Environmental Engineering

Dr. Balaji Kannan

Dr. S. P. Jeyapriya

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-: Course Content Developed By :-

Dr. Balaji Kannan

Assistant Professor (SWC Engg.)

Department of Remote Sensing and GIS, TNAU, Coimbatore

-:Content Reviewed by :-

Dr. S. P. Jeyapriya

Department of Civil Engg.

Government College of Technology, Coimbatore

INDEX

Module 1. IMPORTANCE OF SAFE WATER SUPPLY SYSTEM

Lesson-1 Water supply system

INTRODUCTION

No life can exist without water as it is the elixir of life. Air, Water, Food and Shelter the essential items for any living being in the decreasing order of their importance. Without air, one cannot live even for a few minutes. Next to air, it is water which attains paramount importance for any living being. It is almost available as a free gift to the mankind. It occupies about 17 % of the earth's surface and is an essential element for the survival of human life on earth.

HISTORICAL DEVELOPMENT

Since old ages, there has been search for pure water. The story of water supply begins with the growth of ancient capitals, religious towns, etc. Some of the earliest civilizations flourished along the banks of the rivers Tigris, The Euphrates, the Nile and the Indus. Archaeological excavation reveals that as early as 2500 BC, the people of Harappa, Mohanjodaro and around Indus river basin had well organized water supply systems. Rig Veda makes a mention of digging of wells. Similarly, Indian epics like Ramayana and Mahabharatha make mention of wells as the principal source of water supply. Those wells are mostly of shallow depth, dug near river banks. As the need for water increased and tools were developed, wells were made deeper. Brick-lined wells were built by city dwellers in the Indus River basin as early as 2500 B.C., and wells almost 500 metres (more than 1,600 feet) deep are known to have been used in ancient China.

Apart from India, other major civilizations of the World used wells for their settlements which were located slightly away from springs, lakes and rivers. However, these wells caused water supply problems in times of drought. Hence, Cisterns were constructed for collecting rain water while reservoirs were constructed to store water from streams and rivers during monsoon period. The stored water was conveyed to towns through masonry conduits and aqueducts.

The need to channel water supplies from distant sources was an outcome of the growth of urban communities. Among the most notable of ancient water-conveyance systems are the aqueducts built in the Roman Empire. Some of these impressive works are still in existence.

There was not much drastic improvement in water supply systems in the middle ages. The development in the field of water supply system remained almost static until 17th and 18th centuries but it was again confined to the Europe. It was only the 19th century that the Americans had developed more advanced systems for water supply, its treatment and disposal. The scientific discoveries and engineering inventions of the 18th and 19th centuries created centralized industries to which people flocked for employment. This caused serious water supply problems in those cities and towns. No great schemes of water supply were started until the Industrial Revolution had well passed its first half century. The development of large impounding reservoir was largely due to the necessity of feeding canals constructed during the first phase of the Industrial Revolution.

Water treatment is the alteration of a water source in order to achieve a quality that meets specified goals. At the end of the 19^{th} century and the beginning of the 20^{th}, the main goal was elimination of deadly waterborne diseases. The treatment of public drinking water to remove pathogenic, or disease-causing, microorganisms began about that time. Treatment methods included sand filtration as well as the use of chlorine for disinfection.

The first known illustrated description of sand filters was published in 1685 by Luc Antonio Porzio, an Italian physician. The first filters built in the USA were of the slow-sand type, similar to British design. About 1890 rapid-sand filters were developed in the United States, and coagulants were later introduced to increase their efficiency.

It is astonishing to note that to the middle of the nineteenth century there was no marked progress in sewerage. In 1842, sewerage system was installed in the city of Hamburg, Germany. In 1847, the connection between water supply and sewage pollution was proven in London, England.

The earliest recorded knowledge of water treatment is in the Sanskrit medical lore and Egyptian wall inscriptions. Sanskrit writings dating about 2000 B.C. tell how to purify foul water by boiling in copper vessels, exposure to sunlight, filtering through charcoal, and cooling in an earthen vessel.

ESSENTIALS OF ANY WATER SUPPLY PROJECT / SCHEME

The most important aspect of any water supply scheme is the choice of source of supply. The source should be permanent, reliable and should provide water with minimum impurities. Lakes, streams, springs, are surface sources, whereas wells, infiltration galleries are ground sources. The existence of such a kind of water supply scheme will help in attracting industries and thus promote industrialization and ensuring better living standards.

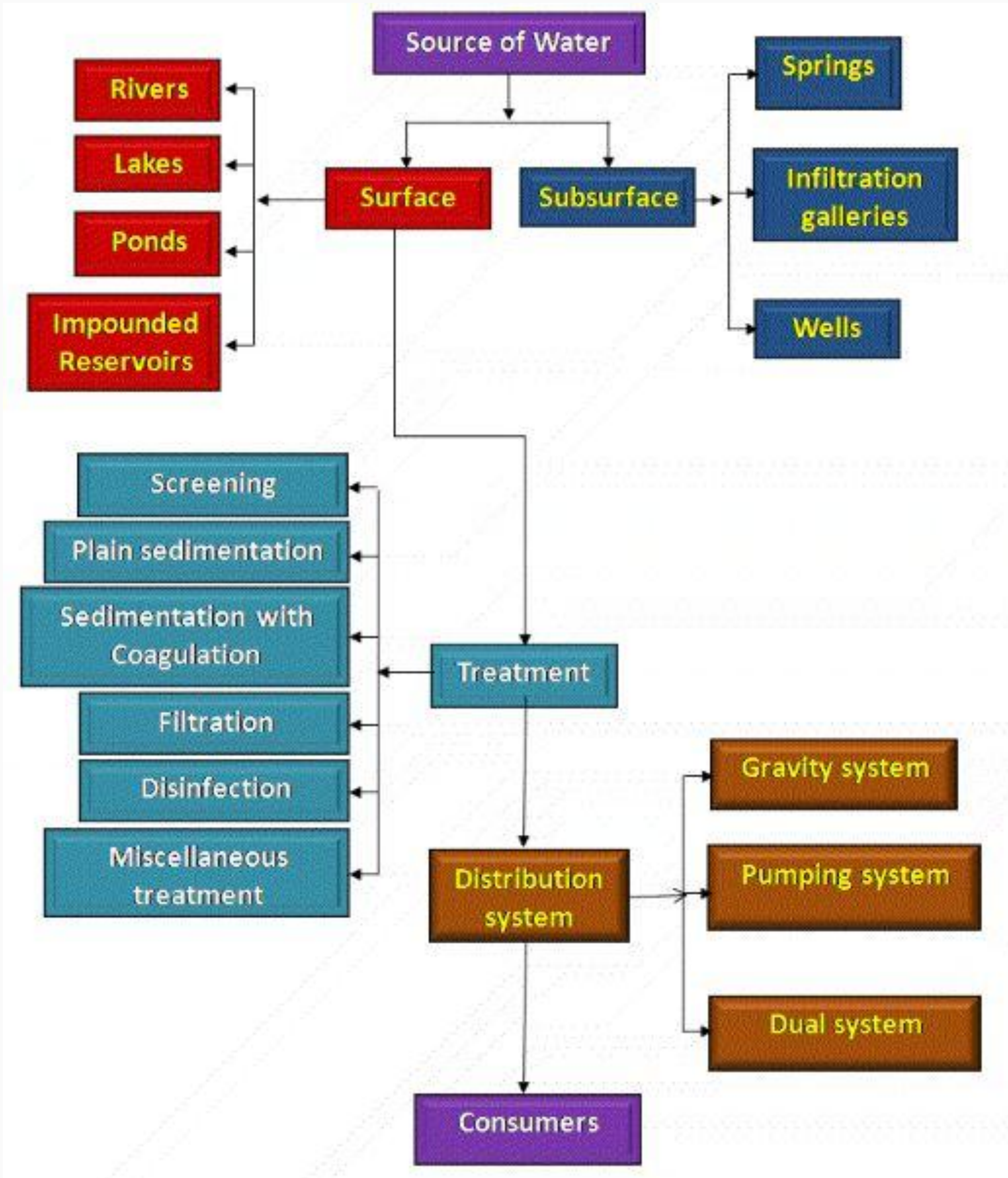
After the selection of source of water, the next step is to construct suitable intake works to collect and carry water to treatment plants for treatment. The treatment of water depends on the source of supply, and the amount and nature of impurities present in it. Water generally has suspended, dissolved, and colloidal impurities. Underground sources are comparatively clear, cool and free from bacteria. However, the treatment may be necessary to remove hardness, iron and manganese. Surface waters may require chemical treatment with coagulation, flocculation and sedimentation, prior to filtration through sand filters.

Aeration and activated carbon process etc. are used for the removal of tastes and odours. Chlorination is almost always essential for disinfection. To prevent cavity formation in teeth, sometimes, soluble fluorides are also mixed with water.

Water is carried through pipes from source to treatment plant, and then from treatment plant to distribution system. Distribution system consists of large arterial mains, distribution mains, minor distributors and appurtenances, including valves, meters and hydrants.

Treated water is stored in clear water reservoirs from where it is distributed to the consumers through distribution system of pipes. In low level areas water will flow directly under gravity but for high level areas, elevated tanks and pumps will have to be installed. The complete outline of water supply system (Fig. 1) is explained in the following flow chart.

Fig. 1 Outline of water supply system



Preliminary investigations for water supply scheme

Any water supply system / project has to be meticulously planned and studied for various view points. The following points should be looked into while considering any water supply system

Sources of water supply

It is quite clear that the success of a water supply scheme entirely depends on good sources of water supply. The sources should be selected while keeping in view its adequacy throughout the year, quality of water and cheapness. The present source of water supply should also be adjusted properly in the new water supply scheme.

Population

From the available census of previous years, the present population should be determined and it is a general practice to make the scheme to accommodate population after three or four decades.

Financial aspects

The availability of fund for the completion of the water supply scheme should be obtained in the initial stages of the scheme itself. The scheme should then be adjusted according to the fund available. Every step should be taken to make the scheme as economical as possible and to take the maximum advantage of it.

Quantity of water

The demand of water depends on various uses such as domestic, industrial, public, trade, etc. The rate of consumption per capita should be decided by carefully considering all these possible uses. This rate, when multiplied by the population, gives the total quantity of water required for the water supply scheme.

Quality of water

The quality of available water decides the line of treatment of water. The more pure water is, the less it the cost of the treatment. Hence, samples of available sources of water should be taken and properly analysed and the results of various tests should be thoroughly studied to suggest an economical water supply scheme for the localit

Sanitary survey

The sanitary survey of area surrounding the available water sources should be carefully carried out. Such a survey helps in estimating the possible pollution or contamination of water from such sources. The sanitary survey includes the collection of information regarding the likely sources of water pollution

Topography

The topographical map of the area to be served by the scheme should be prepared and it should be studied in relation to low lying area, ridges, density of population, etc. The study is essential to evolve a simple but cheap water supply scheme.

Town development trend

The trends of town development in future should be predicted and properly adjusted in the water supply scheme. Such trends may take various forms such as possibility of new industries, public recreation centres, public institutions, residential blocks, etc.

Lesson-2 Importance of a safe water supply system

Water is a basic need for every human being. Most of the world population still does not have centralized water supply with connections to individual households. According to the World Health Organization (WHO), roughly 2.4 billion of the world's population does not have access to an improved sanitation facility and about 1.1 billion people does not have access to safe drinking water. The provision of safe and adequate drinking water to the burgeoning urban population continues to be one of the major challenging tasks for any state.

Water constitutes one of the important physical environments of man and has a direct bearing on the health and hygiene of mankind. There is no denying the fact that the contamination of water leads to numerous health hazards. Water is precious to man and therefore WHO refers to "control of Water supplies to ensure that they are pure and wholesome as one of the primary objectives of environmental sanitation".

Safe water is one of the most important felt needs in public health in developing countries in the twenty first century. The year 2005 marked the beginning of the "International Decade for Action: Water for Life" and renewed effort to achieve the Millennium Development Goal (MDG) to reduce by half the proportion of the world's population without sustainable access to safe drinking water and sanitation by 2015.

The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, known as the JMP, reports every two years on access to drinking water and sanitation worldwide and on progress towards related targets under Millennium Development Goal (MDG). MDG drinking water target, which calls for halving the proportion of the population without sustainable access to safe drinking water between 1990 and 2015, was met in 2010, five years ahead of schedule. However, the report also shows why the job is far from finished. Many still lack safe drinking water, and the world is unlikely to meet the MDG sanitation target. Continued efforts are needed to reduce urban-rural disparities and inequities associated with poverty.

Water is a good carrier of disease germs. If water is not made safe against disease germs, it may become responsible for so many diseases and epidemics. Diseases such as typhoid, cholera, dysentery, etc are the direct causes of defective water supply. Water is a also a very good solvent. If water contains excessive amounts of minerals or poisonous dissolved substances, it will again cause so many difficulties to the public. Therefore, water which is used by the public should be wholesome and must be free from disease producing bacteria, poisonous substances and excessive amount of minerals, and organic matter. Therefore, it is very important that water works must remove all the impurities and bacteria from water and make it wholesome.

The issue of potable water has been attracting attention of the government and the international agencies. The United Nations initiative in the water sector at the global level, Vancouver Habitat 1977 Conference, International Drinking Water and Sanitation Decade

Programme, UN Resolution regarding safe water by 2000 AD etc., bear testimony to the interest, that the inland government and agencies abroad are taking in this regard. Back home, the Rajiv Gandhi National Drinking Water Mission (RGNDWM) under the auspices of the Ministry of Rural Development has been implementing the programmes of potable water supply to the population in rural areas. Thus, there is great need for the improvement in the provision of drinking water, being a basic amenity and it deserves the highest priority in the development efforts of most of the countries which have large gap between the demand of water and of actual availability.

India has a large population and also high rate of growth, and it is very difficult for the government to provide adequate drinking water supply within limited resources. The distinctive feature of the Indian rural water supply scenario was a Mission Approach with appropriate combining of technological, social and organizational innovation. Technologically more efficient water supply systems, including regional pipe water supply schemes on the one hand and dug-wells with energized pump-sets on the other, have been brought in on a large scale. Bhore Committee constituted in 1944, was the first body to draw attention to safe-drinking water supply at the national scale. During the pre-independence period, this Committee laid emphasis on the safe-drinking water supply. In 1947, Madras Government followed the course by appointing a committee. The state government was interested in the formulation of some new policies regarding urban and rural areas in the entire state.

The Environmental Hygiene Committee was appointed in 1948-49 by the Union Government. This committee was the first agency for an overall assessment of the country-wide problems in the entire field of environmental hygiene and it made notable recommendations in the broader field of environmental hygiene and urged for greater activities in this direction. This committee recommended particularly a broad plan to provide water supply and sanitation amenities for 90 per cent of the people within a period of 40 years and also advised a scheme of priorities for certain areas.

The city or town should be given the benefit of water supply scheme, wherever possible. Any water supply project grants the following advantages:

- The growth of new industries for various pipe appurtenances such as air valves, etc. takes place in the locality granting employment opportunities.
- The industries which require pure water for their working are saved from the expenditure of installing their own water purification plant.
- The installation and maintenance of the water supply scheme grant opportunities of employment to the local people.
- The public in general gets treated reliable water for consumption and other uses.
- The sanitation of the area is considerably improved by the adequate water supply
- There are less chances of water borne diseases to occur resulting in saving of human lives and working hours.

- The available water in the locality is used in the best possible manner and its misuse and wastage are avoided to a considerable extent.

Module 2. DOMESTIC WATER REQUIREMENTS FOR URBAN AND RURAL AREAS. SOURCES OF WATER SUPPLY INTAKES AND TRANSPORTATION OF WATER

Lesson-3 Domestic water requirements of urban and rural areas

A small quantity of water is required by a man under normal conditions for his personal use. But this demand of water for other purposes will naturally depend upon the standard of living and degree of culture.

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

We will briefly analyse each category and will discuss how the quantity of water under each category is worked out for the purpose of estimating rate of demand of water.

Domestic purposes

The quantity of water required for domestic purposes can be sub divided as follows:

1. 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, as will be seen, 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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 requirements per capita per day.

Civic or public purposes

The quantity of water required for civic or public purposes can be sub divided as follows:

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.

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.

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.

Fire demand

Usually, a fire occurs in factories and stores. The quantity of wter 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.

Industrial purposes

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

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.

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.

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 per cent of per capita consumption will be required for industrial purposes.

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.

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 per cent of per capita consumption.

Factors affecting water requirement

There are various factors which influence the water requirement. These factors are to be analysed carefully and properly before arriving at the rate of demand for a particular locality. Following are the factors affecting rate of demand

1. Climatic conditions

The requirement of water in summer is more than that in winter. So also is the case with hotter and cooler places. In extreme cold, people may keep water taps open to avoid freezing of pipes. This may result in increased rate of consumption.

2. Cost of water

The rate at which water is supplied to the consumers may also affect the rate of demand. The higher the cost, the lower will be the rate of demand and vice-versa.

3. Distribution pressure

The consumption of water increases with the increase in the distribution pressure. This is due to increase in loss and waste of water at high pressure. For instance, an increase of pressure from 2 to 3 kg/cm^2 may lead to an increase in consumption to the extent of about 25 to 30 per cent. The designer therefore should only provide for distribution pressure which is necessary for rendering satisfactory service.

4. 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.

5. 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.

6. 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.

Lesson-4 Sources of water supply

Sources from which water is available for water supply schemes can conveniently be classified into the following two categories according to their proximity to the ground surface, viz., surface and underground source

Surface waters

In this type of source, the surface runoff is available for water supply schemes. Usual forms of surface sources are as follows:

1. Lakes and streams
2. Ponds
3. Rivers
4. Storage reservoirs

Lakes and streams

A natural lake represents a large body of water within land with impervious bed. Hence, it may be used as source of water supply scheme for nearby localities. The quantity of runoff that goes to the lake should be accurately determined and it should be seen that it is at least equal to the expected demand of locality. Similar is the case with streams which are formed by the surface runoff. It is found that the flow of water in streams is quite ample in rainy season. But it becomes less and less in hot season and sometimes the stream may even become absolutely dry.

The catchment area of lakes and streams is very small and hence, the quantity of water available from them is also very low. Hence, lakes and streams are not considered as principal sources of water supply schemes for the large cities. But they can be adopted as sources of water supply schemes for hilly areas and small towns.

The water which is available from lakes and streams is generally free from undesirable impurities and can therefore be safely used for drinking purposes.

Ponds

A pond is a man-made body of standing water smaller than a lake. Thus ponds are formed due to excessive digging of ground for the construction of roads, houses, etc and they are filled up with water in rainy season. The quantity of water in pond is very small and it contains many impurities.

