following advantages:

i. In case of a fire, the motor pumps can be used to develop high pressure or a fire demand can directly be satisfied from pump house after closing the inlet valve for elevated reservoir.
ii. In this method the pumps are generally worked at uniform rate. Hence, they suffer less wear and tear.

3. **Pumping system:** In this system, the water is directly pumped into the mains leading to the consumers. The number of pumps required in this system will depend on the demand of water.

Methods of supply: Following are the two systems of supply of water which are based on the duration of supply.

1) Continuous system: In this system of supply, the water is supplied to the consumers for 24 hours of day. This is the most ideal system of supply and it should be adopted as far as possible.

The only disadvantage of this system is that considerable wastage of water occurs, if consumers do not possess civic sense regarding the importance of treated water. One recommended way to avoid this defect of this system is to supply water through meters. Whether it is desirable to install meters or not is a debatable question and hence, the decision to install meters should be taken after careful considerations and deliberations.

2) **Intermittent system:** In this system of supply the water is supplied during certain fixed hours of day only. The usual period is about one to four hours in the morning and about same period in the afternoon. For instance, the water may be supplied from 6.30 a.m. to 10.30 p.m. and from 5.30 p.m. to 8.30 p.m. The timing of supply of water may be changed to suit the seasons of year and it is more or less a matter of convenience only. This system of supply of water proves to be useful for the following two conditions:

I. The available pressure is poor and

II. The quantity of water available is not sufficient to meet with various demands for water.

Methods of layout of distribution of pipes: Following are the four main methods of laying distribution pipes:

1) Dead end method

2) Grid iron method

3) Circular method

4) Radial method

1) Dead - end method: This is also known as the free system of layout and it consists of one supply main from which sub-mains are taken. The sub-mains again divided into several branch lines from which service connections are given to the consumers.

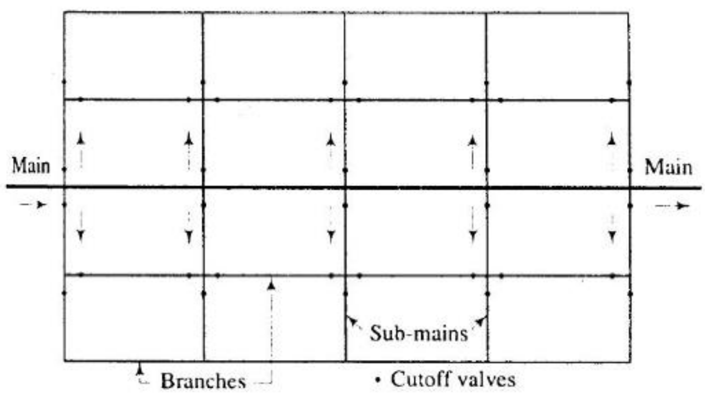
Advantages: Followings are the advantages of the dead - end method -

- It is possible to workout accurately the discharge and pressure at any point in the distribution system. The design calculations are simple and easy.
- The cut-off valves required in this system of layout are comparatively less in number.

Disadvantage: Following is the disadvantage of dead-end method:

- During repairs the large portion of distribution area is affected. It results into great inconvenience to the consumers of that area.

2) Grid-iron method: This is also known as the interlaced system or reticulation system. The mains, sub-mains and branches are



interconnected with each other.

(Grid – iron method layout)

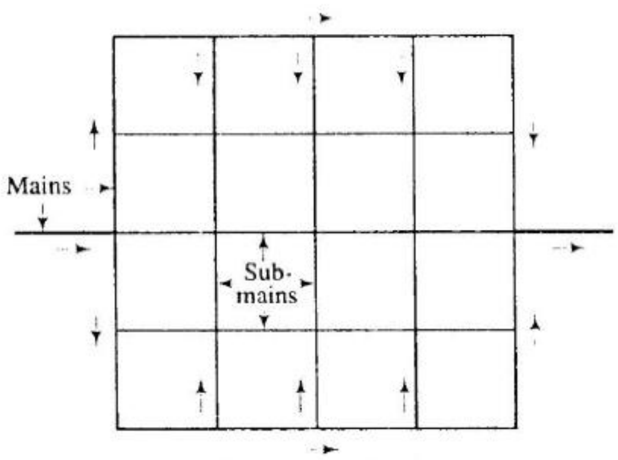
Advantages: Followings are the advantages of grid-iron method:

- In case of repairs a very small portion of the distribution area will be affected.
- There is free circulation of water and hence, it is not liable for pollution due to stagnation.

