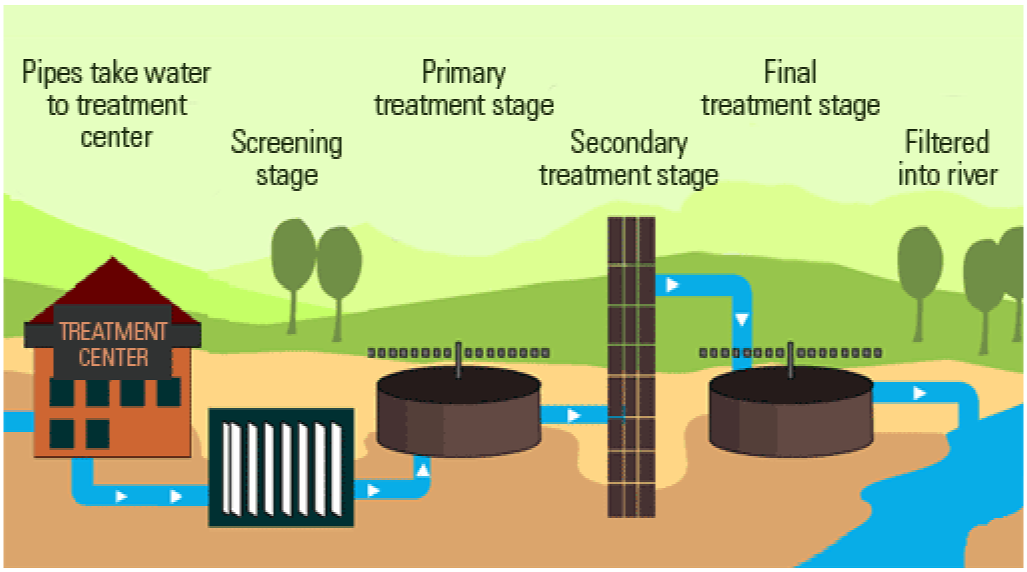
OEN351 DRINKING WATER SUPPLY AND TREATMENT

COMPUTER SCIENCE AND ENGINEERING

2021 REGULATION

SEMESTER VII



OEN351 DRINKING WATER SUPPLY AND TREATMENT L T P C
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COURSE OBJECTIVE:
To equip the students with the principles and design of water treatment units and distribution system.

UNIT I SOURCES OF WATER 9

Public water supply system Planning, Objectives, Design period, Population forecasting; Water demand Sources of water and their characteristics, Surface and Groundwater Impounding Reservoir Development and selection of source Source Water quality Characterization Significance Drinking Water quality standards.

UNIT II CONVEYANCE FROM THE SOURCE 9

Water supply intake structures Functions; Pipes and conduits for water Pipe materials Hydraulics of flow in pipes Transmission main design Laying, jointing and testing of pipes appurtenances Types and capacity of pumps Selection of pumps and pipe materials.

UNIT III WATER TREATMENT 9

Objectives Unit operations and processes Principles, functions, and design of water treatment plant units, aerators of flash mixers, Coagulation and flocculation - sand filters - Disinfection - Construction, Operation and Maintenance aspects.

UNIT IV ADVANCED WATER TREATMENT 9

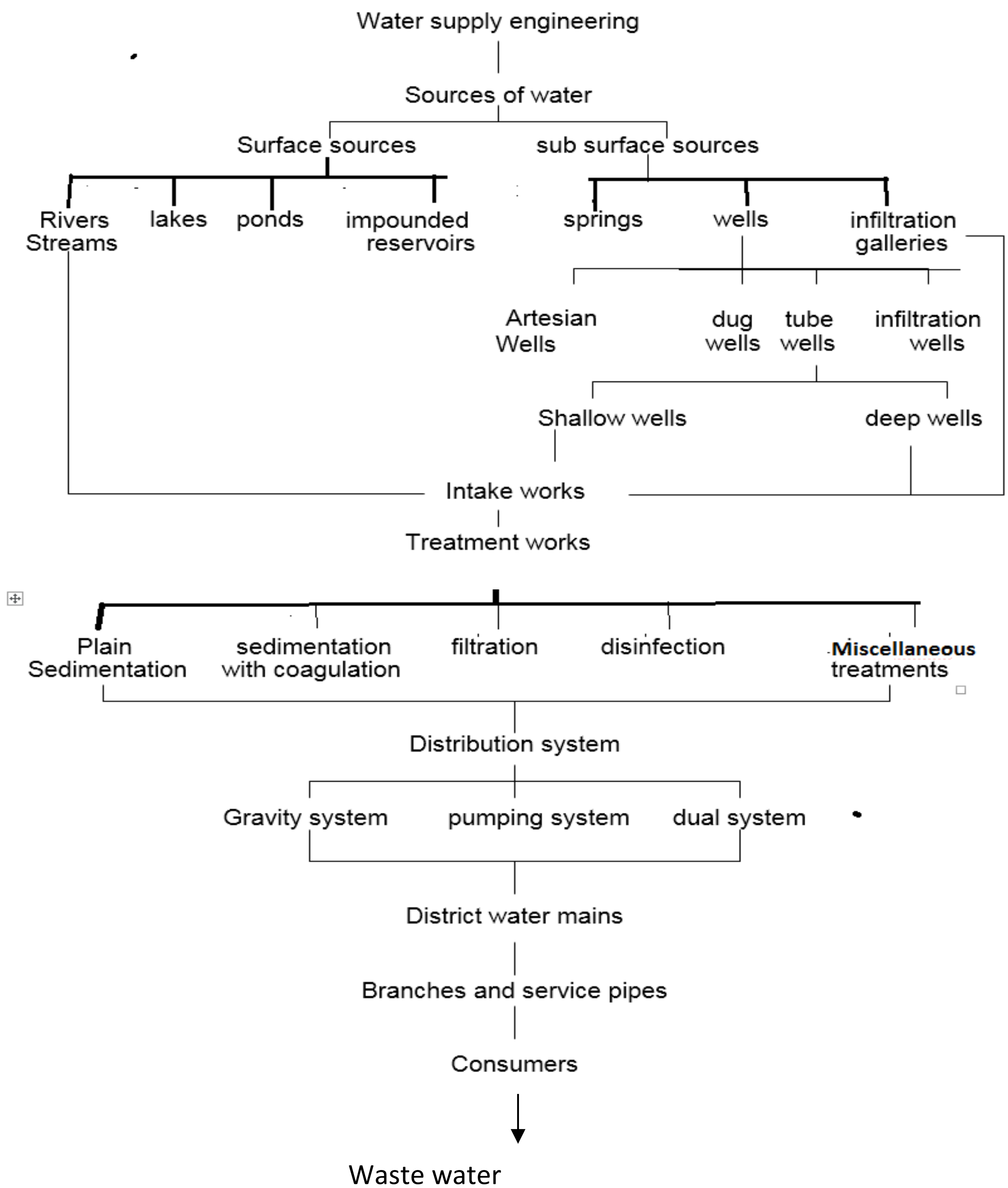
Water softening Desalination- R.O. Plant demineralization Adsorption - Ion exchange Membrane Systems - Iron and Manganese removal - Defluoridation - Construction and Operation and Maintenance aspects

UNIT V WATER DISTRIBUTION AND SUPPLY 9

Requirements of water distribution Components Selection of pipe material Service reservoirs - Functions Network design Economics - Computer applications Appurtenances Leak detection - Principles of design of water supply in buildings House service connection Fixtures and fittings, systems of plumbing and types of plumbing.
TOTAL: 45 PERIODS
TEXTBOOKS :
1. Garg. S.K., "Water Supply Engineering", Khanna Publishers, Delhi, September 2008.
2. Punmia B.C, Arun K.Jain, Ashok K.Jain, Water supply Lakshmi publication private limited, New Delhi, 2016.
3. Rangwala "Water Supply and Sanitary Engineering", February 2022
4. Birdie.G.S., "Water Supply and Sanitary Engineering", Dhanpat Rai and sons, 2018.
REFERENCES :
1. Fair. G.M., Geyer.J.C., "Water Supply and Wastewater Disposal", John Wiley and Sons, 1954.
2. Babbit.H.E, and Donald.J.J, "Water Supply Engineering" , McGraw Hill book Co, 1984.
3. Steel. E.W.et al., "Water Supply Engineering" , Mc Graw Hill International book Co, 1984.
4. Duggal. K.N., of public Health S.Chand and Company Ltd, New Delhi, 1998.

UNIT I

1. Give a flowchart of water supply.



2. What are the objectives of the community water supply system?

- To provide whole some water to the consumers for drinking purpose.

- To supply adequate quantity to meet at least the minimum needs of the individuals
- To make adequate provisions for emergencies like firefighting, festivals, meeting etc.,
- To make provision for future demands due to increase in population, increase in standard of living, storage and conveyance
- To prevent pollution of water at source, storage and conveyance
- To maintain the treatment units and distribution system in good condition with adequate staff and materials
- To design and maintain the system that is economical and reliable.

3. What is meant by whole some water? What are the requirements of wholesome water?

Definition: Wholesome water is defined as the water which containing the minerals in small quantities at requisite levels and free from harmful impurities

Characteristics:

1. It should be free from bacteria
2. It should be tasteless, colorless and odourless.
3. It should not contain dissolved salts.
4. It should be free from objectionable matter
5. It should not corrode pipes
6. It should have dissolved oxygen.

4. What is water demand? Discuss its types.

Water demand is the amount of water that **users need** to meet their needs.

Following are the various types of water demands of a city or town:

- Domestic water demand
- Industrial demand
- Institution and commercial demand
- Demand for public use
- Fire demand
- Loses and wastes

DOMESTIC WATER DEMAND

The quantity of water required in the houses for drinking, bathing, cooking, washing etc is called domestic water demand and mainly depends upon the habits, social status, climatic conditions and customs of the people. The details of the domestic consumption are

Type of consumption	**Usage in liters**
Drinking	5
Cooking	5
Bathing	55
Clothes washing	20
Utensils washing	10
House washing	10
Total Consumption	135 litres

INDUSTRIAL DEMAND

The water required in the industries mainly depends on the type of industries. The water required by factories, paper mills, Cloth mills, Cotton mills, Breweries, Sugar refineries etc. comes under industrial use. The quantity of water demand for industrial purpose is around 20 to 25% of the total demand of the city.

Type of consumption	Unit production/Raw material used	**Usage in Kilo liters**
Automobiles	Vehicle	40
Fertilizer	Ton	80 - 200
Paper	Ton	200 - 400
Textile	Ton	80 - 140
Steel	Ton	200 - 250

INSTITUTION AND COMMERCIAL DEMAND

Universities, Institution, commercial buildings and commercial centers including office buildings, warehouses, stores, hotels, shopping centers, health centers, schools, temple, cinema houses, railway and bus stations etc comes under this category.

Type of Institution/Commercial Establishment	Usage in liters/head/day
Offices	45 – 90
Factories	45 – 90
Hostels	135 – 180
Hotels	180 per bed
Hospitals	340 per bed

DEMAND FOR PUBLIC USE

Quantity of water required for public utility purposes such as for washing and sprinkling on roads, cleaning of sewers, watering of public parks, gardens, public fountains etc., comes under public demand.

FIRE DEMAND

Fire may take place due to faulty electric wires by short circuiting, fire catching materials, explosions etc. During the fire breakdown large quantity of water is required to extinguish it.

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

Where 'Q' is quantity of water required in litres/min

'P' is population of town or city in thousands

LOSES AND WASTES

- Losses due to defective pipe joints, cracked and broken pipes, faulty valves and fittings.
- Losses due to, consumers keep open their taps of public taps even when they are not using the water and allow the continuous wastage of water

5. What is per capita demand? Discuss the factors affecting the same.

Per capita demand of water is the average amount of water each person in a community uses **per day or year**

If'Q'isthetotalquantityofwaterrequiredbyvariouspurposesbyatownper year and 'p' is population of town, then per capita demand will be

Per capita demand = $\boxed{Q/P \times 365 \text{ liters/day}}$

Per capita demand of the town depends on various factors like standard of living, no. and type of commercial places in a town etc .For an average Indian town, the requirement of water in various uses is as under

S.NO.	USE	QUANTITY litres/capita/day
1	Domestic purpose	135
2	Industrial use	40
3	Public use	25
4	Fire Demand	15
5	Losses, Wastage and thefts	55
	TOTAL	270 liters/capita/day

The total quantity of water required by the town per days shall be270 divided by the total population in litres/day.

FACTORS AFFECTING PER CAPITA DEMAND

The following are the main factors affecting for capita demand of the city or town.

Climatic conditions:

- The quantity of water required in hotter and dry places is more than cold countries because of the use of air coolers, air conditioners, sprinkling of water in lawns, gardens, courtyards etc.
- In very cold countries sometimes the quantity of water required may be more due to wastage due to use of hot water for keeping the rooms warm.

Size of community: Water demand is more with increase of size for town because more water is required in street washing, running of sewers, maintenance of parks and gardens.

Living standard of the people: The per capita demand of the town increases with the standard of living of the people.

Industrial and commercial activities: The quantity of water required in certain industries is much more than domestic demand, their presence in the town will enormously increase per capita demand of the town.

Pressure in the distribution system: The rate of water consumption increase in the pressure of the building and even with the required pressure at the farthest point, the consumption of water will automatically increase.

System of sanitation: Per capita demand of the towns having water carriage system will be more than the town where this system is not being used.

Cost of water: If the cost of water is more, less quantity of water will be used by the people as compared when the cost is low.

VARIATIONS IN DEMAND

The per capita demand of town is the average consumption of water for a year. It various from season to season, even hour to hour.

SEASONAL VARIATIONS

The water demand varies from season to season. In summer the water demand is maximum than in winter.

DAILY VARIATIONS

More water demand will be on Sundays and holidays due to more comfortable bathing, washing etc. as compared to other working days.

HOURLY VARIATIONS

On Sundays and other holidays the peak hours may be about 8 A.M. due to late awakening where as it may be 6 A.M. to 10 A.M. and 4 P.M. to 8 P.M. and minimum flow may be between 12P.M. to 4P.M.

6. What is design period?

The number of years for which the designs of the water works have been done is known as design period. Mostly water works are designed for design period of 22-30 years, which is fairly good period.

Design period = 30 years

Project completing period = 02 years

Total = 32 years

Discuss in detail the various Population Forecasting Methods.

When the design period is fixed the next step is to determine the population of a town or city which depends upon the factors like births, deaths, migration and annexation.

- The future development of the town mostly depends upon trade expansion, development industries, and surrounding country, discoveries of mines, construction of railway stations etc.

The following are the standard methods by which the forecasting population is done.

- Arithmetical increase method
- Geometrical increase method
- Incremental increase method
- Simple graph method
- Decrease rate of growth method
- Comparative graph method
- The master plan method

Arithmetic Increase method:

- It is the simple method of population forecast.
- This method is based on the assumption that the **population increase at a constant rate** i.e. dp/dt= constant k

- This method is ideal for old and large and already developed towns and cities. For developing cities it gives lower values. This formula and technique is similar to simple interest calculation.

P_n= (P + n. I) where
P_n = Future population at the end of 'n' decade

P → Present population

n → No. of decades

I → Average increment for a decade.

Problem:
Population of 5 decades from 1930 – 1970 are given below. Find out the population after 1, 2 and 3 decades beyond the last known decade using arithmetic increase method.

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

YEAR	POPULATION	INCREASE IN POPULATION
1930	25000	-
1940	28000	300
1950	34000	600
1960	42000	800
1970	47000	500
	TOTAL	2200
	AVERAGE	550

Solution:

Formula: P_n = (P + n. I)

Population after 1 decade period beyond 1970

P_{1980} = P1970 + 47000 + 1 x 5500 = 52500

YEAR	POPULATION
1980	47000 + 1 x 5500 = 52500
1990	47000 + 1 x 5500 = 58000
2000	47000 + 1 x 5500 = 63500

GEOMETRICAL INCREASE METHOD

- This method is based on the assumption that the **percentage increase in population** from decade to decade remains constant.
- In this method the average percentage of growth of last few decades is determined; the population forecasting is done on the basis that percentage increase per decade will be the same.
- This method is more suitable for a young .and developing city

P_1 = Population after 1 decade = $P_0 + r/100.\ P_0$

= $P_0\,[1 + r/100]$

P_n= Population after 'n' decade

$$P_n = = \quad P_0\ [\,1 + \ r/100\,]^n$$

P_0 = Initial population

P_n = Future population after ;n; decades

r = Assumed growth rate

Assumed growth rate can be calculated as

$$r_n = \frac{Increase\ in\ population}{Original\ population} * 100$$

Geometric mean of growth rate

$$r = \sqrt[t]{r1 * r2 * r3 * \ldots \ldots rn}$$

Problem:

Population of 5 decades from 1930 – 1970 are given below. Find out the population after 1, 2 and 3 decades beyond the last known decade using geometric increase method.

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

YEAR (1)	**POPULATION (2)**	**INCREASE IN POPULATION (3)**	**Percentage increase in population/growth rate 'r' r = Column (3)/Column (2)**
1930	25000	---	
1940	28000	3000	3000/25000 x 100 = 12%
1950	34000	6000	6000/28000 x 100 = 21.4%
1960	42000	8000	8000/42000 x 100 = 23.5%
1970	47000	5000	5000/27000 x 100 = 11.9%

$$\mathrm{r} = \sqrt[t]{r1 * r2 * r3 * \ldots \ldots rn}$$

Geometric mean of growth rate = $\sqrt[4]{12 * 2.4 * 23.5 *}\ 11.9$

= 16.37%

Assume the future population increases at the constant rate of 16.37%

Population after 1 decade = P_{1980} = 47000 [1 + 0.1637]^{1}

= 54694

Population after 2 decade

P_{1990} = 47000 [1 + 0.1637]^{2}

$= 63647$

Population after 3 decade

$$P_{1990} = 47000\ [1 + 0.1637]^3$$

$$= 74066$$

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. This method is best for any cities whether it is new/old.

Mean arithmetic average $= \dot{x}$

Average of incremental increase method $= \bar{y}$

Growth in the first decade $= (\dot{x} + 1. \bar{y})$

Growth in the second decade $= (\dot{x} + 2. \bar{y})$

Growth in the third decade $= (\dot{x} + 3. \bar{y})$

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

Problem:

Population of 5 decades from 1930 – 1970 are given below. Find out the population after 1, 2 and 3 decades beyond the last known decade using incremental increase method.

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

Solution:

YEAR (1)	POPULATION (2)	INCREASE IN POPULATION (3)	Incremental increase /increment on the increase
1930	25000	---	
1940	28000	3000	
1950	34000	6000	(+) 3000
1960	42000	8000	(+) 2000
1970	47000	5000	(-) 3000
Total		22000	(+) 2000
		$\dot{x}$ = 22000/4 = 55000	$\bar{y}$ = 2000/3 = (+) 667

The population at the end of the various decades shall be as follows:

YEAR	EXPECTED POPULATION
1980	$P_{1970} + n\,\dot{x} + \frac{n(n+1)}{2} * \bar{y}$
1990	22500 + (4833 + 1250) x 2 = 34666
2000	22500 + (4833 + 1250) x 3 = 40749

Explain in detail the various sources of water?

Source of water:

On our mother earth only 3% of the total water are fresh or potable water in that 70% of the water is as ice or glacier only the remaining water is accessible. In this all the sources of water can be broadly divided into

1. Surfaces sources and
2. Sub surface sources

Surface sources

- Ponds and Lakes
- Streams and Rivers
- Storage reservoirs
- Oceans

Ponds and Lakes

- The quality of water in the natural ponds and lakes depends upon the basin's capacity, catchment area, annual rainfall, porosity of ground etc.
- Lakes and ponds situated at higher altitudes contain almost pure water which can be used without any treatment.
- But ponds formed due to construction of houses, road, and railways contains large amount of impurities and therefore cannot be used for water supply purposes.

Streams and Rivers

- Rivers and streams are the main source of surface source of water.
- In summer the quality of river water is better than monsoon because in rainy season the run-off water also carries with clay, sand, silt etc., which make the water turbid. So river and stream water require special treatments.

Impounding Reservoirs

- In some rivers the flow becomes very small and cannot meet the requirements of hot weather. In such cases, the water can be stored by constructing a bund, a weir or a dam across the river at such places where minimum area of land is submerged in the water and maximum quantity of water to be stored.

- When water is stored for long time in reservoirs it should be aerated and chlorinated to kill the microscopic organisms which are born in water.

Oceans

- They are highly saline (Brackish water). After desalination only we can consume or use it.

SUBSURFACE SOURCES

It is divided into

- Infiltration galleries
- Infiltration wells
- Springs etc.,

INFILTRATION GALLERIES

- A horizontal nearly horizontal tunnel which is constructed through water bearing strata for tapping underground water near rivers, lakes or streams are called "Infiltration galleries".

INFILTRATION WELLS

- To obtain large quantity of water, the infiltration wells are sunk in series in the banks of river. The wells are closed at top and open at bottom. The water filtrates through the bottom of such wells and as it has to pass through sand bed, it gets purified to some extent. The infiltration well in turn are connected by porous pipes to collecting sump called jack well and their water is pumped to purification plant for treatment.

SPRINGS:

Sometimes ground water reappears at the ground surface in the form of springs. Springs generally supply small quantity of water and hence suitable for the hill towns.

Types of springs:

1. **Gravity Springs:**
2. **Surface Spring:**
3. **Artesian Spring:**

WELLS:

➢ A well is defined as an artificial hole or pit made in the ground for the purpose of tapping water. The three factors which form the basis of theory of wells are

1. Geological conditions of the earth's surface
2. Porosity of various layers
3. Quantity of water, which is absorbed and stored in different layers.

The following are different types of wells

1. Shallow wells
2. Deep wells
3. Tube wells
4. Artesian wells

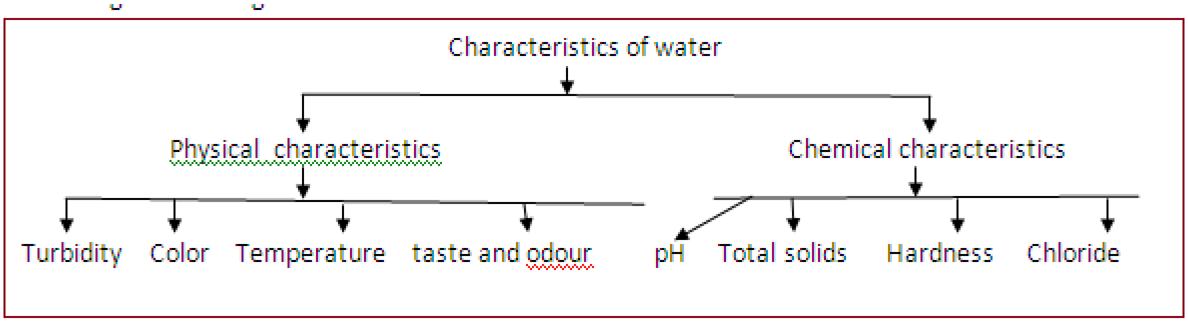
Discuss in detail the characteristics of water.

INTRODUCTION

Absolutely pure water is never found in nature and contains number of impurities in varying amounts. So this water before supplying to the public should be treated and purified for the safety of public health, economy and protection of various industrial process, it is most essential for the water work engineer to thoroughly check analyze and do the treatment of the raw water obtained the sources, before its distribution. The water supplied to the public should be strictly according to the standards laid down from time to time.

CHARACTERISTICS OF WATER

For the purpose of classification, the impurities present in water may be divided into the following three categories.



PHYSICAL CHARACTERISTICS

The following are the physical characteristics

1. Turbidity
2. Colour and temperature
3. Taste and odour

TURBIDITY

- Turbidity is caused due to presence of suspended and colloidal matter in the water.
- Turbidity is a measure of resistance of water to the passage of light through it.
- Turbidity is expressed as NTU (Nephelometric Turbidity Units) or PPM (parts per million) or Milligrams per litre (mg/l). Turbidity is measured by
  1) Turbidity rod or Tape
  2) Jacksons Turbidimeter
  3) Bali's Turbidimeter
- The Sample to be tested is poured into a test tube and placed in the meter and units of turbidity is read directly on the scale by a needle or by digital display. Drinking water should not have turbidity more than 10 N.T.U.

COLOUR ANDTEMPERATURE

- Color in water is usually due to organic matter, mineral and dissolved organic impurities.
- The color produced by one milligram of platinum in a litre of water has been fixed as the unit of color.
- The permissible colour for domestic water is 20ppm on platinum cobalt scale. The colour in water is not harmful but objectionable.
- Temperature of water is measured by means of ordinary thermometers.
- The most desirable temperature for public supply between 4.4°C to 10°C.

TASTE AND ODOUR

- Taste and odour in water may be due to presence of dead or live micro-organisms, dissolved gases such as hydrogen sulphide, methane, carbon dioxide etc.
- The tests of these are done by sense of smell and taste.
- The water having bad smell and odour is objectionable and should not be supplied to the public.
- The intensities of the odour are measured in terms of threshold number. This number is numerically equal to the amount of sample of water required to be added to one litre of fresh odourless water.

CHEMICAL CHARACTERISTICS

- Total solids
- PH value
- Hardness of water
- Chloride content etc.

TOTAL SOLIDS AND SUSPENDED SOLIDS

- Total solids include the solids in suspension colloidal and in dissolved form.
- **The total solids in a water sample** can be directly determined by evaporating the water and weighing the residue
- The **quantity of suspended solids is** determined by filtering the sample of water through fine filter, drying and weighing.
- The filtered water contains **dissolved solids can be determined** by evaporating and weighing the residue.

