

INTRODUCTION

Human activities and environment pollution

Humans impact the environment in several ways. Common effects include decreased water quality, increased pollution and greenhouse gas emissions, depletion of natural resources and contribution to global climate change. Some of these are the direct result of human activities, whereas others are secondary effects that are part of a series of actions and reactions.

Water Pollution

Perhaps the most obvious examples of a negative human impact on the environment is water pollution. It's obvious we need water to survive but few people realize how much we need and just how much is available. Consider these facts from the United Nations Environment Programme:

- 1 Of all the water on Earth, only 2.5% of it is freshwater.
- 2 Of that 2.5%, less than 1% is available to us.
- 3 Humans each require up to 13 gallons (50 litres) a day of fresh water for drinking, cooking and cleaning. This does NOT take into account the countless gallons of water needed to grow food or care for animals.
- 4 70% of all freshwater usage goes to irrigation.

According to Organic Farming Research Foundation, only 2% of farms are organic. This equates to almost 69% of our freshwater supply is being contaminated by chemical pesticides, herbicides, and chemical fertilizers, while also compounded with fossil fuels and emissions from heavy farming machinery. These chemical compounds contribute to acid rain. Since very little can live in an acidic environment, acid rain has harmful effects on plants, animals, and aquatic life, as well as humans and even buildings, statues or other objects. Acid rain also contaminates our limited freshwater supply, and thus the cycle of water pollution continues. According to the U.S. Environmental Protection Agency, 45% of assessed stream miles, 47% of assessed lake acres, and 32% of assessed bay and estuarine square miles were not clean enough to support uses such as swimming or fishing. The following reasons and possible sources for this include: Sediments, pathogens and habitat alterations from agricultural activity and hydrologic modifications (such as dams Excessive nutrients, metals and organic enrichment from agricultural activity and

atmospheric deposition (the movement of pollutants from one environment to another, such as from water to air) Heavy metals (primarily mercury), excess nutrients and "organic enrichment" from industrial and municipal discharges ("treated" or untreated waste water released from sewer plants and industrial factories into natural water sources) These points listed above lead to a poisoned and uninhabitable environment for plants and aquatic life, as well as affect land animals and humans reliant on these systems for survival and other land-bound plant life in need of clean water for growth.

Land Pollution

Land pollution, the degradation of the Earth's surfaces and soil, is caused by human activity and a misuse of natural resources. Causes of land pollution and degradation include:

1. Urban sprawl: Natural habitats are removed to make room for communities, usually with inefficient or irresponsible planning. Urban sprawl generally results in a waste of land area for unused development (such as excessive roads, decorative and unused areas, etc).
2. Poor agricultural practices: Animal manure runoff from CAFO (Confined Animal Feeding Operations), the use of chemical fertilizers, herbicides and pesticides, the practice of growing monocultures (only one crop season after season) and the deforestation required to expand farm land all contribute to degradation and pollution.
3. Personal consumption: Our modern culture's desire to have more, bigger and better "things", as well as our relationship to and habit of waste, has led to stripping of the land, excessive mining and pollution from industrial activities.
4. Industrial activities: The production of chemical-laden plastics, poor quality of products, unethical practices (such as illegal dumping), and extreme emissions affect both surrounding and far-reaching areas.

None of this takes into account illegal dumping, diminishing landfill space, litter, overproduction of synthetic materials, radioactive waste and more. All land pollution is caused by a human impact on the environment and thus can be averted by our actions alone. Two of the necessary actions must be proper planning and proper usage of natural resources. For instances, animals could be taken out of CAFO and allowed to graze on mountainous or wooded areas unsuitable for buildings or crops. Using organic and sustainable farming techniques can eliminate our need for

chemical applications. Clean energy, such as wind or solar power, can slowly begin to replace coal or nuclear plants. And as consumers we can lessen our human impact on the environment by demanding better quality products, environmentally ethical practices from industries and a shift toward sustainable energy.

Air Pollution

One bit of good news about our human impact on the environment is that air pollution is lowering and air quality is increasing. According to the U.S. Environmental Protection Agency, since 1990 to 2008:

Ozone decreased 14%

Lead decreased 78%

Nitrogen dioxide decreased 35%

Carbon monoxide decreased 68%

Sulfur dioxide decreased 59%

However, 127 million people still live in areas that exceed quality standards. And some of the quality standards are far from ideal, such as ozone. The question is: what amount of air pollution is really okay? Shouldn't we be striving for technologies or practices that virtually eliminate major polluters, such as: Better public transit, electric cars, rail, and city planning etc to replace heavy commutes, fossil fuels, air travel and unwalkable communities Retrofitting or otherwise upgrading existing factories with greener technologies such as solar panels or air filtration systems Removing animals from factory farms and raising them on natural diets and rotating pasture to reduce methane emissions and pollution The greatest human impact on the environment we can have is to vote with our pocket book and our actions. By supporting companies that use greener technologies, we can start a trend toward better solutions. By getting involved in community planning and zoning we can have a global impact on a local level. And by buying less "stuff", eating less animal products and sourcing our food from sustainable farms, we can spread the word that better solutions do exist and they don't have to cater to mega-corporations and lobbyist pressure.

Some important impacts of human activities on environment are outlined below:

1. **Deforestation:** In order to provide timber and farm land to increased population, large number of forest trees are cut and forest area is converting to farm lands. The rate of deforestation is so faster that around 1.5 million hectare of forest cover is lost every year in India alone. The process of deforestation results in decreasing rainfall, increasing global temperature, loss of top soil, modification of climatic conditions etc.
2. **Industrialization:** Although the industrial activities of man provide basic need of the society, simultaneously the same release a lot of pollutants to the environment. The pollutants in environment cause loss of raw materials, health hazards, increase in death rate, damage to crop, making environment unfit for living organisms etc.
3. **Loss of ecological balance:** The excessive use, misuse and mis-management of biosphere resources results in disturbance in ecosystem or ecological imbalance.
4. **Air pollution:** The anthropogenic release of various air pollutants to the environment causes a number of dreaded phenomena like green house effect, ozone layer depletion, acid rain and smog formation etc.
5. **Water pollution:** Human activities in respect of disposal of sewage wastes, solid wastes, municipal wastes, agricultural and industrial wastes cause the environment unfit for day to day use. Besides, polluted water spreads or leads to different diseases.
6. **Increased consumption of natural resources:** Since the starting of industrial era, the natural resources are constantly utilised for the production of one or more products for the day to day use of society.
7. **Production of waste:** Rapid industrialization and unplanned urbanization release a lot of toxic waste material either in solid or liquid or gaseous state which induces a number of serious environmental hazards.
8. **Extinction of Wildlife:** Since forests are natural habitats of wild life (both plants and animals) deforestation leads to the extinction of valuable wild life and loss of biodiversity.

9. **Habitual destruction:** The commercial and industrial activities associated with mining, construction of dams, fishing, agriculture etc. cause habitat destruction which is a pathway to pollution.

10. Noise pollution: The man-made noise due to mechanized automobile, industries, trains, aero planes, social functions etc. causes noise pollution which has impact on both biotic and a biotic components of environment.

11. **Radiation pollution:** The radiations from radioactive substances used in nuclear reactors and nuclear weapons can have significant impact on genetic materials of body (DMA, RHA etc.)

12. **Soil erosion:** The anthropogenic processes like deforestation and overgrazing induce soil erosion which causes soil moisture reduction, lowering of productivity, decline in soil fertility etc.

NEED FOR PROTECTED WATER SUPPLY

Protected water supply means the supply of water that is treated to remove the impurities and made safe to public health. Water may be polluted by physical and bacterial agents. Water is also good carrier of disease causing germs. The causes of outbreak of epidemics are traced to pollute water and poor sanitation hospital are continued to be flooded with the sick due to ignorance about health continues to be profound. However during the last few decades, improvements in the public health protection by supplying safe water and sanitation to all the people in the developing countries. In 1977, united nations declare to launch a movement known as “HEALTH FOR ALL BY THE YEAR 2000 A.D.” India is also a signatory to that conference. The working group appointed by the planning commission while suggesting strategies for achieving the above goal emphasized that potable water from protected water supply should be made available to the entire population. Pure and whole some water is to be supplied to the community alone can bring down the morbidity rates.

Sl.No.	Description	India 1970-75	U.S.A 1970-75
1	Average per capita G.N.P.	133	7024
2	Infant mortality rate (per	129	15

	thousand)		
3	Life Expectancy (years)	49	73
4	Literacy	34	99

The objectives of the community water supply system are

1. To provide whole some water to the consumers for drinking purpose.
2. To supply adequate quantity to meet at least the minimum needs of the individuals and to make adequate provisions for emergencies like fire fighting, festivals, meeting etc
3. To make provision for future demands due to increase in population, increase in standard of living, storage and conveyance
4. To prevent pollution of water at source, storage and conveyance
5. To maintain the treatment units and distribution system in good condition with adequate staff and materials
6. To design and maintain the system that is economical and reliable

WATER DEMANDS

VARIOUS TYPES OF WATER DEMANDS

While designing the water supply scheme for a town or city, it is necessary to determine the total quantity of a water required for various purposes by the city. As amatter of fact the first duty of the engineer is to determine the water demand of the town and then to find suitable water sources from where the demand can be met. But as there are so many factors involved in demand of water, it is not possible to accurately determine the actual demand. Certain empirical formulae and thumb rules are employed in determining the water demand, which is very near to the actual demand.

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

1. Domestic water demand
2. Industrial demand
3. Institution and commercial demand
4. Demand for public use

5. Fire demand
6. Losses 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. As per IS: 1172-1963, under normal conditions, the domestic consumption of water in India is about 135 litres/day/capita. But in developed countries this figure may be 350 litres/day/capita because of use of air coolers, air conditioners, maintenance of lawns, automatic household appliances.

The details of the domestic consumption are

a) Drinking-----	5 litres
b) Cooking-----	5 litres
c) Bathing-----	55 litres
d) Clothes washing-----	20 litres
e) Utensils washing-----	10 litres
f) House washing-----	10 litres

135 litres/day/capita	

INDUSTRIAL DEMAND

The water required in the industries mainly depends on the type of industries, which are existing in the city. 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.

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. As per IS: 1172-1963, water supply requirements for the public buildings other than residences as follows.

Sl.No.	Type of Building	Construction per capita per day (litres)
1.	a) Factories where bathrooms are required to be provided.	45
	b) Factories where no bathrooms are required to be provided	30
2.	Hospitals per bed	
	a) No. of beds not exceeding 100 No.	340
	b) No. of beds exceeding 100 No.	450
3.	Nurses homes and medical quarters.	135
4.	Hostels	135
5.	Offices	45
6.	Restaurants (per seat)	70
7.	Hotel (per bed)	180
8.	Cinema concert halls and theatres (per seat)	15
9.	Schools	
	a) Day schools	45
	b) Boarding schools	135
10.	Garden, sports grounds	35 per sq.m
11.	Animal/vehicles	45

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. To meet the water demand for public use, provision of 5% of the total consumption is made designing the water works for a city. The requirements of water for public utility shall be taken as given in Table

Sl.No.	Purpose	Water Requirements
1.	Public parks	1.4 litres/m ² /day

2.	Street washing	1.0-1.5 litres/m ² /day
3.	Sewer cleaning	4.5 litres/head/day

FIRE DEMAND

Fire may take place due to faulty electric wires by short circuiting, fire catching materials, explosions, bad intension of criminal people or any other unforeseen mishappenings. If fires are not properly controlled and extinguished in minimum possible time, they lead to serious damage and may burn cities.

All the big cities have full fire-fighting squads. As during the fire breakdown large quantity of water is required for throwing it over the fire to extinguish it, therefore provision is made in the water work to supply sufficient quantity of water or keep as reserve in the water mains for this purpose. In the cities fire hydrants are provided on the water mains at 100 to 150 m apart for fire demand.

The quantity of water required for fire fighting is generally calculated by using different empirical formulae. For Indian conditions kuichings formula gives satisfactory results.

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

Where 'Q' is quantity of water required in
litres/min 'P' is population of town or
city in thousands

Buston's formula

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

Freeman's formula

$$Q = 1136 (P/5+10)$$

And

$$F = 2.8 \sqrt{p}$$

Where F= number of simultaneous fire streams

$$Q = 4637\sqrt{p (1-0.01\sqrt{p})}$$

Though the total demand of water for extinguishing fire is usually very small, the rate of consumption is very high. It depends upon bulk, congestion and fire resistance buildings. The minimum limit of fire demand is the amount and rate of supply that would extinguish the largest probable fire in the city. Fire hydrants of 15 to 20 cm diameter are normally provided on all street corners, and at suitable intermediate points. These are generally connected to water supply mains. When fire occurs, pumps installed on fire brigade trucks are rushed to the site and connected to fire hydrants from where they throw jet of water under very high pressure. The pressure varies between 1 to 2 kg/cm². For a fire of moderate, three streams each of 1100 litres/minute are required. For a city of one lac population, the fire flow required, by National Board of Fire Underwriters comes out to be 40500 litres/minute. Assuming an average total consumption of 150 litres/day, thus the rate of flow required for the fire demand, is very much higher than the total flow rate required for the purposes. However, the provision for fire demand is made only for 3 to 5 hours fire flow. The total quantity of water calculated on yearly basis is usually very small because fire breaks out only few times in a year.

LOSSES AND WASTES

All the water, which goes in the distribution, pipes does not reach the consumers. The following are the reasons

1. Losses due to defective pipe joints, cracked and broken pipes, faulty valves and fittings.
2. 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
3. Losses due to unauthorised and illegal connections

While estimating the total quantity of water of a town; allowance of 15% of total quantity of water is made to compensate for losses, thefts and wastage of water

PER CAPITA DEMAND

If 'Q' is the total quantity of water required by various purposes by a town per year and 'p' is population of town, then per capita demand will be

$$\text{Per capita demand} = \frac{Q}{P \times 365} \text{ litres/day}$$

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

i. Domestic purpose -----	135 litres/c/d
ii. Industrial use-----	40 litres/c/d
iii. Public use-----	25 litres/c/d
iv. Fire Demand-----	15 litres/c/d
v. Losses, Wastage and thefts -----	55 litres/c/d

Total : 270 litres/capita/day	

The total quantity of water required by the town per day shall be 270 multiplied with 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, washing of rooms, more washing of clothes and bathing etc. But in very cold countries sometimes the quantity of water required may be more due to wastage, because at such places the people often keep their taps open and water continuously flows for fear of freezing of water in the taps and use of hot water for keeping the rooms warm.

Size of community : Water demand is more with increase of size of 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 because of the use of air conditioners, room coolers, maintenance of lawns, use of flush, latrines and automatic home appliances etc.

Industrial and commercial activities : As 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. As a matter of fact the water required by the industries has no direct link with the population 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. This increase in the quantity is firstly due to use of water freely by the people as compared when they get it scarcely and more water loss due to leakage, wastage and thefts etc.

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: The cost of water directly affects its demand. If the cost of water is more, less quantity of water will be used by the people as compared when the cost is low.

POPULATION FORECASTING METHODS AND PROBLEMS

When the design period is fixed the next step is to determine the population of a town or city population of a town 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 may produce sharp rises, slow growth, stationary conditions or even decrease the population. For the prediction of population, it is better to study the development of other similar towns, which have developed under the same circumstances, because the development of the predicted town will be more or less on the same lines.

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

- i. Arithmetical increase method
- ii. Geometrical increase method
- iii. Incremental increase method
- iv. Simple graph method
- v. Decrease rate of growth method
- vi. Comparative graph method and The master plan method

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

YEAR	POPULATION
1940	8000
1950	12000
1960	17000
1970	22500

Find the probable population in the year 1980, 1990 and 2000.

ARITHMETICAL INCREASE METHOD

This method is based on the assumption that the population is increasing at a constant rate. The rate of change of population with time is constant. The population after 'n' decades can be determined by the formula.

$$P_n = P + n.c \text{ where}$$

P → population at present n → No.

of decades

c → Constant determined by the average of

increase of 'n' decades

Solution:

YEAR	POPULATION	INCREASE IN POPULATION
1940	8000	---
1950	12000	4000
1960	17000	5000
1970	22500	5500
	TOTAL	14500
	AVERAGE	4833

YEAR	POPULATION
1980	$22500 + 1 \times 4833 = 27333$

1990	$22500 + 2 \times 4833 = 32166$
2000	$22500 + 3 \times 4833 = 36999$

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.

The population at the end of 'n' decades is calculated by

I_G

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

100

Year	Population	Increase in population	Percentage increase in population
1940	8000	---	
1950	12000	4000	$\frac{4000}{8000} \times 100 = 50\%$
1960	17000	5000	$\frac{5000}{12000} \times 100 = 41.7\%$
1970	22500	5500	$\frac{5500}{17000} \times 100 = 32.4\%$
	TOTAL	14500	124.1%
	AVERAGE	4833	41.37%

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

YEAR	EXPECTED POPULATION
1980	$22500 + 41.37 / 100 \times 22500 = 31808$
1990	$31800 + 41.37 / 100 \times 31800 = 49935$
2000	$49935 + 41.37 / 100 \times 49395 = 68524$

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.

Solution:

Year	Population	Increase in population	Incremental increase
1940	8000	---	---
1950	12000	4000	---
1960	17000	5000	+ 1000
1970	22500	5500	+ 1500
	TOTAL	14500	+ 2500
	AVERAGE	4833	1,250

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

YEAR	EXPECTED POPULATION
1980	$22500 + (4833 + 1250) \times 1 = 28583$
1990	$22500 + (4833 + 1250) \times 2 = 34666$
2000	$22500 + (4833 + 1250) \times 3 = 40749$

VARIATIONS IN DEMAND

The per capita demand of town is the average consumption of water for a year. In practice it has been seen that this demand doesnot remain uniform throughout the year but 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, because the people will use more water in bathing, cooling, lawn watering and street sprinkling. This demand will become minimum in winter because less water will be used in bathing and there will be no lawn watering. The variations may be up to 15% of the average demand of the year.

DAILY VARIATIONS

This variation depends on the general habits of people, climatic conditions and character of city as industrial, commercial or residential. More water demand will be on Sundays and holidays due to more comfortable bathing, washing etc as compared to other working days. The maximum daily consumption is usually taken as 180% of the average consumption.

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 12 P.M. to 4 P.M. when most of the people are sleeping. But in highly industrial city where both day and night shifts are working, the consumption in night may be more. The maximum consumption may be rise up to 200% that of average daily demand.

The determination of this hourly variations is most necessary, because on its basis the rate of pumping will be adjusted to meet up the demand in all hours.

DESIGN PERIOD

The complete water supply project includes huge and costly constructions such as dams, reservoirs, treatment works and network of distribution pipelines. These all works cannot be replaced easily or capacities increased conveniently for future expansions.

While designing and constructing these works, they should have sufficient capacity to meet future demand of the town for number of years. 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 is estimated based on the following:

1. Useful life of the component, considering obsolescence, wear, tears, etc.
2. Expandability aspect. Anticipated rate of growth of population, including industrial, commercial developments & migration-immigration.
3. Available resources.
4. Performance of the system during initial period

CHAPTER-2

SOURCES OF WATER SUPPLY

INTRODUCTION

Water is the most abundant compound in nature. It covers 75% of the earth surface. About 97.3% of water is contained in the great oceans that are saline and 2.14% is held in icecaps glaciers in the poles, which are also not useful. Barely the remaining 0.56% found on earth is in useful form for general livelihood. Total quantity of water available on the planet “EARTH” in various states and religions are given in the table

LOCATION	VOLUME (m ³)	% OF TOTAL
<u>Land Areas</u>		
Fresh water lakes	152×10^{12}	0.009
Saline lakes	104×10^{12}	0.008
Inland seas, Rivers	1.25×10^{12}	0.001
Soil moisture	67×10^{12}	0.005
Ground water	8350×10^{12}	0.005
Icecaps and glaciers	52×10^{12}	0.610

TOTAL	$37,800 \times 10^{12}$	2.80

<u>Atmosphere</u>		
Water vapour (clouds)	13×10^{12}	0.001
<u>Oceans</u>		
Water in the oceans	$13,20,000 \times 10^{12}$	97.3
	-----	-----
TOTAL ON PLANET	$13,60,000 \times 10^{12}$	100
	-----	-----

Hydrological concepts

Hydrology is the science, which deals with the increment of the water on the ground, under the ground, evaporation from the land and water surface and transportation from the vegetation and going back into atmosphere where it precipitates.

Definition

The water which goes in atmosphere by evaporation and transpiration again comes back in the form of precipitation under favourable climatic conditions is known as hydrological cycle of water.

Precipitation

The evaporated water from the surfaces of streams, rivers, sea, ponds, wet surfaces, trees and plants etc again returned to the earth surface by the condensation in the form of rain, hails, dew, sleet etc is known as precipitation. The major part of the precipitation occurs in the form of rain and other forms quantities are very small. The water of precipitation further goes off in the following ways.

Run-off: After precipitation a portion of its water flows over the ground in the form of rivers and streams and some water flows towards lakes and ponds and collected there.

Infiltration: A portion of precipitation, percolates in the ground and it is stored in the form of sub-soil or ground water.

Evaporation: some portion of the precipitation is also evaporated from the lakes, rivers, reservoirs and wet surfaces in the form of vapour due to sun's heat is known as evaporation

Evapo-transpiration: The roots of the trees suck water from the ground and some portion of it evaporates in the atmosphere through leaves in the form of transpiration.

Surface sources

All the sources of water can be broadly divided into

1. Surface sources and
2. Sub surface sources

The surface sources further divided into

1. Streams
2. Rivers
3. Ponds
4. Lakes

5. Impounding reservoirs etc.

Natural ponds and lakes

In mountains at some places natural basin's are formed with impervious bed by springs and streams are known as "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. But 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, railways contains large amount of impurities and therefore cannot be used for water supply purposes.

Streams and rivers

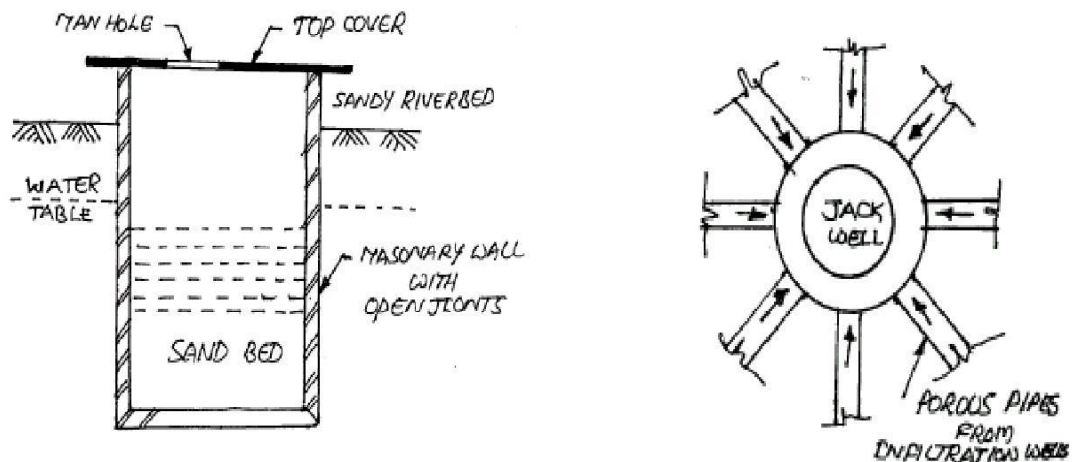
Rivers and streams are the main source of surface source of water. In summer the quality of river water is better than monsoon because in rainy season the run-off water also carries with clay, sand, silt etc which make the water turbid. So river and stream water require special treatments. Some rivers are snow fed and perennial and have water throughout the year and therefore they do not require any arrangements to hold the water. But some rivers dry up wholly or partially in summer. So they require special arrangements to meet the water demand during hot weather. Mostly all the cities are situated near the rivers discharge their used water of sewage in the rivers, therefore much care should be taken while drawing water from the river.

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 max. Quantity of water to be stored. In lakes and reservoirs, suspended impurities settle down in the bottom, but in their beds algae, weeds, vegetable and organic growth takes place which produce bad smell, taste and colour in water. Therefore

INFILTRATION WELLS

In order 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. They are constructed by brick masonry with open joints as shown in fig



Infiltration Well Jack Well

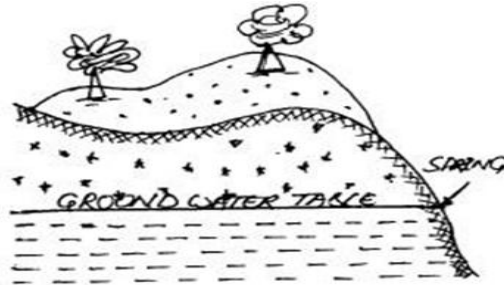
For the purpose of inspection of well, the manholes are provided in the top cover. The water filtrates through the bottom of such wells and as it has to pass through sand bed, it gets purified to some extent. The infiltration wells are connected by porous pipes to collecting sump called jack well and there water is pumped to purification plant for treatment.

