Environmental Engineering and Disaster Management (Elective)

VII Sem.

Water Supply System 1

Important Questions

Part-A

Q.1 ***Write the Kuichling's formula for fire demand.***

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

Where, Q = fire demands in litre per minutes

P = population in thousands

Q.2 ***What is per capita demand.***

Ans. Per Capita Demand (q) : This is the annual amount of daily water required by one person, and includes the domestic use, industrial and commercial use, public use, wastes, thefts etc.

Per capita demand (q) in litres per day per head

= Total yearly water requirement of the city in litres /(365 × Designs of population).

Q.3 ***What do you mean by design period.***

Ans. Design Period : The future period or the number of years for which a provision is made in designing the capacities of various components of the water supply scheme is known as design period.

Q.4 ***What do you mean by corrosion in pipes.***

Ans. Corrosion in Pipes : When water flows through a metal pipe (such as a cast iron or a steel pipe), it attacks and disintegrates the surface of the pipe. The material of the pipe thus gets dissolved and rusted, thereby reducing the life and carrying capacity of the pipe. This phenomenon is known as corrosion. The corrosion of pipes reduces their lives and carrying capacities, it also imparts colour and odors to the flowing water.

Q.5 ***What is coincident draft?***

Ans. Coincident Draft : For general community purposes, the total draft is not taken as the sum of maximum hourly demand and fire-demand, but is taken as sum of maximum daily demand and fire demand or the maximum hourly demand, which every is more. The maximum daily demand (i.e., 1.8 × average daily demand) when added to the fire demand is known as the coincident draft.

Part-B

Q.6 ***What is the importance of public water supply system in the present day civil life?***

Ans. Importance of Public Water Supply System in the Present day Civil Life : Water is a chemical compound and may occur in a liquid form or in a solid form or in a gaseous form. All these three forms of water are extremely useful to man, providing him the luxuries and comforts, in addition to fulfilling his basic necessities of life. Everyone of us knows how important and precious the water is. Whenever there is no water in our taps, we become helpless. No life can exist without water, since water is as essential for life as air is. It has been estimated that two-third of human body is constituted of water. Water is absolutely essential not only for survival of human beings, but also for animals, plants and all other living beings. Further, it is necessary that the water required for their needs must be good, and it should not contain unwanted impurities or harmful chemical compounds or bacteria in it. Therefore, in order to ensure the availability of sufficient quantity of good quality water, it becomes almost imperative in a modern society, to plan and build suitable water supply schemes, which may provide potable water to the various sections of community in accordance with their demands and requirements. The provision of such a scheme shall ensure a constant and a reliable water supply to that section of the people for which it has been designed. Such a scheme shall not only help in supplying safe wholesome water to the people for drinking, cooking, bathing, washing, etc. so as to keep the diseases away and thereby promoting better health; but would also help in supplying water for fountains, gardens, etc. and thus helping in maintaining better sanitation and beautification of surroundings, thereby reducing environmental pollution. Besides promoting overall hygiene and public health, it shall ensure safety against fire by supplying sufficient quantity of water to extinguish it. The existence of such a water supply scheme shall further help in attracting industries (since industries require large amounts of water) and thereby helping in industrialisation and modernisation of the society, consequently reducing unemployment and ensuring better living standards. Such schemes shall, therefore, help in promoting wealth and welfare of the entire humanity as a whole.

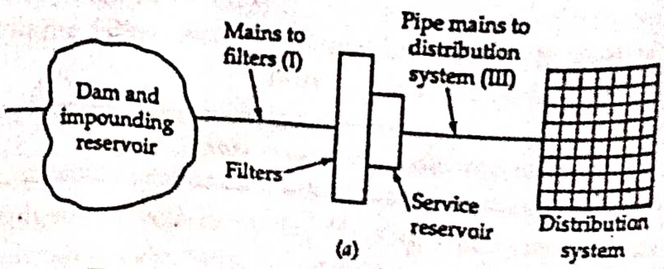
Q.7 ***What is the planning of modern water supply schemes?***

Ans. Planning of Modern Water Supply Schemes : In planning a water supply scheme, it is essential, to first of all, search a source of water in the vicinity of the town or the city for which the scheme is to be designed. Sometimes, the water may be available nearby, and sometimes it may be far away. Further it may be an underground well, or it may be a river, stream or a lake. It is, therefore, necessary to seek out all the possible sources and evaluate each in terms of quantity, quality and cost and then to take a final decision regarding the utilization of a particular source or sources depending upon the availability of water in those sources and the water demand of the town or the city.

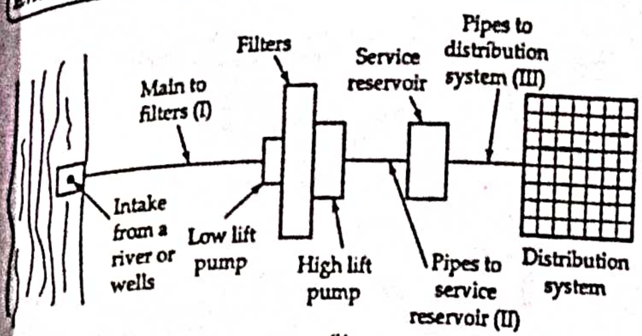
Suitable systems should then be designed for collecting, transporting, and treating this water. The treated water is finally distributed to the residents and industries depending upon their requirements, through a network of distribution system. The essential elements of a public water supply scheme may, therefore, consist of Intakes and reservoirs; a water treatment plant having screening, sedimentation, filtration, disinfection units, etc.; elevated tanks and stand, pipes which provide storage to meet peak demands occurring for limited periods; valves which control the flow of water in the pipe system; hydrants which provide a connection with the water in the mains for fighting fires, flushing streets, etc.; mains, sub-mains and branch lines which carry the water to streets; services which carry the water to the individual.

Q.8 ***Draw the flow diagram of a typical water supply scheme using an impounded reservoir as the source of supply and show therein the different works involved.***

Ans. Two simple sketches showing the possible layouts of water supply schemes are given in following fig. In fig. (a), a dam and a reservoir are used, and thus, there is generally no need of pumps; while fig.(b), a well or a river is used as the source, needing pumping equipment.



(a)



(b)

Fig. : Layouts of water supply schemes

The various units involved in such schemes should be designed not only to serve the average daily demand but to serve the maximum demand as and when it arises and also the variations in the demand. The following recommendations may be adopted for designing the capacities of different components.

(1) The sources of supply such as wells, etc., may be designed for maximum daily consumption or sometimes for average daily consumption.

(2) The pipe mains (type I and II, Fig.(b)) taking the water from the source upto the service reservoir may be designed for maximum daily consumption.

(3) The filter and other units at water treatment plant may also be designed for maximum daily draft. Sometimes, an additional provision for reserve is also made for break-downs and repairs. Therefore, they may be designed for twice the average daily instead of 1.8 times the average daily.

(4) The pumps lifting the water may be designed for maximum daily draft plus some additional reserve for break-downs and repairs; say, for twice the average daily instead of 1.8 times the average daily.

Note : When the pumps do not work for all the 24 hours, such as in small town supplies, the design draft should be multiplied by

$$\left[\frac{24}{\text{No. of hours in the day for which the pumps are running}}\right]$$

(5) The distribution system (including the pipes carrying water from service reservoir to distribution system (i.e. Type III, Fig.(b)) should be designed for maximum hourly draft of the maximum day or coincident draft with fire, whichever is more. Generally, no provision for reserve is made.

(6) The service reservoir is designed to take care of the hourly fluctuations, fire demands, emergency reserve, and the provision required when pumps have to pump the entire-day's water in fewer hours than 24 hours. Only two hours storage may be considered for fire allowance as sufficient. Ordinarily, the required storage approximates a day's consumption.

Q.9 ***What is the per capita demand and also write per capita demands for an average Indian city.***

Ans. The Per Capita Demand (q) : It is the annual average amount of daily water required by one person, and includes the domestic use, industrial and commercial use, public use, wastes, thefts, etc. It may, therefore, be expressed as

Per capita demand (q) in litres per day per head

$$= \frac{\text{Total yearly water requirement of the city in litres}}{365 \times \text{Design population}} \quad \text{...(i)}$$

Total yearly water requirement of the city can, therefore, be worked out by using equation (i), provided the per capita demand is known or assumed. The per capita demand depends upon various factors and will vary according to the living conditions of the consumers and also with the extent and type of industries developed or likely to be developed in that region. For an average Indian city, as per recommendations of I.S. code, the per capita demand (q) may be taken as given table.

Table : Break up of per capita demand (q) for an average Indian city

Use	Demand in l/h/d
(i) Domestic use	200
(ii) Industrial use	50
(iii) Commercial use	20
(iv) Civic or public use	10
(v) Wastes and thefts, etc.	55
	Total = 335 = Per capita demand (q)

This figure of 335 litres/head/day when multiplied by the prospective population at the end of the design period, shall give the annual average water requirement of the city per day. When multiplied by 365, it will give the volume of the yearly water requirement in litres.

Q.10 ***Explain intakes for collecting surfaces water.***

Ans. Intakes for Collecting Surface Water : Whenever the water is withdrawn from surface source such as a lake or a river and the entrance of the withdrawal conduit is not an integral part of a dam or any other related structure, then an intake structure must be constructed at the entrance of the conduit.

- The intake must be located in the pure zone of source so that the best possible quality of water is withdrawn from the source, thereby reducing the load on the treatment plant.
- The intake should never be located near the navigation channels, as otherwise, there are chances of intake water getting polluted due to the discharge of refuse and waste from ships and boats.
- The intake must be located at a place from where it can draw water even during the driest period of the year. Thus, the intake must be located in deep waters, sufficiently away from the shore line.
- In meandering rivers, the intakes should not be located on curves or at least on sharp curves. If they have to be located on curves, it will be better to locate them on concave blanks. Although scouring tendencies will be more on the concave side, yet at least, the water will remain available on this side, whereas on a convex bank water may not remain available due to silting and consequent blockage.

Types of Intake

(1) Submerged Intake : A simple submerged intake consist of a simple concrete block or a rock filled timber crib supporting the intake end (with a bell – mouth) of the withdrawl pipe as shown in figure below :

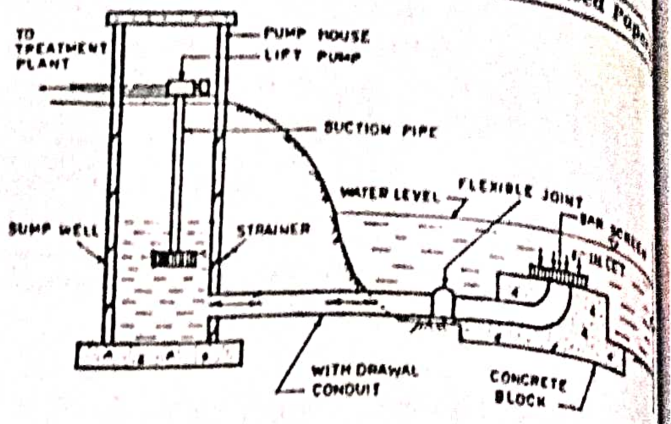


Fig. 1 : Submerged intake

This type of intake is cheap and there is no obstruction to navigation.

(2) Tower Type Intakes

- They are also known as exposed intakes
- They are tower like structures.
- Used for tapping water from reservoirs, lakes and most commonly from rivers.
- In case of reservoirs, sometimes an exposed intake is provided and it is known as "gate house".
- Depending upon the water tapping source they are classified as river intake or reservoir intakes.

River Intake are Classified into Four Types

(a) Intake Well

- They are circular masonry or concrete tower of two to six meter diameter.
- The water flows into the intake well through the penstocks located at different level.

(b) Pipe Intake : When a small quantity of water is to be drawn the pipe intakes are economical.

(c) Weir Intakes : Water is drawn from the weir through a channel into a sump well.

(d) Floating Pantoon Intake : In case of wide rivers with great fluctuations in flow, weir intake are not economical. In such case floating intakes with a strained bell mouth are provided.

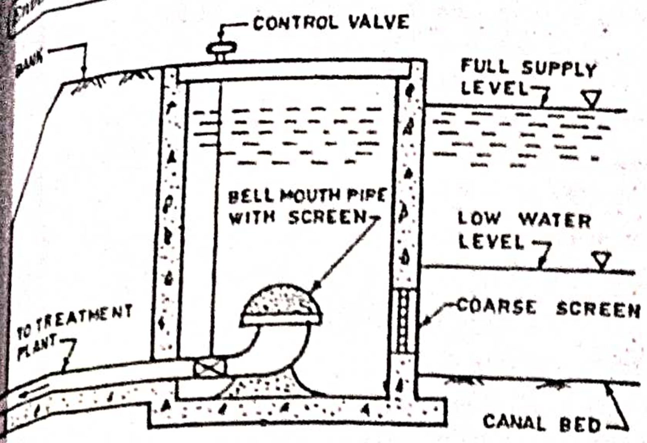


Fig. 2 : A typical canal intake

(3) Canal Intakes

- It consists of a pipe intake placed at the canal bed and enclosed in a concrete well.
- The end of the pipe is provided with a bell mouth fine screens.
- They are similar to submerged intakes.

(4) Lake Intakes

- Lake intakes are also of tower type intakes.
- Special precaution is to be taken while locating the intakes so that polluted shores water may not enter into the intake conduit.
- To avoid entry of sediments, wet wells may be provided with a blow off valve.

Q.11 ***What are the factors affecting water requirements?***

Ans. 1. Habits of Population : For high value premises, the consumption rate of water will be more due to better standard of living of persons. For middle-class premises, the consumption rate will be average while in case of slum areas, it will be much lower. A single water tap may be serving several families in low value areas.

2. Industries : The presence or absence of industries in a city may also affect its rate demand. As there is no direct relation between the water requirement for industries and population, it is necessary to calculate carefully present and future requirements of industries.

3. Policy of Metering : The quantity of water supplied to a building is recorded by a water meter and the consumer is then charged accordingly. The installation of meters reduces the rate of consumption. But the fact of adopting policy of metering is a disputable one as seen from the following arguments which are advanced for and against it.

PART-C

Q.12 ***What are the various types of water demands? Explain in detail.***

Ans. Various Types of Water Demands : While planning a water supply scheme, it is necessary to find out not only the total yearly water demand but also to assess the required average rates of flow (or draft) and the variations in these rates. The following quantities are, therefore, generally assessed and recorded:

(i) Total annual volume (V) in liters or million liters.

(ii) Annual average rate of draft in the per day, i.e. V/365.

(iii) Annual average rate of draft in liters per day per person (i.e. liters per capita per day or lpcd), called per capita demand (q).

(iv) Average rate of draft in liters per day per service, i.e.

$$\frac{V}{365} \times \frac{1}{\text{No.of service}}$$

(v) Fluctuations in flows expressed in terms of percentage ratios of maximum or minimum yearly, monthly, daily or hourly rates to their corresponding average values.

It is very difficult to precisely assess the quantity of water demanded by the public, since there are many variable factors affecting water consumption. Certain thumb rules and empirical formulas are, therefore, generally used to assess this quantity, which may give fairly accurate results. The use of a particular method or a formula for a particular case has, therefore, to be decided by the intelligence and foresightedness of the designer.

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

(i) Domestic water demand;
(ii) Industrial water demand;
(iii) Institution and commercial water demand;
(iv) Demand for public uses;
(v) Fire demand;
(vi) Water required to compensate losses in wastes and thefts.

In order to estimate, as correctly as possible, the total water demand of a particular section of the community, all these demands must be considered and suitable provision made, depending upon the needs of those people for whom the water supply scheme is to be designed. These demands are described below :

1. Domestic Water Demand : This includes the water required in residential buildings for drinking, cooking, bathing, lawn sprinkling, gardening, sanitary purposes, etc. The amount of domestic water consumption per person shall vary according to the living conditions of the consumers. As per IS : 1172-1993, the minimum domestic consumption for a town or a city with full flushing system should be taken at 200 *l*/h/d; although it can be reduced to 135 *l*/h/d for economically weaker sections and LIG colonies depending upon prevailing conditions. The break up of 200 *l*/h/d and 135 *l*/h/d are given in table 1 and table 2, respectively.

Table 1 : Minimum Domestic Water Consumption (Annual Average) for Indian Towns and Cities with Full Flushing Systems as per IS : 1172-1993

Use	Consumption in liters per head per day (*l*/h/d)
Drinking	5
Cooking	5
Bathing	75
Washing of clothes	25
Washing of utensils	15
Washing and cleaning of houses and residences	15
Lawn watering and gardening	15
Flushing of water closets, etc.	45
Total	200

Table 2 : Minimum Domestic Water Consumption (Annual Average) for Weaker Sections and LIG Colonies in Small Indian Towns and Cities

Use	Consumption in *l*/h/d
Drinking	5
Cooking	5
Bathing	55
Washing of clothes	20
Washing of utensils	10
Washing and cleaning of houses and residences	10
Flushing of water closets, etc.	30
Total	135

The IS code infact lays down a limit on domestic water consumption between 135-225 *l*/h/d (with 200 *l*/h/d being minimum under ordinary circumstances with flushing system.

In a developed and an effluent country like U.S.A, this figure usually goes as high as 340 *l*/h/d. This is because more water is consumed in rich living in air-cooling, bathing in bath-tubs, dish washing of utensils, car washing, home laundries, garbage grinders, etc.

The total domestic water consumption usually amounts to 50-60% of the total water consumption.

The total domestic water demand shall be equal to the total design population multiplied by per capita domestic consumption.

2. Industrial Water Demand : The 'industrial water demand', represents the water demand of industries, which are either existing or are likely to be started in future, in the city for which water supply is being planned. This quantity will thus vary with the number and types of industries present in the city. The ordinary per capita consumption on account of industrial needs of a city is generally taken as 50 litres/person/day, which may suffice only to meet the water demand of small scattered industries, without catering to larger industries. Separate provision will have to be made to meet the water demand of such specific industries. Their requirement will have to be approximated on the basis of the nature and magnitude of each industry, and the quantity of water required per unit of production. The potential for industrial expansion should also be investigated, so that the availability of water supply may attract such industries, and add to economic prosperity of the community. Some of the industries may develop their own water supplies, and may place a very little or virtually no demand on the public supplies.

In industrial cities, the per capita water requirement may finally be computed to be as high as 450 litres/person/day or so, as compared to the normal industrial requirement of 50 litres/person/day.

The approximate quantities of water required by different industries per unit of their production, are shown in table 3, which may serve as a rough guide in estimating the total industrial demand.

3. Institutional and Commercial Water Demand : The water requirements of institutions, such as hospitals, hotels, restaurants, schools and colleges, railway stations, offices, factories, etc. should also be assessed and provided for, in addition to domestic and industrial water demands, discussed above. This quantity will certainly vary with the nature of the city and with the number and types of commercial establishments and institutions present in it. On an average, a per capita demand of 20 litres/ head/ day is usually considered to be enough to meet such commercial and institutional water requirements, although of course, this demand may be as high as 50 l/h/d for highly commercialized cities. The individual approximate water requirements of such institutions/ commercial units, are shown in table 4, and these values may be used for better assessment of their water needs.

Table 3 : Water Demand of Certain Important Industries

S. No.	Name of industry and product	Unit of production or raw material used	Approximate quantity of water required per unit of production / raw material in kilo liters
1.	Automobiles	Vehicle	40
2.	Distillery (Alcohol)	Kilo liter	122-170
3.	Fertilizer	Tonne	80-200
4.	Leather (Tanned)	Tonne	40
5.	Paper	Tonne	200-400
6.	Special Quality Paper	Tonne	400-1000
7.	Straw board	Tonne	75-100
8.	Petroleum Refinery	Tonne (crude)	1-2
9.	Steel	Tonne	200-250
10.	Sugar	Tonne (crusted cane)	1-2
11.	Textile	Tonne (goods)	80-140

Table 4 : Water Requirements of Individual Institutions and Commercial Establishments

S. No.	Type of Institution or Commercial Establishment	Average water consumption in liters / head /day
1.	Offices	45-90
2.	Factories (a) Where bath rooms are provided (b) Where no bath rooms are provided	 45-90 30-60
3.	Schools (a) Day scholars (b) Residential	 45-90 135-225
4.	Hostels	135-180
5.	Hotels	180 (per bed)
6.	Restaurants	70(per bed)
7.	Hospitals (including laundry) (a) Number of beds not exceeding 100 (b) Number of beds exceeding 100	340(per bed) 450(per bed)
8.	Nurses homes and medical quarters	135-225
9.	Railway stations (a) Junctions and intermediate stations where mail and express trains stop (b) Intermediate stations where mail and express trains do not stop (c) Terminal railway stations	70(with bathing facilities) 45(without bathing facilities) 45(with bathing facilities) 23(without bathing facilities) 45
10.	Airports – international and domestic	70
11.	Cinema halls and theatres (per seat)	15

4. Demand for Public Uses : This includes the quantity of water required for public utility purposes, such as watering of public parks, gardening, washing and sprinkling on roads, use in public fountains, etc. For most of the water supply schemes in India, these needs are not believed as essentials, and 'a nominal amount not exceeding 5% of the total consumption may be added to meet this demand on an arbitrary basis.

5. Fire Demand : In thickly populated and industrial areas, fires generally break out and may lead to serious damages, if not controlled effectively. Big cities, therefore, generally maintain full fire-fighting squads. Fire-fighting personnel require sufficient quantity of water, so as to throw it over the fire at high speeds. A provision should, therefore, be made in modern public water supply schemes for fighting fires. The quantity of water required for extinguishing fires should be easily available and kept always stored in storage reservoirs. Fire hydrants are usually fitted in the water mains at about 100 to 150 metres apart, and fire-fighting pumps are immediately connected into them by the fire brigade personnel, as soon as a fire breaks out. These pumps then throw water on the fire at very high pressures, so as to bring under control. The minimum water pressure available at fire hydrants should be of the order of 100 to 150 kN/m^2 (10 to 15 m of water head) and should be maintained even after 4 to 5 hours of constant use of fire hydrant.

Generally, in a moderate fire break out, three jet streams are simultaneously thrown from each hydrant; one on the burning property, and one each on adjacent property on either side of the burning property. The discharge of each stream should be about 1100 litres/

minute. Hence, in a big city having a population of say 50 lakhs, if six fires break out in a day and each fire lasts for 3 hours, the total amount of water required shall be given as :

$$= 6 \times (3 \times 1100) \times (3\times60)$$

[i.e. No. of fires × Discharge × Time of each fire]

$$= 3564000 \text{ litres/day}$$

The amount of water required per person

$$= \frac{3564000}{50 \text{ lakhs}}$$

$$= \frac{3564000}{5000000} < \text{litre/person/day}$$

From the above example, it therefore, follows that although the rate at which water is required for fire-fighting is very large, the total amount of water consumption hardly amounts to 1 litre/head/day. The per capita fire demand is thus generally ignored while computing the total per capita water requirement of a city. However, for cities having populations exceeding 50,000, the water required in kilo litres may be computed by using the relation.

$$\text{Kilo litre of water required} = 100\sqrt{P} \quad \text{...(i)}$$

Where P is Population in thousands.

The high rate of water consumption during a fire considerably affects the design of distribution system, and hence while designing public water supply schemes, the rate of fire demand is sometimes treated as a function of population, and is worked out on the basis of certain empirical formulas, which are given below :

(1) Kuichling's formula : It states that

$$Q = 3182\sqrt{P} \quad \text{...(ii)}$$

Where Q = Amount of water required in litres/minute

P = Population in thousands.

(2) Freeman formula : It states that

$$Q = 1136\left[\frac{P}{10}+10\right] \quad \text{...(iii)}$$

Where Q and P have the same meaning as in equation (ii).

(3) National Board of Fire Under Writers Formulas : According to the recommendations given by the Board (now known as American Insurance Association), the fire requirements are as follows :

(a) For a central congested, high valued city :

(i) When population is less than or equal to 2,00,000

$$Q = 4637\sqrt{P}\left[1-0.01\sqrt{P}\right] \quad \text{...(iv)}$$

(ii) When population is more than 2 lakhs, a provision for 54,600 litres/minute may be made with an extra additional provision of 9,100 to 36,400 litres/minute for a second fire.

(b) For a residential city :

The required draft for fire-fighting may be as follows :

(i) Small or low buildings = 2,200 litres/minute.

(ii) Larger or higher buildings = 4,500 litres/minute.

(iii) High values residences, apartments, tenements = 7,650 to 13,500 litres/minute.

(iv) Three storeyed buildings in densely built-up sections = upto 27,000 litres/minute.

(4) Buston's formula : It states that

$$Q = 5663\sqrt{P} \quad \text{...(v)}$$

Where P and Q have the same meaning as given above.

The formulas at (2), (3) and (4) above, give higher results and, therefore, only 2 hours storage with those rates may be assumed as fairly good allowance, while working out the total stand-by storage capacity or the volume of water required for fire demand, as for as Indian conditions are concerned ; although 5-10 hours storage is considered as minimum requirement in USA.

All the above formulae suffer from the drawback that they are not related to the type of district served. These formulas, therefore, give equal results for industrial as well as non-industrial areas, although the possibility of occurrence of a fire with a given duration is more for an industrial area as compared to a non-industrial area.

This probability of occurrence of a fire, which, in-turn, depends upon the type of the city served, has been taken into consideration in developing a formula (equation vi), on the basis of actual water consumption in fire fighting for Jabalpur city of India. The formula is given as :

$$Q = \frac{4360\, R^{0.275}}{(t+12)^{0.757}} \qquad \text{...(vi)}$$

Where R = Recurrence interval of fire, i.e. period of occurrence of fire in years, which will be different for residential, commercial and industrial cities. Its recommended minimum value is one year.

t = Duration of fire in minutes, its recommended minutes value is 30 minutes.