PH VALUE OF WATER

- PH value denotes the concentration of hydrogen ions in the water and it is a measure of acidity or alkalinity of a substance.

$$PH = - \log 10[H+]$$

- For pure water, PH value is 7 and 0 to 7 acidic and 7 to 14 alkaline range.
- For public water supply PH value may be **6.5 to 8.5**.
- The lower value may cause corrosion.
- High value may produce sediment deposits and other bad effects.

- PH value of water is generally determined by PH papers or by using PH meter.

HARDNESS OF WATER

- It is a property of water, which prevents the lathering of the soap. Hardness is of two types.
- Temporary hardness: It is caused due to the presence of carbonates and sulphates of calcium and magnesium. It is removed by boiling.
- 2. Permanent hardness: It is caused due to the presence of chlorides and nitrates of calcium and magnesium. It is removed by zeolite method.
- Hardness is usually expressed in gm/litre or p.p.m. of calcium carbonate in water. Hardness of water is determined by EDTA method. For potable water hardness ranges from 5 to 8 degrees.

Drawbacks:

1. Large soap consumption in washing and bathing
2. Hard water is not fit for industrial use like textiles, paper making etc.
3. Precipitates can choke pipe lines and values
4. It forms scales in the boilers tubes and reduces their efficiency.
5. Very hard water is not palatable.

METHODS OF REMOVAL OF HARDNESS

1. Boiling
2. Lime soda process
3. Caustic soda process
4. Zeolite process
5. Demineralization or exchange process.

CHLORIDE CONTENT

- The natural waters near the mines and sea dissolve sodium chloride and also presence of chlorides may be due to mixing of saline water and sewage in the water.
- Excess of chlorides is dangerous and unfit for use. The chlorides can be reduced by diluting the water.
- Chlorides above 250p.p.m. are not permissible in water.

NITROGEN CONTENT

- The presence of nitrogen in the water indicates the presence of organic matters in the water. The nitrogen may be present in the water may be in one or more of the following forms.

  1. Nitrates
  2. Nitrates
  3. Free ammonia

- Excess presence of nitrogen will cause "MATHEMOGLOBINEMIA" disease to the children.

METALS AND OTHER CHEMICAL SUBSTANCES

- Water contains various minerals or metal substances such as iron, manganese, copper, lead, barium, cadmium, selenium, fluoride, arsenic etc.
- The concentration of iron and manganese should not allow more than 0.3 ppm.
- Excess will cause discoloration of clothes during washing.
- Lead and barium are very toxic, low ppm of these is allowed.
- Arsenic, Selenium are poisonous and may cause totally, therefore they must be removed totally.

DISSOLVED GASES

- Oxygen and carbon di-oxide are the gases mostly found in the natural water.
- The presence of oxygen in the water in dissolved form keep it fresh and sparkling

BACTERIAL AND MICROSCOPICAL CHARACTERISTICS

- The examination of water for the presence of bacteria is important for the water supply engineer from the viewpoint of public health. The bacteria may be harmless or harmful to mankind

BIO-CHEMICAL OXYGEN DEMAND

- It is the measure of extent of pollution
- It is defined as the amount of oxygen required by the bacteria for the oxidation of organic matter present in water.

Write a note on Drinking water quality standards

IS 10500:2012 gave a standard quality for the drinking water parameters. Since drinking water is for consumption of humans certain limits have been given in order for the safety of consumer's health.

Parameters	Permissible Limit
pH	6.5-8.5
Odour	Agreeable
Taste	Agreeable
Colour	5 Hazen units
Turbidity	1 NTU
Total Dissolved Solids	500 mg/l
Aluminum	0.05 mg/l
Calcium	75 mg/l
Chloride	250 mg/l
Fluoride	1 mg/l
Cadmium	0.003 mg/l
Iron	0.3 mg/l
Magnesium	30 mg/l
Nitrate	45 mg/l
Copper	0.05 mg/l
Silver	0.1 mg/l
Zinc	5 mg/l
Lead	0.01 mg/l
Mercury	0.001 mg/l
Nickel	0.02 mg/l
Chromium	0.05 mg/l
Hardness (as CaCo3 mg/l)	200
Alkalinity (as CaCo3 mg/l)	200

Unit II

WATER SUPPLY OR DISTRIBUTION SYSTEM

After treatment, water is to be stored temporarily and supplied to the consumers through the network of pipelines called distribution system. The distribution system also includes pumps, reservoirs, pipe fittings, instruments for measurement of pressures, flow leak detectors etc. Ultimate aim is to supply potable water to all the consumers whenever required in sufficient quantity with required pressure with least lost and without any leakage.

1. What are the requirements of a distribution system?

- They should convey the treated water up to consumers with the same degree of purity.
- The system should be economical and easy to maintain and operate
- The diameter of pipes should be designed to meet the fire demand
- It should safe against any future pollution.
- As per as possible should not be laid below sewer lines.
- Water should be supplied without interruption even when repairs are undertaken

- The system should be so designed that the supply should meet maximum hourly demand.
- A peak factor 2.5 is recommended for the towns of population
- For larger population a factor of 2.0 will be adequate.
- Capable of supplying water at all places with adequate pressure head.
- Capable of meeting firefighting needs.
- Cheap, simple and easy to operate and repair.
- Safe against pollution.

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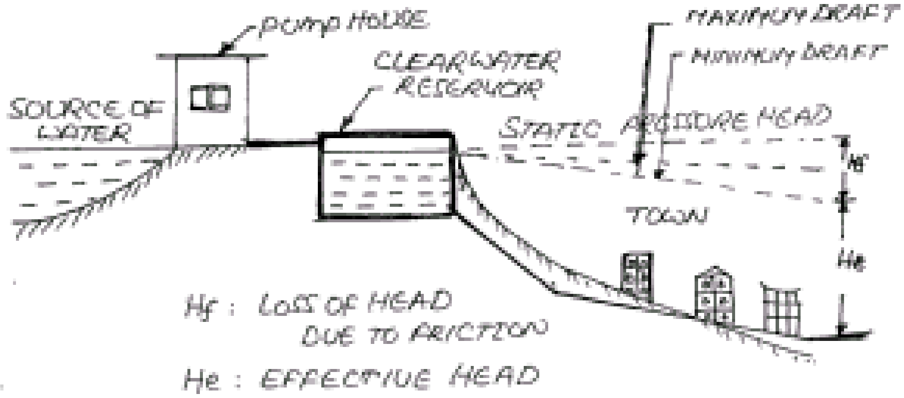
2. What are the different types of distribution system?

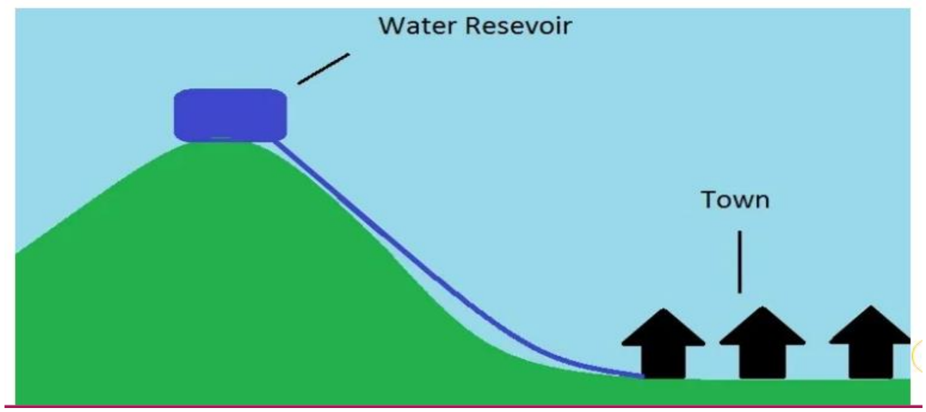
Depending upon the methods of distribution, the distribution system is classified as the follows

1. Gravity system
2. Pumping system
3. Dual system or combined gravity and pumping system

GRAVITY SYSTEM

- In this system, the water from the high leveled source is distributed to the consumers to the lower levels by the action of gravity without any pumping.
- This method is suitable when the source of supply such as lake, river or impounding reservoir is at sufficiently higher than city.
- This method is the most economical and reliable, since no pumping is involved at any stage.

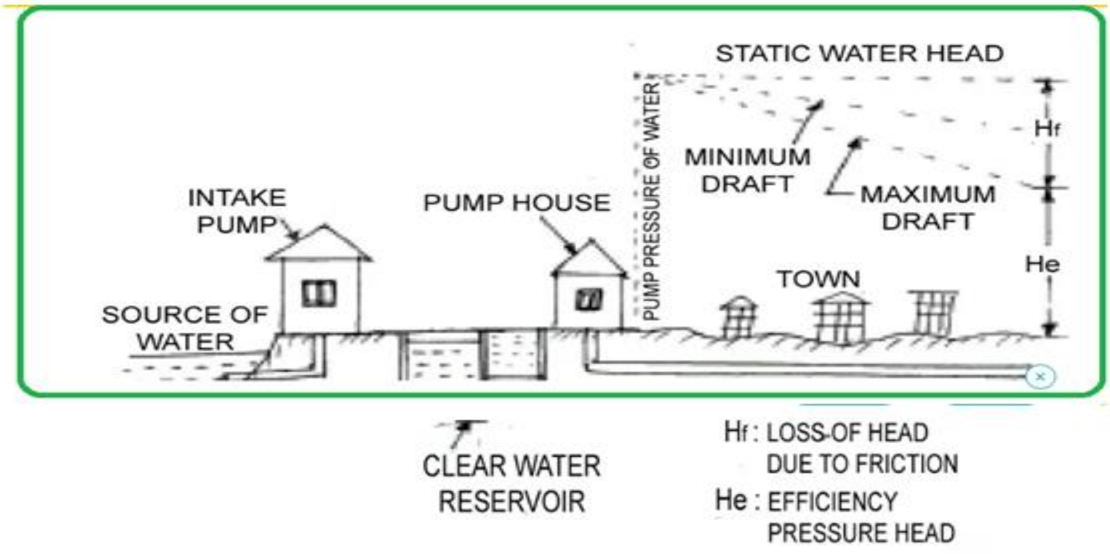




PUMPING SYSTEM

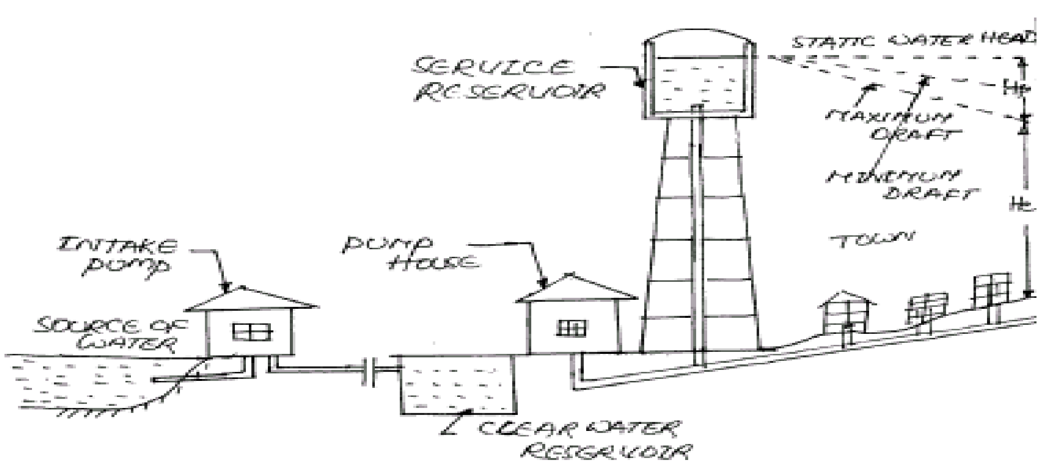
- In the pumping system, the treated water is directly pumped in to the distribution mains without storing it anywhere.
- High lift pumps are required in this system, which have to operate at variable speeds, so as to meet the variable demand of water.
- Constant pressure can be maintained in the system by direct pumping into mains.

If the power supply fails, there will be complete stoppage of water supply. Hence diesel pumps also in addition to electrical pumps as stand by to be



COMBINED PUMPING AND GRAVITY SYSTEM

- In this system, the treated water is pumped at a constant rate and stored into a elevated distribution reservoir, from where it is distributed to the consumers by the mere action of gravity.
- This method thus, combines pumping as well as gravity flow, and is sometimes called pumping with storage system.
- As in this system water comes from two sources one from reservoir and second from pumping station, it is called dual system. This system is more reliable and economical



CONTINUOUS SYSTEM

- This is the best system and water is supplied for all 24 hours.
- This system is possible when there is adequate quantity of water for supply.
- In this system sample of water is always available for firefighting and due to continuous circulation water always remains fresh.
- In this system less diameter of pipes are required and rusting of pipes will be less.
- Losses will be more if there are leakages in the system.

INTERMITTENT SYSTEM

- If plenty of water is not available, the supply of water is divided into zones and each zone is supplied with water for fixed hours in a day or on alternate days.
- As the water is supplied after intervals, it is called intermittent system.
- The system has following disadvantages:
    - Pipelines are likely to rust faster due to alternate wetting and drying.
    - This increases the maintenance cost.
    - There is also pollution of water by ingress of polluted water through leaks during non-flow periods.
    - More wastage of water due to the tendency of the people to store more water than required quantity and to waste the excess to collect fresh water each time.

Intake Structures:

The main function of the intakes work is to collect water **from the surface source** and then discharge water so collected, by means of pumps or directly **to the treatment of water**.

Intakes are structures which essentially consist of opening, grating or strainer(screen) through which the raw water from river, canal or reservoir enters and carried to the sump well by means of conduits. Water from the sump well is pumped through the rising mains to the treatment plant.

The following points should be kept in mind while selecting a site for intake:

1. Where the best quality of water available so that water is purified economically in less time.
2. At site there should not be heavy current of water, which may damage the intake structure.
3. The intake can draw sufficient quantity of water even in the worst condition, when the discharge of the source is minimum.
4. The site of the work should be easily approachable without any obstruction.
5. The site should not be located in navigation channels.
6. As per as possible the intake should be near the treatment plant so that conveyance cost is reduced from source to the water works.
7. As far as possible the intake should not be located in the vicinity of the point of sewage disposal for avoiding the pollution of water.
8. At the site sufficient quantity should be available for the future expansion of the water-works.

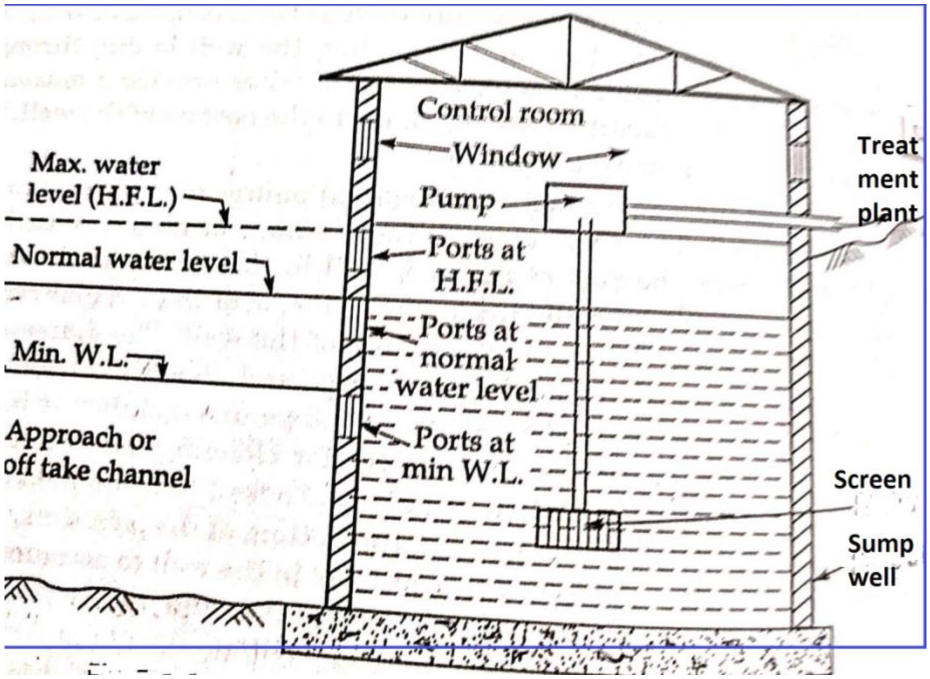
Types of Intake structures

Depending upon the source of water the intake works are classified as following

- River Intake
- Reservoir Intake
- Lake Intake
- Canal Intake

River intake

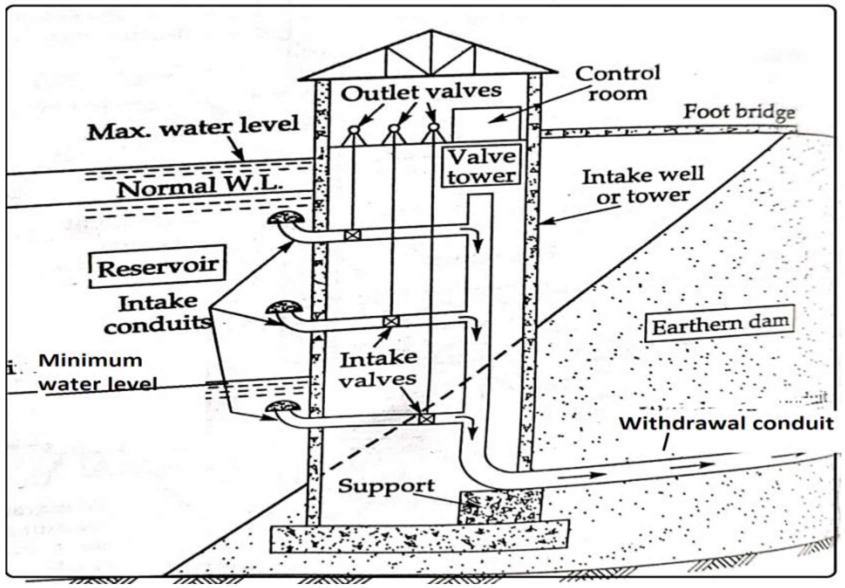
- It is a type of intake which may either located sufficiently inside the river or they may be located near the river bank where a sufficient depth of water is available.
- Sometimes, an approach channel is constructed and water is led to the intake tower.
- It is circular masonry tower of 4 to 7 m in diameter constructed along the bank of the river
- The water enters in the lower portion of the intake known as sump well from penstocks.



Reservoir intake

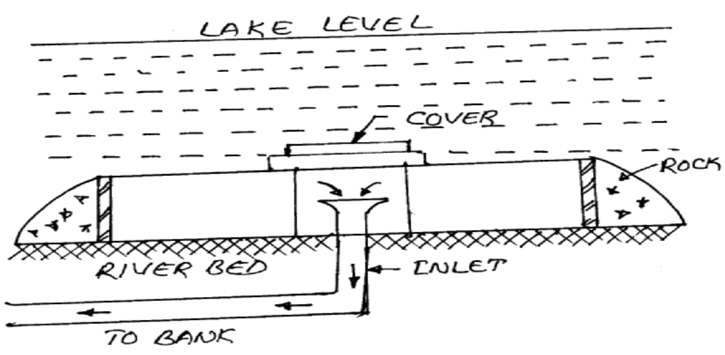
- It consists of an intake well, which is placed near the dam and connected to the top of dam by footbridge.
- The intake pipes are located at different levels with common vertical pipe.
- The valves of intake pipes are operated from the top and they are installed in a valve room.
- Each intake pipe is provided with bell mouth entry with perforations of fine screen on its surface.
- The outlet pipe is taken out through the body of dam. The outlet pipe should be suitably supported.
- The location of intake pipes at different levels ensures supply of water from a level lower than the surface level of water.
- When the valve of an intake pipe is opened the water is drawn off from the reservoir to the outlet pipe through the common vertical pipe.

- To reach up to the bottom of intake from the floor of valve room, the steps should be provided in Zigzag manner.



Lake Intake

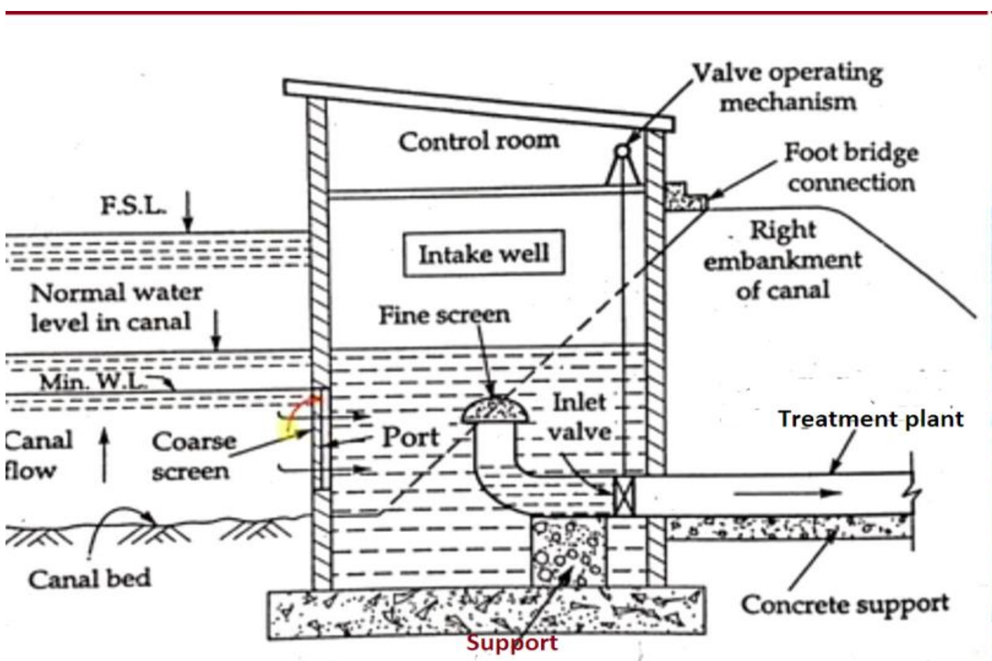
- For obtaining water from lakes mostly submersible intakes are used.
- These intakes are constructed in the bed of the lake below the water level; so as to draw water in dry season also.



Lake intake

Canal Intake

- An intake chamber is constructed in the canal section. This results in the reduction of water way which increases the velocity of flow. It therefore becomes necessary to provide pitching on the downstream and upstream portion of canal intake. The entry of water in the intake chamber takes through coarse screen and the top of outlet pipe is provided with fine screen. The inlet to outlet pipe is of bell-mouth shape with perforations of the fine screen on its surface. The outlet valve is operated from the top and it controls the entry of water into the outlet pipe from where it is taken to the treatment plant.



Design considerations

- Provide for withdrawal from more than one place.
- Provide under sluices to release less desirable water.
- Intake near a navigation channel.
- Protect against blows by providing cluster of piers.
- Understanding of foundations due to scour to be avoided.
- Provide overturning pressures due to silt deposition.
- Coarse Screens: Prevent entrance of large particles.

- Fine Screen: Exclusion of small fish and small objects.
- Area of opening: entrance velocity less than 8 m/min (avoid entry of settelable matter into intake port).
- Submerged ports: depth of water over the port = 3 x D opening.
- Under Conduits: Standard CI pipe, Steel, Concrete.
- Velocity in conduit: 60 to 90 cm/s (lower velocity through ports).
- Area of suction well: 3 to 5 times the area of the conduit.
- Intake conduit: Continuously rising / falling.

What are the requirements of pipe material?

Pipes convey raw water from the source to the treatment plants in the distribution system.

Requirements of pipe material

1. It should be capable of withstanding internal and external pressures
2. It should have facility of easy joints
3. It should be available in all sizes, transport and erection should be easy.
4. It should be durable
5. It should not react with water to alter its quality
6. Cost of pipes should be less
7. Frictional head loss should be minimum.
8. The damaged units should be replaced easily.

What are the different types of Pipes and mention its Characteristics?

The principal types of pipes that are available in the market in the water distribution systems are as follow.

- Cast iron pipes and fitting
- Plastic or PVC pipes
- Galvanized steel (GI) pipes
- Stoneware pipes
- Asbestos Cement (AC) pipes
- Concrete pipes

CAST IRON PIPES

- Cast iron pipes and fitting are primarily used for designing of soil and rain water disposal systems.
- These pipes are made by the sand cast process or by spinning.
- Sand cast pipes are made by pouring molten cast iron into vertically mounted sand mould.
- Spun pipes are made by pouring molten grey cast iron into a revolving water cooled mould, producing a seamless pipe in length up to 3 meter with thickness less than sand cast pipes.

PLASTIC OR PVC PIPES

There are 3 common types of plastic pipes

1. Unplasticized PVC (UPVC) or rigid pipes for use with cold water
2. Plasticized PVC pipes which are plasticized with addition of rubber. It has lower strength and lower working temperature than UPVC pipes.
3. Chlorinated PVC (CPVC) pipes which can withstand higher temperatures upto 120^0 (used to carry hot water)
   - Rigid PVC pipes are used for distribution of water with temperature below 45^0C.
   - These pipes are costlier than AC pipes but cheaper than GI pipes.

GALVANIZED STEEL (GI) PIPES

- GI pipes are made from steel pipes. The galvanizing process deposits a thin coating of zinc which protects it from corrosion.
- They are available in light, medium and heavy grades depending on the thickness of the metal.
- Generally the medium grade pipes are used for internal plumbing in building.
- These pipes corrode easily if it carries brackish water or concealed in lime concrete and brickwork or buried under the ground.
- These pipes are costlier than PVC pipes.