Disadvantages: - Followings are the disadvantages of grid-iron method:

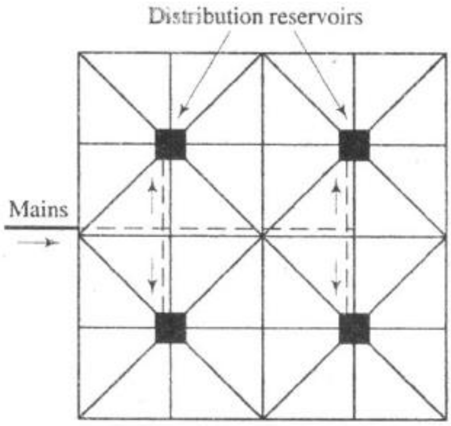
- The cost of laying water pipe is more.
- The grid - iron system of layout requires longer lengths of pipes.

3) Circular method: - This is also known as the ring system and a ring of mains is formed around the distribution area. This system possesses advantages and disadvantages as those of grid-iron system.



(Circular Method)

4) Radial method: This method of layout is just the reverse of the ring method. In this system, the water is taken from the mains and pumped into the distribution reservoirs which are situated at centres of different zones. The water is then supplied through radially laid pipes. The radial method of layout gives quick service and the calculations for design of sizes of pipes are simple. The radial method is most suitable for towns having roads laid out radially.

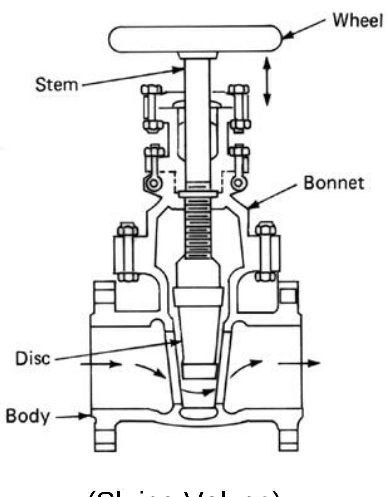


(Radial Method)

Valves: Generally valves are needed to control the flow of water to regulate pressure to release or admit air to prevent flow of water in opposite direction. Valves are fitted according to the purpose of distribution. Some different types of valves are

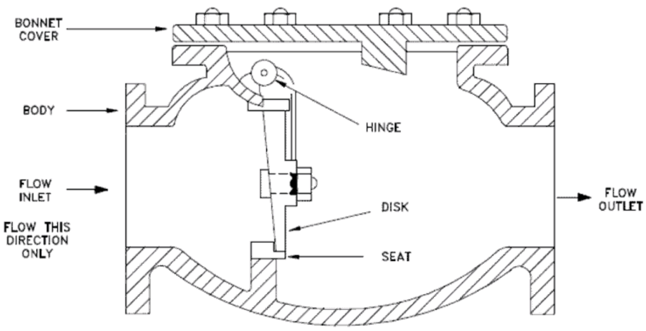
(i) Sluice valves
(ii) Check Valves
(iii) Air valves
(iv) Scour Valves

(i) Sluice valves: These are also known as gate valves and are mostly used in water work. This is cheap and offer less resistance to flow of water. Gate valves control the flow of water through pipes and fixed in the main lines bringing water from the source to a town at 3 to 5 km interval.