Thus, if fire fighting provision is to be made for fighting a fire occurring once in three years, and lasting for two hours, then

$$Q = \frac{4360\,(3)^{0.275}}{(2\times 60+12)^{0.757}}\ l/\text{min}$$

$$= 146.4\, l/\text{min}$$

6. Water Required to Compensate Losses in Thefts and Wastes : This includes the water lost in leakage due to bad plumbing or damaged meters, stolen water due to unauthorized water connections, and other losses and wastes. These losses should be taken into account while estimating the total requirements. These losses can be reduced by careful maintenance and universal metering. Even in the best managed water works, this amount may, however, work to be as high as 15% of the total consumption.

Q.13 ***Explain various factors affecting per capita demand.***

Ans. Factors Affecting Per Capita Demand : The annual average demand for water (i.e. per capita demand) considerably varies for different towns or cities. This figure generally ranges between 100 to 360 litres/capita/day for Indian conditions. These variations in total water consumption of different cities or towns depend upon various factors, which must be thoroughly studied and analysed before fixing the per capita demand for design purposes. These factors are discussed below :

(1) Size of the City: The per capita demand for big cities is generally large as compared to that for smaller towns. This is because of the fact that in big cities, huge quantities of water are required for maintaining clean and healthy environments. For example, big cities are generally sewered, and as such require large quantities of water (a sewered house requires four to five times the water required by an unsewered home). Similarly, in a big city, commercial and industrial activities are generally more, thus requiring more water. Affluent rich living in air cooled homes may also increase the water consumption in cities.

In fact, the effect of population on the size of the city is an indirect one, because even a smaller town may have high water consumption, if it is fully industrialized or is having some industry requiring tremendous quantities of water, or if rich affluent people are living in it. On an average, the per capita demand for Indian towns may vary with the population, as shown in Table.

(2) Climatic Conditions : At hotter and dry places, the consumption of water is generally more, because more of bathing, cleaning, air cooling, sprinkling in lawns, gardens, roofs, etc., are involved. Similarly, in extremely cold countries, more water may be consumed, because the people may keep their taps open to avoid freezing of pipes, and there may be more leakage from pipe joints, since metals contract with cold.

(3) Types of Gentry and Habits of People : Rich and upper class communities generally consume more water due to their affluent living standards. Middle class communities consume average amounts, while the poor slum dwellers consume very low amounts. The amount of water consumption in thus directly dependent upon the economic status of the consumers.

Table : Variations in Per Capita Demand (q) with Population in India

S.No.	Population	Per capita demand in liter /day /person
1.	Less than 20,000	110
2.	20,000 - 50,000	110 – 150
3.	50,000 – 2 lakhs	150 – 240
4.	2 lakhs – 5 lakhs	240 – 275
5.	5 lakhs – 10 lakhs	275 – 335
6.	Over 10 lakhs	335 – 360

(4) Industrial and Commercial Activities : The pressure of industrial and commercial activities at a particular place increases the water consumption by large amounts. Many industries require really huge amounts of water (much more than the domestic demand), and as such, increase the water demand considerably. As pointed out earlier, the industrial water demand is having no direct connection with the population or the size of the city, but more industries are generally situated in big cities, thereby increasing the per capita demand for big cities. However, for properly planned zoned city, the water requirement can be more accurately predicted by estimating the industrial and commercial demands separately.

(5) Quality of Water Supplies : If the quality and taste of the supplied water is good, it will be consumed more, because in that case, people will not use other sources such as private wells, hand pumps, etc. Similarly, certain industries such as boiler feeds, etc., which require standard quality waters will not develop their own supplies and will use public supplies, provided the supplied water is up to their required standards.

(6) Pressure in the Distribution System : If the pressure in the distribution pipes is high and sufficient to make the water reach at 3rd or even 4th storey, water consumption shall definitely be more. This water consumption increases because of two reasons :

(i) People living in upper storeys will use water freely as compared to the case when water is available scarcely to them.

(ii) The losses and wastes due to leakage are considerably increased if this pressure is high. For example, if the pressure increases from 20 m head of water, (i.e. 200 kN/m^2) to 30 m head of water (i.e. 300 kN/m^2), the losses may go up by 20 to 30 percent.

(7) Development of Sewerage Facilities : As pointed out earlier, the water consumption will be more, if the city is provided with 'flush system' and shall be less if the old 'conservation system' of latrines is adopted.

(8) System of Supply : The water may be supplied either continuously for at the 24 hours of the day, or may be supplied, only for peak periods during the morning and evening. The second system, i.e. the intermittent supplies, may read to some saving in water consumption due to losses occurring for lesser time and a more vigilant use of water by the consumers. But at many places, the intermittent supplies may not give much saving over the continuous supplies, because of the following reasons :

(i) In intermittent supply system, water is generally stored by consumers in tanks, drums, utensils, etc, for non-supply periods. This water is thrown away by them even if unutilized as soon as the fresh supply is restored. This increases the wastage and losses considerably.

(ii) People have a general tendency to keep the taps open during non-supply hours, so that they may come to know of it as soon as the supply is restored. Many a times, water goes on flowing unattended even after the supply is restored, thus resulting in wastage of water.

(9) Cost of Water : If the water rates are high, lesser quantity may be consumed by the people. This may not lead to large savings as the affluent and rich people are little affected by such policies.

(10) Policy of Metering and Method of Charging : Water tax is generally charged in two different ways :

(i) On the basis of meter reading (meters fitted at the head of the individual house connections and recording the volume of water consumed).

(ii) On the basis of certain fixed monthly flat rate.

In the 2nd case, i.e. when the supplies are unmetered and the charges are fixed, people generally do not practice economy in the use of water, because they think that they have to pay only a fixed amount irrespective of the quantity of water used by them. They are, therefore, generally liberal in consuming water, and many a times, leave their taps flowing unused. All this leads to high wastage and high consumption of water. However, when the supplies are metered, people use only that much of water as much is required by them. Although metered supplies are preferred because of lesser wastage, they generally lead to lesser water consumption by poor and low income groups, leading to unhygienic conditions. Moreover, meters put unnecessary hinderance to the flow, resulting in loss of pressure and increased cost of pumping. Meters are also liable to be stolen and the cost of installing, repairing and reading the meters is generally high. In a good water works management, it is, therefore, generally desired to work out the economics of metering and to balance the cost of meterage against the value of water conserved by reduction of wastages. At certain places, the saving in water due to meterage has really been large enough, as to permit postponing the otherwise needed extensions of supplies.

Q.14 *What are the various population forecasting methods? Explain any two in details.*

Ans. Population Forecasting Methods : The various methods which are generally adopted for estimating future populations by engineers are described below. Some of these methods are used when the design period is small, and some are used when the design period is large. The particular method to be adopted for a particular case or for a particular city depends largely upon the factors discussed in these methods, and the selection is left to the discretion and intelligence of the designer. However, as pointed out earlier, none of these methods is exact, and they are all based on the laws of probability, and thus, only approximate estimates for the possible future populations can be made.

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

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

1. Arithmetic Increase Method : This method is based upon the assumption that the population increases at a constant rate; i.e. the rate of change of population with time $\left(\text{i.e. } \frac{dP}{dt}\right)$ is constant. Thus,

$$\frac{dP}{dt} = \text{Constant} = k$$

or $$dP = k.dt$$

or $$\int_{P_1}^{P_2} dP = k.\int_{t_1}^{t_2} dt$$

or $$P_2 - P_1 = k.(t_2 - t_1)$$

Where suffixes 1 and 2 represent the last and first decades or census, respectively. Thus, $t_2 - t_1$ = No. of decades.

The population data for the last 4 to 5 decades, is, therefore, obtained and the population increase per decade (x) is calculated; the average of which $(\bar{x})$ is then used as the design growth rate for computing future population.

Thus, P_1 = Population after 1 decade from present

$$= P_0 + 1.\bar{x}$$

P_2 = Population after 2 decades from present

$$= P_1 + 1.\bar{x}$$

or $$P_2 = [P_0 + 2\bar{x}] \quad ...(i)$$

Similarly $$P_3 = P_2 + 1.\bar{x}$$

or $$P_3 = [P_0 + 3\bar{x}] \quad ...(ii)$$

Writing in this fashion, we get

$$\boxed{P_n = [P_0 + n.\bar{x}]} \quad ...(iii)$$

Where P_n = Prospective or forecasted population after n decades from the present (i.e. last known census)

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

n = No. of decades between now and future.

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

2. Geometric Increase Method : In this method, the per decade percentage increase or percentage growth rate (r) is assumed to be constant, and the increase is compounded over the existing population every decade. This method is, therefore, also known as uniform increase method.

The basic difference between arithmetic and geometric progression methods of forecasting future populations is that : whereas, in arithmetic method, no compounding is done; in geometric method, compounding is done every decade. The computations in two methods are, thus, comparable to simple and compound interest computations, respectively.

Hence, if population increases from 1 lakh to 1.1 lakh in a past decade i.e. @ 10%; then the population in the next decade will increase from 1.1 lakh to 1.21 lakh (i.e. 10% increase over the present decade population of 1.1 lakh). In simple arithmetic method, this value would have been 1.20 lakh only (i.e. 10% simple increase over 1 lakh for 2 decades).

Hence, the assumed constant value of percentage growth rate per decade (r) is analogous to the 'rate of interest per annum'.

The above geometric increase can be expressed as :

P_1 = Population after 1 decade

$$= P_0 + \frac{r}{100}.P_0$$

Where r is in percent.

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

Similarly,

P_2 = Population after 2 decades

$$= P_1 + \frac{r}{100}.P_1$$

$$= P_1\left(1+\frac{r}{100}\right) = P_0\left(1+\frac{r}{100}\right)^2$$

Similarly,

P_3 = Population after 3 decades

$$= P_2 + \frac{r}{100}.P_2$$

$$= P_2\left(1+\frac{r}{100}\right) = P_0\left(1+\frac{r}{100}\right)^3$$

Proceeding in this way, we can write

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

Where P_0 = Initial population; i.e. the population at the end of last known census.

P_n = Future population after n decades.

r = Assumed growth rate (%).

This assumed growth rate (r) can be computed in several ways from the past known population data. One method is to compute, r, as :

$$r = \sqrt[t]{\frac{P_2}{P_1}} - 1 \quad ...(v)$$

Where

P_1 = initial known population

P_2 = final known population

t = No. of decades (period) between P_1 and P_2.

The other method to determine r, is to compute the average of the percentage growth rates of the several known decades of the past. The growth rates; i.e. $\frac{\text{increase in population}}{\text{original population}} \times 100$ values, are computed for each known decade, and their average may be taken as the assumed constant per decade increase (r).

The average may again be either the arithmetic average i.e.

$$\frac{r_1 + r_2 + r_3 + \ldots r_t}{t} \quad \ldots\text{(vi)}$$

or the geometric average i.e. $\sqrt[t]{r_1 . r_2 . r_3 \ldots r_t}$ ...(vii)

The design engineers in the field generally consider the arithmetic mean here, because it is slightly higher than the geometric mean, and hence gives conservative higher value of forecasted population. However, the "GoI Manual on Water and Water Treatment" recommends the use of geometric mean here; and hence, we can safely use that value.

Q.15 ***What are the various sources of water for supply? Explain.***

Ans. Various Sources of Water for Supply

1. Surface Water Source
2. Ground Water Source

Surface water sources are those sources of water in which the water flow over the surface and earth, and is thus directly available for water supplies.

Important surface sources of water are :

(i) Natural ponds and lakes

(ii) Streams and rivers and

(iii) Impounding reservoirs.

Note : Rivers are the most important sources of water for public water supply schemes because :

(a) Most of the cities are settled near the rivers where water is easily available for water supplies.

(b) The quality of river water is generally good (due to self purification) and does not need much purification.

Various Ground Water Sources are :

1. Infiltration Galleries

(i) IG are the horizontal tunnels constructed at shallow depth (3 to 5 meters) along the banks of rivers through the water bearing strata.

(ii) They are sometimes called horizontal wells.

(iii) These galleries are generally constructed of masonry walls with roof slabs, and extract water from the aquifer by various porous lateral drain pipes located at suitable intervals in the gallery.

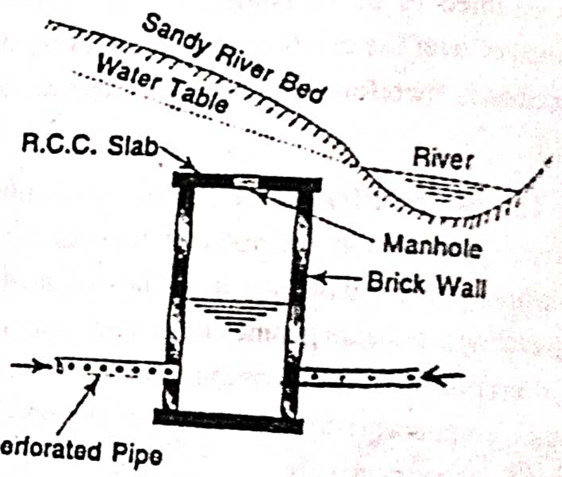


Fig. 1 : Infiltration gallery

2. Infiltration Wells

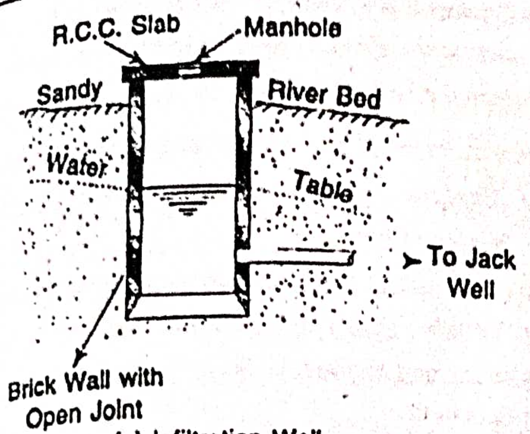
(i) Infiltration wells are the shallow wells constructed in series along the banks of a river, is order to collect the river water seeping through their bottoms.

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

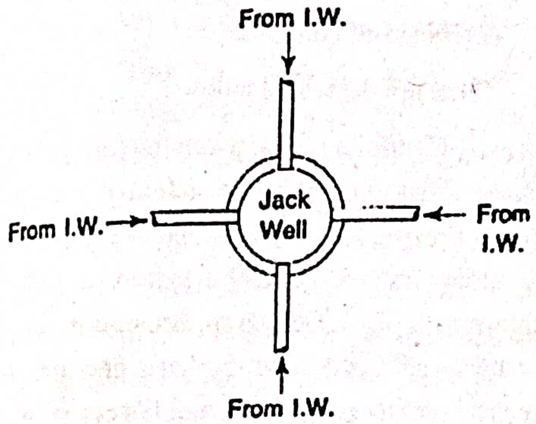
(iii) The water percolates through these joints and gets collected in these wells.

(iv) The various infiltration wells are connected by porous pipes to a sump well called jack well.

(v) The water reaching the jack well from different IW is lifted, treated and distributed to the consumers.



(a) Infiltration Well



(b) Jack Well

Fig. 2 : Infiltration well and jack well

3. Springs

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

(ii) A spring indicates the outcropping of the water table.

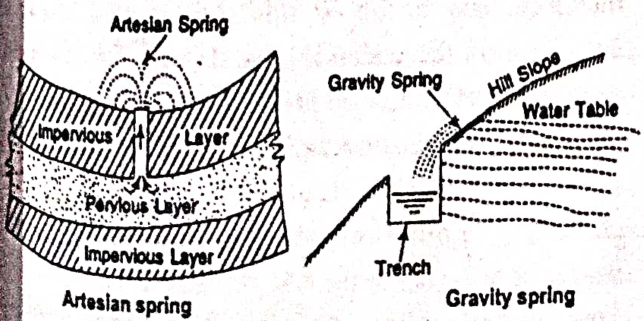
(iii) The springs are generally capable of supplying very small amount of waters, and are therefore, generally not regarded as sources of water supplies.

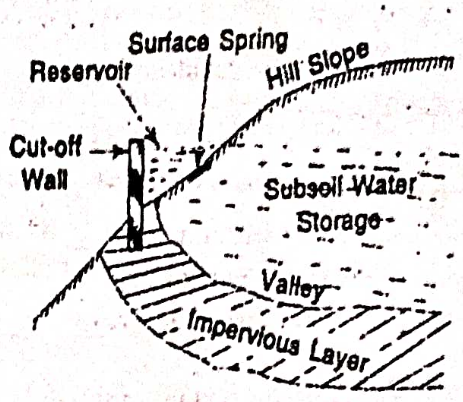
(iv) Following are the different forms of spring :

(a) Artesian spring

(b) Gravity spring

(c) Surface spring





Surface spring

Fig. 3 : Spring

Note : Certains springs sometimes discharge hot water due to the presence of sulphur in them.

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

Classification of well

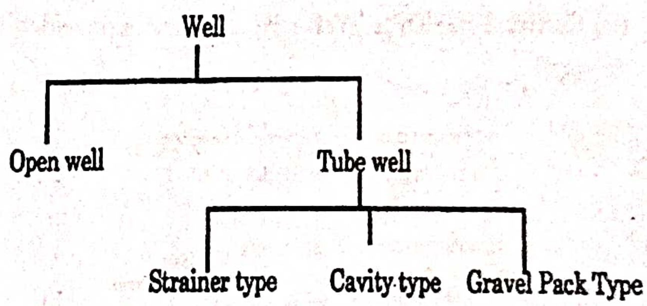


Fig. 4 : Classification of well

(i) Strainer Type Well

- A strainer tube well uses assembled strainer lengths over perforated pipe which are lowered into the bore hole located opposite to the water bearing formation whereas plain pipe lengths (blind pipes) are located opposite the non water bearing strata.
- Water enters into the well through these strainers and perforations in pipe from the sides, and the flow in the well is thus radial.
- A strainer consists of a perforated pipe with a fine wire mesh wrapped round the pipe which prevents sands particles of size larger than mesh entering into the well.

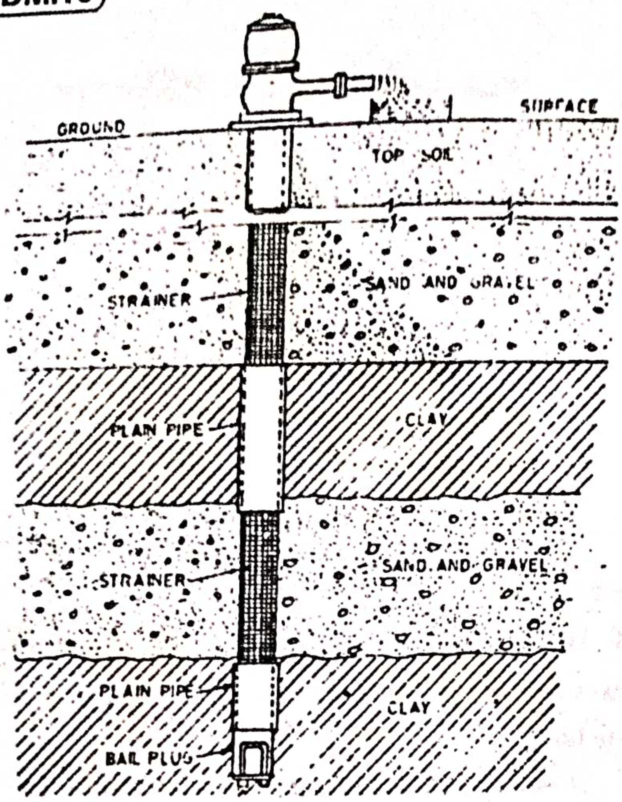


Fig. 5 : Strainer Tubewell

(ii) Cavity Type Tube Well : No strainer is provided in this well.

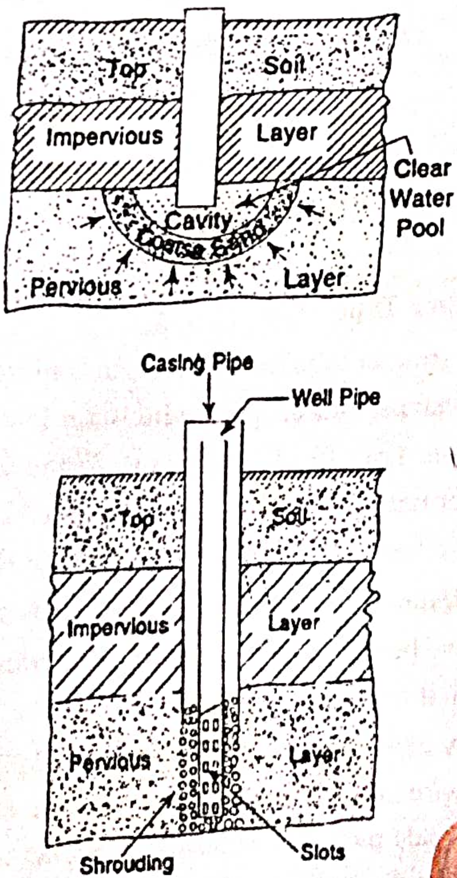


Fig. 6 : Cavity Tube well

(iii) Gravel Pack Type : A slotted pipe is lowered into the bore hole and the external gap between the bore hole and slotted pipe is filled up with graded gravel.

Q.16 ***Explain various conduits for transportation of water supply.***

Ans. Various Types of Conduits : Depending upon the conditions and characteristics of flow, the conduits may be divided into :

(1) Gravity conduits; and

(2) Pressure conduits.

These are described below :

1. Gravity Conduits : Gravity conduits are those in which the water flows under the mere action of gravity. In such a conduit, the hydraulic gradient line will coincide with the water surface and will be parallel to the bed of the conduit, as shown as in fig.1. This is so, because in such a flow, the water is all along at atmospheric pressure, and thus there is no pressure term in Bernouli's equation.

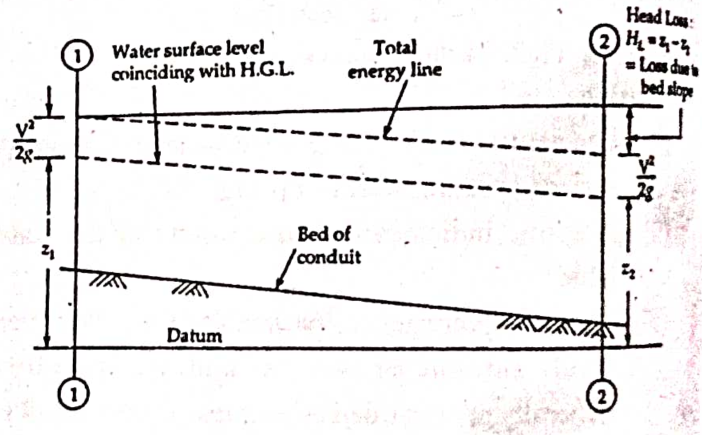


Fig. 1 : Flow illustration in a Gravity Conduit

Since the bed of such a conduit has to follow the gradual slope of the hydraulic gradient line (which governs the flow velocities, etc.), the gravity or grade conduit will, therefore, have to follow this small gradual slope and cannot follow the available natural slope. These conduits cannot, therefore, go up and down hills and valleys as desired by the existing topography of the area. Hence, the gravity conduits will have to be taken above the NSL on trestles, or pillars in valleys and depressions; or will have to be taken below the NSL through tunnels or through canals in deep cuttings. Alternatively, they may be carried along zig-zag paths like roads, highways, etc. thus requiring enormous length of conduit and increased cost.

Gravity conduits can be in the form of canals, flumes, or aqueducts , as given below :

(i) **Canals :** Canals are the open channels which are constructed by cutting high grounds and constructing banks on low grounds. They are generally constructed in balanced cut and fill, and are cheap to build in suitable soils. They may be either lined or unlined depending upon the nature of the ground available slopes, design velocities, quality of water required, losses of water, etc. However, they are generally not used for water supplies but are often used for irrigation. When used for water supplies, they have to be lined so as to obtain better quality water.

(ii) **Flumes :** Open channels supported above the ground over trestles, etc., are called flumes. They are used to convey water across valleys and minor depressions or over drains and other obstructions in their path. They may be made of masonry, R.C.C., metal or wood, and are usually circular or rectangular in cross- section.

(iii) **Aqueducts :** Aqueducts or strictly speaking grade aqueducts are closed, rectangular or circular or horse shoe sections, built of masonry or R.C.C. They wind their way through landscape, with gradual slopes, like roads, railways and highways. Although they are covered or closed, yet water does not flow under pressure as they are not allowed to run full. They are generally designed full. The aqueducts which have been designed as grade aqueducts should not run full under pressure, because the tension developed under such circumstances may open out the joints of masonry work endangering the structural stability, thus causing serious leakage of water. Inspite of being closed, their waters are susceptible to contamination, as the pollution can seep into their waters through cracks and leaky joints. The shape of the section to be chosen is discussed below.

From hydraulic point of view, a circular section provides the maximum hydraulic mean depth or maximum area per unit of wetted perimeter $\left(\text{i.e}, R = \dfrac{A}{P}\right)$ and is, therefore, the most efficient.

Moreover, since the perimeter per unit of cross-section is the least, the construction cost or , material required is also the least. But circular sections cannot be easily supported on ground and, therefore, seldom used. A rectangular shape is hydraulically inefficient and requires more material and construction, but is more stable to support on the ground. Rectangular sections are, therefore, widely used. Horse shoe shape, as shown in Fig.2, is a compromise between the circular and rectangular shapes, and may be used with great advantage. However, their construction is a little more difficult.