A pond cannot be adopted as a source of water supply and its water can only be used for washing of clothes or animals only.

Rivers

Since the dawn of civilization, the ancient man settled on the banks of river, drank river water and ate fish caught from river water and sailed down rivers to find out unknown lands.

Large rivers constitute the principal source of water supply schemes for many cities. Some rivers are perennial while others are non-perennial. The former rivers are snowfed and hence, water flows in such rivers for all the seasons. The latter type of rivers dries in summer either wholly or partly and in monsoon, heavy flood visits them. For such types of rivers, it is desirable to store the excess water of flood in monsoons by constructing dams across such rivers. This stored water may then be used in summer.

In order to ascertain the quantity of water available from the river, the discharges at various periods of the year are taken and recorded. The observations over a number of years serve as a good guide for estimating the quantity of water available from the river in any particular period of the year.

Generally, the quantity of water available from non-perennial rivers is variable throughout the year and it is likely to fall down in hot season when demand of water is maximum. It becomes therefore essential to augment such source of water supply by some other sources so as to make the water supply scheme successful.

The quality of surface water obtained from rivers is not reliable. It contains silt and suspended impurities. When completely or partly treated sewage is being discharged into the river at some upstream point, the river water is to be suspected for high contamination. The river water requires to be properly analyzed as regards to the contents of disease bacteria, harmful impurities, etc. The presence of all such undesirable elements in river water requires an exhaustive treatment of water before it can be make fit for drinking purposes. It should however be noted that the quality of river water is subject to the widest variations because it depends on various uncertain factors such as character of the catchment area, the discharges of sewage and industrial wastes, climatic conditions, season of the year, etc. The character of the water differs not only with each individual river, but also at many points along the course of the same river. It is usually found that the quality of river water at its head is good, but it goes on deteriorating as the river proceeds along its course.

The chief use points to be considered in investigating a river supply of water are as follows:

- Adequacy of storage of purified water so as not to disturb the distribution system during periods of fold when the river water is turbid
- Efficiency of the subsequent stages of purification system adopted
- General nature of river, the rate of flow and the distance between the sources of pollution and the intake of the water and
- Relative proportions of the polluting matter and the flow of river when at its minimum.

Storage reservoirs

An artificial lake formed by the construction of dam across a valley is termed as a storage reservoir. It essentially consists of the following three parts

- A dam to hold water
- A spillway to allow the excess water to flow and
- A gate chamber containing necessary valves for regulating the flow of water

At present, this is rather the chief source of water supply schemes for very big cities. The multi purpose reservoirs also make provisions for other uses in addition to water supply such as irrigation and power generation.

Underground sources

In this type of source, the water that has percolated into the ground is brought on the surface. The difference between the terms infiltration and percolation should be noted. The entrance of rain water or melted snow into the ground is referred to as infiltration. The movement of water after entrance is called percolation

It is observed that the surface of earth consists of alternate courses of pervious and impervious strata. The pervious layers are those through which water can easily pass while it is not possible for water to go through an impervious layer.

The pervious layers are known as aquifers or water-bearing strata. If aquifer consists of sand and gravel strata, it gives good supply of drinking water. The aquifer of limestone strata can supply good amount of drinking water, provided there is presence of cracks or fissures in it.

Forms of underground sources

Following are the four forms in which underground sources are found

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

Each of the above form will now be separately discussed in brief

Infiltration galleries

An infiltration gallery is a horizontal or nearly horizontal tunnel which is constructed through water bearing strata. It is sometimes referred to as horizontal well

The gallery is usually constructed of brick walls with slab roof as shown in the figure. The gallery obtains its water from water bearing strata by various porous drain pipes. These pipes are covered with gravel, pebble, etc. so as to prevent the entry of very fine material into the pipe.

The gallery is laid at a slope and the water collected in the gallery is led to a sump from where it is pumped and supplied to consumers after proper treatment. The manholes are provided along the infiltration gallery for the purposes of cleaning and inspection.

The infiltration galleries are useful as sources of water supply when ground water is available in sufficient quantity just below ground level or so. The galleries are usually constructed at depth of about 5 to 10 metres from the ground level.

The infiltration galleries are useful as sources of water supply when ground water is available in sufficient quantity just below ground level or so. The galleries are usually constructed at depth of about 5 to 10 metres from the ground level.

Infiltration wells

In order to collect large quantities of water, infiltration wells are sunk in series in the banks of river. The wells are closed at top and open at bottom. They are constructed of brick masonry with open joints as shown in figure

Lesson-5 Intakes for water supply

Intakes are the structures used for admitting water from the surface sources (i.e., river, reservoir or lake) and conveying it further to the treatment plant. Generally, an intake is a masonry or concrete structure with an aim of providing relatively clean water, free from pollution, sand and objectionable floating material. Its main purpose is to provide calm and still water conditions, so that comparatively purer water may be collected from the source. If intake well has to withstand the effects of severe forces which may be due to striking of high water currents, it may be made from reinforced cement concrete.

Site for location of intake

While selecting a site for location of intakes, the following points should be taken into account:

- Intake work should provide purer water so that its treatment may be less exhaustive
- Heavy water currents should not strike the intake directly
- Intake should be located at such a situation where sufficient quantity of water remains available under all the circumstances
- Site should be well connected by good type or roads
- Site should be such that intake should be in a position to provide more water, if requied to do so.
- Site should not be located in navigation channels, the reason being water in such channels are generally polluted.
- During floods, the intake should not be submerged by the flooding waters.
- As far as possible, the site should be located on the upstream side of the town / city.
- The intake should be so located that good foundation conditions are prevalent and the possibility of scouring is minimal.
- The site should be selected in such a manner that there is ample scope for further expansion.

Design of intake

An intake should be designed keeping in mind the following considerations:

- Intake should be sufficiently heavy so that it may not start floating due to upthrust of water.

- All the forces which are expected to work on intake should be carefully analysed and intake should be designed to withstand all these forces.
- The foundation of the intake should be taken sufficiently deep to avoid overturning.
- Strainers in the form of wire mesh should be provided on all the intake inlets to avoid entry of large floating objects.
- Intake should be of such size and so located that sufficient quantity of water can be obtained from the intake in all circumstances.

Types of intakes

Submerged intake

Submerged intake is the one which is constructed entirely under water. Such an intake is commonly used to obtain supply from a lake. An exposed intake is in the form of a well or tower constructed near the bank of a river, or in some cases even away from the river banks. Exposed intakes are more common due to ease in its operation. A wet intake is that type of intake tower in which the water level is practically the same as the water level of the sources of supply. Such an intake is sometimes known as jack well and is most commonly used. In the case of dry intake, however, there is no water in the water tower. Water enters through entry point directly into the conveying pipes. The dry tower is simply used for the operation of valves etc.

River intake

A river intake is located to the upstream of the city so that pollution is minimized. They are either located sufficiently inside the river so that demands of water are met with in all the seasons of the year, or they may be located near the river bank where a sufficient depth of water is available. Sometimes, an approach channel is constructed and water is led to the intake tower. If the water level in the river is low, a weir may be constructed across it to raise the water level and divert it to the intake tower.

Reservoir intake

When the flow in the river is not guaranteed throughout the year a dam is constructed across it to store water in the reservoir so formed. The reservoir intakes are practically similar to the river intake, except that these are located near the upstream face of the dam where maximum depth of water is available.

Lake Intake

Lake intakes are similar to reservoir intakes if the depth of the water near the banks is reasonable. If however, the depth of the water near the banks is shallow, and greater depth is available only at its centre, a submerged intake is provided.

Canal intake

Sometimes, the source of water supply to a small town may be an irrigation canal passing near the town. The canal intake essentially consists of concrete or masonry intake chamber of rectangular shape, admitting water through a coarse screen. A fine screen is provided over the bell mouth entry of the outlet pipe. The bell mouth entry is located below the expected low water level in the canal. Water may flow from outlet pipe under gravity if the filter house is situated at a lower elevation. Otherwise, the outlet pipe may serve as suction pipe, and the pump house may be located on or near the canal bank. The intake chamber is so constructed that is does not offer any appreciable resistance to normal flow in the canal. Otherwise, the intake chamber is located inside the canal bank. Near the location of the intake work, canal is lined.

Lesson-6 Transportation of water

The term conveyance / transportation refer to taking of water from source to purification plants and from treatment plant to consumers. Water supply system broadly involves transportation of water from the sources to the area of consumption, through free flow channels or conduits or pressure mains. Depending on the topography of the land, conveyance may be in free flow and/or pressure conduits. Transmission of water accounts for an appreciable part of the capital outlay and hence careful consideration fo the economics is called for before deciding on the best mode of conveyance. Care should be taken so that there is no possibility of pollution from surrounding areas.

If the source is at higher level than the treatment plant, the water can flow under gravity, automatically. Similarly after necessary purification of water, it has to be conveyed to the consumers. Therefore, for conveyance of water some sort of devices or structures is required. The arrangement may be in the form of open channels, aqueducts, tunnels or pipes.

Open channels

In any water supply systems, raw water from source to treatment plants may be carried in open channels. Economical sections of open channels are generally trapezoidal while rectangular sections prove economical when rock cutting is involved. The channels are to be properly lined to prevent seepage. Also these kind of channels need to be taken along the gradient and therefore the intitial cost and maintenance cost may be high. While open channels are not recommended for conveyance of treated water, they may be adopted for conveying raw water. If these kind of channels are unlined, they have to be run with limited velocity of flow so that it does not effect scouring.

Aqueducts

The term aqueduct is usually restricted to closed conduits made up of masonry. These can be used for conveyance of water from source to treatment plant or for distribution. Aqueducts normaly run half to two-third full at required capacity of supply in most circumstances. In ancient times, rectangular aqueducts were most commonly used, but these days circular or horse-shoe shaped ones are more common. Masonry aqueducts unless reinforced with steel, are usually constructed in horse-shoe cross-section. This cross-section has good hydraulic properties and resists earth pressure well. It is economical and easy to build.

Tunnels

Tunnels are also like aqueducts. Tunnels which are not under pressure are usually constructed in horse-shoe shape. But if they convey water under pressure, circular cross-section is the best. In pressure tunnels, the depth of cover is generally such that the weight of overlying material overcomes the bursting pressure. Tunnels are used to convey water into the cities from outside sources.

Pipes

Pipe is a circular closed conduit used to convey water from one point to another, under gravity or under pressure. Usually pipes follow the profile of the ground surface closely. If pipes do not run full, they are called to flowing under gravity. But flow under gravity is possible only if the pipe is given a definite longitudinal slope. Pipes running full will be said to be running under pressure. Pipes are mostly made up of materials like cast iron, wrought iron, RCC, asbestos cement, plastic, timber, etc.

Cast iron pipes

Cast iron pipes are used in majority of water conveyance mains because of centuries of satisfactory experience with it. Cast iron pipe is resistant to corrosion and accordingly long lived; its life may be over 100 years.

Advantages

- Cast iron pipes are of moderate cost
- Their jointing is easier
- They are resistant to corrosion
- They have long life

Disadvantages

- They are heavier and hence uneconomical when their diameter is more than 120 cm
- They cannot be used for pressures greater than 7 kg / cm^2.
- They are fragile

Wrought iron and galvanized iron pipes

Wrought iron pipes are manufactured by rolling flat plates of the wrought iron to the proper diameter and welding the edges. Such pipes are much lighter than the cast iron pipes and can be more easily cut, threaded and worked. They look much neater, but are much costlier. They corrode quickly, and hence are used principally for installation within buildings. These pipes are usually protected by coating them with a thin film of molten zinc. Such coated pipes are known as galvanized iron pipes, and they are commonly jointed by screwed and socketed joints.

Steel pipes

Steel pipes of small diameter can be made from the solid, but larger sizes are made by riveting or welding together the edges of suitably-curved plates, the sockets being formed later in a press. The joints may be either transverse or longitudinal. Steel pipes cannot be easily made to resist high external pressures.

Cement concrete pipes

Cement concrete pipes may be either plain or reinforced, and are best made by the spinning process. They may be either precast, or may be cast-in-situ. The plain cement concrete pipes are used for heads up to 7 m while reinforced cement concrete pipes are normally used for head upto 60 m.

Advantages

- They are more suitable to resist the external loads and loads due to backfilling.
- The maintenance cost is low.
- The inside surface of pipes can be made smooth, thus reducing the frictional losses.
- The problem of corrosion is not there.
- Pipes can be cast at site and hence the transportation problems are reduced.
- Due to their heavy weight, the problem of floatation is not there when they are empty.

Disadvantages

- Unreinforced pipes are liable to tensile cracks and they cannot withstand high pressure.
- The tendency of leakage is not ruled out as a result of its porosity and shrinkage cracks.
- It is very difficult to repair them.
- Precast pipes are very heavy, and it is difficult to transport them.

Module 3. DRINKING WATER QUALITY AND INDIAN STANDARDS OF DRINKING WATER.

Lesson-7 Drinking water quality - physical properties

INTRODUCTION

The quality of water is determined by the impurities present in it. The impurities may be physical, chemical or bacteriological in nature. In order to ascertain the quality of water, it is subjected to various tests viz., physical, chemical and bacteriological tests. In this chapter, introduction to quality of water and different physical tests will be dealt.

Impurities in water

It is not possible to find pure water in nature. The rain water as it drops down to the surface of earth absorbs dust and gases from the atmosphere. It is further exposed to organic matter on the surface of earth and by the time, it reaches the source of water supply, it is found to contain various other impurities also.

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

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

Analysis of water

In order to ascertain the quality of water, it is subjected to various tests. These tests can be divided into the following three categories:

1. Physical tests
2. Chemical tests
3. Bacteriological tests

Before we take up the discussion of various tests, it will be necessary to note the precautions which are to be taken while collecting the sample of water to be analysed. In fact, the sampling is the most important part of any analysis because the final results obtained, even from the most accurate analysis, will be misleading, if the samples on which such analysis is carried out, are not representative ones of the liquids to be tested. As a matter of fact, it will be ideal to carry out all the analysis immediately after the collection of samples and quicker the analysis, the more representative will be the results of analysis of the liquid at the time the samples are taken. These precautions are as follows:

1. The water should be collected in bottles, especially of white glass, having well-fitted stoppers. Bottles having holding capacity of about 2 litres of water are necessary for chemical analysis. For bacteriological examination, bottles with smaller capacities will be sufficient

2. Bottles should be thoroughly cleansed, filled thrice with water and thrice emptied before collecting the sample. However, it will not be necessary to carry out such process, if the sealed bottles are directly obtained from the laboratories.

3. When the sample of water is to be collected from a pipe, the water tap should be turned on and the water should be allowed to go waste for at least two minutes so as to prevent the entry of impurities of the pipe in the sample of water. If the sample is to be collected for conducting a bacteriological analysis, the nozzle of the tap should be flamed and made unbearably hot and then cooled by the running water before the bottle is filled.

4. For collecting the sample of water from lake, streams, spring or well the whole bottled with stopper closed should be immersed deep into the surface of water and then only the stopper of the bottle should be removed by means of a clean piece of string and the bottle is filled. Thus the entry of floating materials will be prevented in the bottle.

5. The bottle should be held as far away from its neck as possible. In no case, the water entering the bottle should come into contact with the hand.

6. After collecting the sample, the stopper of bottle should be well secured and the bottles containing samples of water should be labeled stating the source, date and time of collection.

Physical test

Under this category, tests are carried out to examine water fro the following:

1. Colour

2. Taste and Odour

3. Temperature

4. Turbidity

Other physical characteristics for which tests are sometimes carried out are density, electrical conductivity, radioactivity and viscosity.

Colour

An undesirable appearance is produced by colour in water. It spoils the clothes and affects various industrial processes. The measurement of colour in water is carried out by means of a tintometer. The instrument has an eye piece with two holes. A slide of standard coloured water is seen through one hole and in the other hole, the slide of water to be tested is inserted. The intensity of colour in water is measured on a arbitrary scale. The unit of colour on cobalt scale is the colour produced by one milligram of platinum cobalt in one litre of distilled water. The slide of standard numbers are kept ready in the laboratory. For public water supply, the number on cobalt scale should not exceed 20 and should preferably less than 10**.**

It should, however, be remembered that the examinations of colour by matching with slides of standard colours will be sufficient for most of the purposes and it is obvious that the results will be influenced by the personal factor, the conditions of lighting under which the tests are carried out, etc.

Taste and odour

The water possesses taste and odour due to various causes and they make the water unpleasant for drinking. The test is conducted by inhaling through two tubes of osmoscope. One tube is kept in a flask containing diluted water and other one in a flask containing water to be tested. The taste and odour of water may also be tested by threshold number. In this method, water to be tested is diluted with odour-free water and mixture at which odour becomes detectable is determined. It indicates threshold number and other intensities of odour are then worked out. The results of test are greatly affected by the sensitiveness of the observer. For public water supply, the threshold number should not be more than 3.

Temperature

The test for temperature of water has no meaning in the sense that it is not possible to give any treatment to control the temperature in any water supply project. The temperature of water to be supplied from storage reservoir depends on the depth from which it is drawn. The desirable temperature of potable water is 10°C while temperature of 25°C is considered to be objectionable.

The multiplication of bacteria in the waters is more rapid at higher temperatures than in the waters at lower temperature. Hence, when waters with a temperature of about 15°C are collected for bacteriological analysis, they should be cooled down as quickly as possible. It should further be remembered that the air temperature at the time of taking the water sample should always be recorded.

The measurement of temperature of water is done with the help of ordinary thermometers. From the study of temperature, the characteristics of water such as density, viscosity, vapour pressure and surface tension can be determined. It also helps in determining the saturation values of solids and gases which can be dissolved in water and also the rates of chemical, biochemical and biological activity.

Turbidity

The colloidal matter present in water imparts turbidity to water. The turbidity in water may also be due to clay and silt particles, discharges of sewage or industrial wastes, presence of large numbers of micro-organisms etc., and the cloudy appearance developed in water due to turbidity is aesthetically unattractive and it may also be harmful to the consumers.

The turbidity is expressed in terms of parts of suspended matter per million parts of water or shortly written as ppm. It is to be noted that the expression ppm is equivalent to mg per litre. The standard unit of turbidity is the form of finely divided silica in a million parts of distilled water. The permissible turbidity for drinking water is 5 to 10 ppm.

The measurement of turbidity in the field is done by means of a turbidity rod. For laboratory, various turbidimeters are found out to measure the turbidity of water, the most common being Jackson turbidimeter and Baylis turbidimeter.