STONEWARE PIPES

- These pipes are available in the form of internal diameters 10 mm to 600 mm with thickness varying from 12 mm to 43 mm.
- A good stoneware pipe should give a sharp clear tone when struck with a light hammer.

- These pipes are extensively used as underground drainage pipes in low cost construction buildings. These pipes are cheap.

ASBESTOS CEMENT (AC) PIPES

- These pipes are used for drainage of rainwater from roofs, soil and waste and also for ventilation.
- They come in two profiles – one with beading around socket (WB) and the other without beading around socket (WOB).
- The pipes come in lengths of 3 meters.
- The principal defects of these pipes are that they are heavy and they break easily.
- These pipes are cheaper than PVC pipes.

CONCRETE PIPES

- Unreinforced pipes of small diameters as well as reinforced and prestressed concrete pipes of large diameters are available for water supply and other uses.
- Small unreinforced concrete pipes are very much used for drainage of rain water.
- Large diameter pipes are generally used for major water supply works.

What are the ways to maintain the pipes?

Hygienic quality and adequate flow in the pipe lines are to be maintained, preventive maintenance of pipes includes the following

- Detection of leaks in faulty joints ferrule connections, pipes and fittings inside the consumer premises.
- Detection of corrosion in pipes, fractures and replacement of these portions.
- The wastage of water 15 to 25% of leakage through pipe joints should be brought down to the minimum possible extent by adopting suitable preventive measures.
- Cleaning of pipes by flushing and disinfection of pipes.
- Protection against pollution.

What is Pipe Corrosion? Mention its Causes And Prevention.

The term pipe corrosion is used to indicate the loss of pipe material due to action of water (Internal pipe corrosion) and action of water logged soil above the pipe surface (external pipe corrosion).

The various factors contributing the pipe corrosion are

- **ACIDITY:** The water having low PH value due to the presence of carbonic acid or other acids may cause corrosion.
- **ALKANITY:** The water possessing sufficient calcium bicarbonate alkalinity is anti-corrosive in nature.
- **BIOLOGICAL ACTION:** The growth of iron-bacteria, and sulphur bacteria may develop aerobic and anaerobic corrosion respectively.
- **CHLORINATION:** The presence of free chlorine or chloramines makes the water corrosive.
- **ELECTRICAL CURRENTS:** Corrosion canals also be developed by the union of dissimilar metals or by the earthen of electrical system to water pipes.
- **MINERAL AND ORGANIC CONSTITUENTS:** The presence of high total solids in water accelerates the process of corrosion.
- **OXYGEN:** the presence of oxygen is found in both the corrosive and non-corrosive waters. The aeration is employed in some cases for prevention of corrosion.

EFFECTS OF PIPE CORROSION

- ✓ Pipe corrosion may lead to the tuberculation (formation of small projections on the inside surface of pipe) which decreases carrying capacity of water.
- ✓ The pipe corrosion leads to the disintegration of pipeline and it demands heavy repairs.
- ✓ The pipe corrosion imparts colour, taste and odour to the flowing water.
- ✓ The pipe connections are seriously affected by pipe corrosion.
- ✓ The pipe corrosion may make the water dangerous for drinking and other purposes.

PREVENTION OF PIPE CORROSION

Pipe corrosion is not possible to completely eliminate but we can minimize by the following methods.

- **Cathodic protection:** By connecting the pipe line to the negative pole of D.C. generator or to the anode metals like magnesium so that the entire pipe acts as cathode. This cathodic treatment is most effective. It is expensive and involves many practical problems.

- **Proper pipe material:** The alloys of Iron or steel with chromium, copper or nickel are found to be more resistance.
- **Protective Linings:** The pipe surface should be coated with asphalt, bitumen, cement mortar, paints, resins, tar, zinc etc.
- **Treatment of water:** By proper treatment and adjustment of PH value, control of calcium carbonate, removal dissolved oxygen and carbon dioxide, addition of sodium silicate etc prevent the pipe corrosion.

What are the various testing of pipes?

- Pipe lines carrying water are laid 0.6m to 1m below the ground surface.
- Just before covering the trench with the earth, the pipe joints are to be tested for leakage.
- Joints are inspected visually during the test and re-laid wherever required.
- Pressure of pumping mains is tested for 1½times the operating pressure in the pipe for 24hours.
- The pressure is increased gradually at the rate of 1kg/cm2/minute.
- Loss of water by leakage is made up at not more than 0.1lit/mm of diameter of pipe per km per day for every 0.3N/mm2 pressure applied.

Leakage test

Allowable leakage during test is calculated by a formula $QL = ND\sqrt{p}/3.3$

Where

QL→ Allowable leakage in cm3/hr

N→ No. of joints in the length of pipe line

P→ Average test pressure during the leakage test in kg/cm2

D→ diameter of pipe in mm

The above value is applicable for C.I., A.C. and concrete pipes. For steel and pre stressed concrete pipes 3 times the above value is allowed. Gravity pipes are tested with hydro static head of 2.5m at the highest point in the pipe for 10minutes and permissible leakage is 0.2litres/mm of diameter pipe per day per kilometer length.

Write a note on Pipe joints

The pipe joints are required to join together pipes which are available in smaller lengths say 36m to 6m only. The requisites of a jointing material are

–Imperviousness
–Elasticity
–Strength
–Durability
–Adhesiveness
–Availability
–Workability
–Economy

Types of joints

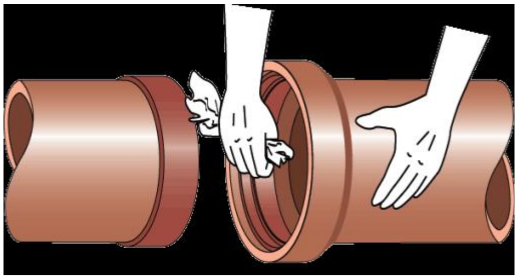
- Poured joints
- Spigot and Socket joint
- Flanged joint
- Mechanical joints
- Joints for concrete and Asbestos cement pipes
- Screwed and socketed joint
- Special joints

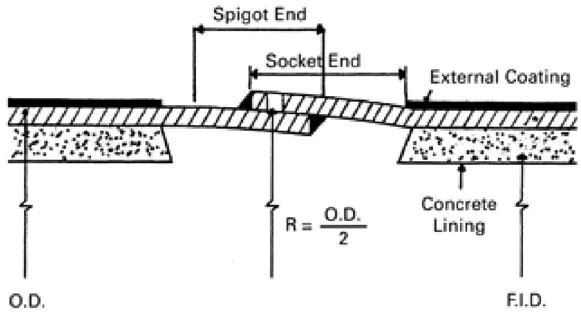
Poured joints

- Materials chiefly used are lead, cement grout, Sulphur and sand compounds.
- Nowadays, substitutes of lead like leadite, hydrotite and metalium are being increasingly used.
- They have such advantages to offer as light in weight.

Spigot and Socket joints

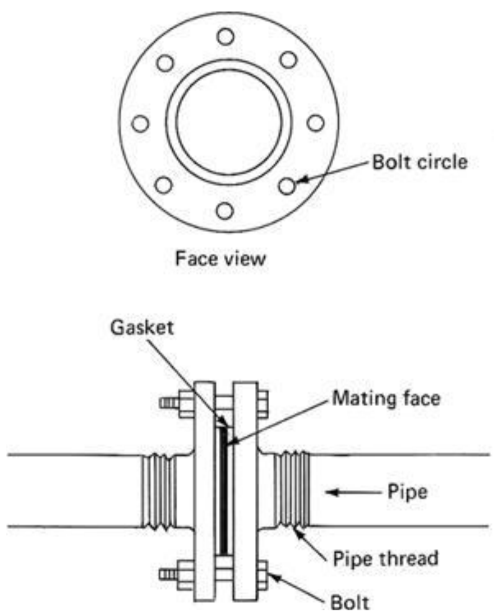
- Spigot and sockets involve a normal pipe end, the spigot, being inserted into the socket or bell of another pipe or fitting with a seal being made between the two with in the socket.
- Normal spigot and socket joints do not allow direct metal to metal contact with all forces being transmitted through the elastomeric seal.
- They can consequently flex and allow some degree of rotation, allowing pipes to shift and relieve stresses imposed by soil movement.
- A large number of different socket and seals exist.





Flanged joint

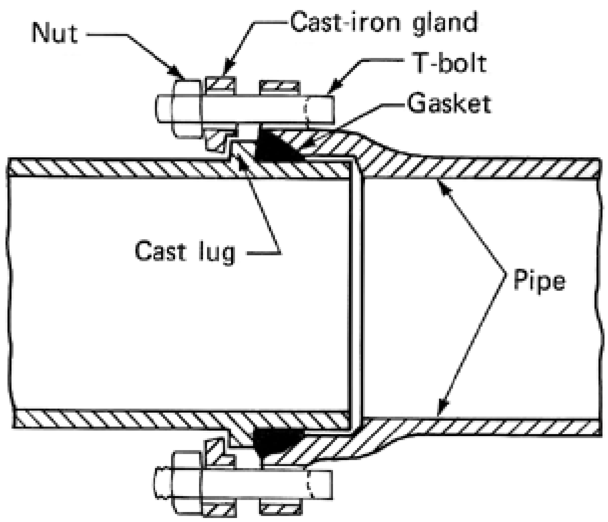
- A gasket of rubber, canvas or lead is introduced in between the two flange plates of cast iron pipes, which is then tightened with bolts and nuts.
- Flanged joints are strong and rigid and are easy to disjoint; as such used where the pipe-joints have to be occasionally opened out for carrying out repair work, as in pumping chambers.



Mechanical Joint

- The joint has four parts: a flange cast with a bell; a rubber gasket that fits in the bell socket; a gland, or follower ring, to compress the gasket; and tee head bolts and nuts for tightening the joint.

- Joint assembly is labor-intensive but very simple and requires only one tool an ordinary ratchet wrench.
- The mechanical joint is used mainly with fittings rather than pipe.



Screwed and Socketed Joint

The two ends of the pipes are threaded on the outside and on the suitable jointing compound with a grummet of a few strands of fine yarn are used before screwing a socket having corresponding threads from inside.

Pipe fittings:

- Fittings
- Elbows
- Tee
- Union
- Bushing
- Reducer
- Coupling
- Cap/Plug
- Nipple

Fitting: a joint or connector, as an elbow, union, or tee, used in a pipe system.

Couplings: require significant motion of pipes, particularly along the axis of the pipe. Typically used during installation of a plumbing system.

Unions: Require minimal longitudinal motion of the pipe. Typically used to install and exchange appliances after plumbing system has been constructed.

Bushings: used to change pipe size.

Elbows: 90ºand45º

Nipple: a short piece of pipe, threaded on both ends, used to connect two fittings.

What are Appurtenances in the Distribution System? Discuss in detail.

The various devices fixed along the water distribution system are known as Appurtenances. The necessity of the various appurtenances in distribution system is as follows

1. To control the rate of flow of water
2. To release or admit air into pipeline according to the situation
3. To prevent or detect leakages
4. To meet the demand during emergency and
5. Ultimately to improve the efficiency of the distribution

The following are the some of the fixtures used in the distribution system.

(i) Valves

(ii) Fire hydrants and

(iii)Water meter

TYPES OF VALVES

In water works practice, to control the flow of water, to regulate pressure, to release or to admit air, prevent flow of water in opposite direction valves are required. The following are the various types of valves named to suit their function

1. Sluice valves
2. Check valves or reflex valves
3. Air valves
4. Drain valves or Blow off valves
5. Scour valve

SLUICE VALVES

- These are also known as gate-valves or stop valves.

- These valve control the flow of water through pipes.
- These valves are cheaper, offers less resistance to the flow of water than other valves.
- The entire distribution system is decided into blocks by providing these valves at appropriate places.
- They are provided in straight pipeline at 150-200m intervals. When two pipes lines interest, valves are fixed in both sides of intersection.
- When sluice valve is closed, it shuts off water in a pipeline to enable to undertake repairs in that particular block. The flow of water can be controlled by raising or lowering the handle or wheel.

CHECK VALVE or REFLUX VALVE

- These valves are also known as non-return valves.
- A reflux valve is an automatic device which allows water to go in one direction only.
- When the water moves in the direction of arrow, the valve swings or rotates around the pivot and it is kept in open position due to the pressure of water. When the flow of water in this direction ceases, the water tries to flow in a backward direction. But this valve prevents passage of water in the reverse direction.
- Reflux valve is invariably placed in water pipe, which obtain water directly from pump. When pump fails or stops, the water will not run back to the pump and thus pumping equipment's will be saved from damage.

AIR VALVES

These are automatic valves and are of two types namely

1. Air inlet valves
2. Air relief valves

AIR INLET VALVES

- These valves open automatically and allow air to enter into the pipeline so that the development of negative pressure can be avoided in the pipelines. The vacuum pressure created in the down streamside in pipelines due to sudden closure of sluice valves. This situation can be avoided by using the air inlet valves.

AIR RELIEF VALVES

- Sometimes air is accumulated at the summit of pipelines and blocks the flow of water due to airlock. In such cases the accumulated air has to be removed from the pipe lines.
- This is done automatically by means of air relief valves. This valve consists of a chamber in which one or two floats are placed and is connected to the pipe line.
- When there is flow under pressure in the pipeline water occupies the float chamber and makes the float to close the outlet. But where there is accumulation of air in the pipeline, air enters the chamber, makes the float to come down, thus opening the outlet. The accumulated air is driven out through the outlet.

DRAIN VALVES OR BLOW OFF VALVES

- These are also called wash out valves they are provided at all dead ends and depression of pipelines to drain out the waste water. These are ordinary valves operated by hand.

SCOUR VALVES

- These are similar to blow off valves. They are ordinary valves operated by hand. They are located at the depressions and dead ends to remove the accumulated silt and sand. After the complete removal of silt; the value is to be closed.

WATER METER

- These are the devices which are installed on the pipes to measure the quantity of water flowing at a particular point along the pipe. The readings obtained from the meters help in working out the quantity of water supplied and thus the consumers can be charged accordingly. The water meters are usually installed to supply water to industries, hotels, big institutions etc. metering prevents the wastage of purified water.

FIRE HYDRANTS

- A hydrant is an outlet provided in water pipe for tapping water mainly in case of fire. They are located at 100 to 150 m a part along the roads and also at junction roads. They are of two types namely.

  1. Flush Hydrants.

  2. Post Hydrants

Flush Hydrants

The flush hydrants is kept in underground chamber flush with footpath covered by C.I. cover carrying a sign board "F-H".

Post Hydrants

The post hydrant remain projected 60 to 90cm above ground level. They have long stem with screw and nut to regulate the flow. In case of fire accident, the firefighting squad connect their hose to the hydrant and draw the water and spray it on fire. A good fire hydrant

1. Should be cheap
2. Easy to connect with hose
3. Easily detachable and reliable
4. Should draw large quantity of water

BERNOULLI'S THEOREM

It states that in a steady, irrational flow of an incompressible fluid, the total energy at any point is constant. The above statement is based on the assumption that there are no losses due to friction in pipe

Mathematically $Z + \frac{V2}{2g} + \frac{P}{W} = \text{constant}$

Where

Z = Potential energy

V2 / 2g = Velocity energy

P/w = Pressure energy

LOSSES OF HEAD IN PIPES

When a liquid is flowing in pipe, it loses energy or head due to friction of wall, change of cross section or obstruction in the flow. All such losses are expressed in terms of velocity head. The following are losses which occur in a flowing fluid.

1. Loss of head due to friction
2. Loss of head due to sudden enlargement
3. Loss of head due to sudden contraction

4. Loss of head due to bends

5. Loss of head at entrance

6. Loss of head at exit.

LOSS OF HEAD DUE TO FRICTION

When the water is flowing in a pipe, it experiences some resistance to its motion. This reduces the velocity and ultimately the head of water available. The major loss is due to frictional resistance of the pipe only.

Darcy's formula is used to calculate the loss of head in pipes due to friction; neglecting minor losses

$$Hf = \frac{4 f l v2}{2 g d}$$

Where

f → frictional resistance

l → Length of pipe

f → frictional resistance

v → velocity of water in the pipe

d → diameter of pipe

hf → loss of head due to friction

QL → discharge through pipe

LOSS OF HEAD DUE TO SUDDEN ENLARGEMENT

Consider a liquid flowing in a pipe ABC, having sudden enlargement at 'B'. There is a loss of head due to this sudden enlargement as given below.

$$he = \frac{(V1 - V2)2}{2 g}$$

Where

V1 = Velocity of liquid at section 1 – 1

V2 = Velocity of liquid at section 2 – 2

G = acceleration due to gravity

He = Loss head due to sudden enlargement

LOSS OF HEAD DUE TO SUDDEN CONTRACTION

Consider a liquid flowing in a pipe ABC, having sudden contraction at B, when flowing through a narrow pipe, the liquid will get contracted at 1 – 1 forming vena contracta. It is note that the loss of head due to sudden contraction is not due to the contraction itself but it is due to sudden enlargement which takes place after contraction

Loss of head due to sudden contraction

$$hc = \frac{(V1 - V2)2}{2\,g}$$

[∴ a1 V1 = a2 V2]

V1 = V2 / 0.62

[∴ a2 / a1 = Cc]

[V2 / 0.62 – V2]

Note:

1) The above equation is valid when Cc = 0.62, which actually depends upon type of orifice.

2) The actual loss of head depends upon ratio d1 / d2.

LOSS OF HEAD DUE TO BENDS

When the direction of a length changes such as at the bends in a pipe line, some of the liquid energy is lost.

Loss of head due to bends = k V2 / 2 g

Where

'k' coefficient which depends upon angle and radius of bend

K = 1 for 90° elbows

V = Velocity of liquid in the pipe

g = acceleration due to gravity

LOSS OF HEAD AT THE ENTRANCE

The loss of head due to entrance in a pipe is actually a loss of head due to sudden contraction and depends upon the form of entrance.

Loss of head at entrance = 0.5 $V2 / 2g$

Where

V = Velocity of liquid in the pipe

g = acceleration due to gravity

LOSS OF HEAD DUE TO EXIT

The loss of head due to exit in a pipe is actually a loss due to energy of head of flowing liquid by virtue of its motion.

Loss of head at exit by experimentally = $V2 / 2g$

Where

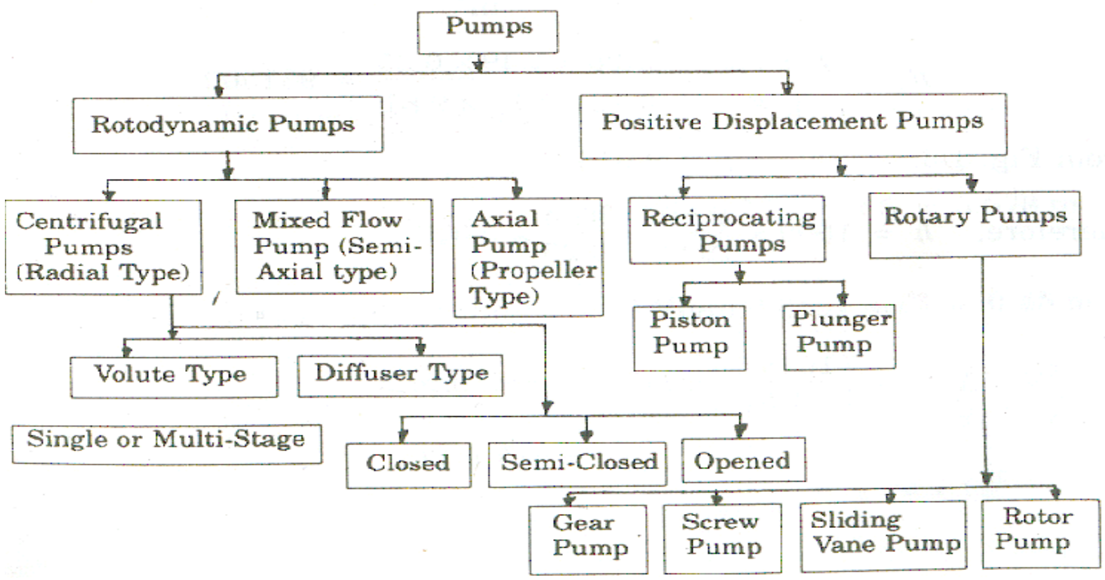
V = Velocity of liquid in the pipe

g = acceleration due to gravity

What is the function of pipe? How it is classified?

- Water pumps are devices designed to convert mechanical energy to hydraulic energy.
- They are used to move water from lower points to higher points.
- Used to “lift” water from a low elevation to a higher elevation.
- Used to “boost” pressures and/or maintain velocities in a system.

Classification of pipes



Pump Classification

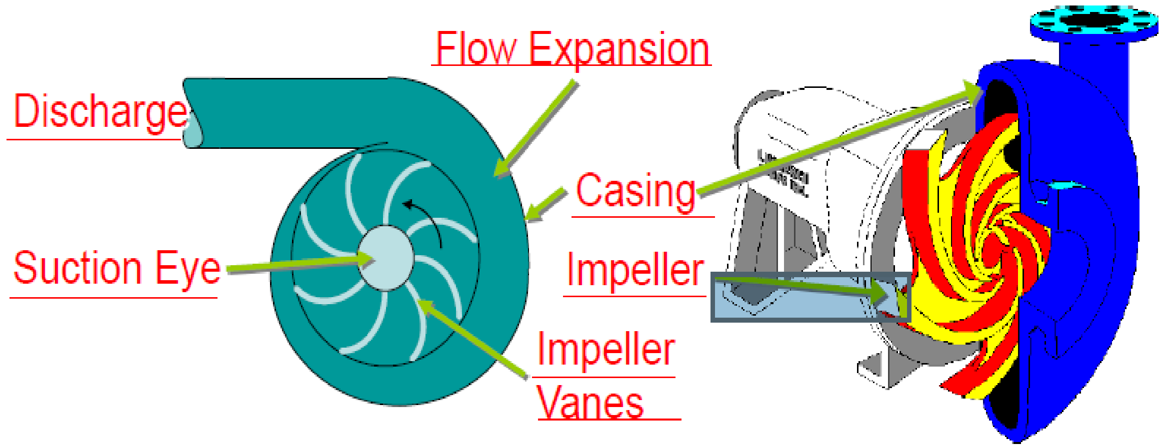
- Turbo-hydraulic (kinetic) pumps
    a. Centrifugal pumps (radial-flow pumps)
    b. Propeller pumps (axial-flow pumps)
    c. Jet pumps (mixed-flow pumps)
- Positive-displacement pumps
    a. Screw pumps
    b. Reciprocating pumps

Discuss in detail the construction and the working of centrifugal pump.

Centrifugal pump

- The pump consists of an Impeller which is enclosed in a water tight casing.
- Water at lower level is sucked into the impeller through a suction pipe.
- Suction pipe should be air tight and bends in this pipe should be avoided.
- A strainer foot valve is connected at the bottom of the suction pipe to prevent entry of foreign matter and to hold water during pumping.

- Suction pipe is kept larger in diameter than delivery pipe to reduce cavitations and losses due to friction. An electric motor is coupled to the central shaft to impart energy.



WORKING PRINCIPLE

When the impellor starts rotating it creates reduction of pressure at the eye of the impellor, which sucks in water through the suction pipe. Water on entering the eye is caught between the vanes of the impeller. Rapid rotation of the impellor sets up a centrifugal force and forces the water at high velocity outwards against the causing convert the velocity energy into pressure energy which is utilized to overcome the delivery head

OPERATION AND MAINTENANCE

Priming – Priming means filling up of the suction and casing completely with water. Pressure and suction developed by the impellor is proportional to the density of the fluid and the speed of rotation. Impellor running in air will produce only negligible negative pressure on the head.

Hence it is required that is the casing and impellor is filled with water through a funnel and cock. Trapped air is released through pet cock. Initially the delivery valve is closed and the pump started. The rotation impellor pushes the water in the casing into the delivery pipe and the water in the casing into the delivery pipe and the resulting vacuum is filled by water raising through the suction pipe. The pass valve is opened while closing the bypass valve, while stopping the pump delivery valve is closed first and the pump switched off.

Maintenance may be

1) Preventive maintenance
2) Break down maintenance.

Preventive maintenance

Locates the sources of trouble and keep the equipment in good operating condition. It involves oiling, greasing of stuffing boxes, observing the temperature of the motor and the pump bearings, checking the valves, strainer, electrical contacts, earthings etc.

Break down maintenance

Involves replacement of worn out components and testing. Sufficient amount of spares of impellors, bearings, slip-ring brushes, stater-contacts, gland packing, greases, oils, jointing materials, valves are to be kept in stock to attend to the emergencies. It is usual to have one stand by pump in addition to the required number of pumps.

Discuss in detail the construction and the working of Reciprocating pump.

- The working of the reciprocating pump is very simple and just like an I.C engine.
- The piston has the function of providing the suction force, so that the liquid can be lift up or can be sucked in with great force.
- The compression part will impart the required pressure energy to the fluids.
- The liquid is compressed properly and its pressure is increased to the desired level.
- The inlet and the outlet valve open at a certain pressure which is set by the manufacturer.
- In a single acting type it can suck from one side and transmit to the same side only.
- But in the double reciprocating pump too which have the function of the giving suction and discharge simultaneously in each stroke. This pump can be used as the compressor also but for that we have to have a good valve arrangement which can operate with good frequency.