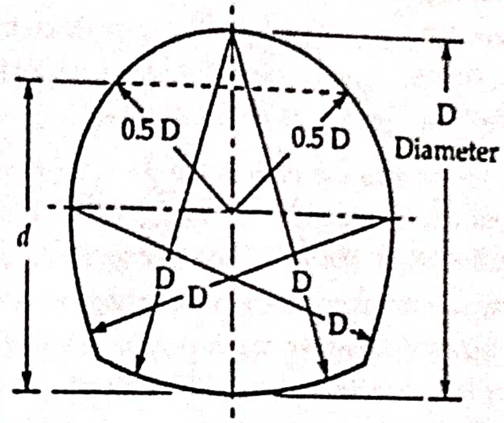


Fig. 2 : Common proportions of Horse Shoe Sections

2. Pressure Conduits : In pressure conduits, which are closed conduits and as such no air can enter into them, the water flows under pressure above the atmospheric pressure. The hydraulic gradient line for such a conduit can be obtained by joining the water surface elevations in the piezometers installed in the conduit at various places, as shown in fig. 3. The bed or the invert of the conduit in pressure flows in thus independent of the grade of the hydraulic gradient line which really governs the flow velocities.

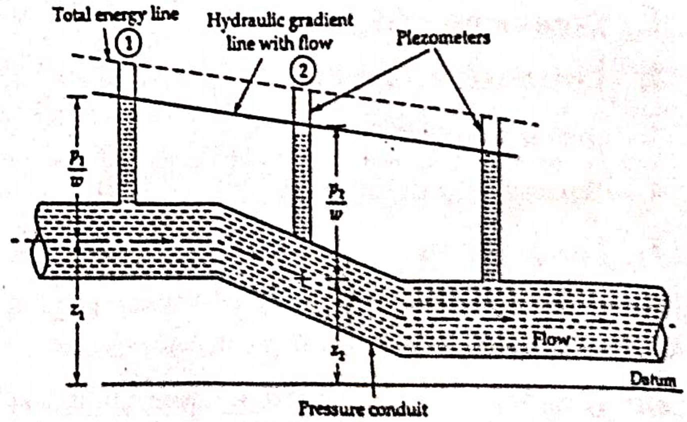


Fig. 3 : Flow illustration in a Gravity Conduit.

The pressure pipes can, therefore, follow the natural available ground surface and can freely go up and down hills or can dip beneath valleys or mountains, sometimes even rising above the hydraulic gradient lines and thus requiring lesser length of conduit.

The Pressure aqueducts may be in the form of closed pipes or closed aqueducts and tunnels called pressure aqueducts of pressure tunnels. The aqueduct as well as tunnel sections are generally kept circular for hydraulic as well as structural reasons. Due to their circular shapes, every pressure conduits generally termed as a pressure pipe. When a pressure pipe drops beneath a valley, stream, or some other depression, it is called a sag or a depressed pipe or an inverted, siphon.

As pointed out earlier, the pressure pipes prove economical than canals or flumes because they can generally follow shorter routes. However, their biggest advantage is that the water moving through such a conduit is not exposed anywhere, and hence, there are no changes or very less chances of its getting polluted. The pressure pipes are, therefore, invariably and, universally carrying sewage and drainage. Since the water wasted in percolation, evaporation, etc. in the canals, also gets saved in the pressure conduits, they are preferably used when the water is scarce.

Q.17 ***Explain domestic water requirements of urban and rural areas.***

Ans. In order to arrive at a reasonable water requirement for any particular town, the demand of water for various purposes is divided under the following five categories:

1. Domestic purposes
2. Civic or public purposes
3. Industrial purposes
4. Business or trade purposes
5. Loss and waste

1. Domestic Purposes : The quantity of water required for domestic purposes can he sub divided as follows:

(i) Drinking : A human body contains about 70% of water. The consumption of water by a man is required for various physiological processes such as blood formation, food assimilation, etc. The quantity of water which a man would require for drinking depends on various factors. But on the average and under normal conditions, it is about 2 litres per day. This amount is very small as compared to various other uses of water. But it is most essential to supply water for drinking purposes with a high degree of purity. If water for drinking contains undesirable elements, it may lead to epidemic. In fact, the drinking water should be protected, potable and palatable.

(ii) Cooking : Some quantity of water will also be required for cooking. The quantity of water required for this purpose will depend upon the stage of advancement of the family in particular and society in general. However, for the purpose of estimation, amount of water required for cooking may be assumed as about 5 litres per capita per day.

(iii) Bathing : The quantity of water required for bathing purpose will mainly depend on the habits of people and type of climate. For an Indian bath, this quantity may be assumed as about 30 to 40 litres per capita per day and for tub-bath, it may be taken as about 50 to 80 litres per capita per day.

(iv) Washing Hands, Face etc. : The quantity of water required for this purpose will depend on the habits of people and may roughly be taken as 5 to 10 litres capita per day.

(v) Household Sanitary Purposes : Under this division, the water is required for washing clothes, floors, utensils, etc. and it may be assumed to be about 50 to 60 litres per capita per day.

(vi) Private Gardening and Irrigation : In case of developed cities, there will be practically no demand of water for this purpose. In case of undeveloped cities, private wells are generally used to provide water for private gardening and irrigation. It is therefore not essential to include the quantity of water required for this purpose in case of public water supply project.

(vii) **Domestic Animals and Private Vehicles :** The amount of water required for the use of domestic animals and private vehicles is not of much concern to a water supply engineer. With the growth and development of town, the cattle disappear and commercial stables come into existence. The water required for animal drinking and cleaning of stables is around 13.5 litres per capita per day.

The requirement of water for domestic purposes is a minimum of 135 litres per capita per day which amounts to 50% of the total water requirement per capita per day.

2. Civic or Public Purposes : The quantity of water required for civic or public purposes can be sub divided as follows:

(i) **Road Washing :** The roads with heavy amount of dust are to be sprinkled with water to avoid inconvenience to the users. On the average, the quantity of water required for this purpose may be taken as about 5 litres per capita per day.

(ii) **Sanitation Purposes :** In this division, water is required for cleaning public sanitary blocks, large markets, etc. and for carrying liquid wastes from houses. The quantity of water required for this purpose will depend on the growth of civilization and may be assumed to be about 2 to 3 litres per capita per day.

(iii) **Ornamental Purposes :** In order to adorn the town with decorative features, fountains or lakes or ponds are sometimes provided. These objects require huge quantity of water for their performance. As far as Indian towns are concerned, the quantity of water required for this purpose may be treated as quite negligible since in most of the towns, the quantity of water available is not enough even with the most urgent needs of the society.

(iv) **Fire Demand :** Usually, a fire occurs in factories and stores. The quantity of water required for fire fighting purposes should be easily available and always kept stored in the storage reservoir.

In case of public water supply, fire demand is treated as a function of population and some of the empirical formulae, commonly used for calculating the fire demand are as follows:

Buston's Formula

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

Q = Quantity of water required in litres per minute

P = Population in thousands

This formula is used in England for moderate provision

John R, Freeman's formula

Q = Quantity of water required in litres per minute

P = Population in thousands

Kuichling's Formula

Q = Quantity of water required in litres per minute

P = Population in thousands

National Board of Fire Underwriters Formula

Q = Quantity of water required in litres per minute

P = Population in thousands

As for Indian conditions are concerned, a moderate allowance of one litre per capita per day for fire demand will be sufficient.

3. Industrial Purposes : The quantity of water required for industrial or commercial purposes can be sub divided as follows:

(i) **Factories :** The quantity of water required for the processes involved in factories will naturally depend on the nature of products, size of factory, etc. and it has no relation with the density of population. It is quite likely that the demand of water for factories may equal or even exceed the demand of water for domestic purposes. The possibility of recycling of water in the plant will also have appreciable effect on the demand of water for a particular product.

(ii) **Power Stations :** A huge quantity of water will be required for working of power stations. But generally, the power stations are situated away from the cities and they do not represent a serious problem to public water supply.

(iii) **Railways :** In most of the cases, the railways make their own arrangements regarding their water requirements and hence, the quantity of water to be consumed by railways is not ordinarily included in any public water supply system.

It is thus not possible to connect the requirement of water for industrial purposes to the population of the city. It is therefore advisable to study each case independently in this regard and decide the quantity of water required for industrial purposes accordingly. For a city with moderate factories, it is estimated that about 20 to 25 percent of per capita consumption will be required for industrial purposes.

4. Business or Trade Purposes : Some trades such as dairies, hotels, laundries, motor garages, restaurants, stables, etc : require a large quantity of water. Such trades are to be maintained in hygienic conditions and sanitation of such places should be strictly insisted. The number of such business centres will depend upon the population and for a moderate city, an average value of about 15 to 25 litres per capita per day may be taken as water requirements for this purpose.

5. Loss and Waste : The quantity of water required under this category is sometimes termed as unaccounted requirement. It includes careless use of water, leakage in mains, valves, other fittings, etc. unauthorized water connections and waste due to other miscellaneous reasons. The quantity of water lost due to all these reasons is uncertain and cannot be effectively predicted. However, for the purpose of calculating the average rate of demand it may be estimated to be about 30 to 40 percent of per capita consumption.

□□□

DRINKING WATER QUALITY 2

IMPORTANT* QUESTIONS

PART-A

Q.1 ***Define the hardness of water.***

Ans. Hardness of Water : Hardness in water is that characteristic which prevents the formation of sufficient leather or foam, when such hard waters are mixed with soap. It is usually caused by the presence of Calcium and Magnesium salts present in water, which form scum by reaction with soap.

Q.2 ***Define the term turbidity of water.***

Ans. Turbidity is the measure of extent to which light is either absorbed or scattered by suspended material in water. It is not a direct quantitative measure of suspended solids.

Q.3 ***What is the permissible limit of pH for drinking water?***

Ans. Permissible value of pH in water : 7-8.5 is acceptable limit and < 6.5 and > 9.2 is cause for rejection.

Q.4 ***What are the various units used in water treatment plants.***

Ans.

(a) Screening

(b) Aeration

(c) Flocculation

(d) Filtration

(e) Disinfection

(f) Softening

(g) Deformation

(h) De-fluoridation

Q.5 ***What are the various common coagulants added in water for purification.***

Ans. (a) Alum (b) Copperas (c) Chlorinated copperas (d) Sodium aluminate (e) Lime.

PART-B

Q.6 ***What do you mean by quality of drinking water.***

Ans. Water quality is very important and many nations strive to protect the safety of their water and to increase the access of potable water. Some countries have laws governing water safety, with severe penalties for polluters. These nations test water on regular basis for contaminants. In developing countries, many non-governmental organizations (NGOs) are working to improve water quality conditions along with other basic sanitations.

The most common contamination of water is human sewage. In 2006, water borne diseases were estimated to cause 1.8 million deaths each year while about 1.1 billion people lacked proper drinking water. It is clear that people in the developing world need to have access to good quality water in sufficient quantity. They also need water purification technology and availability and distribution systems for water.

When the quality or composition of water changes directly or indirectly as a result of human activities then it becomes unfit for any purpose. There are national and international standards for the quality of water to be supplied for human consumption. The state government may have a slight relaxation in the standards depending upon the local conditions but in general, they are the same throughout the country.

The water quality can be disturbed by two types of sources i.e. point sources and non-point sources. When a source of pollution can be easily identified as it has a definite source and place where it enters the water it is said to come from a point source e.g. municipal and industrial discharge pipes. When a source of pollution cannot be easily identified, such as agricultural run off, acid rain, etc. they are said to be non-point sources of pollution.

To ensure the quality of safe drinking water or potable water, the water is to be tested for its physical, chemical, biological and radiological characteristics.

Q.7 ***What is the importance of water quality standards?***

Ans. Importance of Water Quality Standards : Water quality standards are important because they help to project and restore the quality of the Nation's surface water consistent with the requirements of the clean water act. Standards help to identify water quality problems caused by improperly treated waste water discharge, runoff or discharge from active or abandoned mixing sites. Sediment, fertilizers and chemicals from agricultural areas and erosion to stream banks caused by improper grazing practice. Standards also support efforts to achieve and maintain protective water quality condition.

Q.8 ***Explain various methods of water softening in brief to remove permanent hardness.***

Ans. For large scale water softening and for removal of permanent hardness, some specific methods are to be used. These are :

(i) Lime-soda method

(ii) Zeolite method

(iii) Ion exchange method.

(i) Lime-soda Method : In this method, all the soluble compounds of calcium and magnesium are converted into corresponding calcium carbonate ($CaCO_3$) and magnesium hydroxide [$Mg(OH)_2$] precipitate by using lime [$Ca(OH)_2$] and soda (Na_2CO_3). Some reactions are shown below :

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

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

$CaCl_2 + Na_2\,CO_3 \rightarrow CaCO_3 \downarrow + 2NaCl$

$CaSO_4 + Na_2\,CO_3 \rightarrow CaCO_3 \downarrow + Na_2SO_4$

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

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

By using above reactions in hot and cold medium, hardness can be removed.

(ii) Zeolite Method : Zeolites are complex compounds of aluminium, silica and soda. These are available in natural and synthetic forms. It has the property of removing calcium and magnesium ions from water and substituting sodium by ion exchange method when hard water is passed through zeolite. General chemical formula of zeolite is $Na_2O.Al_2O_3.xSiO_2.yH_2O$. The reaction taking place with zeolite are as follows :

$Na_2Al_2Si_2O_8 + CaSO_4 \rightarrow CaAl_2Si_2O_8 + Na_2SO_4$

$Na_2Al_2Si_2O_8 + MgCl_2 \rightarrow MgAl_2Si_2O_8 + 2NaCl$ (Exhausted zeolite)

Exhausted zeolite can be regenerated by using brine solution i.e. 10% NaCl solution.

$CaAl_2Si_2O_8 + 2NaCl \rightarrow Na_2Al_2Si_2O_8 + CaCl_2$

$MgAl_2Si_2O_8 + 2NaCl \rightarrow Na_2Al_2Si_2O_8 + MgCl_2$

(iii) Ion Exchange Method : In this method, both cations and anions are exchanged by H^+ or OH^- ions. For this purpose, specific polymeric resins are used consisting of three dimensional network of cross linked polymeric chains having ionizable functional groups. There are two types of ion-exchangers, cation and anion exchanger. After use, they become exhausted so, can be regenerated by using acid or alkali.

Q.9 *Explain the term sanitation of water.*

Ans. There are different technologies available for dealing with waste water management and excreta. Some are suitable for dealing with off-site sanitation and other can be applied to on site sanitation.

Sanitation refers to excreta and waste water management as well as runoff water, solid and industrial waste. It is whole range of strategies used to solve problems raised by excreta, solid industrial waste and runoff water, excluding production and distribution of drinking water. Two main types can be distinguished : off-site sanitation and on-site sanitation.

On-site sanitation is the whole of actions related to the treatment and disposal of domestic waste water that cannot be carried away by an off-site sanitation system because of low density of population.

For small communities in rural or semi urban areas or even in most of the towns of India where sewerage system is still a dream, on-site system of sanitation prevails. The conventional off-site excreta disposal method, water borne sewerage system followed by a sewage treatment and disposal plant is generally not affordable in these areas. Some on-site low cost disposal methods like septic tanks and soak pits have been developed to have some alternative methods. These are not so effective as the sewerage system even then they are in use because of the economy considerations. Actually there is a growing scarcity of water and the present water carriage system where a very small amount of waste like excreta (say 1%) is carried by a large quantity of water (say 99%), has to be replaced by some other more economic way. It was good when the population was not so high and it was scattered on the earth. Now as the population is exponentially increasing and the rural area is becoming urban and more and more population is concentrating towards the cities, the waste assimilation capacity of the nature is falling short and short. In these conditions the on-site sanitation has become a useful solution, though undesirable.

Q.10 *Compare the slow sand and rapid gravity filters.*

Ans. Comparison of slow sand and rapid gravity filters :

S. No.	Item	Slow sand filters	Rapid gravity filters
1.	Pre-treatment requirements	Effluents either from plain sedimentation tanks or raw waters without any treatment are generally fed into them; and coagulation is not at all required.	Coagulation, flocculation, and sedimentation is a must.
2.	Base material	The gravel base supports the sand. It varies from 3 to 65 mm in size and 30 to 75 cm in depth.	The gravel base supports the sand and also distributes the wash water uniformly on the surface of sand. It varies from 3 to 40 mm in size and its depth is slightly more, i.e. about 60 to 90 cm.
3.	Filter sand	The effective size of filter sand ranges between 0.2 to 0.4 mm and uniformity coefficient between 1.8 to 2.5 or 3.0. The grain size distribution is generally uniform throughout the depth of filter media, except that the top 10 to 15 cm may be laid of finer variety.	The effective size of the filter sand ranges between 0.35 to 0.55 and uniformity coefficient between 1.2 to 1.8. The sand is laid in layers with smallest grain size at the top and coarsest grain size at the bottom.

4.	Under-drainage system	Laid in order to receive filtered water. Open jointed pipes or drains covered with blocks may be used.	Laid in order to receive filtered water and also to pass water for back washing at a very high rate. Perforated pipe laterals discharging into mains or diffuser plate bottom may be used.
5.	Size of each unit	Large, such as (30 m × 60m). The area varying from 100 to 2000 sq. m or more.	Small, such as 5m × 8m. The area varying from 10 to 80 sq. m.
6.	Rate of filtration	Small, such as 100 to 200 liters per hour per sq. m of filter area.	Large, such as 3000 to 6000 liters per hour per sq. m of filter area.
7.	Economy	High initial cost of both land and materials, but low cost of operation and maintenance.	Low initial cost, but higher cost of operation and maintenance. Overall, it is cheaper and economical.
8.	Depreciation cost	Relatively low.	Relatively high.
9.	Efficiency	Very efficient in removing bacteria (98 to 99 percent) but less efficient in removing colour. Overall turbidity removal in these filters using plain sedimentation is also low. They cannot handle turbid waters containing turbidities more then 50 mg/l.	Less efficient in removing bacteria (80 to 90 percent) but very efficient in removing colour. The overall turbidity removal in these filters using coagulation sedimentation, is also high. They can, therefore, handle very turbid waters.
10.	Flexibility	Not flexible for meeting variations in demand.	Quite flexible for meeting reasonable variations in demand.
11.	Suitability and adaptability	May be adopted for treating smaller village suppliers or for individual industrial supplies, especially at hotter places where no covers are required to protect the filters from freezing. They are however, becoming obsolete.	They are widely and almost universally adopted for treating public supplies, especially at all major cities and towns.
12.	Post treatment, required, if any	Almost pure water is obtained. However, it may be disinfected slightly to make it completely safe. Other miscellaneous treatments may or may not be reqd.	Disinfection is a must and some other miscellaneous treatments may be given, if needed.
13.	Ease in construction	Simple	Complicated, as under drainage is to be property designed.
14.	Skilled supervision, if reqd.	Not required.	Essential.
15.	Loss of head	Approximately 0.1 m is the initial loss, and 0.8 to 1.2 m is the final limit when cleaning is required.	Approximately 0.3 m is the initial loss, and 2.5 to 3.5 m is the final limit when cleaning is required.

16.	Method of cleaning	(a) Scrapping and removing the top 1.5 to 3 cm thick layer, and washing down by hoses. (b) Laborious method.	(a) Agitating the sand grains and back washing with or without compressed air. (b) Short and easy method.
17.	Qty. of wash water required	Very small amount of wash water, varying from 0.2 to 0.6 percent of the total water filtered is generally needed.	Large amount of wash water varying from 1 to 5 percent of the total water filtered, is generally required.
18.	Period of cleaning	Cleaned at intervals of 1 to 3 months.	Cleaned frequently at intervals of 1 to 3 days.

Q.11 ***Explain 'Reuse and Saving' in use of water.***

Ans. Water related problems are increasingly recognized as one of the most immediate and serious environmental threats to mankind. Water use has more than tripled globally since 1950, and one out of every six persons does not have regular access to safe drinking water. These problems may be attribute to many factors. Inadequate water management is accelerating the depletion of surface water and ground water resources. In urban areas demand for water has been increasing steadily due to population growth and industrial development.

Many parts of the world are facing charges in climatic conditions such as rainfall pattern, flood cycle and drough which affect the water cycle.

Facing with these challenges, there is an urgent need to improve the efficiency of water consumption and to augment the existing sources of water with more sustainable alternatives. In this context water reuse has become increasingly important in water resource management for both environmental and economic reasons.

In cities and regions of developed countries, where waste water collection and treatment have been the common practice waste water is used with proper attention to sanitation, public health and environmental protection. But, it is different in many developing countries due to lack of resources in waste water treatment plant.

Water Reuse in Industries : Waste water reuse for irrigation is quite common in many places. Table shows the different categories of waste water reuse.

Category of Reuse	Examples of Applications
Urban use	
Unrestricted	Landscape irrigation of parks, playgrounds, school, yards, golf courses, cemeteries, residential, green belts, snow melting.
Restricted	Irrigation of areas with infrequent and controlled access
Other	Fire protection, disaster preparedness, construction
Agricultural	
Food crops	Irrigation for crops grown for human consumption
Non-food crops and crops consumed after processing	Irrigation for fodder, fiber, flowers, seed crops, pastures, commercial nurseries, sod farms
Recreational use	
Unrestricted	No limitation on body contact: lakes and ponds used for swimming, snow making
Restricted	Fishing, boating, and other non-contact recreational activities
Environmental enhancement	Artificial wetlands creation, natural wetland enhancement, stream flow
Groundwater recharge	Groundwater replenishment for potable water, salt water intrusion control, subsidence control
Industrial reuse	Cooling system water, process water, boiler feed water, toilets, laundry, construction wash-down water, air conditioning
Residential use	Cleaning, laundry, toilet, air conditioning
Potable reuse	Blending with municipal water supply, pipe to pipe supply

Practices of waste water reuse vary among countries, as target applications and technology options differ significantly depending on socio-economic circumstances, industrial structure, climate, culture, religious preference, as well as policy readiness.

Water Reuse in Homes : Some tips on saving and reuse water at home :

- Turn off the tap when not in use. Regularly check taps and pipes for leaks and repair any leaks detected.
- Never pour water away when there may be another use for it.
- Washing machine rinse water, especially the last few batches of rinse water can be used for toilet flushing and floor cleaning.
- Reuse water from washing of fruits, vegetables, and kitchen utensils (final washing) water to water plants.
- Install water-efficient taps and shower heads to cut water usage.
- Take shorter showers and turn off the shower while lathering and washing your hair.
- Use a tumbler of water to rinse your mouth instead of leaving the tap running while you brush your teeth.
- Use a pail of water to wash your car rather than a hose.
- Rinse dishes in a plugged sink rather than under running water.
- Do not use running water to defrost frozen food.

Q.12 ***What do you mean by chlorination.***

Ans. Chlorination : Chlorine in its various forms is invariably and almost universally used for disinfecting public water supplies. It is cheap, reliable, easy to handle, easily measurable, and above all, it is capable of providing residual disinfecting effects for long periods, thus affording complete protection against future recontamination of water in the distribution system. Its only disadvantage is that when used in greater amounts, it imparts bitter and bad taste to the water, which may not be liked by certain sensitive-tongued consumers.

PART-C

Q.13 ***Explain the characteristics of safe drinking water.***

Ans. To ensure the quality of safe drinking water or potable water, the water is to be tested for its physical, chemical, biological and radiological characteristics.

1. Physical Characteristics : These are the characteristics which respond to touch, taste, smell, sight etc. These include color, temperature, turbidity, odor etc.

(a) Temperature : The temperature should be optimum according to human being, It also depends upon the climatic and weather condition. Generally, 15°C is suitable at normal conditions.

(b) Color : This characteristic is more objectionable from aesthetic point of view than the health. Unwanted color is imparted by dissolved organic matter, inorganic materials, aquatic plants, industrial wastes from various industries like textile, paper, pulp, food processing dairy industries etc. Color is measured in labs by Nessler's tube by comparing the sample with the known color intensities.

(c) Taste and Odor : The water must not contain any undesirable or objectionable taste or odor. The dissolved inorganic salts, decaying organic matter and dissolved gases are responsible for unwanted taste and odor. The extent of taste and odor is measured by a term called odor intensity which is related with threshold odor number (TON).

$$TON = \frac{A+B}{A}$$

Here, A = Volume of sample in ml

B = Volume of distilled water in ml.

(d) Turbidity : It is the cloudiness, haziness or muddy appearance in water. It is caused by suspended or colloidal

...ticles which cause hindrance to the path of light. It is ...o objectionable from aesthetic point of view. It is ...asured by turbidity rod or a turbidity meter and ...pressed as suspended matter in mg/lt or ppm.

...Conductivity : The conductivity of water is measured ...terms of specific conductivity. It shows the presence ...dissolved solids in water. Greater the amount of ...solved solids, higher will be the conductivity. It can be ...asured by digital instrument i.e. conductivity meter. It is expressed in micro mhos per cm at 25°C. The specific conductivity is multiplied by coefficient i.e. 0.65 so as to obtain the dissolved salt in ppm.

2. Chemical Characteristics : Chemical analysis of water is done to determine the chemical characteristics of water. Some important characteristics are pH, hardness, alkalinity, total dissolved solids, chlorides, fluorides, sulphates, phosphates, nitrates, metals etc. All these chemical characteristics are tabulated in following table.

Table : Important chemical impurities of water, their difficulties and removal.