SPRINGS:

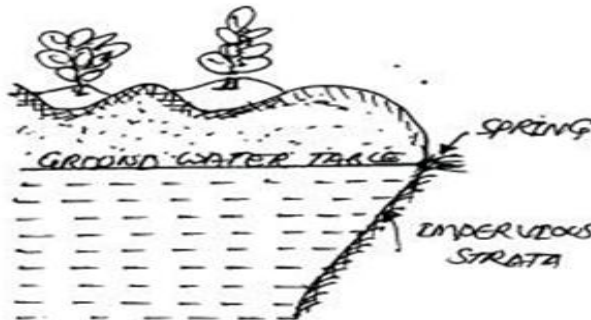
Sometimes ground water reappears at the ground surface in the form of springs. Springs generally supply small quantity of water and hence suitable for the hill towns. Some springs discharge hot water due to presence of sulphur and useful only for the cure of certain skin disease patients.

Types of springs:

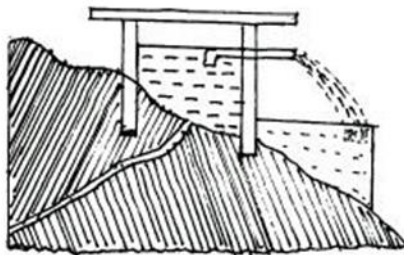
1. Gravity Springs: When the surface of the earth drops sharply the water bearing stratum is exposed to atmosphere and gravity springs are formed as shown in fig



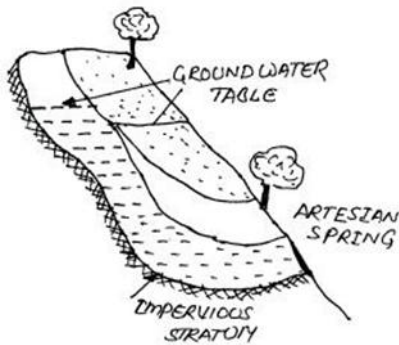
2. Surface Spring: This is formed when an impervious stratum which is supporting the ground water reservoir becomes out crops as shown in fig



3. Artesian Spring: When the ground water rises through a fissure in the upper impervious stratum as shown in fig



When the water-bearing stratum has too much hydraulic gradient and is closed between two impervious stratum, the formation of Artesian spring from deep seated spring



Wells:

A well is defined as an artificial hole or pit made in the ground for the purpose of tapping water. In India 75 to 85% of Indian population has to depend on wells for its water supply.

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.

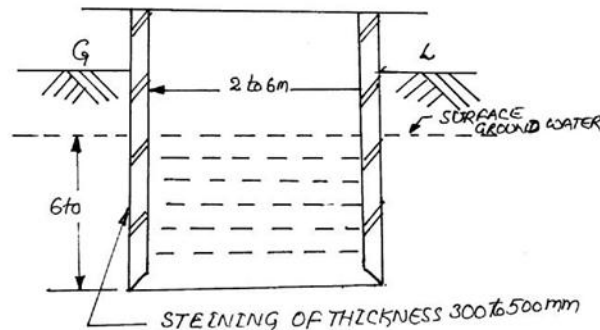
The following are different types of wells

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

Shallow Wells :

Shallow wells are constructed in the uppermost layer of the earth's surface. The diameter of well varies from 2 to 6 m and a maximum depth of 7m. Shallow wells may

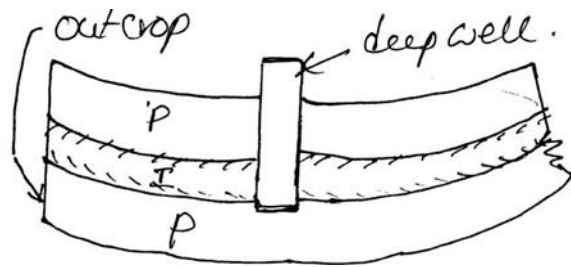
be lined or unlined from inside. Fig. shows a shallow well with lining (steining). These wells are also called draw wells or gravity wells or open wells or drag wells or percolation wells.



Quantity of water available from shallow wells is limited as their source of supply is uppermost layer of earth only and sometimes may even dry up in summer. Hence they are not suitable for public water supply schemes. The quantity of water obtained from shallow wells is better than the river water but requires purification. The shallow wells should be constructed away from septic tanks, soak pits etc because of the contamination of effluent. The shallow wells are used as the source of water supply for small villages, undeveloped municipal towns, isolated buildings etc because of limited supply and bad quality of water.

(b) Deep Wells :

The Deep wells obtain their quota of water from an aquifer below the impervious layer as shown in fig No. The theory of deep well is based on the travel of water from the outcrop to the site of deep well. The outcrop is the place where aquifer is exposed to the atmosphere. The rain water entered at outcrop and gets thoroughly purified when it reaches to the site of deep well. But it dissolves certain salts and therefore become hard. In such cases, some treatment would be necessary to remove the hardness of water.



The depth of deep well should be decided in such a way that the location of out crop is not very near to the site of well. The water available at a pressure greater atmospheric pressure, therefore deep wells are also referred to as pressure wells.

Intakes for collecting surface water:

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

Intakes are structures which essentially consist of opening, grating or strainer 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 works.

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 per 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.

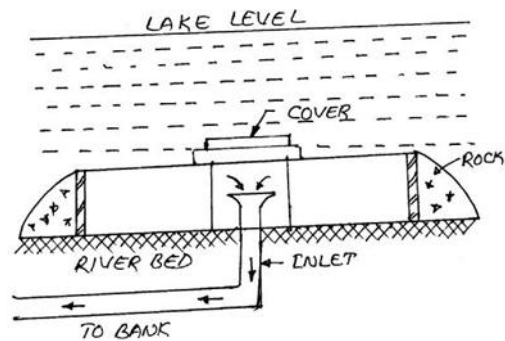
Types of Intake structures:

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

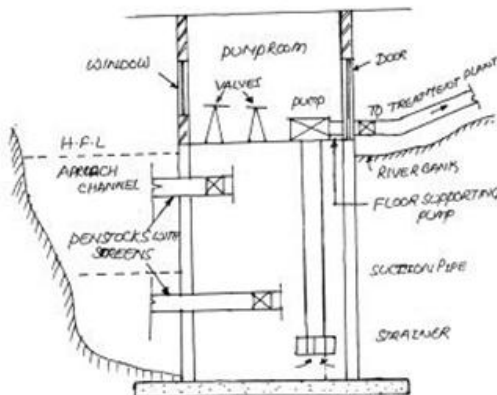
- 1.Lake Intake
- 2.Reservoir Intake
- 3.River Intake
- 4.Canal Intake

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. These intakes have so many advantages such as no obstruction to the navigation, no danger from the floating bodies and no trouble due to ice. As these intakes draw small quantity of water, these are not used in big water supply schemes or on rivers or reservoirs. The main reason being that they are not easily approachable for maintenance.



River intake



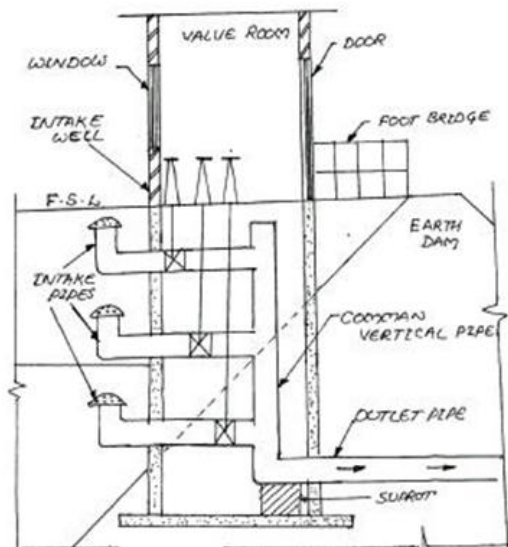
Water from the rivers is always drawn from the upstream side, because it is free from the contamination caused by the disposal of sewage in it. It is circular masonry tower of 4 to 7 m in diameter constructed along the bank of the river at such place from where required quantity of water can be obtained even in the dry period. The water enters in the lower portion of the intake known as sump well from penstocks.

Reservoir intake:

Fig shows the details of reservoir intake. It consists of an intake well, which is placed near the dam and connected to the top of dam by foot bridge. 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

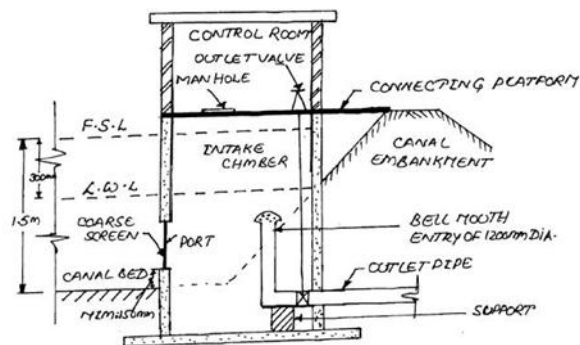
intake pipes at different levels ensures supply of water from a level lower than the surface level of water.

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 upto the bottom of intake from the floor of valve room, the steps should be provided in Zigzag manner.



Canal intake:

Fig shows the details of canal intake. A 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.



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.

Pumps

The function of pump is to leave the water or any fluid to higher elevation or at higher pressure. Pumps are driven by electricity, diesel or steam power. They are helpful in pumping water from the sources that is from intake to the treatment plant and from treatment plant to the distribution system or service reservoir. In homes also pumps are used to pump water to upper floors or to store water in tanks over the buildings.

Types of pumps and their suitability

Based on the mechanical principle of water lifting pumps are classified as the following

Sl.No	Type of Pump	Examples	Suitability
1.	Displacement pumps	Reciprocating pumps. Rotary, chain, gear wheel, pump and wind mills.	This type of pumps are suitable for moderate heads and small discharges suitable for fire protection, water supply of individual houses.
2.	Velocity pumps	Centrifugal pumps, deep well, turbine pumps, jet pumps	This type of pumps are used widely in water supply schemes containing sand, silt etc.
3.	Boyancy pumps	Airlifting pumps	Airlifting pumps are generally adopted for pumping of water from deep wells to a lift of about 60m containing mud, silt, debries etc.
4.	Impulse pumps	Hydraulic Ram	Used for Small water supply projects to lift the water for a height of about 30m or so.

Centrifugal pumps – components

Centrifugal force is made use of in lifting water . Electrical energy is converted to potential or pressure energy of water

Centrifugal pump consists of the following parts as shown in fig

Centrifugal Pump

1.**Casing:** The impellor is enclosed in the casing, which is so designed that kinetic energy of the liquid is converted into pressure energy before it leaves the casing.

2.Delivery pipe

3.Delivery valve

4.Impeller

5.Prime mover

6.Suction pipe

7.Strainer and foot valve

Description

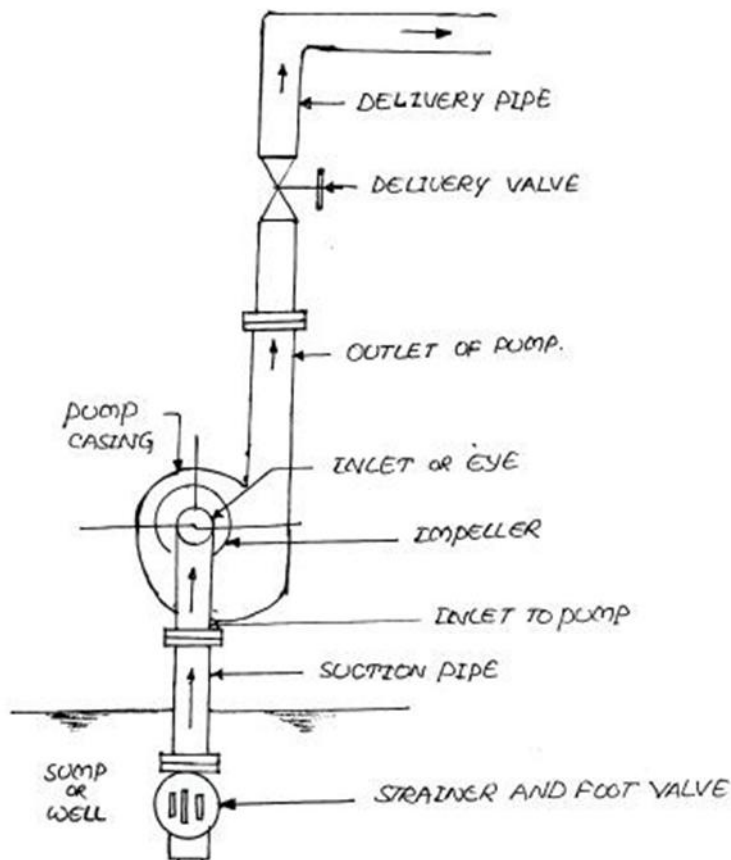
The pump consists of a Impeller is enclosed in a water tight casing. Water at lower level is sucked into the impellor through a suction pipe. Suction pipe should be air tight and bends in this pipe should be avoided. A strainer foot valve is connected at the bottom of the suction pipe to prevent entry of foreign matter and to hold water during pumping .Saction 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 casing 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 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 wornout components and testing . Sufficient amount of spares of impellers, bearings, slip-ring brushes, stator-contacts, gland packing, greases,

oils, jointing materials, valves are to be kept instock to attend to the emergencies. It is usual to have one stand by pump in addition to the required number of pumps.

Selection of pump horse power

Basic data regarding the water availability like diameter, depth of the well, depth of the water table, seasonal variations of water table, drawdown duration of pumping and safe yield are to be collected accurately before selecting a pump. There are many varieties of specifications and choices available in the market and it is a tricky problem facing an engineer to select the best suited for his requirement.

Point to be observed in selecting a pump

- 1.Capacity and efficiency - The pump should have the capacity required and optimum efficiency.
- 2.Lift - Suction head from the water level to the pump level
- 3.Head – It is also called delivery head. Generally the total head (suction and delivery head) should meet all possible situations with respect to the head.
- 4.Reliability – A reputed manufacture or similar make pump already in use may give the failure rate and types of troubles.
- 5.Initial cost: The cost of the pump and its installation cost should be minimum.
- 6.Power – Power requirements should be less for operation
- 7.Maintenance – Maintenance cost should be minimum. Availability of spares and cost of spares are to be ascertained.

Horse-power of pump

The horse-power (H.P.) of a pump can be determined by calculated the work done by a pump in raising the water upto H height.

Let the pump raise 'W' kg of water to height 'H' m

$$\text{Then workdone by pump} = W \times H \text{ Kg m}$$

$$= WQH \text{ mkg/sec}$$

Where $W \rightarrow$ density of water in kg/m^3 .

$Q \rightarrow$ water discharge by pump in m^3/sec

$$\text{The water horse power} = \frac{\text{Discharge} \times \text{Total head}}{75}$$

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

$$\text{Break Horse Power} = \frac{\text{W. H. P}}{\text{Efficiency}}$$

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

Pipes and requirements

Pipes convey raw water from the source to the treatment plants in the distribution system. Water is under pressure always and hence the pipe material and the fixture should withstand stresses due to the internal pressure, vacuum pressure, when the pipes are empty, water hammer when the valves are closed and temperature stresses.

Requirements of pipe material

1. It should be capable of with standing 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.

Different types of pipes

The following are the different types of pipes

1. Cast Iron
2. Steel
3. Prestressed concrete
4. R.C.C
5. A.C. Pipes
6. Galvanised Iron (G.I)
7. P.V.C and plastic pipes

Different types of pipes

Sl.No.	Type of Pipe	Advantages	Disadvantages
1.	Cast iron Pipes	<p>Cost is</p> <ol style="list-style-type: none"> 1. moderate 2. The pipes are easy to join 3. The pipes are not subjected to corrosion 4. The pipes are strong and durable 5. Service connections can be easily made 6. Usual life is about 100 years 	<ol style="list-style-type: none"> 1. Breakage of pipes are large 2. The carrying capacity of these pipes decreases with the increase in life of pipes. 3. The pipes are not used for pressure greater than 0.7 N/mm^2 4. The pipes are heavier and uneconomical beyond 1200 mmdia.
2.	steel Pipes	<ol style="list-style-type: none"> 1. No. of Joinings are less because these are available in long lengths 2. The pipes are cheap in first cost 3. The pipes are durable and strong enough to resist high internal water pressure 4. The pipes are flexible to 	<ol style="list-style-type: none"> 1. Maintenance cost is high 2. The pipes are likely to be rusted by acidic or alkaline water 3. The pipes require more time for repairs during breakdown and hence not suitable for distribution pipes 4. The pipes may deform in

		<p>some extent and they can therefore laid on curves</p> <p>5. Transportation is easy because of light weight.</p>	<p>shape under combined action of external forces</p>
3.	Prestressed concrete pipes	<p>1. The inside surface of pipes can be made smooth</p> <p>2. Maintenance cost is low</p> <p>3. The pipes are durable with life period 75 years</p> <p>4. No danger of rusting</p> <p>5. These pipes donot collapse or fail under normal traffic</p>	<p>1. The pipes are heavy and difficult to transport</p> <p>2. Repairs of these pipes are difficult</p> <p>3. The pipes are likely to crack during transport and handling operations</p> <p>4. There pipes are affected by alkalie acids, s and salty</p>
4.	R.C.C Pipes	<p>1. There are pipes are most durable with usual life of about 75 years</p> <p>2. The pipes can cast at site work and thus there is reduction in transport charges</p> <p>3. Maintenance cost is less</p> <p>4. Inside surface of pipe can made smooth</p> <p>5. No danger of rusting.</p>	<p>1. Transportation is difficult Repair work is</p> <p>2. difficult</p> <p>3. Initial cost is high</p> <p>4. These pipes are affected by acids, alkalies and salty waters.</p>
5.	A.C. Pipes	<p>1. The inside surface of pipes are very smooth</p> <p>2. The joining of pipe is very good and flexible</p> <p>3. The pipes are anticorrosive and cheap in cost</p> <p>4. Light in weight and transport is easy</p> <p>5. The pipes are suitable for distribution pipes of small size.</p>	<p>1. The pipes are brittle and therefor e handling is difficult</p> <p>2. The pipes are not durable</p> <p>3. The pipes cannot be laid in exposed places</p> <p>4. The pipes can be used only for very low pressures</p>
6.	Galvanised Iron	<p>1. The pipes are cheap</p>	<p>1. The pipes are affected by</p>

	pipes	2. Light in weight and easy to handle 3. The pipes are easy to join	acidic or alkaline waters 2. The useful life of pipes is short about 7 to 10 years.
7.	P.V.C. Pipes	1. Pipes are cheap 2. The pipes are durable 3. The pipes are flexible 4. The pipes are free from corrosion 5. The pipes are good electric insulators 6. The pipes are light in weight and it can easy to mould any shape	1. The co-efficient of expansion for plastic is high 2. It is difficult to obtain the plastic pipes of uniform composition 3. The pipes are less resistance to heat 4. Sometypes of plastic impart taste to the water.

Maintenance of pipes

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

1. Detection of leaks in faulty joints ferrule connections, pipes and fittings inside the consumer premises,
2. Detection of corrosion in pipes, fractures and replacement of these portions
3. 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
4. Cleaning of pipes by flushing and disinfection of pipes
5. Protection against pollution
6. The records of regarding the lengths of pipe laid, length of pipe repaired or replaced, expenditure incurred, no. of fire hydrants , no. of service connections and all other

relevant data in connection with the distribution system should be maintained for ready reference.

Pipe corrosion – 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) by the results of corrosion, troublesome to both the water authority and consumers. The various factors contributing to the pipe corrosion are

1. Acidity: The water having low PH value due to the presence of carbonic acid or other acids may cause corrosion
2. Alkalinity: The water possessing sufficient calcium bicarbonate alkalinity is anti-corrosive in nature
3. Biological action: The growth of iron-bacteria, and sulphur bacteria may develop aerobic and anaerobic corrosion respectively.
4. Chlorination: The presence of free chlorine or chloramines makes the water corrosive
5. Electrical currents: Corrosion canals also be developed by the union of dissimilar metals or by the earthing of electrical system to water pipes.
6. Mineral and organic constituents: The presence of high total solids in water accelerates the process of corrosion
7. Oxygen: the presence of oxygen is found in both the corrosive and non-corrosive waters. The aeration in fact is employed in some cases for prevention of corrosion.

Effects of pipe corrosion

1. Pipe corrosion may lead to the tuberculation (formation of small projections on the inside surface of pipe) which decreases carrying capacity of water
2. The pipe corrosion leads to the disintegration of pipeline and it demands heavy repairs
3. The pipe corrosion imparts colour, taste and odour to the flowing water

4. The pipe connections are seriously affected by pipe corrosion
5. 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 minimise by the following methods.

1. 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
2. Proper pipe material: The alloys of Iron or steel with chromium, copper or nickel are found to be more resistance
3. Protective Linings: The pipe surface should be coated with asphalt, bitumen, cement mortar, paints, resins, tar, zinc etc.
4. 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.

CHAPTER-3

QUALITY OF WATER

Introduction

Absolutely pure water is never found in nature and contains number of impurities in varying amounts. The rainwater which is originally pure, also absorbs various gases, dust and other impurities while falling. This water when moves on the ground further carries salt, organic and inorganic impurities. 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 analyse 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.

Objectives of water quality management

The primary objective of water treatment and purification is to collect water from best available sources and subject it to processing which will ensure water of good physical quality , free from unpleasant taste or odour and containing nothing which might be detrimental to health. It is not possible to find absolutely pure water in nature. Chemically pure waater is the one which contains two parts of hydrogen and one part of oxygen. Wtater drops just emitting out of the clouds may be considered as chemically pure water, but as the drops falls down they absorb some gases and other matter. It is however not essential to have chemically pure water. Sometimes presence of some minerals gives good taste to water. Supplies of water may be obtained y drawing directly upon rivers, lakes or springs. Depending largely upon the souces from which they are derived, the various waters so obtained may differ greatly in purity and suitability for the purposes for which they are required. Underground water may contain much matter dissolved from state through which it passes. Shallow wells are much more prone to bacterial pollution than are deep wells. Streams and rivers collect impurities from the

earth and through the discharge of sewage and industrial effluents and these are carried to ponds, lakes and reservoir. In the past, there have been many cases of recurring epidemics of enteric fevers traceable to drinking water supplies.

Water borne diseases

World health organization has observed that 80% of communicable diseases that are transmitted through water. The diseases like cholera, gastroenteritis, typhoid, amoebiasis, diarrhoea, polio, hepatitis (Jaundice), Leptospirosis, Dracontiasis are caused by bacteria.

Excess of fluorides present in water [above 1.5 mg/litre] cause diseases like dental fluorosis, skeletal fluorosis. This is a permanent irreversible disease that weakens the bone structure. The patient becomes immobile and bedridden.

Excess of nitrates in water causes Methaemoglobinaemia or blue baby symptoms in infants. It affects the hemoglobin in the blood and reduces its capacity to transport oxygen to the cells. Nitrates in water are caused by industrial effluents, agricultural runoff. Toxic ions of chromium, lead, arsenic and pesticides in water cause diseases affecting the kidney, liver and high blood pressure, paralysis, cancer etc. These toxic substances are due to industrial effluents reaching the surface and ground water sources.

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. The character and amount of turbidity depends upon the type of soil over which the water has moved ground waters are less turbid than the surface 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) Bal'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. This test is useful in determining the detention time in settling for raw water and to dosage of coagulants required to remove turbidity.

1) Turbidity rod or Tape:

Turbidity rod is used for measuring turbidity of water in the field. It consists of a graduated aluminium rod, about 20.3 cm in length, at the upper end of which is attached a graduated non-stretchable tape of about 12.2 cm long. At the lower end of the aluminium rod, a screw containing a platinum needle and a nickel ring is inserted. The graduated tape has a mark at its top end specifying the position of eye during the test. In order to find the turbidity, the lower end of the rod is gradually immersed in water whose turbidity is to be determined. Eye is kept constantly at the marked position and the platinum needle is watched. The rod is moved slowly in water till the platinum needle just disappears from the vision due to turbidity of water. The reading of the graduated tape near the water surface directly gives turbidity in p.p.m. the rod gives only rough value of the turbidity of water.