Maintenance required on the reciprocating pump:

- The reciprocating pump provides the pressure as much as we want but since there are so many moving parts in this pump. So the wear and tear is lot in this pump. So there are various maintenances which are done on this pump in order to keep it working and also for its long life. This is the reason why these pumps are limited in use and only used in places where there is high suction and high pressure head is required. Following are the maintenances which are carried on this pump.
- The piston rings which are used are always in direct contact with the liner body and hence they wear a lot. So we have to change them time to time.
- The valves used in this pump have to be taken care properly as it will lead leakage if they go bad. So they have to take care off while maintaining of the pump.
- The gland packing from where the shaft comes out of the pump has to be taken care in order to check its leakage.
- In coupling or the crosshead of the pump by which the piston get the liner motion also have to checked for any type of misalignment and wear and tear.

Uses of reciprocating pump

- The lubricating pump is a reciprocating pump and it supplies the lubrication oil to the main engine.
- Main bilge suction pump is also a reciprocating pump.
- For ballast they are sometimes used.

Advantages of Reciprocating pump

- Gives high pressure at outlet.
- Gives high suction lift.
- Priming is not required in this pump.
- They are used for air also.

Disadvantages of Reciprocating pump

- High wear and tear, so requires a lot maintenance.
- The flow is not uniform, so we have to fit a bottle at both ends.
- The flow is very less and cannot be used for high flow operations.
- More heavy and bulky in shape.

- Initial cost is much more in this pump.

UNIT III

WATER TREATMENT

The objective of water treatments

1. To remove colour, dissolved gases, and murkiness of water.
2. To remove objectionable tastes and odour.
3. To remove disease producing microorganism to provide safe drinking water.
4. To remove hardness of water.
5. To make water suitable for many industrial purposes brewing, dyeing and steam generation.
6. To eliminate the tuberculation and corrosive properties of water this affects the conduits and pipes.

Method of purification of water treatment for water supplies

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

1. Screening
2. Plain sedimentation
3. Sedimentation aided with coagulant
4. Filtration
5. Disinfection
6. Aeration
7. Softening
8. Miscellaneous treatments, such as fluoridation, recarbonation, liming, desalination, etc.

UNIT OPERATION AND TREATMENT PROCESS OR UNIT PROCESS

There are a number of unit operations for water treatment. The choice of unit operations depends primarily on the substances needing to be removed. The key unit operations can be classified accordingly as follows:

Classified unit operations

<table>
<tr><td rowspan="3">Insoluble solids
(Organic /Inorganic)</td><td colspan="3">Dissolvedsubstances</td></tr>
<tr><td colspan="2">Organic substance</td><td rowspan="2">Inorganic
substance</td></tr>
<tr><td>Biodegradable</td><td>Non-Biodegradable</td></tr>
<tr><td>Mechanical Process</td><td>Biological process</td><td colspan="2">Physical/Chemical process</td></tr>
<tr><td>1. Flotation
2. Sedimentation
3. Filtration</td><td>1. Aerobic process
2. Anaerobic process</td><td colspan="2">1 Adsorption
2 Membrane Separation Processes
3 Ion Exchange
4 Precipitation / Flocculation
5 Chemical Oxidation</td></tr>
</table>

Removal of solids is effected by mechanical processes. Dissolved substances can be removed by either biological or physical/chemical processes. The aim of biological processes is to remove organic, biodegradable substances. Microorganisms use such substances as a source of nutrition, thereby degrading them. If this process takes place in the presence of dissolved oxygen, they are termed aerobic. They include the activated sludge process and biofilm process. Their main field of application is in the treatment of domestic wastewater by wastewater treatment plants. By contrast, anaerobic processes exclude oxygen. Anaerobic processes are used in the treatment of heavily organically polluted wastewater e.g. from industries like food processing and paper manufacturing. Non-biodegradable organic and inorganic substances can be removed by means of physical/chemical processes. Examples of this are water softening by ion exchange and the adsorption of chlorinated hydrocarbons on activated carbon.

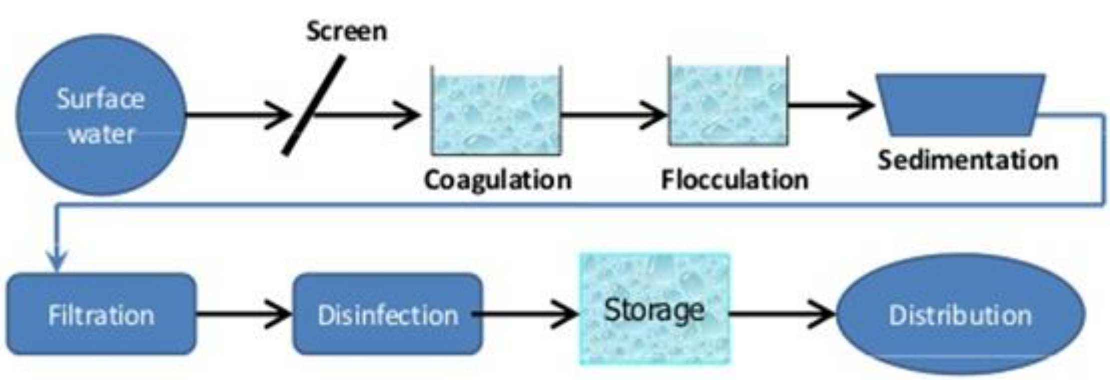
Treatment process involved in raw water

S.NO	**Impurities**	**Process used for removal**
1	Floating matters as trees, branches, sticks, vegetables, fish, animal life, etc.,	**Screening**

2	Impurities as silt, clay, sand etc.,	Plain sedimentation
3	Find suspended matter.	Sedimentation with coagulation
4	Micro organisms and colloidal matter.	Filtration
5	Dissolved gases, taste and odour.	Aeration
6	Hardness	Water softening
7	Pathogenic bacteria	Disinfection

Water treatment plant and role of each unit

The available raw water must be treated and purified before they can be supplied to the general public for their domestic, industrial or any other uses. Water treatment includes many operations like Aeration, Flocculation, Sedimentation, Filtration, Softening, Chlorination and demineralization. Depending upon the quality of raw water and the quality of water desired. Several combinations of the above processes may be adopted as shown in the flow diagram.



Screening

Most of the big and floating materials such as trees, branches, sticks, vegetables, fish, animal life, etc.present in raw water of surface sources can be removed by screening.

Plain sedimentation

The coarser suspended materials can then be removed by allowing the water to stand undisturbed in sedimentation basins. The process is called plain sedimentation.

Sedimentation aided with coagulation

The effectiveness of sedimentation may be increased by mixing certain chemicals with the water, so as to form flocculants precipitate, which carries the suspended particles as it settle.

Filtration

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

Disinfection

Water disinfection means the destruction of disease causing bacteria by adding chemicals or passing UV rays.

SCREENING

- A screen is a device with openings for removing bigger suspended or floating matter in water which would otherwise damage equipment or interfere with satisfactory operation of treatment units.

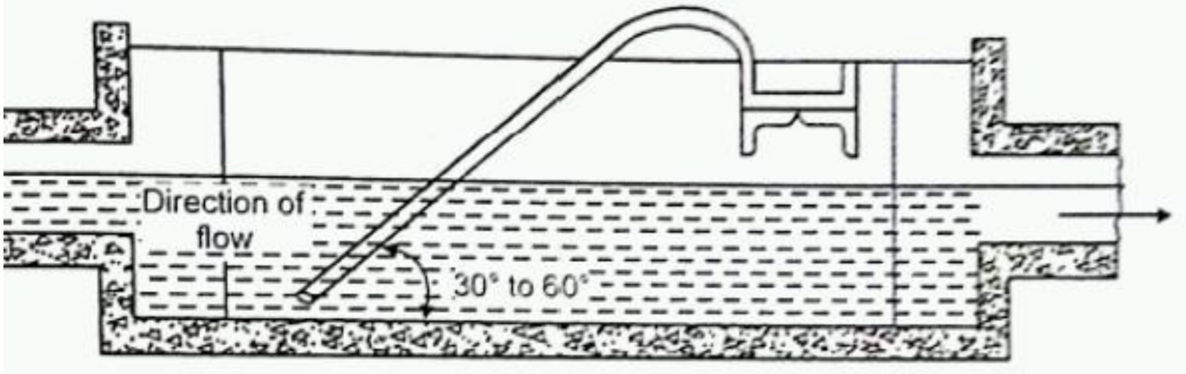
Types of Screens

1. **Coarse Screens:**
    - Coarse screens also called racks, are usually bar screens, composed of vertical or inclined bars spaced at equal intervals across a channel through which water flows.
    - Bar screens with relatively large openings of 75 to 150 mm are provided ahead of pumps, while those ahead of sedimentation tanks have smaller openings of 50 mm.
    - Bar screens are usually hand cleaned and sometimes provided with mechanical devices.

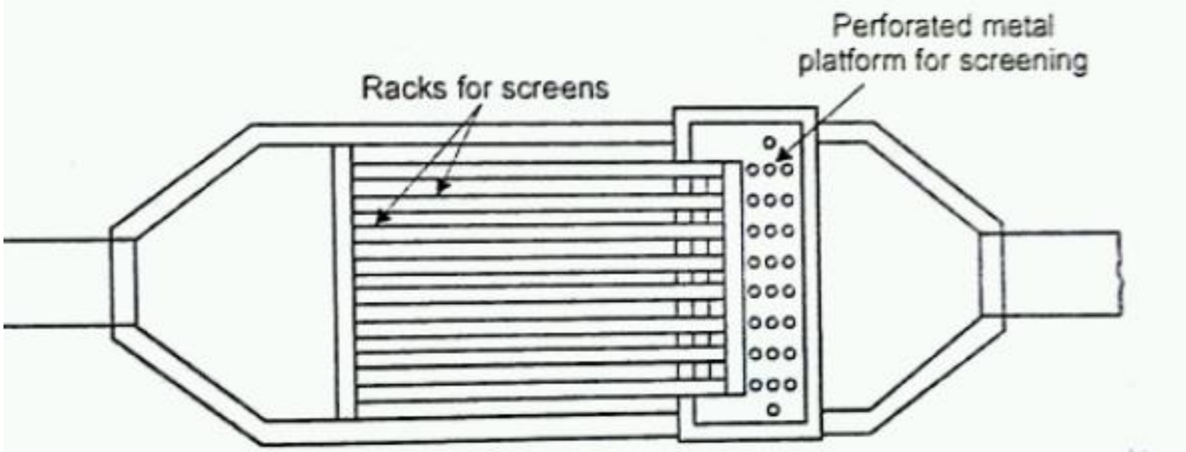
2. **Medium Screens:**
    - Medium screens have clear openings of 20 to 50 mm.
    - Bars are usually 10 mm thick on the upstream side and taper slightly to the downstream side.
    - The bars used for screens are rectangular in cross section usually about 10 x 50 mm, placed with larger dimension parallel to the flow.
3. **Fine Screens:**

<u>Velocity</u>

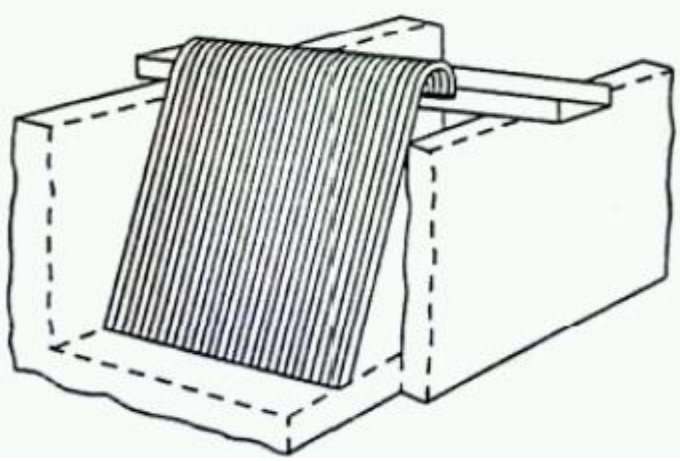
The velocity of flow ahead of and through the screen varies and affects its operation. The lower the velocity through the screen, the greater is the amount of screenings that would be removed from sewage. However, the lower the velocity, the greater would be the amount of solids deposited in the channel. Hence, the design velocity should be such as to permit 100% removal of material of certain size without undue depositions. Velocities of 0.6 to 1.2 mps through the open area for the peak flows have been used satisfactorily. Further, the velocity at low flows in the approach channel should *not be less than 0.3 mps* to avoid deposition of solids.



(a) Section



(b) Plan



(c) Prospective view

Design of screening chamber

- The objective of screens is to remove large floating material and coarse solids from wastewater.
- It may consist of parallel bars, wires or grating placed across the flow inclined at 30^o-60^o.
- According to method of cleaning; the screens are hand cleaned screens or mechanically cleaned screens. Whereas, according to the size of clear opening, they are coarse screens (≥ 50 mm), medium screens (25-50 mm) and fine screens (10-25 mm). Normally, medium screens are used in domestic wastewater treatment.

Dimensions of an approach channel

Used in wastewater treatment is mostly rectangular in shape. Wastewater from the wet well of the pumping station is pumped into the approach channel from where it flows by gravity to the treatment plant. Its main function is to provide a steady and uniform flow after pumping.

- Select the size of bar/clear opening, say 10mm x 10 mm (medium screens)
- No. of bars; {(n + 1) + (n) = B}, and {Be = B – (width of bar)(n)}
- Head loss, hL = 0.0729 (V2 – Vh2) ------ {Vh 0.75m/sec, hL ≤ 0.5 ft}
- For perforated plate; amount of screening produce = (1-2) ft^3/MG
- Length of bar; L = D/sinθ, and Lh = L * cosθ.
- Screen chamber. Lc = inlet zone (2-3 ft) + Lh + outlet zone {outlet zone = width of p plate + (0.5-1.0 ft)}

Head loss

Head loss varies with the quantity and nature of screenings allowed to accumulate between cleanings. The head loss created by a clean screen may be calculated by considering the flow and the effective areas of screen openings, the latter being the sum of the vertical projections of the openings. The head loss through clean flat bar screens is calculated from the following formula:

$$\mathbf{h = 0.0729\ (V^2 - v^2)}$$

where, h = head loss in m

V = velocity through the screen in mps

v = velocity before the screen in mps

Another formula often used to determine the head loss through a bar rack is Kirschmer's equation:

$$\mathbf{h = b\ (W/b)^{4/3}\ h_v \sin q}$$

where h = head loss,m

b = bar shape factor (2.42 for sharp edge rectangular bar, 1.83 for rectangular bar with semicircle upstream, 1.79 for circular bar and 1.67 for rectangular bar with both u/s and d/s face as semicircular).

W = maximum width of bar u/s of flow, m

b = minimum clear spacing between bars, m

h_v = velocity head of flow approaching rack, m = $v^2/2g$

q = angle of inclination of rack with horizontal

The head loss through fine screen is given by

$$\mathbf{h = (1/2g)\ (Q/CA)}$$

where, h = head loss, m

Q = discharge, m^3/s

C = coefficient of discharge (typical value 0.6)

A = effective submerged open area, m^2

The quantity of screenings depends on the nature of the wastewater and the screen openings.

SEDIMENTATION

- Most of the suspended impurities present in do have specific gravity greater than that of water (i.e., 1.0). and settle down under gravity.
- The basin in which the flow of the water is reduced is called the settling tank or sedimentation tank or sedimentation basin or clarifier, and the theoretical average time for which the water is detained in the tank is called the detention period.

Sedimentation with coagulant

- To remove very fine particles, some substances are added (called coagulants).
- They hydrolyzed to form precipitates which enhances easy settling of very fine suspended particles.
- The operation is called sedimentation with coagulation.

Factors affecting the sedimentations are

a. Size, shape, density and nature of the particles
b. Viscosity and temperature of water
c. Surface overflow rate
d. Velocity of flow
e. Inlet and outlet arrangements
f. Detention period
g. Effective depth of settling zone.

Settling

Solid liquid separation process in which a suspension is separated into two phases –

- Clarified supernatant leaving the top of the sedimentation tank (overflow).
- Concentrated sludge leaving the bottom of the sedimentation tank (underflow).

Purpose of Settling

- To remove coarse dispersed phase.
- To remove coagulated and flocculated impurities.
- To remove precipitated impurities after chemical treatment.
- To settle the sludge (biomass) after activated sludge process / tricking filters.

Principle of Settling

- Suspended solids present in water having specific gravity greater than that of water tend to settle down by gravity as soon as the turbulence is retarded by offering storage.
- Basin in which the flow is retarded is called **settling tank**.
- Theoretical average time for which the water is detained in the settling tank is called the **detention period**.

Types of Settling

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

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

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

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

FILTRATION

- The process of passing the water through beds of sand or other granular materials is known as filtration. For removing bacteria, colour, taste, odours and producing clear and sparkling water, filters are used by sand filtration 95 to 98% suspended impurities are removed.

THEORY OF FILTRATION

The following are the mechanisms of filtration

- Mechanical straining – Mechanical straining of suspended particles in the sand pores.
- Sedimentation – Absorption of colloidal and dissolved inorganic matter in the surface of sand grains in a thin film
- Electrolytic action – The electrolytic charges on the surface of the sand particles, which opposite to that of charges of the impurities are responsible for binding them to sand particles.
- Biological Action – Biological action due to the development of a film of microorganisms layer on the top of filter media, which absorb organic impurities.

Filtration is carries out in three types of filters

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

SLOW SAND FILTER

Slow sand filters are best suited for the filtration of water for small towns. The sand used for the filtration is specified by the effective size and uniformity coefficient. The effective size, D10, which is the sieve in millimeters that permits 10% sand by weight to pass. The uniformity coefficient is calculated by the ratio of D60 and D10.

CONSTRUCTION

- Slow sand filter is made up of a top layer of fine sand of effective size 0.2.to 0.3mm and uniformity coefficient 2 to 3. he thickness of the layer may be 75 to 90 cm.

- Below the fine sand layer, a layer of coarse sand of such size whose voids do not permit the fine sand to pass through it. The thickness of this layer may be 30cm.
- The lowermost layer is a graded gravel of size 2 to 45mm and thickness is about 20 to 30cm.
- Water collected by the under drainage is passed into the out chamber.

OPERATION

- The water from sedimentation tanks enters the slow sand filter through a inlet. This water is uniformly spread over a sand bed without causing any disturbances.
- The water passes through the filter media at an average rate of 2.4 to 3.6 m3/m2/day.
- This rate of filtration is continued until the difference between the water level on the filter and in the inlet chamber is slightly less than the depth of water above the sand.
- The difference of water above the sand bed and in the outlet chamber is called the loss of head.
- During filtration as the filter media gets clogged due to the impurities, which stay in the pores, the resistance to the passage of water and loss of head also increases.
- When the loss of head reaches 60cm, filtration is stopped and about 2 to 3cms from the top of bed is scrapped and replaced with clean sand.
- The filter can run for 6 to 8 weeks before it becomes necessary to replace the sand layer.

USES

- The slow sand filters are effective in removal of 98 to 99% of bacteria of raw water and completely all suspended impurities and turbidity is reduced to 1 N.T.U.

- Slow sand filters also removes odours, tastes and colors from the water but not pathogenic bacteria.

Draw backs:

- The slow sand filters requires large area for their construction and high initial cost for establishment.
- The rate of filtration is also very slow.

MAINTENANCE

- The algae growth on the overflow weir should be stopped.
- Rate of filtration should be maintained constant and free from fluctuation. F
- Filter head indicator should be in good working condition.
- No coagulant should be used before slow sand filtration since the floc will clog the bed quickly.

RAPID SAND FILTER

- Rapid sand filter have high rate of filtration ranging from 100 to 150m3/m2/day and small area of filter required.

The main features of rapid sand filter are as follows

Effective size of sand - 0.45 to 0.70mm

Uniformity coefficient of sand - 1.3 to 1.7

Depth of sand - 60 to 75cm

Filter gravel - 2 to 50mm size

(Increase size towards bottom)

Depth of gravel - 45cm

Depth of water over sand during filtration - 1 to 2m

Overall depth of filter including 0.5m free board - 2.6m

Area of single filter unit - $100m^2$ in two parts of each $50m^2$

Loss of head - Max 1.8 to 2.0m

Turbidity of filtered water - 1 NTU

OPERATION

- The water from coagulation sedimentation tank enters the filter unit through inlet pipe and uniformly distributed on the whole sand bed.
- Water after passing through the sand bed is collected through the under drainage system in the filtered water well.
- The outlet chamber in this filter is also equipped with filter rate controller. In the beginning the loss of head is very small. But as the bed gets clogged, the loss of head increases and the rate of filtration become very low. Therefore the filter bed requires its washing.

WASHING OF FILTER

- Washing of filter done by the back flow of water through the sand bed .First the value 'A' is closed and the water is drained out from the filter leaving a few centimeter depth of water on the top of sand bed. Keeping all values closed the compressed air is passed through the separate pipe system for 2-3 minutes, which agitates the sand bed and stirrer it well causing the loosening of dirt, clay etc. inside the sand bed. Now value 'C' and 'B' are opened gradually, the wash water tank, rises through the laterals, the strainers gravel and sand bed. Due to back flow of water the sand expands and all the impurities are carried away with the wash water to the drains through the channels, which are kept for this purpose.

CONSTRUCTION

Rapid sand filter consists of the following five parts

1. Enclosure tank – A water tight tank is constructed either masony or concrete
2. Under drainage system – may be perforated pipe system or pipe and stracher system
3. Base material – gravel should free from clay, dust, silt and vegetable matter. Should be durable, hard, round and strong and depth 40cm.
4. Filter media of sand – The depth of sand 60 to 75cm
5. Appurtenances – Air compressors useful for washing of filter and wash water troughs for collection of dirty water after washing of filter.

Washing process is continued till the sand bed appears clearly. The washing of filter is done generally after 24 hours and it takes 10 minutes and during back washing the sand bed expands by about 50%.

Rapid sand filter bring down the turbidity of water to 1 N.T.U. This filter needs constant and skilled supervision to maintain the filter gauge, expansion gauge and rate of flow controller and periodical backwash.

COMPARISION OF SLOW SAND FILTER AND RAPID FILTER

S.No	ITEM	Slow sand filter	Rapid sand filter
1	Area	Need very large area	Needs small area
2	. Raw Water Turbidity	Not more than 30 NTU	Not more than 10NTU hence needs coagulation
3	Sand Media	Effective size 0.2 to 0.3 mm uniformity coefficient 2 to 3 single layer of uniform size	Effective size 0.45 to 0.7mm uniformity coefficient1.3 to 1.7 multiple graded layers of sand.
4	Filtration	2.4 to 3.6m3/m2/day	100-150 m3/m2/day
5.	Loss of Head	0.6m to 0.7 m	1.8m to 2.0m
6.	Supervision	No skilled supervision is Required	Skilled supervision is required
7	Cleaning of Filter	Scraping of 21/2cm thick layer washing and replacing. Cleaning interval that is replacement of sand at 1 to 2 months.	Back wash with clean water under pressure to detach the dirt on the sand. Backwashing daily or on alternate days.

8	Efficiency	Bacterial, taste,odour, colour and turbidity are removed.	Only taste,odour, colour and turbidity are removed. Bacterias are not removed.

PRESSURE FILTER

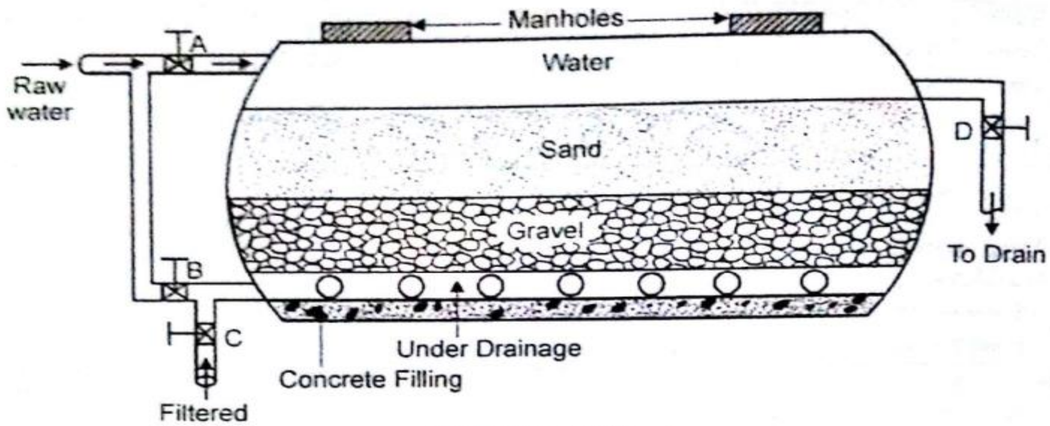
- Pressure filter is type of rapid sand filter in a closed water tight cylinder through which the water passes through the **sand bed under pressure**.
- All the operations of the filter is similar to rapid gravity filter, expect that the coagulated water is directly applied to the filter without mixing and flocculation.
- Pressure filters may be vertical pressure filter and horizontal pressure filter.