Lesson-8 Drinking water quality - chemical and biological properties

INTRODUCTION

This chapter deals with the different types of chemical and bacteriological tests done to assess the quality of water

Chemical tests

Under this category, tests are carried out to examine water for the following

1. Chlorides
2. Dissolved gases
3. Hardness
4. pH
5. Alkalinity
6. Nitrogen
7. Total solids

Chlorides

The chloride contents, especially of sodium chloride or salt, are worked out for a sample of water. The excess presence of sodium chloride indicates pollution of water due to sewage, minerals, etc. The water has lower contents of salt than sewage due to the fact that salt consumed in food is excreted by body. For potable water, the highest desirable level of chloride content is 200 mg/litre and its maximum permissible level is 600 mg per litre.

The measurement of chloride contents is carried out as follows:

1. 50 cc of sample of water is taken by pipette in a porcelain dish.
2. Two or three drops of potassium chromate solution are added to the sample of water
3. The chloride content is then determined by titrating with standard solution of silver nitrate.

The silver reacts first with all chlorides and silver chloride thus formed then reacts with potassium chromate. The silver chromate appears as reddish precipitate and the amount of silver nitrate required to produce such reddish precipitate determines the amount of chlorides present in water.

Dissolved gases

The water contains various gases from its contact with the atmosphere and ground surfaces. The usual gases are nitrogen, methane, hydrogen sulphide, carbon dioxide and oxygen. The contents of these dissolved gases in a sample of water are suitably worked out.

The methane concentration is to be studied for its explosive property. The hydrogen sulphide gives disagreeable odour to water even if its amount is very small. The carbon dioxide content indicates biological activities, causes corrosion, increases solubility of many minerals in water and gives taste to water.

Oxygen in the dissolved state is obtained from atmosphere and pure natural surface water is usually saturated with it. The simple test to determine the amount of dissolved oxygen present in a sample of water is to expose water for 4 hours at a temperature of 27°C with 10% acid solution of potassium permanganate. The quantity of oxygen absorbed can then be calculated. This amount, for potable water, should be about 5 to 10 ppm.

Hardness

The hardness or soap-destroying power of water is of two types – temporary hardness and permanent hardness. The temporary hardness is also known as carbonate hardness and it is mainly due to the presence of bicarbonates of calcium and magnesium. It can be removed by boiling or by adding lime to the water. The permanent hardness is also known as non-carbonate hardness and it is due to the presence of sulphates, chlorides and nitrates of calcium and magnesium. It cannot be removed by simply boiling the water. It requires special treatment of water softening.

Total hardness = carbonate hardness or alkalinity + Non carbonate hardness

The excess hardness of water is undesirable because of various reasons such as it causes more consumption of soap, affects the working of dyeing system, provides scales on boilers, causes corrosion and incrustation of pipes, makes food tasteless, etc.,

The hardness is usually measured by the soap solution test. The standard soap solution is added in the sample of water. It is then vigorously shaken for about five minutes and formation of lather is observed. The difference between the total amount of soap solution and the latter factor indicates the hardness of water.

The water, having hardness of about 5 degrees, is reasonably soft water and a very soft water is tasteless. Hence, for potable water, the hardness should preferably be more than 5 degrees but less than 8 degrees or so.

Hydrogen ion concentration (pH)

The acidity or alkalinity of water is measured in terms of its pH value or H-ion concentration. It is desirable to maintain pH value of water very close to 7. The acidic water causes tuberculation and the alkaline water causes incrustation. For potable water, the pH value should be between 7 and 8.50

Following are the two methods which are employed to measure the pH value of water:

Electrometric method

In this method, potentiometer is used to measure the electrical pressure exerted by positively charged H-ions. The pH value is then correspondingly expressed.

Colourimetric method

In this method, chemical reagents are added to water and the colour produced is compared with standard colours of known pH values. A set of sealed tubes containing coloured waters of known pH values is kept in the laboratory for ready reference. This test is simple and hence, it is commonly carried out in public health laboratories. The usual indicators are Benzol yellow, Methyl red, Bromphenol blue, etc., for acidic range and Thymol blue, Phenol red, Tolyl red, etc. for alkaline range.

Alkalinity

The alkalinity is the capacity of a given sample to neutralize a standard solution of acid. The alkalinity is due to the presence of bicarbonate (HCO_3), carbonate (CO_3) or hydroxide (OH).

The determination of alkalinity is very useful in waters and wastes because it provides buffering to resist changes in pH value. The alkalinity is usually divided into the following two parts:

Total alkalinity i.e. above pH 4.5

Caustic alkalinity i.e. above pH 8.2

The alkalinity is measured by volumetric analysis. The commonly adopted two indicators are:

1. Phenolphthalein : pink above pH 8.5 and colourless below pH 8.2
2. Methyl orange : red below pH 4.5 and yellow orange above pH 4.5

Alkalinity in mg/l as $CaCO_3$ = (total reading / volume of sample in ml) x 1000

Nitrogen and its compounds

The nitrogen is present in water in the following four forms:

- Free ammonia
- Albuminoid ammonia
- Nitrites
- Nitrates

The amount of free ammonia in potable water should not exceed 0.15 ppm and that of albuminoid ammonia should not exceed 0.3 ppm. The terms albuminoid ammonia is used to represent the quantity of nitrogen present in water before decomposition of organic matter has started.

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

The presence of nitrites indicates that the organic matter present in water is fully oxidized and the water is no longer harmful. For potable water, the highest desirable level of nitrates is 45 mg per litre.

The free ammonia is measured by simply boiling the water. The ammonia gas is then liberated. The albuminoid ammonia is measured by adding strong alkaline solution of potassium permanganate to water and then boiling it. The ammonia gas is then liberated. The nitrites and nitrates are converted chemically into ammonia and then measured by comparison with standard colours.

Total solids

In this test, the amounts of dissolved and suspended matter present in water are determined separately and then added together to get the total amount of solids present in water. The highest desirable level of total solids is 500 mg/litre and its maximum permissible level is 1500 mg/litre.

For measuring suspended solids, water is filtered through a fine filter and dry material retained on the filter is weighed. The filtered water is evaporated and weight of residue that remains on evaporation represents the amount of dissolved water in water.

Bacteriological tests

The examination of water for the presence of bacteria is very important. The bacteria are very small organisms and it is not possible to detect them by microscopes. Hence, they are detected by circumstantial evidences or chemical reactions. The growth of bacteria takes place by cell division and there are various classifications of bacteria depending upon their shapes, oxygen requirements and effects on mankind. The last classification is important for the water supply engineer from the view point of public health. The bacteria may be harmless to mankind or harmful to mankind. The former category is known as non-pathogenic bacteria and the latter category is known as pathogenic bacteria. It is not possible to isolate pathogenic bacteria with the help of laboratory instruments. Their chances of presence in a sample of water are increased in relation to the amount of non-pathogenic bacteria present in the sample of water.

The combined group of pathogenic and non-pathogenic bacteria is designated by bacillus coli or B-coli group. This group of bacteria is present in the intestines of all living warm-blooded animals.

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

1. Total count or Agar plate count test

2. B-coli test

Total count or Agar plate count test

In this test, bacteria are cultivated on specially prepared medium of agar for different dilutions of sample of water with sterilized water. The diluted sample is placed in an incubator for 24 hours at 37°C or for 48 hours at 20°C. These represent the so-called hot counts and cold counts respectively. The bacterial colonies which are formed, are than counted and the results are computed for 1cc. For potable water, the total count should not exceed 100 per cc.

B-coli test

This test is divided into the following three parts:

1. Presumptive test

2. Confirmed test

3. Completed test

The presumptive test is based on the ability of coliform group to ferment the lactose broth and producing gas. The confirmed test consists of growing cultures of coliform bacteria on media which suppress the growth of other organisms. The completed test is based on the ability of the culture grown in the confirmed test to again ferment the lactose broth.

Presumptive test

Following procedure is adopted in this test:

1. The definite amounts of diluted samples of water are taken in multiples of ten, such as 0.1 cc, 1.0 cc, 10 cc, etc.

2. The water is diluted in standard fermentation tubes containing lactose broth.

3. The tube is maintained at a temperature of 37°C for a period of 48 hours.

4. If gas is seen in the tube after this period is over, it indicates presence of B-coli group and the result of test is treated as positive. If reverse is the case, it indicates the absence of B-coli group and the result of test is treated as negative.

5. A negative result of presumptive test indicates that water is fit for drinking.

Confirmed test

A small portion of lactose broth showing positive presumptive test is carefully transferred to another fermentation tube containing brilliant green lactose bile. If gas is seen in the tube after 48 hours, the result is considered positive and the completed test becomes essential.

Completed test

This test is made by introducing or inoculating bacterial colonies into lactose broth fermentation tubes and agar tubes. The incubation is carried out at 37°C for 24 to 48 hours. If gas is seen after this period, it indicates positive result and further detailed tests are carried out to detect the particular type of bacteria present in water. The absence of gas indicates negative result and water is considered safe for drinking.

B-coli index

This is an index or number which represents approximately the number of B-coli per cc of sample of water under consideration. The presumptive tests are carried out with different dilution ratios of the sample of water with sterilized water. A number of tests is carried out for each proportion and percentage of positive results is recorded. The difference between successive percentages is worked out and it is multiplied by the reciprocal of quantity of solution. The sum of such values indicates B-coli index. For potable water, B-coli index should be preferably less than 3 and it should not exceed 10 in any case.

Lesson-9 Indian Standards of drinking water

This chapter deals with the Indian standards for safe drinking water

Sl. No.	Substance or characteristic	Requirement Desirable limit	Undesirable effect outside the desirable	Permissible limit in the absence of alternate Source	Remarks
Essential Characteristic					
1.	Colour Hazen Units, Max	5	Above 5, consumer acceptance decreases	25	Extended to 25 only if toxic Substance are not suspect in absence of alternate sources
2.	Odour	Unobjectionable	-	-	a) test cold and when heated b) test are several dilutions
3.	Taste	Agreeable	-	-	Test to be conducted only after safely has been established
4.	Turbidity (NTU) Max	5	Above 5, consumer acceptance decreases	10	-
5.	pH value	6.5 to 8.5	Beyond this range the water will after the mucous membrane and/or water supply system	No relaxation	-
6.	Total Hardness (mg/L) $CaCO_3$	300	Encrustation in water supply structure and adverse effects on domestic use	600	-
7.	Iron (mg/L, Fe) Max	0.3	Beyond this limit taste/appearance are affected; has adverse effects on domestic uses and water supply structure and promotes iron bacteria	1.0	-

8.	Chlorides 250 (mg/L, Cl) Max	250	Beyond effects outside the desirable limit	1000	-
9.	Residual free Chlorine (mg/L), Max	0.2	-	-	To be applicable only when water is chlorinated. Tested at customer end. When protection against viral infection is required, it should be min. 0.5 mg/L.
Desirable Characteristics					
10.	Dissolved solids mg/L. Max	500	Beyond this, palatability decreases and may cause gastrointestinal irritation.	2000	-
11.	Calcium (mg/L, Ca) Max.	75	Encrustation in water supply structure and adverse effects on domestic use.	200	-
12.	Magnesium (mg/L, Mg) Max	30	Encrustation in water supply structure and adverse effects on domestic use.	100	-
13.	Copper (mg/L, Cu) Max	0.05	Astringent taste dis coloration and corrosion of pipes fittings and utensils will be caused beyond this.	1.5	-
14.	Manganese (mg/L, Mn) Max	0.1	Beyond this limit taste/appearance are affected, has advers effect on domestic use and water supply structure	0.3	-
15.	Sulphate (mg/L, SO4) Max.	200	Beyond this causes gastro intestinal irritation when magnesium or sodium are present	400	May be extended upto 400 provided magnesium (as Mg) does not exceed 30
16.	Nitrate (mg/L, NO_3) Max.	45	Beyond this methaemo globinemia takes place.	100	-
17.	Fluoride (mg/L, F)	1.0	Fluoride may be kept as low as possible. High	1.5	-

	Max.		fluoride may cause fluorosis.		
18.	Phenolic Compounds (mg/L C6H5OH) Max.	0.001	Beyond this, it may cause objectionable taste and odour	0.002	-
19.	Mercury (mg/L Hg) Max	0.001	Beyond this the water becomes toxic	No Relaxation.	To be tested when pollution is suspected
20	Cadmium (mg/L, Cd) Max	0.01	Beyond this the water becomes toxic	No Relaxation.	To be tested when pollution is suspected
21.	Selenium (mg/L, Se) Max	0.01	Beyond this the water becomes toxic.	No Relaxation.	To be tested when pollution is suspected
22.	Arsenic (mg/L, As) Max.	0.05	Beyond this the water becomes toxic	No Relaxation	To be tested when pollution is suspected
23.	Cyanide	0.05	Beyond this the water becomes toxic	No Relaxation	To be tested when pollution is suspected
24.	Lead (mg/L Pb) Max.	0.05	Beyond this the water becomes toxic	No Relaxation	To be tested when pollution is suspected
25.	Zinc (mg/L, Zn) Max.	5	Beyond this limit it can cause astringent taste and an opalescence in water	15	To be tested when pollution is suspected
26.	Anionic detergents (mg/L, MBAS) Max	0.2	Beyond this limit it can cause a light froth in water	1.0	To be tested when pollution is suspected
27.	Chromium (mg/L, Cr^{6+})	0.05	May be carcinogenic above this limit	-	-
28.	Polynuclear Aromatic Hydrocarbons (mg/l, PAH) Max	-	May be carcinogenic	-	-
29.	Mineral oil	0.01	Beyond this limit,	0.03	To be tested when

	(mg/L)		undesirable taste and odour after chlorination takes place		pollution is suspected
30.	Pesticides (mg/L) max	Absent	Toxic	0.001	-
Radioactive materials					
31.	Alpha emitters Bq/L Max	-	-	0.1	-
32.	Beta emitters Pci/L Max	-	-	1.0	-
33.	Alkalinity (mg/L,) Max	200	Beyond this limit, taste becomes unpleasant	600	-
34.	Aluminum (mg/L, Al) Max	0.03	Cumulative effect is reported to cause dementia	0.2	
35.	Boron (mg/L) Max	1.0	-	5.0	-

Module 4. INTRODUCTION TO WATER TREATMENT, DOMESTIC WATER: QUANTITY, TREATMENT

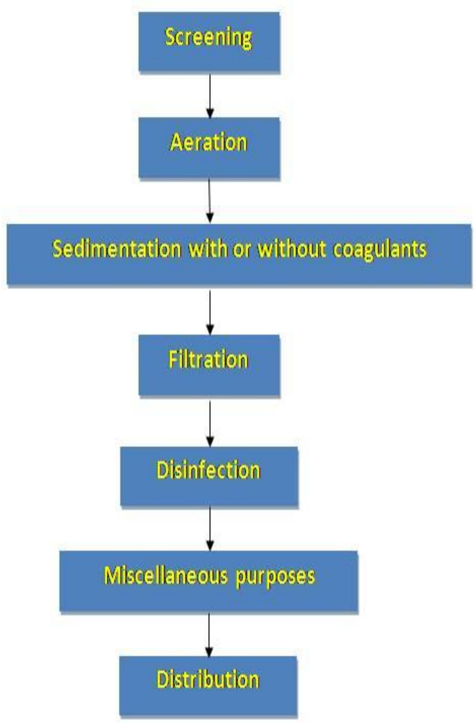
Lesson-10 Introduction to water treatment

In this lesson, you will be exposed to various water treatment process in hierarchial order

The available raw waters must be treated and purified before they can be supplied to the public for their domestic, industrial or any other uses. The extent of treatment required to be given to the particular water depends upon the characteristics and quality of the available water, and also upon the quality requirements for the intended use.

Raw water may contain suspended, colloidal and dissolved impurities. The purpose of water treatments is to remove all those impurities which are objectionable either from taste and odour perspective or from public health perspective.

The layout of a conventional water treatment plant is shown below



For surface waters, following are the treatment processes that are generally adopted

Screening

This is adopted to remove all the floating matter from surface waters. It is generally provided at the intake point

Aeration

This is adopted to remove objectionable tastes and colour and also to remove the dissolved gases such as carbon-dioixide, hydrogen sulphide etc. The iron and manganese present in water also oxidized to some extent. This process is optional and is not adopted in cases where water does not contain objectionable taste and odour.

Sedimentation with or without coagulants

The purpose of sedimentation is to remove the suspended impurities. With the help of plain sedimentation, silt, sand etc. can be removed. However, with the help of sedimentation with coagulants, very fine suspended particles and some bacteria can be removed.

Filtration

The process of filtration forms the most important stage in the purification of water. Filtration removes very fine suspended impurities and colloidal impurities that may have escaped the sedimentation tanks. In addition to this, the micro-organisms present in the water are largely removed.

Disinfection

It is carried out to eliminate or reduce to a safe minimum limit, the remaining micro-organisms and to prevent the contamination of water during its transit from the treatment plant to the place of its consumption

Miscellaneous processes

These include water softening, desalination, removal of iron, manganese and other harmful constituents.

Lesson-11 Quantity of water

INTRODUCTION

It is very difficult to ascertain the quantity of water required for a particular town. It involves the assumptions of many variable factors and foresight of the designer plays an important role in arriving at this quantity. This lesson deals with the estimation of quantity of water and the factors involved in its estimation

The problem of estimating the quantity of water may be tackled by studying in detail the following two factors:

Rate of demand

The requirements of water for various uses are properly analysed and ultimately, the rate of consumption per head is worked out.

Population

The persons to be served by the scheme are calculated and estimate of future population if worked out with the help of suitable method.

Rate of demand

A small quantity of water is required by a man under normal conditions for his personal use. But his demand of water for other purposes will naturally depend upon the standard of living and degree of culture. In order to arrive at a reasonable value of rate of demand 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

We will briefly analyse each category and will discuss how the quantity of water under each category is worked out for the purpose of estimating rate of demand of water.

Domestic purposes

The quantity of water required for domestic purposes can be sub divided as follows:

Drinking

A human body contains about 70 per cent 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, as will be seen, 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.

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 head per day.

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 head per day and for tub-bath, it may be taken as about 50 to 80 litres per head per day.

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 head per day

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 head per day

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

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 requirement of water for domestic purposes roughly works about to 40% to 5% of the total water requirements per capita per day.

Civic or public purposes

The quantity of water required for civic or public purposes can be sub divided as follows:

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 head per day.

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 head per day.

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.

Fire demand

Usually, a fire occurs in factories and stores. The quantity of wter 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 day

P = population in thousands

This formula is used in England for moderate provision

John R. Freeman's formula

$$1136.50\left(\frac{P}{5}\right)+10$$

Q = quantity of water required in litres per minute

P = population in thousands

Kuichling's formula

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

Q = quantity of water required in litres per minute

P = population in thousands

National Board of Fire Underwriters' formula

$$Q = 4637\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

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 head per day for fire demand will be sufficient.