2. Jacksons Turbidimeter

This is a laboratory apparatus which is used to measure turbidity when it is more than 100 p.p.m. it consists of a metal stand holding a metal container and a graduated glass tube in it. A standard candle is placed below the stand. The water sample is poured in the sample and the image of the flame of the standard candle is seen through the turbid water in the glass tube. The level of water in the glass tube is gradually increased till the image of the flame ceases to be seen. The height of the water column, measured in the graduated glass tube provides the measure of the turbidity of the water. The longer the light path of 21.5 cm corresponds to 11 JTU while light path of 10.8 cm corresponds to 200 JTU where 1 JTU= 1 p.p.m.

3. Bali's Turbidimeter

This is a very accurate and is preferred when the turbidity of the sample is less than 5 units. It consists of a galvanized iron box in which two glass tubes are kept at one end and a 250 watt bulb with reflector is placed at the other end. One tube contains standard solution of known turbidity while in the other tube the water sample is kept. The tube is held firmly in a platform with beveled holes at its bottom end. The tubes are surrounded on all its four sides by blue cobalt plates and at its bottom by a white opal glass plate. Because of blue cobalt plates, blue light is cast in both the tubes, and a comparison is made. If the light differs, another tube containing standard solution of different turbidity is introduced in the place of the first one till the color in both the tube matched. The standard solution at this stage give the turbidity of the given water sample. The turbidity is expressed either as p.p.m or BTU both being equivalent.

Colour and temperature

Colour in water is usually due to organic matter in colloidal condition but some times it is also due to mineral and dissolved organic impurities. The colour produced by one milligram of platinum in a litre of water has been fixed as the unit of colour. 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 temperature of surface water is generally at atmospheric temperature, while that of ground water may be more or less than atmospheric temperature. The most desirable temperature for public supply between 4.4°C to 10°C. The temperature above 35°C are unfit for public supply, because it is not palatable.

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 or oxygen combined with organic matter, mineral substances such as sodium chloride, iron compounds and carbonates and sulphates of other substances. The tests of these are done by sense of smell and taste because these are present in such small proportions that it is difficult to detect them by chemical analysis. The water having bad smell and odour is objectionable and should not be supplied to the public.

The intensities of the odours are measured in terms of threshold number. This number is numerically equal to the amount of sample of water in C.C's required to be added to one litre of fresh odourless water.

Chemical characteristics

In the chemical analysis of water, these tests are done that will reveal the sanitary quality of the water. Chemical tests involve the determination of

1. total solids
2. PH value
3. Hardness of water
4. Chloride content
5. Metal and other chemical substances

6. Nitrogen and its compounds

7. Dissolved gases

pH value of water

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

$$PH = -\log_{10}[H^+] \text{ or } 1 / \log_{10}[H^+]$$

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
						Acidity	←	Neutral	→	Alkalinity				

Depending upon the nature of dissolved salts and minerals, the PH value ranges from 0 to 14. 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 tuberculation and corrosion; whereas high value may produce incrustation, sediment deposits and other bad effects.

pH value of water is generally determined by pH papers or by using pH meter. pH can read directly on scale or by digital display using pH meter.

Measurement of pH:

pH measurement is important since it provides means of classifying and of correlating other characteristics or behaviors such as corrosive activity or other inter-related factors controlling biological function in a body of water. Its knowledge is also helpful in controlling softening and coagulation processes in water treatment. There are two methods of determing pH value of water: (i) Colourimetric method, and (ii) Electrometric method

1. Colourimetric method

This is probably the most single method in which some indicator is added to the water sample, and the colour of the solution of known pH value. These standard colours may be in the form of coloured liquids in glass tubes, coloured glass discs or coloured charts supplied by the manufacturers, with each indicator. For acidic range, the common indicators are thymol blue (acid range) bromophenol blue, methyl red and chlorophenol red. For alkaline range, the common indicators are thymol blue (alkaline range), phenolphthalein red and toyl red.

2. Electrometric method

In this method, a pH meter is used. The specimen of water is kept in a beaker and the two electrodes of the instrument are dipped in water connected to a dry cell. The current passing through the circuit indicates the pH value which is read directly on the dial. The electrodes commonly used are made of calomel, glass or quinhydrone. In some of the latest pH meters, the pH value is displayed electronically on the dial, upto second decimal place of the value.

Total solids and suspended solids

Total solids includes the solids in suspension colloidal and in dissolved form. The quantity of suspended solids is determined by filtering the sample of water through fine filter, drying and weighing. The quantity of dissolved and colloidal solids is determined by evaporating the filtered water obtained from the suspended solid test and weighing the residue. The total solids in a water sample can be directly determined by evaporating the filtered water obtained from the suspended solid test and weighing the residue. The total solids in a water sample can be directly determined by evaporating the water and weighing the residue of the residue of total solids is fused in a muffle furnace the organic solids will decompose where as only inorganic solids will remain. By weighing we can

Hardness of water

It is a property of water, which prevents the lathering of the soap. Hardness is of two types.

1. 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.

There are three methods of determining total hardness of water

- a. Clarke's method
- b. Hehner's method
- c. Versenate method

Clarke's method

This method is based on the premise that hardness-producing substances react with soap and form insoluble compounds before lather is produced. Hence total hardness is found by determining the standard soap solution required to obtain a permanent lather with the water sample of known volume with constant shaking. This method has become obsolete.

Hehner's method

In this method the temporary hardness is determined by titration with a standard solution of sulphuric acid, using methyl orange indicator. To determine the permanent hardness, standard sodium carbonate solution is added to the water sample and evaporated to dryness. The amount of sodium carbonate in excess over that required to convert the sulphates and chlorides into carbonates gives the permanent hardness.

Versenate method

in this method, hardness is determined by titrating against Di-Ethlenediaminetetracetic acid solution using Eri chrome black T as indicator at pH 8.5 to 11. For potable water, hardness is objectionable because (i) great deal of soap is required for washing clothes etc., (ii) scale is formed in boilers and hot water heating systems and (iii) corrosion and incrustation of pipe lines and plumbing fixtures is promoted.

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 250 p.p.m. are not permissible in water. Chlorides are estimated by titration with standard silver nitrate solution using potassium chromate as indicator. For this 50 c.c. of water sample is taken by a pipette, in a porcelain dish, and two or three drops of potassium chromate solution is added to the water in the dish. The water sample is then titrated with standard solution of silver nitrate.

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. Nitrites
3. Free ammonia
4. Albuminoidal nitrogen.

Excess presence of nitrogen will cause “METHEMOGLOBINEMIA” disease to the children.

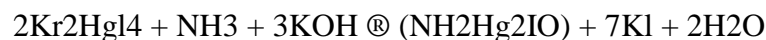
Nitrate

Nitrate constitutes the final stage in the oxidation of nitrogen compounds, and normally reaches important concentrations in the final stages of biological oxidation. The

nitrate contained in pure well water derived from an extensive catchment is largely the result of biological activity in the surface layers of the soil, enhanced by cultivation and the application of manures. When the nitrate is in excessive amounts, it contributes to the illness known as infant methemoglobinemia. Nitrate is measured either by reduction to ammonia or by matching the colours produced with phenoldisulphonic acid.

Nitrites

Nitrite in water is either due to oxidation of ammonium compounds or due to reduction of nitrate. As an intermediate stage in the nitrogen cycle, it is unstable. A usual concentration in natural water is in the range of some tenths of mg/L. Higher concentrations are present in industrial wastes, sewage and in biologically purified effluents and in polluted streams. In chlorinated supplies, levels of nitrite are often less than the limit of detection, i.e. 0.005mg/L NO₂-N but high levels may occur in unchlorinated water. Very high nitrite levels are usually associated with water of unsatisfactory microbiological activity.



Nitrites can be determined by the following methods

1. Colorimeter or spectro-photometer that can be operated at 543nm.
2. Nessler tubes or 100mL capacity volumetric flask.

Sulphanilamide reagent: dissolve 5g sulphanilamide in a mixture of 50mL conc. HCl and about 300mL water. Dilute to 500mL with water. This solution is stable for many months. NED-dihydrochloride solution: dissolve 500mg N-(1-Naphthyl)-ethylenediaminedihydrochloride in 500mL water. Store in a dark bottle and replace monthly or immediately when it develops a strong brown colour. Sodium oxalate (0.05N): dissolve 3.35g Na₂C₂O₄ in water dilute to 1000mL. Stock nitrite solution: dissolve 1.2320 sodium nitrite (NaNO₂) in water and dilute to 1000mL; 1mL = 250µg N. Standard nitrite solution: Dilute appropriate aliquot of stock nitrite solution to 1000mL with

distilled water so that 1mL = 0.5 µg N in the solution. If sample contains suspended solids, filter through a 0.45 mm pore diameter membrane filter. To 50mL clear sample neutralized to pH 7 or to a portion diluted to 50mL, add 1mL sulfanilamide solution. Let reagent react for 2 to 8 min. Add 1.0mL NED dihydrochloride solution and mix immediately. Measure absorbance after 10 min but before 2 h at 543 nm. Prepare blank in the same way substituting water for the sample.

Free ammonia

Ammonia is produced by the microbiological degradation of organic nitrogenous matter. It appears, therefore, in many groundwaters as well as surface waters. Concentrations of ammonia above a certain level in water polluted either due to sewage or industrial waste is toxic to fish. The proportions of the two forms of ammonia nitrogen in surface water depend on pH. For accurate results, it is generally preferable to distill off ammonia from the sample, and absorb in boric acid. It is then determined either by titration or colorimetrically using Nessler reagent. Direct nesslerisation of the sample is quicker depending upon interference. Ammonia produces a yellow coloured compound when reacts with alkaline Nessler reagent, provided the sample is clarified properly. Pretreatment with ZnSO₄ and NaOH precipitates Ca, Fe, Mg and sulphide and removes turbidity and apparent colour. Addition of EDTA (Before Nessler reagent) or Rochelle salt solution prevents precipitation of residual Ca and Mg in the presence of alkaline Nessler reagent. The chemical reaction of the method is given below:

Zinc sulphate: dissolve 10g ZnSO₄·7H₂O in distilled water and dilute to 100mL. Sodium hydroxide, 6N: dissolve 24g NaOH and dilute to 100mL. EDTA reagent: dissolve 50g EDTA in 60mL water containing 10g NaOH. Cool and dilute to 100mL. Rochelle salt solution: dissolve 50g potassium sodium tartarate in 100mL. Remove ammonia by boiling off 30mL solution, cool and dilute to 100mL. Nessler reagent: mix well 100g HgI₂ and 70g KI. Dissolve in small quantity of water. Add this mixture to a cooled solution of 160g NaOH in 500mL water. Dilute to 1000mL. Keep overnight, store supernatant in coloured bottle. Standard ammonium solution: dissolve 3.819g NH₄Cl dried at 100°C in

distilled water and dilute to 1000mL. Dilute 10mL of the solution to 1000mL. 1mL = 10µg NH₃. Take 100mL of sample. Add 1 mL ZnSO₄ solution and 0.4 or 0.5 mL NaOH to obtain the pH of 10.5. Allow to settle and filter the supernatant through 42 No. Whatman filter paper. Take suitable aliquot of sample. Add 3 drops of Rochelle salt solution or 1 drop of EDTA mix well. Add 3mL Nessler reagent if EDTA is used or 1mL if Rochelle salt solution is used. Make up to 100mL. Mix well and read percent transmission after 10 minutes at 410nm using a blank prepared in the same way by taking distilled water instead of sample.

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 discolouration of clothes during washing and incrustation in water mains due to deposition of ferric hydroxide and manganese oxide. Lead and berium are very toxic, low p.p.m of these are allowed. Arsenic, Selenium are poisonous and may cause totally, therefore they must be removed totally. Human beings are effected by presence of high quality of copper in the water. Fewer cavities in the teeth will be formed due to excessive presence of fluoride in water more than 1 p.p.m. A laxative effect is caused in the human body due to excessive presence of sulphate in the water.

Dissolved gases

oxygen and carbondi-oxide are the gases mostly found in the natural water. The surface water contain large amount of dissolved oxygen because they absorb it from the atmosphere. Algae and other tiny plant life of water also give oxygen to the water. The presence of oxygen in the water in dissolved form keep it fresh and sparkling. But more quantity of oxygen causes corrosion to the pipes material.

Water absorbs carbon-dioxide from the atmosphere. If water comes across calcium and magnesium salts, carbon-dioxide reacts with the salts and converts them into

bicarbonates, causes hardness in the water. The presence of carbon-dioxide is easily determined by adding lime solution to water gives milky white colour.

Bio-chemical oxygen demand

If the water is contaminated with sewage, the demand of oxygen by organic matter in sewage is known as biochemical oxygen demand. The aerobic action continues till the oxygen is present in sewage. As the oxygen exhausts the anaerobic action begins due to which foul smell starts coming. Therefore indirectly the decomposable matters require oxygen, which is used by the organisms. The aerobic decomposition of organic matters is done in two stages. The carbonaceous matters are first oxidized and the oxidation of nitrogenous matters takes place in the latter stage. The Biochemical Oxygen Demand (BOD) is an empirical standardized laboratory test which measures oxygen requirement for aerobic oxidation of decomposable organic matter and certain inorganic materials in water, polluted waters and wastewater under controlled conditions of temperature and incubation period. The quantity of oxygen required for above oxidation processes is a measure of the test. The test is applied for fresh water sources (rivers, lakes), wastewater (domestic, industrial), polluted receiving water bodies, marine water (estuaries, coastal water) and also for finding out the level of pollution, assimilative capacity of water body and also performance of waste treatment plants.

This test measures the oxygen utilised for the biochemical degradation of organic material (carbonaceous demand) and oxidation of inorganic material such as sulphides and ferrous ions during a specified incubation period. It also measures the oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand) unless their oxidation is prevented by an inhibitor. Temperature effects are held constant by performing a test at fixed temperature. The methodology of BOD test is to compute a difference between initial and final DO of the samples incubation. Minimum 1.5 L of sample is required for the test. DO is estimated by iodometric titration.

Since the test is mainly a bio-assay procedure, it is necessary to provide standard conditions of temperature, nutrient supply, pH (6.5-7.5), adequate population of microorganisms and absence of microbial-growth-inhibiting substances. The low solubility of oxygen in water necessitates strong wastes to be diluted to ensure that the demand does not increase the available oxygen. A mixed group of microorganisms should be present in the sample; otherwise, the sample has to be seeded. Generally, temperature is controlled at 20°C and the test is conducted for 5 days, as 70 to 80% of the carbonaceous wastes are oxidized during this period. The test can be performed at any other temperature provided the correlation between BOD₅ 20°C is established under same experimental condition (for example BOD₅, 27°C) is equivalent to BOD₃, 27°C) for Indian conditions. While reporting the results, the incubation period in days and temperature in °C is essential to be mentioned

Equipment and apparatus

a. BOD bottles 300mL capacity (clean with a detergent, rinse thoroughly and drain before use) with a water seal.

b. Incubator or water-bath to be controlled at 20°C or at any desired temperature 1°C. Exclude all light to prevent photosynthetic production of DO.

All reagents listed in DO estimation are used for BOD. In addition following reagents are required:

.Phosphate buffer: Dissolve 8.5g KH₂PO₄, 21.75g K₂HPO₄, 33.5g Na₂HPO₄.7H₂O and 1.7g NH₄C; in distilled water and dilute to 1000mL. The pH should be 7.2 without further adjustment. Discard reagent if there is any sign of biological growth.

b. Magnesium sulphate: Dissolve 22.5g MgSO₄.7H₂O in about 700mL of distilled water and dilute to 1 Litre.

c. Calcium chloride: Dissolve 27.5g anhydrous CaCl₂ in about 7000mL of distilled water and dilute to 1 Litre.

d. Ferric chloride: Dissolve 0.25g $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ in about 700mL of distilled water and dilute to 1 L.

e. Sodium sulphate solution 0.025N: Dissolve 1.575g Na_2SO_3 in distilled water and dilute to 1000mL. Solution should be prepared daily.

f. Acid and Alkali solutions 1N: Prepare 1N H_2SO_4 and 1N NaOH or neutralization of caustic or acidic sample

g. Nitrification inhibitor: 2-chloro-6-(trichloromethyl) pyridine [Nitrification inhibitor 2570-24 (2.2% TCMP), Hach Co. equivalent]

h. Glucose-glutamic acid solution: Dry reagent grade glucose and glutamic acid at 103°C for 1h. Dissolve 150 mg glucose and 150mg glucose acid in distilled water and dilute to 1000mL. Prepare fresh immediately before use.

Preparation of dilution water:

a. The source of dilution water may be distilled water, tap or receiving-stream water free of biodegradable organics and bioinhibitory substances such as chlorine or heavy metals.

b. Aerate the required volume of dilution water in a suitable bottle by bubbling clean-filtered compressed air for sufficient time to attain DO saturation at room temperature or at $20^\circ\text{C}/27^\circ\text{C}$. Before use stabilise the water at $20^\circ\text{C}/27^\circ\text{C}$.

c. Add 1mL each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride solutions in that order for each Litre of dilution water. Mix well. Quality of dilution water may be checked by incubating a BOD bottle full of dilution water for 5 days at 20°C for 3 days at 27°C . DO uptake of dilution water should not be more than 0.2mg/L and preferable not more than 0.1mg/L.

d. For wastes which are not expected to have sufficient microbial population, seed is essential. Preferred seed is effluent from a biological treatment system. Where this is not available, supernatant from domestic wastewater (domestic sewage) settled at room

temperature for at least 1h but not longer than 36hours is considered sufficient in the proportion 1-2mL/L of dilution water. Adopted microbial population can be obtained from the receiving water microbial population can be obtained from the receiving water body preferably 3-8 km below the point of discharge. In the absence of such situation, develop an adapted seed in the laboratory.

e.Determine BOD of the seeding material. This is seed control. From the value of seed control determine seed DO uptake. The DO uptake of seeded dilution water should be between 0.6mg/L and 1mg/L.

Sample preparation:

a.Neutralise the sample to pH 7, if it is highly acidic or alkaline.

b.The sample should be free from residual chlorine. If it contains residual chlorine remove it by using $\text{Na}_2\text{S}_2\text{O}_3$ solution as described below.

c.Take 50mL of the sample and acidify with addition of 10mL 1 + 1 acetic acid. Add about 1g KI. Titrate with 0.025N $\text{Na}_2\text{S}_2\text{O}_3$, using starch indicator. Calculate the volume of $\text{Na}_2\text{S}_2\text{O}_3$ required per Litre of the sample and accordingly add to the sample to be tested for BOD.

d.Certain industrial wastes contain toxic metals, e.g. planting wastes. Such samples often require special study and treatment.

e.Bring samples to $20 \pm 1^\circ\text{C}$ before making dilutions.

f.If nitrification inhibition is desired, add 3mg 2-chloro-6-(trichloromethyl) pyridine (TCMP) to each 300mL bottle before capping or add sufficient amount to the dilution water to make a final concentration of 30mg/L. Note the use of nitrogen inhibition in reporting results.

g.Samples having high DO contents, $\text{DO} \geq 9\text{mg/L}$ should be treated to reduce the DO content to saturation at 20°C . Agitate or aerate with clean, filtered compressed air.

Dilution of sample: Dilutions that result in a residual DO of at least 1mg/L and DO uptake of at least 2mg/L produce reliable results. Make several dilutions of the pre-treated sample so as to obtain about 50% depletion of DO or DO uptake of 2mg/L. Prepare dilutions as follows

Siphon out half the required volume of seeded dilution water in a graduated cylinder or volumetric flask without entraining air. Add the desired quantity of mixed sample and dilute to the appropriate volume by siphoning dilution water. Mix well with plunger type mixing rod to avoid entraining air.

General guidelines for dilution range are as follows:

0.1% to 1% : Strong trade waste

1% to 5% : Raw or settled sewage

5% to 25% : Treated effluent

25% to 100% : River water

Sample processing:

- a. Siphon the diluted or undiluted sample in three labeled bottles and stopper immediately.
- b. Keep 1 bottle for determination of the initial DO and incubate 2 bottles at 20°C for 3 days. See that the bottles have a water seal.
- c. Prepare a blank in triplicate by siphoning plain dilution water (without seed) to measure the O₂ consumption in dilution water.
- d. Also prepare a seed blank in triplicate to measure BOD of seed for correction of actual BOD.
- e. Determine DO in a BOD test can in the blank on initial day and end of incubation period by Winkler method as described for DO measurement.

f. DO estimation in a BOD test can also be done by membrane electrodes. A DO probe with a stirrer is used to determine initial and final DO after incubation in BOD samples. The semi-permeable membrane provided in the DO probe acts as a diffusion barrier against impurities between sensing element and sample.

10.6 Calculations

Calculate BOD of the sample as follows:

- a. When dilution water is not seeded

$$\text{BOD as O}_2 \text{ mg/L} = (D_1 - D_2) \times 100/\% \text{ dilution}$$

- b. When dilution is seeded

$$\text{BOD O}_2 \text{ mg/L} = (D_1 - D_2) - (B_1 - B_2) \times 100/\% \text{ dilution}$$

- c. When material is added to sample or to seed control

$$\text{BOD O}_2 \text{ mg/L} = (D_1 - D_2) - (B'_1 \times B'_2) \times F \times 100/\% \text{ dilution}$$

where,

D_1 = DO of sample immediately after preparation, mg/L

D_2 = DO of sample after incubation period, mg/L

B_1 = DO of blank (seeded dilution water) before incubation, mg/L

B_2 = DO of blank (seeded dilution water) after incubation, mg/L

F = ratio of seed in diluted sample to seed in seed control (Vol. of seed in diluted sample / Vol. of seed in seed control)

B'_1 = DO of seed control before incubation, mg/L

B'_2 = DO of seed control after incubation, mg/L

In calculations, do not make corrections for DO uptake in dilution water

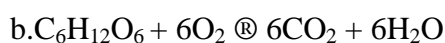
Chemical Oxygen Demand (COD)

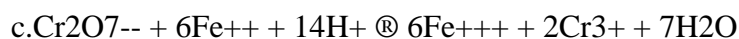
Chemical Oxygen Demand (COD) test determines the oxygen requirement equivalent of organic matter that is susceptible to oxidation with the help of a strong chemical oxidant. It is an important, rapidly measured parameters as a means of measuring organic strength for streams and polluted water bodies. The test can be related empirically to BOD, organic carbon or organic matter in samples from a specific source taking into account its limitations. The test is useful in studying performance evaluation of wastewater treatment plants and monitoring relatively polluted water bodies. COD determination has advantage over BOD determination. COD results can be obtained in 3-4 hrs as compared to 3-5days required for BOD test. Further, the test is relatively easy, precise, and is unaffected by interferences as in the BOD test. The intrinsic limitation of the test lies in its inability to differentiate between the biologically oxidisable and biologically inert material and to find out the system rate constant of aerobic biological stabilization.

Principle

The open reflux method is suitable for a wide range of wastes with a large sample size. The dichromate reflux method is preferred over procedures using other oxidants (e.g. potassium permanganate) because of its superior oxidizing ability, applicability to a wide variety of samples and ease of manipulation. Oxidation of most organic compounds is up to 95-100% of the theoretical value.

The organic matter gets oxidised completely by potassium dichromate ($K_2Cr_2O_7$) with silver sulphate as catalyst in the presence of concentrated H_2SO_4 to produce CO_2 and H_2O . The excess $K_2Cr_2O_7$ remaining after the reaction is titrated with ferrous ammonium sulphate $[Fe (NH_4)_2(SO_4)_2]$. The dichromate consumed gives the oxygen (O_2) required for oxidation of the organic matter. The chemical reactions involved in the method are as under:





Apparatus and equipment

- a. 250 or 500mL Erlenmeyer flask with standard (24/40) tapered glass joints
- b. Friedrich's reflux condenser (12 inch) with standard (24/40) tapered glass joints
- c. Electric hot plate or six-unit heating shelf
- d. Volumetric pipettes (10, 25, and 50mL capacity)
- e. Burette, 50mL with 0.1mL accuracy
- f. Burette stand and clamp
- g. Analytical balance, accuracy 0.001g
- h. Spatula
- i. Volumetric flasks (1000mL capacity)
- j. Boiling beads, glass
- k. Magnetic stirrer and stirring bars.