ADVANTAGES

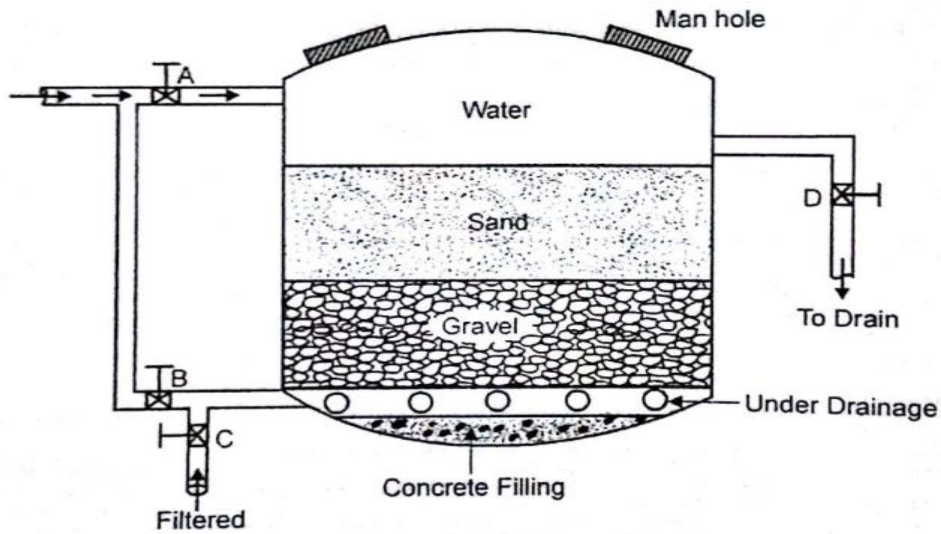
1. It is a compact and automatic operation
2. These are ideal for small estates and small water works
3. These filters requires small area for installation
4. Small number of fittings are required in these filters
5. Filtered water comes out under pressure no further pumping is required.
6. No sedimentation and coagulant tanks are required with these units.

DISADVATAGES

1. Due to heavy cost on treatment, they cannot be used for treatment large quantity of water at water works
2. Proper quality control and inspection is not possible because of closed tank
3. The efficiency of removal of bacteria & turbidity is poor.
4. Change of filter media, gravel and repair of drainage system is difficult.



(a) Horizontal Type



(b) Vertical Type

DISINFECTION OF WATER

The process of killing the infective bacteria from the water and making it safe to the user is called **disinfection.** The water which comes out from the filter may contain some disease – causing bacteria in addition to the useful bacteria. Before the water is supplied to the public it is utmost necessary to kill all the disease causing bacteria. The chemicals or substances which are used for killing the bacteria are known as **disinfectants.**

REQUIREMENTS OF DISINFECTANTS

1. They should destroy all the harmful pathogens and make it safe for use.

2. They should not take more time in killing bacteria

3. They should be economical and easily available

4. They should not require high skill for their application

5. After treatment the water should not become toxic and objectionable to the user.

6. The concentration should be determined by simply and quickly.

METHODS OF DISINFECTION

Disinfection of water by different physical and chemical methods

I. PHYSICAL METHODS

1. BOILING:

Boil the water for 15 to 20 minutes and kills the disease causing bacteria. This process is applicable for individual homes.

2. ULTRA-VIOLET RAYS:

Water is allowed to pass about 10cm thickness by ultraviolet rays. This process is very costly and not used at water works. Suitable for institutions.

3. ULTRASONIC RAYS: Suitable for institutions.

II. CHEMICAL METHODS

1. **CHLORINATION :**

   Using chlorine gas or chlorine compounds.

2. **BROMINE AND IODINE :**

   It is expensive and leaves taste and odour.

3. **POTASSIUM PERMANGANATE:**

   This method is used for disinfection of dug well water, pond water or private source of water.

4. **OZONE :**

   Very expensive process, leaves no taste, odour or residual.

5. **EXCESS LIME TREATMENT:**

Needs long detention time for time interval and large lime sludge to be treated.

CHLORINATION

Chlorination is the addition of chlorine to kill the bacteria Chlorination is verywidely adopted in all developing countries for treatment of water for public supply.Chlorine is available in gas, liquid or solid form (bleaching powder)

ADVANTAGES OF CHLORINE

1. Chlorine is manufactured easily by electrolytes of common salts (NaCl)
2. It is powerful oxidant and can penetrate the cell wall of organism and its contents.
3. Dosage can be controlled precisely
4. Can be easily detected by simple test
5. Does not form harmful constituents on reaction with organics of inorganics in water.

PRECAUTIONS IN USING CHLORINE

1. Chlorine gas or liquid is highly corrosive and it is to be stored carefully in sealed container at a distance.
2. If the water contains phenolic compounds, there is a reaction with chlorine can result in cancer causing substances.

RESIDUAL CHLORINE AND CHLORINE DEMAND

When chlorine is applied in water some of it is consumed in killing the pathogens, some react organs & inorganic substances and the balance is detected as “Residual Chlorine”. The difference between the quantity applied per litre and the residual is called

“Chlorine Demand”. Polluted waters excert more chlorine demand. If water is pre-treated by sedimentation and aeration, chlorine demand may be reduced. Normally residual chlorine of 0.2 mg/litre is required.

BEHAVIER OF CHLORINE IN WATER

When chlorine is dissolved in water forms hypo chlorous acid and hydro chloric acid.

$$Cl_2 + H_2O \rightarrow HOCl + HCl \text{ ---------- } (1)$$

After some time hydo chlorous acid further Ionizes as follows

$$HOCl \leftrightarrow H^+ + OCl^- \text{ ------ } (2)$$

The two prevailing species (HOCl) and (OCl -) are called free available chlorine are responsible for the disinfection of water.

Chlorine reacts with ammonia in water to form Monochloramine, (NH_2Cl), dichloramine ($NHCl_2$) and trichloramine, (NCl_3) released and their distribution depends on the pH value of water.

DOSAGE OF CHLORINE

(A) PLAIN CHLORINATION

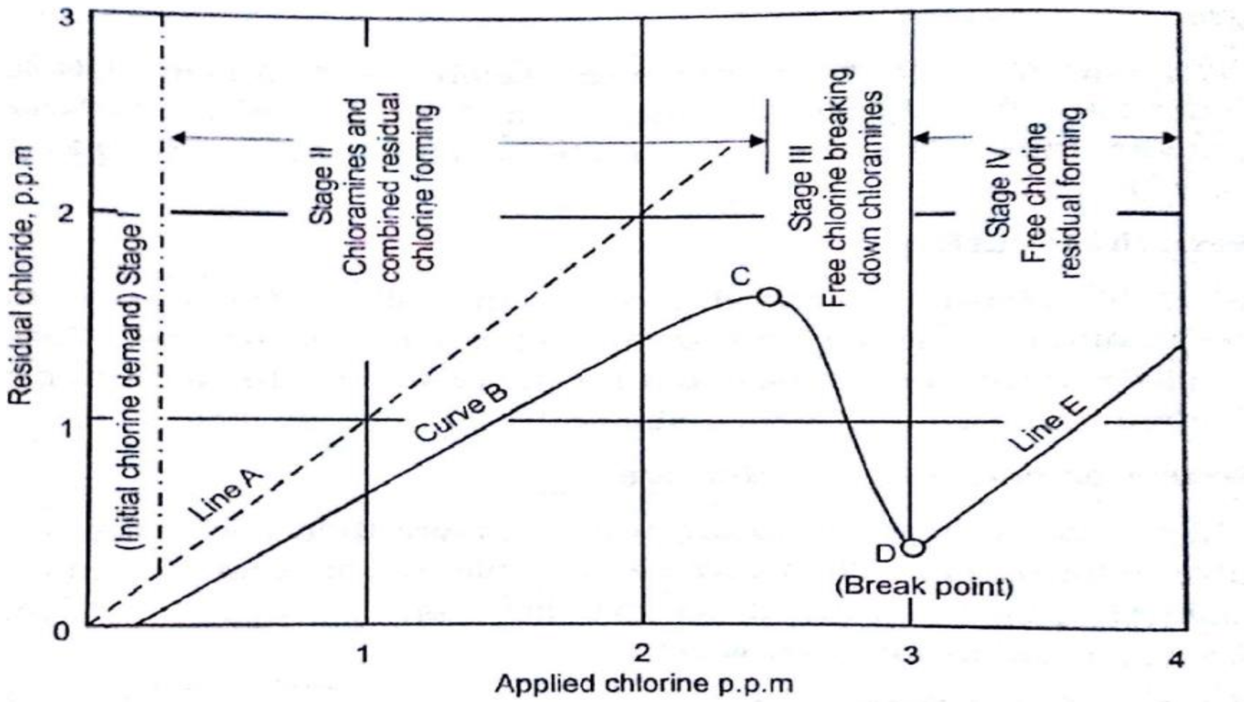
Plain chlorination is the process of addition of chlorine only when the surface water with no other treatment is required. The water of lakes and springs is pure and can be used after plain chlorination. A rate of 0.8 mg/lit/hour at 15N/cm2 pressure is the normal dosage so as to maintain in a residual chlorine of 0.2 mg/lit.

(B) SUPER CHLORINATION

Super chlorination is defined as administration of a dose considerably in excess of that necessary for the adequate bacterial purification of water. About 10 to 15 mg/lit is applied with a contact time of 10 to 30 minutes under the circumstances such as during epidemic breakout water is to be dechlorinated before supply to the distribution system.

(C) BRAKE POINT CHLORINATION

When chlorine is applied to water containing organics, micro organisms and ammonia the residual chlorine levels fluctuate with increase in dosage Upto the point B it is obsorbed by reducing agents in water (like nitrates, Iron etc) further increases forms chloramines with ammonia in water. Chloramines are effective as CL and OCL formed. When the free chlorine content increases it reacts with the chloramines and reducing the available chlorine



. At the point 'D' all the chloramines are converted to harmless compounds and Beyond 'D' free residual chlorine appear again. This point 'D' is called break point chlorination. **(D) DECHLORINATION**

Removal of excess chlorine resulting from super chlorination in part or completely is called 'Dechlorination'. Excess chlorine in water gives pungent smell and corrode the pipe lines. Hence excess chlorine is to be removed before supply. Physical methods like aeration, heating and absorption on charcoal may be adopted. Chemical methods like sulphur dioxide (SO_2) , Sodium Bi-sulphate ($NaHSO_3$), Sodium thiosulphate are used.

POINTS OF CHLORINATION

Chlorine applied at various stages of treatment and distribution accordingly they are known as pre, post and Re-chlorination.

a) PRE-CHLORINATION

- Chlorine applied prior to the sedimentation and filtration process is known as

Prechlorination. Pre-chlorination improves coagulation and post chlorination dosage may be reduced.

b) POST CHLORINATION

When the chlorine is added in the water after all the treatment is known as Postchlorination.

c) RE-CHLORINATION

- In long distribution systems, chlorine residual may fall makes the water unsafe.
- Application of excess chlorine lead to unpleasant smell to consumers at the points nearer to treatment point and the excess chlorine is removed at intermediate points generally at service reservoirs and booster pumping stations.

DEFLUORIDATION – BY NALGONDA TECHNIQUE

Defluoridation is process of removal of excess fluoride present in the water. The excess fluoride in the water causes dental abnormalities, hypertension, peptic ulcer, Skin infections, defective vision, coronary thrombosis etc. The permissible level of fluoride in the water is 1mg/litre.

METHODS OF REMOVAL

1. Activated carbons prepared from various materials can be used.
2. Lime – soda process of water softening removes fluorides also along with magnesium
3. The materials like calcium phosphate, bone charcoal, synthetic tricalcium phosphate may remove excess fluoride.
4. The water may be allowed to pass through filter beds containing fluoride retaining materials.

In this technique, sodium aluminate or lime, bleaching powder and filter alum are added to fluoride water in sequence. The water is stored for ten minutes and settled for one hour and the water is then withdrawn without disturbing the sediments. The sodium aluminate or lime accelerates the settlement of precipitate and bleaching powder ensures disinfection. The alum dose required will depend upon the concentration of fluorides, alkanity and total dissolved solids in the raw water. It is found that this technique is simple in operation and economical. It can be used with advantage in villages either on an individual scale or on a mass scale.

CONSTRUCTION AND OPERATION & MAINTENANCE ASPECTS OF WATER TREATMENT PLANTS

- The design of treatment processes and devices shall depend on the evaluation of the nature and quality of the particular water to be treated, seasonal variations, the desired quality of the finished water, and the mode of operation planned.
- Water treatment facilities should be designed such that major process equipment and facilities are capable of supplying the maximum day demand for the 20 to 25 year projected design flows, plus an additional amount that will be sufficient to accommodate plant losses.
- Maximum Day demand is the maximum amount of water supplied to the system on any given day within a calendar year. Peak flows are the short-term flows expected to be experienced by a particular component of the system and will govern the sizing of many system components
- Minor process equipment such as piping, valves and chemical feed systems should be designed to accommodate future design flow, within the life expectancy of the components.
- Water treatment facilities should be designed to facilitate future expansion, if necessary. In each case, the designer may consider modularity and expandability as an option to the provision of surplus capacity.

Clarification Plants designed for processing surface water shall:

1. Provide a minimum of two units each for rapid mix, flocculation and sedimentation;
2. Permit operation of the units either in series or parallel where softening is performed, and should permit series or parallel operation where plain clarification is performed;
3. Be constructed to permit units to be taken out of service without disrupting operation, and with drains or pumps sized to allow dewatering in a reasonable period of time;
4. Provide multiple-stage treatment facilities when required by the DOEC;

5. Be started manually following shutdown; and 6. Minimize hydraulic head losses between units to allow future changes in processes without the need for re-pumping.

PRE SEDIMENTATION

Waters containing high turbidity may require pre-treatment, usually sedimentation either with or without the addition of coagulation chemicals.

1. Basin design – pre sedimentation basins should have hopper bottoms or be equipped with continuous mechanical sludge removal apparatus, and provide arrangements for dewatering.
2. Inlet – incoming water shall be dispersed across the full width of the line of travel as quickly as possible: short-circuiting must be prevented.
3. 3. Bypass – provisions for bypassing presedimentation basins shall be included.
4. 4. Detention time – 3 hours detention is the minimum period recommended; greater detention may be required.

RAPID MIX

Rapid mix means the rapid dispersion of chemicals throughout the water to be treated, usually by violent agitation. The engineer shall submit the design basis for the velocity gradient (G value) selected, considering the chemicals to be added and water quality parameters.

1. Equipment – basins should be equipped with mechanical mixing devices. Static mixing may be considered if treatment flow is not variable and can be justified by the design engineer.

2. Mixing – detention period should be not more than 30 seconds.

3. Location - the rapid mix and flocculation basin shall be as close together as possible.

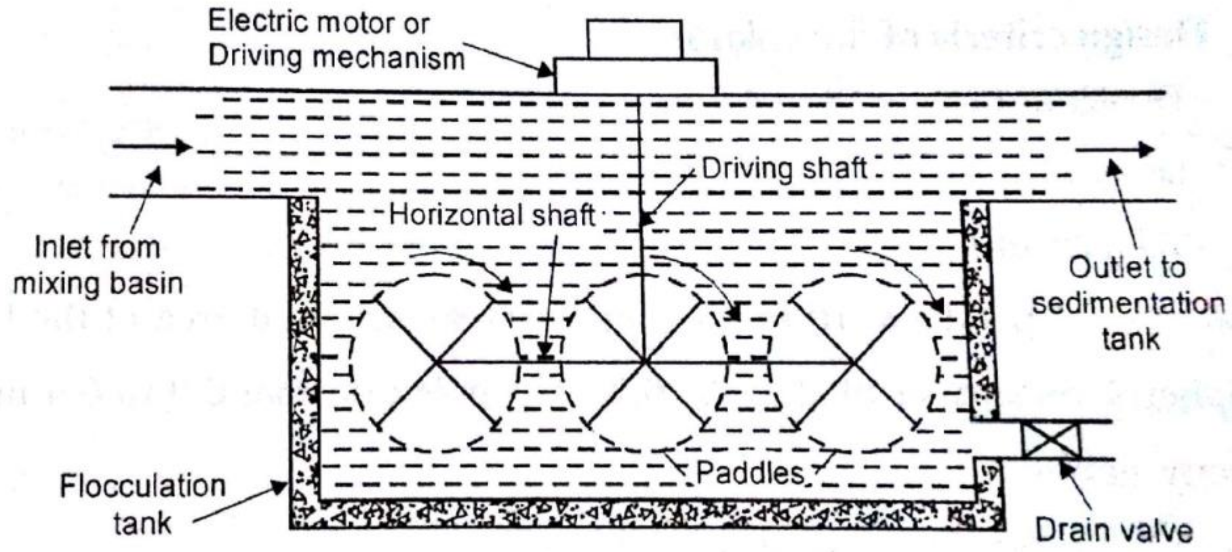
FLOCCULATION

Flocculation is the agitation of water at low velocities to promote the formation and growth of a settleable floc.

Inlet and outlet design should prevent short-circuiting and destruction of floc. Basin drains should be provided and should be a minimum of 200 mm diameter.

a. Detention The flow-through velocity shall be no less than 0.15 m or greater than 0.45 m/min with a detention time of at least 30 min.

b. Equipment Agitators shall be driven by variable speed drives with the peripheral paddle speed ranging from 0.15 to 0.6 m/s.



A typical flocculator fixed with paddles

c. Piping Flocculation and sedimentation basins should be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins shall be between 0.15 and 0.6 m/s. Allowances must be made to minimize turbulence at bends and changes in direction.

d. Alternate Design Baffling may be used to provide for flocculation in small plants only after consultation with the DOEC. The design should be such that the velocities and flows noted above would be maintained.

e. Superstructure A structure over the flocculation basins may be required.

SEDIMENTATION

Sedimentation shall follow flocculation and the basins should provide quiescent settling for the removal of floc and other suspended solids. Basins may be either rectangular or circular and should have continuous mechanical sludge removal equipment. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to conventional sedimentation units.

1. **Detention**

   The minimum detention time should be 4 hours. This may be reduced to 2 hours for lime-soda softening facilities treating only groundwater. Reduced sedimentation time may also be approved when equivalent effective settling is demonstrated, or when overflow rate is not more than 1.2 m/hr.

2. **Inlet**

   Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. A baffle should be constructed across the basin, close to the inlet end, and should project a sufficient distance below the water surface to dissipate inlet velocities and provide uniform flows across the basin.

3. **Outlet**

   Outlet weirs or submerged orifices shall maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices when there are fluctuations in flow. Outlet weirs and submerged orifices shall be designed as follows:

   1. The rate of flow over the outlet weirs or through the submerged orifices shall not exceed 250 m3 /day/m of the outlet launder;
   2. Submerged orifices should not be located lower than 0.9 m below the flow line; and 3. The entrance velocity through the submerged orifices shall not exceed 0.15 m/s.

4. Velocity

The velocity through settling basins should not exceed 0.15 m/s. The basins must be designed to minimize short-circuiting. Fixed and adjustable baffles must be provided, as necessary, to achieve the maximum potential for clarification.

5. **Overflow**

An overflow weir or pipe, which will establish the maximum water level desired on top of the filters, should be installed. The overflow shall discharge by gravity with a free fall at a location where the discharge will be noted.

6. Drainage

Basins must be provided with a means of dewatering. Basin bottoms should slope at approximately 8% toward the drain unless mechanical sludge removal equipment is installed. The discharge of drainage from any mixing or settling tank must be approved by the DOEC.

7. Superstructure

A superstructure over the sedimentation basins may be required. If there is no mechanical equipment in the basins, or if provisions are included for adequate monitoring under all expected weather conditions, a cover may be provided in lieu of a superstructure. The cover should be provided with manholes, equipped with raised curb and covers, as well as drop light connections, so that observations can be made, at several points, of the efficiency of sedimentation.

8. Sludge Collection

Mechanical sludge collection equipment should be provided.

9. Flushing Lines

Flushing lines or hydrants shall be provided, and must be equipped with backflow prevention devices acceptable to the DOEC.

10. Safety

Permanent ladders or handholds should be provided on the inside walls of the basin above the water level. Guardrails should be included. Compliance with other applicable safety requirements, such as the Occupational Health and Safety Act (OHSA), and regulations under the Act, shall be required.

11. **Sludge Removal**

Sludge removal design shall provide that:

1. Sludge pipes shall be not less than 75 mm in diameter and so arranged as to facilitate cleaning;
2. Entrance to sludge withdrawal piping shall prevent clogging;
3. Valves shall be located outside the tank for accessibility; and
4. The operator may observe and sample sludge being withdrawn from the unit.

UNIT IV

ADVANCED WATER TREATMENT

INTRODUCTION

The normal treatment process of coagulation, sedimentation, filtration, disinfection and softening removes most impurities of the water and makes it palatable. But in certain case iron, manganese, dissolved gases, colour, odour, tastes etc., and remains in water and become necessary to remove then before the water is supplied to the public.

NECESSITY OF ADVANCED WATER TREATMENT

1. To remove unwanted minerals like ion, manganese and fluoride.
2. To remove unwanted gases – carbon dioxide, hydrogen sulphide
3. To remove bad taste, and odour from the water.

AERATION

- Aeration removes odour and tastes due to volatile gases like hydrogen sulphide and due to algae and related organisms.
- Aeration also oxidize iron and manganese, increases dissolved oxygen content in water, removes CO2 and reduces corrosion and removes methane and other flammable gases.
- Principle of treatment underlines on the fact that volatile gases in water escape into atmosphere from the air-water interface and atmospheric oxygen takes their place in water provided the water body can expose itself over a vast surface to the atmosphere. This process continues until equilibrium is reached depending on the partial pressure of each specific gas in the atmosphere.

Types of Aerators

1. Gravity aerators
2. Fountain aerators
3. Diffused aerators
4. Mechanical aerators.

Gravity Aerators (Cascades):

In gravity aerators, water is allowed to fall by gravity such that a large area of water is exposed to atmosphere, sometimes aided by turbulence.

Fountain Aerators:

These are also known as spray aerators with special nozzles to produce a fine spray. Each nozzle is 2.5 to 4 cm diameter discharging about 18 to 36 l/h. Nozzle spacing should be such that each m3 of water has aerator area of 0.03 to 0.09 m2 for one hour.

Injection or Diffused Aerators:

It consists of a tank with perforated pipes, tubes or diffuser plates, fixed at the bottom to release fine air bubbles from compressor unit. The tank depth is kept as 3 to 4 m and tank width is within 1.5 times its depth. If depth is more, the diffusers must be placed at 3 to 4 m. depth below water surface. Time of aeration is 10 to 30 min and 0.2 to 0.4 liters of air is required for 1 liter of water.

Mechanical Aerators:

Mixing paddles as in flocculation are used. Paddles may be either submerged or at the surface.

IRON AND MANGANESE REMOVAL

Iron and manganese removal is the most common type of municipal water treatment. Iron and manganese occur naturally in water, especially groundwater. Neither of the elements causes adverse health effects; they are, in fact, essential to the human diet. However, water containing excessive amounts of iron and manganese can stain clothes, discolor plumbing fixtures, and sometimes add a “rusty” taste and look to the water.

Iron and manganese control

Methods to control iron and manganese in distribution systems include arranging for alternate water sources, adding phosphate to the water to keep iron and manganese in solution, and oxidizing and removing both by filtration.

Alternate Sources

In some situations, abandoning a well and drilling a new one into an aquifer with a lower iron or manganese concentration may be cost-effective. It may also be possible to blend the water from the well with the high concentrations with water from another source with lower concentrations.

Methods in removal of Iron and Manganese

1. Phosphate Treatment
2. Feeding Phosphate Solutions
3. Removal By Ion Exchange
4. Oxidation Using Aeration
5. Oxidation With Chlorine
6. Oxidation With Permanganate
7. Operation Of Iron And Manganese Filter

Phosphate treatment

- Phosphate can be effective when the water contains less than 0.3 ppm of iron or 0.1 ppm of manganese.
- Phosphate delays the precipitation of oxidized manganese and iron, thereby greatly reducing the layer of scale that forms on the pipe. The effect is called sequestration.
- The most effective is sodium phosphate in low concentrations.
- The proper dose and type of phosphate should be selected only after bench-scale testing is performed by a qualified technician or consultant.

Feeding Phosphate Solutions

- Phosphate feed points should be separated from the chlorine injection point by as much distance as possible.
- The phosphate feed point should also be ahead of the chlorine injection point.
- It consists of a storage tank, solution tank, feed pump, and controller to pace the feed rate. The storage tank and solution tank must contain at least 10 ppm of free chlorine residual to prevent bacterial growth in the phosphate solution .
- Phosphate solutions can be made up from powder.
- It is important that any solution be fed within 48 hours of its production.

- The amount of phosphates required sequestering iron and manganese generally has to be approximately two parts actual phosphate (as product) for one part of iron and manganese.
- If the total detention time in the distribution system exceeds 72 hours, the phosphates may break down and release the iron and manganese in the outer portions of the system. If the detention is exceeded, the iron or manganese problem may not be resolved with phosphate.

Removal by Ion Exchange

- Ion exchange may also remove iron and manganese. If the water has not been exposed to oxygen, the resins in the softener will remove the iron and manganese ions from the water.
- If the water contains any dissolved oxygen, the resin can be fouled with iron and manganese deposits. The resin can be cleaned, but the process is expensive and the capacity of this resin is reduced with each cleaning.
- This method is not recommended for municipal treatment.

Removal by Iron and Manganese

- Filtration removing iron and manganese from drinking water containing over 0.3 ppm of iron or 0.05 ppm of manganese.
- These elements can be removed during softening with lime
- Most commonly iron and manganese is removed by filtration after oxidation (with air, potassium permanganate, or chlorine).
    - The operator should frequently check to see that all the iron in the water entering the filter has been converted to the ferric (or insoluble particulate) state. The operator collects a water sample, passes it through a filter paper, and runs an iron test on the clean, filtered water (filtrate). If no iron is present, it has all been oxidized and is being removed in the filtration process.