Industrial purposes

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

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

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.

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 per cent of per capita consumption will be required for industrial purposes.

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 head per day may be taken as water requirements for this purpose.

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 per cent of per capita consumption.

Factors affecting rate of demand

There are various factors which influence the rate of demand of water. These factors are to be analysed carefully and properly before arriving at the rate of demand for a particular locality. Following are the factors affecting rate of demand

Climatic conditions

The requirement of water in summer is more than that in winter. So also is the case with hotter and cooler places. In extreme cold, people may keep water taps open to avoid freezing of pipes. This may result in increased rate of consumption.

Cost of water

The rate at which water is supplied to the consumers may also affect the rate of demand. The higher the cost, the lower will be the rate of demand and vice-versa.

Distribution pressure

The consumption of water increases with the increase in the distribution pressure. This is due to increase in loss and waste of water at high pressure. For instance, an increase of pressure from 2 to 3 kg/cm^2 may lead to an increase in consumption to the extent of about 25 to 30 per cent. The designer therefore should only provide for distribution pressure which is necessary for rendering satisfactory service.

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

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.

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. The engineers dealing with water supply schemes, recommend installation of water meters, when the following two conditions are existing:

1. Quantity of water that is available from the source is limited

2. Total cost of water supply scheme is an important consideration.

Quality of water

The improvement in quality of water may result in the increase of rate of consumption. The public using the improved water will consider it safe and may make various uses of the available water. On the other hand, if water has unpleasant taste or odour, the rate of consumption will come down.

Sewerage

The existence of sewerage system in a locality will lead to an increase in use of water for civic or public purposes. The people will also use more quantity of water for flushing sanitary units such as urinals and water closets.

Size of city

Generally, the smaller the city, the lower is the rate of demand. But the presence of a water-consuming industry in a small town may result in a higher rate of demand, even if the town is small.

System of supply

The supply of water may be continuous or intermittent. In the former case, water is supplied for 24 hours and in the latter case, it is supplied for certain duration of the day only. It is claimed that the intermittent supply system will reduce rate of demand. But sometimes, the results are proved to be disappointing, mainly for the following two reasons

- During non-supply period, the water taps are kept open and hence, when the supply starts, water flowing through open taps is unattended and this results in waste of water.

- There is tendency of many people to throw away water stored previously during non-supply hours and to collect fresh water. This also results in waste of water.

Lesson-12 Water treatment - sedimentation and coagulation

INTRODUCTION

Sedimentation and coagulation is the starting phase of treating water. This chapter deals with the theory of sedimentation and coagulation and their processes.

Sedimentation

Having examined the quality of water, a line of treatment is to be recommended for impure water to make it potable or fit for drinking purposes. The first stage of treatment is the prefiltration of water and it includes provision of sedimentation tanks or settling tanks or clarifiers. These tanks remove inorganic impurities and make water fit for the next process of filtration.

The sedimentation tanks are designed to give complete rest to the flowing water or water is allowed to flow at a very low velocity. The heavier inorganic impurities settle at the bottom of tanks and the lighter inorganic impurities float on the surface of liquid level. The former impurities are removed from the bottom while the latter impurities are removed from the top.

The actual amount of matter removed by sedimentation tanks depends on several factors such as design of tank, detention period, size of suspended particles, velocity of flow, etc. It is estimated that plain sedimentation tank can remove about 60% of suspended matter and about 75% of bacterial load from water.

In order to make the sedimentation tanks effective, coagulants are added to water before it is bought to the sedimentation tanks. The topic of coagulation is discussed at length in the next chapter.

The sedimentation tanks are located near filter units and in case of variations in demand, they may even be called upto to work as storage reservoirs. The height of location of sedimentation tank should be decided by keeping in view the natural configuration of locality and the pressure head required.

Where filtration is to be adopted, it is essential to provide sedimentation tanks. The treated water from sedimentation tanks enters filter units for further purification.

Theory of sedimentation

The particles which are heavier than water are naturally likely to settle down due to force of gravity. In water, there are mainly two types of impurities.

(1) Inorganic suspended solids having specific gravity of about 2.65; and

(2) Organic suspended solids having specific gravity of about 1.04

The particles having specific gravity of about 1.20 or so readily settle down at the bottom of tank. But it is difficult to cause the settlement of lighter particles. This phenomenon of settling down of particles at the bottom of sedimentation tank is known as **hydraulic subsidence** and every particle has its own hydraulic settling value which will cause its hydraulic subsidence.

The process of settlement of a particle is obstructed or opposed by the following three forces:

(1) Velocity of flow: The particle is moved in the horizontal direction by the velocity of flow

(2) Size and shape of particle : The force of gravity depends on the weight of particle and tends to move the particle in vertical direction. Consequently, small particles will settle down very slowly.

(3) Viscosity of water: This force offers frictional resistance to the movement of water and it mainly depends on the temperature of water

In 1815, G.G. Stokes developed and expression known as Stokes's law and it is applicable to the discrete particles. The particles which do not change in size, shape or mass during settling are known as discrete particles. The expression is as follows:

$$v=418{d^2}\left({s-{s_1}}\right)\frac{{3\cdot T+70}}{{100}}$$

v = Velocity of settlement in mm per second

s= Specific gravity of the particle

s_1= Specific gravity of water

d = Diameter of particle in mm

T= Temperature in ^{o}C

It was found by Hazen the Stoke's law was applicable for particles having diameter small than 0.10mm or so. For particles of greater diameter than 0.0mm, he found that velocity of settlement was proportional to the first power of diameter and not to the second power of diameter as expressed in Stoke's law. Hence, Stokes's law for bigger particles would be :

Now, out of three forces which oppose the tendency of settlement of particle, attempts are made to control the first and second forces in purification process of water. The third force, namely, viscosity of water, is unpracticable to control as it is dependent on temperature. The control of temperature of a huge quantity of water becomes unreasonable and uneconomical.

The velocity of flow can be decreased by increasing the length of travel and thus a particle is allowed to stay for a longer period in the sedimentation tank. The particle is thus given maximum opportunity to come down and settle at the bottom of tank.

The size and shape of the particle are altered by the addition of certain chemicals in water. These chemicals are known as coagulants.

Coagulation

The source of water supply for the most of public water supply project is surface water. This water is turbid and contains many suspended impurities. It also possesses colour which may be due to colloidal matter and dissolved organic material in water. The turbidity is mainly due to the presence of very fine particles of clay, silt and organic matter.

All these impurities are in a finely divided state and it is not possible to detain them in plain sedimentation tanks unless such tanks are designed for longer detention periods. The other alternative to remove such particles is to increase their size so that they become settleable. The purpose of coagulation is thus to make particles of bigger size by adding certain chemicals know as coagulants to water. The coagulants react with the impurities in water and convert them in settleable size.

The coagulation is to be adopted when turbidity of water exceeds about 40 p.p.m. It should, however, be remembered that it is not complete process by itself. It simply assists plain sedimentation and it is to be followed by the process of filtration. Thus, coagulation is merely a process by which impure water is prepared for successful purification by rapid sand filtration.

Principle of coagulation

The principal of coagulation can be explained from the following two considerations.

1. Floc formation

When coagulants are dissolved in water and thoroughly mixed with it, they produce a thick gelatinous precipitate. This precipitate is known as floc and this floc has got the property of arresting the suspended impurities in water during its downward travel towards the bottom of tank.

2.Electric charges

The ions of the floc are found to possess positive electric charge. Hence, they will attract the negatively charged colloidal particles of clay and thus they cause the removal of such particles from water.

Flocculation

The floc produced by the action of coagulants with water is heavy and hence, it starts to settle down at the bottom of tank. As it descends, it absorbs and catches more and more suspended impurities present in water. It thus slowly goes on increasing in size. During this process, some amount of bacterial removal also takes place. The surface of floc is sufficiently wide to arrest colloidal and organic matter present in water. The term flocculation is used to denote the process of floc formation and thus flocculation follows the addition of coagulant and its efficiency depends on the following factors.

1. Dosage of coagulant

The dosage or quantity of coagulant should be carefully determined so as to cause visible floc. The quantity of coagulants should be such that turbidity of water is brought down to the limit of 10 to 25 p.p.m.

2. Feeding

The feeding of coagulants may be in powder form or in solution form, the latter being more popular

3. Mixing

The coagulants should be properly mixed with water so as to cause a uniform mass. In the beginning, the mixing may be quick for a period of about 30 to 60 seconds or so.

4. pH value

Depending upon the quality of water and coagulant adopted, suitable pH value should be determined. The pH value should be actually tested in the laboratory at regular intervals. To remove acidity, lime is added to water and to remove alkalinity, sulphuric acid is added to water.

5. Velocity

The floc should be allowed to move gently after initial quick mixing, The gentle movement of floc results in collision of particles and ultimately, the floc grows in size. The detention period of coagulated sedimentation tanks is about 3 to 4 hours.

The processes of coagulation and flocculation are greatly influenced by the physical characteristics of water, its dissolved constituents and the temperature. The failures in coagulation plant are due to incorrect does of the coagulant, inadequate mixing arrangements, improper tank design, etc. Hence, the characteristics of water to be submitted to the coagulation plant should be properly studied before deciding the details of the plant.

Usual coagulants

Following six are the usual coagulants which are adopted for coagulation

1. Aluminium sulphate
2. Chlorinated chopperas
3. Ferrous sulphate and lime
4. Magnesium carbonate
5. Polyelectrolytes
6. Sodium aluminate

Lesson-13 Water treatment - Filtration

INTRODUCTION

In this chapter, the concept of filtration and various types of filter are discussed

Theory of filtration

The process of filtration forms the most important stage in the purification of water. It usually consists in allowing water to pass through a thick layer of sand. It has been noticed from experience that during the process of filtration, the following effects occur on water:

1. The suspended and colloidal impurities which are present in water in a finely divided state are removed to a great extent
2. The chemical characteristics of water are altered
3. The number of bacteria present in water is also considerably reduced.

The theory of filtration to explain why such effects take place is based on the following four actions:

1. Mechanical straining
2. Sedimentation
3. Biological metabolism
4. Electrolytic changes

Mechanical straining

The suspended particles which are unable to pass through the voids of sand grains are arrested and removed by the action of mechanical straining.

Sedimentation

The voids between sand grains of filter act more or less like small sedimentation tanks. The particles of impurities, arrested in these voids, adhere to particles of sand grains, mainly for the following two reasons:

1. Due to the presence of a gelatinous film or coating developed on sand grains by previously caught bacteria and colloidal matter and
2. Due to the physical attraction between the two particles of matter.

Biological metabolism

The growth and life process of the living cells is known as biological metabolism and the action of filter is explained on the basis of biological metabolism. When bacteria are caught in the voids of sand grains, a zoological film is formed around the sand grains. The film contains large colonies of living bacteria. The bacteria feed on the organic impurities contained in water. They convert such impurities into harmless compounds by the complex biochemical reactions

Electrolytic changes

The action of filter is also explained by the ionic theory. It states that when two substances with opposite electric charges are brought into contact with each other, the electric charges are neutralized and in doing so, new chemical substances are formed. It is observed that some of the sand grains of filter are charged with electricity of some polarity. Hence, when particles of suspended and dissolved matter containing electricity of opposite polarity come into contact with sand grains, they neutralize each other and it ultimately results in the alteration of chemical characteristics of water. After some interval of time, the electrical power of sand grains gets exhausted. At that time, it becomes necessary to clean the filter and restore it with its property.

Filter sand

The sand to be used for filter should be free from clay, loam, vegetable matter, organic impurities, etc. It should also be uniform in nature and size. The filter sand is classified on the basis of its effective size and uniformity coefficient.

The **effective size** of sand indicates the size of sieve in mm through which ten per cent of the sample by weight will pass.

The **uniformity coefficient** of sand is the ratio of sieve size in mm through which 60 per cent of the sample of sand by weight will pass to the effective size of sand. For instance, suppose the effective size of sand is 0.50 mm. If 60 percent of sand from the same sample passes through 0.60 mm sieve, the uniformity coefficient will be 0.60 / 0.50 = 1.20

Instead of sand, sometimes anthrafilt is used. It is made from anthracite which is a stone-coal that burns nearly without flame or smoke. It almost entirely consists of carbon. This material is found to possess many advantages such as low cost in handling, high rate of filtration, durability, better efficiency, etc. But as sand is readily available, the usual practice is to recommend bed of sand for filters.

Classification of filters

The filters are classified into the following categories:

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

SLOW SAND FILTERS

Purpose

In case of slow sand filtration, the water is allowed to pass slowly through a layer of sand placed above the base material and thus the purification process aims at simultaneously improving the biological, chemical and physical characteristics of water. The slow sand filtration is very well suited for rural areas in developing countries because of its simple operation and maintenance procedures. It thus provides safe drinking water at low recurrent cost.

Rate of filtration

The rate of filtration for a normal slow sand filter varies from 100 to 200 litres per hour per m^2 of filter area.

Efficiency of slow sand filters

1. Bacterial load: The slow sand filters are highly efficient in the removal of bacterial load from water. It is expected that they remove about 98 to 99 per cent of bacterial load from raw water and this percentage may be as high as 99.50 to 99.90, when pre-treatment has been given to the raw water. However, for complete removal of bacteria, disinfection is essential.

2. Colour: The slow sand filters are less efficient in the removal of colour of raw water. It is estimated that they remove about 20 to 25 per cent of colour of raw water.

3. Turbidity: The slow sand filters can remove turbidity to the extent of about 50 ppm. For water having greater turbidity than 60 ppm, it is necessary to give preliminary treatment and bring down is turbidity below 50 ppm

RAPID SAND FILTERS (GRAVITY TYPE)

Purpose

The great disadvantage of a slow sand filter is that it requires considerable space for its installation. This requirement makes it uneconomical for places where land values are high. The area required for slow sand filter, only for a moderate town of 15000 population, works out to be 1000 m^2 and with future expansion, other additional equipment etc., the area required for water supply project would be about 2000 m^2 or so.

The difficulty of requiring more space for slow sand filters led the engineers and scientists to find out means to increase the rate of filtration. It was observed that rate of filtration can be increased in two ways:

1. By increasing the size of sand so that friction to water passing through filter media is minimized and

2. By allowing water to pass under pressure through the filter media

The former is achieved in rapid sand filters (gravity type) and it is the most popular method of filtration for public water supply projects. The latter principle is adopted in the working of pressure filters.

Efficiency of rapid sand filter

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

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

3. Turbidity: The rapid sand filters can remove turbidity to the extent of 35 to 40 ppm. As water entering rapid sand filter is invariably given the treatment in coagulation sedimentation tank, it posses less turbidity. This turbidity is easily brought down to permissible limits by rapid sand filters.

PRESSURE FILTERS

The term pressure filter indicates that a filter is enclosed in space and water passes under pressure greater than atmospheric pressure. This pressure can be developed by pumping and it may vary from 0.3 to 0.7 N/mm^2.

Rate of filtration

The rate of filtration of pressure filters is high as compared to that of rapid sand filters. It is about 6000 to 15000 litres per hour per m^2 of filter area as compared to that of 3000 to 6000 litres per hour per m^2 of rapid sand filters.

Efficiency

The pressure filters are found to be less efficient than rapid sand filters in terms of bacterial load, colour and turbidity.

Suitability

The pressure filters are not suitable for public water supply projects. But they can be installed for small water supply water projects such as colonies of a few houses, industrial plants, private estates, swimming pools, railway stations, etc.

Double filtration

Sometimes the water is filtered twice to achieve better results. This known as double filtration and it may be carried out in different ways as follows:

1. The water is allowed to pass through two or more slow sand filters arranged one after the other.

2. The water is allowed to pass through two or more rapid sand filters arranged one after the other.

3. The water is allowed to pass through a rapid sand filter before it is sent to a slow sand filter.

In practice, the last alternative is most commonly adopted to increase the rate of filtration The rapid sand filter in such a case is known as a roughing filter. The coarse materials are used in the construction of a roughing filter and consequently, its rate of filtration is as high as 7000 litres per hour per m^2 of filter area. The roughing filters generally do not require water treated with the coagulant.

The double filtration, especially of last combination as stated above, is adopted at places where land available for the installation of slow sand filters is restricted. The installation of roughing filters practically doubles the capacity of slow sand filters.

Module 5. SEWER: TYPES, DESIGN DISCHARGE AND HYDRAULIC DESIGN

Lesson-14 Introduction to sewers

INTRODUCTION

Sewers are underground pipes or conduits which carry sewage to the point of discharge or disposal. The sewage originating from a building passes through fixtures and then lead to lateral sewers, which in turn discharge into sub mains or main sewers.

Important points to be considered before selecting sewer material

The following points are to be considered before selecting a material for constructing sewer:

Strength and durability

The sewer should have sufficient strength to withstand all the forces that are likely to fall on them. Sewers are subjected to considerable external loads of backfill material and traffic load, if any. They are not subjected to internal pressure of water. To withstand external load safely without failure, sufficient wall thickness of pipe or reinforcement is essential. In addition, the material selected should be durable and should have sufficient resistance against natural weathering action to provide longer life to the pipe.

Resistance to abrasion

Sewage mostly contains grit. These particles moving at high velocity can cause wear and tear of sewer material. This abrasion can reduce thickness of pipe and reduces hydraulic efficiency of the sewer by making the interior surface rough. Therefore, the material of the sewer should be in a position to offer enough resistance to abrasion.

Resistance to corrosion

Sewer carries wastewater that releases gases such as H_2S. This gas in contact with moisture can be converted in to sulphuric acid. The formation of acids can lead to the corrosion of sewer pipe. Hence, selection of corrosion resistance material is needed for long life of pipe.

Weight

To facilitate easy handling and transportation, the sewers should have less specific weight.

Imperviousness

This property is also important in selecting a sewer material. To eliminate chances of sewage exfiltration and infiltration, the material selected for pipe should be impervious.

Cost

Sewer should be less costly to make the sewerage scheme economical.

Hydraulically efficient

The sewer shall have smooth interior surface to have less frictional coefficient

Materials for sewer

Asbestos Cement Sewers

These types of sewers are manufactured from a mixture of asbestos fibre, silica and cement. These pipes are available in size 10 to 100 cm internal diameter and length up to 4.0 m. These kind of sewers are normally used for house drainage. They are not recommended for underground situations. These pipes are used for vertical transport of water. For example, transport of rainwater from roofs in multistoried buildings, for transport of sewage to grounds, and for transport of less foul sullage i.e., wastewater from kitchen and bathroom.