No.	Constituents	Chemical formula	Difficulties caused	Removal or treatment
1.	Hardness	Calcium ($CaCO_3$) and magnesium ($MgCO_3$) salts	Chief source of scales in heat exchange equipment, boilers pipe lines etc. Do not form lather with soap, interferes with dyeing etc.	Softening, demineralization, internal boiler water treatment, surface active agents.
2.	Alkalinity	Bicarbonates (HCO_3^-), Carbonates (CO_3^{-2}) and Hydroxides (OH^-)	Foam and carry over of solids with steam; embrittlement of boiler steel, bicarbonate and carbonate produce CO_2 in steam, a source of corrosion.	Lime and lime-soda softening, acid treatment, hydrogen zeolite softening, demineralization, dealkalization by anion exchange.
3.	Free mineral acid	H_2SO_4, HCl etc. expressed as $CaCO_3$	Corrosion	Neutralization with alkalies.
4.	Carbon dioxide	CO_2	Corrosion in water lines particularly steam and condensate lines.	Aeration, deaeration, neutralization with alkalies.
5.	pH	Hydrogen ion concentration defined as $pH = \log 1/[H^+]$	pH varies according to acidic or alkaline solids in water, most natural waters have a pH of 6.0 – 8.0.	pH can be increased by alkalies and decreased by acids.
6.	Sulphate	SO_4^{-2}	Adds to solid contents of water. Combines with calcium to form calcium sulphate scale.	Demineralization, reverse osmosis, electrodialysis, evaporation.
7.	Chloride	Cl^-	Adds to solid contents and increase corrosion character of water.	Demineralization, reverse osmosis, electrodialysis, evaporation.
8.	Nitrate	NO_3^-	Adds of water contents but is not usually significant, high concentrations cause mathemoglobinemia in infant, useful for control of boiler metal embrittlement.	Demineralization, reverse osmosis, electrodialysis, evaporation.

9.	Fluoride	F^-	Cause molted enamel in teeth also used for control of dental decay.	Adsorption with magnesium hydroxide, calcium, phosphate or bone black alum coagulation.
10.	Sodium	Na^+	Adds to solid contents of water, when combined with OH^-, cause corrosion in boiler under certain conditions.	Demineralization, reverse osmosis, electrodialysis, evaporation.
11.	Silica	SiO_2	Scale in boilers and cooling water systems, insoluble turbine blade depositors due to silica vaporization.	Hot and warm process removal by magnesium salts, adsorption by highly basic anion exchange resins, in conjugation with demineralization, reverse osmosis, evaporation.
12.	Iron	Fe^{+2} (ferrous) Fe^{+3} (ferric)	Dicolorization of water on precipitation source as deposits in water lines, boilers etc. interferes with dyeing, tanning paper making.	Aeration, coagulation and filtration, lime softening cation exchange, contact filtration. Surface active agents for iron retention.
13.	Manganese	Mn^{+2}	Same as iron.	Aeration, coagulation and filtration, lime softening cation exchange, contact filtration. Surface active agents for iron retention.
14.	Aluminium	Al^{+3}	Usually present as a result of flock carryover from clarifier, can cause deposits in cooling systems and contribute to complex boiler scales.	Improved clarifier and filter operation.
15.	Oxygen	O_2	Corrosion of water lines heat exchange equipment, boilers, return lines, etc.	Deaeration; Sodium sulphite, corrosion, inhibitors.
16.	Hydrogen Sulphide	H_2S	Cause of rotten egg odor, corrosion.	Aeration, chlorination highly basic anion exchange.
17.	Ammonia	NH_3	Corrosion of copper and zinc alloys by formation of complex soluble ion.	Cation exchange with hydrogen zeolite, chlorination, deaeration.
18.	Suspended solids		Refer to the measure of undissoloved matter determined gravimetrically, deposits in heat exchange boilers water lines etc.	Subsidence filtration, usually preceded by coagulation and setting.
19.	Dissolved solids		Refer to total amount of dissolved matter, determined by evaporation, high concentrations are objectionable because of process interference and as a cause of foaming in boiler.	Lime softening and cation exchange by hydrogen zeolite, demineralization, reverse osmosis, electrodialysis, and evaporation.
20.	Total Solids		Refer to the sum of dissolved and suspended solids, determined gravimetrically.	Same as dissolved and suspended solids.

3. Biological Characteristics : The biological characteristic of a water body refers to a variety of living organisms that may be present in water. These include microscopic viruses, bacteria, protozoans, phytoplanktons (floating over small plants or algae), zooplanktons (tiny water animals associated with small plants), insects, worms, larger plants and fishes. Most important biological organisms in water are pathogens, as they transmit diseases to human body. Some important biological impurities are discussed below :

(a) Algae : Algae are photosynthetic aquatic organisms. These are microscopic in nature but when amassed, it can be seen as a green, brown or blue-green scum. Excess growth of algae may cause algal bloom which is disadvantageous to other aquatic life. Examples include cynophyta (blue-green algae) viz. Oscillatoria, Microcystis etc., Chrysophyta (yellow-green algae) viz. Navicula, Cymbella etc., Rhodophyta (red algae) vle. Lemanea.

(b) Bacteria : Bacterial examination of water is very important since it indicates the degree of pollution, water polluted by sewage contain one or more species of disease producing pathogenic bacteria causing water borne diseases e.g. Coliform, Straptococci etc.

(c) Fungi : The occurrence of fungi in drinking water has received increased attention in the last decade. Now, fungi are generally accepted as drinking water contaminants. However the relevance of water borne fungi for water quality and human health is poorly understood. Effective treatments against fungi are also very few.

(d) Virus : Drinking water must essentially be free from virus to ensure negligible risk of transmitting viral infection. Some common examples are hepatitis, cholera etc.

4. Radiological Characteristics : It is caused both by natural resources as well as by human activities.

Nuclear plants produce small amounts of radioactive isotopes. Although the radioactive wastes are diluted before being released into the seas but many living organisms selectively absorb them. Thus radioactive isotopes of Cs, Zn and Co are accumulated in the soft tissues and those of Ra, Sr and Ca are found in the bones. Sea weeds concentrate cobalt and iodine. Radioactive impurities causes genetic disorders which are carried down to generations. Leakage of as little as one gram of plutonium could cause lung cancer to one million people.

Q.14 *Explain the various methods of treatment of water for drinking purpose.*

Ans. Drinking water is supplied by municipalities using the sources of natural water. The natural water obtained from rivers, canals, wells etc. do not confirm the quality standards prescribed for domestic water or municipal water and such are not suitable for municipal supply. Hence to make these waters suitable for municipal supply the following treatment processes are adopted, which depend upon the exact nature of impurities present in raw water.

The various methods are as follows :

(i) Screening

(ii) Sedimentation

(iii) Sedimentation with coagulants

(iv) Filtration

(v) Disintegration

(vi) Aeration

(vii) Softening

(viii) Miscellaneous treatment

1. Screening : It is a process of removing floating materials like leaves and twinges etc. from water. Raw water is passed through screens having holes, when the floating matter is retained by them and is allowed to pass.

2. Sedimentation : The process of allowing water to stand undisturbed in big tanks for some time in order to facilitate the settling down of the coarse suspended particles due to the force of gravity is called sedimentation.

This is the process of removing suspended impurities by allowing the water to stand undisturbed in big tanks for 2-8 hours. Most of the suspended particles settle down at the bottom of the tank due to the force of gravity. The clear supernatant water is then drawn out from the tank with the help of pumps. This process removes only 70-75% of the suspended matter.

3. Sedimentation with coagulation : When water contains finely divided silica, clay and organic matter do not settle down easily and cannot be removed by mere sedimentation. Most of these are in colloidal form and carry definite type of charge. Thus, they do not coagulate due to mutual repulsions. For their removal coagulation is required. In this process, fine suspended and colloidal particles are removed by addition of requisite amount of chemicals (as coagulants) to water before sedimentation. Coagulants, like alum or ferrous sulphate produce Al^{+3} or Fe^{+2} ions which neutralize the oppositively charged colloidal and clay particles. After losing their charge, these particles come nearer to one another and combine to form bigger particles which settle down due to the force of gravity. The process is known as flocculation.

Some common chemicals used as coagulants are as follows :

(i) Alum : It is the most widely used as coagulating agent. Alum reacts with impurities in water in the presences of alkalinity of water

$$\underset{\text{Coagulant}}{Al_2(SO_4)_3} + \underset{\substack{\text{Calcium bicarbonate}\\\text{(present in water)}}}{3Ca(HCO_3)_2} \rightarrow \underset{\substack{\text{Aluminium hydroxide}\\\text{(flocculent precipitate)}}}{2Al(OH)_3\downarrow} + 3CaSO_4 + 6CO_2$$

(ii) Aluminium Sulphate : This is used either as filter alum $[Al_2(SO_4)_3]$, or as alum $[K_2SO_4.Al_2(SO_4)_3.24H_2SO_4]$. It hydrolyses in water to form $Al(OH)_3$ which acts as a coagulant.

$$Al_2(SO_4)_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2SO_4$$

In order to render the $Al(OH)_3$ filterable and to neutralize the H_2SO_4 produced during hydrolysis, some alkali should be present. If water possesses a little or no natural alkalinity, and alkali like Na_2CO_3 or $Ca(OH)_2$ is added.

$$Al_2(SO_4)_3 + 3Na_2CO_3 + 3H_2O \rightarrow \underset{\text{(flocculent precipitate)}}{2Al(OH)_3\downarrow} + 3Na_2SO_4 + 3CO_2\uparrow$$

(iii) Sodium Aluminate : It is generally used along with $Al_2(SO_4)_3$ for treatment of acidic water.

$$NaAlO_2 + 2H_2O \xrightarrow{pH=5.5-8.0} \underset{\substack{\text{Gelatinous floc}\\\text{of aluminium}\\\text{hydroxide}}}{Al(OH)_3\downarrow} + NaOH$$

$$6NaAlO_2 + Al_2(SO_4)_3 + 12H_2O \rightarrow 8Al(OH)_3\downarrow + 3Na_2SO_4$$

Aluminium hydroxide floc causes sedimentation. The sodium hydroxide thus, produced, during the above reaction precipitate magnesium salt as $Mg(OH)_2$.

$$MgSO_4 + 2NaOH \rightarrow Mg(OH)_2\downarrow + Na_2SO_4$$

Since $NaAlO_2$ decreases hardness due to Mg^{+2} and to remove finely divided particles.

(iv) Ferrous Sulphate $[FeSO_4.7H_2O]$: It is also commonly used as a coagulant. It is used for treatment of slightly alkaline (above pH value of 8.5) water. If water does not contain alkalinity, sufficient lime is to be added.

$$FeSO_4 + \underset{\substack{\text{Magnesium bicarbonate}\\\text{(Present in water)}}}{Mg(HCO_3)_2} \xrightarrow{pH=8.5} Fe(OH)_3\downarrow + MgCO_3 + \underset{\text{Coagulant}}{CO_2} + H_2O$$

$$FeSO_4 + 2H_2O \rightarrow Fe(OH)_3\downarrow + H_2SO_4$$

$$4Fe(OH)_2 + \underset{\substack{\text{(Dissolved}\\\text{Oxygen)}}}{O_2} + 2H_2O \rightarrow \underset{\substack{\text{(Ferric hydroxide)}\\\text{(Heavy floc)}}}{4Fe(OH)_3\downarrow}$$

$Fe(OH)_3$ is in the form of heavy floc alkalinity present in water or lime added neutralizes the H_2SO_4 produced during hydrolysis of ferrous sulphate.

The process of coagulation depends upon various factor like-

(i) pH of the medium
(ii) Amount of coagulant
(iii) Temperature of water

4. Filtration : This is the process of removal of coarse impurities (e.g. coagulated colloidal material, suspended matter etc.) and some of micro-organisms by passing water through a porous material consisting of a bed of fine sand and other granular materials. The porous material used for filtration is called a filter.

The filters used for water treatment are of two types (i) gravity type filters, and (ii) pressure type filters. The gravity type filters can further classified as slow sand filter and rapid sand filters. The water for municipal supply is usually filtered by gravity sand filter.

(i) Gravity Sand Filters : Gravity filtration is carried out in large rectangular tank consisting of a porous medium, known as filter medium, which retain solid particles but allows the passage of water. Several different forms of filter media are available. Common filter plants contain the filter media of fine sand at the top and then coarse sand below and gravel at the bottom to a depth of 1-2 meter. Water from the sedimentation tank enters in at the top of the filter plants and passes through the layers of fine sand, coarse sand and gravel. Thus the rest of suspended matter and much of the remaining bacteria are taken out from the water. In gravity filters water passes through the bed at an atmospheric pressure due to gravity only.

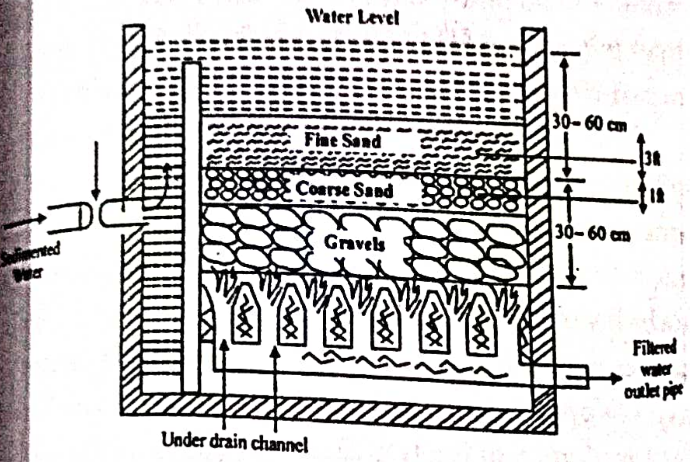


Fig. 1 : Gravity Sand Filter Employed for Municipal Water

(ii) **Pressure Filters :** These have the same type of arrangement of filter media as gravity filters. The filter material is kept in a close cylinder and water is forced through filter bed under pressure. These filters can be installed in water supply line so that repumping of filtered water can be avoided. These filters are very widely used for industrial water cooling.

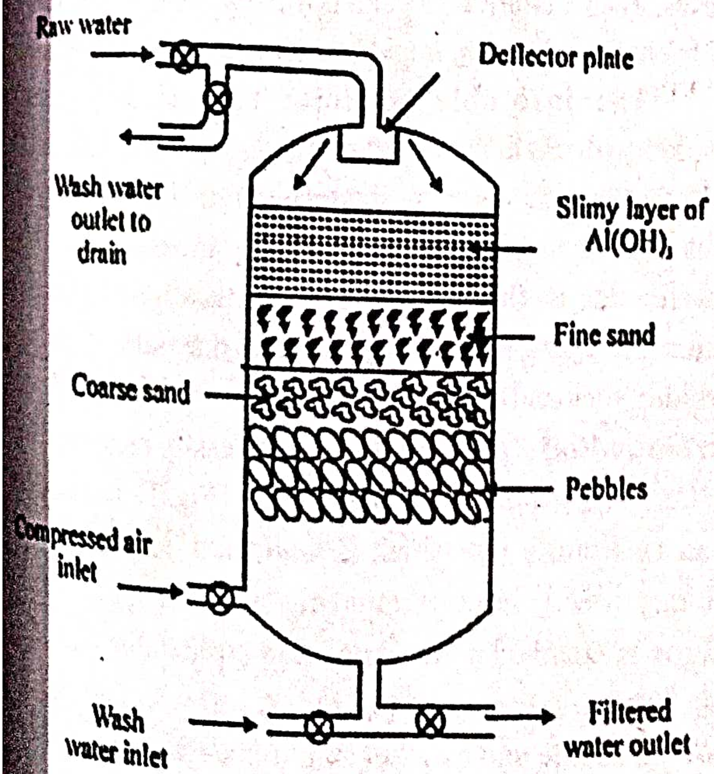


Fig. 2 : Vertical Pressure Filter

5. Sterilization (Disinfection) of Water : The filtered water still contains small amount of pathogenic (disease producing) bacterias which must be removed or destroyed if the water has to be used for drinking or municipal purpose.

The process of destroying/killing of pathogenic bacteria and other micro-organisms from water to make it safe for use is known as disinfection and the chemicals used for this purpose are called disinfectants. Disinfection does not ensure total destruction of all living organisms. On the other hand, sterilization means complete destruction of all living organisms which is possible by boiling the water over a period of time.

Characteristics of an ideal disinfectant

(i) It should kill the pathogens quickly at room temperature.

(ii) It should be inexpensive.

(iii) It should not be toxic to human.

(iv) It should provide protection against any contamination in water during conveyance or storage.

The disinfection of water can be carried out by following methods :

(i) Boiling of water

(ii) Bleaching powder method

(iii) Chlorination method

(iv) Chloramine process

(v) Ozonization process

(vi) Iodine method

(vii) Potassium permangnate ($KMnO_4$) method

(viii) Chlorine dioxide

(ix) By ultra violet light

Treatment with chlorine is the most popular and economic method. Chlorine reacts with water to form HCl and hypochlorous acid (HOCl). This hypochlorous acid produces nascent oxygen which act as germicide.

$$Cl_2 + H_2O \rightarrow HCl + \underset{\text{Hypochlorous acid}}{[HOCl]}$$

$$HOCl \rightarrow HCl + \underset{\text{(Nascent oxygen)}}{[O]}$$

$$[O] \rightarrow \text{Germicide}$$

The factors affecting the efficiency of disinfection are:

- Type and concentration of micro-organisms
- Type and concentration of disinfectant
- Contact time
- Chemical and physical characteristics of water to be treated like temperature, pH, minerals etc.

Potable water should always contain some extra amount of chlorine i.e. residual chlorine in the range of 0.2 – 0.3 ppm to prevent the future contamination. The limiting value of chlorination is known as 'break point chlorination'. Excess amount of chlorine changes the organoleptic properties of water that is unwanted taste and odor is produced.

6. Aeration : Water aeration is done to remove unwanted taste and odor. It is performed to exchange the gases between water and the atmosphere. Water aeration is often required in ponds that suffer from anodic conditions, usually caused by adjacent human activities. This can be achieved through the infusion of air into the bottom of the pond or lake or by surface agitation from a spray like device to allow for oxygen exchange at the surface and the release of toxic gases. Aeration is generally performed for the following purposes:

(i) To add oxygen to water for imparting freshness.

(ii) For expulsion of toxic gases and volatile substances like carbon dioxide, hydrogen sulphide etc. which cause unwanted taste and odor.

(iii) For precipitation of impurities like iron and manganese.

7. Water Softening : The process of removing the hardness causing salts from water is called softening of water. Water becomes hard due to presence of bicarbonates, chlorides and sulphate of calcium and magnesium. Bicarbonate are responsible for temporary hardness whereas chlorides and sulphates are responsible for permanents hardness. Temporary hardness can be easily remove by boiling for small scale as boiling converts the soluble impurities into precipitate as shown below:

$$Ca(HCO_3) + \text{Heat} \rightarrow CaCO_3\downarrow + H_2O + CO_2\uparrow$$

$$Mg(HCO_3)_2 + \text{Heat} \rightarrow MgCO_3\downarrow + H_2O + CO_2\uparrow$$

Q.15 ***What do you mean by turbidity of water and also explain its measurements.***

Ans. Turbidity : If a large amount of suspended matter such as clay, silt, or some other finely divided organic materials are present in water, it will appear to be muddy or cloudy or turbid in appearance. The turbidity depends upon the finesse and concentration of particles present in water. Although, the clay or other inert suspended particles may not be harmful to health, yet they are to be removed or reduced for aesthetic and psychological reasons.

Since people do not like turbid water, the turbidity of raw water must be measured, and then reduced by treatment to permissible values, so as to make it almost invisible under naked eye. The turbidity is measured by a turbidity rod or by a turbidimeter with optical observations, and is expressed as the amount of suspended matter in mg/l or ppm. The standard unit is that which is produced by 1 milligram of finely divided silica in 1 litre of distilled water. A turbidity in excess of 5 units is easily detectable in a glass of water, and is thus, usually objectionable. Turbidity in a clear lake water is about 25 units; and for muddy waters, it exceeds about 100 units. Although certain health standards lay down a permissible limit of 5 to 10 units of turbidity for drinking waters, yet the modern approach is to put no safe limit to turbidity, as in certain cases, even a slight trace in a normally clear water, such as in chalk-well water, might be a sign of serious pollution.

The insoluble particles of soil, organics, microorganisms and other material, impeding the passage of light through water by scattering and absorbing rays, thus causes turbidity, which con be measured as the interference to the passage of light through the given water. Turbidity can be measured in the field by using turbidity rods and turbidmeters.

Turbidity Rod : The turbidity can be easily measured in the field with the help of a turbidity rod (Fig. 1). It consists of an aluminium rod which is graduated, as to give the turbidity directly in silica units (mg/l). To the upper end of this rod is attached a graduated non-stretchable tape, so as to help in lowering of the rod. A screw containing a platinum needle and a nickel ring is inserted at the lower end of the rod, as shown. The standard platinum needle is

1 mm in diameter and 25 mm long. A vertical rod or a stick is inserted in the nickel ring, so as to support and keep the rod in a vertical position. There is a make for eye position on the graduated tape, as shown.

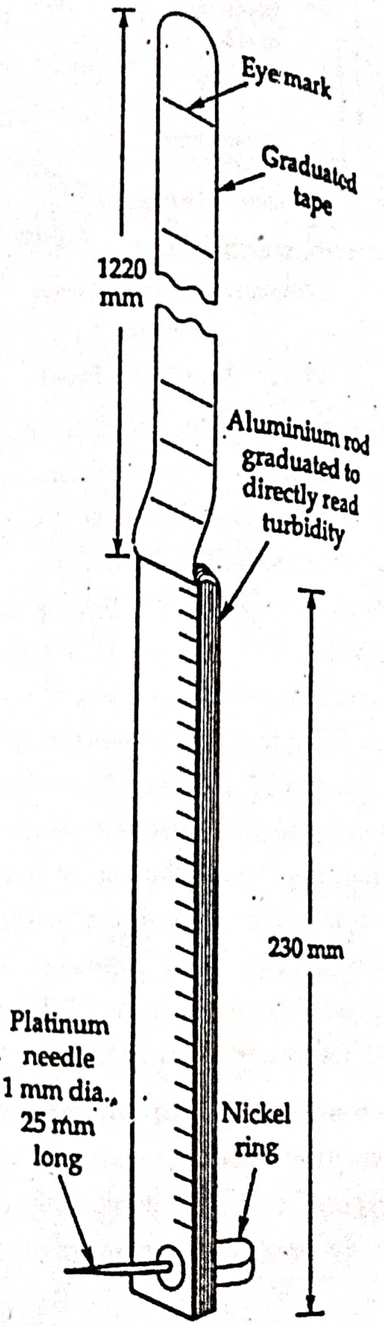
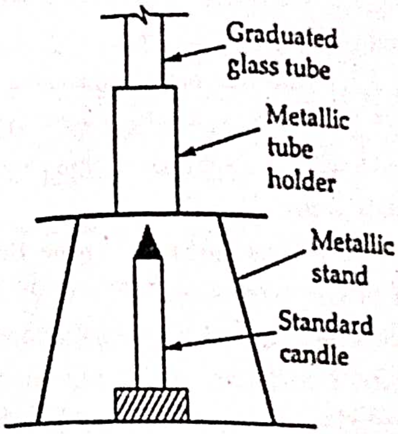


Fig. 1 : Turbidity Rod

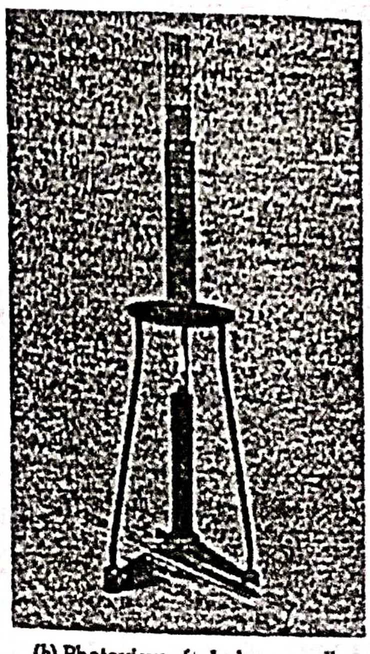
In order to measure the turbidity, the graduated aluminium rod is lowered in water, and keeping the eye at its upper end the submerged needle is viewed. Then rod is then slowly moved downwards (and the eye along with it) till the needle just disappears due to the turbidity of water. The length of the rod under water is a measures of the turbidity. The lesser the length, the greater is the turbidity and vice versa. The rod is graduated specially and the reading on it near the surface of water directly gives the turbidity in ppm.

Turbidimeters : The turbidity can be measured in the laboratory with the help of instruments called turbidimeters. In general, a turbidimeter works on the principle of measuring the interference caused by the water sample to the passage of light rays.

Jackson's turbidimeter : A Jackson's turbidimeter, also called a Jackson's candle turbidimeter can be used to measure turbidities in the range between 25-1000 mg/l. It consists of a calibrated glass tube, which can be placed on a metallic cylindrical tube holder fixed over a metallic stand provided with a fixed standard candle at its bottom, as shown in Fig.2 (a) and (b).



(a) Section through a Jackson candle turbidimeter



(b) Photoview of a Jackson candle turbidimeter

Fig. 2

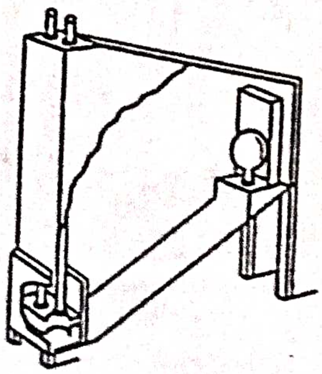
With the glass tube in place over the lighted candle, the water sample is gradually added to the glass tube to increase the height of the water column in the tube, and the candle flame is observed from the top of the tube. The addition of water is stopped as soon as the image of the candle flame ceases to be seen. At this stage, the height of the turbid water will provide just enough turbidity for preventing the candle light to pass through it. This height of water column will, therefore, be more for less turbid water, and vice versa.