Oxidation with aeration

- Iron is easily oxidized by atmospheric oxygen. Aeration provides the dissolved oxygen needed to convert the iron and manganese from ferrous and manganous (soluble) forms to insoluble.
- Oxidized ferric and manganic forms. It takes 0.14 ppm of dissolved oxygen to oxidize 1 ppm of iron, and 0.27 ppm of dissolved oxygen to oxidize 1 ppm of manganese.

If water flow is too great, not enough air is applied to oxidize the iron and manganese. If water flow is too small, the water can become saturated with dissolved oxygen and, consequently, become corrosive to the distribution system. Corrosive water may lead to increased lead and copper levels at customers' taps. During aeration, slime growths may develop on the aeration equipment, and if these growths are not controlled, they can produce taste and odor problems in the water. The growth of slime can be controlled by adding chlorine at the head of the treatment plant.

The process should be inspected regularly to catch problems early. A detention basin can be provided after aeration to allow complete oxidation. These basins should be cleaned regularly to avoid sludge accumulation. Detention time can also be provided with head on the filters rather than requiring a separate tank. Detention time before filtration should be at least 20 minutes, more if possible. The pH of the water influences how much time is needed for the reaction to be completed.

After oxidation of the iron and manganese, the water must be filtered to remove the precipitated iron and manganese. Oxidation of iron and manganese with air is by far the most cost-effective method since there is no chemical cost; however, there are disadvantages. The oxidation process can be slowed and the reaction tank has to be quite large (if there are high levels of manganese). In addition, small changes in water quality may affect the pH of the water and the oxidation rate may slow to a point where the plant capacity for iron and manganese removal is reduced.

Oxidation with chlorine

- Iron and manganese in water can also be oxidized by chlorine, converting to ferric hydroxide and manganese dioxide.

- he precipitated material can then be removed by filtration.
- Most treatment plants use 1 – 2 parts of chlorine to 1 part of iron to achieve oxidation.

Oxidation with permanganate

- Using potassium permanganate to oxidize iron or manganese is fairly common.
- Potassium permanganate oxidizes iron and manganese into their insoluble states.
- Potassium permanganate is typically more effective at oxidizing manganese than aeration or chlorination.
- Potassium permanganate is often used with manganese greensand, a granular material that is charged with potassium permanganate after the backwashing process.
- This method allows the oxidation process to be completed in the filter itself and is a buffer to help avoid pink water in distribution. After the filter is backwashed, it regenerates for a period of time with a high level of permanganate before it is put back into operation.

FLUORIDATION

- Water fluoridation is the controlled addition of fluoride to a public water supply to reduce tooth decay. Fluoridated water has fluoride 0.5 to 1.5 mg/L at a level that is effective for preventing cavities;

DEFLUORIDATION

Introduction

Defluoridation is a treatment used to remove fluoride from drinking water. The process of this technique is to remove fluoride, which is a highly toxic chemical, to prevent health issues and dental issues that contains in humans. It is supposed to help save the environment so people can drink safe water. Many methods have been developed for removal of fluoride from drinking water. These methods can be broadly classified into four basic groups.

- Ion exchange or adsorption methods
- Coagulation and precipitation methods
- Electro – chemical defluoridation or electro dialysis

- Reverse osmosis

Methods of defluoridation

1. Defluoridation using activated alumina

- Activated alumina is the common name for γ- aluminium oxide.
- The crystal structure of alumina contains cation lattice discontinuities giving rise to localized areas of positive charge. This makes alumina attract various anionic species.
- The maximum capacity of activated alumina is found to be 3.6 mg F - / g of alumina.
- Alumina has a high preference for fluoride compared to other anionic species, and hence is an attractive adsorbent. In practice, alumina is first treated with HCl to make it acidic.

$$\text{Alumina} \cdot H2O + HCl \longrightarrow \text{Alumina} \cdot HCl + H2O$$

This acidic form of alumina when contacted with fluoride ions displaces the chloride ions and gets attached with the alumina.

$$\text{Alumina} \cdot HCl + NaF \longrightarrow \text{Alumina} \cdot HF + NaCl$$

To regenerate the adsorbent a dilute solution of sodium hydroxide is mixed with the adsorbent to get a basic alumina

$$\text{Alumina} \cdot HF + 2NaOH \longrightarrow \text{Alumina} \cdot NaOH + NaF + H2O$$

Further treatment with acid regenerates the acidic alumina.

$$\text{Alumina} \cdot NaOH + 2\,HCl \longrightarrow \text{Alumina} \cdot HCl + NaCl + H2O$$

A disadvantage of this process is that the regeneration steps result in an aqueous solution containing fluoride. On the other hand, if the spent alumina is discarded, the cost of the defluoridation increases. Apart from that, spent alumina may leach out fluoride ions when it comes in contact with alkali

Defluoridation using serpentine

- Serpentine is a material containing one or both of the minerals chryostile and antigorite.
- These minerals contain mainly silica and magnesium oxide.

- Serpentine is first powdered to less than 30 mesh size and then treated with concentrated HCl.
- Treated serpentine is then dried and then mixed with fluoride water.
- Maximum fluoride adsorption is achieved when acid is used along the fluoride containing water in the ratio 1:5.
- This method has some disadvantages. Serpentine tends to be deactivated with repeated use. When used in acidic conditions, other ions such as aluminium, magnesium or iron leach out into the water. Further, the pH of the treated water must be increased before it can be used for drinking.

Alum coagulation

- The alum (Al2(SO4)3 .18 H2O) can be used to coagulate fluoride, which then be removed by filtration.
- Alum, in the presence of sodium carbonate reacts with fluoride ions to give a complex,

$$2\ AL_2(SO_4)_3\ 18\ H_2O + NaF + 9\ Na_2CO_3 \longrightarrow [5\ AL(OH)_3\ AL(OH)\ 2F] + 8CO_2 + 9Na_2SO_4 + NaHCO_3 + 45\ H_2O$$

$$3\ AL_2(SO_4)_3\ 18\ H_2O + NaF + 17\ NaHCO_3 \longrightarrow [5\ AL(OH)_3\ AL(OH)\ 2F] + 9Na_2SO_4 + 17\ CO_2 + 18\ H_2O$$

The 250 mg alum is required to reduce the CF from 3.6 mg/L to 1.5 mg/L in 1 L of water. It has been shown that this method can be used to treat water with high values of CF.

Defluoridation of water using fired clay chips

- Fired clay chips are reported to have good fluoride removal capacity. The maximum capacity of the adsorbent was found to be 0.2 mg F - / g of the adsorbent.

Defluoridation by carbonaceous adsorbents

- Fluoride can be removed by carbonaceous adsorbents such as wood charcoal or bone charcoal
- They are obtained either by direct carbonization or by sulphuric acid treatment of saw dust, coconut coir or animal bones.
- The adsorbents are washed, sieved to a size 80 µm, dried at 110 ºC, and then mixed with water containing fluoride. The contact time required for reducing CF from 10 mg/L to 1 mg/L is found to be a few hours. It is being found that at acidic pH, the fluoride uptake is much higher compared to neutral or basic pH limits. The fluoride adsorption capacity of the coal - based sorbents is around 7 mg F - / g of adsorbent.

WATER SOFTENING

- Water softening is the reduction of the concentrations of calcium, magnesium, and other ions in hard water.
- Water softening methods mainly rely on the removal of Ca^{2+} and Mg^{2+} from a solution *or* the sequestration of these ions.
- Removal is achieved by ion exchange and by precipitation methods.
- Sequestration entails the addition of chemical compounds called sequestration (or chelating) agents.

Necessity of water softening

1. More quantity of soap is consumed at home and in laundries for washing of clothes.
2. The fabric of cloths get spoiled while washing it to remove precipitate formed by soap in hard water.
3. Hard water choke and clog plumbing due to precipitation of salts in term.
4. Hard water creates serious troubles in the manufacturing process of textile, ice making, dying etc.,
5. In industries hard water forms scale in boiler leads to danger.

Types of Hardness

1. Carbonate or Temporary Hardness

2. Non-carbonate or Permanent Hardness

Carbonate and Non-carbonate Hardness

- Carbonate hardness (Temporary hardness) is primarily caused by the carbonate and bicarbonate salts of calcium and magnesium. It can be removed by boiling or by adding lime.
- Non-carbonate hardness (Permanent hardness) is due to sulphates and chlorides of calcium and magnesium.

$$\underset{(\text{mg/L as } CaCO_3)}{\text{Total hardness}} = \underset{(\text{mg/L as } CaCO_3)}{\text{Carbonate hardness}} + \underset{(\text{mg/L as } CaCO_3)}{\text{Non-carbonate hardness}}$$

Methods of removing temporary Hardness

1. By boiling
2. By adding lime

By boiling

When water is heated, the carbon dioxide gas will get out, leading to the precipitation of $caco_3$ which can be sediment out in settled tank. The reaction be represented as

$$\underset{\text{Calcium bicarbonate}}{\underset{\uparrow}{Ca(HCO_3)_2}} + \text{heat} \longrightarrow \underset{\text{Calcium carbonate}}{\underset{\uparrow}{CaCO_3}} + CO_2 + H_2 0$$

This method is not suitable for large scale (like public supplies).

By adding of lime

If the water contains temporary hardness the water of lime is added in the water. The following chemical reaction is take place in adding lime in the water,

$$Mg(HCO_3)_2 + Ca(OH)_2 \dashrightarrow \underline{CaCO_3} + MgCO_3 + 2H_2 0$$

$$Ca(HCO_3)_2 + Ca(OH)_2 \dashrightarrow \underline{2\ CaCO_3} + 2\ H_2 0$$

The calcium carbonate and magnesium hydroxide are insoluble in water and gets precipitated and can be removed by sedimentation tanks. This method is used in softening water which contains only temporary hardness.

Removal of Permanent Hardness

Softening of water means the removal of calcium, magnesium, iron salts and similar other metallic ions, which would form insoluble metallic soaps. The three important industrial methods employed for softening of water are:

1. Cold and hot lime-soda process.
2. Permutit or zeolite process.
3. Ion-exchange or demineralization process.

Lime-soda process.

Cold Lime-Soda

- In this Process, calculated quantity of chemicals and water, along with accelerators and coagulators are added to a tank fitted with a stirrer.
- On vigorous stirring, thorough mixing takes place.
- After softening the soft water rises upwards and the heavy sludges settle down.
- The softened water passes through a filtering media ensuring complete removal of the sludge and finally the filtered water flows out through the top.
- Magnesium hardness is brought down to almost zero but calcium hardness remains about 40 ppm.

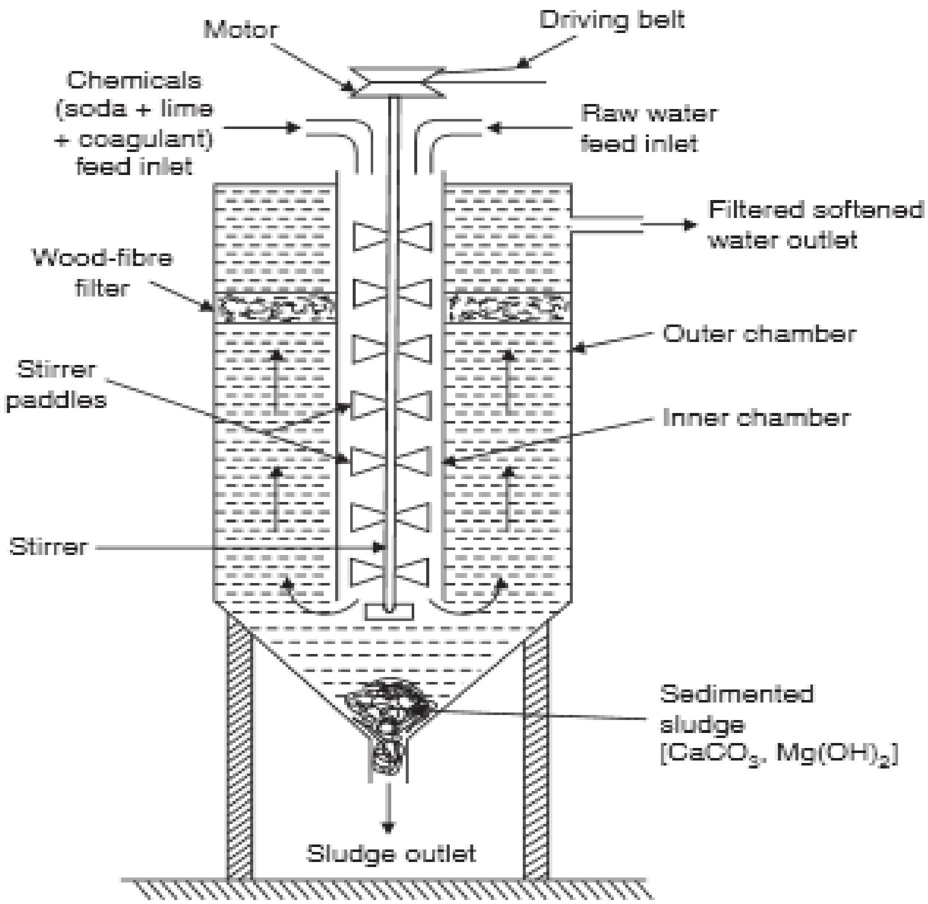


Figure 4.7.1 cold lime soda softener

Hot Lime-Soda Process

This process is similar to the cold lime-soda process. Here the chemicals alongwith the water are heated near about the boiling point of water by exhaust steam. As the reaction takes place at high temperature, there are the following advantages:

(i) The precipitation reaction becomes almost complete.

(ii) The reaction takes place faster.

(iii) The sludge settles rapidly.

(iv) No coagulant is needed.

(v) Dissolved gases (which may cause corrosion) are removed

(vi) Viscosity of soft water is lower, hence filtered easily.

(vii) Residual hardness is low compared to the cold process.

Hot lime-soda process consists of three parts:

(a) 'Reaction tank' in which complete mixing of the ingredients takes place.

(b) 'Ionical sedimentation vessel' where the sludge settles down and

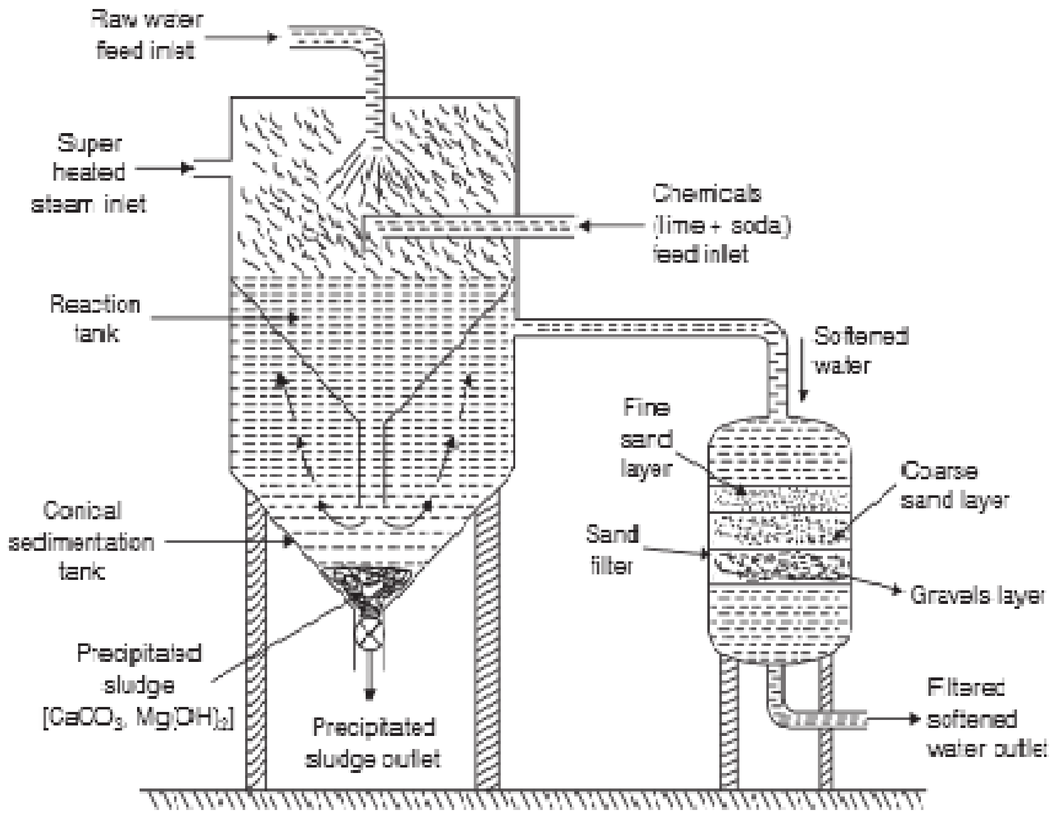
(c) 'Sand filter' where sludge is completely removed. The soft water from this process is used for feeding the boilers

Advantages Include:

(i) Lime soda process is economical.
(ii) The process improves the corrosion resistance of the water.
(iii) Mineral content of the water is reduced.
(iv) pH of the water rises, which reduces the content of pathogenic bacteria.

Disadvantages Include:

(i) Huge amount of sludge is formed and disposal is difficult.
(ii) Due to residual hardness, water is not suitable for high pressure boiler.



hot lime soda softener

Permutit or Zeolite Process

- Zeolite is hydrated sodium alumino silicate capable of exchanging reversibly its sodium ions for Ca^2+ and Mg^2+.
- General formula $Na_2O.Al_2O_3$.$xSiO_2$ .yH_2O. Common zeolite is Na_2O $Al2O_3$.$3SiO_2$.$2H_2O$ and is known as natrolith.
- Artificial zeolite used for softening purpose is permutit.
- These are porous and glassy and have greater softening capacity. They are prepared by heating together with china clay, feldspar and soda ash.
- Method of Softening: Hardwater is passed through a bed of zeolite at a specific rate at ordinary temperature; the hardness causing cations i.e., Ca^2+ and Mg^2+ are exchanged for Na and it is converted to CaZe and MgZe.

Reactions taking place are:

$$Na_2Ze + Ca(HCO_3)_2 \longrightarrow 2NaHCO_3 + CaZe$$

$$Na_2Ze + Mg(HCO_3)_2 \longrightarrow 2NaHCO_3 + MgZe$$

$$Na_2Ze + CaSO_4 \longrightarrow Na_2SO_4 + CaZe$$

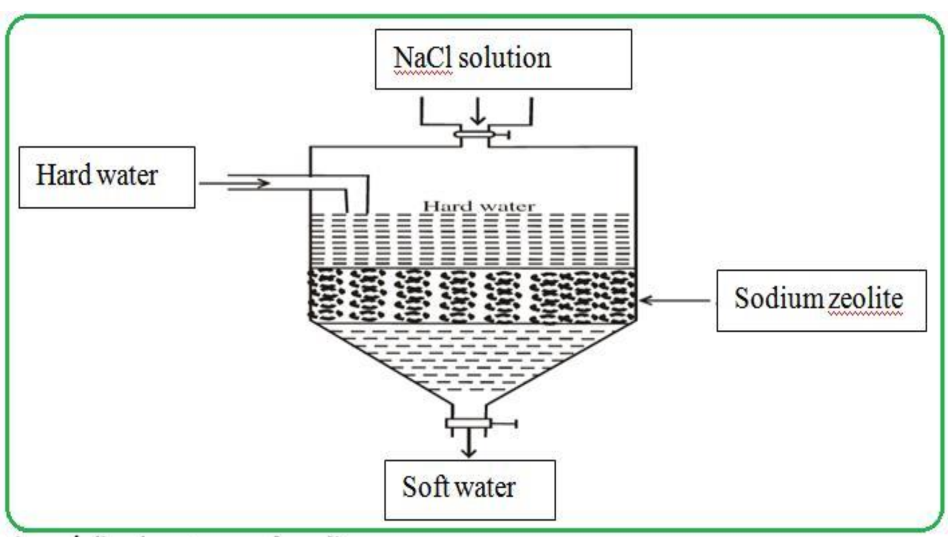
$$Na_2Ze + CaCl_2 \longrightarrow 2NaCl + CaZe$$

Regeneration of Zeolite:

The process is also commercially successful since the Ca/Mg zeolites formed by passing hard water through the bed can be easily regenerated into Na_2Ze by passing brine through the bed of inactivated zeolite.

$$CaZe \text{ or } MgZe + 2NaCl \longrightarrow Na_2Ze + CaCl_2 \text{ (Or } MgCl_2\text{)}$$

The washings containing $CaCl_2$ or $MgCl_2$ are wasted. The water softened by this process can be used for laundry purposes.



Advantage

(i)Hardness of water can be removed completely up to about 10 ppm;

(ii)The equipment used is small and easy to handle;

(iii)It requires less time for softening;

(iv)There is no sludge formation, hence the process is clean;

(v)Easy to regenerate;

(vi)Any hardness can be removed without any adjustment of the process.

Disadvantages.

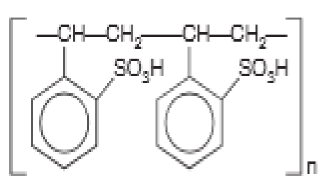
(i) Coloured water or water containing suspended impurities cannot be used before filtration;

(ii) Water containing acid cannot be used for softening since acid may destroy the zeolite;

(iii) Since on removal of Ca_{2+} and Mg_{2+} the soft water contains large amount of $NaHCO_3$, this on heating liberates CO_2, which causes corrosion in the boilers and hence this soft water is not suitable for boilers.

Ion Exchange or Demineralization

Ion exchange resins are organic polymers which are cross linked having micro porous structure and the functional groups are attached to the chains which are responsible for the ion exchange properties**. (i) Cation exchange resins (RH^+)** are phenol-sulfonic acid-formaldehyde resin, styrenedivinyl benzene copolymers which exchange their H+ ions with the cations present in the water i.e., Ca^{2+} and $Mg^{2+.}$



Cation exchange resin

(ii) Anion exchange resins (ROH): The styrene divinyl benzene or amine formaldehyde copolymers contain quaternary ammonium tertiary sulphonium or amino group in the resin. The resin on treatment with NaOH solution is capable of exchanging the OH with different anions of water i.e., Cl , SO_4^{2-} etc.

Method:

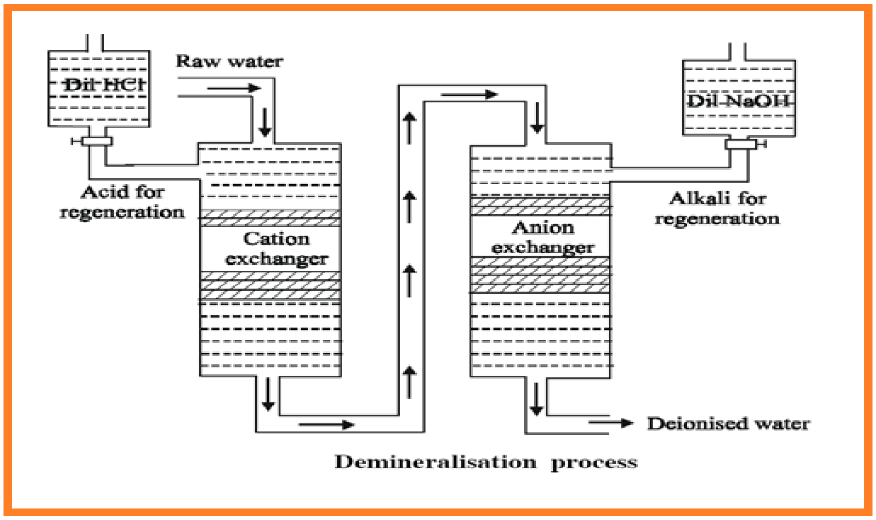
The hard water is passed first through cation exchange resin similar to the permutit process whereby the cations like Ca2+, Mg2+ are removed from the hard water and exchanged with H^+ as follows:

$$CaCl_2 + RH_2 \longrightarrow RCa + 2HCl$$
$$MgCl_2 + RH_2 \longrightarrow RMg + 2HCl$$
$$MgSO_4 + RH_2 \longrightarrow RMg + H_2SO_4$$
$$CaSO_4 + RH_2 \longrightarrow RCa + H_2SO_4$$
$$Ca(HCO_3)_2 + RH_2 \longrightarrow RCa + H_2CO_3$$
$$Ma(HCO_3)_2 + RH_2 \longrightarrow RMg + H_2CO_3$$
$$NaCl + RH_2 \longrightarrow RNa_2 + 2HCl$$

After this the hard water is again passed through anion exchange column, which exchanges all the anions like SO_4^{2-}, Cl^- etc. present in the water with OH^-

$$R'(OH)_2 + 2\,HCl \qquad R'Cl_2 + 2H_2O$$
$$R'(OH)_2 + H_2SO_4 \qquad R'SO_4 + 2\,H_2O$$

These H^+ and OH^- combine to form water molecule. Thus the water coming out finally from the two exchangers is ion free and called deioinized or demineralized water.



Regeneration:

The inactivated or exhausted cation exchange resin is regenerated by dil. H_2SO_4 /HCl.

$$RCa + 2HCl \longrightarrow RH_2 + CaCl_2$$

Similarly, the exhausted anion exchange resin is regenerated by dil. NaOH

$$R'Cl_2 + 2\,NaOH \longrightarrow R'(OH)_2 + 2NaCl$$

Advantages of ion exchangers include (i) Easy regeneration; (ii) both acidic and alkaline water can be softened; (iii) residual hardness is very low and hence the water is suitable for high pressure boilers also.

Disadvantages are (i) the equipment and the process is costly and (ii) turbid water cannot be directly charged for softening. It needs prior filtration.

DESALINATION

Desalination can be defined as any process that removes salts from water. Desalination processes may be used in municipal, industrial, or commercial applications.