Advantages

- These pipes are light in weight and hence, easy to carry and transport.
- Easy to cut and assemble without skilled labour.
- Interior is smooth (Manning's roughness coefficient = 0.011) hence, can make excellent hydraulically efficient sewer, offering least resistance to flow.
- They are durable against corrosion.

Disadvantages

- These pipes are not very strong and hence should not be subjected to heavy super-imposed loads.
- These are susceptible to corrosion by sulphuric acid. When bacteria produces H_2S, in presence of water, H_2SO_4 can be formed.

Plain Cement Concrete or Reinforced Cement Concrete

Plain cement concrete (1: 1.5: 3) pipes are available up to 0.45 m diameter and reinforcement cement pipes are available up to 1.8 m diameter. Large sized cement concrete sewers are generally reinforced. These pipes can be cast in situ or precast pipes. Precast pipes are better in quality than the cast in situ pipes. The reinforcement in these pipes can be different such as single cage reinforced pipes, used for internal pressure less than 0.8 m; double cage reinforced pipes used for both internal and external pressure greater than 0.8 m; elliptical cage reinforced pipes used for larger diameter sewers subjected to external pressure; and hume pipes with steel shells coated with concrete from inside and outside. Cement concrete pipes may be used for surface water drains in all diameters.

Advantages

- Economical for medium and large sizes.
- It is possible to effect saving in the cost of jointing, owing to the longer lengths in which these pipes are generally available.
- They can be made of any desired strength.
- Strong in tension as well as compression.
- These pipes are available in wide range of size and the trench can be opened and backfilled rapidly during maintenance of sewers.

Disadvantages

- These pipes can get corroded and pitted by the action of H_2SO_4.
- The carrying capacity of the pipe reduces with time because of corrosion.
- The pipes are susceptible to erosion by sewage containing silt and grit.

When cement concrete pipes are subjected to chemical and corrosive actions, one method of protecting them from such actions is the lining of the sewer by vitrified clay blocks. These blocks have projections, projecting downwards and are fixed in cement concrete of the sewers. The joints between adjacent blocks are filled with cement mortar or with bituminous compounds.

Brick Sewers

Brick sewers are generally made at site. They are used for construction of large size sewers or particularly for storm water drains. The pipes are plastered from outside to avoid entry of tree roots and ground water through brick joints. These are lined from inside with stone ware or ceramic block to make them smooth and hydraulically efficient. Lining also make the pipe resistant to corrosion. If brick sewers are to be used on a large scale, the purpose made bricks should be used instead of ordinary bricks. The advantage of brick sewers is that these could be constructed to any required shape and size.

Galvanized iron sewers

Corrugated iron sewers are used for storm sewers. They are made from ingot iron or rust resisting alloys, with galvanizing for additional protection. Bituminous coatings are also used inside and outside, and the invert is sometimes, covered with abrasion resistant bituminous material. It is made in varying metal thickness and in diameters up to 4.5 m.

Cast Iron

Cast iron pipes may be used in the form of sewers, where they have to withstand high internal pressures and external loads. However, these are costly. Cast iron pipes are used for outfall sewers, rising mains of pumping stations, and inverted siphons, where pipes are running under pressure. These are also suitable for sewers under heavy traffic load, such as sewers below railways and highways. Light cast iron pipes are used for house drainage works, whereas, heavy ones are adopted for city sewers.

Steel pipes

These types of sewers are used where lightness, imperviousness and resistance to high pressure are of paramount importance. These sewers are flexible and can absorb vibrations and shocks efficiently. They are more ductile and can withstand water hammer pressure better. They are susceptible to corrosion and are not generally used for partially flowing sewers. They are protected internally and externally against the action of corrosion. These sewers may be protected from corrosion by galvanizing or by applying a bituminous coating or by using special corrosion-resistant steel. Their use may be made in outfall or trunk sewers.

Stoneware sewers

The stoneware sewers are also known as vitrified clay sewers. This type of sewer is made of clay or shale which has been ground, mixed with water, moulded into shape, dried and finally burnt in the kiln at a very high temperature. At the end of the burning period, some common salt is put in the kiln. The intensive heat cause the salt to vaporize and there is a reaction between salt vapours and the clay to form a hard water proof glaze. The heat also causes a fusion or vitrification of the clay which makes it very dense and hard. The temperature in the kiln is maintained at 150°C for several hours in the beginning, but it is raised later to about 650°C to 750°C. Finally, the temperature is raised to 1200°C where vitrification takes place.

These sewers are normally favoured for house drainage connections and laterals. The interior surface of these sewers is smooth and impervious. If properly laid, they are strong enough to take the load of back-filling and traffic. They are cheap, easy to lay and join, resistant to corrosion and extremely durable. But they are brittle, heavy and get damaged while handling and transportation.

Plastic sewers

Plastic is recent material used for sewer pipes. These are used for internal drainage works in house. These are available in sizes 75 to 315 mm external diameter and used in drainage works. They offer smooth internal surface. The additional advantages they offer are resistant to corrosion, light weight of pipe, economical in laying, jointing and maintenance, the pipe is tough and rigid, and ease in fabrication and transportion of these pipes.

High Density Polythylene (HDPE) Pipes

Usage of HDPE sewers is in its nascent stage of development. They are not brittle like asbestos cement pipes and other pipes and hence does not cause damage to pipes during loading, unloading and handling. They can be joined by welding or can be jointed with detachable joints up to 630 mm diameter. These are commonly used for conveyance of industrial wastewater. They offer all the advantages offered by PVC pipes.

Glass fibre reinforced plastic pipes

This material is widely used where corrosion resistant pipes are required. GRP or FRP can be used as a lining material for conventional pipes to protect from internal or external corrosion. It is made from the composite matrix of glass fiber, polyester resin and fillers. These pipes have better strength, durability, high tensile strength, low density and high corrosion resistance. These are manufactured up to 2.4 m diameter and up to 18 m length.

Pitch Fibre Pipes

The pitch impregnated fibre pipes are of light weight and have shown their durability in service. The pipes can be easily jointed in any weather condition as internally tapered couplings join the pipes without the use of jointing compound. They are flexible, resistant to heat, freezing and thawing and earth currents which set up electrolytic action. They are also unaffected by acids and other chemicals, water softeners, sewer gases, oils and greases and laundry detergents. They can be cut to required length on the site. Because of the larger lengths, cost of jointing, handling and laying is reduced. These are generally recommended for uses such as house connection to sewers and septic tanks, farm drainage, down pipes, storm drains, industrial waste drainage, etc. These have recently been manufactured in India.

Lesson-15 Types of sewers

INTRODUCTION

Types of sewers normally refers to the different shapes of sewers. The shapes of sewers play an important role in the construction and design process, handling and maintenance and decide in reducing / increasing the cost.

Sewers are generally circular in shape. The advantages of circular sewers are:

- The perimeter of circular sewer is the least with respect to the sewer of other shape.
- The inner surface is smooth hence the flow of sewage is uniform and there is no chance of deposition of suspended particles.
- The circular sewers are easy to construct.

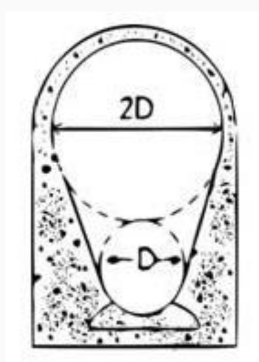
However non-circular shaped sewers are also adopted for the following reasons:

- They can be construct in such a convenient shape and size so that a man can enter the sewer for cleaning, maintenance, etc.
- The process of construction is easy.
- The structural strength is more.
- Cost of construction is low.

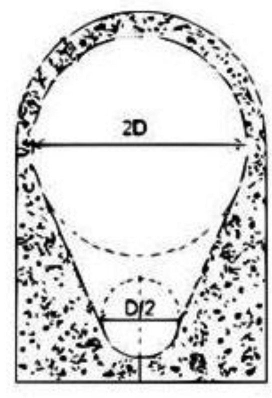
The following are the non-circular shaped sewers that are more commonly adopted

Standard Egg-shaped sewer

These types of sewers are generally used in combined sewers. These sewers can generate self cleansing velocity during dry weather flow.

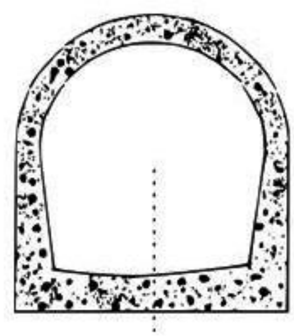


New egg-shaped sewer



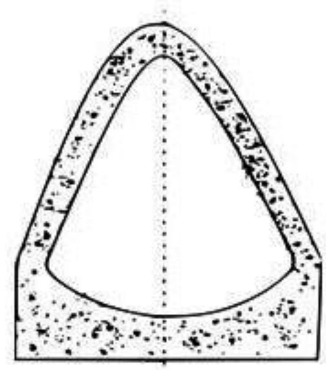
Horse shoe shaped sewer

This type of sewer is constructed for carrying heavy discharge. This is like a tunnel and resembles a horse-shoe. The size is so large that the maintenance works within the sewer are very easy.

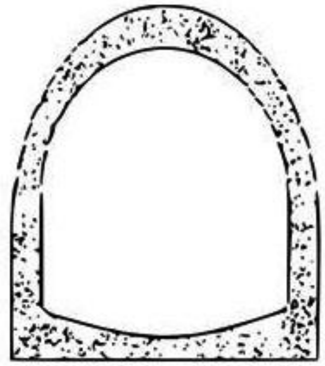


Parabolic shaped sewer

The upper surface of the sewer is of the shape of a parabola and the invert is in the form of an ellipse. This type of sewer is suitable for carrying small discharges.



Semi-elliptical section

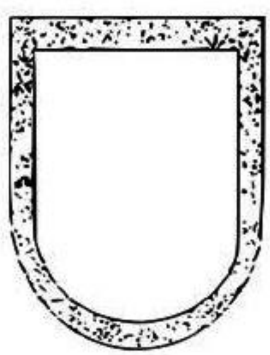


Rectangular shape section

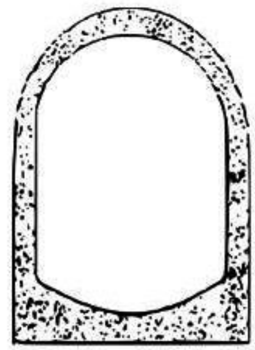
This type of sewer can be easily constructed. These are suitable for large sewers to carry heavy discharge of sewage. The maintenance works are easy in this section

U-shaped section

The shape of sewer resembles the letter 'U'. The sewer is suitable for carrying heavy discharges. Maintenance works are very easy in this type of sewers.

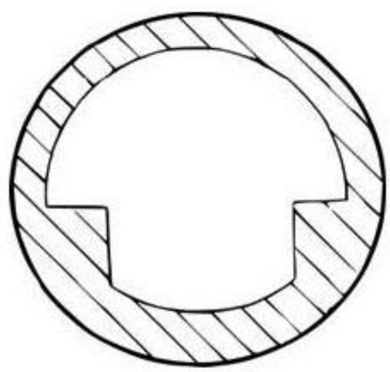


Semi-circular shaped sewer



Basket handled shape sewer

In this type of sewer, the outer surface is circular. The inner surface is divided into two portions. The upper portion resembles a basket-handle and the lower portion is like a channel. During dry season, the sewage flows through the lower portion and during monsoon, the combined sewage flows through the full section.



Lesson-16 Design discharge for sewers

INTRODUCTION

Sewers need to be designed before commencing the actual laying work. Designing involves estimation of period or duration for the which the sewer will serve for an expected population and the discharge for which the sewer is to be designed.

Design Period

The length of time up to which the capacity of a sewer will be adequate is referred to as the design period. In fixing a period of design, consideration must be given for the useful life of structures and equipment employed, taking into account obsolescence as well as wear and tear. Because the flow is largely a function of population served, population density and water consumption, lateral and sub main sewers are usually designed for peak flows of the population at saturation density as set forth in the Master Plan.

Population Forecasting

There are several methods for estimation or forecasting of population which can predict or forecast population for a specific design period, usually three to four decades.

Tributary area

The natural topography, layout of buildings, political boundaries, economic factors, etc., determine the tributary area. For larger drainage areas, though it is desirable that the sewer capacities be designed for the total tributary area, sometimes, political boundaries and legal restrictions prevent the sewers to be constructed beyond the limits of the local authority. However, in designing sewers for larger areas, there is usually an economic advantage in providing adequate capacity initially for a certain period of time and adding additional sewers, when the pattern of growth becomes established. The need to finance projects within the available resources necessitates the design to be restricted to political boundaries. The tributary area for any section under consideration has to be marked on a key plan and the area can be measured from the map.

Per capita sewage flow

The entire spent water of a community should normally contribute to the total flow in a sanitary sewer. However, the observed dry weather flow quantities usually are slightly less than the per capita water consumption, since some water is lost in evaporation, seepage into ground, leakage, etc. In arid regions, mean sewage flows may be as little as 40% of water consumption and in well developed areas, flows may be as high as 90%. However, the conventional sewers shall be designed for a minimum sewage flow of 100 litres per capita per day or higher as the case may be. Non-conventional sewers shall be designed as the case may be.

The flow in sewers varies from hour to hour and also seasonally. But for the purpose of hydraulic design, estimated peak flows are adopted. The peak factor or the ratio of maximum to average flows depends upon contributory population as given in following Table.

Table. Peak factor for contributory population

Contributory Population	Peak Factor
up to 20,000	3.00
above 20,001 to 50,000	2.50
above 50,001 to 7,50,000	2.25
above 7,50,001	2.00

The peak factors also depend upon the density of population, topography of the site, hours of water supply and therefore individual cases may be further analysed if required. The minimum flow may vary from 1/3 to 1/2 of average flow.

Infiltration

Estimate of flow in sanitary sewers may include certain flows due to infiltration of groundwater through joints. Since sewers are designed for peak discharges, allowances for groundwater infiltration for the worst condition in the area should be made as in Table..

Table. Ground water Infiltration

Description	Unit	Minimum	Maximum
Area	litres/ha/day	5000	50000
Length of sewers	litres/km/day	500	5000
Number of manholes	litres/day/manhole	250	500

Once the flow is estimated as per the above Table, the design infiltration value shall be limited to a maximum of 10% of the design value of sewage flow.

Sewage from Commercial institutions

Industries and commercial buildings often use water other than the municipal supply and may discharge their liquid wastes into the sanitary sewers. Estimates of such flows have to be made separately.

STORM WATER

Wherever possible, the storm water is to be collected and conveyed in sewers at proper places for the following reasons:

- Damp conditions are created which are unhygienic as they provide flourishing ground for micro organisms
- Existence of waterpools affects the foundations of structures
- Initial washings of streets by storm water contain organic matter and hence such water requires to be collected and to be taken to the treatment plant
- Low lying areas get flooded and transport system is paralysed. It leads to loss of revenue.
- Stagnant waterpools serve as breeding places for mosquitoes.

The quantity of storm water, which is known as wet weather flow (WWF) entering the sewer is to be carefully determined. It involves various factors such as intensity of rainfall, characteristics of catchment area, duration of storm, etc. Following two methods are generally employed for calculating the quantity of storm water for the purpose of designing sewers:

- Rational method
- Empirical method

Rational method

In this method, the following three factors are combined in the form of an equation:

$Q = K\,I\,A / 360$

Where,

Q = peak runoff in m^3 per second

K = Impermeability factor

I = Intensity of rainfall, mm per hour

A = Area in hectares

Catchment area

The catchment area to be served by a storm water sewer is measured directly from the map of the locality.

Impermeability factor

Some quantity of rain water that falls on the ground is absorbed by soil and the percentage of rain water that enters the sewer is known as impermeability factor. The following table gives the impermeability factors for various types of surfaces.

Type of surface	Impermeability Factor
Water tight roofs and such other covered surface	0.70 – 0.95
Pavements of asphalt or concrete	0.85 – 0.90
Areas with many buildings	0.70 – 0.90
Pavements of bricks, stones or wooden blocks	0.75 – 0.85
Pavements of bricks, stones or wooden blocks with open joints	0.50 – 0.70
Areas with adjacent well build up sections	0.50 – 0.70
Macadam roads	0.25 – 0.60
Residential areas having detached houses	0.25 – 0.50
Areas with few buildings	0.10 – 0.25
Gravel roads	0.15 – 0.30
Open spaces, railway yards and unpaved surfaces	0.10 – 0.30
Gardens, lawns, parks, etc	0.05 – 0.25
Areas with wooden surfaces	0.01 – 0.20
Fertilized lands and forest land	0.01 – 0.20

Intensity of rainfall

The intensity of rainfall can be worked out from the rainfall records of the area under consideration. Where rainfall records are not available, the intensity of rainfall is obtained by applying suitable empirical formula.

The general empirical formula adopted to calculate intensity of rainfall is:

$$R=\frac{25.4\cdot a}{t + b}$$

Where, R = Intensity of rainfall in mm per hour

t = Duration of storm in minutes

a and b are constants

The values of a and b are as follows:

a = 30 and b = 10 when duration of storm is 5 to 20 minutes

a = 40 and b = 20 when duration of storm is 20 to 100 minutes

Lesson-17 Hydraulic design of sewers

INTRODUCTION

If the velocity and depth of flow is the same for the length of a conduit, it is termed as steady flow and as otherwise, it is non-steady flow. The hydraulic analysis of sewers is simplified by assuming steady flow conditions though the actual flow conditions are different during morning peak flows and varying flows in other parts of the 24 hours.

General approach for the design of sewer is the same as that of water mains. But the following are the two main differences between the basic principles of design of sewers and those of water mains.

Presence of particles The water carried by water mains is practically free from particles of any solid matter – organic and inorganic. Sewage, on the other hand, contains such particles in suspension and the heavy particles settle down at the bottom of sewers which may ultimately result in the clogging of sewers. The sewers are, therefore, to be laid down at gradient and they should be capable of resisting the wear and tear due to abrasion of these particles.

Pressure The water mains normally carry water under pressure and hence, within certain limits, they may be carried up and down the hill. The sewers, on the other hand, are treated as open channels and they must, therefore, be laid at continuous gradient in downward direction. If sewage has to be carried under pressure, it will require elaborate equipment at each house which is to be connected to the drainage system.

Minimum and Maximum velocities

The silting or deposition of particles of solid matter is undesirable in sewers and hence, the sewers should be laid at such a gradient that a minimum velocity which will prevent the silting of particles in sewers is developed over a wide variation in discharge of sewage. Such a minimum velocity is known as self-cleansing velocity and for keeping the sewers free from any trouble, this velocity should be developed at least once in a day, preferably twice a day.