Reagents and standards

- a. Standard potassium dichromate solution, 0.25N (0.04167 M): Dissolve 12.259g $\text{K}_2\text{Cr}_2\text{O}_7$ dried at 103°C for 24h in distilled water and dilute to 1000mL. Add about 120mg sulphamic acid to take care of 6 mg/L $\text{NO}_2 - \text{N}$.
- b. Sulphuric acid reagent: Add 10g of Ag_2SO_4 to 1000mL concentrated H_2SO_4 and let stand for one to two days for complete dissolution.

c. Standard ferrous ammonium sulphate approx. 0.25N (0.25M): Dissolve 98g $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ in about 400mL distilled water. Add 20mL concentrated H_2SO_4 and dilute to 1000mL.

d. Ferroin indicator: Dissolve 1.485g 1, 10-phenanthroline monohydrate and 695mg $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ in distilled water and dilute to 100mL.

e. Mercuric Sulphates: HgSO_4 , crystals, analytical grade

f. Potassium hydrogen phthalate (KHP) Standard: Dissolve 425mg lightly crushed dried potassium hydrogen phthalate ($\text{HOOC} \cdot \text{C}_6\text{H}_4 \cdot \text{COOK}$) in distilled water and dilute to 1000mL. This solution has a theoretical COD of $500\mu\text{g O}_2/\text{mL}$. This solution is stable when refrigerated, up to 3 months in the absence of visible biological growth.

Procedure

Sample preparation: All samples high in solids should be blended for 2 minutes at high speed and stirred when an aliquot is taken for analysis. Select the appropriate volume of sample based on expected COD range, e.g. for COD range of 50-500 mg/L take 25-50mL of sample. Sample volume less than 25mL should not be pipetted directly, but serially diluted and then a portion of the diluted sample taken. Dilution factor should be incorporated in calculations.

a. 500mL of sample diluted to 1000mL = 0.5mL sample/mL of diluent, 50mL = 25mL of sample.

b. 100mL of sample diluted to 1,000mL = 0.1mL sample/mL diluent, 50mL of diluent = 5mL of sample.

Reflux of samples:

a. Place 0.4g HgSO_4 in a 250mL reflux sample

b. Add 20mL sample or an aliquot of sample diluted to 20mL with distilled water. Mix well.

c. Add clean pumic stones or glass beads.

d. Add 10mL 0.25N (0.04167M) $K_2Cr_2O_7$ solution and mix.

e. Add slowly 30mL concentrated H_2SO_4 containing Ag_2SO_4 mixing thoroughly. This slow addition along with swirling prevents fatty acids to escape due to generation of high temperature. Alternatively attach flask to condenser with water flowing and then add H_2SO_4 slowly through condenser to avoid escape of volatile organic substance due to generation of heat.

f. Mix well. If the colour turns green, either take fresh sample with lesser aliquot or add more potassium dichromate and acid.

g. Connect the flask to condenser. Mix the contents before heating. Improper mixing will result in bumping and blow out of flask content.

h. Reflux for a minimum of 2 hours. Cool and then wash down condenser with distilled water.

i. Disconnect reflux condenser and dilute the mixture to about twice its volume with distilled water. Cool to room temperature and titrate excess $K_2Cr_2O_7$ with 0.1M FAS using 2-3 drops of ferroin indicator. The sharp colour change from blue green to reddish brown indicates end-point or completion of the titration. After a small time gap, the blue-green colour may reappear. Use the same quantity of ferroin indicator for all titrations.

j. Reflux blank in the same manner using distilled water instead of sample.

Alternate procedure for low COD samples less than 50mg/L: Follow similar procedure with two exceptions (i) use standard 0.025N (0.004167M) $K_2Cr_2O_7$ and (ii) titrate with standardize 0.025M FAS. The sample volume should be 5.mL. Exercise extreme care with this procedure because even a trace of organic matter on the glassware or from the

atmosphere may cause gross errors. Compute amount of HgSO_4 to be added based on chloride concentrations. Carry blank reagent through the same procedure.

Calculations

$\text{COD as mg/L} = (a - b) \times N \times 8000 / \text{mL sample}$

Where, a = mL FAS used for blank

b = mL FAS used for sample

N = normality of FAS

8000 = Milieq. wt. of $\text{O}_2 \times 1000$

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 to mankind or harmful to mankind. The former category is known as non-pathogenic bacteria and the later category is known as pathogenic bacteria. Many of the bacteria found in water are derived from air, soil and vegetation. Some of these are able to multiply and continue their existence while the remaining die out in due course of time. The selective medium that promote the growth of particular bacteria and inbuilt the growth of other organisms is used in the lab to detect the presence of the required bacteria, usually coliform bacteria. For bacteriological analysis the following tests are done.

Plate count test

In this method total number of bacteria presents in a millilitre of water is counted. 1 ml of sample water is diluted in 99ml of sterilized water and 1ml of dilute water is mixed with 10ml of agar of gelatine. This mixture is then kept in incubator at 37°C for 24 hours or 20°C for 48 hours. After the sample will be taken out from the incubator and colonies

of bacteria are counted by means of microscope. Drinking water should not have more than 10 coliforms/100ml

Multiple tube fermentation technique for coliform bacteria (MPN test):

In the multiple-tube method, a series of tubes containing a suitable selective broth culture medium (lactose-containing broth, such as MacConkey broth) is inoculated with test portions of a water sample. After a specified incubation time at a given temperature, each tube showing gas formation is regarded as “presumptive positive” since the gas indicates the possible presence of coliforms. However, gas may also be produced by other organisms, and so a subsequent confirmatory test is essential. The two tests are known respectively as the presumptive test and the confirmatory test.

For the confirmatory test, a more selective culture medium (brilliant green bile broth) is inoculated with material taken from the positive tubes. After an appropriate incubation time, the tubes are examined for gas formation as before. The most probable number (MPN) of bacteria present can then be estimated from the number of tubes inoculated and the number of positive tubes obtained in the confirmatory test. Using specially devised statistical tables. This technique is known as the MPN method

Equipment and supplies:

1. Culture tubes containing inverted vials (Durham tubes): each tube should be large enough for a vial, completely filled with medium, to be submerged in it.
2. Gas burner: a Bunsen or similar burner is adequate
3. Inoculation loop and holder: lengths of 2 or 26 gauge wire (7.5-10 cm) should be used. Nichrome wire is acceptable, but platinum-iridium is better. The wire is set in a handle made of metal or glass, of diameter similar to that of a pencil. To make the inoculation loop, the wire is bent to form a circle 3-4 mm in diameter.
4. Clearing and maintenance equipment: items such as brushes for cleaning tubes, bottles, etc., a waste bin, and a tool kit are required.

5. Safety equipment: there should be an adequate first-aid and a fire extinguisher or other means of fire control in every laboratory.

The following consumable items are required:

Culture media / Reagents: the following culture media and reagents are required

- MacConkey Broth with neutral red (double strength)
- MacConkey Broth with neutral red (single strength)
- Brilliant Green Blue broth (BGB)
- Tryptone water/Peptone water (for indole test)
- Kovac's Reagent

6. Laboratory disinfectant: for cleaning laboratory surfaces and the pipette discard bin.

7. Detergent: for washing glassware, etc

8. Sodium thiosulphate solution: required when chlorinated supplies are tested. Sodium thiosulphate neutralizes any residual chlorine in samples at the time of collection, preventing it from acting on any micro-organisms present in water samples.

9. Autoclave tape

Culture media preparation

Commercially available dehydrated media simplify the preparation of culture broths and are therefore recommended for laboratory work. Various manufacturers produce these media as powders, which can then be easily weighed, dissolved in distilled water, and dispensed into culture tubes before sterilization.

Preparation of media: Media should be prepared in accordance with the manufacturer's instruction, as follows:

a. Dissolve the stated amount of the dehydrated medium in distilled water to obtain the double-strength or single-strength presumptive medium (MacConkey broth). The confirmatory medium (BGB) is required only in single-strength.

b. Dispense the requisite volume into culture tubes containing an inverted Durham tube, and cap the culture tubes; simple cotton plugs may be used or more ideally metal slip-on caps may be used to cap the tubes.

c. Sterilise in an autoclave at 115°C for 10 minutes (or in accordance with the manufacturer's specifications). It is particularly important that media containing disaccharides, e.g. lactose, are not autoclave at higher temperatures.

d. The sterilized medium may be stored at room temperature (approximately 25°C) or, ideally, at 2-8°C. Media should in any case be warmed to room temperature before use to ensure that all components have re-dissolved. In addition, since several dyes are light sensitive, the solution should be protected from exposure to light.

Procedure for inoculation of samples: The procedure to be used for testing relatively unpolluted water, such as treated water from waterworks or distribution system or end user's tap.

Note down the details of the sample collected (from the label on the bottle) in the register.

a. With the stopper in position, shake the bottle vigorously to achieve a homogeneous dispersion of bacteria. (If the bottle is completely full, remove the stopper and discard about 20-30 mL of water; then replace the stopper and shake. This ensures thorough mixing).

b. Add 50 mL of sample to a tube / flask containing 50 mL of presumptive broth (double strength). With a sterile 10 mL pipette, inoculate 10 mL of the sample into each the five tubes containing 5 mL presumptive broth (single strength). It is advisable to shake the

tubes gently to distribute the sample uniformly throughout the medium. Be careful as to not shake so hard that air is introduced into the inverted tubes.

c. Incubate the tubes at $35^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for 24 hours.

d. At the end of the 24-hour incubation period, examine each tube for the presence of gas. If present, gas can be seen in the Durham tube. If none is visible, gently shake the tube; if any effervescence (streams of fine bubbles) is observed, the tubes should be considered positive.

e. Record the number of positive tubes after 24 hours.

f. Re-incubate negative tubes for a further 24-hour period. At the end of this period, check the tubes again for gas production as in 5 above. Gas production at the end of either 24 or 48 hours' incubation is presumed to be due to the presence of coliforms in the sample.

g. Record the number of positive tubes after 48 hours.

h. The confirmatory test should be carried out at the end of both the 24-hour and the 48-hour incubation. Using a sterile loop, transfer one or two loops-full from each presumptive positive tube into two tubes containing respectively confirmatory broth (BGB) and tryptone water. (Sterilise the inoculation loop before each transfer by flaming and allow cooling). To confirm the presence of thermotolerant coliforms, incubate the subculture tubes from each presumptive positive tube for 24 hours at $44.5 \pm 0.5^{\circ}\text{C}$.

[Alternatively, transfer a loopful of a positive MacConkey broth tube into BGB medium and incubate at 35°C for 24-48 hours. This will be a better confirmation of Total Coliforms.]

i. At the end of 24 hours' incubation, examine each broth tube for growth and the presence of gas in the Durham tube. Record the results, as done previously.

j. To each tube of tryptone water, add approximately 0.1 mL of Kovacs reagent and mix gently. The presence of indole is indicated by a red colour in the Kovacs reagent, forming a film over the aqueous phase of the medium.

k. Confirmatory tests positive for indole, growth, and gas production show the presence of E.

Membrane filtration method for total coliform and thermotolerant (faecal) coliforms

Principle: The method is based on the filtration of a known volume of water through a membrane filter consisting of a cellulose compound with a uniform pore diameter of 0.45 or 0.2 μm ; the bacteria are retained on the surface of the membrane filter. When the membrane containing the bacteria is incubated in a sterile container at an appropriate temperature with a selective differential culture medium, characteristic colonies of coliforms/ thermotolerant coliforms develop, which can be counted directly. In contrast to the multiple-tube method, the membrane-filtration method gives as a direct count of total coliforms and thermotolerant coliforms present in a given sample of water. Volume of water sample for filtration: Since the filtration area is relatively small, it can support the growth of only a limited number of colonies: the optimum number is between 20 and 80, with a maximum of 200. If this figure is exceeded, very small atypical colonies or superimposed colonies may develop, or there may be growth inhibition due to overpopulation. The choice of the volume of sample to be filtered will depend on the type of water.

Volumes less than 10 mL should be added to the filtration apparatus after addition of at least 10 mL of sterile diluent to ensure adequate dispersal across the surface of the membrane filter.

Equipment and glassware: In addition to the basic equipment and glassware used in the multiple-tube method, the following items are needed for the membrane-filtration technique.

1. Membrane-filtration apparatus: including an electric or hand-powdered vacuum pump, a vacuum flask (e.g. an Erlenmeyer side-arm flask), and a filter support. One such commercially available filter assemble is shown below to illustrate the various components.
2. Residual Petri dishes: made from glass or metal (disposable plastic Petri dishes may also be used).
3. Blunt-ended forceps: For safe handling of filter membranes handle membrane filters without damage using highly polished stainless steel forcep blades with beveled, unserrated tips. Sterilise by autoclaving or by flaming.
4. Reusable (autoclavable) bottles: for culture media (e.g. / 25 mL polypropylene bottles).
5. A magnifying lens: with 34 or 35 magnification for examining and counting the colonies on the membrane filters. Alternatively, a colony counter (such as Quebec Colony Counter) may also be used.
6. A boiling bath / pan: if filtration apparatus is to be disinfected in boiling water between analyses.
7. Sterile pipettes: 1 mL and 10 mL
8. A graduated cylinder: 100 mL
9. In addition to the consumables needed for the MPN, the following are required:
10. Membrane filters: 47 mm in diameter, with a pore diameter of 0.45 μm . Singly packed, presterilised membrane filters are very convenient. Unsterilised membrane filters can also be used, however, and should be wrapped in paper packets in convenient numbers (depending on the number of water samples to be tested). These can then be sterilized in the autoclave and dried by rapid exhaustion of the steam.
11. Nutrient absorbent pads: These are essentially filter-paper discs about 1 mm thick, with the same diameter as the membrane filters. They are available with suitable dispensers which help in rapidly dispensing large numbers of pads without individual forceps-handling and hence reduce contamination risks.

12. Culture media: different types are available
13. Wax pencils: for labeling Petri dishes
14. Polythene bags: for wrapping Petri dishes if a dry incubator is used, to prevent drying of the sample and media

Culture media and dilution water: Various media can be used for the examination of coliform organisms by the membrane-filtration method. Of these, lactose Tergitol agar, lactose TTC Tergitol agar and membrane lauryl sulfate lactose broth may be used for coliform organisms at 35 or 37°C and for thermotolerant coliform organisms at 44°C or 44.5°C. Membrane faecal coliform (MFC) broth should be used only at 44 or 44.5°C for thermotolerant coliform counts. Although the use of all these media for the detection of presumptive coliform organisms is based on the fermentation of lactose, the characteristic reaction varies with each medium (Table 3.3: IV and 3.3: V). It is common to confirm sheen colonies from mENDO by inoculating confirmatory broth media with colonies. Your might require technician to swab the filter surface with a sterile cotton swab and use this to inoculate MacConkey, BGB and EC broths.

Procedure:

The procedure generally used is described here, but different types of filtration units and equipment exist.

- a. Connect the Erlenmeyer (side-arm) flask to the vacuum source (turned off) and place the porous support in position. If an electric pump is used, it is advisable to put a second flask between the Erlenmeyer flask and the vacuum source; this second flask acts as a water trap, and thus protects the electric pump.
- b. Open a sterile Petri dish and place a sterile absorbent pad in it.
- c. Add broth medium to saturate the pad; remove excess broth.

d. Place a sterile 47 mm dia. membrane filter on the porous support surface or screen, using blunt forceps sterilised by flaming. The gridded surface should be if you are using gridded membrane filter. Assemble the filter unit in the order shown in.

e. Place the upper container in position and secure it. The type of clamp used will depend on the type of equipment.

f. Pour the volume of sample chosen as optimal for the types of water into the upper container. If the test sample is less than 10 mL, at least 20 mL of sterile dilution water should be added to the top container before filtration. Apply the vacuum.

g. Take the filtration unit apart and, using the sterile forceps, place the membrane filter in the Petri dish on the pad with the grid side up. Make sure that no air bubbles are trapped between the pad and the filter.

h. Leave the Petri dish at room temperature or at 35 or 37°C for 2-4 hours, for resuscitation of stressed microbes.

i. Place the dishes in an incubator at $44 \pm 0.5^\circ\text{C}$ for 18-24 hours with 100% humidity. Alternatively, tight-fitting or sealed petri dishes may be placed in waterproof plastic bags for incubation.

j. Place the dishes in an incubator at $44 \pm 0.5^\circ\text{C}$ for 18-24 hours with 100% humidity. Alternatively, tight-fitting or sealed petri dishes may be placed in waterproof plastic bags for incubation.

k. Submerge the bags in a water-bath maintained at $44 \pm 0.5^\circ\text{C}$ for 18-24 hours. The plastic bags must be below the surface of the water throughout the incubation period. They can be held down by means of a suitable weight, e.g. a metal rack.

The colonies of coliform/thermotolerant coliform bacteria should be identified from their characteristics on the medium used. The number of coliforms/thermotolerant coliforms per 100 mL is then given by:

Coliform / thermotolerant coliforms per 100 mL

= [(No. of coliforms/thermotolerant coliform colonies counted) / (no. of mL of sample filtered) x 100

WATER BORNE DISEASES

World health organization has observed that 80% of communicable diseases that are transmitted through water. The diseases like cholera, gastroenteritis, typhoid, amoebiasis, diarrhoea, polio, hepatitis (Jaundice), Leptospirosis, Dracontiasis are caused by bacteria. Excess of fluorides present in water [above 1.5 mg/litre] cause diseases like dental fluorosis, skeletal fluorosis. This is a permanent irreversible disease that weakens the bone structure. The patient becomes immobile and bedridden.

Excess of nitrates in water causes Methaemoglobinemia or blue baby symptoms in infants. It affects the hemoglobin in the blood and reduces its capacity to transport oxygen to the cells. Nitrates in water are caused by industrial effluents, agricultural runoff. Toxic ions of chromium, lead, arsenic and pesticides in water cause diseases affecting the kidney, liver and high blood pressure, paralysis, cancer etc. These toxic substances are due to industrial effluents reaching the surface and ground water sources.

Health significance of fluoride

Fluoride ions have dual significance in water supplies. High concentration of F⁻ causes dental fluorosis (disfigurement of the teeth). At the same time, a concentration less than 0.8mg/L results in 'dental caries'. Hence, it is essential to maintain the F⁻ concentration between 0.8 to 1.0mg/L in drinking water. Among the many methods suggested for the determination of fluoride ion in water, the Colorimetric method (SPANDS) and the ion selective electrode method are the most satisfactory and applicable to a variety of samples. Because all of the Colorimetric methods are subject to errors due to presence of interfering ions, it may be necessary to distill the sample before making the fluoride estimation. When the fluoride electrode is dipped in sample whose

concentration is to be measured, a potential is established by the presence of fluoride ions by any modern pH meter having an expanded millivolt scale.

The fluoride ion selective electrode can be used to measure the activity or concentration of fluoride in aqueous sample by use of an appropriate calibration curve. However, fluoride activity depends on the total ionic strength of the sample. The electrode does not respond to bound or complexed fluoride. Addition of a buffer solution of high total ionic strength containing a chelate to complex aluminium preferentially overcomes these difficulties.

Nitrogen (Nitrate) (NO_3^-)

Determination of nitrate (NO_3^-) is difficult because of the relatively complex procedures required, the high probability that interfering constituents will be present and the limited concentration ranges of the various techniques. Nitrate is the most highly oxidised form of nitrogen compounds commonly present in natural waters. Significant sources of nitrate are chemical fertilizers, decayed vegetable and animal matter, domestic effluents, sewage sludge disposal to land, industrial discharge, leachates from refuse dumps and atmospheric washout. Depending on the situation, these sources can contaminate streams, rivers, lakes and ground water. Unpolluted natural water contains minute amounts of nitrate. Excessive concentration in drinking water is considered hazardous for infants because of its reduction to nitrite in intestinal track causing methemoglobinaemia. In surface water, nitrate is a nutrient taken up by plants and converted into cell protein. The growth stimulation of plants, especially of algae may cause objectionable eutrophication. Dissolved organic matter, nitrite, hexavalent chromium and surfactants are interferences. The latter three substances may be compensated for by independent analysis of their concentrations and preparation of individual correction curves. Organic matter can cause a positive but variable interference. The degree of interference depends on the nature and concentration of the organic matter in the sample. Clean all glassware thoroughly and rinse to reduce the error that might result from streaks or particles on the outside of the curves, as well as traces of

surfactants or dichromate cleaning solution that might adhere on the interior glass surfaces..

Arsenic (As)

Severe poisoning can arise from the ingestion of as little as 100mg of Arsenic trioxide. Chronic effects may result from the accumulation of arsenic compounds in the body at low intake levels. Carcinogenic properties also have been observed to arsenic compounds. For the protection of aquatic life, the average concentration of As^{3+} in water should not exceed $72\mu\text{g/L}$. And maximum should not exceed $140\mu\text{g/L}$. FAO-recommended max level for irrigation water is $100\mu\text{g/L}$. USEPA water standard is 0.05mg/L . BIS desirable limit is 0.05mg As/L .

Although certain metals, viz. chromium, cobalt, copper, mercury, molybdenum, nickel, platinum, silver, and selenium influence the generation of arsine, their concentrations in water seldom are high enough to interfere. H_2S interferes, but the interference is removed with lead acetate. Antimony is reduced to stibine, which forms a coloured complex with absorption maximum at 510nm and interferes with the arsenic determination. Methylarsenic compounds are reduced at pH 1 to methylarsines, which form coloured complexes with the absorber solution. If methylarsenic compounds are present, measurements of total arsenic and arsenate are unreliable. Methyl arsenic compounds do not influence the results for arsenite.

Cadmium (Cd)

Cadmium occurs in sulphide minerals that also contain zinc, lead or copper. The metal is used in electroplating, batteries, paint pigments and in alloys with various other metals. Cadmium is usually associated with zinc. Cadmium is highly toxic and has been implicated in some cases of poisoning through food. Minute quantities of cadmium are suspected of being responsible for adverse changes in arteries of human kidneys. Cadmium also causes generally cancers in laboratory animals and has been linked epidemiologically with certain human cancers. A cadmium concentration of $200\mu\text{g/L}$ is

toxic to certain fishes. Cadmium may enter water as a result of industrial discharges or the deterioration of galvanized pipe. The FAO-recommended maximum level for cadmium for irrigation water is $10\mu\text{g/L}$. USEPA drinking water standard for cadmium is 0.005mg/L . BIS desirable limit is 1mg/L .

Lead (Pb)

Lead in a water supply may come from industrial, smelter discharges and mine or from the dissolution of plumbing and plumbing fixture. Tap water that are inherently not corrosive or not suitably treated may contain lead resulting from an attack on lead service pipes, lead interior plumbing, brass fixtures and fittings on solder pipe joints chiefly from galena (PbS). It is used in batteries, ammunition, solder, piping, pigments, insecticides and alloys. Lead also was used in gasoline for many years as an anti-knock agent in the form of tetraethyl lead. The Food and drug administration regulates lead content in food and in house paints. Under the lead-copper rule, the US EPA drinking water standard for lead is $15\mu\text{g/L}$. The BIS desirable limit is 0.05mg/L .

DRINKING WATER STANDARDS

S.No.	CHARACTERISTICS	NORMALLY ACCEPTABLE VALUE	MAX. PERMISSIBLE LIMIT
1.	Temperature	10°C – 15°C	-
2.	Turbidity (N.T.U)	2.5	10
3.	Colour (platinum cobalt scale)	5.0	25
4.	Taste and odour	Unobjectionable	
5.	PH	7.0-8.5	6.5-9.2
6.	Total dissolved solids(mg/litre)	500	1500
7.	Total hardness mg/l (as CaCO_3)	200	600
8.	Chlorides (as Cl) mg/l	200	1000
9.	Sulphates (as SO_4) mg/l	200	400
10.	Nitrates (as NO_3) mg/l	45	45
11.	Fluorides (as F) mg/l	1.0	1.5
12.	Calcium (as Ca) mg/l	75	200
13.	Magnesium (as mg) mg/l	30-120	150
14.	Iron (as Fe) mg/l	0.1	1.0
15.	Manganese (As Mn) mg/l	0.05	0.5
16.	Phenolic compounds (as phenol) mg/l	0.001	0.002
17.	Arsenic (as mg) mg/l	0.05	0.05
18.	Chromium (as Cr^{+6}) mg/l	0.05	0.05
19.	Cyanides (as CN) mg/l	0.05	0.05
20.	Coliform count per 100ml of water sample	Zero	-

UNIT-4

WATER TREATMENT

INTRODUCTION

Water available in various sources contains various types of impurities and cannot be directly used by the public for various purposes, before removing the impurities. For potability water should be free from unpleasant tastes, odours and must have sparkling appearance. The water must be free from disease-spreading germs. The amount and type of treatment process will depend on the quality of raw water and the standards of quality of raw water and the standards of quality to be required .

The surface sources generally contains large amount of impurities therefore they requires sedimentation, filtration and chlorination as treatment. If the water contains algae or other micro organisms, pre chlorination has to be done tastes and odours , dissolved gases like CO₂, H₂S are removed by aeration. During the flood season , the turbidity of the surface water may be high and flocculation may become necessary to remove turbidity.