The height of the water column, measured in the calibrated glass tube, will thus, provide a measure of the turbidity of the water. The longer the light path, the lower the turbidity; say for example, a light path of 10.8 cm corresponds to the turbidity of 200 JTU, of 21.5 cm to 100 JTU, and of 72.9 cm to 25 JTU.

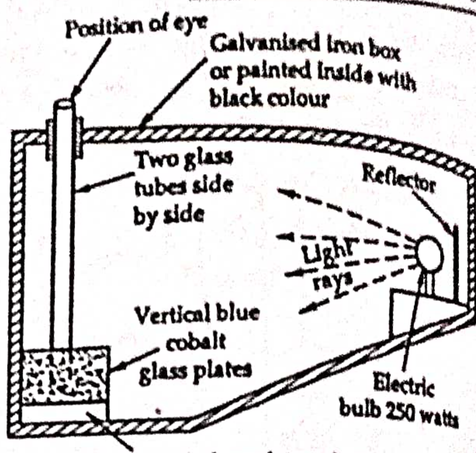
Such a turbidimeter cannot measure turbidities lower than 25 JTU or 25 mg/l, which is the typical value for a clear lake water, as against a value exceeding 100 JTU for muddy water.

Since the lowest turbidity value that can be measured on this instrument is 25 JTU or 25 mg/l or so, such a turbidimeter is limited in application to turbid raw water of natural source only, and it can not be used to measure the turbidities of treated supplies, for which Baylis turbidimeters or modern nephelometers are used.

Baylis turbidimeter : A Baylis turbidimeter, shown in Fig.3 is generally used to measure turbidities in the range of 0-10 mg/l. It consists of a closed galvanized iron box, on one side of which, two glass tubes can be held vertically side by side. On the other side, in front of the tubes, a 250 watts electric bulb is located with a reflector, so as to throw light on the tubes. The glass tubes are supported at bottom by a white opal glass plate and are surrounded by blue cobalt plates, as shown.



(a) Prospective view



(b) Section

Fig. 3 : Baylis turbidimeter

One of the two glass tubes is filled with water sample (whose turbidity is to be measured) and the other is filled with standard water solution of known turbidity. The standard electric bulb is lighted, and its light thus, falls on the water samples in the glass tubes through the cobalt glass plates. The blue colour in both the tubes is observed from the top of the instrument. If the colour of both the tubes differ, the standard solution tube is replaced by anther standard tube of different known turbidity. The process is continued till a matching is obtained in the colours of both the tubes. The known turbidity of the standard solution will then correspond to the turbidity of the sample of water. Baylis turbidimeter is generally used for measuring turbidities in the range of 0-10 ppm, although it can measure higher turbidities up to about 100 mg/l also.

Modern commercial turbidimeters, called Nephelometers have since been designed, and are being used these days on a large scale, particularly for measuring very low turbidities of drinking waters (up to less than one unit).

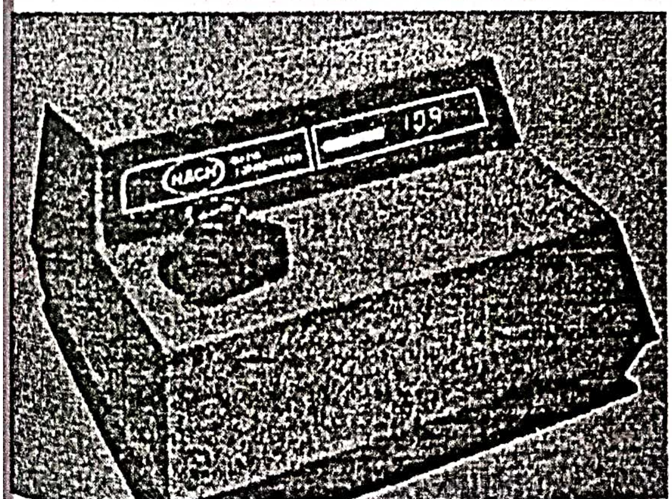
The basic difference between the old and the new turbidimeters is that : in the old instrument, the light was seen or measured after the same passed straight through the turbid water; while in a modern turbidimeter, the light intensity is measured at right angles to the incident light. Such an instrument therefore uses a photometer to measure the intensity of light passing through the turbid water, after the same is scattered at right angles to the incident light.

Since no direct relationship exists between the intensity of light scattered at 90° and Jackson candle turbidity, calibration of a nephelometer in terms of candle or silica units is not valid. To distinguish between the turbidities measured from instrumental and visual methods, nephelometric turbidity units are abbreviated as NTU (Naphelometric Turbidity Units). Occasionally, the nephelometric turbidity units are referred to as FTU (Formazin Turbidity Units), since formazin polymer is used as reference turbidity standard suspension in place of silica suspension.

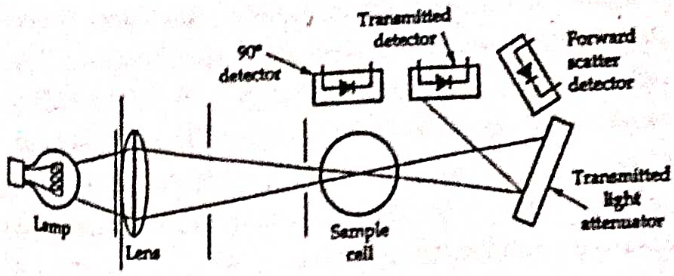
A commercial Ratio turbidimeter which can measure the ratio of the 90° scattered light to the transmitted light is illustrated in Fig.4.

In such an instrument, light is focused by a lens before passing horizontally through the water sample. In an ordinary turbidimeter, this measurement alone would be used to determine the turbidity. In addition, the ratio turbidimeter detects the transmitted light.

At low or moderate turbidity levels, the forward scatter signal is negligible compared to the transmitted signal, and the output is simply a ratio of the 90° scattered light to the transmitted light. This ratioing stabilizes the instrument and negates the effect of colour, if present in water. At high turbidity levels, the instrument records the ratio of the 90° scattered light to the sum of the forward scatter and the transmitted light, thus allowing linearity over the entire range.



(a) Photoview of a Ratio turbidimeter



(b)

Fig. 4 : Light path diagram for a ratio turbidimeter, to accurately measure the turbidities for natural cloudy as well as treated waters with turbidities less than 1 NTU.

Q.16 ***Explain various types of chlorination in treatment of water.***

Ans. Types of chlorination and certain important definitions : Depending upon the quantity of chlorine added, or the stage at which it is added, or upon the results of chlorination, various technical terms in relation to the chlorination are used. They are:

(i) Plain chlorination

(ii) Pre-chlorination

(iii) Post-chlorination

(iv) Double chlorination

(v) Break point chlorination

(vi) Dechlorination

(i) Plain chlorination : This term is used to indicate that only the chlorine treatment and no other treatment has been given to the raw water. Under plain chlorination, therefore, raw water is fed into the distribution system after giving chlorine treatment only. This helps in removing bacteria, organic matter and colour from the raw water. This technique may be used for treating relatively clearer waters (with turbidities less than 20 to 30 mg/l) obtained from lakes, reservoirs, deep tube wells, etc. It may also be used during emergencies, when full-fledged treatment cannot be given, such as for supplying water to army troops during war times. The used quantity of chlorine required for plain chorination is about 0.5 mg/l or more.

(ii) Pre-chlorination : Pre-chlorination is the process of applying chlorine to the water before filtration or rather before sedimentation coagulation. It helps in improving coagulation, and reduces the loads on the filters. It also reduces the taste, odour, algae and other organisms. The chlorine dose should be such that about 0.1to 0.5mg/l of residual chlorine comes to the filter plant. The normal doses required are as high as 5 to 10 mg/l. Pre-chlorination is, however, always followed by post chlorination, so as to ensure the final safety of water.

(iii) Post-chlorination: Post chlorination or sometimes simply called chlorination is the normal standard process of applying chlorine in he end, when all other treatments have been completed. While treating normal public supplies the post chlorination is adopted after filtration and before the water enters the distribution system. The dosage of chlorine should be such as to leave a residual chlorine of about 0.1 to 0.2 mg/l, after a contact period of about 20 minutes. This residual will ensure the disinfection of water, if at all any future recontamination occurs in the distribution system.

(iv) Double chlorination : The term double chlorination is used to indicate that the water has been chlorinated twice. The pre-chlorination and post chlorination are generally used in double chlorination. Post chlorination, however, is generally always used, while the pre-chlorination is also used when the waters are highly turbid and contaminated. Since the double chlorination uses pre-chlorination prior to the normal post chlorination, its advantages are the same as those of pre-chlorination. In addition, the second unit of chlorination plant required for per-chlorination may serve as a stand by unit for emergencies.

(v) Break-point chlorination : Break point chlorination is a term which gives us an idea of the extent of chlorine added to the water. In fact, it represents, that much does of chlorination, beyond which any further addition of chlorine will equally appear as free residual chlorine.

When chlorine is added to the water, it first of all, generally reacts with the ammonia present in the water, so as to form chloramines. These chloramines respond to the D.P.D. test in the same manner as does free chlorine, Therefore, the D.P.D. test will indicate the quantum of total residual chlorine, "combined" as well as "free".

Hence, if chlorine is slowly added to the water, and the residual is tested, it will be found that the residual will go on increasing with the addition of chlorine. However, some chlorine is consumed for killing bacteria, and thus the amount of residual chlorine shall be slightly less than that added, as shown by the curve AB in Fig.

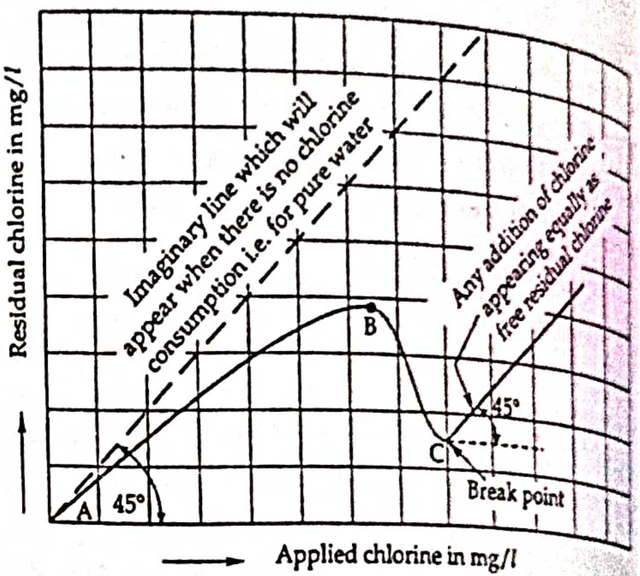


Fig. : Figure indicating break-point chlorination

If the addition of chlorine is continued beyond the pint B, the organic mater present in water starts getting oxidized, and, therefore, the residual chlorine content suddenly falls down, as shown by the curve BC. The point C is the point beyond which any further addition of chlorine will appear equally as free chlorine, since nothing of it shall be utilized. This point "C" is called the **break point**, as any chlorine that is added to water beyond this point, breaks through the water, and totally appears as residual chlorine. The addition of chlorine beyond break point is call **break point chlorination.**

At the point B, when oxidation of organic matter starts, a bed smell and taste generally appears, which disappears at the break point C, when the oxidation has been completed.

It is a general practice to add chlorine beyond break point, and thus to ensure a residual of 0.2 to 0.3 mg/l of free chlorine. This residual of free chlorine, appearing after the break point, is not easily removed except by sun light and, therefore, it take care of the future recontamination of water in the distribution system.

(vi) **Super chlorination :** Supper chlorination is a term which indicates the addition of excessive amount of chlorine (i.e. 5 to 15mg/l) to the water. This may be required in some special cases of highly polluted waters, or during epidemics of water borne diseases. It may be used when there is a reason to believe that the water contains cysts of histolytica (i.e. the organism which causes amoebic dysentery).

The huge quantity of chlorine which is added in super chlorination is such as to give about 1 to 2 mg/l of residue beyond the break point, in the treated water. Sometimes, even higher doses may be used and the resultant water is dechlorinated after the end of the desired contact period, by using dechlorinating agents such as sodium thiosulphate, activated carbon, sulphur dioxide, etc. This ensures the removal of bad tastes and odours caused by the presence of excess chlorine, but may render the water free from chlorine and susceptible to recontamination. Hence, in such cases, it is desirable to again chlorinate the water by a dose of about 0.1 to 0.2 mg/l.

(vii) **Dechlorination :** As indicated above, the dechlorination means removing the chlorine from water. This is generally required when super chlorination has been practiced. The dechlorination process may either be carried out to such an extent that sufficient residual chlorine (0.1 to 0.2 mg/l) do remains in water after dechlorination; or otherwise, if full chlorine has been removed, additional chlorine will generally be added to maintain such residues.

The dechlorination may be carried out be adding certain chemicals to water or by simply aerating the water. These chemicals are called dechlorinating agents.

The common **dechlorinating agents** are : Sulphur dioxide gas ($SO_2\downarrow$), Activated carbon, Sodium thiosulphate ($Na_2S_2O_3$), Sodium metabisulphate ($Na_2S_2O_5$), Sodium sulphite (Na_2SO_3), Sodium bisulphate ($NaHSO_3$), and Ammonia as NH_4OH.

SO_2 gas may be applied to water somewhat in the same manner as chlorine, with a minimum contact period of about 10 to 15 minutes, with a dose of about 0.3 to 0.6 ppm, depending upon the excess chlorine present in water. The required SO_2 to excess chlorine ratio is 1.12 : 1 with an additional 25 % of SO_2 over this theoretical requirement.

Q.17 ***What are the water quality standards.***

Ans. Water quality standards are the foundation of the water quality based control program mandated by the Clean Water Act. Water quality standard define the goals for a water body by designated its uses, setting criteria to protect those users, and establishing provisions to protect water quality from pollutants. A water quality standard consists of four basic elements :

1. Designated uses of the water body (i.e. recreation, water supply, aquatic life, agriculture).
2. Water quality criteria to protect designated uses (numeric pollutants concentration and narrative requirements).
3. An anti-degradation policy to maintain and protect existing uses and high quality waters.
4. General policies addressing implementation issues (i.e. low flows, variance, mixing zones).

Water quality standards consist of statement that describe water quality requirements. They also contain numeric limits for specific physical, chemical, biological or radiological characteristics of water. These statement include general and specific descriptions, because not all requirements for water quality can be numerically defined. The standards can be adjusted constantly according to technology and information available to water board and other agencies such as :

(1) Indian Standards Institution (ISI)

(2) World Health Organization (WHO)

(3) Indian Council of Medical Research (ICMR)

(4) United States Public Health Science (USPHS)

(5) Ministry of Work and Housing (MWH)

(6) National Drinking Water Management (NDWM, DRD Govt. of India)

Table : The different parameters and their respective permissible limits

S. No.	Parameters	International standard WHO		ICMR, New Delhi		ISI 100500-1991		NDWM, DRD Govt. of India	
		Highest desirable limit	Maximum permissible limit	Highest desirable limit	Maximum permissible limit	Highest desirable limit	Maximum permissible limit	Highest desirable limit	Maximum permissible limit
Physical Parameters									
1.	Color	5PCu	50Pcu	5Pcu	25Pcu	5Hu	20 Hu	Hu	25 Hu
2.	Taste and odor	Unobjectionable	u.o	u.o	u.o	u.o	u.o	u.o	u.o
3.	Turbidity	5JTU	25JTU	4JTU	25JTU	5JTU	25JTU	5JTU	10JTU
4.	TDS(mg/l)	500	1500	500	3000	500	2000	5000	1500
5.	pH	7.0-8.5	6.5-9.2	7.0-8.5	6.5-9.2	7.0-8.5	6.5-9.0	6.5-8.5	6.5-8.5
Chemical Parameters									
6.	($CaCO_3$mg/l)	100	500	300	600	300	300	300	600
7.	Calcium (Ca,mg/l)	75	200	75	200	75	200	75	200
8.	Magnesium (Mg, mg/l)	30	150	50	100	-	1	50	100
9.	Chloride(Cl, mg/l)	200	600	200	1000	250	1000	200	1000
10.	Sulphate (SO_4, mg/l)	200	400	200	400	200	400	200	400
11.	Nitrate (NO_3, mg/l)	45	-	20	100	45	100	45	100
12.	Fluoride (F, mg/l)	0.7	1	1	1.5	0.3	1	1	1
13.	Iron (Fe, mg/l)	0.1	1	0.1	1	0.3	1	0.1	1
14.	Manganese (Mn, mg/l)	0.05	0.5	0.1	0.5	0.1	0.3	0.1	0.5
15.	Copper (Cu)	1	3	1	3	-	3	-	-
16.	Zinc mg/l	0.001	0.005	0.001	0.002	-	0.001	-	-
17.	Toxic Arsenic	-	0.05	-	0.05	-	0.05	-	-
18.	Cadmium	-	0.005	-	0.01	-	0.01	-	-
19.	Lead	-	0.05	-	0.1	-	0.1	-	-
20.	Mercury	-	0.001	-	0.001	-	0.001	-	-

□□□

DOMESTIC WASTE WATER 3

IMPORTANT QUESTIONS

PART-A

Q.1 *Write the chezy's formula for velocity.*

Ans. **Chezy's Formula :** The formula was evolved by Chezy in 1775, and states that

$$V = c\sqrt{rs} \quad ...(1)$$

where

V = velocity of flow in the channel in m/sec.

r = hydraulic mean radius of channel, i.e. hydraulic mean depth of channel

$$= \frac{a}{p}$$

where a is the area of channel and p is the wetted perimeter of the channel.

For a circular sewer running full, r is given by

$$r = \frac{\frac{\pi D^2}{4}}{\pi D} = \frac{D}{4}$$

where D is the diameter of the sewer.

s = hydraulic gradient, equal to the ground slope for uniform flows, i.e. the head drop between the two points divided by the length.

c = a constant, called Chezy's constant.

Q.2 *Write the manning's equation for calculating velocity.*

Ans. $\text{Velocity}(v) = \frac{1}{n}R^{2/3}S^{1/2}$

Where, v = velocity of flow in sewer

R = hydraulic radius

S = slope of sewer

Q.3 *What is aerobic bacteria?*

Ans. **Aerobic bacteria** are those which flourish in the presence of free dissolved oxygen in waste water, and consume organic matter for their food, and thereby oxidising it to stable end products.

Q.4 *What do you mean by facultative bacteria?*

Ans. **Facultative bacteria** can operate either as aerobically or as anaerobically. Hence, they can survive and cause decomposition of organic matter, either in the presence or in the absence of free dissolved oxygen in waste water.

Q.5 *What is self cleansing velocity?*

Ans. **Self-cleansing velocity** may be defined as the minimum velocity of flow at which the solid particles present in the sewage will be held in suspension and also at which the scour of the deposited particles will take place so that the sewer will be kept clean.

PART-B

Q.6 ***Explain population equivalent.***

Ans. Population Equivalent : Industrial waste waters are generally compared with per capita normal domestic waste waters, so as rationally charge the industries for the pollution caused by them. The strength of the industrial sewage is, thus, worked out as below :

$$\begin{bmatrix}\text{Standard BOD} \\ (\text{BOD}_5)\text{ of} \\ \text{industrial sewage}\end{bmatrix} = \begin{bmatrix}\text{Standard BOD }(\text{BOD}_5) \\ \text{of domestic sewage per} \\ \text{person per day}\end{bmatrix} \times \begin{bmatrix}\text{Population} \\ \text{equivalent}\end{bmatrix} \quad \text{...(1)}$$

The average standard BOD_5 of domestic sewage is worked out be about 0.08 kg/day/person. Hence, if the BOD_5 of sewage coming from an industries is worked out as 300 kg/day, then

The population equivalent

$$= \frac{\text{BOD}_5 \text{ of the industry in kg/day}}{0.08 \text{ kg/day/person}} \quad \text{...(2)}$$

$$= \frac{300}{0.08} = 3750$$

The population equivalent, thus, indicates the strength of the industrial waste waters for estimating the treatment required at the municipal sewage treatment plant, and also helps in assessing realistic charges for this treatment to be charged from the industries instead of charging them simply by the volume of sewage.

Q.7 ***Explain disposal of domestic waste water on land.***

Ans. Disposal of Sewage Effluents on Land for Irrigation : In this method, the sewage effluent (treated or diluted) is generally disposed of by applying it on land.

The percolating water may either join the water-table, or is collected below by a system of under-drains. This method can then be used for irrigating crops.

This method, in addition to disposing of the sewage, may help in increasing crop yields (by 33% or so) as the sewage generally contains a lot of fertilizing minerals and other elements. However, the sewage effluent before being used as irrigation water, must be made safe. In order to lay down the limiting standards for sewage effluents, and the degree of treatment required, it is necessary to study as to what happens when sewage is applied on to the land as irrigation water.

When raw or partly treated sewage is applied on to the land, a part of it evaporates, and the remaining portion percolates through the ground soil. While percolating through the soil, the suspended particles present in the sewage are caught in the soil voids. If proper aeration of these voids is maintained, the organic sewage solids caught in these voids get oxidised by aerobic process. Such aeration and aerobic conditions will more likely prevail, if the soil is sufficiently porous and permeable (such as sands and porous loams). However, if the land is made up of heavy, sticky and fine grained materials (such as clay, rock, etc.), the void spaces will soon get choked up, and thus resulting in non-aeration of these voids. This will lead to the developing of non-aerobic decomposition of organic matter, and evolution of foul gases. Moreover, excessive clogging may also result in ugly ponding of sewage over the farm land, where mosquitoes may breed in large number, causing further nuisance.

Application of too strong or too heavy load of sewage will also similarly result in the quick formation of anaerobic conditions. The greater is the sewage load, more likely it will be for the soil to get clogged. Hence, if the sewage load is reduced either by diluting it or by pre-treating it, it may be possible to avoid the clogging of the soil pores. The degree of treatment required will, however, considerably depend upon the type of the soil of the land. If this soil, to be irrigated, is sandy and porous, the sewage effluents may contain more solids and other wastes, and thus requiring lesser treatment, as compared to the case where the soil is less porous and sticky.

Q.8 ***Explain self purification of natural streams.***

Ans. When sewage is discharged into a natural body of water, the receiving water gets polluted due to waste products, present in sewage effluents. But the conditions do not remain so for ever, because the natural forces of purification, such as dilution, sedimentation, oxidation-reduction in sunlight, etc., go on acting upon the pollution elements, and bring back the water into its original condition. This automatic purification of polluted water, in due course, is called the self-purification phenomenon. However, if the self-purification is not achieved successfully either due to too much of pollution discharged into it or due to other causes, the river water itself will get polluted, which, in turn, may also pollute the sea where the river outfalls.

The **various natural forces of purification** which help in effecting self-purification process are summarized below :

1. Physical forces are :
   (i) Dilution and dispersion,
   (ii) Sedimentation, and
   (iii) Sunlight (acting through bio-chemical reactions).
2. Chemical forces aided by biological forces (called bio-chemical forces) are :
   (iv) Oxidation (Bio),
   (v) Reduction.

Q.9 ***What are the differences in the design of the water supply pipes and sewer pipes?***

Ans. Differences in the Design of Water Supply Pipes and Sewer Pipes : The hydraulic design of sewers and drains, which means finding out their sections and gradients, is generally carried out on the same lines as that of the water supply pipes. However, there are two major differences between the characteristics of flows in sewers and water supply pipes. These differences are :

(i) The water supply pipes carry pure water without containing any kind of solid particles, either organic or inorganic in nature. The sewage, on the other hand, does contain such particles in suspension ; and the heavier of these particles may settle down at the bottom of the sewers, as and when the flow velocity reduces, thus ultimately resulting in the clogging of the sewers. In order to avoid such clogging or silting of sewers, it is necessary that the sewer pipes be of such a size and laid at such a gradient, as to generate self-cleansing velocities at different possible discharges. The sewer materials must also be capable of resisting the wear and tear caused due to abrasion of the solid particles present in the sewage, with the interior of the pipe.

(ii) The water supply pipes carry water under pressure, and hence, within certain limits, they may be carried up and down the hills and the valleys ; whereas, the sewer pipes carry sewage as gravity conduits (or open channels), and they must, therefore, be laid at, a continuous gradient in the downward direction up to the outfall point, from where the sewage will be lifted up, treated and disposed of.

Q.10 ***Draw the various shape of sewer pipes.***

Ans. Shape of Sewer Pipes

(a) Circular Shaped Sewer (Most widely used for all types of sewers)

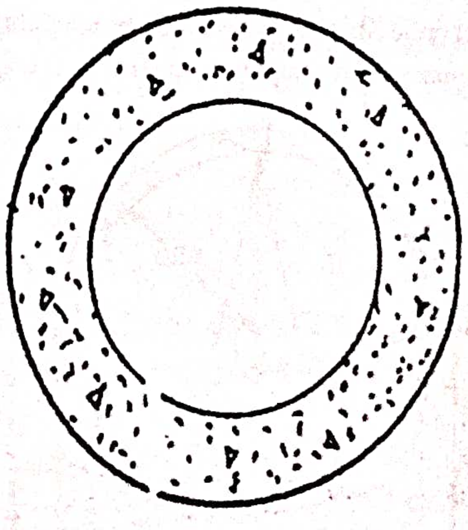


Fig.