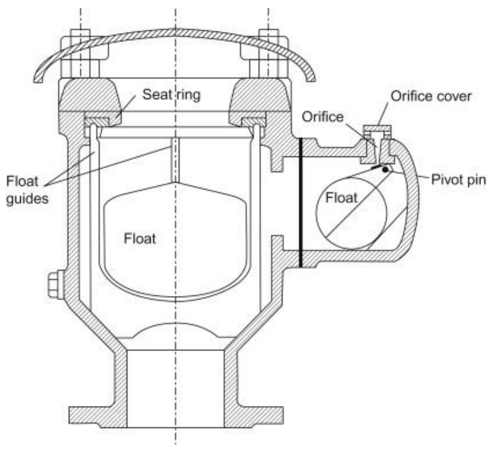
(Sluice Valves)

(ii) Check Valves: This is also known as return or non return valves. It automatically allows water to flow only in one direction and prevent it flowing in reverse direction. This type of valves has typical rises in one directional flow of water.



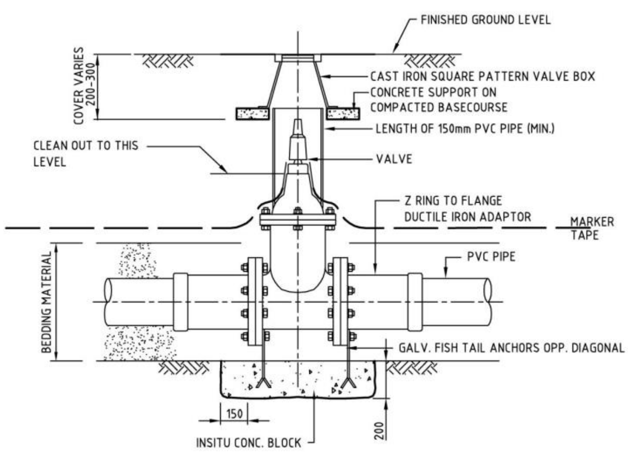
(Check Valves)

(iii) Air Valves: When water enters in pipe line some it also carries some air with it which tends to accumulate at high point of the pipe. When the quantity of air increases it causes severe blockage to the flow of water therefore it is most essential to remove the accumulated air from the pipe line. Air valves are used for this purpose.



(Air Valves)

(iv) Scour Valves: Scour valves are located at low points or between valved sections of the pipeline. Their function is to allow periodic flushing of the lines to remove sediment and to allow the line to be drained for maintenance and repair work. The scour valve should be sized to allow a minimum scour velocity of 0.6 m/s to be



achieved in the main pipe. Scour tees over nominal size 100 should be offset tees to allow the debris to be taken from the invert of the pipe.

(Scour Valves)

Fire Hydrants:

This device are used for tapping water from mains for fire extinguisher, Street washing flushing swear line etc. This are generally provided at all junction of road and at 100 -130mt. apart along road.

The hydrants are of two types.

Flush hydrants: This type of hydrants are installed in an underground bricks chamber flush with the footpath. It is covered from top by a C.I. cover. Some distinct sign is provided at it in order to locate the position of hydrant even at night.

Post hydrant: This type of hydrants barrel is projected about 60 - 90cm above the ground surface. These hydrant have a long steam with screw and nut at the top to regulate the flow of water. The post hydrant is connected to the main pipes through a branch pipes and it is operated by means of a gate valve.

Water meters:

This types of device are used to determine the quantity of water flowing through pipes. This are usually installed to measure the water amount supplied to provide house, industries public building etc. as

Uses: For the typical use of water meter the wastage of water is reduced. It mostly used for private building, industries and other public sector. It may be adopted by fire brigade.

CHAPTER – 5

W/s Plumbing in Building

Method of water connection from water mains to building supply:

The water receiving tank method, in which water is supplied via a water receiving tank, is generally used in apartment buildings and other high-rise structures, but there is also an approach known as the direct-connect method, in which water is supplied directly to faucets in the building without using a water receiving tank. This direct-connect method includes the direct-connect/direct-pressure method, in which water is supplied directly using only the water pressure in the water main, and the direct-connect/boost method, in which a boost pump is installed on the water pipe to bring the water pressure in the water main up to a sufficient level.