The self-cleansing velocity depends on the nature of suspended matter in sewage and the size of the sewer. The following table shows the self-cleansing velocities for different materials in suspension as recommended by Beardmore.

Name of the material	Self-cleansing velocity in cm/sec
Angular stones	100
Round pebbles	60
Fine gravel	30
Coarse sand	20
Fine sand and clay	15

The following table shows the self-cleaning velocities for sewers for different sizes as recommended by Badwin Latham. Usually, a self-cleaning velocity of about 80 cm to 90 cm per second is adopted for normal sewage.

Diameter of sewer in cm	Self-cleansing velocity in cm/sec
15 to 25	100
30 to 60	75
Above 60	60

The maximum velocity of flow is also to be taken in to consideration. If the velocity of flow exceeds a certain limit, the particles of solid matter start to damage the inside smooth surface of sewers or in other words, a scouring action takes place. The maximum permissible velocity at which no such scouring action will occur is known as non-scouring velocity and it will mainly depend on the material used in the construction of sewers. The following table shows the non-scouring velocities for common sewer materials.

Material of sewer	Non-scouring velocity in cm/sec
Earthen channels	60 to 120
Brick-lined sewers	150 to 240
Cement Concrete sewers	240 to 300
Stoneware sewers	300 to 450

The velocity which can cause automatic self-cleansing can be found out by the following formula given by Shield:

$$V=\sqrt{\frac{8k}{f}\left[\frac{P_s-P}{P}\right]gd}$$

Where. f = Darcy's coefficient of friction having a value of 0.05 for usual type of sewers.

k = Characteristics of solid particles carried in suspension by the sewage. .

P_s= Specific gravity of the particles.

P = specific gravity of transporting liquid which is water in the case of sewage.

g = acceleration due to gravity.

d = diameter of the particle in mm to be carried in suspension.

From general observation and also from Shield's formula, it is clear that heavier and sticky particles need larger velocity for their transportation, while smaller particles need smaller velocity. This aspect can be made clear from irrigation canals also. During rainy days water flowing in canals carries more coarser silt and thus silting of the canals takes place only in rainy season.

In sewers, the velocity of flow depends, on the following factors:

- Longitudinal slope or gradient in the sewer
- Hydraulic mean depth
- Coefficient of roughness of internal surface of the sewers

The sewage to be transported is mostly liquid containing 0.1 to 0.2 % solid matter in the form of organic matter, sediments and minerals

Following are the six common empirical formulae used in the determination of velocity of flow.

Chezy's formula:

The formula given by Chezy in 1775 as follows:

$$=V\sqrt{RS}$$

Where, V = velocity of flow in metres per second

R = hydraulic mean depth in metres

S = slope or hydraulic gradient

C = Chezy's constant

Bazin's formula

According to Bazin, the value of constant C in chezy's formula can be obtained by the following equation

$$C = \frac{157.6}{1.81 + \frac{K}{\sqrt R}}$$

Where, R = hydraulic mean depth in metres

K = Bazin's constant

Manning's formula

This formula, as given by Manning, is as follows:

$$V = \frac{1}{n}{R^{0.66}}{S^{0.50}}$$

Where, R = hydraulic mean depth in metres

S = slope or hydraulic gradient

Crimp and Bruges formula

$$V=\frac{1}{n}{R^{0.66}}{S^{0.50}}$$

Where, R = hydraulic mean depth in metres

S = slope or hydraulic gradient

Hazen and Williams formula

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

Where, C = friction coefficient based on the type and the condition of sewer

R = hydraulic mean depth in metres

S = slope or hydraulic gradient

Size of sewers

The minimum size of a sewer depends upon the practice followed in the locality. Usually, sewers of 10 cm diameter are allowed upto a maximum length of 6 m or so. But when the length of sewer line exceeds about 6 m, a sewer of minimum diameter 15 cm is allowed. The smaller the diameter of sewer, the greater will be the slope and hence, in order to take advantage of available fall, sewers of large diameter are sometimes used.

The design of sewers should be made in such a way that it ends in sections of sewers which are commercially available. The non-commercial sizes are difficult to obtain and they prove to be costly. For sewers to be constructed on site of work, this problem does not arise.

There is no upper limit for the size of sewer. It is however submitted that it is desirable to lay duplicate sewer line when sewer diameter exceeds about 3 m or so.

Time of concentration

This term is used in connection with the design of storm water drains. As the rain falls on the ground, all the area to be served by the sewer does not start to contribute immediately to the flow of sewer. But the flow is build-up gradually as follows:

- The area just near the sewer line will start contributing first and it will go on increasing as more and more area starts to contribute.

- When the whole area is contributing to the flow of sewer, the maximum limit of flow will be reached and it will be equal to the rate of precipitation of rain water.
- The maximum flow continues until the storm stops. The flow then gradually falls down as the area near the sewer line stops contributing firstly, while flow continues to come for considerable time from the distant areas.

The importance of time of concentration in the design of storm water sewers lies in the fact that out of all the storms of equal frequency of occurrence, that storm which has duration equal to the time of concentration, produces maximum flow in sewer.

Module 6. INTRODUCTION TO DOMESTIC WASTEWATER TREATMENT, WASTE WATER – QUANTITY AND CHARACTERISTICS, DISPOSAL IN URBAN AND RURAL AREAS, DESIGN OF SEPTIC TANK.

Lesson-18 Importance of sanitation

INTRODUCTION

The main purpose of sanitation is to maintain such environments as will not affect the public health in general. Thus sanitation aims at the creation of such conditions of living which will not result into serious outbreak of epidemic or in other words, it is a preventive measure for the preservation of health of community in general and individual in particular. It is to be noted that the word health indicates the physical and mental soundness of human body such that it is in a position to discharge its daily routine functions. This lesson deals about the principles of sanitation and terms related to it.

Principles of sanitation

Following are some of the fundamental or rather ideal principles of sanitation which, if observed, result in better living conditions

Collection and conveyance

The basic principle of sanitation is to remove any waste matter as early as possible after its formation. The earlier it is removed, the easier it becomes to render it harmless. The waste matter may be in any of the three forms – solid, liquid or gas

Interior decoration

The interior decoration of the building should be done after giving a serious thinking. The substances which are likely to catch dust should not be generally placed in room or if placed, arrangement should be made to clean them periodically

Orientation of building

In order to achieve natural ventilation, the orientation of building should be made to adjust with the prevailing natural conditions at site of construction of building. The building should be so oriented with respect to the local climatic conditions that all the rooms are properly lighted naturally and that there is free circulation of fresh air.

Prevention of dampness

The construction of building should be damp proof. The health of human body is considerably affected when there is presence of damp in the surroundings. The preventive measures to admit damp should invariably be taken to achieve proper sanitation of the building

Supply of water

There should be plentiful supply of pure water to the building. The scarcity of water leads to the development of unhygienic conditions in the building

Treatment of water

All the waste matter received from the building should be disposed off only after giving proper treatment to it. Thus the effluent from sewage plant should be thrown into natural river or stream after it has been made harmless.

Site for sewage treatment works

The site for treatment units sewage of any town should be carefully selected and the following aspects are to be considered at the time of its final selection

1. Good foundation soil should be available for various sewage treatment units to rest firmly on the ground and thus to grant the structural stability to them
2. The general slope of the site should neither be too steep nor too flat. It will assist in placing various treatment units at such levels that sewage may flow from one unit to the other by gravity only
3. The general level of the site should be lowest level area of the town or city so that the sewage from the entire town or city can be collected and conveyed by gravity only
4. The location of site should be appropriate with respect to the method of sewage treatment to be adopted for the project
5. The location of site should be such that enough area is available nearby when it becomes necessary in future to expand the existing project.
6. The proximity of water course near the site or enough waste land for irrigation will be considered as an additional advantage.
7. The site should be safe from floods for all the time
8. The site should be situated on the leeward side of wind so that the undesirable odours will be prevented from entering the town or city
9. The site should not be, as far as possible, far away from the town or city
10. The subsoil water level at the site should remain low even during monsoon

Design aspects

Following aspects should be kept in mind while making design of the sewage treatment plant:

1. Every unit of the plant should have flexibility in control and operation

2. The design of the plant should be aimed at granting the safety of health of the personnel operating the plant

3. The major units of the plant should have bypass facilities which can be put into commission during emergency

4. The overall design of the plant should be such that there is easy accessibility for operating and maintaining valves, sampling points and various other operating devices.

5. There should be adequate alternative provisions in case the plant fails or is shut down for repairs or any other reason

6. There should be some alternative for operating of the plant when its outlet is submerged under high water.

7. The treatment plant should accommodate a full-fledged laboratory in which routine tests can be carried out for the performance of various units of the plant.

Some definitions

In order to simplify the understanding of the subject, the following five important definitions are mentioned at this stage

Bacteria

These are microscopic unicellular plants or organisms and for the study of sanitary engineering, they are divided into three groups, aerobic, anaerobic and facultative.

The aerobic bacteria require light and free oxygen for their existence and development

The anaerobic bacteria do not require light and free oxygen for their existence and development

The facultative bacteria can exist in presence or absence of oxygen but they grow in plenty in absence of air.

Invert

The lowermost level or surface of a sewer is known as the invert and in the construction of sewers, the invert levels are to be carefully checked for the proper functioning of the sewer line.

Refuse

The term refuse is used to indicate what is rejected or left as worthless and for the study of sanitary engineering, it is divided into five categories:

Garbage

The term garbage is used to indicate dry refuse and it includes decayed fruits, grass, leaves, paper pieces, sweepings, vegetables, etc.

Sewage

The term sewage is used to indicate the liquid waste from the community and it includes sullage, discharge from latrines, urinals, stables, etc., industrial water and storm water. The term night soil is sometimes used to indicate the human and animal excreta.

Storm water

The term storm water is used to indicate the rain water of the locality

Subsoil water

This indicates the ground water which finds its entry into sewers through leaks.

Sullage

The term sullage is used to indicate the wastewater from bath rooms, kitchens, etc. It is merely waste water and does not create bad smell.

Sewer

The underground conduits or drains through which sewage is conveyed are known as sewers.

Sewerage

The entire science of collecting and carrying sewage by water carriage system through sewers is known as sewerage and the sewage thus collected and conveyed is taken to a suitable place for its disposal.

Lesson-19 Domestic waste water – quantity and characteristics

INTRODUCTION

This chapter deals with the quantity and characteristics of domestic waste water .

Quantity of domestic waste water

In order to find out a suitable section for the sewer, it is necessary to determine the quantity of sewage that will flow through the sewer. The sewage consists of the following two categories:

1. Dry weather flow
2. Storm water

DRY WEATHER FLOW

This is sometimes written as D.W.F. and it consists of two types of sewage:

1. Domestic or sanitary sewage
2. Industrial sewage

The quantity of D.W.F. is determined by considering the following four factors:

1. Infiltration and exfiltration
2. Nature of industries
3. Population
4. Rate of water supply

Infiltration and exfiltration

The term infiltration is used to indicate the leakage of water from the ground surrounding the sewer and the term exfiltration is used to indicate the leakage of sewage from the sewer into the ground surrounding the sewer.

The infiltration and exfiltration are both undesirable. The infiltration unnecessarily increases the quantity of sewage. The exfiltration pollutes the underground sources of water, if any. The infiltration, however, is preferred to exfiltration.

The infiltration and exfiltration can be prevented to some extent by constructing watertight joint of sewers.

The quantity of water through infiltration depends on the following four factors:

- Head of subsoil water level
- Length of sewer
- Nature and type of soil through which sewer is laid and
- Size of sewer

Nature of industries

The quantity of industrial sewge will depend upon the nature of industries. A careful study is, therefore, made of the industries contributing to the flow of sewage and the quantity of industrial sewage is then accordingly worked out.

Population

Just as in case of water supply projects, the future population after two or three decades is determined by applying any suitable method of population forecast. The design period of different parts of the sewerage system is different and the following factors are taken into account while fixing the probable life of a particular part of the sewerage system

- Chances of improvement in the equipment
- Cost of adding an extra unit of the equipment
- Labour conditions having important influence on the cost of equipment
- Maintenance cost and overhead charges
- Operation methods and
- Original cost of the part

Usually, the design periods of the following parts of sewerage system are:

- Laterals: These are designed for 50 years or so
- Branches and submains: These are also designed to last for 50 years or more
- Main sewers and trunk sewers: These are designed for 30 to 50 years
- Pumping plant: As additional pump can be installed with short notice, the design period of pumping plant is about 5 to 10 years.
- Treatment units: These are designed for 10 to 30 years.

Rate of water supply

Usually the quantity of water entering the sewer will be slightly less than the quantity of water supplied. For practical purposes, it is assumed that the quantity of water which does not enter sewer is very nearly equal to the extra quantity of water which enter sewer. In other words, the rate of sewage is assumed as equal to the rate of water supply. The rate of sewage may, however, be assumed lower than the rate of water supply to the extent of about 60 to 70 per cent where there are sufficient reasons to justify such assumption.

Following two factors should be carefully considered while comparing rate of sewage with rate of water supply.

- Intensity of pressure: If water is supplied at high pressure, there is more consumption of water and more wastage of water from leakage in pipes, valves etc.
- Use of water: The use for which water is consumed should be carefully studied. It is quite likely that water which is supplied may not appear as sewage after its consumption. For instance, water that is supplied to fill up the tanks of railway locomotives will not appear as sewage. Similarly, the quantity of water supplied and the quantity of sewage formed by various prominent industries such as cotton mills, milk plants, etc. should be studied and accordingly the rate of sewage should be decided.

STORM WATER

Wherever possible, the storm water is to be collected and conveyed in sewers at proper places for the following reasons:

- Damp conditions are created which are unhygienic as they provide flourishing ground for micro organisms
- Existence of waterpools affects the foundations of structures
- Initial washings of streets by storm water contain organic matter and hence such water requires to be collected and to be taken to the treatment plant
- Low lying areas get flooded and transport system is paralysed. It leads to loss of revenue.
- Stagnant waterpools serve as breeding places for mosquitoes.

The quantity of storm water, which is known as wet weather flow and mentioned as W.W.F., that will enter sewer is to be carefully determined. It involves various factors such as intensity of rainfall, characteristics of catchment area, duration of storm, etc. Following two methods are generally employed for calculating the quantity of storm water for the purpose of designing sewers:

- Rational method
- Empirical method

Rational method

In this method, the following three factors are combined in the form of an equation:

Q= K I A / 360

Where,

Q = peak runoff in m^3 per second

K = Impermeability factor

I = Intensity of rainfall, mm per hour

A = Area in hectares

Catchment area

The catchment area to be served by a storm water sewer is measured directly form the map of the locality

Impermeability factor

Some quantity of rain water that falls on the ground is absorbed by soil and the percentage of rain water that enters the sewer is known as impermeability factor.

Intensity of rainfall

The intensity of rainfall can be worked out from the rainfall records of the area under consideration. Where rainfall records are not available, the intensity of rainfall is obtained by applying suitable empirical formula.

The general empirical formula adopted to calculate intensity of rainfall is:

$$R=\frac{25.4\cdot a}{t + b}$$

Where, R = Intensity of rainfall in mm per hour

t = Duration of storm in minutes

a and b are constants

The values of a and b are as follows:

a = 30 and b = 10 when duration of storm is 5 to 20 minutes

a = 40 and b = 20 when duration of storm is 20 to 100 minutes

Characteristics of domestic waste water

In order to determine the line of treatment, constituents of which sewage is composed are to be properly determined. Quality of sewage plays an important role in the design and construction of various treatment units. The treatment given to sewage should be such that it can be easily disposed off in natural stream or river.

Properties of sewage

The properties of sewage will be studied in the following three groups:

1. Physical properties
2. Chemical properties
3. Biological properties

Physical properties

Specific gravity of sewage is very nearly equal to that of water and as such, no modification of hydraulic formulae is necessary.

Colour of fresh sewage is earthy or grey and it has soapy or oily smell. It starts to give objectionable odour after few hours of its production.

Normal sewage is usually turbid and it contains some matter which can be easily identified when the sewage is fresh. Such matter includes faecal matter or night soil, pieces of paper, cigarette ends, grease, fruit skins, soap, match sticks, vegetable debris, etc.

Sewage contains a very small amount of solid in relation to large amount of water. Liquid content of normal sewage is about 99.90 per cent and the total amount of solid matter present either in suspension state or dissolved state is only about 0.10 per cent. For normal sewage, it is estimated that two tones or 2000 kg of sewage will hardly contain 1 kg of solids. The amount of 1 kg of solids will normally include 0.50 kg in solution stage, 0.25 in settleable state and 0.25 kg in suspension state.

Sewage contains organic and inorganic matter. It will be interesting to note the proportions of these matters in a normal sewage. For illustration, one lakh parts of sewage will normally contain only 100 parts of solids. Distribution of 100 parts of solids in sewage will roughly be as follows:

As a general rule, presence of inorganic solids in sewage is not harmful. It requires only mechanical appliances for its removal in the treatment plants. Suspended and dissolved organic solids require treatment and they are as such responsible for creating troubles in sewage disposal. As seen above, the amount of such solids in one lakh parts of sewage is about (20 + 25) = 45, say 50 parts only, i.e., they form only 1/2000th part of the entire quantity of sewage and such a small part requires heavy treatment for its purification.

Inorganic solids in sewge include mineral matter such as gravel, grit, debris, dissolved salts, sand, chlorides, sulphates, etc. Organic solids in sewage can be grouped in the following three categories:

- Carbohydrates such as cellulose, cotton filter, starch, sugar, etc.

- Fats and oils received from kitchens, laundries, garages, shops, etc.
- Nitrogenous compounds which are nothing but proteins and their decomposed products and they include wastes from animals, urea, fatty acids, hydrocarbons, etc.

Chemical properties

Nature of fresh sewage and treated or purified sewage is alkaline. Nature of stale sewage is acidic.

In addition to solids and liquids, sewage also contains various gases such as hydrogen sulphide, methane, ammonia and carbon dioxide. These gases are obtained either from atmosphere or formed by the decomposition of organic matter present in sewage.

It may be noted that the sewage containing industrial wastes may possess unusual chemical properties.

Biological properties

Sewage contains bacteria and other living micro-organisms such as algae, fungi, protozoa, etc.

Bacteria are present in sewage in large number and depending upon their nature, they may be classified as pathogenic bacteria and non-pathogenic bacteria. Pathogenic bacteria are harmful and they are responsible for causing diseases. Sewage obtains such bacteria from the discharges of persons and animals suffering from various diseases. Non-pathogenic bacteria are harmless.