Desalination Technologies

- Desalination refers to the process by which pure water is recovered from saline water using different forms of energy.
- Saline water is classified as either brackish water or seawater depending on the salinity and water source.

1. Distillation

- In this method, Saline water is heated, producing water vapour that in turn condenses to form distilled water.
- These processes include multistage flash (MSF), multiple-effect distillation (MED), vapour compression (VC) and low temperature evaporation (LTE).
- In all these processes, condensing steam is used to supply the latent heat needed to vapourize the water.
- Thermal processes are capable of producing high purity water and suited for industrial process applications.

- The basic principle involved in the MSF process is to heat the sea water to about 90–120°C using the heat of condensation of the vapour produced and supplementing with external steam.
- The heated sea water is subsequently flashed in successive stages maintained at decreasing levels of pressure.
- The vapor produced is condensed and recovered as pure water.

Membrane Technologies

2. Electrodialysis (ED) and Electrodialysis Reversal (EDR)

Electrodialysis (ED) is a voltage-driven membrane process. An electrical potential is used to move salts through a membrane, leaving fresh water behind as product water

ED depends on the following general principles: - Most salts dissolved in water are ions, either positively charged (cations), or negatively charged (anions). - Since like poles repel each other and unlike poles attract, the ions migrate toward the electrodes with an opposite electric charge - Suitable membranes can be constructed to permit selective passage of either anions or cations. In a saline solution, dissolved ions such as sodium (+) and chloride (-) migrate to the opposite electrodes passing through selected membranes that either allow cations or anions to pass through (not both).

Membranes are usually arranged in an alternate pattern, with anion-selective membrane followed by a cation-selective membrane. During this process, the salt content of the water channel is diluted, while concentrated solutions are formed at the electrodes. Concentrated and diluted solutions are created in the spaces between the alternating membranes, and these spaces bound by two membranes are called cells. ED units consist of several hundred cells bound together with electrodes, and is referred to as a stack. Feed water passes through all the cells simultaneously to provide a continuous flow of desalinated water and a steady stream of concentrate (brine) from the stack.

Advantages of Electrodialysis

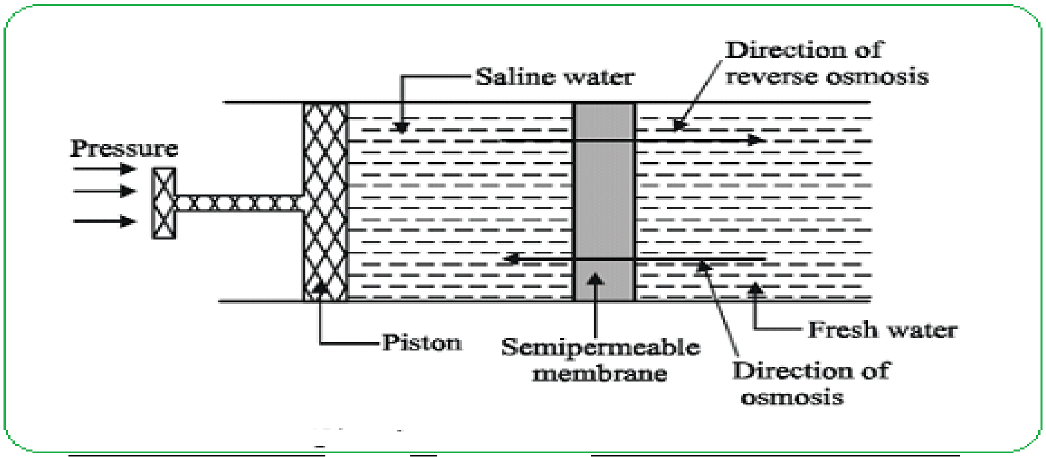
1. It is compact unit
2. The cost of installation process and its operation is economical
3. If 100% population is not required. This is the best method than all other methods.
4. If electricity is easily available, electrodialysis method is best suited method.

3. Reverse osmosis

The ***removal of common salt (NaCl) from sea water*** is known as **Desalination**. Water containing 1000 – 35000 ppm dissolved salt, having a salty taste is known as brackish water.

Osmosis: It is defined as the spontaneous flow of solvent (water) from a dilute solution to the concentrated solution through semi permeable membrane.

Reverse osmosis: **When pressure higher than osmotic pressure is applied,** solvent (water) flows from the concentrated solution to the dilute solution through semi permeable membrane.



Advantages of reverse osmosis:

- It removes ionic, nonionic and colloidal impurities in water.
- Replacement of semi permeable membrane is easy.
- The life time of the membrane is high.
- Low capital cost, low operating cost.

UNIT V

WATER DISTRIBUTION SYSTEM

INTRODUTION

The pupose of the distribution system is to convey wholesome water t6to to the consumer at aadequate residual pressure in sufficient quantity at conventent points. Water distribution usually amounts for 40 to 70% of the capital cost of the water supply system. As such proper design and layout of the system is of great importance.

The purpose of distribution system is to deliver water to consumer with appropriate quality, quantity and pressure. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage.

REQUIREMENTS OF WATER DISTRIBUTION SYSTEM

1. Water quality should not get deteriorated in the distribution pipes.
2. It should be capable of supplying water at all the intended places with sufficient pressure head.
3. It should be capable of supplying the requisite amount of water during fire fighting.
4. The layout should be such that no consumer would be without water supply, during the repair of any section of the system.
5. All the distribution pipes should be preferably laid one meter away or above the sewer lines.
6. It should be fairly water-tight as to keep losses due to leakage to the minimum.

COMPONENT OF WATER DISTRIBUTION SYSTEM

1. Water mains

The distribution system consists of supply main, sub mains, branches and lateral usually made of C.I and joined by means of “spigot” and socketed joints”. The service connections are made of galvanised cast iron pipes.

2. Valves for controlling flow

(i) Sluice valves or gate values are placed along the straight length of the pipes at suitable intervals and also all the junctions and branching of points, so as to control the flow of the water into the different sections.

(ii) Drain valves are placed at all the low points in the distribution pipe systems so as to drain off the water from the pipes for carrying out any repair

(iii) Air valves are placed at all the high points so as to remove air from the pipe during the filling operations and also to admit air while empting the pipe.

3. Fire hydrants

Fire hydrants are fixed in the supply main for the purpose of using fire fighting.

4. Pumps

Pumps are used for lifting the water and also for distribution purposes.

5. Service Reservoir

a. Surface Reservoir
b. Elevated Reservoir
c. Stand pipes etc

DISTRIBUTION RESERVOIRS

Distribution reservoirs, also called service reservoirs, are the storage reservoirs, which store the treated water for supplying water during emergencies (such as during fires, repairs, etc.) and also to help in absorbing the hourly fluctuations in the normal water demand.

Functions of Distribution Reservoirs:

- To absorb the hourly variations in demand.
- To maintain constant pressure in the distribution mains.
- Water stored can be supplied during emergencies.

Location and Height of Distribution Reservoirs:

- Should be located as close as possible to the center of demand.
- water level in the reservoir must be at a sufficient elevation to permit gravity flow at an
- Adequate pressure.

Types of Reservoirs

- Underground reservoirs.
- Small ground level reservoirs.
- Large ground level reservoirs.
- Overhead tanks.

Storage Capacity of Distribution Reservoirs

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

1. **Balancing Storage:** The quantity of water required to be stored in the reservoir for equalising or balancing fluctuating demand against constant supply is known as the balancing storage (or equalising or operating storage). The balance storage can be worked out by mass curve method.

2. **Breakdown Storage:** The breakdown storage or often called emergency storage is the storage preserved in order to tide over the emergencies posed by the failure of pumps, electricity, or any othe mechanism driving the pumps. A value of about 25% of the total storage capacity of reservoirs, or 1.5 to 2 times of the average hourly supply, may be considered as enough provision for accounting this storage.

3. **Fire Storage:** The third component of the total reservoir storage is the fire storage. This provision takes care of the requirements of water for extinguishing fires. A provision of 1 to 4 per person per day is sufficient to meet the requirement.

Service reservoirs, other than normal reservoirs, are provided because of the following reasons

(i) In case of the breakdown of pumping stations and water treatment plants, it provides a temporary storage of water in emergency situation like firefighting.

(ii) Since the demand of water supply from customers varies with time, the provision of service reservoirs aims to balance the fluctuation rate of water demand.

(iii) It provides a constant head of water to the distribution system under the design pressure.

(iv) In the event of the occurrence of water hammer or surge during the rapid closure and opening of pumping stations, the reservoir acts to attenuate the surge and performs like a surge tank.

(v) It leads to a reduction of the size of pumps and trunk mains connecting to the distribution system as the pumps are not required to directly cope with the peak rates of water demand by the introduction of service reservoirs. As such, there is substantial cost savings arising from the use of smaller pumping pipelines and smaller pumps.

Pipe Network Analysis

Analysis of water distribution system includes determining quantities of flow and head losses in the various pipe lines, and resulting residual pressures. In any pipe network, the following two conditions must be satisfied:

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

Based on these two basic principles, the pipe networks are generally solved by the methods of successive approximation. The widely used method of pipe network analysis is the Hardy-Cross method.

Hardy-Cross Method

This method consists of assuming a distribution of flow in the network in such a way that the principle of continuity is satisfied at each junction. A correction to these assumed flows is then computed successively for each pipe loop in the network, until the correction is reduced to an acceptable magnitude.

If Q_a is the assumed flow and Q is the actual flow in the pipe, then the correction d is given by

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

Now, expressing the head loss (HL) as

$$H_L=K.Q_a$$

We have, the head loss in a pipe

$$H_L=K.(Q_a+d)^{185}$$

$$Q=Q_a+\Delta$$

$$HL=K.[Q_a+\Delta]^X$$

$$=K.[Q_a^x + x.Q_a^{x-1}\Delta]$$

Neglecting terms contaioning higher power of Δ.Now, around a closed loop, the summation of head losses must be zero.

$$\sum_K.[Q_a^x + x.Q_a^{x-1}\Delta] = 0$$

$$\text{or}\sum(K.Q_a^x) = - \sum(K^x\ Q_a^{x-1}.x.\Delta)$$

Since, Δ is the same for all the pipes of the considered loop, it can be taken out of the summation.

$$\sum K.Q_a^x = - \Delta.\ \sum Kx\ Q_a^{x-1}$$

$$\text{or } \Delta=-\sum(K.Q_a^x)/ \sum(x.KQ_a^{x-1})$$

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

$$\text{or } \Delta=-\sum K.Q_a^x/ \sum (x.KQ_a^{x-1})$$

$$\text{or } \Delta =-\sum H_L / x.\ \sum(H_L/Q_a)$$

Where H_L is the head loss for assumed flow Q_a.

The numerator in the above equation is the algebraic sum of the head losses in the various pipes of the closed loop computed with assumed flow. Since the direction and magnitude of flow inbthese pipes is already assumed, their respective head losses with due regard to sign can be easily calculated after assuming their diameters. The absolute sum of respective KQa x-1 or HL/Qa is then calculated. Finally the value of d is found out for each loop, and the assumed flows are corrected. Repeated adjustments are made until the desired accuracy is obtained. The value of x in Hardy- Cross method is assumed to be constant (i.e. 1.85 for Hazen-William's formula, and 2 for Darcy-Weisbach formula)

Computer Application for Water Distribution Network Analysis

Computer application for water distribution network is carried out through computer models using specifically designed algorithms

Computer Models

Widespread introduction of personal computers has enhanced hydraulic design of distribution networks. Commercial programmes available on the market, sometimes even free of charge, enable a very precise and quick calculation, which makes them equally suitable for the design of simple rural systems or large urban networks of a few thousand pipes. Accessibility of such software and PCs to the engineers of developing countries has been significantly improved since the mid-nineties.

The computer programmes in use are all pretty similar in concept, with the following common features:

- PC-Windows™ based applications
- Allow extended period hydraulic simulations
- Possess integrated module for water quality simulations
- Handle virtually unlimited size of the network in any configuration
- Have excellent graphical interface for presentation of results

The main distinctions between these programmes are in specific formats of input data used, as well as in the way the calculation results are processed.

The modelling process consists of the following steps:

1. Input data collection

2. Network schematic
3. Model building
4. Model testing
5. Problem analysis

Input data collection

Powerful computational tools have enabled the focus to be shifted from the calculation to the collection of reliable input data. High quality information about demands, system dimensions and materials is crucial for accurate results. Operation and maintenance data are important too, in the case of rehabilitation of existing systems. This is often a limitation for the model. Well-conducted fieldwork data collection is therefore a very important initial step of the modelling procedure. The information to be investigated is listed below.

1. General

General layout of the network is taken from the maps available in the water distribution company. The specific data to look for are:

1.1 Topography - ground elevations in the area of the system; some specific natural barriers.

1.2 Type of the system - distribution scheme: gravity, pumping, combined; location and role of each system component.

1.3 Population - distribution and estimated growth.

2. Water demand

2.1 Demand categories present in the system: domestic, industry, tourism, etc.

2.2 Average consumption, patterns of variation: daily, weekly and seasonal.

2.3 Type of domestic water use: direct supply, roof tanks, etc.; average household size; habits with respect to the water use.

2.4 Demand forecasting.

3. Network layout

Nodes (discharge points) –

Concerns predominantly the supply points of at least a few hundred consumers or major industry. Relevant for each point are

- Location (X, Y) in the system
- Ground elevation (Z)
- Average consumption and dominant categories

Pipes –

Concerns predominantly the pipes, D > 50 mm. Relevant for each pipe are

- Length
- Diameter (internal)
- Material and age
- Assessment of corrosion level (k or C value, if available)

Service reservoirs –

Type (ground, elevated), capacity, minimum and maximum water level, shape (e.g. through the “volume-depth” curve).

a. Individual roof tanks (where applicable) –

Type and height of the tank, capacity, inflow/outflow arrangement, average number of users per house connection, description of house installations (existence of direct supply in the ground floor).

Pumping stations –

Number and type of pumps; duty head and flow and preferably the pump characteristics for each unit; age and condition of pumps.

Others –

Description of appurtenances that may significantly influence the system operation (e.g. valves, measuring equipment, etc.).

4. System operation & monitoring

Important (and preferably simultaneous) measurements for calibration of the model are:

- Pressure in a few points covering the entire network
- level variations in the service reservoirs and roof tanks (where applicable)
- pressures and flows in the pumping stations
- flows in a few main pipes in the network
- valve operation (where applicable)

All this information may not be easy to collect. However, some knowledge about the system should exist, even in descriptive form. For instance, in which period of the day is a certain reservoir empty (full), a certain pump on (off), a certain valve open (closed), a certain consumer with (without) water or with (without) sufficient pressure, etc. Where there is a possibility of continuous measurements, typical days should be compared: the same day of the week in various seasons, or various days of the week in the same season

5. System maintenance

Type of maintenance, water metering, the unaccounted-for water level and sources (leakage, faulty water meters, illegal connections, etc.), water quality in distribution network.

6. Water company

Organisation, facilities, practice, plans for future extension of the system. This information can be used to opt for a certain degree of reliability i.e. reserves capacity in the system. It may also have implications on the way the phased development should be approached. Some components of the system can deliberately be oversized to cater for future development of particular areas or connection to a new water source.

Network schematic

Hydraulic calculation of looped networks is based on systems of equations with a complexity directly proportional to the size of the system. Thus, some schematisation (also called skeletonisation) is necessary up to the level where the model accuracy will not be substantially affected, enabling quicker calculations at the same time. The answers should be reached with the minimum necessary number of pipes and nodes. Expanding the model by the system parts that have no significant impact on its operation only adds to the calculation time and the volume of printout.

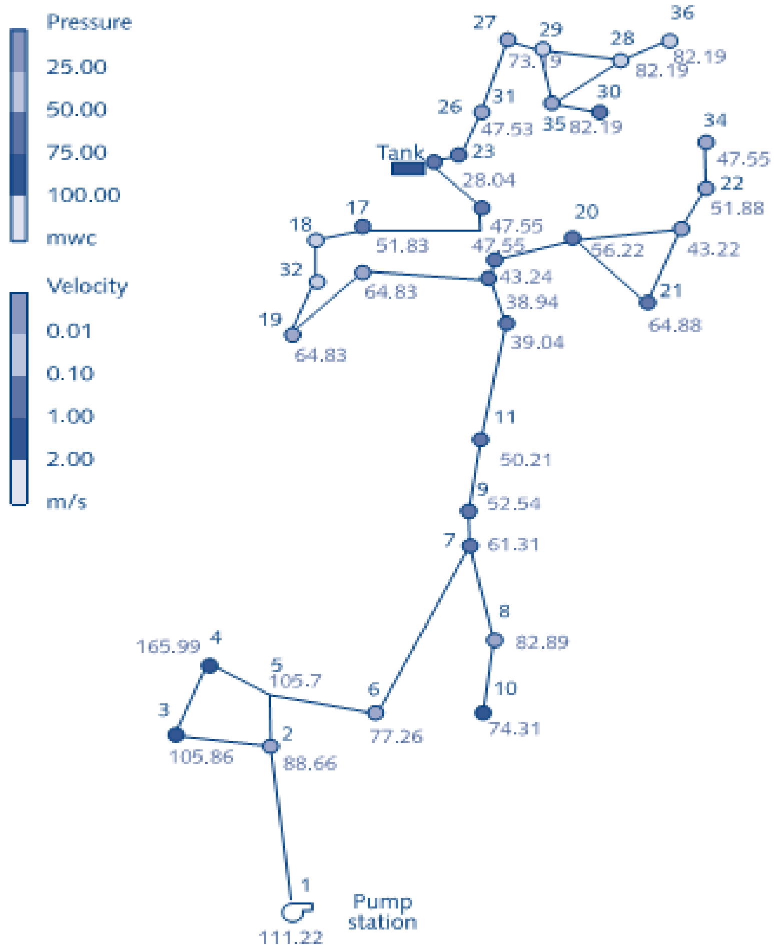
Model building

Just as in reality, it is advisable to build the network model in stages, increasing the level of detail gradually. Starting immediately with the full-size network with all components included will almost certainly yield lots of troubles during the testing of the model. In many cases the input file format has to be obeyed strictly; this is the only code the programme can understand while reading the data. Making errors during the model building is therefore common. Some programmes allow input in an interactive way so the chance of false network configuration will be diminished. In other cases the error check and warning messages will be activated after running the calculation.

Model testing

Once the first simulation run is completed the immediate concern is whether the result matches the reality. In this phase several runs have to be executed that should confirm that

- The model gives a logical response to any altering of the input data (model validation)
- The model's behaviour corresponds to the reality (model calibration)


Pressure
25.00
50.00
75.00
100.00
mwc
Velocity
0.01
0.10
1.00
2.00
m/s
27
29
28
36
73.19
82.19
82.19
26
31
30
47.53
35
82.19
34
Tank
23
47.55
28.04
22
51.88
17
18
47.55
20
51.83
47.55
56.22
43.22
32
43.24
64.83
38.94
21
19
64.88
39.04
64.83
11
50.21
9
52.54
7
61.31
8
82.89
165.99
4
5
105.7
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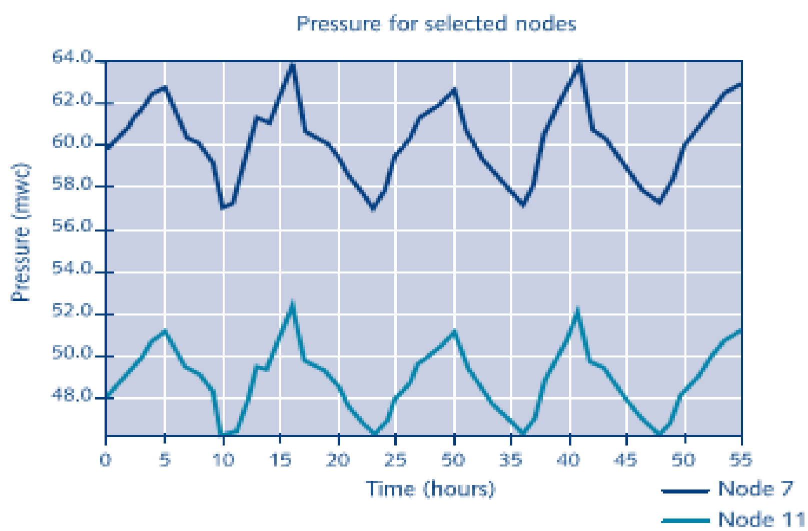
10
3
74.31
2
77.26
105.86
88.66
1
Pump
station
111.22


Pressure for selected nodes
64.0
62.0
60.0
58.0
56.0
54.0
52.0
50.0
48.0
Pressure (mwc)
0
5
10
15
20
25
50
35
40
45
50
55
Time (hours)
Node 7
Node 11

The reasons for any inaccuracy may be that

- Some input data were badly estimated because of lack of the field data
- the network is wrongly interpreted by the model due to possible typing errors, omitted data or inaccurate field measurements
- format of the input file is incorrect but the error is 'unknown' to the error library of the programme

It should never be forgotten that the computer models cannot match the real situation totally; the results should be judged based on the quality of the input data and the measurements used for model calibration

Problem analysis

With correct execution of all other steps, the real analysis of the problem is the final and the shortest step. After a few simulations a well-managed model will show the full picture of the selected alternative.

One of the most popular computer programmes in the market at present is EPANET made by the US Environmental Protection Agency. The programme possesses all of the above listed features. Graphical layout of the simulation results in EPANET is shown in figure.

Software for Water Distribution Network Analysis

1. Aqua Net
2. Archimede
3. Branch / Loop
4. Cross
5. Epanet 2.0
6. Eraclito
7. H_2O net/ H_2O map

8. Helix delta-Q
9. Mike Net
10. Netis
11. OptiDesigner
12. Pipe2000
13. Stanet
14. Wadiso SA
15. WaterCAD 5.0

OPERATION AND MAINTENANCE OF DISTRIBUTION SYSTEMS

The amount of water that can be billed will always be smaller than the amount supplied. Moreover, the water actually passing through the taps is also smaller than the amount supplied, be it charged or not. The difference in the first case refers to the unaccounted-for water (UFW) while the second one represents leakage. Thus, the leakage is a component of UFW. Other important sources can be faulty water meters, illegal connections, poor education of consumers, etc.

UFW is an important element of water demand and a great concern of many water companies. In some systems UFW is the most significant" consumer", reaching up to 50% of the total water supply. There can be various ways of fighting this problem but due to high costs of such programmes the real consideration tends to start only when the UFW levels exceed 20-30%. Limited capacity of the source can also be an important factor in such cases. Water conservation is increasing in importance as more and more regions begin to experience serious water shortages, and reducing UFW is a good way to start.

Leakage is usually the most significant contributor to high UFW levels. The factors influencing leakage are

- Soil characteristics, soil movement, traffic loading
- defects in pipes, poor quality of joints

- poor quality of workmanship, damage due to excavation for other purposes
- pipe age and corrosion level
- high pressures in the system
- extreme temperatures

There are a variety of managerial and technical ways to address the UFW problem. Managerial measures include the following:

- Regular checks by caretakers or by alerts from consumers for pipeline damage, leakage and illegal connections
- Regular checks by the water point committee, caretakers and technicians on the quality and leakage of connections (also the presence of illegal connections), meters (if present) and taps
- Arrangements at the water-vending points, public taps and group connections to minimise the waste of water by good caretaking

Global estimates of leakage levels come from an annual balance of the delivery and metered consumption for the whole network. Bursts of main pipes can be detected by the flow measurements at supply points.

For more detailed analysis of the leakage, suspected parts of the system have to be inspected during several hours or days, depending on the size of controlled area. Those temporary measurements are usually carried out overnight, when real consumption and overall noise level are minimal. The area is isolated from the rest of the system by closing the border valves and its inflow and outflow are measured. Some knowledge about the actual night consumption should exist in advance; flows detected on top of that are part of the UFW, mostly leakage.

Measurements are repeated at weekly intervals for a period of a few months. Any pipe burst between two measurements would be reflected in sudden increase in registered demand. Average leakage level can also be estimated by monitoring pressures in the system. A sudden drop of pressure could also indicate a major pipe failure. Under normal conditions night pressures should be kept as low as possible in order to reduce the leakage levels.

Finding a precise leak location can be a difficult problem. In case of severe breaks the

water may appear on the surface and the exact position of the leak can be determined by drilling test holes alongside the pipe route. If the leak is not visible on the surface, leak detection equipment has to be used. The most common devices are an acoustic (sound) detector and a leak noise correlator.

Acoustic detectors rely on sounding directly on the pipe or fitting, or indirectly on the ground surface. The noise generated from the leak is transmitted by the receiver attached to a stick, to the amplifier connected to a stethoscope. This method is not always reliable; leaks at lower pressures and specifically those in plastic pipes may produce undetectable noise. However, with skilled personnel working under silent (night) conditions, some 70-80% of the leaks should be discovered.

Leak noise correlators detect the exact burst location by registering the noise spreading through the water. By placing microphones at the ends of the controlled pipe section (up to a few hundred metres), the difference in time required for the leak noise to reach the microphones can be measured. The leak position can then be calculated from the known length of the section. This method is very effective in detecting leaks under background noise levels. However, it may be less accurate when being used in sections with plastic pipes or with more than one leak.

Faulty water meters are the second main source of unaccounted-for water. Typical water meters register flows with average accuracy of about 2%, when they are new. However, this error becomes higher for small flows, below 50 l/h. When not properly maintained the water meter may register flows with errors between 20 and 40% after a couple of years in service. This lack of accuracy can cause serious revenue losses.