General layout of plumbing arrangement for water supply in multi-storied building: For plumbing purposes, the term multi-storey is applied to buildings that are too tall to be supplied throughout by the normal pressure in the public water mains. These buildings have particular needs in the design of their sanitary drainage and venting systems. Water main supply pressures of 8–12 metres (25–40 feet) can supply a typical two-storey building, but higher buildings may need pressure booster systems. In hilly areas, the drinking-water supply pressures will vary depending on the ground elevation. In these cases, the water authority may have to specify areas where particular supply pressures can be relied upon for the design and operation of buildings. Where a building of three or more storey‘s is proposed a certificate should be obtained from the drinking-water supply authority guaranteeing that the present and future public drinking-water supply pressure will be adequate to serve the building. If the public water pressure is inadequate, suitable means shall be provided within the building to boost the water pressure.

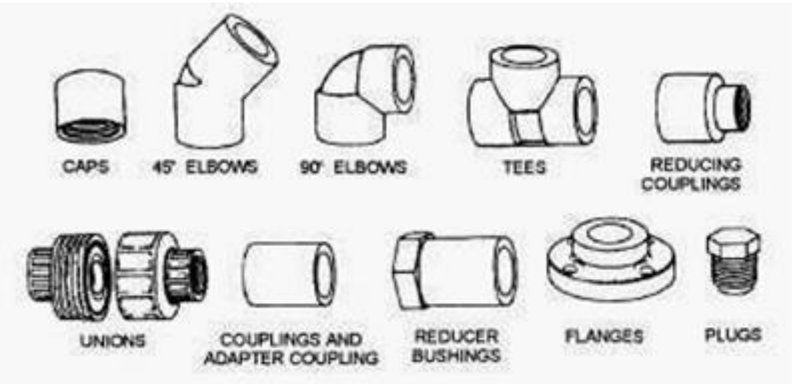
Water supply fittings-features, uses, purpose, fixing and jointing:

PIPES AND PIPE FITTINGS: Various types of materials which are used in the construction of sewer pipes. All those materials are also used in the construction of pipes required in house drainage. In house drainage works stoneware, asbestos cement, lead and iron pipes are used.

For jointing, laying and fixing of soil waste, rain water and vent pipes of various types of fitting are required.

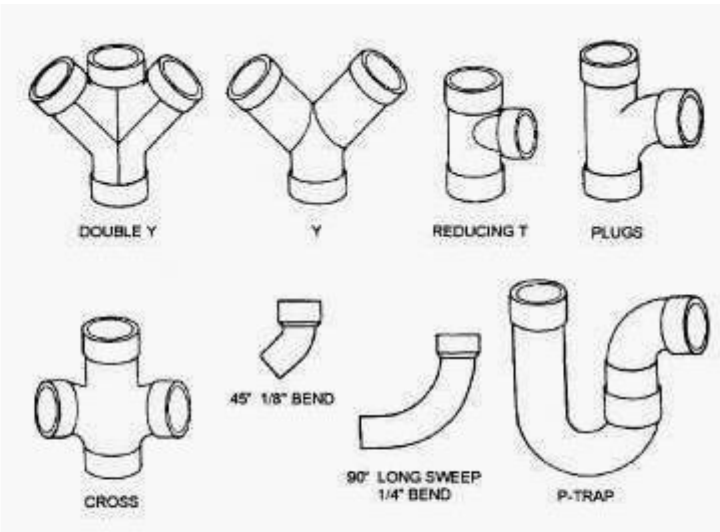
FIXING AND JOINTTING, PIPES AND ACCESSORIES:

Rain water, soil waste and vent pipes can be embedded in the walls and floors or fixed on them. When they are embedded no fixing devices are required. But for ease in repairs and maintenance usually they are fixed on the outside of walls. For fixing those special types of brackets are required. fig shows one most common type of fixing bracket having aluminium painted clips. These brackets fit closely round the pipe or accessory directly beneath the socket and have ears for securing to the face of the face of the structure. When fixed, they present a neat appearance.