The major part of bacteria in sewage is engaged in carrying out the process of breaking the complex organic compounds into simple and stable compounds which may be organic or inorganic

Lesson-20 Introduction to domestic waste water treatment

INTRODUCTION

In this chapter, we will learning on the basic processes involved in the treatment of domestic waste water

The raw sewage must be treated before it is discharged into the river stream. The extent of treatment required to be given depends not only upon the characteristics and quality of the sewage but also upon the source of disposal, its quality and capacity to tolerate the impurities present in the sewage effluents without itself getting potentially polluted.

The unit operations and processes commonly employed in domestic wastewater treatment, their functions and units used to achieve these functions are as follows:

Screening

The main purpose of the installation of screens is to remove floating matter of comparatively large size. If such materials are not removed, they will choke up the small pipes or affect seriously the working of sewage pumps. Thus, the main idea of providing screens is to prevent the pumps and other equipment from the possible damage due to floating matter of the sewage. Screens should preferably be located just before grit chambers. If the quality of grit is of not much importance, as in case of land filling, screens may even be placed after the grit chambers. Screens are usually placed in an inclined position with an angle of about 30) to 60) with the direction of flow. Screens are sometimes accommodated in the body of grit chambers.

Grit removal

Sewage contains both types of material, namely, organic and inorganic. The purpose of providing grit chamber in the sewage treatment process is to remove grit, sand and such other inorganic matter from sewage. To achieve this purpose, velocity of flow in grit chamber is decreased to such an extent that the heavier inorganic materials settle down at bottom of grit chamber and lighter organic materials are carried forward for further treatment.

In general, grit chambers are placed after pumping stations and before the screens. But, there is no fixed rule regarding the location of grit chambers.

Primary Sedimentation

Sedimentation tanks are also known as settling tanks or clarifier and the overall features of these tanks are more or less the same as for those tanks which are provided in water supply schemes.

Following are the objects of installing sedimentation tanks in sewage treatment works

- The process of sedimentation reduces the strength of sewage to the extent of about 30 to 35 per cent.
- Quantity of settleable solids in sewage is reduced to the extent of about 80 to 90 per cent.
- There is reduction in B.O.D. to the extent of about 30 to 35 per cent.
- Sewage after being treated in sedimentation tanks becomes fit for further treatment processes.

Sedimentation process

When velocity of flow is decreased or when sewage is allowed to stand at rest, the suspended particles carried by the sewage tend to settle at the bottom of tanks. Material collected at the bottom of sedimentation tanks is knows as sludge and the partially treated sewage is known as effluent. Sludge and effluent both require further additional treatment to make them unobjectionable.

Aerobic biological suspended growth process

Its function is to convert the colloidal, dissolved and residual suspended organic matter into settleable biofloc and stable inorganics. This can be achieved by activated sludge process, waste stabilization ponds and aerated lagoons

Aerobic biological attached growth process

Its function is similar to that of the previous process, viz., aerobic biological suspended growth process. This can be achieved by trickling filter and rotating biological contactor

Anaerobic biological growth processes

The purpose of this process is to convert organic matter into methane and carbondioxide and relatively stable organic residues. Anaerobic filter, Fluid bed submerged media anaerobic reactor, Upflow anaerobic sludge blanket reactor, Anaerobic rotating biological contactor are some of the treatment methods adopted for this process.

Lesson-21 Disposal of domestic waste water in rural and urban areas

INTRODUCTION

The domestic waste water (sewage) begins to cause nuisance as it becomes stale. If it is possible to dispose off sewage within four to five hours after its production, the treatment required is less in magnitude. This lesson deals with the methods of disposing domestic waste water.

The methods of sewage disposal can classified as follows:

Disposal by dilution

Disposal by land treatment

Disposal by dilution

In this process, the raw sewage or the partially treated sewage is thrown into natural waters having large volume. The sewage in due course of time is purified by what is known as the self-purification capacity of natural waters. The limit of discharge and degree of treatment of sewage are determined by the capacity of self-purification of natural waters.

Conditions favorable for dilution

Following conditions are favourable for sewage to be disposed off by dilution into natural waters

1. It is possible only to provide primary treatment to sewage i.e., removal of floating matter and settleable solids.
2. Currents of flow of diluting waters should be favourable which means that nuisance should not be caused when sewage is discharged into diluting waters
3. Diluting waters are not used for the purpose of navigation for at least some reasonable distance on the downstream from the point of sewage disposal.
4. Diluting waters should not have habitation or they should not hage been used as source of water supply for at least some reasonable distance on the downstream from the point of sewage disposal
5. Dissolved oxygen content of diluting waters should be high
6. The place is situated near natural waters having large volumes

7. The sewage is relatively fresh and it is possible to bring it to the point of discharge within four or five hours of its production.

Types of natural waters

Following are the natural waters into which the sewage can be discharged for dilution

1. Creeks
2. Estuaries
3. Ground waters
4. Lakes
5. Ocean or sea
6. Perennial rivers and streams

Self purification of natural waters

When sewage is discharged into natural water, its organic matter gets oxidized by the dissolved oxygen content in water. The oxidation of organic matter converts such matter into simple inoffensive substances. Deficiency of dissolved oxygen thus created in natural waters is filled up by the absorption of atmospheric oxygen. Thus, the oxygen of water is consumed by sewage and at the same time, it is replenished by the atmosphere. This phenomena which occurs in all natural waters is known as self-purification of natural waters. It is thus seen that natural waters, polluted by sewage, are purified in natural course by the phenomena of self-purification

The rate of self-purification will depend on various factors such as rate of re-aeration type of organic matter present in sewage, temperature, velocity of flow, presence of available oxygen in receiving waters, sedimentation, etc

Disposal by land treatment

Here, the raw domestic waste water (sewage) is applied on the land. A part of sewage evaporates and the remaining portion percolates through the ground and is caught by the underground drains for disposal into natural waters. The sewage adds to the fertilizing value of land and crops can be profitably raised on such land. The term sewage farming is also sometimes used for indicating disposal of sewage by land treatment. The design of a good land treatment system demands the services of environmental engineers, hydraulic engineers, irrigation engineers, agronomists, soil scientist, etc.

Conditions favourable for land treatment

1. The area of land treatment is composed of sandy, loamy or alluvial soils. Such soils are easily aerated and it is easy to maintain aerobic conditions in them
2. The depth of water table is more even in rainy season so that there are no chances of pollution of underground water sources by land treatment

3. The rainfall in the area is low as it will assist in maintaining good absorption capacity of soil
4. There is absence of river or other natural water sources in the vicinity of disposal of sewage
5. There is demand for cash crops which can be easily grown on sewage farms
6. There is availability of large open areas in the surrounding locality for practicing broad irrigation by sewage

Advantages of land treatment

1. It increases the fertility of land
2. It is cheap where land is available in plenty
3. Application of sewage on land is the best method of supplying manure to the soil
4. Crops grown on land treated with sewage possess high calorific value and more vitamins.
5. Increased fertility of land results in profitable returns of crops
6. The method becomes very much useful at places where disposal of sewage by dilution is not possible.
7. The method does not require costly equipment for its working.
8. The method proves economical and safe where available irrigation water is scarce in quantity
9. The method to some extent charges the underground aquifers
10. Water of irrigation canal is saved when this method is practised.

Disadvantages of land treatment

1. If proper precautions are not taken, nuisance developed by sewage farming may lead to possible dangers to the health of men. It is therefore, necessary that the sewage farms should be operated under skilled technical supervision
2. Crops grown on sewage farms are generally not liked by ordinary public
3. The method is not applicable for all the seasons of year. In monsoon, some other arrangement of sewage disposal has to be found out.
4. The method requires large area of land which may not be available in some cases
5. Types of crops grown on sewage treated land are limited in number.

Sewage sickness

If sewage is applied continuously on a piece of land, pores or voids of soil are filled up or clogged. Free circulation of air is thereby prevented and anaerobic conditions develop. At this stage, the land is unable to take any further sewage load. Organic matter decomposes and foul smelling gases are produced. The phenomena of soil is known as sewage sickness of land.

Preventive measures

In order to prevent sewage sickness of land, the following preventive measures may be adopted

Alternative arrangement: There should be ample provision of extra land so that land with sewage sickness can be given the desired rest. Alternatively, sewage should be disposed off by some other method when sewage farms are taking rest

Depth of sewage: If sewage is applied in excess, the chances of sewage sickness are increased. The land is unable to receive the excess sewage in a satisfactory way and it ultimately clogs up. Depth of sewage on land should be carefully decided by keeping in view the climatic conditions, drainage facilities, nature of crops and characteristics of soil.

Drainage of soil: Subsoil drain pipes should be laid in sufficient number to collect the percolated effluent

Intermittent application: Sewage should be applied on land at intervals. The period between successive applications depends on general working of sewage farm and the permeability of soil. Depending on the nature of the soil, this period between successive applications varies from few hours to few weeks.

Pretreatment of sewage: sewage should be given some pretreatment before it is applied on land.

Rotation of crops: It is desirable to grow different types of crops on a piece of land instead of one single crop. Rotation of crops minimizes the chances of sewage sickness.

Treatment to land: The land affected by sewage sickness should be properly treated before it is put up in use again. Clogged surfaces should be broken by suitable equipment.

Lesson-22 Design of septic tank

INTRODUCTION

In order to provide the satisfactory disposal of sewage received or obtained from isolated buildings, small institutions, big hotels, camps etc. septic tanks may be adopted. Thus, they are suitable for isolated or undeveloped areas of the locality where municipal sewers are not laid and there is no facility to convey and to treat the sewage in the public sewage treatment units or plants. This chapter deals with the constructional features and design of septic tank.

Septic tank is just like a plain sedimentation tank. But in septic tank, the bio-chemical reactions by anaerobic bacteria take place as in case of sludge digestion tanks. During the detention period, sewage is purified and the effluent is taken to soak pits for disposal. Bad smells occur during the digestion period of sludge and hence, the septic tanks are provided with cover at top.

Constructional features.

1. Septic tanks should be constructed of materials which are resistant to corrosion. The tanks are constructed watertight.

2. Construction of septic tank should be such that direct currents are not established between the inlet and outlet. This is achieved by using submerged pipe tees or by baffle walls near the inlet and outlet ends. Scum boards may be provided near the inlet and outlet ends to prevent the escape the scum. Level of outlet is about 15 cm lower than that of inlet level

3. Septic tank should be properly ventilated by the provision of air vent pipes

4. Top cover of septic tank is usually made of R.C.C. and a manhole is provided in R.C.C. slab for the purpose of inspection and cleaning of tank. If necessary, cast-iron steps may be provided in the tank to facilitate descent in the tank.

5. Sludge is allowed to be accumulated at the bottom of tank and it is removed at intervals either by manual labour or by pumping. For large septic tanks, sludge removal pipe is provided and it leads the sludge to the nearby sump from where it is periodically pumped and removed.

6. Tank should be filled with water at the time of putting a into working condition. Effluent of tank should be properly disposed off. The direct discharge of such effluent into natural waters should be discouraged.

7. Septic tanks may be constructed in series to act like two-stage sludge digestion tanks. But single-stage septic tanks are very popular

8. A septic tank thus combines the functions of a sedimentation tank, a sludge digestion tank and a sludge storage tank.

9. Accumulation of sludge at the bottom of tank decreases its storing capacity and hence, the septic tanks should be cleaned every 6 to 12 months. But this period should not preferably exceed 3 years in any case.

Design aspects

Capacity: Volume of septic tank is decided by taking into consideration the quantity of flow and the detention period. It can also be designed on per capita basis which varies from 60 to 110 litres per person to be served by the septic tank. The space for sludge is kept usually at the rate of 15 to 45 litres per capita per year.

Detention period: The detention period varies from 12 to 72 hours, common being 24 hours

Freeboard: This should be about 40 cm to 60 cm

Shape: Septic tanks are generally rectangular in shape. The ratio of length to width is about 2 to 4

Advantages:

- It does not practically require any special attention or skilled supervision. It can be constructed easily
- Cost is reasonable as compared to the advantages it offers
- Performance of a properly constructed septic tank is very good. It can remove about 90 per cent of B.O.D. and about 80 per cent of suspended solids
- There is absence of any moving parts
- There is reduction in the volume of sludge. As compared to sludge of plain sedimentation tank, it is about 60 per cent less in volume and about 30 per cent less in weight
- Sludge, effluent and scum obtained from the septic tanks can be disposed off easily without causing serious nuisance

Disadvantages

- If the tank is not properly functioning, the effluent is dark and foul-smelling. It is even worse than the influent
- It requires excessive large size for serving more persons
- Leakage of gases through the top of septic tanks leads to air pollution
- Occasional removal of sludge adds to its maintenance cost and it is very tedious job

- Working of septic tank is unpredictable and non-uniform
- Use
- Septic tanks are at present are not generally recommended for treating sewage on a large scale. They however are still useful for isolated structures or localities where drainage connection to municipal sewers is not possible.

Module 7. SOLID WASTE: QUANTITY, CHARACTERISTICS AND DISPOSAL FOR URBAN AND RURAL AREAS

Lesson-23 Introduction to solid wastes

The particular lesson introduces the concept of solid wastes, its definition, management of solid wastes, hazards of mismanagement of solid wastes and the elements of a typical solid waste management system

Solid waste

Any solid material in the material flow pattern that is rejected by society is called solid waste. All human activities viz., domestic, commercial, industrial, healthcare and agriculture generate solid waste. The quantity and nature of the waste vary with the activity and with the level of technological development in a country. Solid wastes are all the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted.

Solid waste is the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services. Wastes that arise from a typical urban society comprise of garbage, rubbish (package materials), construction and demolition wastes, leaf litter, hazardous wastes, etc. If not managed properly, these wastes can have an adverse impact on the environment and public health arising from contamination of soil, water and pollution of air and through spread of diseases via vectors living on waste. The relationship between public health and the improper storage, collection and disposal of solid wastes is quite clear. Because of their intrinsic properties, discarded waste materials are often reusable and may be considered a resource in another setting. Ecological phenomena such as water and air pollution have also been attributed to improper management of solid wastes

From the days of primitive society, humans and animals have used the resources of the earth to support life and to dispose wastes. In those days, the disposal of human and other wastes did not pose significant problems as the population was very small and the area of land available for the assimilation of such wastes was large. However, today, serious consideration is being given everywhere to this burgeoning problem of solid wastes. Rapid population growth and uncontrolled industrial development are seriously degrading the urban and semi-urban environment in many of the world's developing countries, placing enormous strain on natural resources and undermining efficient and sustainable development.

Solid waste management

Management of solid waste may be defined as that discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accord withthe best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations. In its scope, solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in the whole spectrum of solutions to problems of solid wastes thrust upon the community by its inhabitants

Solid waste management in India

India, as any other developing country, is currently facing an acute problem in the management of Municipal Solid Wastes. Open dumping of waste is wide spread throughout the country. This is because of the mistaken belief that it is the easiest and cheapest disposal method. Also there is insufficient will and allocation of resources to improve the prevailing disposal practices. The deposition of wastes along roadsides and on riverbanks and on marginal lands and then 'hoping' it will go away is both naive and dangerous. It is inevitable that chemical and biological contaminants in waste will pollute the surrounding natural environment and find their way back to humans to affect health, quality of life and working activities. Thus, in the ultimate run the society has to pay dearly for open dumping.

Solid waste management has become a major environmental issue in India. The per capita of MSW generated daily, in India ranges from about 100 g in small towns to 500 g in large towns. The population of Mumbai grew from around 8.2 million in 1981 to 12.3 million in 1991, registering a growth of around 49%. On the other hand, Municipal Solid Wastes generated in the city increased from 3 200 tonnes per day to 5 355 tonnes per day in the same period registering a growth of around 67% (CPCB 2000). This clearly indicates that the growth in Municipal Solid Wastes in our urban centres has outpaced the population growth in recent years. This trend can be ascribed to our changing lifestyles, food habits, and change in living standards. Municipal Solid Wastes in cities is collected by respective municipalities and transported to designated disposal sites, which are normally low lying areas on the outskirts of the city.

Now-a-days the concern for solid waste management has increased and government has created lot of awareness among the public for proper separation of solid wastes at the source level itself, so that it will become easier for treatment / disposal.

Hazards of mismanagement of solid wastes

There are innumerable potential hazards due to the mismanagement of solid wastes. It has the potential to pollute all the vital natural resources viz., land, water and air. Some of the hazards caused by solid wastes are listed below:

- Environmental pollution from waste leachates and gas evolving from dumped solid waste
- Air pollution from smoke by burning of waste and health hazards to the people through inhalation of dust and smoke
- Health hazards to waste workers and pickers through direct contact with waste.
- Generation of noxious odours
- Promotion of micro organisms that cause diseases

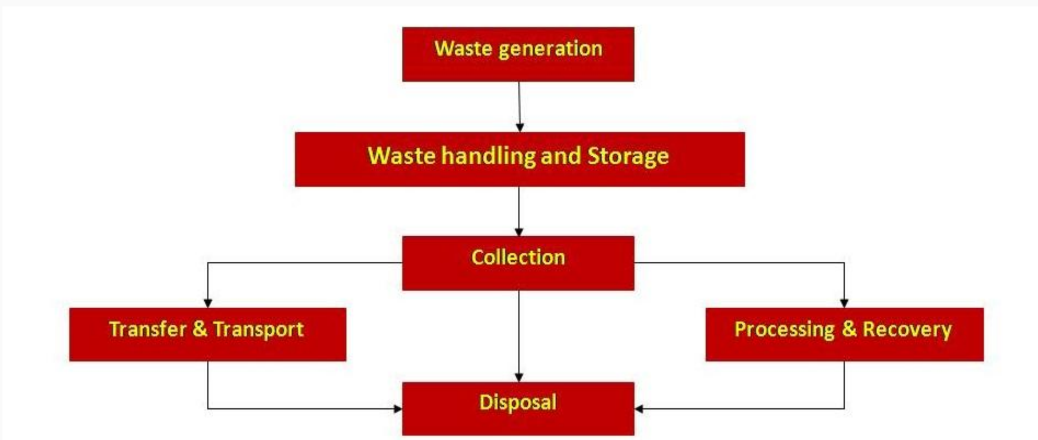
- Attraction and support of disease vectors (rodents and insects that carry and transmit disease carrying micro-organisms)
- Unaesthetic appearance
- Poor living ambience

Functional elements of a solid waste management system

The following are the key functional elements for implementing a solid waste management system:

- source reduction
- onsite storage
- collection and transfer
- processing techniques
- disposal

The following flow chart describes the relationship between the key functional elements of a solid waste management system



Waste generation

Waste generation encompasses activities in which materials are identified as no longer being of value (in their present form) and are either thrown away or gathered together for disposal.