Treatment unit flow diagram

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.

I. When turbidity of water is less than 10 N.T.U



GROUND WATER

Raw Water

Treated water



SURFACE WATER

The location of treatment plant

One complete water treatment plant requires the following process starting from the source of water upto the distribution zone in order of sequence

Sl.No.	Name of the unit	Purpose
1.	Intake work including pumping plant	Raw water from the source for treatment
2.	Plain sedimentation	To remove suspended impurities such as silt, clay, sand etc.
3.	Sedimentation with coagulation	To remove the suspended matter
4.	Filtration	To remove microorganisms and colloidal matter
5.	Water softening plant	To remove hardness of water
6.	Miscellaneous treatment plants	To remove dissolved gases, tastes and odours.
7.	Disinfection	To remove pathogenic bacteria
8.	Clear water reservoir	To store the treated water
9.	Pumps for pumping the water in service reservoirs	If town or city is situated at higher elevation then pumping is required.
10.	Elevated or underground service reservoir	For distribution of treated water.

The following points should be kept in mind while giving layout of any treatment plant.

1. The W.T.P. should be located as near to the town so as to avoid the contamination.
2. All the units of plant should be located in order of sequence and flow from one unit to other by gravity.
3. All the units are arranged in such a way that minimum area is required so as to reduce the cost of construction.
4. Sufficient area should be reserved for the future expansion
5. Staff quarters and office should be provided near the treatment plants so that the operators can watch the plants easily.
6. The site of treatment plant should be very neat and give very good asthetic appearance.

The layout of the treatment plant is as shown in the fig

Aeration

1. Aeration removes odour and tastes due to volatile gases like hydrogen sulphide and due to algae and related organisms.
2. Aeration also oxidise iron and manganese, increases dissolved oxygen content in water, removes CO₂ and reduces corrosion and removes methane and other flammable gases.
3. 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 an 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 litres of air is required for 1 litre of water.

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

Settling

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

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

Purpose of Settling

To remove coarse dispersed phase.

1. To remove coagulated and flocculated impurities.
2. To remove precipitated impurities after chemical treatment.
3. To settle the sludge (biomass) after activated sludge process / trickling filters.

Principle of Settling

1. 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.
2. Basin in which the flow is retarded is called settling tank.
3. Theoretical average time for which the water is detained in the settling tank is called the detention period.

Screening

Screens are fixed in the intake works or at the entrance of treatment plant so as to remove the floating matters as leaves, dead animals etc.

Sedimentation

It is the process in which the suspended solids are made to settle by gravity under still water conditions is called plain sedimentation.

Plain sedimentation

By plain sedimentation the following are the advantages.

1. Plain sedimentation lightens the load on the subsequent process.
2. The operation of subsequent purification process can be controlled in better way.
3. The cost of cleaning the chemical coagulation basins is reduced.
4. No chemical is lost with sludge discharged from the plain settling basin.
5. Less quantity of chemicals are required in the subsequent treatment processes.

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.

Settling of discrete particles (Type I Settling)

1. Size, shape and specific gravity of the particles do not change with time.
2. Settling velocity remains constant.
3. If a particle is suspended in water, it initially has two forces acting upon it: force of gravity: $F_g = \rho_p g V_p$
4. Buoyant force quantified by Archimedes as: $F_b = \rho g V_p$
5. If the density of the particle differs from that of the water, a net force is exerted and the particle is accelerated in the direction of the force: $F_{net} = (\rho_p - \rho) g V_p$
6. This net force becomes the driving force.
7. Once the motion has been initiated, a third force is created due to viscous friction. This force, called the drag force, is quantified by: $F_d = C_D A_p \rho v^2 / 2$
8. C_D = drag coefficient.
9. A_p = projected area of the particle
10. Because the drag force acts in the opposite direction to the driving force and increases as the square of the velocity, acceleration occurs at a decreasing rate until a steady velocity is reached at a point where the drag force equals the driving
11. force:
12. $(\rho_p - \rho) g V_p = C_D A_p \rho v^2 / 2$
13. For spherical particles,

14. $V_p = \sqrt{\frac{4}{3} g d (\rho_p - \rho)}$ and $A_p = \frac{\pi d^2}{4}$

15. Thus, $v^2 = \frac{4g(\rho_p - \rho)d}{3C_D\rho}$

16. Expressions for C_D change with characteristics of different flow regimes. For laminar, transition, and turbulent flow, the values of C_D are:

17. $C_D = \frac{24}{Re}$ (laminar)

$C_D = \frac{24}{Re} + \frac{3}{Re^{1/2}} + 0.34$ (transition)

$C_D = 0.4$ (turbulent)

where Re is the Reynolds number

$Re = \frac{\rho v d}{\mu}$

Reynolds number less than 1.0 indicate laminar flow, while values greater than 10 indicate turbulent flow. Intermediate values indicate transitional flow.

Stokes Flow

For laminar flow, terminal settling velocity equation becomes:

$$v = \frac{(\rho_p - \rho) g d^2}{18\mu}$$

which is known as the stokes equation.

Transition Flow

Need to solve non-linear equations:

$$v^2 = \frac{4g(\rho_p - \rho)d}{3C_D\rho}$$

$$C_D = \frac{24}{Re} + \frac{3}{Re^{1/2}} + 0.34$$

$$Re = \frac{\rho v d}{\mu}$$

Calculate velocity using Stokes law or turbulent expression.

Calculate and check Reynolds number.

Calculate CD.

Use general formula.

Repeat from step 2 until convergence.

Types of Settling Tanks

1. Sedimentation tanks may function either intermittently or continuously. The intermittent tanks also called quiescent type tanks are those which store water for a certain period and keep it in complete rest. In a continuous flow type tank, the flow velocity is only reduced and the water is not brought to complete rest as is done in an intermittent type.
2. Settling basins may be either long rectangular or circular in plan. Long narrow rectangular tanks with horizontal flow are generally preferred to the circular tanks with radial or spiral flow.
3. Long Rectangular Settling Basin
4. Long rectangular basins are hydraulically more stable, and flow control for large volumes is easier with this configuration.
5. A typical long rectangular tank have length ranging from 2 to 4 times their width. The bottom is slightly sloped to facilitate sludge scraping. A slow moving mechanical sludge scraper continuously pulls the settled material into a sludge hopper from where it is pumped out periodically drag of sedimentation tank

A long rectangular settling tank can be divided into four different functional zones:

Inlet zone: Region in which the flow is uniformly distributed over the cross section such that the flow through settling zone follows horizontal path.

Settling zone: Settling occurs under quiescent conditions

Outlet zone: Clarified effluent is collected and discharge through outlet weir. Sludge

zone: For collection of sludge below settling zone.

Inlet and Outlet Arrangement

Inlet devices: Inlets shall be designed to distribute the water equally and at uniform velocities. A baffle should be constructed across the basin close to the inlet and should project several feet below the water surface to dissipate inlet velocities and provide uniform flow;

Outlet Devices: Outlet weirs or submerged orifices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank. However, peripheral weirs are not acceptable as they tend to cause excessive short-circuiting.

Weir Overflow Rates

Large weir overflow rates result in excessive velocities at the outlet. These velocities extend backward into the settling zone, causing particles and flocs to be drawn into the outlet. Weir loadings are generally used upto 300 m³/d/m. It may be necessary to provide special inboard weir designs as shown to lower the weir overflow rates.

Circular Basins

1. Circular settling basins have the same functional zones as the long rectangular basin, but the flow regime is different. When the flow enters at the center and is baffled to flow radially towards the perimeter, the horizontal velocity of the water is continuously decreasing as the distance from the center increases. Thus, the particle path in a circular basin is a parabola as opposed to the straight line path in the long rectangular tank.
2. Sludge removal mechanisms in circular tanks are simpler and require less maintenance.
3. Settling Operations
4. Particles falling through the settling basin have two components of velocity:

Vertical component: $v_t = \frac{(\rho_p - \rho)gd^2}{18\mu}$

Horizontal component: $v_h = Q/A$

The path of the particle is given by the vector sum of horizontal velocity v_h and vertical settling velocity v_t .

- Assume that a settling column is suspended in the flow of the settling zone and that the column travels with the flow across the settling zone. Consider the particle in the batch analysis for type-1 settling which was initially at the surface and settled through the depth of the column Z_0 , in the time t_0 . If t_0 also corresponds to the time required for the column to be carried horizontally across the settling zone, then the particle will fall into the sludge zone and be removed from the suspension at the point at which the column reaches the end of the settling zone.
- All particles with $v_t > v_0$ will be removed from suspension at some point along the settling zone.
- Now consider the particle with settling velocity $< v_0$. If the initial depth of this particle was such that $Z_p/v_t = t_0$, this particle will also be removed. Therefore, the removal of suspended particles passing through the settling zone will be in proportion to the ratio of the individual settling velocities to the settling velocity v_0 .
- The time t_0 corresponds to the retention time in the settling zone.

$$t = \frac{V}{Q} = \frac{LZ_0W}{Q}$$

$$\text{Also, } t_0 = \frac{Z_0}{v_0}$$

$$\text{Therefore, } \frac{Z_0}{v_0} = \frac{LZ_0W}{Q} \text{ and } v_0 = \frac{Q}{LW}$$

Thus, the depth of the basin is not a factor in determining the size particle that can be removed completely in the settling zone. The determining factor is the quantity Q/As , which has the units of velocity and is referred to as the overflow rate q_0 . This overflow rate is the design factor for settling basins and corresponds to the terminal setting velocity of the particle that is 100% removed

Design Details

1. Detention period: for plain sedimentation: 3 to 4 h, and for coagulated sedimentation: 2 to 2.5 h.
2. Velocity of flow: Not greater than 30 cm/min (horizontal flow).
3. Tank dimensions: L:B = 3 to 5:1. Generally L= 30 m (common) maximum 100 m. Breadth= 6 m to 10 m. Circular: Diameter not greater than 60 m. generally 20 to 40 m.
4. Depth 2.5 to 5.0 m (3 m).
5. Surface Overflow Rate: For plain sedimentation 12000 to 18000 L/d/m² tank area; for thoroughly flocculated water 24000 to 30000 L/d/m² tank area.
6. Slopes: Rectangular 1% towards inlet and circular 8%.

Sedimentation Tank Design

Problem: Design a rectangular sedimentation tank to treat 2.4 million litres of raw water per day. The detention period may be assumed to be 3 hours

Solution:Raw water flow per day is 2.4×10^6 l. period is 3h

Detention. Volume of tank = Flow x Detention period = $2.4 \times 10^3 \times 3/24 = 300 \text{ m}^3$ Assume depth of tank = 3.0 m.

$$\text{Surface area} = 300/3$$

$$= 100 \text{ m}^2 \quad L/B = 3$$

(assumed). $L = 3B$.

$$3B^2 = 100 \text{ m}^2 \text{ i.e.}$$

$$B = 5.8 \text{ m} \quad L =$$

$$3B = 5.8 \times 3 =$$

$$17.4 \text{ m}$$

Hence surface loading (Overflow rate) = $\frac{2.4 \times 10^6}{(OK) 100} = 24,000 \text{ l/d/m}^2 < 40,000 \text{ l/d/m}^2$

The time t_0 corresponds to the retention time in the settling zone.

The amount of matter removed by sedimentation tank depends upon the factors.

1. Velocity of flow
2. size and shape of particles
3. Viscosity of water

The particles which do not change in size, shape or mass during settling are known as the discrete particles. The velocity of discrete particles with dia less than 0.1 mm is given by

$$V = 418 (S - S_1) d^2 (3T + 70)$$

Where $V \rightarrow$ Velocity of settlement in mm/sec

$S \rightarrow$ Specific gravity of the particle

$S_1 \rightarrow$ Specific gravity of water

$D \rightarrow$ dia of the particle in mm

$T \rightarrow$ Temperature in $^{\circ}\text{C}$

If the dia of the particle is greater than 0.1mm then the velocity is measured by

$$V = 418 (S - S_1) d (3T + 70)$$

In practice settling of the particles governed by the resultant of horizontal velocity of water and the vertical downward velocity of the particle.

Design aspects of sedimentation tanks

The design aspects of sedimentary tanks are

1. Velocity of flow
2. Capacity of tank
3. Inlet and outlet arrangements

4. Shapes of tanks

5. Miscellaneous considerations.

(1)Velocity of flow: The velocity of flow of water in sedimentation tanks should be sufficient enough to cause the hydraulic subsidence of suspended impurities. It should remain uniform throughout the tank and it is generally not allowed to exceed 150mm to 300mm per minute.

(2)Capacity of tank: capacity of tank is calculated by i) detention period ii) Overflow rate

(i) Detention period: The theoretical time taken by a particle of water to pass between entry and exit of a settling tank is known as the detention period. The capacity of tank is calculated by

$C = Q \times T$ where $C \rightarrow$ Capacity of tank

$Q \rightarrow$ Discharge or rate of flow

$T \rightarrow$ Detention period in hours

The detention period depends on the quality of suspended impurities present in water. For plain sedimentation tanks, the detention period is found to vary from 4 to 8 hours.

(ii) Overflow Rate: in this method it is assumed that the settlement of a particle at the bottom of the tank doesnot depend on the depth of tank and depends upon the surface area of the tank.

Distance of descend D

Detention period, $T = \frac{D}{V} = \frac{C}{Q} \text{-----(1)}$

Velocity of descend V

C

But, $T = \frac{C}{Q} \text{----- (2)}$

Q

From (1) & (2)

$$\frac{CD}{QV} = \frac{\text{-----}}{\text{-----}}$$

$$\text{Surface overflow rate, } V = \frac{D.Q}{C} = \frac{D \times Q}{L \times B \times D} = \frac{Q}{L \times B}$$

Where $L \rightarrow$ Length of tank

$B \rightarrow$ Breadth of tank

$D \rightarrow$ Depth of tank = Side water depth = S.W.D

$C \rightarrow$ Capacity of tank

$T \rightarrow$ Detention period

$U \rightarrow$ Discharge or rate of flow $V \rightarrow$ Velocity of descend of a particle to the bottom of tank = Surface overflow rate = S.O.R

Inlet and outlet arrangements

The inlet is a device, which is provided to distribute the water inside a tank, and the outlet is a device, which is meant to collect outgoing water. These arrangements should be properly designed and located in a such a way that they do not form any obstruction or cause any disturbance to the flowing water.

(4) shapes of tanks

Following are the three shapes of settling tank.

- (i) Rectangular tanks with horizontal flow
- (ii) Circular tanks with radial or spiral flow
- (iii) Hopper bottom tanks with vertical flow

The following are the parameters for satisfactory performance.

1. Detention period	3 to 4 hours for plain settling 2 to 2 1/2 hours for coagulant settling 1 to 1 1/2 hours for up flow type
2. Overflow rate	30 – 40 m ³ /m ² /day for horizontal flow 40-50m ³ /m ² /day for up flow
3. Velocity of flow.....	0.5 to 1.0 cm/sec
4. Weir loading.....	300m ³ /m/day
5. L:B	1:3 to 1:4
Breadth of tank.....	(10 to 12m) to 30 to 50m
6. Depth of tank.....	2 1/2 – 4m
7. Dia of circular tank....	upto 60m

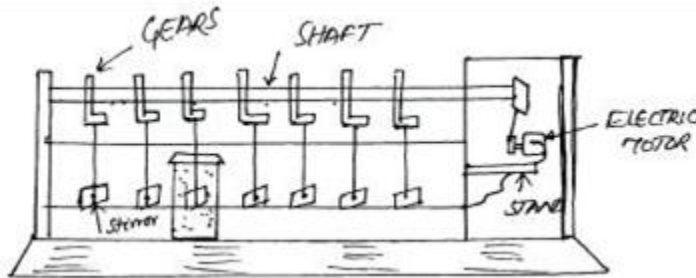
The following are the mostly used Coagulants with normal dose and PH values required for best floc formation as shown in Table

Sl.No.	Coagulant	PH Range	Dosage mg/l
1.	Aluminiumsulphate $\text{Al}_2(\text{SO}_4)_3, 18 \text{ H}_2\text{O}$	5.5 – 8.0	5 – 85
2.	Sodium Aluminate, $\text{Na}_2\text{Al}_2\text{O}_4$	5.5 – 8.0	3.4 – 34
3.	Ferric Chloride (FeCl_3)	5.5 – 11.0	8.5 – 51
4.	Ferric Sulphate $\text{Fe}_2(\text{SO}_4)_3$	5.5 – 11.0	8.5 – 51
5.	Ferric Sulphate $\text{FeSO}_4 7\text{H}_2\text{O}$	5.5 – 11.0	8.5 - 51

Sedimentation aided with coagulation

When water contains fine clay and colloidal impurities which are electrically charged are continually in motion and never settle down due to gravitational force. Certain chemicals are added to the water so as to remove such impurities which are not removed by plain sedimentation. The chemical form insoluble, gelatinous, flocculent precipitate absorbs and entangle very fine suspended matter and colloidal impurities during its formation and descent through water. These coagulants further have an advantage of removing colour, odour and taste from the water. Turbidity of water reduced upto 5-10 ppm and bacteria

removes upto 65%. Coagulants are chosen depending upon the PH of water. Alum or Aluminium sulphate is normally used in all treatment plants because of the low cost and ease of storage as solid crystals over long periods. The dosage of coagulants, which should be added to the water, depends upon kind of coagulant, turbidity of water, colour of water, PH of water, temperature of water and temperature of water and mixing & flocculation time. The optimum dose of coagulant required for a water treatment plant is determined by a Jar test as shown in Fig.

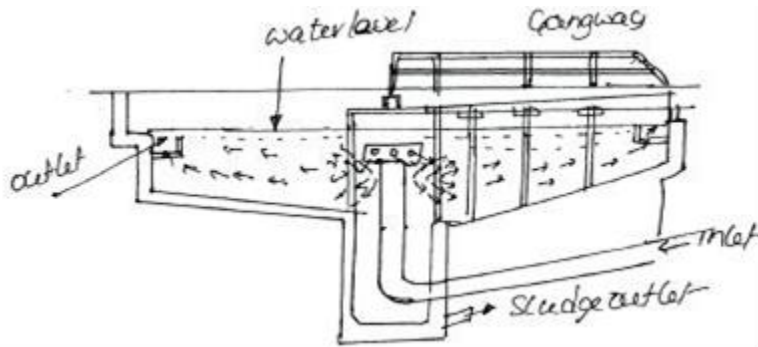


For starting the experiment first of all the sample of water is taken in every jar and added the coagulant in a jar in varying amounts. The quantity of coagulant added in each jar is noted. Then with the help of electric motor all the paddles are rotated at a speed of 30-40 R.P.M. for about 10 minutes. After this the speed is reduced and paddles are rotated for about 20-30 minutes. The rotation of paddles is stopped and the floc formed in each Jar is noted and is allowed to settle. The dose of coagulant which gives the best floc is the optimum dose of coagulants.

The coagulants may be fed or allowed to enter either in powder form called dry feeding or in solution form called wet feeding. The mixing of coagulant with the water to form the floc by the following methods.

1. Centrifugal pump
2. compressed air
3. hydraulic jump
4. mixing channel
5. mixing basins with baffle walls
6. Mixing basins with mechanical means

Now a days some firms manufacture combined unit comprising of feeding, mixing, flocculator and clarifier device. The Fig shows used for sedimentation with coagulation



Sedimentation with Coagulation

Water enters in this tank through central inlet pipe placed inside the deflector box. The deflector box deflects the water downwards and then it goes out through the holes provided sides of the deflector box. The water flows radially from the deflector box towards the circumference of the tank, where outlet is provided on the full periphery as shown in the Fig. All the suspended particles along with floc settle down on the slopy floor and clear water goes through outlet. The sludge is removed by scrapper which continuously moves around the floor with very small velocity. Disinfection and repainting is to be carried out once in a year before monsoon. Sludge pipes are to be flushed and kept clean. Bleaching powder may be used to control the growth of algae on the weirs. Scraper mechanism should be oiled and greased periodically.

Method of feeding coagulants

There are two methods of feeding coagulants to water

1. Dry feeding
2. Wet feeding

Dry Feeding:

Dry feeding is simple in operation and requires relatively less space for its working. The feeding machines are also cheaper. However, control of dose is difficult. In this case, the coagulant, in the powder form, is kept in the tank with hopper bottom. In order to prevent the arching of chemicals, agitator plates are placed inside the tank. The feeding is

regulated by the speed of the toothed wheel which is connected to the venture device in the raw water pipe.

The chemicals can be fed into water directly by dry feeding in the powder form. Alum being fairly fine and uniform in size can be fed easily by dry feeding. However, copperas and lime can not be fed by dry feeding. Dry feeding devices are generally in the form of a tank with hopper bottom. Agitating plates are placed inside the tank, so as to prevent arching of the coagulant. The coagulant in the powder form filled in the tank, and is allowed to fall in the mixing basin. The dose is regulated by the speed of a toothed wheel or a helical screw. The speed of the toothed wheel or the helical screw is, in turn controlled by connecting it to a venture-device installed in the raw water pipes feeding water to the mixing basin. The quantity of coagulant released is, thus controlled in proportion to the quantity of the raw water entering the mixing basin. Dry feeding devices are utilized in smaller plants.

Wet Feeding:

The dosage in the wet feeding equipment can be adjusted more readily and can be easily controlled by means of automatic devices. However the chemicals which are corrosive in nature create problem in wet feeding. In the case of wet feeding, the solution of the coagulant, of the required strength is prepared and stored in tank, from where it is allowed to fall in the mixing channel. The quantity of the mixture falling in the raw water channel is regulated in proportion to the quantity of flow.

In wet feeding, the solution of required strength of coagulant is prepared and stored in a tank, from where it is allowed to trickle down into the mixing tank through an outlet. The level of coagulant solution in the feed tank is maintained constant by means of a float controlled valve, in order to ensure a constant rate of discharge for a constant feed rate of raw water flow into the mixing basin. When inflow of raw water changes, the rate of coagulant feed is adjusted by a conical type arrangement. The working of a conical plug type arrangement is very simple. The mixing basin and the float chamber are interconnected together, so that the water level remains the same in both of them. As the

rate inflow of raw water increases the depth of water in the mixing basin as well as float chamber increases, thereby lifting the float. As the float rises, the pinion and pulley rotates in the same direction, thereby lifting the conical plug and allowing more quantity of coagulant solution to release to the mixing basin. When the rate of flow decreases the conical plug descends down and reduces the feeding rate of coagulant to lower rate. Larger water treatment plants are generally use wet feeding devices since they are costlier than dry feeding devices.

Rapid Mixing

Rapid mixing after coagulant dosing is an important design parameter. The coagulant must be uniformly mixed with the raw water. In case mixing is poor, local under- and overdosing occurs, resulting in poor performance of the process. In the flash mixer, coagulant chemicals are added to the water and the water is mixed quickly and violently to evenly distribute the chemicals through the water. Flash mixing typically lasts for 30 to 60 sec. If the water is mixed for less than 30 seconds, then the chemicals will not be properly mixed into the water. However, if the water is mixed for more than 60 seconds, then the mixer blades will shear the newly forming floc back into small particles. After flash mixing, coagulation occurs.

Mixing is an important unit operation where one substance must be completely intermingled with another. In water treatment coagulant is mixed into water by rapid mixing. The process of dispersing chemical by mixing is known as rapid mix or flash mix.

UNIT-5

FILTRATION

INTRODUCTION

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

1. Mechanical straining – Mechanical straining of suspended particles in the sand pores.
2. Sedimentation – Absorption of colloidal and dissolved inorganic matter in the surface of sand grains in a thin film
3. 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.
4. 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

Filter Materials

Sand: Sand, either fine or coarse, is generally used as filter media. The size of the sand is measured and expressed by the term called effective size. The effective size, i.e. D10 may be defined as the size of the sieve in mm through which ten percent of the sample of sand by weight will pass. The uniformity in size or degree of variations in sizes of particles is measured and expressed by the term called uniformity coefficient. The uniformity coefficient, i.e. (D_{60}/D_{10}) may be defined as the ratio of the sieve size in mm through which 60 percent of the sample of sand will pass, to the effective size of the sand.

Gravel: The layers of sand may be supported on gravel, which permits the filtered water to move freely to the under drains, and allows the wash water to move uniformly upwards.

Other materials: Instead of using sand, sometimes, anthrafil is used as filter media. Anthrafil is made from anthracite, which is a type of coal-stone that burns without smoke or flames. It is cheaper and has been able to give a high rate of filtration.

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.