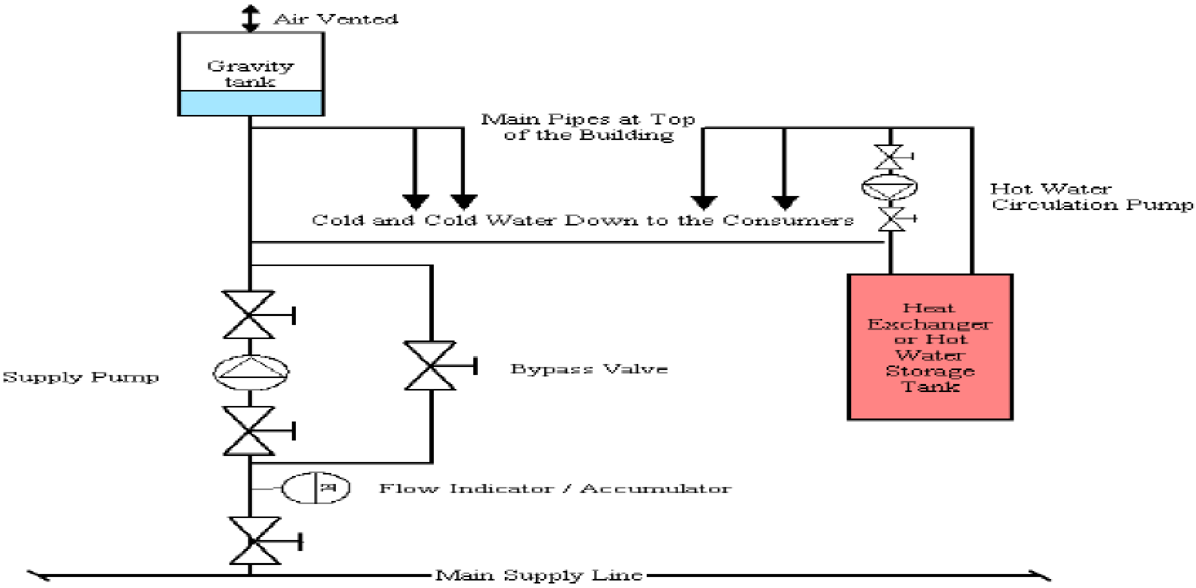
(Plastic Pipe Fittings)

The jointing of pipes and accessories is done as follows. First a gasket or hemp yarn saturated with Bitumastic jointing compound is caulked to about 2.5cm depth. Then the space between the collar and plain end is ground with stiff mortar of cement. Fig shows the method of jointing A.C. pipe.



(Waste Pipe Fitting)

(Waste Drainage Pipe Fitting)



(Domestic Hot water supply system with Gravity Tank)

After fixing and jointing all pipes and accessories must be tested for water tightness. This is done by dividing the whole work in section and testing each section one by one.

DISTRIBUTION SYSTEM:

There are four basic methods of distribution of water lo a multi- storeyed buildings.

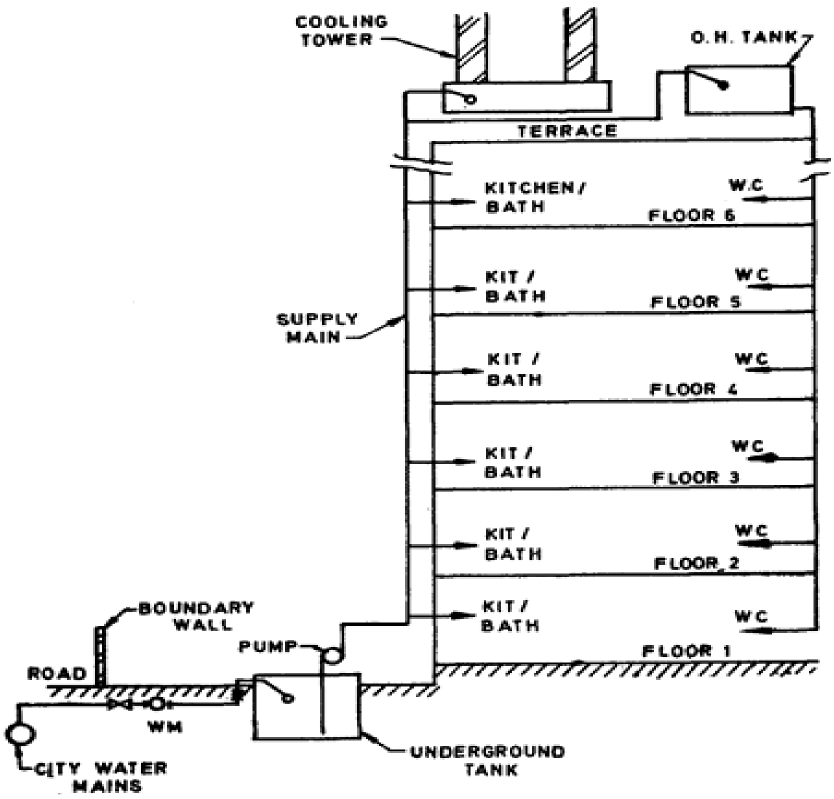
Direct supply from mains to ablutionary taps and kitchen with WCs and urinals supplied by overhead tanks.