(b) Standard Egg Shaped Sewer (May be preferred for combined sewers)

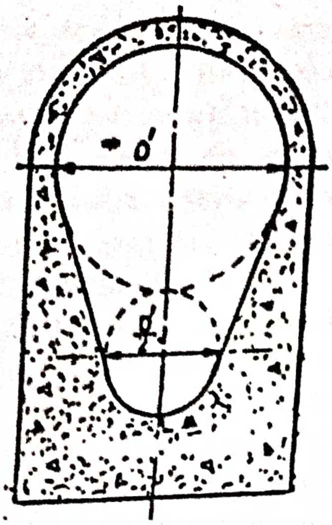


Fig.

(c) Horse Shoe Shaped Sewer (May be used for large sewers with heavy discharge, such as Trunk and Outfall Sewers)

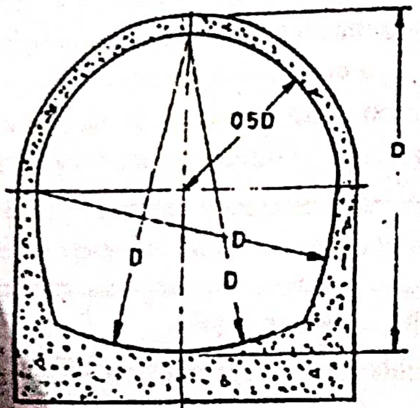


Fig.

(d) Parabolic Shaped Sewer (May be used for carrying comparatively smaller quantities of sewage)

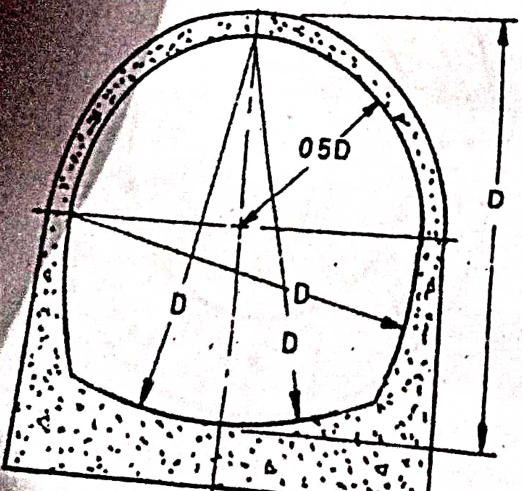


Fig.

Q.11 *Explain the egg shaped sewer.*

Ans. Egg Shaped Sewer

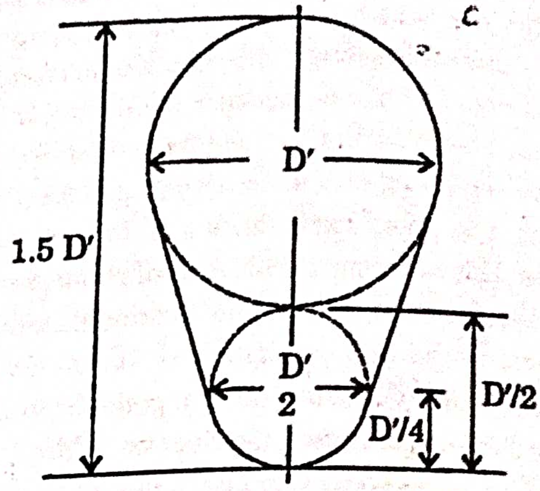


Fig.

- Circular sewer sections are mostly used for separate sewage system. But the advantage of circular sewer is obtained only when the section runs atleast half full. When the depth the velocity reduces considerably.
- If a circular sewer is used for combined system it will be effective only during maximum rain water flow but during dry weather flow, velocity generated would be very less. Thus to take advantage of a circular sewer, two such circular sewers are assumed to be combined into one to form an egg shaped sewer in which smaller circular portion will be effective during dry weather and full section is effective during maximum rain water flow.
- Two sewers (of different shape) are hydraulically equivalent when they discharged at the same rate "while flowing full" on the same grade.
- The egg shaped sewer of an equivalent section, whose top diameter $D' = 0.84D$; where D = diameter of circular sewer of the same cross-sectional area obtained for passing the requisite discharge.

Note: In circular sewers for combined system, fluctuation in discharge could be as large as 25 times. Egg shaped produces 2-15% higher velocity than that provided by hydraulically equivalent circular sewer.

Q.12 *Write short note on drop manholes.*

Ans. Drop Manholes : A Manhole is constructed to connect the high level branch sewer (>0.6m) to the low level main sewer by vertical dropping pipe is known as drop manhole.

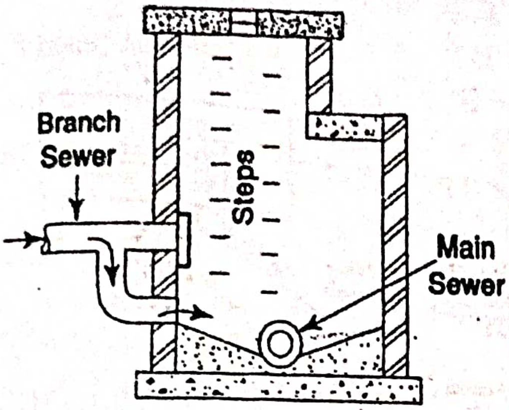


Fig. Drop Manhole

As shown in figure, a branch sewer passes at higher level and the main sewer runs at lower level. So the sewage will fall in the main sewer in the form of a spring. This will cause much inconvenience to the workers at the working chamber. So, the end of the branch pipe is plugged and a vertical dropping pipe is taken from the branch pipe and connected to the manhole near the bottom to allow the sewage to fail in main sewer smoothly.

Q.13 *Using n = 0.015 in Manning's formula, design a sewer running half-full at a flow rate of 650 litres per second and laid at an invert slope of 0.0001.*

Ans. Half full discharge = 650 l/sec = 0.65 m^3/s

$$n = 0.015$$

Let sewer dia. be D

$$R = \frac{D}{4}$$

Since sewer in half full

$$\therefore \quad \frac{q}{Q} = 0.5$$

$$\therefore \quad Q = \frac{0.65}{0.5} = 1.3\ \text{m}^3/\text{s}$$

$$\therefore \quad Q = \frac{1}{n}\frac{\pi}{4}D^2\left(\frac{D}{4}\right)^{2/3} S^{1/2}$$

$$1.3 = \frac{1}{0.015}\frac{\pi}{4}\left(\frac{D^{8/3}}{4^{2/3}}\right)(0.0001)^{1/2}$$

$$\therefore \quad D = 1.99\text{m}$$

$$\therefore \quad \text{Say } D = 2\text{m}$$

Ans.

PART-C

Q.14 *Explain aerobic and anaerobic decomposition of organic matter.*

Ans. The organic matter, which is decomposed by bacteria, under biological action, is called the biodegradable organic matter. Most of the organic matter present in sewage is biodegradable, and hence undergoes biological decomposition, which can be divided two types, i.e.

(i) aerobic decomposition, called aerobic oxidation; and

(ii) anaerobic decomposition, called putrefaction.

Aerobic Decomposition : If air or oxygen is available freely to the waste water in dissolved form, then the biodegradable organic matter will undergo aerobic decomposition, caused by aerobic bacteria as well as by facultative bacteria-operating aerobically. These bacteria will then utilise the free oxygen as electron acceptor, thereby oxidising the organic matter to stable and unobjectionable end products. The stable end products like nitrates, carbon dioxide, sulphate are formed, respectively for the three forms of matter, i.e. nitrogenous, carbonaceous and sulphurous matter. Water, heat, and additional bacteria will also be produced in this biological oxidation, which can be represented by the following equation:

(i) Nitrogenous organic matter $\xrightarrow[\text{Aerobics}]{\text{Oxidation by}} NO_3^-$

$+ NH_3\uparrow + \text{Energy}$ ...(1)

(ii) Carbonaceous organic matter $\xrightarrow[\text{Aerobics}]{\text{Oxidation by}} CO_2\uparrow$

$+ H_2O + \text{Energy}$ ...(2)

(iii) Sulphurous organic matter $\xrightarrow[\text{Aerobics}]{\text{Oxidation by}} SO_4^{--}$

$+ \text{Energy}$ ...(3)

It may also be noted that the during the decomposition of nitrogenous organic matter, the ammonia formed in the initial stages, may linger on till the end, depending upon the available oxygen, retention time, temperature, biological activity, etc. , because the facultative bacteria are incapable to break ammonia to nitrates.

Anaerobic Decomposition : If free dissolved oxygen is not available to the sewage, then anaerobic decomposition, called putrefaction, will occur, Anaerobic bacteria as well as facultative bactria-operating anaerobically, will then flourish and convert the complex organic matter into simpler organic compounds of nitrogen, carbon, and sulphur. These anaerobic bacteria, infact, survive by extracting and consuming the bounded molecular oxygen present in compounds like nitrates (NO_3) and sulphate (SO_4). Gases like ammonia, nitrogen, hydrogen sulphide, methane, etc. are also evolved in this decomposition, producing obnoxious odours. The various stages, at which these gases are evolved are shown in Fig., which represents nitrogen, carbon and sulphur cycles together, for the above anaerobic decomposition. The final equations, representing this decomposition, are given below:

(i) Nitrogenous organic matter $\xrightarrow[\text{Anaerobics}]{\text{Reduction by}} N_2\uparrow$

$+ NH_3\uparrow + \text{Organic acids} + \text{Heat (Energy)}$ ...(4)

(ii) Carbonaceous organic matter $\xrightarrow[\text{Anaerobics}]{\text{Reduction by}}$

$C_2O\uparrow + \text{Heat (Energy)}$ ...(5)

(iii) Sulphurous organic matter $\xrightarrow[\text{Anaerobics}]{\text{Reduction by}} H_2S\uparrow$

$+ \text{Heat (Energy)}$ ...(6)

The organic acids including alcohols produced in eq. (4), are further converted into methane gas ($CH_4\uparrow$), carbon dioxide gas ($CO_2\uparrow$), etc., if methane-forming bacteria are also especially present in the sewage. This conversion is represented by the equation:

(iv) Organic acids $\xrightarrow[\text{Anaerobic bacteria}]{\text{Methane forming}} CH_4\uparrow + CO_2\uparrow$

$+ \text{Heat (Energy)}$ ...(7)

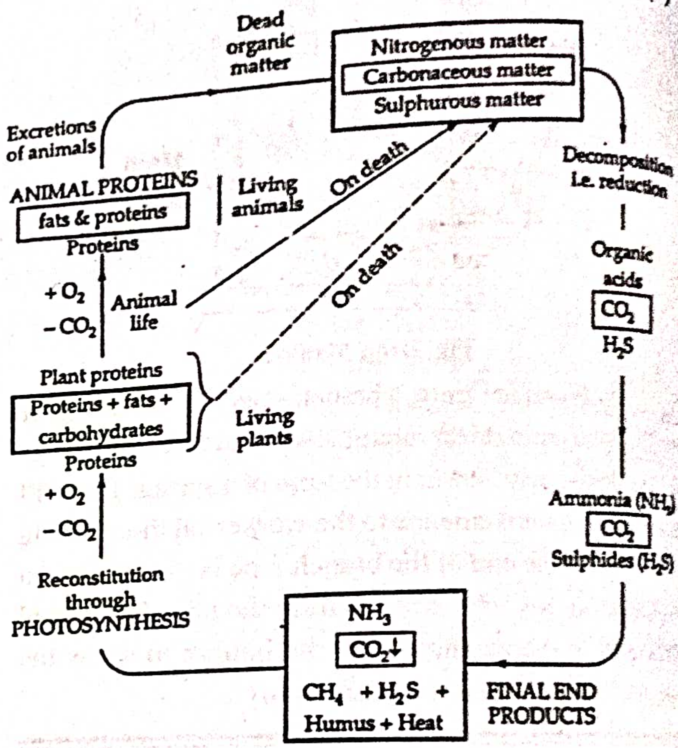


Fig. : Nitrogen, carbon and sulphur cycles under anaerobic oxidation

An understanding of these cycles will help us in determining the stage of decomposition of sewage by testing for the products of decay. For example, a well oxidized, sewage will contain nitrates and, sulphates, but very little ammonia and hydrogen sulphide. On the other hand, lesser oxidized sewage will contain nitrites and sulphur instead of nitrates and sulphates.

Q.15 ***Explain the characteristics of domestic waste water (sewage).***

Ans. The quality of sewage can be checked and analyzed by studying and testing its physical, chemical and bacteriological (biological) characteristics, as explained below :

Physical Characteristics of Sewage and Their Testing

Physical examination of sewage is carried out in order to determine its physical characteristics. This includes : tests for determining (i) turbidity; (ii) colour; (iii) odour; and (iv) temperature. These tests are summarized below :

(i) Turbidity: Sewage is normally turbid, resembling dirty dish water or waste water from baths having other floating matter like fecel matter, pieces of paper, cigarette-ends, match-sticks, greases, vegetable debris, fruit skins, soaps, etc., The turbidity increases as sewage becomes stronger.

The degree of turbidity can be measured and tested by turbidity rods or by turbidimeters, as is done for testing raw water supplies.

(ii) Colour : The colour of sewage can normally be detected by the naked eye, and it indicates the freshness of sewage. If its colour is yellowish, grey, or light brown, it indicates fresh sewage. However, if the colour is black or dark brown, it indicates stale and septic sewage. Other colours, may also be formed due to the presence of some specific industrial wastes.

(iii) Odour : Fresh sewage is practically odourless. But, however, in 3 to 4 hours, it becomes stale with all oxygen present in sewage being practically exhausted. It then starts omitting offensive odours, especially that of hydrogen sulphide gas, which is formed due to decomposition of sewage.

The odour of water or wastewater can be measured by a term called the Threshold odour number (TON), which represents the extent of dilution required to just make the sample free of odour.

The minimum odour of the sample that can be detected after successive dilutions with odourless medium, is thus, known as the threshold odour.

The Threshold odour number (TON) can be calculated by the equation :

$$TON = \frac{V_s + V_D}{V_s} \qquad ...(1)$$

where

TON = Threshold Odour Number

V_s = Volume of the sewage

V_D = Volume of distilled or odourless water added to just make the sewage sample loss its odour.

(iv) Temperature : The temperature has an effect on the biological activity of bacteria present in sewage, and it also affects the solubility of gases in sewage. In addition, temperature also affects the viscosity of sewage, which, in turn, affects the sedimentation process in its treatment.

The normal temperature of sewage is generally slightly higher than the temperature of water, because of additional heat added during the utilisation of water. The average temperature of sewage in India is 20°C, which is near about the ideal temperature for the biological activities. However, when the temperature is more, the dissolved oxygen content (D.O.) of sewage gets reduced.

Chemical Characteristics of Sewage and Their Testing

Tests conducted for determining the chemical characteristics of sewage help in indicating : the stage of sewage decomposition, its strength, and extent and type of treatment required for making safe to the point of disposal.

Chemical analysis is, therefore, carried out on sewage in order to determine its chemical characteristics. It includes tests for determining :

(i) total solids, suspended solids, and settleable solids;

(ii) pH value;

(iii) chloride content;

(iv) nitrogen content;

(v) presence of fats, greases, and oils;

(vi) sulphides, sulphates and H_2S gas;

(vii) dissolved oxygen;

(viii) chemical oxygen demand (C.O.D.);

(ix) bio-chemical oxygen demand (B.O.D.).

These tests are briefly discussed below :

(i) Total Solids, Suspended Solids and Settleable Solids : Sewage normally contains very small amount of solids in relation to the huge quantity of water (99.9%).It only contains about 0.05 to 0.1 percent (i.e. 500 to 1000 mg/l) of total solids. Solids present in sewage may be in any of the four forms: suspended solids, dissolved solids, colloidal solids, and settleable solids.

Suspended solids are those solids which remain floating in sewage. Dissolved solids are those which remain dissolved in sewage just as salt in water. Colloidal solids are finely divided solids remaining either in solution or in suspension. Settleable solids are that portion of solid matter which settles out, if sewage is allowed to remain undisturbed for a period of 2 hours. The proportion of these different types of solids is generally found to be as given below :

It has been estimated that about 1000 kg of sewage contains about 0.45 kg of total solids, out of which 0.225 kg is in solution, 0.112 kg is in suspension, and 0.112 kg is settleable.

Further the solids in sewage comprise of both : the organic as well as inorganic solids. The organic matter works out to be about 45 percent of the total solids, and the remaining about 55 percent is the inorganic matter.

Inorganic matter consists of minerals and salts, like : sand, gravel, debris, dissolved salts, chlorides, sulphates, etc.

Organic matter consists of: (i) carbohydrates such as cellulose, cotton, fibre, starch, sugar, etc. (ii) fats and oils received from kitchens, laundries, garages, shops, etc. (iii) nitrogenous compounds like proteins and their decomposed products, including wastes from animals, urea, fatty acids, hydrocarbons, etc.

As a general rule, the presence of inorganic solids in sewage is not harmful. They require only mechanical appliances for their removal in the treatment plant. On the other hand, suspended and dissolved organic solids are responsible for creating nuisance, if disposed of, untreated. The amounts of various kinds of solids present in sewage can be determined as follows :

(a) **The total amount of solids (S_1 in mg/l)** present in a given sewage can be determined by evaporating a known volume of sewage sample, and weighing the dry residue left. The mass of the residue divided by the volume of the sample evaporated, will represent the total solids in mg/l, say S_1.

(b) **The suspended solids (S_2)** are those solids which are retained by a filter of 1 μm pores; and they are, therefore, also called as non-filterable solids. Their quantity can be determined by passing a known volume of sewage sample through a glass-fiber filter apparatus, and weighing the dry residue left. The mass of the residue divided by the volume of sample filtered, will represent the suspended solids, say (S_2) in mg/l.

(c) The difference between the total solids (S_1) and the suspended solids (S_2) will represent nothing but dissolved solids plus colloidals, and represents the filterable solids; say S_3 where $S_3 = S_1 - S_2$.

(d) Now, the total suspended solids (S_2) may either be volatile or fixed. In order to determine their proportion, the-non-filtered dry residue of step (b) above, is burnt and ignited at about 550°C in an electric muffle furnace for about 15 to 20 minutes. Loss of weight due to ignition will represent the volatile solids in the sample volume filtered through the filter. Let the volatile suspended solids concentration be S_4 (in mg/l).

(e) The differences $S_2 - S_4 = S_5$ (say) will evidently represent the fixed solids.

(f) The quantity of settleable solids (S_0) can be determined easily with the help of a specially designed conical glass vessel called Imhoff cone (Fig.). The capacity of the cone is 1 litre, and it is graduated up to about 50 ml.

Sewage is allowed to stand in this Imhoff cone for a period of two hours, and the quantity of solids settled in the bottom of the cone can then be directly read out. However, in order to obtain precise amount of settleable solids, the liquid from the cone should be decanted off, and the settleable solids collected at the bottom of the cone should be dried and weighted.

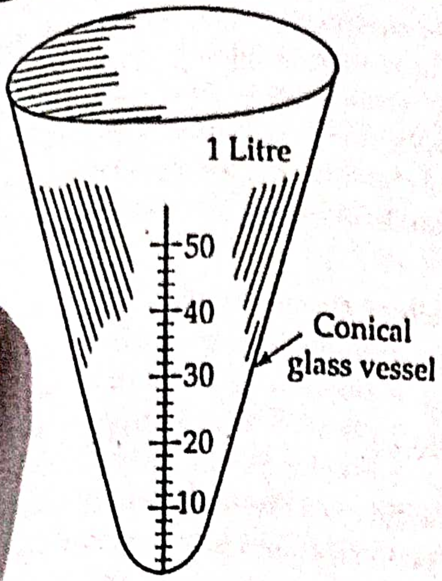


Fig. : Imhoff cone

(ii) pH Value : pH value of sewage indicates the negative log of hydrogen ion concentration present in sewage.

i.e, $\quad pH = -\log H^+ : H^+ = (10)^{-pH}$ ...(2)

It is, thus, an indicator of the alkalinity of sewage. If the pH value is less than 7, the sewage is acidic, and if the pH value is more than 7, the sewage is alkaline. The lesser is the pH value, the lesser is the alkalinity.

The determination of pH value of sewage is ...portant, because of the fact that efficiency of certain ...atment methods depends upon the availability of a ...itable pH value. The pH value can be measured quickly ...d automatically with the help of a potentiometer, which ...easures the electrical potential exerted by the hydrogen ...ns, and thus, indicating their concentration.

The fresh sewage is generally alkaline in nature ...ith pH more than 7) ; but as time passes, its pH tends ...fall due to production of acids by bacterial action in ...aerobic or nitrification processes. The pH, however, ...es upon treatment of sewage.

...) Chloride Contents : Chlorides are generally found ...esent in municipal sewage, and are derived from the ...chen wastes, human feces, and urinary discharges, etc. ...e normal chloride content of domestic sewage is ...0 mg/*l*, whereas, the permissible chloride content for ...ter supplies is 250mg/*l* However, large amount of ...orides may enter from industries like ice cream plants, meat salting, etc., thus, increasing the chloride contents of sewage. Hence, when the chloride content of a given sewage is found to be high, it indicates the presence of industrial wastes or infiltration of sea water, thereby indicating the strength of sewage.

The chloride content can be measured by titrating the waste water (*i.e.* sewage) with standard nitrate solution, using potassium chromate as indicator, as is done for testing water supplies.

(iv) Nitrogen Contents : The presence of nitrogen is sewage indicates the presence of organic matter, and may occur in one or more of the following forms :

(a) Free ammonia, called Ammonia nitrogen

(b) Albuminoid nitrogen, called Organic nitrogen

(c) Nitrites; and

(d) Nitrates

The free ammonia indicates the very first stage of decomposition of organic matter (thus indicating recently, staled sewage) ; albuminoid nitrogen indicates quantity of nitrogen present in sewage before the decomposition of organic matter is started; the nitrites indicate the presence of partly decomposed (not fully oxidised) organic matter; and nitrates indicate the presence of fully oxidised organic matter.

The nitrites thus indicate the intermediate stage of conversion of organic matter of sewage into stable forms, thus indicating the progress of treatment. Their presence will show that treatment given to sewage is still incomplete, and, the sewage is stale. Whereas, the presence of nitrates indicate the most stable form of nitrogenous matter contained in sewage, thus indicating the well oxidised and treated sewage.

Even though 'nitrates' have been defined as the non-objectionable final end product in aerobic treatment of sewage, yet its concentrations in potable waters are controlled, because larger concentrations (above 45 ppm; say), may cause nitrate poisoning in infants. This happens because there exists lower acidity in the intestines of the infants, which permits growth of nitrate reducing bacteria, which convert nitrates to nitrites. The nitrites, when absorbed in blood, prove very harmful, because they have greater affinity for hemoglobin than does oxygen, and thus, nitrite replaces oxygen in the blood complex. The body is, therefore, denied oxygen, causing suffocation in extreme cases. Since suffocation or lack of oxygen, causes the body to turn bluish, it may lead the child to turn blue. Hence, this disease, popularly called blue baby disease, or technically as methaemoglobinemia, is caused in children by the presence of excess nitrates in water. Fortunately, however, when the child grows, say above 6 months or so, the chances of conversion of nitrate into nitrite gets meagre due to development of the child's intestinal tract, and hence such a disease does not normally occur afterwards.

(v) Presence of Flats, Oils and Greases : Greases, fats and oils are derived in sewage from the discharge of animals and vegetable matter, or from the industries like garages, kitchens of hotels and restaurants, etc.

Such matter form scum on the top of sedimentation tanks and clog the voids of the filtering media. They thus interfere with the normal treatment methods, and hence need proper detection and removal.

The amount of fats and greases in a sewage sample is determined by making use of the fact that oils and greases are soluble in ether, and when the ether is evaporated, it leaves behind ether-sobule-matter, which represents the quality of fats and oils. Hence, in order to estimate their amount, a sample of sewage is, first of all, evaporated. The residual solids left are then mixed with ether (hexane). The solution is then poured off and evaported, leaving behind the fats and greases as a residue, which can be easily weighed.

(vi) Sulphides, Sulphates and Hydrogen Sulphide Gas : The determination of sulphides and sulphates in sewage is rarely called far, although their presence reflects aerobic, and/or anaerobic decomposition.

Sulphides and sulphates are formed due to the decomposition of various sulphur containing substances present in sewage. This decomposition also leads to evolution of hydrogen sulphide gas, causing bad smells and odours, besides causing corrosion of concrete sewer pipes.

In aerobic digestion of sewage, the aerobic and facultative bacteria, oxidise the sulphur and its compounds present in sewage to initially form sulphides, which ultimately break down to form sulphates ions ($SO_4^{=}$), which is a stable and an unobjectionable end product. The initial decomposition is associated with formation of H_2S gas, which also ultimately gets oxidised to form sulphate ions.

(vii) Dissolved Oxygen (D.O.) : The determination of dissolved oxygen present in sewage is very very important because : while discharging the treated sewage into some river stream, it is necessary to ensure at least 4 ppm of D.O. in it; as otherwise, fish are likely to be killed, creating nuisance near the vicinity of disposal. To ensure this, D.O. tests are performed during sewage disposal treatment processes.

The D.O. test performed on sewage before treatment, helps in indicating the condition of sewage. It is well known by now, that only very fresh sewage contains some dissolved oxygen, which is soon depleted by aerobic decomposition. Also, the dissolved oxygen in fresh sewage depends upon temperature. If the temperature of sewage is more, the D.O. content will be less. The solubility of oxygen in sewage is 95% of that in distilled water.