Principles of Slow Sand Filtration

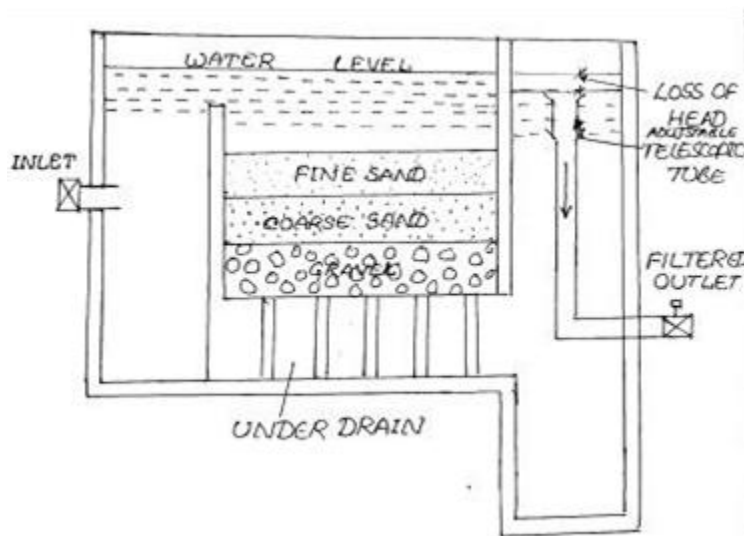
1. In a slow sand filter impurities in the water are removed by a combination of processes: sedimentation, straining, adsorption, and chemical and bacteriological action.
2. During the first few days, water is purified mainly by mechanical and physical-chemical processes. The resulting accumulation of sediment and organic matter

forms a thin layer on the sand surface, which remains permeable and retains particles even smaller than the spaces between the sand grains.

3. As this layer (referred to as “Schmutzdecke”) develops, it becomes living quarters of vast numbers of micro-organisms which break down organic material retained from the water, converting it into water, carbon dioxide and other oxides.
4. Most impurities, including bacteria and viruses, are removed from the raw water as it passes through the filter skin and the layer of filter bed sand just below. The purification mechanisms extend from the filter skin to approx. 0.3-0.4 m below the surface of the filter bed, gradually decreasing in activity at lower levels as the water becomes purified and contains less organic material.
5. When the micro-organisms become well established, the filter will work efficiently and produce high quality effluent which is virtually free of disease carrying organisms and biodegradable organic matter.
6. They are suitable for treating waters with low colors, low turbidities and low bacterial contents.

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 . The 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. The gravel is laid in layers such that the smallest sizes are at the top. The gravel layer is the retains for the coarse sand layer and is laid over the network of open jointed clay pipe or concrete pipes called under drainage. 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 submersible inlet as shown in fig 5.3. 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 3 cms from the top of bed is scrapped and replaced with clean sand before putting back into service to the filter. The scrapped sand is washed with the water, dried and stored for return to the filter at the time of the next washing. 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 colours from the water but not pathogenic bacteria which requires disinfection to safeguard against water-borne diseases. 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. Filter head indicator should be in good working condition. Trees around the plant should be controlled to avoid bird droppings on the filter bed, No coagulant should be used before slow sand filtration since the floc will clog the bed quickly.

Rapid sand filter

Rapid sand filter are replacing the slow sand filters because of 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.

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 becomes very low. Therefore the filter bed requires its washing.

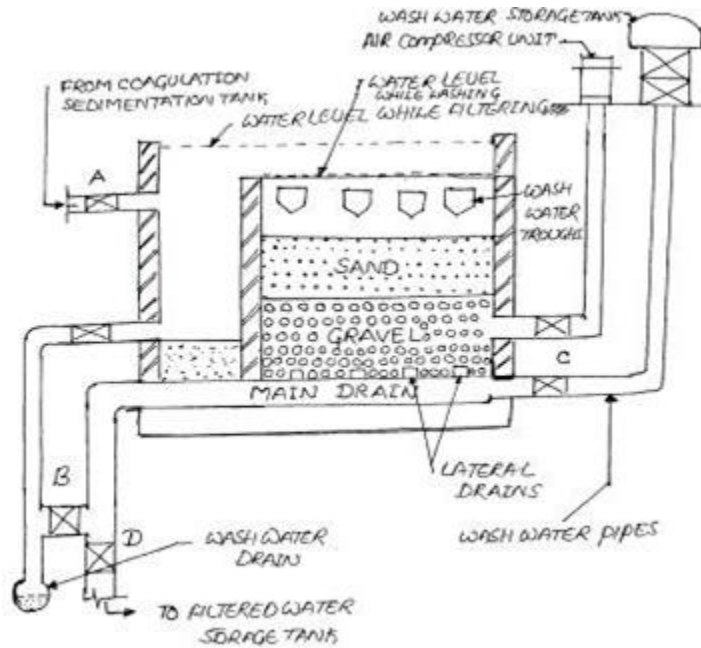
Depth of sand	-	60 to 75cm
Filter gravel	-	2 to 50mm size (Increase size towards bottom)
Depth of gravel	-	45cm
Depth of water over sand during filtration	-	1 to 2m
Overall depth of filter including 0.5m free board	-	2.6m
Area of single filter unit	-	100m^2 in two parts of each 50m^2
Loss of head	-	Max 1.8 to 2.0m
Turbidity of filtered water	-	1 NTU

Effective size of sand - 0.45 to 0.70mm

Uniformity coefficient of sand - 1.3 to 1

Washing of filter

Washing of filter done by the back flow of water through the sand bed as shown in Fig 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 valves 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 masonry 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. Appartenances – 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 eashing of filter is done generally after 24 hours and it takes 10 minutes and during back washing the sand bed expands by about 50%.

Comparison of slow sand filter and rapid sand filter

Sl.No.	ITEM	S.S.F	R.S.F
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 0.7 mm uniformity coefficient 1.3 to 1.7 multiple graded layers of sand.
4.	Rate of Filtration	2.4 to 3.6m ³ /m ² /day	100-150 m ³ /m ² /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 removal, taste, odour, colour and turbidity removal.	There is no removal of bacteria. Removal colour taste, odour and turbidity is good.

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.

Backwashing of Rapid Sand Filter

1. For a filter to operate efficiently, it must be cleaned before the next filter run. If the water applied to a filter is of very good quality, the filter runs can be very long. Some filters can operate longer than one week before needing to be

backwashed. However, this is not recommended as long filter runs can cause the filter media to pack down so that it is difficult to expand the bed during the backwash

2. Treated water from storage is used for the backwash cycle. This treated water is generally taken from elevated storage tanks or pumped in from the clear well.
3. The filter backwash rate has to be great enough to expand and agitate the filter media and suspend the floc in the water for removal. However, if the filter backwash rate is too high, media will be washed from the filter into the troughs and out of the filter.

The filter should be backwashed when the following conditions have been met:

The head loss is so high that the filter no longer produces water at the desired rate; and/or Floc starts to break through the filter and the turbidity in the filter effluent increases; and/or A filter run reaches a given hour of operation.

Operational Troubles in Rapid Gravity Filters

Air Binding

1. When the filter is newly commissioned, the loss of head of water percolating through the filter is generally very small. However, the loss of head goes on increasing as more and more impurities get trapped into it.
2. A stage is finally reached when the frictional resistance offered by the filter media exceeds the static head of water above the and bed. Most of this resistance is offered by the top 10 to 15 cm sand layer. The bottom sand acts like a vacuum, and water is sucked through the filter media rather than getting filtered through it.
3. The negative pressure so developed, tends to release the dissolved air and other gases present in water. The formation of bubbles takes place which stick to the sand grains. This phenomenon is known as Air Binding as the air binds the filter and stops its functioning.

4. To avoid such troubles, the filters are cleaned as soon as the head loss exceeds the optimum allowable value.

Formation of Mud Balls: The mud from the atmosphere usually accumulates on the sand surface to form a dense mat. During inadequate washing this mud may sink down into the sand bed and stick to the sand grains and other arrested impurities, thereby forming mud balls.

Cracking of Filters:

The fine sand contained in the top layers of the filter bed shrinks and causes the development of shrinkage cracks in the sand bed. With the use of filter, the loss of head and, therefore, pressure on the sand bed goes on increasing, which further goes on widening these cracks.

Remedial Measures to Prevent Cracking of Filters and Formation of Mud Balls

Breaking the top fine mud layer with rakes and washing off the particles.

Washing the filter with a solution of caustic soda.

Removing, cleaning and replacing the damaged filter sand

Standard design practice of Rapid Sand filter:

Maximum length of lateral = not less than 60 times its diameter. Spacing of holes = 6 mm holes at 7.5 cm c/c or 13 at 15 c/c. C.S area of lateral = not less than 2 times area of perforations. C.S area of manifold = 2 times total area of laterals. Maximum loss of head = 2 to 5 m. Spacing of laterals = 15 to 30 cm c/c. Pressure of wash water at perforations = not greater than 1.05 kg/cm². Velocity of flow in lateral = 2 m/s. Velocity of flow in manifold = 2.25 m/s. Velocity of flow in manifold for washwater = 1.8 to 2.5 m/s. Velocity of rising washwater = 0.5 to 1.0 m/min. Amount of washwater = 0.2 to 0.4% of total filtered water. Time of backwashing = 10 to 15 min. Head of water over the filter = 1.5 to 2.5 m. Free board = 60 cm. Bottom slope = 1 to 60 towards manifold.

$$Q = (1.71 \times b \times h^{3/2})$$

where Q is in m³/s, b is in m, h is in m. L:B = 1.25 to 1.33:1

Rapid Sand Filter Design

Problem: Design a rapid sand filter to treat 10 million litres of raw water per day allowing 0.5% of filtered water for backwashing. Half hour per day is used for backwashing. Assume necessary data.

Solution: Total filtered water = $\frac{10.05 \times 24 \times 10^6}{24 \times 23.5} = 0.42766 \text{ MI} /$

Let the rate of filtration be 5000 l / h / m²
 of bed. Area of filter = $\frac{10.05 \times 10^6 \times 1}{23.5 \times 5000} = 85.5 \text{ m}^2$

Provide two units. Each bed area $85.5/2 = 42.77$. L/B = 1.3; $1.3B^2 = 42.77$
 $B = 5.75 \text{ m}$; $L = 5.75 \times 1.3 = 7.5 \text{ m}$

Underdrainage system:

Total area of holes = 0.2 to 0.5% of bed area.

Assume 0.2% of bed area = $0.2 \times 42.77 = 0.086$

Area of lateral = 2 (Area of holes of lateral)
 Area of manifold = 2 (Area of laterals)

So, area of manifold = $4 \times \text{area of holes} = 4 \times 0.086 = 0.344 = 0.35 \text{ m}^2$.

Diameter of manifold = $(4 \times 0.35 / \pi)^{1/2} = 66 \text{ cm}$

Assume c/c of lateral = 30 cm. Total numbers = $7.5 / 0.3 = 25$ on either side. Length of lateral = $5.75/2 - 0.66/2 = 2.545 \text{ m}$.

C.S. area of lateral = 2 x area of perforations per lateral. Take dia of holes = 13 mm

Assume depth of sand = 50 to 75 cm.

$$\text{Number of holes: } n \pi (1.3)^2 = 0.086 \times 10^4 = 860$$

$$n = \frac{4 \times 860}{\pi (1.3)^2} = 648, \text{ say } 650$$

$$\text{Number of holes per lateral} = 650/50 = 13$$

$$\text{Area of perforations per lateral} = 13 \times \pi (1.3)^2 / 4 = 17.24 \text{ cm}^2$$

$$\text{Spacing of holes} = 2.545/13 = 19.5 \text{ cm.}$$

$$\text{C.S. area of lateral} = 2 \times \text{area of perforations per lateral} = 2 \times 17.24 = 34.5 \text{ cm}^2.$$

$$\text{Diameter of lateral} = (4 \times 34.5 / \pi)^{1/2} = 6.63 \text{ cm}$$

$$\text{Check: Length of lateral} < 60 d = 60 \times 6.63 = 3.98 \text{ m. } l = 2.545 \text{ m (Hence acceptable).}$$

$$\text{Rising washwater velocity in bed} = 50 \text{ cm/min.}$$

$$\text{Washwater discharge per bed} = (0.5/60) \times 5.75 \times 7.5 = 0.36 \text{ m}^3/\text{s.}$$

$$\text{Velocity of flow through lateral} = \frac{0.36}{\text{Total lateral area}} = \frac{0.36 \times 10^4}{50 \times 34.5} = 2.08 \text{ m/s (ok)}$$

$$\text{Manifold velocity} = \frac{0.36}{\text{Total lateral area}} = 1.04 \text{ m/s} < 2.25 \text{ m/s (ok)}$$

Washwater gutter

$$\text{Discharge of washwater per bed} = 0.36 \text{ m}^3/\text{s. Size of bed} = 7.5 \times 5.75$$

$$\text{m. Assume 3 troughs running lengthwise at } 5.75/3 = 1.9 \text{ m c/c.}$$

$$\text{Discharge of each trough} = Q/3 = 0.36/3 = 0.12 \text{ m}^3/\text{s. } Q$$

$$= 1.71 \times b \times h^{3/2}$$

$$\text{Assume } b = 0.3 \text{ m}$$

$$h^{3/2} = 0.12 =$$

$$\frac{0.234 \times 1.71}{\times 0.3}$$

$$h = 0.378 \text{ m} = 37.8 \text{ cm} = 40 \text{ cm}$$

$$= 40 + (\text{free board}) 5 \text{ cm} = 45 \text{ cm; slope } 1$$

in 40 Clear water reservoir for backwashing

For 4 h filter capacity, Capacity of tank = $\frac{4 \times 5000 \times 7.5 \times 5.75 \times 2}{1000} = 1725$ m³

Assume depth d = 5 m. Surface area = $1725/5 = 345$

m² L/B = 2; $2B^2 = 345$; B = 13 m & L = 26 m.

Dia of inlet pipe coming from two filter = 50 cm.

Velocity < 0.6 m/s. Diameter of washwater pipe to overhead tank = 67.5

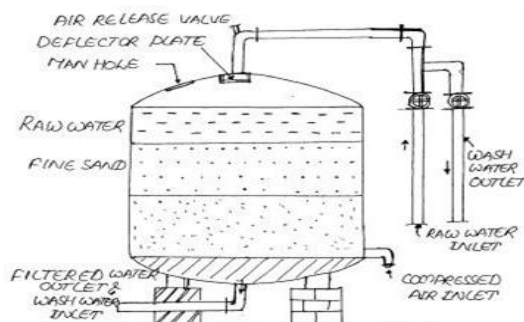
cm. Air compressor unit = 1000 l of air/ min/ m² bed area.

For 5 min, air required = $1000 \times 5 \times 7.5 \times 5.77 \times 2 = 4.32$ m³ of air.

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, except that the coagulated water is directly applied to the filter without mixing and flocculation. These filters are used for industrial plants but these are not economical on large scale.

Pressure filters may be vertical pressure filter and horizontal pressure filter. The Fig 5.5 shows vertical pressure filter. Backwash is carried by reversing the flow with valves. The rate of flow is 120 to 300m³/m²/day.



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.

Disadvantages

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.

UNIT-6
DISINFECTION

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 good 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

sludges to be treated.

Chlorination

Chlorination is the addition of chlorine to kill the bacteria. Chlorination is very widely 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 electrolysis of common salts (NaCl)
2. It is a powerful oxidant and can penetrate the cell wall of an organism and its contents.
3. Dosage can be controlled precisely
4. can be easily detected by simple orthotolidine test
5. Does not form harmful constituents on reaction with organics or inorganics in water
6. leaves required residue in water to neutralise recontamination later.

Precautions in using chlorine

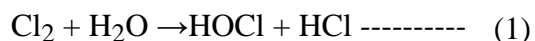
1. Chlorine gas or liquid is highly corrosive and lethal to inhale. Hence it is to be stored carefully in a sealed container at a distance.
2. If the water contains phenolic compounds, there is a reaction with chlorine that can result in cancer-causing substances.

Residual chlorine and chlorine demand

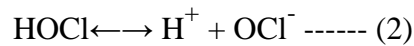
When chlorine is applied in water, some of it is consumed in killing the pathogens, some react with organic & inorganic substances and the balance is detected as "Residual Chlorine". The difference between the quantity applied per litre and the residual is called "Chlorine Demand". Polluted waters exert 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.

Behaviour of chlorine in water

When chlorine is dissolved in water, it forms hypochlorous acid and hydrochloric acid.



After some time hydrochlorous acid further ionizes as follows



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, (NH₂Cl), dichloramine (NHCl₂) and trichloramine, (NCl₃) released and their distribution depends on the PH-value of water.

Dosage of chlorine

(A) Plain chlorination

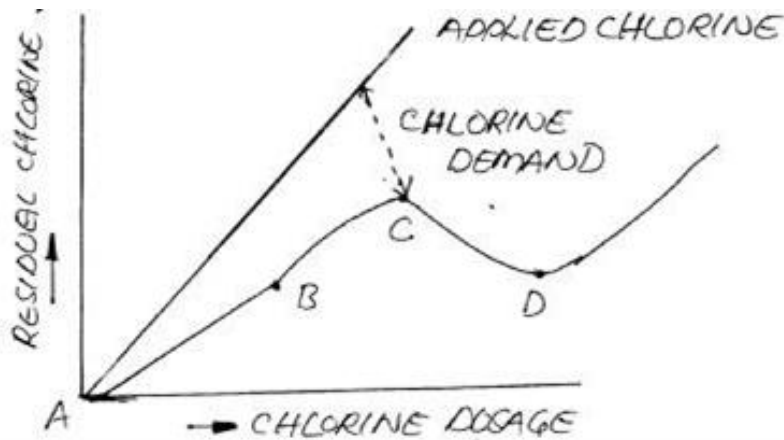
Plain chlorination is the process of addition of chlorine only when the surface water with no other treatment is required. The water of lakes and springs is pure and can be used after plain chlorination. A rate of 0.8 mg/lit/hour at 15N/cm² pressure is the normal dosage so as to maintain in a residual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

When chlorine is applied to water containing organics, micro organisms and ammonia the residual chlorine levels fluctuate with increase in dosage as shown in Fig. Upto the point B it is absorbed 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 effective N₂, N₂O and NCl₃. Beyond point 'D' free residual chlorine appear again. This point 'D' is called break point chlorination. Dosage beyond this point is the same as super chlorination. In super chlorination no such rational measurement is made and the dosage is taken at random.



(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 ($\text{Na}_2\text{S}_2\text{O}_8$) are used.

Points of chlorination

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

Pre-chlorination

Chlorine applied prior to the sedimentation and filtration process is known as Pre-chlorination. This is practiced when the water is heavily polluted and to remove taste, odour, colour and growth of algae on treatment units. Pre-chlorination improves coagulation and post chlorination dosage may be reduced.

Post chlorination

When the chlorine is added in the water after all the treatment is known as Post-chlorination.

Re-chlorination

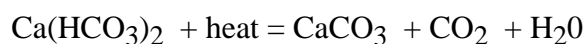
In long distribution systems, chlorine residual may fall tendering the water unsafe. Application of excess chlorine to compensate for this may lead to unpleasant smell to consumers at the points nearer to treatment point in such cases chlorine is applied again that is rechlorinated at intermediate points generally at service reservoirs and booster pumping stations.

WATER SOFTENING

Introduction

Water softening is the process of removing hardness. Hardness is defined as the water's ability to consume soap. Besides making water more pleasing for washing purposes, softening water can also provide benefits of preventing encrustation and scaling inside boilers, water heaters, hot-water lines, as well as some industrial processes. Hardness is usually expressed in terms of "ppm as CaCO_3 ", or ppm as calcium carbonate. The home water softener industry usually measures hardness in the form of grains per gallon, of which 1 gpg equals about 17 ppm hardness. The terms, "hard water" and "soft water" are used loosely, as there are no accepted standards or "measuring scale" to determine if water is soft or hard.

The primary constituents in water that cause hardness are calcium (Ca) and magnesium (Mg), especially calcium. Iron (Fe) and manganese (Mn) can also promote to water hardness, but typically at a much lesser degree. Hardness caused by calcium and manganese is typically carbonate hardness, for the calcium and manganese exists in the water in the form of calcium bicarbonate, $\text{Ca}(\text{HCO}_3)_2$, and magnesium bicarbonate, $\text{Mg}(\text{HCO}_3)_2$. This form of hardness is usually referred to as carbonate hardness, or temporary hardness. On the other hand, the sulfate, chloride and nitrate salts of calcium are usually referred to as permanent hardness, since they cannot be readily precipitated. Water heaters suffer from hard water because when water containing calcium bicarbonate is heated, the insoluble carbonate form of calcium will be precipitated.



where CaCO_3 is calcium carbonate, which will form as the identifiable white, crusty

matter, which precipitates out of the water. It is this white, crusty matter that builds up in water heaters, hot water lines, and on the kitchen tap as well as in the sink.

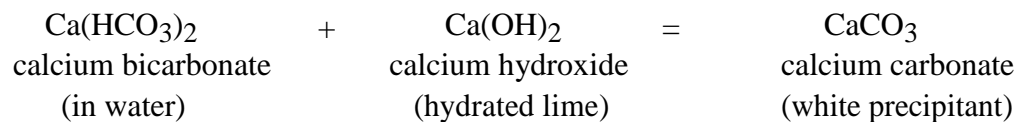
The hardness of water varies with where the source water came from. The mineral content and hardness of water typically reflects the nature of geological formations through which the water comes in contact, for example limestone. In general, ground water sources are much harder than surface waters. It is not uncommon to find ground water with a hardness of 300 ppm. Finished drinking water need not be “completely softened”. Usually, a hardness of around 80-90 ppm is quite sufficient.

The science and chemistry of water softening can be a confusing and frustrating one for water operators, but it is a process that is also quite fascinating and exemplifies the wonders of science and natural processes.

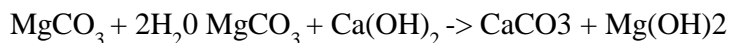
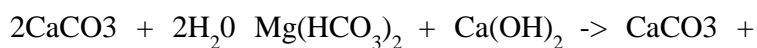
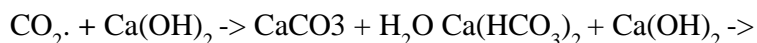
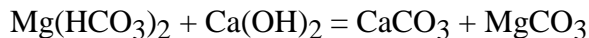
Lime/soda ash method

The most common method of water softening used in water plants is lime softening, or lime/soda ash softening. The reason for this is that lime and soda ash are readily available and cost efficient for softening the large amounts of water processed through a water plant.

In the simplest sense, hydrated lime is fed at a dosage sufficient to cause the carbonate hardness to precipitate out, settle, and be removed from the water. Since carbonate hardness exists in water as calcium bicarbonate, then the chemical reaction as follows occurs,



also, in the event of magnesium bicarbonate in the water causing hardness,



Therefore, lime softening is sort of like fighting fire with fire. It's not uncommon to feed large doses of hydrated lime, which is why a lime softening plant uses a grain-bin size lime feeder and not a small dry chemical feeder using 50-pound bags of hydrated lime!

Non-carbonate hardness

Now, if the hardness of the water is contributed by non-carbonate hardness, soda ash, Na_2CO_3 , may be fed in addition to the hydrated lime to remove non-carbonate hardness. Sometimes liquid caustic soda, NaOH , can be used instead of soda ash. The advantages of using caustic soda are,

1. ease of handling and feeding,
2. lack of deterioration in storage,
3. less calcium carbonate sludge is formed,
4. can precipitate both carbonate and non-carbonate hardness, so the caustic soda can actually replace some of the need hydrated lime.

Whether soda ash or caustic soda is used is based on chemical costs and raw water characteristics.

Recarbonation

As you may have determined, the process of lime softening can dramatically raise the pH of the water. Many times, the final process in lime softening is to recarbonate the water by adding carbon dioxide, CO_2 . This process will lower the pH to a level desirable for the finished water.

Ion-exchange method

Ion exchange is not nearly as cost-efficient as lime softening when producing large amounts of water. Therefore, water plants typically do not use ion exchange to soften the finished product water. However, some water plants do need to soften smaller amounts of water used in some treatment process, for example fluoridation, which can be sufficiently handled with ion-exchange methods. Likewise, most in-home water softeners are ion-exchange units.

Ions can exist with either a positive charge or a negative charge. A positive charge ion is called a cation. A negative charge ion is called an anion. Calcium (Ca) and magnesium (Mg), the principle elements causing hardness, are typically positive charged cations. Therefore, the basic premise of which ion-exchange softening uses is trading one ion for another. Anion-exchange water softener has three main parts,

1. a resin tank containing small beads of synthetic resin,
2. a brine tank,
3. the control valve.