(i) Direct Pumping Systems
(ii) Hydra-pneumatic Systems
(iii) Overhead Tanks Distribution

Direct Supply System:- This system is adopted when adequate pressure is available round the clock at the topmost floor. With limited pressure available in most city mains, water from direct supply is normally not available above two or three floors. This system is covered in IS: 2065-1983.

(i) **Direct Pumping:-** Water is pumped directly into the distribution system without the aid of any overhead tank, except for flushing purposes. The pumps are controlled by a pressure switch installed on the line. Normally a jockey pump of smaller capacity installed which meets the demand of water during low consumption and the main pump starts when the demand is greater. The start and stop operations are accomplished by a set if pressure switches arc installed directly on the line. In some installation, a timer switch is installed to restrict the operating cycle of the pump.

- Direct pumping systems are suitable for buildings where a certain amount of constant use of water is always occurring. These buildings arc all centrally air-conditioned buildings for which a constant make up-supply for air-conditioning cooling towers is required.
- The system depends on a constant and reliable supply of power. Any failure in the power system would result in a breakdown in the water supply system.
- The system eliminates the requirements of overhead tanks for domestic purposes (except for flushing) and requires minimum space.



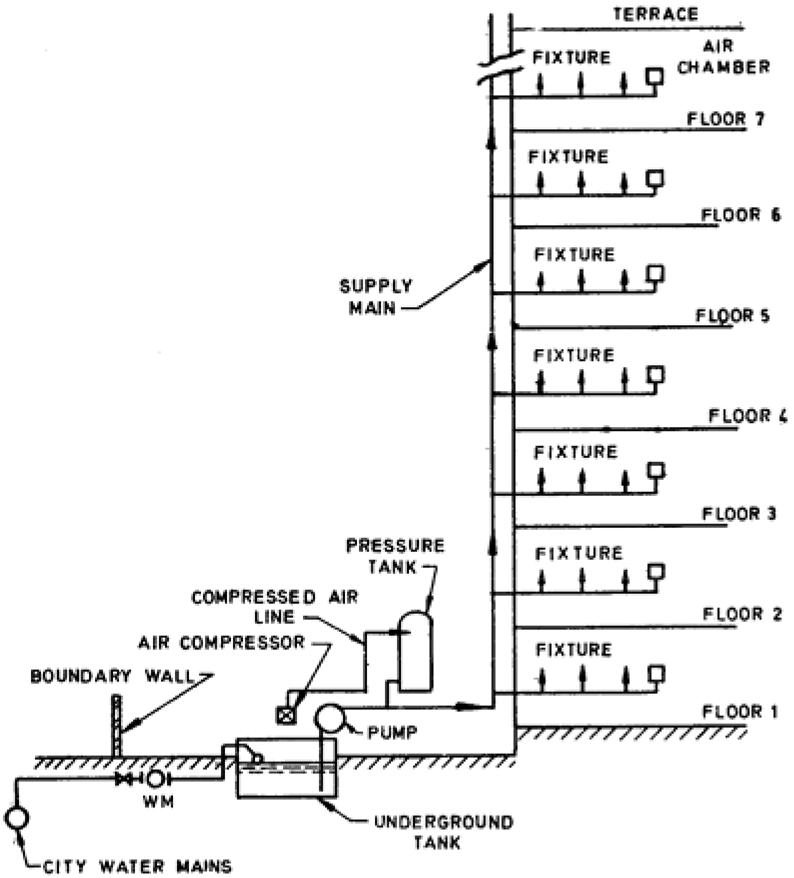
(DIRECT PUMPING & SYSTEM APPLICABLB WHERE THERE CONTINUOUS DEMAND ON SYSTEM)