An D.O. content of sewage is generally determined by the Winkler's method which is an oxidation-reduction process carried out chemically to liberate iodine in amount equivalent to the quantity of dissolved oxygen originally present.

(viii) Chemical Oxygen Demand (COD) : The organic matter present in waste water can be measured in a number of ways; volatile solids determination being a crude measure of organic matter.

Organic matter is most often assessed in terms of oxygen requires to completely oxidise the organic matter to CO_2, H_2O and other oxidised species.

The oxygen required to oxidise the organic matter present in a given waste water can be theoretically computed, if the organics present in waste water are known. Thus, if the chemical formulas and the concentrations of the chemical compounds present in water are known to us, we can easily calculate the theoretical oxygen demand of each of these compounds by writing the balanced reaction for the compound with oxygen to produce CO_2, H_2O and oxidised inorganic components.

(ix) Bio-Chemical Oxygen Demand (B.O.D.) : The organic matter, infact, is of two types ; i.e. that which is biologically oxidised (i.e. oxidised by bacteria) and is called biologically active or biologically degradable ; and (ii) that which cannot be oxidised biologically, and is called biologically inactive. Truly speaking, while testing a waste water, we are mainly interested in finding out the amount of biologically active organic matter present in it; whereas, the above COD test gives us the total of biologically active as well as biologically inactive organic matter. Hence, further testing is carried out to determine the biochemical oxygen demand (B.O.D.) of sewage, which directly gives us the amount of biologically active organic matter present in sewage.

Q.16 ***The following observations were made on a 3% dilution of waste water:***

Dissolved oxygen (D.O.) of aerated water used for dilution = 3.0 mg/l

Dissolved oxygen (D.O.) of diluted sample after 5 days incubation = 0.8 mg/l

Dissolved oxygen (D.O.) of original sample = 0.6 mg/l

Calculate the B.O.D. of 5 days ultimate BOD of the sample assuming that the deoxygenation coefficient at test temp. is 0.1.

Ans. The 100% contents of the diluted sample consists of 3% waste water and 97% of aerated water used for dilution.

Hence its D.O. = D.O. of waste water × Its content + D.O. of dilution water × its content

$$= 0.6 \times 0.03 + 3.0 \times 0.97$$

$$= 0.018 + 2.91 = 2.928 \text{ mg/}l.$$

D.O. of the incubated sample after 5 days

$$= 0.8 \text{ mg/}l.$$

Thus, D.O. consumed in oxidising organic matter

$$= 2.928 - 0.8 = 2.128 \text{ mg/}l.$$

∴ B.O.D. of 5 days

$$= \text{D.O. consumed} \times \text{Dilution factor}$$

$$= 2.128 \times \frac{100}{3} = 70.93 \text{ mg/}l$$

Ultimate B.O.D. is given by L.

By following equation :

$$Y_t = L\left[1-(10)^{-K_D t}\right]$$

or $$Y_5 = L\left[1-(10)^{-K_D \times 5}\right] \quad ...(1)$$

The value of K_D at test temp. is given as 0.1. Substituting the known values in Eq.(1) above, we have

$$70.93 = L\left[1-(10)^{-0.1\times 5}\right]$$

$$= L\left[1-(10)^{-0.5}\right]$$

$$= L\left[1-\frac{1}{(10)^{0.5}}\right] = L\left[1-\frac{1}{3.16}\right]$$

$$= L[1-3.16] = L \times 0.684$$

or $$L = \frac{70.93}{0.684} = 103.7 \text{mg/}l$$

Q.17 ***What are the various sewer appurtenances? Explain.***

Ans. Sewer Appurtenances : Sewer appurtenances are those structures which are constructed at suitable interval along a sewerage system, and help in its efficient operation and maintenance. These are as follows :

(1) Manholes

- A manhole is an opening constructed on the alignent of a sewer for facilitating a person access to the sewer for the purpose of inspection, testing, cleaning and removal of obstruction from the sewerline.

- Manholes should be built at every change of aligment, gradient or diameter, at the head of all sewers and branches and at every junction of two or more sewer.
- The spacing of manholes above 90 to 150 m may be allowed on straight runs for sewers of diameter 0.9 to 1.5 m. Spacing of manholes at 150 to 200m may be allowed on straight runs for sewers of 1.5 to 2 m diameter.
- The depth < 1 m is considered as normal manhole and depth > 1.5 m is considered as deep manhole.

(2) Lamp Hole : A hole or opening which is provided in a sewer line for lowering a lamp inside is known as Lamp hole. It is a vertical pipe made of stoneware which is connected to the sewer by a teeth joint. At the top a box-line compartment is made which carries a cast iron cover.

Functions of Lamp Hole: An electric lamp is inserted into the sewer for inspection purpose if the sewer is clear, the light will be visible from the adjacent manholes. Then the opreation of cleaning will be done accordingly.

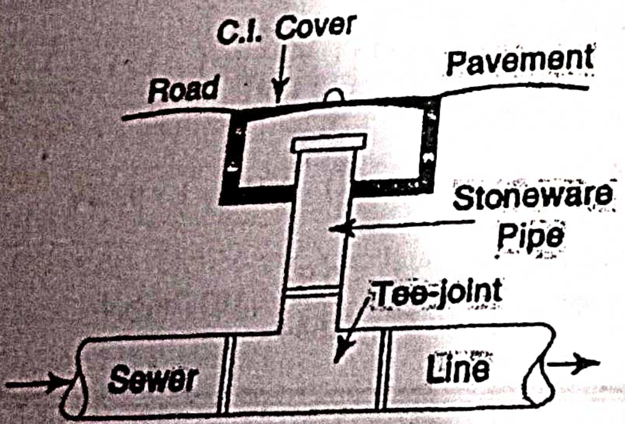


Fig. : Lamp Hole

The construction of lamp hole is advisable for the following conditions:

(i) When the spacings of regular manholes are at longer interval.

(ii) When it is diffcult to construct a regular manhole.

(iii) When a change of direction or change of grade comes in the sewer line.

(3) Grease and Oil Trap : The traps or chambers which are constructed on the sewer line for excluding grease and oil from the sewage are known as grease and oil traps. If sewage contains grease and oil, it sticks to the inter surface of the sewer and decreases the carrying capacity of sewer gradually.

(4) Catch Basin : A catch basin is a rectangular chamber constructed along the sewer line to allow the storm water to enter the sewer by eliminating the silt, grit,etc. at the bottom of the basin.

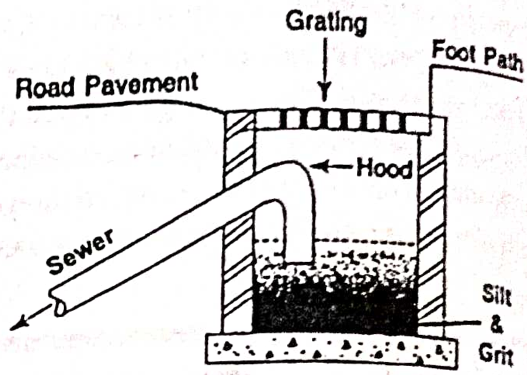


Fig. : Catch Basin

(5) Storm Water Inlet : These are devices meant to admit the surface run off to the sewer storm water inlet having vertical openings is known as the vertical inlet or the curb inlet, and the inlet having horizontal opening is known as the horizontal inlet or gutter inlets.

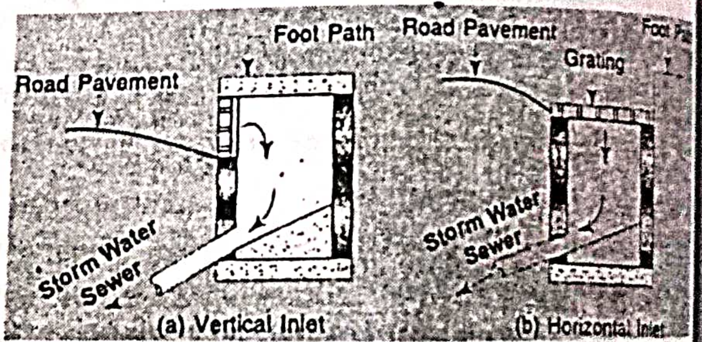


Fig. : Street Inlet

Maximum spacing of inlets would depends upon various conditions of road surface, size and type of inlet and rainfall. A maximum spacing of 30 m is recommended.

(6) Clean Outs : A clean out is an inclined pipe extending from the ground and connected to the under ground sewer for the cleaning sewer pipes.

A clean out is generally provided at the upper ends of lateral sewer in place of manholes.

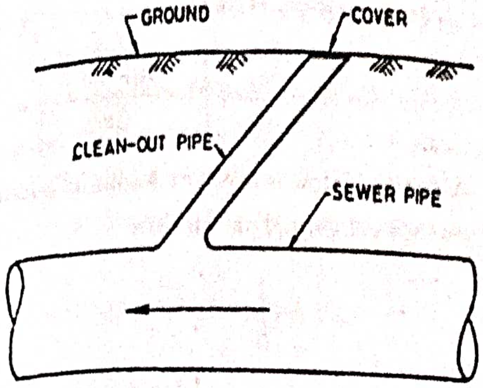


Fig. : Clean Out

(7) **Inverted Siphons (Depressed Sewer) :** Whenever a sewer pipe has to be dropped below the hydraulic gradient line for passing it beneath a valley, a road, a railway, a stream, a tidal estuary or any other depression in the earth's surface or where it passes beneath some other obstructions in its path, it will be known as the inverted siphon or a depressed sewer or a sag pipe. The sewage through such a pipe line will be flowing under pressure (as in the case of water pipe lines)

An inverted siphon is usually made of siphon tubes or pipes made of cast iron or concrete. These pipes are laid between the inlet and the outlet chambers (usually at the same elevation).

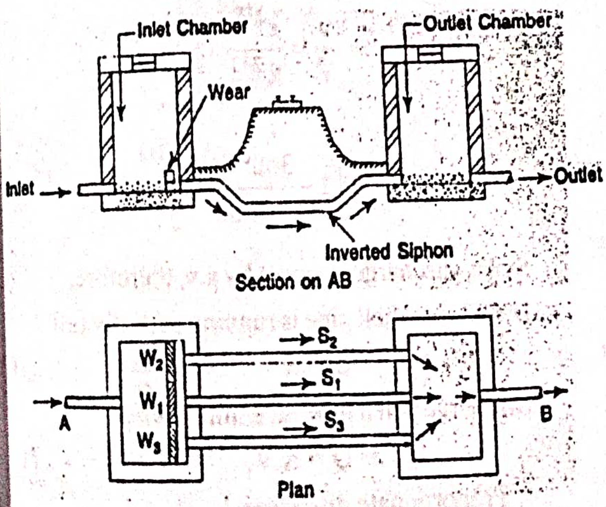


Fig.

To ensure self cleansing velocities (1m/s) for the wide variation in flows, generally two or more pipes not less than 20cm dia are provided in parallel so that upon the average flows, the pipe is used and when the flow exceeds the average flow, the balance flow is taken by the second and subsequent pipes.

Q.18 *Derive the expression of hydraulic characteristics of circular sewer sections running full or partially full.*

Ans. Hydraulic Characteristics of Circular Sewer Sections Running Full or Partially Full : The circular section is most widely adopted for sewer pipes. They may, however, sometimes be of 'egg shape' or 'horse shoe shape' or 'rectangular shape'. The circular sewers may sometimes run full or may run partially full then they run full. Their hydraulic properties will be as given below :

Area of cross-section

$$(a) = A = \frac{\pi}{4}D^2$$

where D is the dia. of the pipe.

Wetted Perimeter

$$(p) = P = \pi D$$

∴ Hydraulic mean depth

$$r = R = \frac{A}{P} = \frac{\frac{\pi}{4}D^2}{\pi D} = \frac{D}{4}$$

When the sewers run partially full, at a depth, say d, as shown in Fig. the hydraulic elements can be worked out as given below :

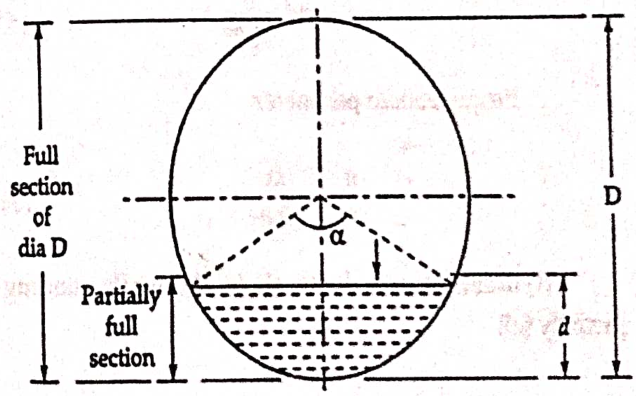


Fig. : Partially full circular sewer section

The depth at partial flow

$$= d = \left[\frac{D}{2} - \frac{D}{2}\cos\frac{\alpha}{2}\right]$$

where α is the central angle in degree, as shown in Fig.

∴ Proportionate depth

$$= \frac{d}{D}$$

$$= \frac{1}{2}\left(1-\cos\frac{\alpha}{2}\right) \quad ...(1)$$

Area of cross section while running partially full

$$= a$$

$$= \frac{\pi D^2}{4}\cdot\frac{\alpha}{360°} - \frac{D}{2}\cos\frac{\alpha}{2}\cdot\frac{D}{2}\sin\frac{\alpha}{2}$$

$$= \frac{\pi D^2}{4}\left[\frac{\alpha}{360°} - \frac{\sin\alpha}{2\pi}\right] \quad ...(2)$$

$$\left[\because \sin\alpha = 2\sin\frac{\alpha}{2}.\cos\frac{\alpha}{2}\right]$$

∴ Proportionate area

$$= \frac{a}{A} = \left[\frac{\alpha}{360°} - \frac{\sin\alpha}{2\pi}\right] \quad ...(3)$$

Wetted perimeter, while running partially full

$$= p = \pi d.\frac{\alpha}{360°} \quad ...(4)$$

∴ Proportionate perimeter

$$= \frac{p}{P} = \frac{\alpha}{360°} \quad ...(5)$$

Hydraulic mean depth (H.M.D), while running partially full

$$= r = \frac{a}{p}$$

$$= \frac{D}{4}\left[1 - \frac{360°\sin\alpha}{2\pi\alpha}\right] \quad ...(6)$$

∴ Proportionate H.M.D

$$= \frac{r}{R} = \left[1 - \frac{360°\sin\alpha}{2\pi\alpha}\right] \quad ...(7)$$

Velocity of flow is given by Manning's formula, as

v = velocity of partial flow

$$= \frac{1}{n}r^{2/3}\sqrt{S_0}$$

[∴ $s = S_0$, i.e., bed slope]

∴ V = velocity, when running full

$$= \frac{1}{N}R^{2/3}\sqrt{S_0}$$

(Bed slope $s = S_0$ remaining constant whether pipe runs full or partially full)

∴ Proportionate velocity

$$= \frac{v}{V} = \frac{N}{n}\cdot\frac{r^{2/3}}{R^{2/3}} \quad ...(8)$$

Assuming that roughness coefficient n does not vary with depth, we have

$$n = N$$

∴ Proportionate velocity

$$= \frac{v}{V} = \frac{r^{2/3}}{R^{2/3}}$$

$$= \left[1 - \frac{360°\sin\alpha}{2\pi\alpha}\right]^{2/3} \quad ...(9)$$

Since, discharge is given by a.v, therefore,

Discharge when pipe is running partially full

$$= q = av \quad ...(10)$$

Discharge when pipe is running full

$$= Q = A.V \quad ...(11)$$

∴ Proportionate discharge

$$= \frac{q}{Q} = \frac{av}{A.V} = \frac{a}{A}\cdot\frac{v}{V}$$

$$= \left[\frac{\alpha}{360°} - \frac{\sin\alpha}{2\pi}\right]\left[1 - \frac{360°\sin\alpha}{2\pi\alpha}\right] \quad ...(12)$$

Q.19 A 25 cm diameter sewer with an invert slope of 1 in 400 is running full. Calculate the velocity and rate of flow in the sewer. Is it self cleansing? Take n = 0.015.

Ans. D = dia. of sewer = 25 cm = 0.25 m

Area of sewer when running full

$$(A) = \frac{\pi}{4}.D^2$$

$$= \frac{\pi}{4}\times(0.25)^2\ m^2 = 0.049\ m^2$$

$$R = \frac{A}{P} = \frac{\frac{\pi}{4}.D^2}{\pi D}$$

$$= \frac{D}{4} = \frac{0.25}{4} = 0.0625 m$$

$$S = \frac{1}{400}$$

$$N = 0.015$$

Using Manning's equation, we have

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

$$= \frac{1}{0.015}\times(0.0625)^{2/3}.\frac{1}{\sqrt{400}}$$

$$= 0.525 m/s$$ **Ans.**

$$Q = V.A = 0.525\times 0.049\ m^3/s$$

$$= 0.0257\ m^3/s.$$ **Ans.**

The velocity in the above sewer is 0.525 m/s, which is slightly more than 0.45 m/s, which is the numerical theoretical value of the self-cleansing velocity. Hence, the sewer can be termed as self-cleansing at full flow, although such self-cleansing should be obtained at partial flow also, such as at 1/2 full. In this case, the velocity at partial flow is likely to be lesser than 0.45 m/s or so, and hence the sewer will no longer remain self-cleansing at partial flow.

Ans.

SOLID WASTE 4

IMPORTANT QUESTIONS

PART-A

Q.1 *What is meant by air quality standards?*

Ans. Air Quality Standards : Ambient air quality criteria, or standards, are concentrations of pollutants in the air and typically refer to outdoor air. The criteria are specified for a variety of reasons including for the protection of human health, buildings, crops, vegetation, ecosystems, as well as for planning and other purposes.

Q.2 *What do you mean by global warming.*

Ans. Global Warming : Global warming is termed to be the increase in the average temperature of Earth's oceans and near surface air. This has been happening in the recent decades and is expected to continue. In fact the term global warming is said to be a specific example of climatic changes. In scientific and common terms, global warming refers to recent warming and also implies a human influence on the same. Global warming is the increase in the average temperature of the Earth's near-surface air and oceans.

Q.3 *Define the term smoke.*

Ans. Smoke : They are finely divided particles resulting from incomplete combustion. it consists mainly of carbon particles and other combustible materials.

Q.4 *Define the aerosols.*

Ans. Aerosols : It refers to the dispersion of solid or liquid particles of microscopic size in gaseous media such as dust, smoke, or mist. It can also be defined as a colloidal system in which the dispersion medium is a gas and the dispersed phase is solid or liquid.

Q.5 *Define the term fumes.*

Ans. Fumes : These are solid particles generated by condensation from the gaseous state, generally after volatilization from melted substances, and often accompanied by a chemical reaction, such as oxidation. Fumes flocculate and sometimes join together.

PART-B

Q.6 *What do you mean by solid waste.*

Ans. Solid Waste : Solid waste is a burning and a critical issue of today as rapid growth in population is directly associated with the increase in the generation of solid waste which further contaminates available natural resources air, water and land. Solid waste maybe defined as a material that has no value to a person who is responsible for it. Solid waste may be any garbage, refuse sludge and other discarded material which may be solid, liquid, semisolid having gaseous material obtained from ndustrial, commercial, mining, and agricultural operations, nd also from community activities (like construction waste, ousehold junk such as furniture, appliances and quipments etc.). Typical solid wastes are leather, rubber, lastics, food wastes, paper, wood and other combustible nd non combustible materials.

.7 *What are the various categories of solid waste.*

ns. **Categories of Solid Waste :** Various types of solid astes obtained from the man made activities are tegorized as :

- Household waste also called municipal waste
- Industrial waste
- Agricultural waste
- Biomedical waste
- Hazardous waste

1. Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue, and waste from streets. This garbage is generated mainly from residential and commercial complexes. Most of the garbage generated in the household can be recycled and reused. Organic kitchen waste such as leftover foodstuff, vegetables peels, and spoilt or dried fruits and vegetables can be recycled by putting them in the compost pits that have been dug in the garden. In 1947 cities and towns in India generated an estimated 6 millions tones of solid waste; in 1997 it was about 48 million tones and more than 25% of the municipal solid waste is not collected at all.

2. Industrial and hospital waste is considered hazardous as they may contain toxic substances. India generates around 7 million tones of hazardous wastes every year, most of which is concentrated in four states: Andhra pradesh, Bihar, Uttar pradesh and Tamilnadu. In the industrial sector, the major generators of hazardous waste are the metal, chemical, paper, pesticide, dye, refining, and rubber goods industries. Some household wastes that can be categorized as hazardous waste include old batteries, shoe polish, paint tins, old medicines, and medicine bottles. The agricultural wastes originate from farms, dust, fertilizers, insecticides, pesticides, harvest residue, pruning in the unused form and are toxic in nature.

3. Hospital waste is generated during the diagnosis, treatment, or immunization of human beings or animals or in research activities in these fields or in the production or testing of biological parameters. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc. These are in the form of disposable syringes, swabs, bandages, body fluids, human excreta etc. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner. It has been roughly estimated that of the 4 kg of waste generated in a hospital at least 1 kg would be infected.

4. Hazardous waste is considered as a poisonous waste that can cause problems for living organisms or the environment. It may be defined as a solid waste or combination of the solid wastes which because of its quality, concentration, or physical, chemical or infectious characteristics may cause serious illness or pose human health hazard when they are improperly stored, treated, transported, disposed or managed. Characterization of hazardous waste is also important and a waste can be considered as hazardous if it shows the characteristics of ignitability, corrosivity, reactivity and toxicity.

Q.8 *Write the causes of solid waste.*

Ans. **Causes of Solid Waste :** The main causes for the rapid growth in the quantity of solid wastes are :

(i) **Over-population :** The ever increasing population is increasing all types of population. Some is true for solid waste pollution too.

(ii) **Urbanization :** Solid waste pollution increases with the increase in urbanization.

(iii) **Affluence :** With production or per capita consumption, there is a tendency to declare items as obsolete, resulting in their discard. This leads to solid waste pollution.

(iv) Technology : Rapidly growing technologies for most economic goods are leading to returnable packaging to non-returnable packaging. For eg. returnable glass bottles/containers being replaced by non-returnable cans, plastic containers etc.

Q.9 ***Explain treatment and disposal of solid waste.***

Ans. Disasters are broadly classified as natural and man made disasters. A detailed classification of disasters is as follows :

1. Geologically Related Disasters

(i) Earthquakes
(ii) Landslides and Mudflows
(iii) Dam Bursts
(iv) Mine Fires

2. Water and Climate Related Disaster

(i) Floods and Drainage Management
(ii) Cyclones
(iii) Droughts
(iv) Tornadoes and Hurricanes
(v) Hailstorm
(vi) Cloud Burst
(vii) Thunder and Lightening
(viii) Snow Avalanches
(ix) Heat Wave and Cold Wave
(x) Sea Erosion

3. Chemical, Industrial and Nuclear Disasters

(i) Chemical and Industrial Disasters
(ii) Nuclear Disasters

4. Accident Related Disasters

(i) Urban Fires
(ii) Village Fire
(iii) Forests Fire
(iv) Electrical Disasters and Fires
(v) Serial Bomb Blasts
(vi) Oil Spill
(vii) Festival Related Disasters
(viii) Air, Road, and Rail Accidents
(ix) Boat Capsizing
(x) Mine Flooding
(xi) Major Building Collapse

5. Biologically Related Disasters

(i) Biological Disasters and Epidemics
(ii) Pest Attacks
(iii) Cattle Epidemics
(iv) Food Poisoning

Q.10 ***What is the importance of disaster management.***

Ans. Disaster may be defined as an event that may occur suddenly or continuously and is responsible for the loss of life and property, destruction of infrastructure and it adversely affects the environment as well. Various types of disasters which have been a recurrent phenomena are Earthquakes, Tsunamis, Cyclones, Floods, Droughts, Landslides, Nuclear, Chemical, Biological, Fire and Environmental Hazards, Air Accidents, Railway Accidents, Nuclear Accident etc. India has been traditionally vulnerable to natural disasters on account of its unique geo- climatic conditions.

Disaster management is a continous and integrated process of planning, organizing, coordinating and implementing the measures which are necessary for prevention of danger or threat of any disaster, mitigation or reduction of risk of any disaster or its severity or consequences, capacity buliding, preparedness to deal with any disaster, prompt response to any threatening disaster situation or disaster, assessing the severity or magnitude of effect of any disaster, evacuation, rescue and relief and rehabilitation and reconstruction.

PART-C

Q.11 ***Define air pollution and discuss about the various air pollutants and their sources.***

Ans. Air Pollution : "Air pollution means the presence in the outdoor atmosphere of one or more contaminants, such as dust, fumes, gas, mist, odor, smoke, or vapor, in quantities of characteristics and of duration such as to be injurious to human, plant or animal life or to property, or which unreasonably interface with the comfortable enjoyment of life and property".

Sources and Classification of Air Pollutants : An inventory of air contaminants is a necessary first step towards control of air pollution. The air pollutants can be either natural or may be the result of the various activities of man in this world like industrial operations. The industrial contaminants can be either by-products of external combustion like smoke, dust, and sulphur oxides or by-products of internal combustion like the reactions in petrol and diesel engines. Further, the emissions can be either primary pollutants or secondary pollutants. The various sources of pollutants can also be broadly grouped under either stationary sources or mobile sources. Sources of air pollution refer to the various locations activities or factors which are responsible for the releasing of pollutants in the atmosphere.

1. Sources of Air Pollution

(i) Anthropogenic sources (human activity) mostly related to burning different kinds of fuel.