Complicated methods of monitoring and leak detection would normally not be employed in small community water supply schemes. They require expensive equipment and trained personnel. Even so, installing at least a few measuring devices at the right points in the network may be of great help in collecting information about the system operation. The minimum is to have flow and/or pressure meters in the pumping stations. Water levels in the reservoirs should also be observed at regular intervals during the day. Ideally, a few pressure gauges should be installed within the network.

Corrosion

Corrosion of metal pipes is one of the major causes of poor operation of water distribution systems. It appears as a result of reaction between the water and metal. This internal corrosion causes three problems:

- The pipe mass is lost through oxidation to soluble iron, resulting in increased rate of pipe bursts
- The second by-product of oxidation is iron-bearing scale that accumulates on the pipe wall in the form of tubercles, causing a reduction of pipe capacity (head loss increase)
- Both soluble and particulate iron affects the water quality creating colour problems (‘brown’ or ‘red’ water)

External corrosion is a result of aggressive soils and may also contribute to the pipe burst rate to a large extent.

To reduce corrosion levels, metal pipes need to have internal and external coatings. Ductile iron and steel pipes are normally delivered with internal cement lining and external coatings made of plastic, epoxy, or bitumen. Steel pipes in pumping stations will usually be protected by painting. Handling of pipes during transport and laying has to avoid damage to the coatings. Once in service the cement lining can be dissolved due to leaching of calcium at low pH values. High turbulence or sudden change of the flow direction at high velocities may also damage the coating.

Water quality adjustment is the easiest and most practical way to make water noncorrosive. However, it is not always effective because of possible differences in water quality at the sources. Two basic methods are pH correction and oxygen reduction. Chemicals commonly used for pH adjustment are lime, caustic soda or sodium (bi) carbonate. Oxygen removal is rather expensive but some control measures can be introduced through optimisation of aeration processes and sizing of well and distribution pumps that will avoid air entry. Other options, such as adding inhibitors or cathodic protection of the pipes are too complex and expensive for small distribution schemes. Bad design of the pipes and structures may cause severe corrosion even in materials that are highly resistant. Some of the important design considerations include

- Selection of appropriate flow velocity
- selection of appropriate metal thickness
- reduction of mechanical stresses
- avoiding sharp bends and elbows
- avoiding grounding of electrical circuits to the system
- providing easy access to the structure for periodic inspection, maintenance and replacement of damaged parts

Pipe cleaning and disinfection

Corrosion deposits in pipes or sediments caused by improper treatment have to be removed to prevent water quality deterioration. Three techniques commonly used are flushing, swabbing and air scouring. These techniques may greatly help to improve the water quality but additional maintenance equipment has to be employed. Moreover, the network layout needs to include a number of hydrants or washouts to connect this equipment.

Flushing is the simplest method of cleaning but with some disadvantages:

- Large amounts of water used (particularly in large diameters)
- It is less effective in low pressure areas
- It may disturb flow patterns upstream of the cleaned section
- In areas with active corrosion, it offers only a temporary improvement

The efficiency of flushing can be increased by injection of compressed air into a continuous but smaller flow of water. Pushed by the air, the water will form into discrete slugs forced along the pipe at high velocities. The length that can be effectively cleaned by air scouring depends on:

- available static pressure (higher pressure - longer length)
- pipe friction (higher friction - shorter length)
- compressor size (larger compressor - longer length)
- pipe gradient (longer lengths when cleaning uphill)

Swabbing is a technique where a cylindrical swab is inserted into the pipe and driven along by the water pressure pushing the deposits ahead. The swab is porous and allows about 10% of the water flow to pass, which aids the transport of the deposits. Swabs are usually made of polyurethane of different hardness and construction for various degrees of reduction in pipe cross-section. Recommended travelling speed of the swab is 0.3-1.2 m/s.

The problem of animal populations appearing in water distribution systems is predominantly aesthetic and it is therefore a matter of maintaining it at such a level that the consumer is unaware of their presence. Pipe disinfection can be done either by cleaning or by chemical treatment. Swimming animals can be removed relatively easily by flushing. Chemical treatment is carried out where the flushing is insufficient. The chemicals commonly used are chlorine, pyrethrins and permethrin. Pyrethrins and permethrin are toxic to fish, so they should be used and disposed of very carefully. When using chlorine, higher concentrations are required than the normal dosages in water leaving the treatment plant. The concentrations applied during pre-chlorination may be effective in reducing animal appearance in the treatment works. An infestation in the distribution system can be controlled in most cases by maintaining 0.5-1.0 mg/l of residual chlorine for a week or two.

Long-term measures include removal of organic matter (restricting nutrients for the animals), which can be achieved by the following methods:

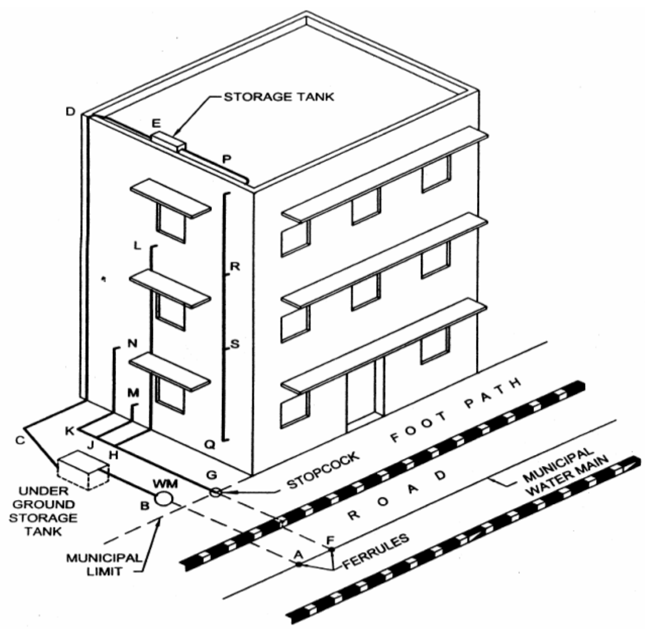
- Improvement of the treatment process regarding suspended solids removal and animal penetration
- Periodic cleaning of pipes and service reservoirs
- Maintenance of a chlorine residual throughout the distribution system
- Proper protection of openings on service reservoirs
- Elimination of dead ends and stagnant waters where ever possible.

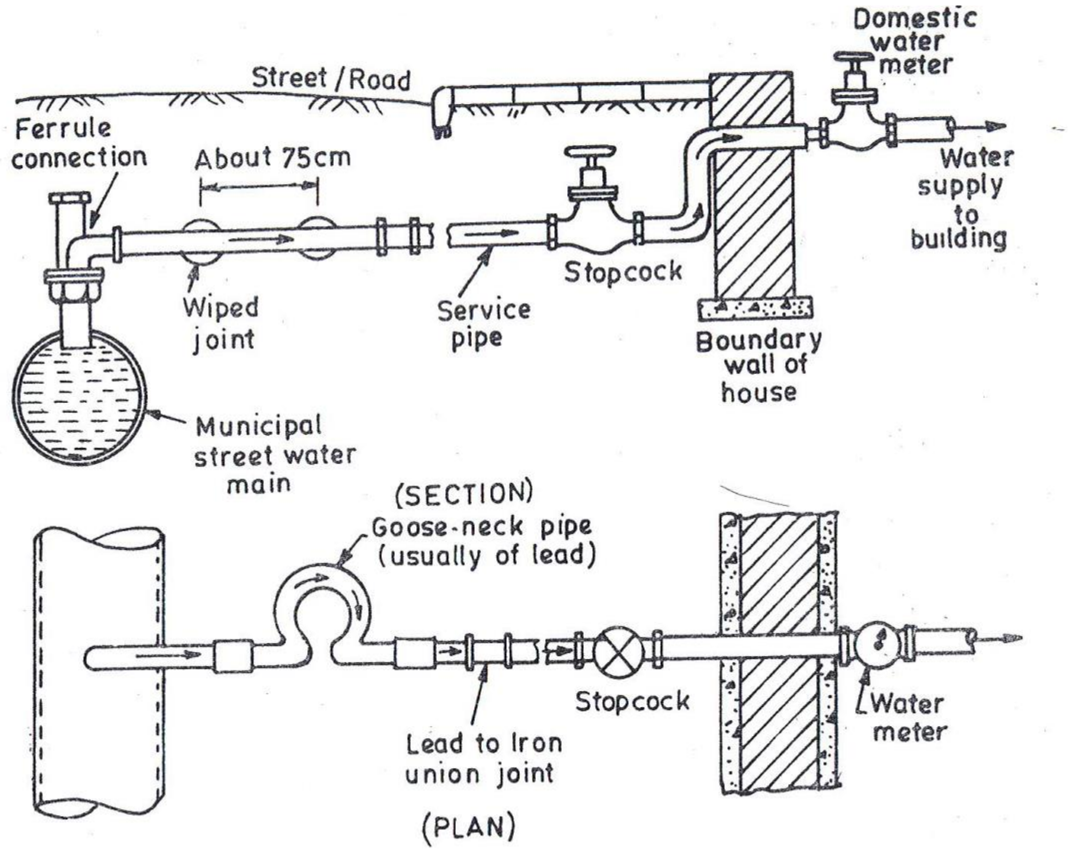
Water supply for a building

The following points should be kept in mind while planning water supply arrangement for a building:

- The layout should be simple and direct to reduce the cost of length of pipe.
- To avoid the losses at the bends, the pipes should be laid in straight line as far as possible.
- The layout should be such that sufficient pressure is available at the point from where the consumer gets the water supply.
- Booster pumps should be avoided because its suction lift decreases pressure of water in the adjoining buildings.
- The outlet pipe in the tank shall be fixed 50 to 75 mm above the bottom of the tank and provided preferably with copper gauge strainers.
- No service or supply pipe shall be connected directly to any hot water system.

- There should be at least a residual head of 0.18 kg/cm2 at the consumer's tap.
- Plumbing of water lines should be such as not to permit back flow from cistern and sinks
- All joints shall be perfectly water tight and no leakage or spill at taps or cocks should be allowed
- Pipelines should not be carried under walls or foundations
- It should not be close to sewers or wastewater drains. There should not be any possibility for cross connections.
- When pipe lines are close to electric cables proper precautions for insulation should be observed
- Plumbing lines should be such as to afford easy inspection and repair of fixtures and joints.
- Number of joints should be less and the number of bends and tees should be less
- It should supply adequate discharge at fixtures economical in terms of material and protected against corrosion, air lock, negative pressure and noise due to flow in pipes and in flushing





House hold connection

Storage of water in buildings

- Storage of water within the premises of a building is usually necessary, because the municipal supplies are usually not available round the clock.
- Such storage may also help in meeting static fire demand, and to provide uninterrupted water supply in the building in case the main municipal or ground water supply is shut off for repairs, or if there is a power failure.
- Storage may also help to supplement the direct municipal supply in case of excess demand.

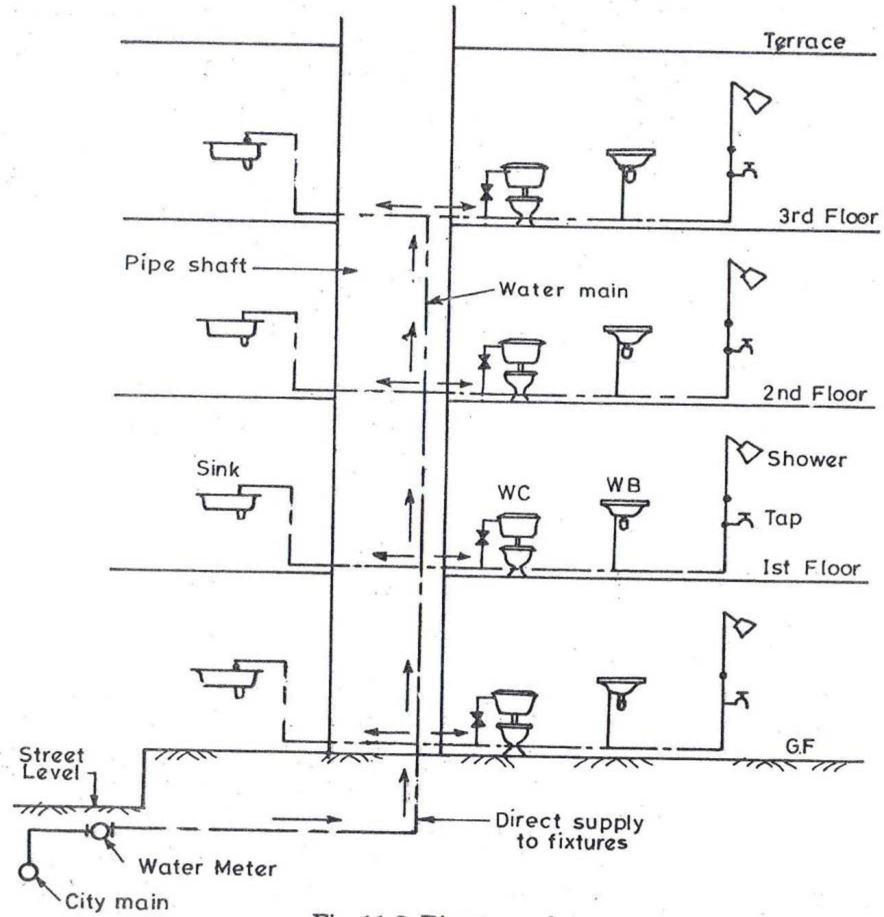
Distribution Systems in Multi-Storeyed Buildings

There are four basic methods of distribution of water to a multistoried buildings. Direct supply from mains to ablutionary taps and kitchen with WCs and urinals supplied by overhead tanks.

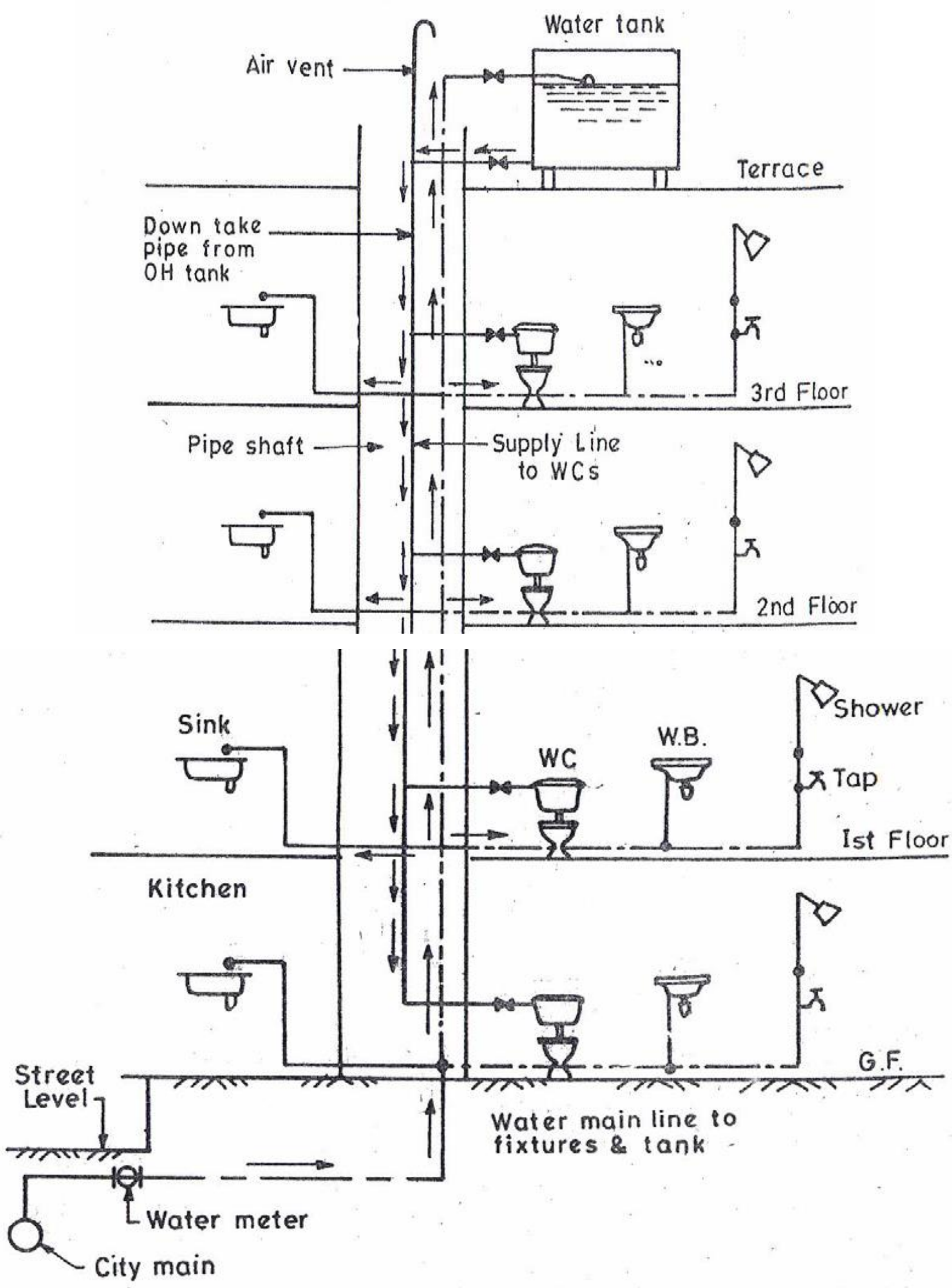
- Direct Pumping Systems
- Hydro-Pneumatic Systems
- Overhead Tanks Distribution

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.



Direct Supply System

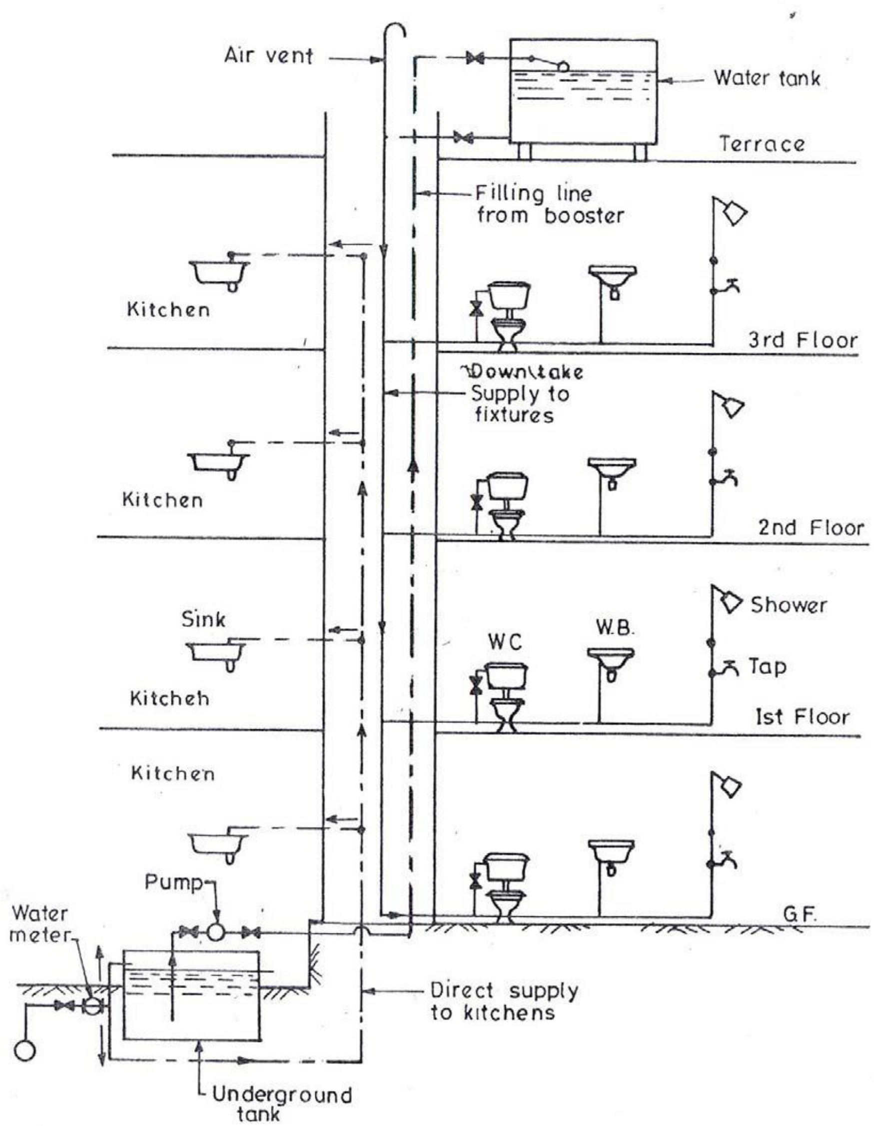


Water tank
Air vent
Terrace
Down take pipe from OH tank
3rd Floor
Pipe shaft
Supply Line to WCs
2nd Floor
Sink
Shower
W.B.
WC
Tap
Ist Floor
Kitchen
G.F.
Street Level
Water main line to fixtures & tank
Water meter
City main

Direct supply with over head tank

Piping system using Underground Overhead Tank supply

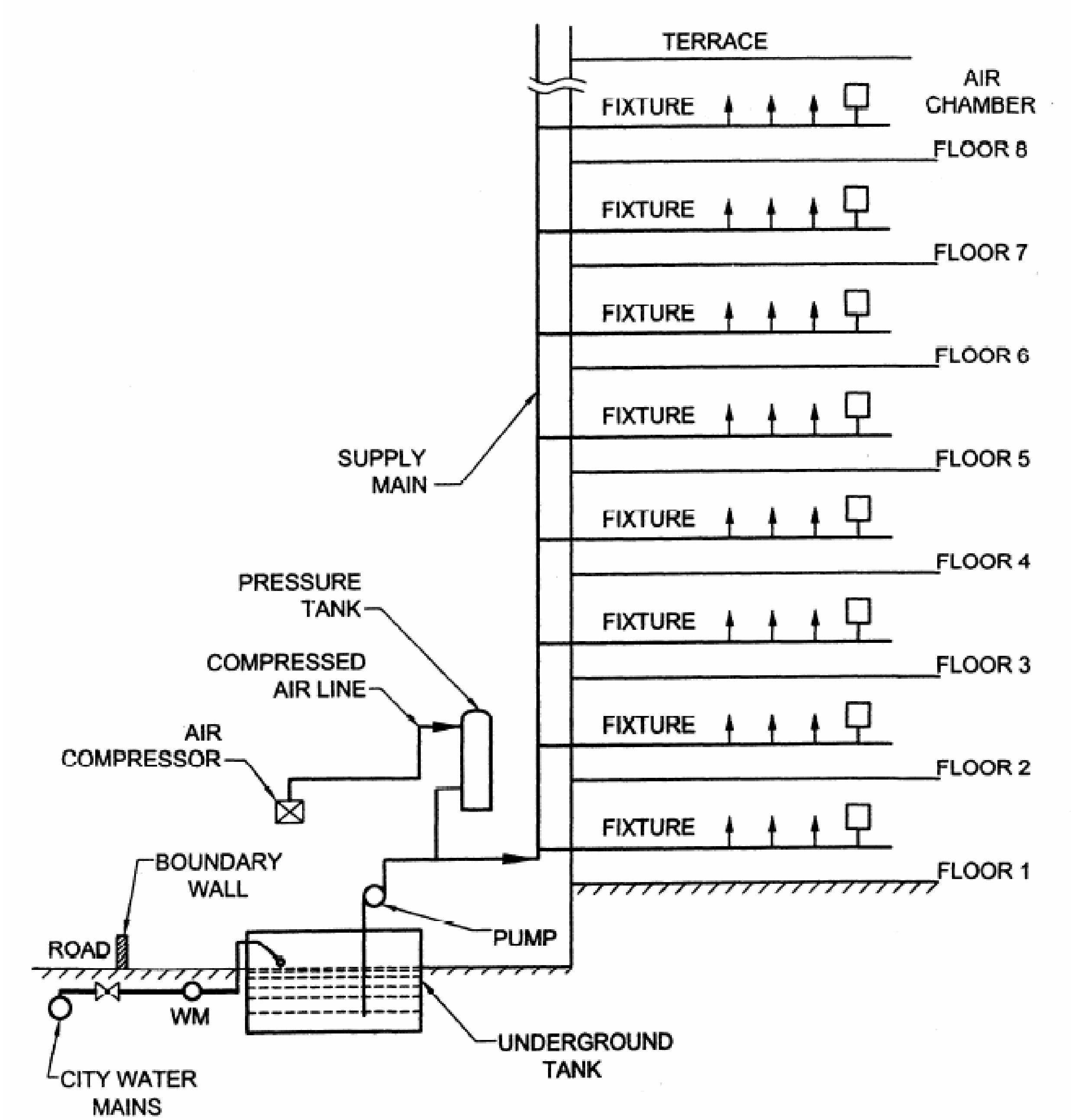
When the municipal water supplies are at low pressure, whether intermittent or continuous, then it becomes necessary to store water in underground tanks. The water collected in underground tank is finally lifted to the overhead tank. Direct supply connections may also be made to the lower sroreyes, as to obtain at least some amount of direct supply for drinking purpose. Ordinary 2-3 storeyed houses will therefore install a direct as well as an underground – overhead tank supply system.



Piping system using underground water supply

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 capacity shall be based on the cut-in and cutout pressure of the pumping system depending upon allowable start/stops of the pumping system.
- As pumps operate, the incoming water is the vessel, compresses the air on top.
- When a predetermined 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 the 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.
- The system shall have reliable power supply to avoid breakdown in the water supply.
- 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