The resin is treated with sodium (Na) from the brine tank. Sodium is also a positive charged cation with a charge of plus one, therefore, Na^+ . As water passes through the resin tank, the sodium ions are exchanged with calcium and magnesium ions, because the calcium and magnesium ions are of a higher positive charge than the sodium ions, Ca^{++} and Mg^{++} . Therefore, the resin is behaving as the negative charge. Since the calcium and magnesium ions are of a stronger positive charge than the sodium ions, the resin “exchanges” the sodium for calcium and magnesium because there is more of an attraction between the resin and the calcium and magnesium than between the resin and the sodium. This process of ion exchange will continue until all available exchange sites are filled, at which point the resin is exhausted and must be regenerated by the sodium (bags of salt) from the brine tank.

As you can see, the main drawback from ion-exchange softeners is that they put sodium into the water. This can present health problems for people who should not ingest excessive amounts of sodium. This is why I recommend that home installations of water softeners be placed on the water line going to the hot water heater. The hot water heater benefits, the hot water lines benefit, the soap consumption is reduced, but you don't have to drink it from the cold-water tap.

A benefit of ion-exchange softeners is that they can remove iron (Fe) to some extent because iron is also a positive charge cation.

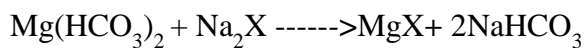
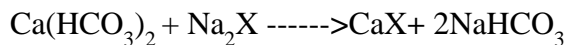
Zeolite softening

The ion-exchange method of water softening has been used extensively in smaller water systems and individual homes. It is based on the ability of the ion-exchange resin, zeolite, to exchange one ion from the water being treated for another ion that is in the resin. Zeolite resin exchanges sodium ions for ions causing hardness in the water, such as calcium and magnesium. Sodium is one component of softening salt, with chlorine being the other.

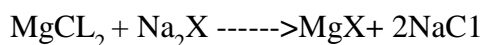
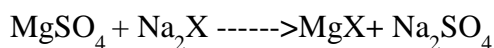
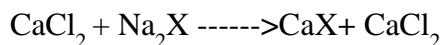
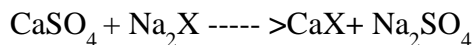
Chemistry of the Ion-Exchange Reaction

The following chemical reactions show the exchange process. The X represents the zeolite, the exchange material.

Removal of carbonate hardness:



Removal of non-carbonate hardness



These reactions represent cation exchange, the exchange of positive ions. To replenish the sodium ions used, the units need to be regenerated with material containing high amounts of sodium, normally a salt brine. This allows the resin to be reused many times.

The ion-exchange softening process does not alter the water's pH or alkalinity. However, the stability of the water is altered due to the removal of the calcium and magnesium and an increase in dissolved solids. For each ppm of calcium removed and replaced by sodium, the total dissolved solids increases by 0.15 ppm. For each ppm of magnesium removed and replaced by sodium, the total dissolved solids will increase by 0.88 ppm.

The measurements used to express water hardness in the ion-exchange process differ from the units that are normally used in the lime-soda softening process. Hardness in the ion-exchange process is expressed as grains per gallon rather than mg/l of calcium carbonate. The following conversions show the relationship between mg/l and grains per gallon:

1 grain 17.12 mg/l

1 grain 0.143 lbs per 1000 gallon

7000 grains 1 lb per gal

Advantages of the Ion-Exchange Process

Compared with lime-soda ash softening, ion-exchange softening has certain advantages, the main ones being its compactness and its low cost. The chemicals used are safer for the operator to handle and the operation of the zeolite-softening process is much easier. It can be almost totally automated. Because the resins have the ability to remove all of the hardness from the water, the treated water must be blended with water that has been by-passed around the softener to obtain the hardness level the operator would like to maintain.

Many utilities have found the ion-exchange process to be the most cost effective way of producing quality water for their customers. If the zeolite units are used to soften surface water, it has to be preceded by the normal surface-water treatment units of rapid mix, flocculation, sedimentation, and filtration. This is needed to remove any material that may otherwise foul the resin. Therefore, the lime-soda process is most likely the more cost-effective method for surface-water softening than the ion-exchange one.

The ion-exchange process requires the following components

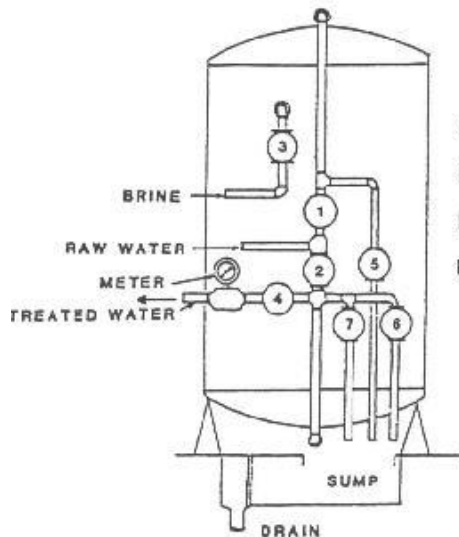
There are a number of materials, including some types of soils, that can act as cation exchangers for softening. A natural green sand called glauconite has very good exchange capabilities, and it was once widely used. Synthetic zeolites, known as polystyrene resins, are the ones most commonly used now. Their cost is reasonable, and it is easy to control the quality of the resin. They also have much higher ion-exchange capacities than the natural material.

The ability of the resin to remove hardness from the water is related to the volume of resin in the tank. The zeolite resin should remove about 50,000 grains of hardness per cubic foot of resin. The resin holds the hardness ions until they are regenerated with a salt brine solution. The hardness ions are exchanged for the sodium ions in the salt brine.

Salt storage

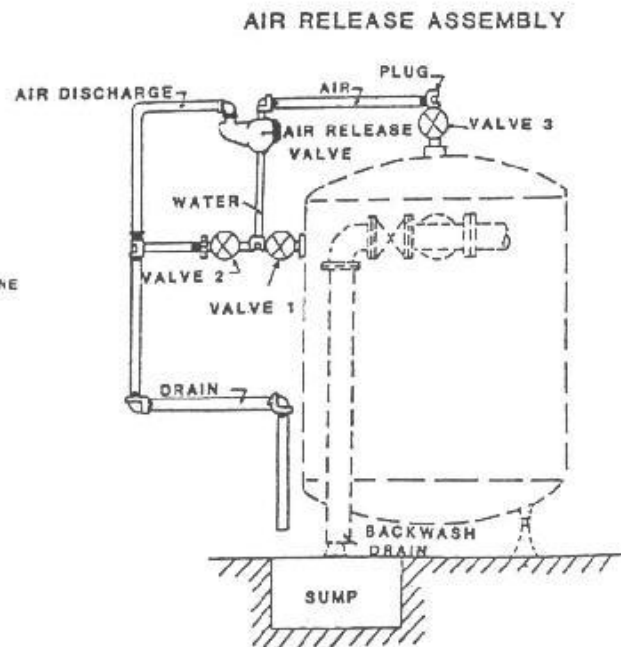
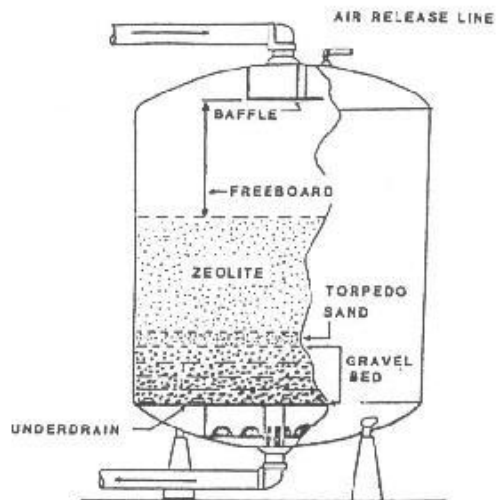
The salt is stored as a brine, ready to be used for the regeneration of the resin. The amount of salt needed ranges from 0.25 to 0.45 pounds for every 1,000 grains of hardness removed. The tank should be coated with a salt-resistant material to prevent corrosion of the tank walls. The salt used should meet the AWWA standards for sodium chloride. Rock or pellet salt is the best for preparing brine. Road salt is not acceptable, due to the dirt that it contains. Salt-storage tanks should be covered to prevent contamination of the salt. A raised curb should be provided at each access hatch to prevent contamination by flood water or rain.

Zeolite Softening Units



Open Valves

Service: 1 and 4
Backwash: 2 and 5
Brine: 3 and 6
Rinse: 1 and 7



then adding salt is the preferred method for making the brine. The brine is heavier than water and settles to the bottom of the tank. The brine is usually pumped from the tank to the ion-exchange units. When making brine, the addition of water must be through an air gap due to the possibility of back siphonage of the brine to the water system.

Brine-feeding equipment

Concentrated brine contains approximately 25 percent salt. The brine should be diluted to about 10 percent before it is added to the tank during regeneration. It is generally injected with the use of a venturi or by the use of a metering pump. The solubility of salt decreases with a rise in temperature, which forces the salt out of solution. The water that remains after the salt has separated out of the solution is subject to freezing. Therefore, the brine piping should be protected from cold temperatures.

Devices for blending

A properly operated ion-exchange unit produces a water with zero hardness but with high corrosivity. Since a total hardness of 85 to 100 mg/l is the most desirable, the effluent from the ion-exchange unit is generally blended with source water to raise the hardness in the finished water. Blending is normally accomplished by metering both the effluent from the softener and the raw water added. Meters are installed in both lines so that the operator can adjust and monitor the blend.

Operation of units

The basic steps in the operation of an ion-exchange softening unit are the softening cycle, backwash, regeneration, slow rinse, and fast rinse.

Softening Cycle

The softening cycle involves the feeding of water into the unit until hardness appears in the effluent from the unit. The cycle ends when 1 to 5 mg/l of hardness is detected in the effluent. Almost all softening units have an alarm on the water meter to indicate when a certain amount of water has passed through the exchange unit. Loading rates for synthetic resins are in the area of 10 to 15 gpm/square foot of media surface area.

Backwash Cycle

Once the hardness breaks through, the softener unit needs to be regenerated. In down-flow units the resin must first be backwashed to loosen the resin since it becomes

compacted by the weight of the water, and to remove any material that has been filtered out of the water by the resin. The backwash rate is normally 6 to 8 gpm/square foot of zeolite bed area. The operator needs to apply enough backwash water to expand the resin bed by about 50 percent. The backwash water is usually discharged to a box containing orifice plates that establish and measure the flow rate.

Distributors at the top of the unit provide for uniform water distribution and uniform wash-water collection. Underdrains help the uniform distribution of the backwash water on the bottom of the resin.

Regeneration

To regenerate an ion-exchange unit, concentrated brine is pumped to the unit from the storage basin. The brine is diluted through the injector to a solution containing about 10 percent salt before it is passed through the resin. The time required for regeneration is about 20 to 35 minutes. The flow rate of brine through the resin is measured in gallons per minute per cubic foot of media.

The brine needs to be in contact with the resin long enough to allow for complete exchange of the hardness ions in the resin with sodium ions in the brine. It is better to allow too much time than to not allow enough. If the resin is not totally recharged, the next softening run will be short.

Rinse Cycle

The regeneration cycle must be followed by a rinse cycle to remove the remaining brine from the tank. The total amount of rinse water needed is 20 to 35 gallons per cubic foot of resin. The rinse is started at a slow rate--2 gpm/square foot of surface area--and continued until the chloride concentration of the effluent, which should be monitored frequently, is quite low.

Disposal of brine

The total volume of the brine that is used during a regeneration cycle, together with the rinse water that follows, varies from 1.5 to 7 percent of the amount of water softened by the unit. The chloride concentration in this wastewater could be as high as 35,000 to 45,000 mg/l. This amount of chlorides will upset a wastewater treatment plant, so the brine usually will have to be disposed of by lagooning. In Minnesota the disposal methods used have to comply with Minnesota Pollution Control Agency's rules.

Operating problems

Problem areas in operation included breakdown of the resin, iron fouling, presence of suspended material in the source water, and unstable water.

Resin Breakdown

The synthetic resins will normally last 15 to 20 years, but certain conditions can cause the resin to breakdown sooner. Oxidation by chlorine is probably the most common cause of resin breakdown. When chlorine is used to oxidize iron in the water, the chlorine should be removed before the ion exchange unit.

Iron Fouling

Iron in the source water will seriously affect the ability of the resin to remove the hardness ions. Ferrous iron can be oxidized during the softening and precipitate out as iron oxide on the resin. No amount of brine will remove the iron fouling. If the iron oxide is formed before the exchange unit, it can be filtered out by the resin and removed during the backwashing of the unit. Normally if the iron concentration in the source water is high, iron removal is provided ahead of the exchange unit to prevent fouling of the unit.

Suspended material

Turbidity, organic chemicals, and bacterial slimes seriously affect the resin by coating it, resulting in the loss of some of the resin's exchange capacity. The best solution to this

problem is the removal of the suspended matter by the normal water treatment methods of coagulation, sedimentation, and filtration before the softening process.

Unstable water

Any water that has been softened by the ion-exchange process will be corrosive and will have to be stabilized to prevent corrosion from taking place in the distribution system. The way to accomplish this is by adding phosphates or other chemicals to reduce the corrosivity of the water.

Operational testing

Testing the quality of the water treated by an ion exchange softener is fairly simple. The testing should consist of the following:

1. Total Hardness of the raw and treated water.
2. The Langelier Index ($\text{pH of stability [pHs]} - \text{pH measured}$). If the Langelier Index is positive, the water will tend to coat the pipes in the distribution system with a calcium scale. If the Langelier Index is negative, the water will tend to be corrosive.
3. Chloride concentration in the rinse water

UNIT-7

MISCELLANEOUS TREATMENT

Taste and Odor

Most customers judge the quality of drinking water by taste and odor. If the customer is satisfied with these qualities, it is assumed the water is safe to drink. Many harmful contaminants in water cannot be detected due to taste or smell and many of the contaminants found in drinking water that have a detectable taste or odor are not harmful. Sources of taste and odor problems can be found in surface water and groundwater.

Source water protection involves the prevention of contaminants from entering the source. Surface water or groundwater may become contaminated by pollutants such as gasoline, industrial solvents or a wide variety of volatile organics. The removal of contaminants from surface water or groundwater is costly and may involve the use of aeration, powdered activated carbon, or both. If taste and odor must be controlled at the treatment plant, oxidation, aeration and adsorption can be effective in reducing taste and odor, and improved coagulation filtration.

Odor measurements

One of the most common methods for measuring odor in water is the threshold odor test. It involves a series of flasks presented to an observer, who is told that some of the samples contain odors and that the series is arranged in order of increasing concentrations. The observer is also given a known odor-free blank for reference during the test.

The observer compares the flasks in ascending order with the blank and then notes whether an odor is detected in any sample flask. Individuals vary in their reactions to certain types of odors. An odor stimulus that is agreeable to one may be disagreeable to another. Such differences complicate the attempts to predict the odor intensity of the mixtures.

Methane and hydrogen sulfide in groundwater

Methane gas from the decomposition of organic matter tastes like garlic and the biggest danger from the presence of methane is its explosiveness. It can be removed by aeration.

Hydrogen sulfide (H_2S) in water is a common problem that is therefore discussed separately from the other taste and odor problems. The most common method of removing hydrogen sulfide from water is by aeration. Carbon adsorption is also effective, but more expensive.

Taste and odor removal

Oxidation

In most cases, oxidation is the best method for controlling taste and odor problems. Oxidation can be carried out with the following chemicals: Potassium permanganate, most often used and is a very strong oxidant. According to the California Department of Health Services Water Treatment Plant Operation, a dosage range of 0.1 to 0.5 mg/l can control taste and odor problems.

Ozone is also effective oxidizing of taste and odor compounds. Ozone changes the characteristics of the taste and odor in addition to reducing the level of the odor-producing compound. Ozone dosages of 2 mg/l to 5 mg/l have been used. Several pilot studies have shown that the combination of ozone and hydrogen peroxide may be superior to the use of ozone alone. Chlorine dioxide or chlorine are also effective methods of taste and odor control, but use as a control chemical must be evaluated carefully due to the formation of THMs and chlorophenol when organics are present.

Aeration

Aeration is a practical solution for taste and odor control when the problem is caused by volatile compounds, such as hydrogen sulfide. It is generally not the best method for controlling taste and odors that are caused by algae. (See Aeration Chapter)

Adsorption

Adding powdered activated carbon to water or using of granular activated carbon (GAC) in the water filter can remove taste and odor. Powdered activated carbon (PAC) is the preferred method when the taste and odor is moderate and infrequent. Two basic types of PAC feed systems are dry storage and dry feeding. If the hourly feed rate is less than 150 pounds, the feed system should be use a solution tank. If the hourly feed rate exceeds 150 pounds, a slurry system should be considered. The powdered activated carbon dosage will vary from 1 to 50 mg/l. A dosage of 25 mg/l is considered by many industry experts to be the maximum dosage.

Granular activated carbon filters should be considered when moderate-to-severe taste and odor problems exist frequently. GAC is similar to normal filters; however, the bed contact time is very important. The contact time should range from 3-to-10 minutes for purposes of taste and odor control and the filter rate will range from 3 to 6 gpm/ft². When the GAC is exhausted, the total volume of the bed must be replaced with new or regenerated GAC, which can be created by heating and re-burning used GAC to destroy the material it removed.

Taste and odor removal from distribution

Taste and odors occurring in the distribution system are primarily the result of corrosion of pipe material and/or growth of iron bacteria, such as crenothrix and leptorix, the water main. If the water has high sulfates and is allowed to stand in dead ends, taste and odor problems may be compounded by sulfate-reducing bacteria. These problems can be rectified only by proper design of the system, such as eliminating dead ends and providing adequate means of flushing the system. Maintenance crews must keep the water lines clean by regularly flushing out deposits and the microorganisms that

accumulate within these deposits. Water treatment plants can also minimize taste and odor problems by maintaining an adequate residual of chlorine to combat the growth of bacteria in the system and by using anti-corrosion measures, either by adjusting the pH of the water or by adding corrosion inhibitors to the finished water.

Use of Copper Sulphate

Copper Sulphate is used to serve two purposes:

1. Removal of colour, odour and taste from water
2. Control of growth of algae, bacteria and aquatic weeds in the water reservoir.

Copper sulphate is generally available in powder form or in crystal form. It may be applied either directly in the distribution pipes or in open reservoirs. In the former case, solution of copper sulphate of required strength is prepared and fed to the water just ahead of the distribution system. The dose may vary from 0.3 to 0.6 p.p.m. for its application to the reservoirs, it is ground into fine powder and sprinkled on the water surface by means of boat. Alternatively, it may be applied by means of sacks of the crystals which are dragged through water by means of boats. The killing of algae may be troublesome because the taste and odours will be temporarily increased. Hence smaller amounts are often successful as prophylactic doses to prevent troubles.

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Adsorption phenomenon

Adsorption is a surface phenomenon with common mechanism for organic and inorganic pollutants removal. When a solution containing absorbable solute comes into contact with a solid with a highly porous surface structure, liquid–solid intermolecular forces of attraction cause some of the solute molecules from the solution to be concentrated or deposited at the solid surface. The solute retained (on the solid surface) in adsorption processes is called adsorbate, whereas, the solid on which it is retained is called as an adsorbent. This surface accumulation of adsorbate on adsorbent is called adsorption. This creation of an adsorbed phase having a composition different from that of the bulk fluid phase forms the basis of separation by adsorption technology.

In a bulk material, all the bonding requirements (be they ionic, covalent, or metallic) of the constituent atoms of the material are filled by other atoms in the material. However, atoms on the surface of the adsorbent are not wholly surrounded by other adsorbent atoms and therefore can attract adsorbates. The exact nature of the bonding depends on the details of the species involved, but the adsorption process is generally classified as physisorption (characteristic of weak Van Der Waals forces) or chemisorption (characteristic of covalent bonding). It may also occur due to

electrostatic attraction. As the adsorption progress, an equilibrium of adsorption of the solute between the solution and adsorbent is attained (where the adsorption of solute is from the bulk onto the adsorbent is minimum). The adsorption amount (q_e , mmol g⁻¹) of the molecules at the equilibrium step was determined according to the following equation:

Types of adsorbents

Different types of adsorbents are classified into natural adsorbents and synthetic adsorbents. Natural adsorbents include charcoal, clays, clay minerals, zeolites, and ores. These natural materials, in many instances are relatively cheap, abundant in supply and have significant potential for modification and ultimately enhancement of their adsorption capabilities. Synthetic adsorbents are adsorbents prepared from Agricultural products and wastes, house hold wastes, Industrial wastes, sewage sludge and polymeric adsorbents. Each adsorbent has its own characteristics such as porosity, pore structure and nature of its adsorbing surfaces. Many waste materials used include fruit wastes, coconut shell, scrap tyres, bark and other tannin-rich materials, sawdust, rice husk, petroleum wastes, fertilizer wastes, fly ash, sugar industry wastes blast furnace slag, chitosan and seafood processing wastes, seaweed and algae, peat moss, clays, red mud, zeolites, sediment and soil, ore minerals etc.

Activated carbons as adsorbent for organic pollutants consists in their adsorption a complex process and there still exists considerable difficulty. The main cause of this difficulty results from the large number of variables involved. These include, for example, electrostatic, dispersive and chemical interactions, intrinsic properties of the solute (for example solubility and ionization constant), intrinsic properties of the adsorbent (such pore size distribution), solution properties (in particular, pH) and the temperature of the system [12].

Activated carbons (AC) (both granular activated carbon (GAC) and powdered activated carbons (PAC)) are common adsorbents used for the removal of undesirable odor, color,

taste, and other organic and inorganic impurities from domestic and industrial waste water owing to their large surface area, micro porous structure nonpolar character and due to its economic viability. The major constituent of activated carbon is the carbon that accounts up to 95% of the mass weight. In addition, active carbons contain other hetero atoms such as hydrogen, nitrogen, sulfur, and oxygen. These are derived from the source raw material or become associated with the carbon during activation and other preparation procedures [13-14]. Putra et al. [15] investigated the removal of Amoxicillin (antibiotic) from pharmaceutical effluents using bentonite and activated carbon as adsorbents. The study was carried out at several pH values. Langmuir and Freundlich models were then employed to correlate the equilibria data on which both models fitted the data equally well. While chemisorption is the dominant adsorption mechanism on the bentonite, both physisorption and chemisorption played an important role for adsorption onto activated carbon.

Adsorption of methane on granular activated carbon (GAC) was studied. The results showed that with decreasing temperature or increasing methane uptake by GAC the adsorption efficacy decreased. Interactions between the methane molecules and the surface of carbon increase the density of adsorbed methane in respect to the density of compressed gas. The effect that the porosity and the surface chemistry of the activated carbons have on the adsorption of two VOC (benzene and toluene) at low concentration (200 ppm) was also studied. The results show that the volume of narrow micropores (size <0.7 nm) seems to govern the adsorption of VOC at low concentration, specially for benzene adsorption. AC with low content in oxygen surface groups has the best adsorption capacities. Among the AC tested, those prepared by chemical activation with hydroxides exhibit the higher adsorption capacities for VOC. The adsorption capacities achieved are higher than those previously shown in the literature for these conditions, especially for toluene. Adsorption capacities as high as 34 g benzene/100 g AC or 64 g toluene/100 g AC have been achieved [16].

Adsorption of dyes

Adsorption techniques are used as high quality treatment processes for the removal of dissolved organic pollutants, such as dyes, from industrial wastewater. Dyes consider as type of organic pollutants. The textile, pulp and paper industries are reported to utilize large quantities of a number of dyes, these pollutant may be found in wastewaters of many industries generating considerable amounts of colored wastewaters, toxic and even carcinogenic, posing serious hazard to aquatic living organisms. Dyes represent one of the problematic groups; they are emitted into wastewater from various industrial branches, mainly from the dye manufacturing and textile finishing and also from food coloring, cosmetics, paper and carpet industries. It is well known that the dye effluents from dyestuff manufacturing and textile industries, may exhibit toxic effects on microbial populations and can be toxic and/or carcinogenic to mammalian animal. Most dyes used in textile industries are stable to light and are not biologically degradable. Furthermore, they are resistant to aerobic digestion. [17].