- "Stationary sources" include smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices.
- "Mobile sources" include motor vehicles, marine vessels, aircraft and the effect of sound etc.
- Chemicals, dust and controlled burn practices in agriculture and forestry management.
- Fumes from paint, hair spray, varnish, aerosol sprays and other solvents.
- Waste deposition in landfills, which generate methane. Methane is not toxic; however, it is highly flammable and may form explosive mixtures with air. Methane is also an asphyxiant and may displace oxygen in an enclosed space. Asphyxia or suffocation may result if the oxygen concentration is reduced to below 19.5% by displacement.
- Military, such as nuclear weapons, toxic gases, germ warfare and rocketry.

(ii) Natural Sources

- Dust from natural sources, usually large areas of land with little or no vegetation.
- Methane, emitted by the digestion of food by animals, for example cattle.
- Radon gas from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occuring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.
- Smoke and carbon monoxide from wildfires.
- Volcanic activity which produces sulphur, chlorine, and ash particulates.

2. Classification of Air Pollutants

Air pollutants can be classified in two different ways :

(i) According to origin

(ii) According to state of matter

(i) According to Origin : The pollutants are mainly of two types according to origin, primary and secondary pollutants.

(a) Primary Pollutants: Those substance which are directly emitted into the atmosphere and do not change into any other form. They are introduced directly from the source.

Examples are oxides of sulphur, nitrogen, carbon (SO_2, NO_x, CO, CO_2), hydrocarbons, smoke, flyash, dust, fumes, mist, solvent, vapours etc.

(b) Secondary Pollutants: Secondary pollutants are formed in the atmosphere by the interaction of primary pollutants and environment. These pollutants are formed by following photo-chemical reactions, hydrolysis and redox reactions.

Examples of these pollutants are ozone, peroxyacylnitrate (PAN), photochemical smog, acid mist of HNO_3 and H_2SO_4, aldehydes, ketones etc.

(ii) According to State of Matter : Pollutants can be also be classified on the basis of state of matter as follows:

(a) Natural Pollutants : Eg : natural fog, pollen grains, bacteria, and products of volcanic eruption.

(b) Particulate Pollutants : Eg : dust, smoke, mists, fog and fumes.

(c) Gaseous Pollutants : The various gases and vapors, which are important air contaminants are given in the following table.

Table : Air Contaminants

S. No.	Group	Examples
1.	Sulphur compounds	SO_2, SO_3, H_2S, mercaptans
2.	Nitrogen compounds	NO, NO_2, NH_3
3.	Oxygen compounds	O_3,CO,CO_2
4.	Halogen compounds	HF, HCl
5.	Organic compounds	Aldehydes, hydrocarbons
6.	Radioactive compounds	Radioactive gases

Q.12 ***Explain various effects of air pollution on human health and animals health.***

Ans. Harmful Effect of Air Pollution

1. Effect of Air Pollution on Human Health : The air we breathe has not only life supporting properties but also life damaging properties. Under ideal conditions the air we inhale has a qualitative and quantitative balance that maintains the well being of man, but when the balance among the air components is disturbed, or in other wörds, if it is polluted, it may affect human health.

Average man breathes 22,000 times a day and take 16 kg of air each day. It far exceeds the consumption of food and water. It has been estimated that a man can live for 5 weeks without food, for 5 days without water, but only for 5 minutes without air.

All the impurities in the inhaled air do not necessarily cause harm. Depending upon the chemical nature of the pollutants, some may cause harm when present in air in small concentrations and others may do so only if they are present in high concentrations. The duration of exposure of the body is also an important factor. Therefore the prime factors affecting human health are :

(1) Nature of the pollutants
(2) Concentration of the pollutants
(3) Duration of exposure
(4) State of health of the receptor
(5) Age-group of the receptor

The effects of air pollution are great among seniors, children, infants, asthmatics and people with chronic diseases of lungs or heart are thought to be at great risk.

Mechanism of Action of Air Pollution : The effects of air pollution on human health generally occur as a result of contact between the pollutants and the body. Normally, body contact occurs at the surface of the skin and exposed membrane. Contact with exposed membrane surfaces is of utmost importance because of their high absorptive capacity compared to that of the skin. Air-borne gases, vapors, fumes, mists, and dusts may cause irritation of the membranes of the eyes, nose, throat, larynx, tracheobronchial tree and lungs. Some irritants even reach the mucosa of the digestive tract.

Health Effects

1. Eye irritation.
2. Nose and throat irritation.
3. Irritation of the respiratory tract.
4. Gases like hydrogen sulphide, ammonia and mercaptans cause odor nuisance even at low concentrations.
5. Increase in mortality rate and morbidity rate.
6. A variety of particulates, particularly pollens, initiate asthmatic attacks.
7. Chronic pulmonary disease like bronchitis, and asthma, is aggravated by a high concentration of SO_2, NO_2, particulate matter, and photochemical smog.
8. Carbon monoxide ties up the hemoglobin in the blood and consequently increases stress on those suffering from cardiovascular and pulmonary disease.
9. Hydrogen fluoride causes diseases of bone (fluoride), and mottling teeth.
10. Carcinogenic agents cause cancer.
11. Dust particles cause respiratory diseases. Diseases like silicosis, asbestosis, etc. result from specific dusts.
12. Certain heavy metals like lead may enter the body through the lungs and cause poisoning.
13. **Effect of radioactive fallout :** The biological effects of radiation may be somatic or genetic damage. In somatic damage the exposed individual is affected, while in genetic damage the future generations become the victims.

Radioactive fallout from testing of nuclear weapons causes :

(i) Cancer
(ii) Shortening of life span
(iii) Genetic effects or mutation

One significant point we have to note about the effect of radioactive fallout is, it causes long range effects affecting the future of man and hence the future of our civilization.

2. Effects of Air Pollution on Animals : The mechanism by which farm animals gets poisoned is entirely different from that by which human beings exposed polluted atmospheres are poisoned. In case of farm animals it is a two step process :

(1) Accumulation of the air-borne contaminant in the vegetation and forage.
(2) Subsequent poisoning of the animals when they eat the contaminated vegetation.

In case of human beings working in polluted atmospheres in factories, the concern is for the harmful substance that is directly inhaled. In the case of farm animal cattle, the danger obviously is not the result of inhaling the polluted air, but rather the ingestion of forage which has become contaminated with pollutant like fluorine from the air.

The three pollutants responsible for most live stock damage are fluorine, arsenic and lead. These pollutants originate from industrial sources or from dusting and spraying.

(i) Fluorine : Of all farm animals, cattle and sheep are the most susceptible to fluorine toxics. Horse appears to be quite resistant to fluorine poisoning. Poultry are probably the most resistant to fluorine, of all farm animals. Lack of appetite, rapid loss in weight, decline in health and vigor, lameness, periodic diarrhea, muscular weakness and death, characterize the acute form of fluorine poisoning. It may also result in considerable increase of bone fluorine. But acute poisoning due to fluorides is unlikely in majority of the cases.

Fluorine is a cumulative poison under conditions of continuous exposure to sub-acute doses. Fluorine is also a protoplasmic poison. It has a marked affinity for calcium and interferes with normal calcification. Animals have been reported to be more resistant than humans to dental mottling. Cattle and sheep are the most frequently affected animals. Teeth in the process of formation are easily affected. Hence tooth symptoms are a sensitive and unique criterion of chronic fluorosis. Excessive wearing of incisor and molar teeth may occur at high level of fluorine intake.

Bone lesions may develop at any age. A bony over growth may be observed on the leg bones, jaw bones and ribs. Their appearance indicates that there has been a high fluoride intake over along period. Lameness may occur as a result of this over growth on the leg bones. This may be followed by stiffness of joints. Effects of fluorides on skeletal structures are usually of a permanent nature.

Symptoms of advanced fluorosis include lack of appetite, general ill health due to malnutrition, lowered fertility, reduced milk production and growth retardation. The symptoms developed in other species such as rabbits, horses and poultry are similar to that for cattle and sheep, i.e., mottling, staining and wearing of the teeth, bony over growths on the skeleton, stiffness and lethargy and general ill health from malnutrition and starvation.

(ii) Arsenic: Arsenic occurs as an impurity in many ores and in coal. It has been reported to cause poisoning of live stock near various industrial processes and smelters. Just like most of other industrial air contaminants, arsenic may spread over a considerable area from a stack sources. Arsenic is used in some insecticides. The use of insecticides in dusts or sprays on plants can lead to poisoning of cattle. In acute cases the symptoms are severe salivation, thirst, vomiting, uneasiness, feeble and irregular pulse and respiration. The animal stamps. lies down and gets up. There is diarrhea and faces have a garlic odor and sometimes bloddy. Ears become cold; body trembles and develops abnormal temperature and convulsion. Death may occur in a few hours or some days.

Arsenic appears to have a depressing effect upon the central nervous system. The animal becomes dull and exhibits a lack of appetite with a resulting weight loss. Also, there may be chronic diarreha may occur continously. There may be thickening of the skin, anemia and abortion or sterility. Chronic poisoning can result in eventual paralyzing and death.

Arsenic as well as its soluble compounds is extermely poisonous. It has been reported that sheep has been poisoned by as little as 0.25 to 0.50 gms of arsenic daily, where as cattle and horses may tolerate 1.3 to 1.9 gms daily. It has also been reported from laboratory experiments that 10 mg of arsenic per kilogram of body weight per day has produced chronic arsenic poisoning in guineapigs.

(iii) Lead : Lead contamination of the atmosphere takes place on account of various industrial sources such as smelters, coke-ovens and other coal - combustion processes. Lead is also used in dusts and sprays containing lead arsenate. In case of acute lead poisoning the onset is sudden and the course relatively short. Prostration, staggering and inability to rise are prominent symptoms. The pulse is always fast but weak. Some animals may fall suddenly, stiffen the legs and have convulsions. There is complete loss of appetite, paralysis of the digestive tract and diarrhea. Other nervous symptoms in cattle are grinding of the teeth and rapid chewing of the cud. In case of horses, it may result in complete loss of appetite, nervous depression, lethargy and death.

Chronic lead poisoning has been observed frequently in horses that have been grazing on forage near smellters, lead mines and in orchards that have been sprayed. Paralysis of the muscles of the larynx and difficulty in breathing are the main symptoms. Convulsions may occur from the paralysis of the throat and the difficulty in breathing may be unusually severe the persistent, during and after exercise.

Lead is a cumulative poison. Therefore, the continuous ingestion of even very small daily doses will be finally as effective as one toxic dose. Hence in case of slight contamination death can occur after many months and in case of severe contamination depth can occur within 24 hours.

It has also been reported that inadequate calcium in diet increases the retention of lead in the animal body. Low calcium diets may result in lead storage of as much as five times more when compared to that found in animals that receive sufficient amounts of calcium. However, extra quanity of calcium above the amount considered sufficient will not offer additional protection against poisoning.

It is also reported that pollution is now beginning to affect pets and domestic animals in Tokyo and other smog affected cities. Canine patients are found to be suffering from bronchitis, asthma and lack of appetite. Many dogs also suffer from coughs, nose and throat diseases due to increasing air pollution. It is interesting to note that average life of pets in japan is seven to eight years, whereas in developing countries they enjoy a life span 12 to 13 years. Radioactive fallout from the nuclear bombs testing in the atmosphere ionizes the radiation, which have severe biological effects. The effects of radiation on animals are similar qualitatively to those in human beings. The effects may be either acute radiation effect or delayed long term effect. Symptoms of acute radiation injury develop within a period of hours to weeks, following exposure. Only fall out occuring close to the nuclear bombs test site can produce acute radiation effects, because of high degree of radiation received by the animal body.

Q.13 ***Explain the control of air pollution.***

Ans. Control of Air Pollution : For controlling the various adverse effect caused by air pollution, it is essential to check the present scenario primarily. Then, to think about various steps which are required to control the situation in future.

Whatever methods and measures are available, the ultimate result depends on the attitude and co-operation of people. Public awareness in necessary about the current problem. Air pollution can be reduced or checked through the combined efforts of government, NGO's, social groups and local people.

All the methods or measured to check air pollution depends on the type of air pollutant i.e. particulate or gaseous pollutant. These methods are classified into two main categories:

1. Control of Particulate Pollutants
2. Control of Gaseous Pollutants

These two broad categories are further classified on the basis of air pollution controlling methods. This classification has been represented in the following flow diagram.

Control of

Particulates Pollutants	Gaseous Pollutants
1. Dilution	1. Absorption
2. Source control method	2. Adsorption
(i) Change in raw material	3. Combustion
(ii) Change in process	(i) Direct flame combustion
(iii) Modification in equipment	(ii) Thermal combustion
(iv) Zoning	(iii) Catalytic combustion
3. Use special equipments	4. Condensation
(i) Setling chambers	5. Biofilteration
(ii) Cyclones	
(iii) Fabric filters	
(iv) Electrostatic precipitators	
(v) Wet scrubbers	

Control of Particulate Pollutants : Particulates are present in air in the form of dust.smoke, mist, smog, aerosol, fly ash etc. Their size varies from 100 to 0.1 microns generally. They introduce in the atmosphere from anthropogenic stationary sources. They affect man, vegetation and material severely.

As the particulates are clearly observable in flue gas, their removal is of prime concern. There are three basic methods to control particulates (listed in flow chart.). These are:

1. Dilution : This method is also known as " diffusion". By this, ground level pollution can be minimized. Dilution of pollutants can be accomplished by the use of tall stacks. Pollutants can be diffused very easily in upper layers of atmosphere and disperse the contaminants so that the ground level pollution is greatly reduced. Dilution of pollutants in air depend on atmospheric temperature, speed and direction of the wind. The disadvantage of this method is that it is only a short term control measure but show highly undesirable long term effect.

2. Source Control Method : It is most satisfactory to control air pollution at the source level before they get introduced in atmosphere. This method can be accomplished by several ways like raw material change, operational change, change in existing equipment, proper use of land w.r.t industries and civilization i.e. zoning adequate plantation is also one of the effective method in this category.

All the various methods to control air pollution at source are briefly discussed below:

(i) Change in Raw Material : Use of poor quality raw material like ore and fuel always lead to high pollution. In metallurgy, ore handling operations usually result in the emission of large quantity of dust. But, the use of pelleted sintered ore can reduce the dust emission.

Similarly, use of low sulphur containing coal can reduce the particulate to a great extent.

Unleaded petrol can be minimize the concentration of lead particle in atmosphere.

Use of compressed Natural Gas (CNG) and Liquified Petroleum Gas (LPG) in place of coal also minimize the particulate level.

(ii) Change in process : Modifications in already existing industrial process is another important method to control particulates.

In metallurgy, open hearth furnaces have been replaced by oxygen furnaces or electric furnaces, which can reduce smoke, metal oxide fumes, dust etc. with less consumption of energy.

In steel industry, a special process has been used to reduce sulphur contaminant from the fuel. In this process, sulphur bearing fuel is mixed with lime stone ($CaCO_3$) and air and kept in molten iron bath. The carbon present in fuel is partially oxidized to carbon monoxide (CO) whithin the molten iron bath. This gaseous CO comes out from the molten bath and then brunt efficiently. In this process, sulphur remains in the molten bath and from slag with lime stone which is finally removed.

In cement plant, rotary kiln is the main source of dust generation which can be controlled upto a certain limit by adjusting gas velocities within the kiln. Fly - ash emission can be reduced to a great extent by washing the coal before pulverization. The use of fertilizers in the form of liquid or gaseous state in place of solid powder, which are given by injection into the earth, also reduce the dust level.

Sulphuric acid emission (in the form of aerosol) can be reduced by supplying lesser amount of air. It prevents the oxidation of SO_2 into SO_3 which finally stop the generation of sulphuric acid.

Proper and adequate supply of air lead to complete combustion of fuel which reduces smoke and fly ash concentration in air.

Q.14 *Explain treatment and disposal of solid waste.*

Ans. Treatment and Disposal of Solid Waste : Municipal solid waste is a mixture of different kinds of wastes collected from various sources with difference in its physical, chemical and biological composition. Disposal of wastes is to be technically considered depending upon the type of waste, quantity, source and the scale of operation.

The disposal method of waste should utilize the waste to a maximum extent in a sustainable way leaving a cleaner and healthier environment. Commonly adapted different disposal methods by the municipal corporations are :

1. Open dumping
2. Land filling
3. Sanitary land filling
4. Composting
5. Incineration

1. Open dumping : Open dumping is referring to uncovered areas that are used to dump solid waste of all kinds. The waste is untreated uncovered, and not segregated. These sites spread foul smell and become breeding grounds for pests flies and rodent while the liquid seeping through the waste or rainwater run-off from these dumps contaminates nearby land and water thereby spreading disease the underground water.

2. Land Filling : Land fillings are generally located in urban areas where a large amount of waste is generated and has to be dumped in a common place. Unlike an open dump, it is a pit that is dug in the ground. The garbage is dumped and the pit is covered thus preventing the breeding of flies and rats. At the end of each day, a layer of soil is scattered on top of it and some mechanism, usually earth-moving equipment is used to compress the garbage, which now forms a cell. Thus, every day, garbage is dumped and becomes a cell. After the landfill is full, the area is covered with a thick layer of mud and the site can thereafter be developed as a parking lot or a park. Landfills have many problems. All types of waste is dumped in landfills and when water seeps through them it gets contaminated and in turn pollutes the surrounding area. This contamination of ground water and soil through landfills is known as leaching.

3. Sanitary Land Filling : An alternative to landfills which will solve the problem of leaching to some extent is a sanitary landfill which is more hygienic and built in a methodical manner. These are lined with materials that are impermeable such as plastics and clay and are also built over impermeable soil. Constructing sanitary landfills is very costly and they have their own problems. Some authorities claim that often the plastic liner develops cracks as it reacts with various chemical solvents present in the waste. The rate of decomposition in sanitary landfills is also extremely variable. This can be due to the fact that less oxygen is available as the garbage is compressed very tightly. It has also been observed that some biodegradable materials do not decompose in a landfill. Another major problem is the development of methane gas, which occurs when little oxygen is present, i.e. during anaerobic decomposition. In some countries, the methane being produced from sanitary landfills is tapped and sold as fuel.

4. Composting : Composting is most common recycling method of municipal solid waste disposal. The waste which contains 35%-40% of organic matter is recycled by the method of composting, one of the oldest forms of disposal. It is the natural process of decomposition of organic waste that yields manure or compost, which is very rich in nutrients. Composting is a biological process in which micro-organisms, mainly fungi and bacteria, convert degradable organic waste into humus like substance. This finished product which looks like soil, is high in carbon and nitrogen and is an excellent medium for growing plants. The process of composting ensures the waste that is produced in the kitchens is not carelessly thrown and left to rot. It recycles the nutrients and returns them to the soil as nutrients. Apart from being clean, cheap and safe composting can significantly reduce the amount of disposable garbage. The organic fertilizer can be used instead of chemical fertilizers and is better specially when used for vegetables. It increases the soil's ability to hold water and makes the soil easier to cultivate. It helped the soil retain more of the plant nutrients.

5. Incineration : Incineration is also one of the important processes of solid waste disposal. One should not be allowed to increase air pollution like dispersion of particulate in atmosphere by incineration. This is an alternative disposal method to land filling. At high temperature oxidation occurs and destroys structure of organic molecule. Capital cost is high for incineration. Incineration may involve generation of heat of combustion by chain reaction or combustion of halogenated organic sulphur, nitrogen or phosphorus compounds. Combustion in a sequence of step is chain reaction. Halogenated hydrocarbons have low heats of combustion and process is complex leading to the formation of CO_2, Cl_2 gas while sulphur containing compounds liberate CO_2 and SO_2. The nitrogenous organic waste gives NO-NOx. Phosphoritic compounds liberate P_4O_{10}. The organometallic waste leads to formation of ash. When metal gets volatized rotary kiln and liquid injection incinerators are most common.

The multiple hearth furnaces can also be used as the incinerator. It was used for incineration of sludge and waste containing metals. Catalytic incinerator are used primarily for burning dilute combustible waste gas stream. Depending upon kind of the incinerator for organics, acidic, oily halogenated compounds, pesticide, PCB and pathological waste particular type of incinerator must be used, but care sholuld be taken to see that there is no air pollution.

Q.15 ***Explain sanitary land fillings.***

Ans. Sanitary Land Fillings : Disposing of waste in a landfill involves burying waste to dispose of it, and this remains a common practice in most countries. Historically, landfills were often established in disused quarries, mining voids or borrow pits. Land filling shall be restricted to non-biodegradable, inert waste and other waste that are not suitable either for recycling or for biological processing. Sanitary land filling a properly-designed and well-managed landfill is an engineered operation, designed and operated according to acceptable standards. It may be defined as a method of disposing refuse on land without creating nuisance or hazards to public health and is hygienic inexpensive method of disposing of waste materials. Older, poorly-designed or poorly-managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid leacheate. Another common by-product of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as organic waste breaks down anaerobically. This gas can create odor problems, kill surface vegetation, and is a greenhouse gas.

Modern sanitary landfills are more hygienic and are lined with materials that are impermeable such as plastics and clay, and are also built over impermeable soil. These landfills are ultimate means of disposal of all types of residual, residential, commercial and institutional waste as well as unutilized municipal solid waste from waste processing facilities and other types of inorganic waste and inerts that cannot be reused or recycled in the foreseeable future. A sanitary landfill is a site where solid wastes are placed on or in the ground at a carefully selected location by means of engineering techniques that minimize pollution of air, water and soil, and other risks to man and animals. In these landfills wastes are spread in thin and compacted layers to increase its density and stability, and covered by a layer of clean earth to prevent attracting vermin (such as mice or rats). Pollution of surface water and ground water is minimized by lining and contouring the fill, compacting and planting the uppermost cover layer, diverting drainage, and selecting proper soil in sites not subject to flooding.

In sanitary land fill operation, refuse is spread and compacted in thin layers within a small area. This layered structure is usually referred to as a cell. To allow for proper compaction, the cell depth should not exceed about 2 meters. The cell is then covered with a layer of soil which is spread uniformly and then compacted. The best soil for a landfill is one which has less permeability and consists of varying proportions of hydrated aluminum silicates (kaolinite, bentinite, illite and montmorillonite) which, when properly compacted, form a soil mass with a very low hydraulic conductivity. To provide an adequate seal the cover should be at least 20 cm thick. When a number of cells reach the final desired elevation, a final cover of about one meter of earth is placed and it is again compacted. This final cover is necessary to prevent rodents from burrowing into the refuse. The landfill operation is essentially a biological method of waste treatment. The refuse stabilization may be divided into five distinct phases within the overall process.

Advantages of Sanitary Landfills : Main advantage of sanitary landfills is that it has the potential for the recovery of landfill gas as, a source of energy as it can be utilized for power generation or as domestic fuel for direct thermal applications. Major limitation of this method is the costly transportation of solid waste to far away landfill sites because of the public resistance as no one wants landfill site close to the residential area. pollution of underground water gets contaminated by the polluted leachates from the landfill in the absence of proper leacheate collection and treatment system. There is risk also of spontaneous ignition/explosion due to possible build up of methane concentrations in air within the landfill or surroundings if proper gas ventilation is not constructed.

Significant Features for Sanitary Landfills

- The landfill site shall be large enough to last for 20-25 years.
- The landfill site shall be away from habitation clusters, forest areas, water body's monuments, national parks, wetlands and places of important cultural, historical or religious interest.
- A buffer zone of no-development shall be maintained around landfill site and shall be incorporated in the town planning departments land-use plans.
- Landfill site shall be away from airport including airbase. Necessary approval of airport or airbase authorities prior to the setting up of the landfill site shall be obtained in cases where the site is to be located within 20 KM of an airport or airbase.
- Wastes subjected to land filling shall be compacted in thin layers using landfill compactors to achieve high rainfall areas where heavy compactors cannot be used alternative measures shall be adopted.
- Wastes shall be covered immediately or at the end of each working day with minimum 10 cm of soil, inert debris or construction material till such time waste processing facilities for composting or recycling or energy recovery are set up as per schedule-I.
- Prior to the commencement of monsoon season, an intermediate cover 40-65 cm thickness of soil shall be placed on the landfill with proper compaction and grading to prevent infiltration during monsoon. Proper drainage shall be constructed to divert run-off away from active cell of the landfill.
- After completion of landfill, a final cover shall be designed to minimize infiltration and erosion. The final cover shall have a barrier soil layer comprising of 60 cms of clay or amended soil with permeability coefficient less that 1×10^{-7} cm/sec and on top of the soil layer there shall be a drainage layer of 15 cm which further have vegetative layer of 45 cm to support natural plant growth and to minimize erosion.
- Diversion of storm water drains to minimize leachate generation and prevent pollution of surface water and also for avoiding flooding and creation of marshy conditions.
- A non-permeable lining system is constructed at the base and walls of waste disposal area. For landfill receiving residues of waste processing facilities or mixed waste or waste having contamination of hazardous materials (such as aerosols, bleaches, polishes, batteries, waste oils, paint products and pesticides) minimum liner specifications shall be a composite barrier having 1.5 mm high density polyethylene (HDPE) geo membrane, or equivalent, overlying 90 cm of soil (clay or amended soil) having permeability coefficient not greater than 1×10^{-7} cm/sec. The highest level of water table shall be at least two meter below the base of clay or amended soil barrier layer.
- Provisions for management of leachates collection and treatment shall be made.
- Prevention of run-off from landfill area entering any stream, river, lake or pond should be there.
- A vegetative cover shall be provided over the completed site to minimize soil erosion and the plants grown are such that their roots do not penetrate more than 30 cms.

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