(ii) **Hydro-pneumatic Systems:-**

Hydro-pneumatic system is a variation of direct pumping system. An air-tight pressure vessel is installed on the line to regulate the operation of the pumps. The vessel is arranged to consist of approximately half the capacity of water. As pumps operate, the incoming water in the vessel, compresses the air on top. When a pre-determined pressure is reached in the vessel, a pressure switch installed on the vessel switches off the pumps. As water is drawn into the system, pressure falls into the vessel starting the pump at preset pressure. The air in the pressure tank slowly reduces in volume due to dissolution in water and leakages from pipe lines. An air compressor is also necessary to feed air into the vessel so as to maintain the required air-water ratio.

There are various types of system available in the market and the designers has to select the system according to the needs of each application.

Hydro-pneumatic system generally eliminates the need for an overhead tank and may supply water at a much higher pressure than available from overhead tanks particularly on the upper floors, resulting in even distribution of water at all floors.

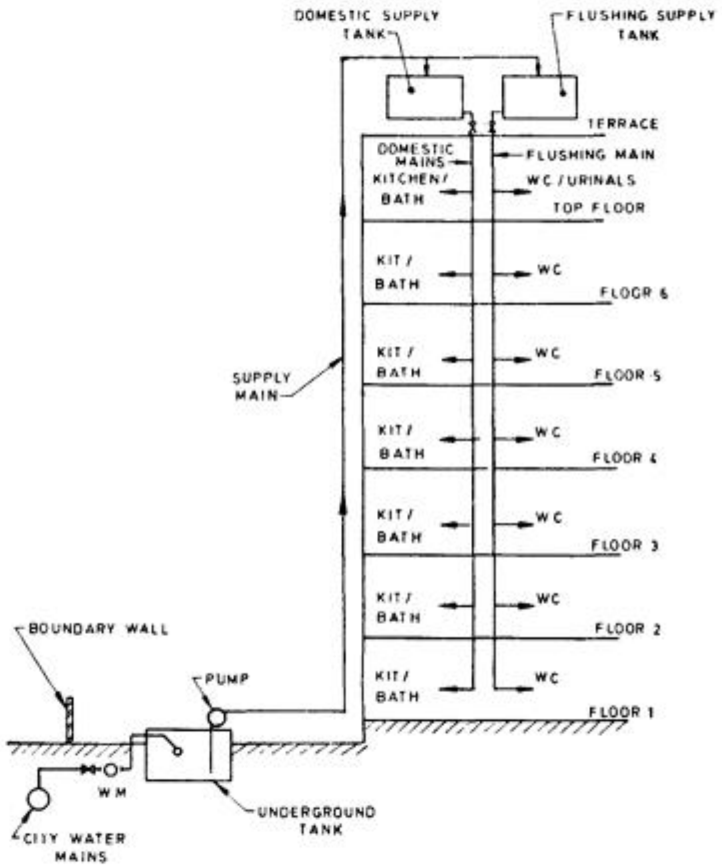


(HYDRO-PNEUMATIC SYSTEM)

(iii) Overhead Tank Distribution:- This is the most common of the distribution systems adopted by various type of buildings. The system comprises pumping water to one or more overhead tanks placed at the top most location of the hydraulic zone.

Water collected in the overhead tank is distributed various parts of the building by a set of pipes located generally terrace.

Distribution is accomplished by providing down takes to various fixtures.



(OVERHEAD TANK DISTRIBUTION)

SECTION B: WASTE WATER ENGINEERING

CHAPTER – 6

Introduction

Sanitation is a term which reseeds to indicate the proper arrangement for the collection, treatment and disposal of air the waste water produced from different sources like bathroom, kitchen, lavatory, street wash etc and the science or technique that stands behind the sanitation is known as sanitary engineering. Proper sanitation is the most essential at every town or city even at every individual for a sound and safe community.