On searching for economical and available starting materials; different low cost adsorbents were used for the removal of dyes. Activated rice husk was used as cheap adsorbent for color removal from wastewater [18]. Hamdaoui [19] reported that the maximum adsorption of basic dye, methylene blue, onto cedar sawdust and crushed brick was 60 and 40 mg L⁻¹, respectively. Wood-shaving bottom ash (WBA) was used for the removal of Red Reactive 141 (RR141), and azo reactive dyes. WBA/H₂O and WBA/H₂SO₄ adsorbents were made by treating WBA with water and 0.1 M H₂SO₄, respectively; to increase adsorption capacity. The effects of different parameters on adsorption (effect of contact time, initial pH of solution, dissolved metals and elution) were studied. The maximum dye adsorption capacities of WBA/H₂O and WBA/H₂SO₄ obtained from a Langmuir model at 30 oC were 24.3, 29.9, and 41.5 mg l⁻¹, respectively. In addition, WBA/H₂O and WBA/H₂SO₄ could reduce colour and high chemical oxygen demand (COD) of real textile wastewater [20]. Beer brewery waste has been shown to be a low-cost adsorbent for the removal of methylene blue dye from the aqueous solution. The results of preliminary adsorption kinetics showed that the diatomite waste could be

directly used as a potential adsorbent for removal of methylene blue on the basis of its adsorption–biosorption mechanisms .

Sewage sludge was applied for the preparation of activated carbon adsorbent. Activated carbon adsorbent prepared from sewage sludge has been identified as a potentially attractive material for wastewater. Research studies have been conducted to demonstrate the uses of] produced activated carbon by chemical activation and pyrolysis of sewage sludge. The properties of this type of material were studied by liquid-phase adsorption using crystal violet, indigo carmine and phenol as adsorbates. Three prepared activated carbon, of different particle sizes, were used ASS-g1 (particle diameter < 0.12 mm), ASS-g2 (0.12 < particle diameter < 0.5 mm) and PSS-g2 (0.12 < particle diameter < 0.5 mm). Crystal violet dye adsorption has been higher (Q_{\max} 263.2 mg/g using AAS, 270 mg/g using ASS and 184 mg/g using PPS) than indigo carmine (Q_{\max} 60.04 mg/g using AAS, 54.8 mg/g using ASS and 30.8 mg/g using PPS). They proposed that activated carbons made from sewage sludge show promise for the removal of organic pollutants from aqueous streams.

Defluoridation – by nalgonda technique

Defluoridation is a 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 1 mg/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, alkalinity 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.

Distribution system

Introduction: 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. The cost of distribution is about 40 to 70% of the total cost of the entire scheme. The efficiency of the system depends upon proper planning, execution and maintenance. Ultimate aim is to supply potable water to all the consumers whenever required in sufficient quantity with required pressure with least loss and without any leakage.

Requirement of a distribution system:

1. The system should convey the treated water up to consumers with the same degree of purity
2. The system should be economical and easy to maintain and operate

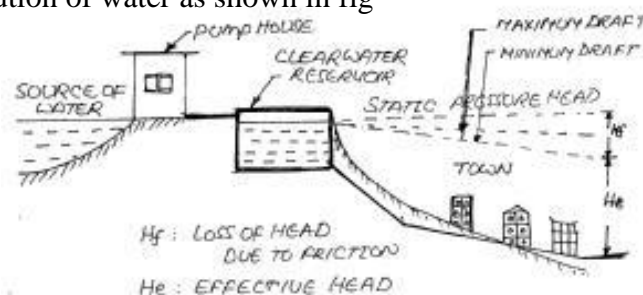
3. The diameter of pipes should be designed to meet the fire demand
4. It should safe against any future pollution. As per as possible should not be laid below sewer lines.
5. Water should be supplied without interruption even when repairs are undertaken
6. The system should be so designed that the supply should meet maximum hourly demand. A peak factor 2.5 is recommended for the towns of population 0.5. to 2 lakhs. For larger population a factor of 2.0 will be adequate.

System of distribution:

For efficient distribution it is required that the water should reach to every consumer with required rate of flow. Therefore, some pressure in pipeline is necessary, which should force the water to reach at every place. Depending upon the methods of distribution, the distribution system is classified as the follows:

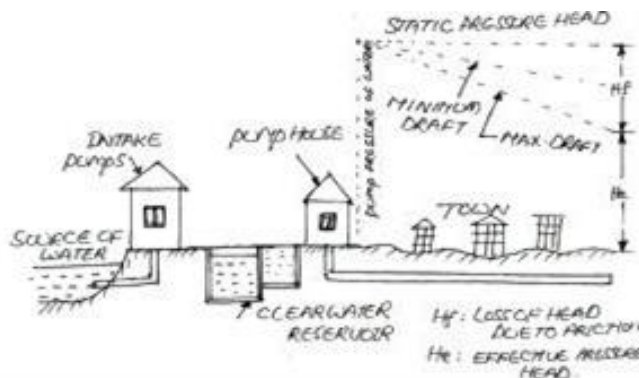
1. Gravity system
2. Pumping system
3. Dual system or combined gravity and pumping system

Gravity system: When some ground sufficiently high above the city area is available , this can be best utilized for distribution system in maintaining pressure in water mains . This method is also much suitable when the source of supply such as lake, river or impounding reservoir is at sufficiently higher than city. The water flows in the mains due to gravitational forces. As no pumping is required therefore it is the most reliable system for the distribution of water as shown in fig



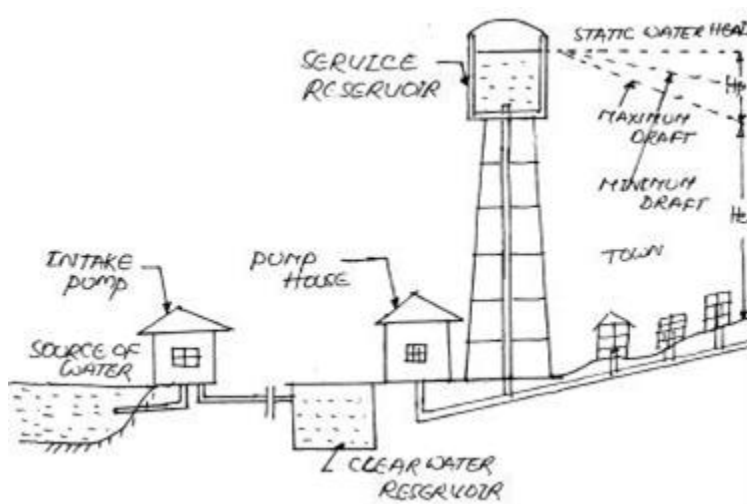
Pumping system:

Constant pressure can be maintained in the system by direct pumping into mains. Rate of flow cannot be varied easily according to demand unless number of pumps are operated in addition to stand by ones. Supply can be effected during power failure and breakdown of pumps. Hence diesel pumps also in addition to electrical pumps as stand by to be maintained. During fires, the water can be pumped in required quantity by the stand by units.



Combined pumping and gravity system:

This is also known as dual system. The pump is connected to the mains as well as elevated reservoir. In the beginning when demand is small the water is stored in the elevated reservoir, but when demand increases the rate of pumping, the flow in the distribution system comes from the both the pumping station as well as elevated reservoir. 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, because it requires uniform rate of pumping but meets low as well as maximum demand. The water stored in the elevated reservoir meets the requirements of demand during breakdown of pumps and for fire fighting



The water may be supplied to the consumers by either of the two systems.

1. 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 fire fighting 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.

2. 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:

1. Pipelines are likely to rust faster due to alternate wetting and drying. This increases the maintenance cost.

2. There is also pollution of water by ingress of polluted water through leaks during non-flow periods.
3. 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.

In spite of number of disadvantages, this system is usually adopted in most of the cities and towns of India. In this system water can be supplied in the high level localities with adequate pressure by dividing the city in zones. The repair work can be easily done in the non-supply hours.

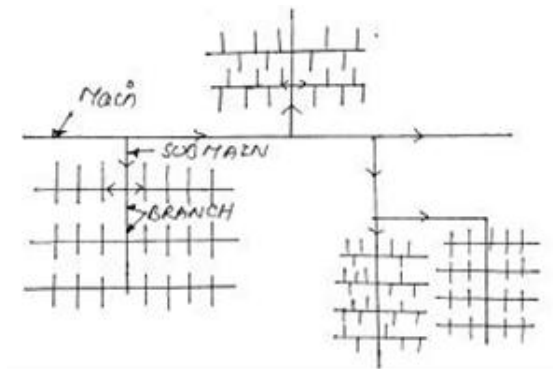
Layouts of distribution system:

Generally in practice there are four different systems of distribution which are used. They are:

1. Dead End or Tree system
2. Grid Iron system
3. Circular or Ring system
4. Radial system

Dead end or tree system:

This system is suitable for irregular developed towns or cities. In this system water flows in one direction only into submains and branches. The diameter of pipe decreases at every tree branch.



Advantages

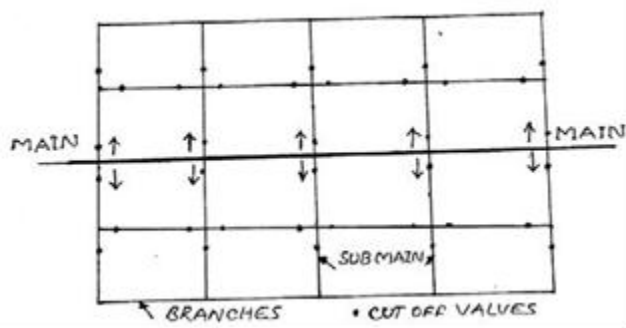
1. Discharge and pressure at any point in the distribution system is calculated easily
2. The valves required in this system of layout are comparatively less in number.
3. The diameter of pipes used are smaller and hence the system is cheap and economical
4. The laying of water pipes is used are simple.

Disadvantages

1. There is stagnant water at dead ends of pipes causing contamination.
2. During repairs of pipes or valves at any point the entire down stream end are deprived of supply
3. The water available for fire fighting will be limited in quantity

Grid iron system

From the mains water enters the branches at all Junctions in either directions into submains of equal diameters. At any point in the line the pressure is balanced from two directions because of interconnected network of pipes.



Advantages

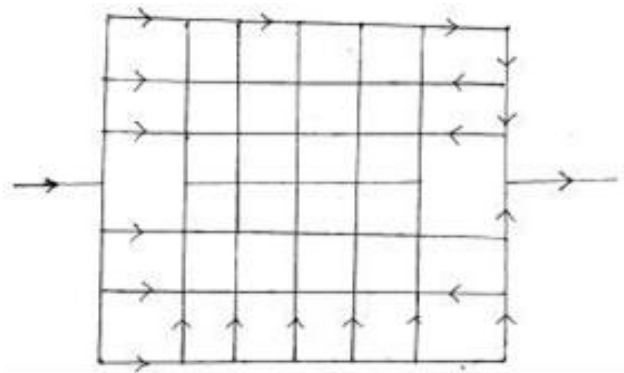
1. In the case of repairs a very small portion of distribution are a will be affected
2. Every point receives supply from two directions and with higher pressure
3. Additional water from the other branches are available for fire fighting
4. There is free circulation of water and hence it is not liable for pollution due to stagnation.

Disadvantages

1. More length of pipes and number of valves are needed and hence there is increased cost of construction
2. Calculation of sizes of pipes and working out pressures at various points in the distribution system is laborious , complicated and difficult.

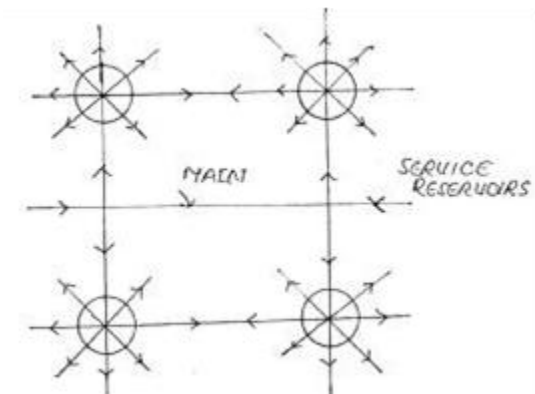
Circular or ring system

Supply to the inner pipes is from the mains around the boundary. It has the same advantages as the grid-Iron system. Smaller diameter pipes are needed. The advantages and disadvantages are same as that of grid-Iron system.



Radial system:

This is a zoned system. Water is pumped to the distribution reservoirs and from the reservoirs it flows by gravity to the tree system of pipes. The pressure calculations are easy in this system. Layout of roads need to be radial to eliminate loss of head in bends. This is most economical system also if combined pumping and gravity flow is adopted.



Distribution reservoirs provide storage for:

- i. Operating storage: to meet demands in excess of the max daily flow, required by the distribution systems at peak periods. Since water treatment plant, water intake structures

and pumping stations are designed for max daily flow, demands on the system in excess of this rate must be met by storage.

ii. Fire storage: storage should provide fire flows:

-12 hrs in large communities

- > 2hrs in small communities

iii. Emergency storage: calculated by multiplying the max daily demand by a factor, K:

K = 0.50 for Turkey

K = 1.0 for Germany

K = 2.0 for Germany long transmission line

K = 3.0 for USA

To provide operating pressure. The service reservoir should be located such that it should provide the required pressure at every point in the distribution system.

Types of Reservoirs:

i. Surface reservoirs (underground type)

ii. Elevated reservoirs (water tower)

According to plan:

In general, service reservoirs can be:

- rectangular or square

- circular

Water towers can be made of concrete or steel. The most suitable form for concrete towers is a cylinder with an intze shaped bottom or with a flat bottom. Steel tanks may have a spherical or dome shaped bottom

1. The lowest water level in the tank is determined according to the pressure requirement in the distribution system, which may vary from 15m to 50m of water, depending on the type of community and the pressure requirement in the different areas of a city.
2. In order to keep pumping cost minimum, the depth of water in the tank is generally kept small.
3. Due to structural considerations, the depth is kept equal to the diameter. For circular tanks, the following formulae for the diameter can be used:

Water tower volume (m ³)	Diameter of the water tower (m)
100 – 500	$5 + \text{Volume}/100$
500 - 1000	$8 + \text{Volume}/250$

Design of reservoirs

The capacity of reservoirs is governed by a number of factors which are covered in IS: 5477 (Parts 1 to 4). From the point of view of sediment deposition, the following points may be given due consideration:

- a) The sediment yield which depends on the topographical, geological and geomorphological set up, meteorological factors, land use/land cover, intercepting tanks, etc;
- b) Sediment delivery characteristics of the channel system;
- c) The efficiency of the reservoir as sediment trap;
- d) The ratio of capacity of reservoir to the inflow;
- e) Configuration of reservoir;
- f) Method of operation of reservoir;
- g) Provisions for silt exclusion.

The rate of sediment delivery increases with the volume of discharge. The percentage of sediment trapped by a reservoir with a given drainage area increases with the capacity. In some cases an increased capacity will however, result in greater loss of water due to evaporation. However, with the progress of sedimentation, there is decrease of storage capacity which in turn lowers the trap efficiency of the reservoir.

The capacity of the reservoir and the size and characteristics of the reservoir and its drainage area are the most important factors governing the annual rate of accumulation of sediment. Periodical reservoir sedimentation surveys provide guidance on the rate of sedimentation. In the absence of observed data for the reservoir concerned, data from other reservoirs of similar capacity and catchment characteristics may be adopted.

Silting takes place not only in the dead storage but also in the live storage space in the reservoir. The practice for design of reservoir is to use the observed suspended sediment data available from key hydrological networks and also the data available from hydrographic surveys of other reservoirs in the same region.

UNIT-8

MISCELLANEOUS

Water main appurtenances

Setting of valve and fittings – Valves and fittings installed in trenches shall be located where indicated by the drawings and as directed by the Engineer. Valves, fittings, plugs, and caps shall be set and joined to pipe in the manner specified for cleaning, laying and joining pipe. Fittings will be blocked using only cast-in-place concrete blocks unless otherwise approved by the Engineer. No wood blocking shall be allowed. The valve box shall not transmit shock or stress to the valve and shall be centered and plumb over the operating nut of the valve, with the box cover flush with the

surface of the finished pavement or such other level as may be directed by the Engineer.

Setting of fire hydrants

Fire hydrants shall be in accordance with the City of Kearney's Standard Fire Hydrant Setting Detail. Hydrants are to be set at such cover. All hydrants shall stand plumb and shall have their steamer nozzle facing the curb or street. Around the base of the hydrant 10 cubic feet (0.28 Cu. M.) of crushed rock or gravel shall be placed so that the hydrant will completely drain when closed. Backfill around the hydrant shall be firmly tamped to the surface of the finished grade and to a distance of 5 feet (1.52 m) around the hydrant. Before placing any hydrant, care shall be taken to see that all foreign material is removed from within the body or barrel. The stuffing boxes shall be tightened and the hydrant or valve opened and closed to see that all parts are in working condition. Hydrants shall be painted two coats

of approved paint, and colors as selected by the Owner, to the ground line and black below the ground line.

Installation of bracing, supporting and anchoring –

Blocking, bracing, anchoring, or other acceptable means for the prevention of movement, shall be installed. All blocking, bracing, supporting and anchoring shall be in accordance with the City of Kearney's Standard Blocking Detail and the City of Kearney's Standard Fire Hydrant Detail with the use of concrete as specified in section #12 Portland Cement Concrete Paving of this standard specification.

A. Anchorage for fire hydrants – The bowl of each hydrant shall be well braced against the undisturbed natural earth at the end of the trench with a concrete anchor placed behind and a precast block beneath the bowl. The fire hydrant valve shall be tied to the fire hydrant tee with anchor pipe or with two (2) $\frac{3}{4}$ inch (1.91 cm) or larger all-thread rods as shown on the City of Kearney's Standard Fire Hydrant Detail, Mega Lugs / retaining glands will be allowed. Whenever a fire hydrant is the means of terminating a water main (such as in a cul-desac); the tie rods and concrete reverse anchors will be required for both the fire hydrant valve (which in this case is also a line valve on the main) and the fire hydrant lateral of the branch feeder pipe connected directly to the fire hydrant. Additional concrete anchors shall be as directed by the Engineer.

B. Anchorage for plugs, caps, tees, taps and bends – Plugs, caps, tees and bends shall be provided with reaction backing in accordance with the City of Kearney's Standard Blocking Detail. Reverse concrete anchor and tie backs are acceptable. Blocking shall be placed between solid ground and the fitting to be anchored; the area of bearing on the pipe and on the ground, in each instance, shall be shown or directed by the Engineer. No wood or precast blocks shall be used as a permanent blocking. Temporary blocking may be used as directed by the Engineer. Blocking will be required regardless of whether a tapping tee or tapping saddle is used. Such blocking will in all cases be sized and placed in a manner that will adequately transfer thrust reaction to solid undisturbed ground or the equivalent thereof.

C. Forming for concrete thrust blocks and anchors – All forming for concrete thrust blocks and anchors will be done by bulk heading around the shape of thrust block or anchor with burlap or reinforced paper sacks which have been filled with sand or earth, or other Engineer approved forming method. Filled sacks used to form concrete blocks will be left in place in the trench and backfill will be placed around and over them in the usual manner. Any bolt head or fitting must be left accessible when pouring concrete about them. If the fitting is to be covered completely upon direction of the Engineer, then the joint must be wrapped with suitable polyethylene. Minimum curing time for concrete anchors regardless of additives shall be thirty-six (36) hours for anchors containing 2 cubic yards (1.53 cu. M) or less, forty-eight (48) hours for anchors containing more than 2 cubic yards (1.53 cu. M) but less than 6 cubic yards (4.59 cu. M) and seventy-two (72) hours for anchors containing more than 6 cubic yards (4.59 cu. M) but less than 12 cubic yards (9.17 cu. M). Anchors containing more than 12 cubic yards (9.17 cu. M) will be cured as directed by the Engineer. Curing time for anchors having flanged rods or other accessories embedded in them for the purpose of tying pipe and/or fittings directly to the anchor will require approximately 25% additional curing time

Understand the various appurtenances in a distribution system

The various devices fixed along the water distribution system are known as appurtenances.

The necessity of the various appurtenances in distribution system are 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

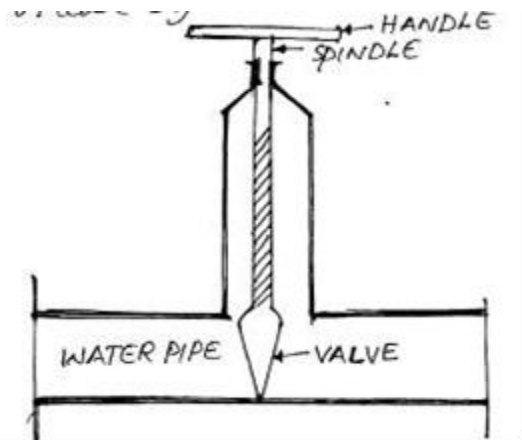
In water works practice, to control the flow of water, to regulate pressure, to release or to admit air, prevent flow of water in opposite direction valves are required.

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

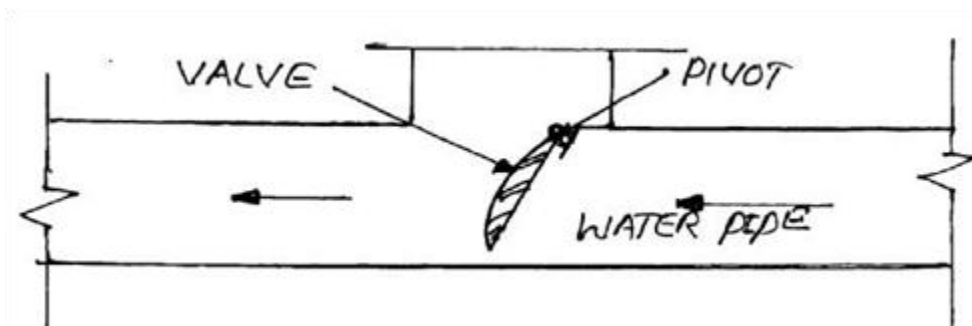
Sluice valves

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 divided into blocks by providing these valves at appropriate places. They are provided in straight pipeline at 150-200m intervals. When two pipes lines intersect, 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. The swing type of reflux valve as shown in fig is widely used in practice. 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 equipments will be saved from damage



Air valves :These are automatic valves and are of two types namely

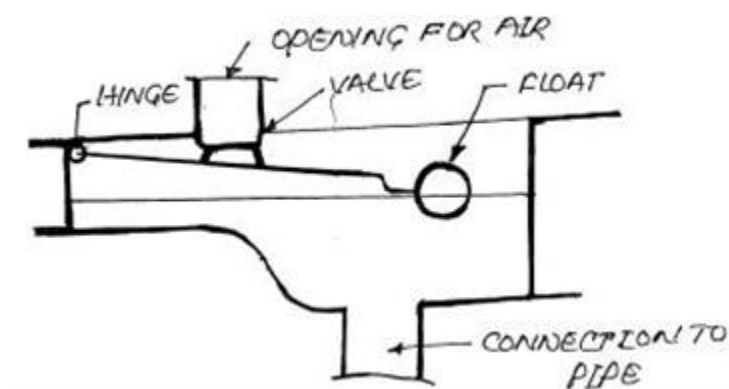
1. Air inlet valves
2. Air relief valves

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 air lock. 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 valve 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 apart along the roads and also at junction roads. They are of two types namely.

1. Flush Hydrants. 2. Post Hydrants

1. Flush Hydrants

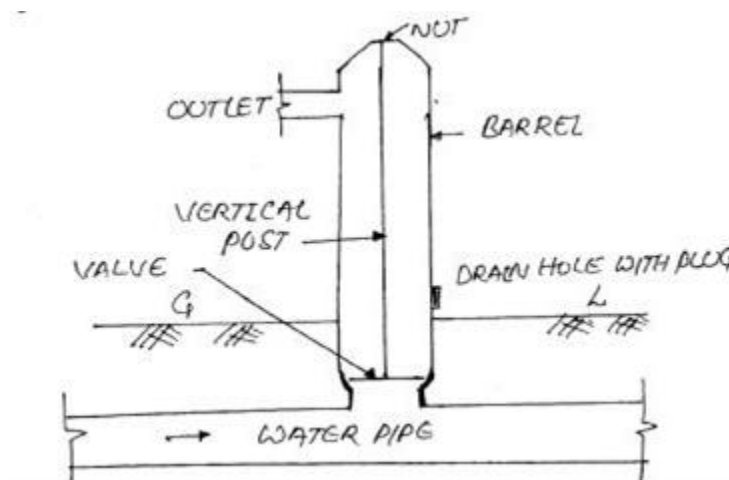
The flush hydrants is kept in under ground chamber flush with footpath covered by C.I. cover carrying a sign board “F-H”.

3. Post Hydrants

The post hydrant remain projected 60 to 90cm above ground level as shown in fig 7.4. They have long stem with screw and nut to regulate the flow. In case of fire accident, the fire fighting 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



Pipe fittings

In addition to the pipes, valves, tapes, various types of pipe fittings such as unions, caps, plugs, flanges, nipples, crosses, tees, elbows, bends etc are used during laying of distribution pipes. The common pipe fittings are shown in