Aims and Objectives:

- The following are the basic aims and object of sanitary engineering.
- For the proper collection and disposal of wastes at every individuals house, public sector etc.
- To prevent the accumulation of disposed water.
- It also makes the final disposal at land or nearly water source after some primary treatment.

Definition and terms related to sanitary engineering :

- **Anti-siphon age pipe:** A pipe which is installed in the house drainage to preserve the water seal of traps is known as anti-siphon age pipe. It maintains the metallization and does not allow the siphonic action.
- **Siphon age**: Water seal of traps may break due to siphonic action and it is known as siphon age. It takes place when water is suddenly discharged from a filterer on ripper flower.
- **Vent Pipe**: The pipe which is reseed for the purpose of ventilation is known as vent pipe.
- **Refuse**: It is reseed to indicate what is left as worthless and for the study of sanitary engineering and it is divided in 5 categories.
  - → **Garbage :** The dry refuse means decayed fruits, grass, leaves, paper pieces etc.
  - → **Sewage :** It is the whole liquid waste generated from latrines, urinals, stables etc. It is the combination of sanitary sewage and storm water.
  - → **Fresh Sewage :** The sewage which has been recently organized or produced.
  - → **Septic Sewage :** The sewage which is undergoing the treatment process.
  - → **Storm water:** It is used to indicate the rain water of the locality.
  - → **Sullage:-** It indicate the waste water from bathrooms , kitchens etc.
- **Sewer:** The underground conduits of the drains trough which the sewage is conveyed.
- **Sewerage:-** The entire science of collection and carrying sewage by water carriage system through sewers.

System of collection of sanitation: For the disposal of waste water collection is the primary step and basically the sanitation of a town or city is done by following two methods. They are

a) Conservancy system
b) Water carriage system.

a) **Conservancy System:-** It is actually a out of date system but in some small town , village or underdeveloped area this system is still present. These systems are also called dry system.

In this system various types of refuse and storm water are collected converged and disposed by different method so it is called **conservancy system**.

- Garbage or dry refuse are collected in the dustbins placed along the roads and streets from where it is conveyed by trucks to the point of disposal. All the non-combustible portion of the garbage are reused for filling of lower level areas to reclaim the lands for future use.
- The combustible portions of the garbage are burnt and the decaying fruits leaves and vegetables are first dried and then disposed of by burning or in the manufacture of manure.
- Similarly, human excreta or night soil is collected separately by human agency and also all the liquid and semi- liquid waste. After removal of night soil they are brought into trenches which are outside of the town and get buried. After 2-3 years they became very good manure.
- In **conservancy system** the silage and storm water are carried separately in closed or open drums up to the point of disposal where they are allowed to mix up with streams, rivers or sea without any treatment.

b) **Water Carriage System:-** With the development and advancement of cities urgent need was felt to replace the conservancy system with the some more improved type of system in which human agency should not be used for collection conveyance of sewage. After many experiments water is found as the cheapest substance for the collection and conveyance of sewage. As in the system water plays an important role. So it is called water carriage system.

- In this system all the refuse liquid and semi liquid waste are mix up with large amount of water and then they are taken out of the city with planned sewage system, where they can be disposed after necessary treatment in satisfactory manner.

Comparison between Conservancy System & Water Carriage System:

Sl.no.	**Conservancy System**	**Water Carriage System**
1.	Initial cost is low	Initial cost is very high
2	Foul smell may found	There is no foul smell is occur
3	Excreta is not removed immediately	Excreta is removed immediately with water.

4	Storm water is carried in ritually surface drains hence no problem of pumping the storm water.	Sewage is treated before disposing off. It may or may not require pumping. It depends upon the topography of the town.
5	This system is fully dependent upon human agency	No human agency is require for this system.
6.	In this system the sewage is disposed without any treatment. So it may pollute the water course or disposed area.	In this system sewage is treated upto required degree of sanitation

CHAPTER – 7