Waste handling, sorting and storage

Waste handling and sorting involves the activities associated with management of wastes until they are placed in storage containers for collection. Handling also encompasses the movement of loaded containers to the point of collection. Sorting of waste components is an important step in the handling and storage of solid waste at the source. For example, the best place to separate waste materials for reuse and recycling is at the source of generation. Households are becoming more aware of the importance of separating newspaper and cardboard, bottles/glass, kitchen wastes and ferrous and non-ferrous materials. On-site storage is of primary importance because of public health concerns and aesthetic consideration. Unsightly makeshift containers and even open ground storage, both of which are undesirable, are often seen at many residential and commercial sites.

Collection

It includes not only the gathering of solid wastes and recyclable materials, but also the transport of these materials, after collection, to the location where the collection vehicle is emptied. This location may be a material processing facility, a transfer station, or a landfill disposal site.

Processing and Recovery

The recovery of sorted materials, processing of solid waste and transformation of solid waste that occurs primarily in locations away from the source of waste generation are encompassed by this functional element. Waste processing is undertaken to recover conversion products and energy. The organic fraction of Municipal Solid Waste can be transformed by a variety of biological and thermal processes. The most commonly used biological transformation process is aerobic composting. The most commonly used thermal transformation process is incineration.

Waste transformation is undertaken to reduce the volume, weight, size or toxicity of waste without resource recovery. Transformation may be done by a variety of mechanical (eg shredding), thermal (e.g. incineration without energy recovery) or chemical (e.g. encapsulation) techniques.

Transfer and Transport

It involves two steps: (i) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and (ii) the subsequent transport of the wastes, usually over long distances, to a processing or disposal site. The transfer usually takes place at a transfer station.

Disposal

The final functional element in the solid waste management system is disposal. Today the disposal of wastes by landfilling or uncontrolled dumping is the ultimate fate of all solid wastes. A municipal solid waste landfill plant is an engineered facility used for disposing of solid wastes on land or within the earth’s mantle without creating nuisance or hazard to public health or safety, such as breeding of rodents and insects and contamination of groundwater.

Municipal solid waste is a potential source of the following useful materials

- Raw material to produce manufactured goods
- Feed stock for composting and mulching processes
- Can be used as a fuel

Lesson-24 Quantity of solid waste estimation

Information on waste quantity and composition is important in evaluating alternatives in terms of equipment, systems, plans and management programmes. Based on the quantity of wastes generated, one can plan appropriate means for separation, collection and recycling programmes. That is to say, the success of solid waste management depends on the appropriate assessment of quantity of wastes generated. This lesson deals with the estimation of quantity of solid waste

The quantity of solid waste generated depends on a number of factors such as

- food habits,
- standard of living
- degree of commercial activities
- seasons

The quantity of solid waste can be expressed in units of volume or in units of weight. The advantage of measuring quantity in terms of weight rather than weight is that weight is fairly constant for a given set of discarded objects, whereas volume is highly variable. Waste generated on a given day in a given location occupies different volumes in the collection truck, on the transfer station, in the storage pit or in a landfill. In addition, the same waste can occupy different volumes in different trucks or landfills. Hence, its always preferable to express the quantity of solid waste on weight basis.

The best method for estimating waste quantity is to install permanent scales at disposal facilities and weigh every truck on the way in and again in the way out. At disposal facilities without permanent scales, portable scales can be used to develop a better estimate of the weight of waste being deliverd. Selected trucks are weighed and environmental engineers use the results to estimate the overall weight of the waste stream. Weighing all trucks entering the disposal facility is a tedious job and hence a method of truck selection must be done. A simple approach will be to weigh every nth truck (for instance, every 4th truck) that delivers waste to the facility. This approach assume that the trucks weighed represent all trucks arriving at the facility. The total waste taonnage can be estimate can be estimated with the following equation

$W = T (w/t)$

Where,

W is the total weight of the waste delivered to the facility

T is the total number of trucks that delivered waste in the facility w is the total weight of the truck that were weighed

t is the number of trucks that were weighed

Similarly the total weight of waste delivered for the whole year is summed up and total tones of waste generated in a year can be calculated.

The quantity of solid waste is often expressed in kg per capita per day so that the waste streams in different areas can be compared. The quantity is typically calculated with the following equation

$Q = 1000\ T / 365 * P$

Where, Q – Quantity of waste in kg per capita per day

T – Tonnes of waste generated in a year

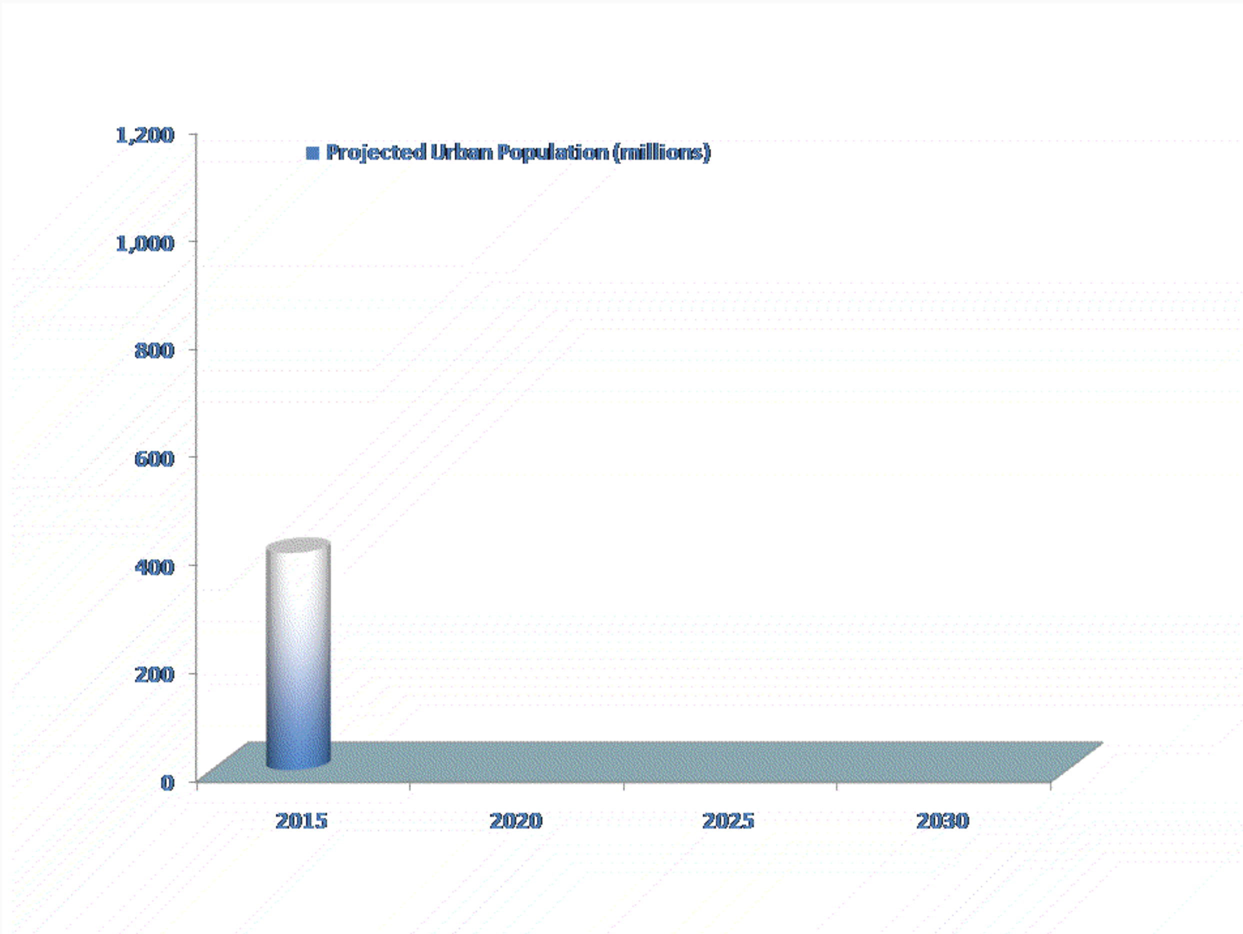
P – Population of the area in which the waste is being generated

Data on quantity variation and generation are useful in planning for collection and disposal systems. Indian cities now generate eight times more municipal solid wastes than they did in 1947 because of increasing urbanization and changing life styles. Municipal solid wastes generation rates in small towns are lower than those of metro cities, and the per capita generation rate of municipal solid wastes in India varies in towns and cities. It was also estimated that the total municipal solid wastes generated by 217 million people living in urban areas was 23.86 million t/yr in 1991, and more than 39 million ton in 2001. Waste generation rate in Indian cities ranges between 200 - 500 grams/day, depending upon the region's lifestyle and the size of the city. The per capita waste generation is increasing by about 1.3% per year in India.

Waste generation and GDP

The per capita waste generation rate is strongly correlated to the gross domestic product (GDP) of a country (Table 2). Per capita waste generation is the amount of waste generated by one person in one day in a country or region. The waste generation rate generally increases with increase in GDP. High income countries generate more waste per person compared to low income countries due to reasons discussed in further sections. The average per capita waste generation in India is 370 grams/day as compared to 2,200 grams in Denmark, 2,000 grams in US and 700 grams in China.

Country	**Per Capita Urban MSW Generation (kg/day)**	
	1999	**2025**
Low Income Countries	0.45 - 0.9	0.6 - 1.0
Middle Income Countries	0.52 - 1.1	0.8 - 1.5
High Income Countries	1.1 - 5.07	1.1 - 4.5



The urban population of India is approx. 341 million in 2010. Figure 1 suggest the projected MSW quantities are expected to increase from 2015 to 2030 and that per capita per day production will increase to 1.032 kg, and urban population as 586 million in 2030.

Lesson-25 Composition to solid waste

Its very important to know about the composition of solid waste before managing them. Hence comes the objective of this lesson, which will deal with the composition of a typical solid waste, the factors affecting the composition and the changing composition over a period of time

Materials in solid wastes can be broadly categorized into three groups, Compostable, Recyclables and Inerts. Compostable or organic fraction comprises of food waste, vegetable market wastes and yard waste. Recyclables are comprised of paper, plastic, metal and glass. The fraction of solid wastes which can neither be composted nor recycled into secondary raw materials is called Inerts. Inerts comprise stones, ash and silt which enter the collection system due to littering on streets and at public places.

Waste composition dictates the waste management strategy to be employed in a particular location. Organics in municipal solid wates are putrescible, and are food for pests and insects and hence need to be collected and disposed off on a daily basis. The amount of recyclables like paper and plastic in solid wastes dictates how often they need to be collected. Recyclables represent an immediate monetary value to the collectors. Organics need controlled biological treatment to be of any value, however due to the general absence of such facilities, organics do not represent any direct value to informal collectors.

A major fraction of urban municipal solid wastes in India is organic matter (51%). Recyclables are 17.5 % of the municipal solid wates and the rest 31% is inert waste. It has to be understood that this composition is at the dump and not the composition of the waste generated. The actual percentage of recyclables discarded as waste in India is unknown due to informal picking of waste which is generally not accounted. Accounting wastes collected informally will change the composition of municipal solid wastes considerably and help estimating the total waste generated by communities.

Waste composition varies with the socio-economic status within a particular community, since income, for example, determines life style, composition pattern and cultural behavior.

Factors affecting quantity and composition of solid waste

Geographic location

The geographical location is related primarily to different climate that can influence both the amount of solid wastes generated and the collection operation. For instance, substantial variations in the amount of yard and garden wastes generated in various parts of India are related to the climate. To illustrate, in the warmer southern areas, where the growing season is considerably longer compared to the northern areas, yard wastes are collected in considerably larger quantities and over a longer period of time.

Season

Seasons of the year have implications for the quantities and composition of certain types of solid wastes. For example, the growing season of vegetables and fruits affect the quantities of food wastes.

Collection frequency

A general observation is that in localities, where there are ultimate collection services, more wastes are c*ollected*. Note that this does not mean that more wastes are *generated*. For example, if a resident has access to only one or two containers per week, due to limited container capacity, he or she will store newspapers or other materials in some specified storage area. However, the same person will tend to throw them away, if there is access to unlimited container services. In this latter situation, the quantity of waste generated may actually be the same but the quantity collected, as it relates to the frequency of collection, is considerably different

Population diversity:

The characteristics of the population influence the quantity and composition of waste generated. The amount of waste generated is more in low-income areas compared to that in high-income areas. Similarly, the composition differs in terms of paper and other recyclables, which are typically more in high-income areas as against low-income areas

Typical waste composition based on income pattern of population

Characteristics	**Low income**	**High income**	**Comments**
Paper	1 to 4 %	20 to 50%	Low paper content indicates low calorific value
Plastics	1 to 6 %	5 to 10%	Plastic is low in low income areas as compared to high-income areas though the use of plastic has increased in recent years.
Ash and Fines	17 to 62 %	3 to 10%	Ash and fines do not contribute to combustion process

Extent of salvaging and recycling

The existence of salvaging and recycling operation within a community definitely affects the quantity of wastes collected.

Public attitude

Significant reduction in the quantity of solid waste is possible, if and when people are willing to change – on their own volition – their habits and lifestyles to conserve the natural resources and to reduce the economic burden associated with the management of solid wastes.

Legislation

This refers to the existence of local and state regulations concerning the use and disposal of specific materials and is an important factor that influences the composition and generation of certain types of wastes.

In a nutshell, elements that relate to waste generation include land use characteristics, population in age distribution, legislation, socio economic conditions, etc.

Changing composition of municipal solid wastes in India

It is rather interesting to study the changes in the composition of waste in India in the past. The following table gives the changing composition of Municipal Waste over the last two decades and is attributed to the changing life styles and increasing consumerism.

Component	% of Wet Weight	
	1971-73 (40 cities)	1995 (23 cities)
Paper	4.14	5.78
Plastics	0.69	3.90
Metals	0.50	1.90
Glass	0.40	2.10
Rags	3.83	3.50
Ash and Fine	49.20	40.30
Total Compostable Matter	41.24	41.80

Lesson-26 Characteristics of solid waste

In order to identify the exact characteristics of municipal wastes, it is necessary that we analyse them using physical and chemical parameters. This lesson will emphasize about the various characteristics of solid wastes and their importance.

Physical characteristics

Information and data on the physical characteristics of solid wastes are important for the selection and operation of equipment and for the analysis and design of disposal facilities. The following physical characteristics are to be studied in detail.

Density

Density of waste, i.e., its mass per unit volume (kg/m^3), is a critical factor in the design of a solid waste management system, e.g., the design of sanitary landfills, storage, types of collection and transport vehicles, etc. To explain, an efficient operation of a landfill demands compaction of wastes to optimum density. Any normal compaction equipment can achieve reduction in volume of wastes by 75%, which increases an initial density of 100 kg/m^3 to 400 kg/m^3. In other words, a waste collection vehicle can haul four times the weight of waste in its compacted state than when it is uncompacted. Significant changes in density occur spontaneously as the waste moves from source to disposal, due to scavenging, handling, wetting and drying by the weather, vibration in the collection vehicle and decomposition

Moisture content

Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total wet weight of the waste. Moisture increases the weight of solid wastes, and thereby, the cost of collection and transport. In addition, moisture content is a critical determinant in the economic feasibility of waste treatment by incineration, because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour. In the main, wastes should be insulated from rainfall or other extraneous water. We can calculate the moisture percentage, using the formula given below

$$\text{Moisture content}(\%)=\frac{Wet\cdot weight-Dry\cdot weight}{Wet \cdot weight}x\ 100$$

A typical range of moisture content is 20 to 40%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 40% are not uncommon. Climatic conditions apart, moisture content is generally higher in low income countries because of the higher proportion of food and yard waste.

Size of Waste constituents

The size distribution of waste constituents in the waste stream is important because of its significance in the design of mechanical separators and shredder and waste treatment process. This varies widely and while designing a system, proper analysis of the waste characteristics should be carried out.

Calorific Value

Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kcal/kg. The calorific value is determined experimentally using Bomb calorimeter in which the heat generated at a constant temperature of $25^{O}C$ from the combustion of a dry sample is measured.

The physical properties that are essential to analyse of wastes disposed at landfills are:

Field capacity

The field capacity of municipal solid waste is the total amount of moisture which can be retained in a waste sample subject to gravitational pull. It is a critical measure because water in excess of field capacity will form leachate, and leachate can be a major problem in landfills. Field capacity varies with the degree of applied pressure and the state of decomposition of the wastes.

Permeability of compacted wastes

The hydraulic conductivity of compacted wastes is an important physical property because it governs the movement of liquids and gases in a landfill. Permeability depends on the other properties of the solid material include pore size distribution, surface area and porosity. Porosity represents the amount of voids per unit total volume of material. The porosity of municipal solid waste varies typically from 0.40 to 0.67 depending on the compaction and composition of the waste.

Compressibility

It is the degree of physical changes of the suspended solids or filter cake when subjected to pressure.

Chemical characteristics

Knowledge of the classification of chemical compounds and their characteristics is essential for the proper understanding of the behaviour of waste, as it moves through the waste management system. The products of decomposition and heating values are two examples of chemical characteristics. If solid wastes are to be used as fuel, or are used for any other purpose, we must know their chemical characteristics, including the following

Chemical: Chemical characteristics include pH, Nitrogen, Phosphorus and Potassium (N-P-K), total Carbon, C/N ratio, calorific value.

Bio-Chemical: Bio-Chemical characteristics include carbohydrates, proteins, natural fibre, and biodegradable factor.

Toxic: Toxicity characteristics include heavy metals, pesticides, insecticides, Toxicity test for Leachates (TCLP), etc.

Lipids

This class of compounds includes fats, oils and grease. Lipids have high calorific values, about 38000 kcal/kg, which makes waste with a high lipid content suitable for energy recovery processes. Since lipids in the solid state become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition. They are biodegradable but because they have a low solubility in waste, the rate of biodegradation is relatively slow.

Carbohydrates

Carbohydrates are found primarily in food and yard waste. They include sugars and polymers of sugars such as starch and cellulose and have the general formula $(CH_2O)_X$. Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane. Decomposing carbohydrates are particularly attractive for flies and rats and for this reason should not be left exposed for periods longer than is necessary.

Proteins

Proteins are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH_2). They are found mainly in food and garden wastes and comprise 5-10% of the dry solids in solid waste. Proteins decompose to form amino acids but partial decomposition can result in the production of amines, which have intensely unpleasant odours.

Natural fibres

This class includes the natural compounds, cellulose and lignin, both of which are resistant to biodegradation. They are found in paper and paper products and in food and yard waste. Cellulose is a larger polymer of glucose while lignin is composed of a group of monomers of which benzene is the primary member. Paper, cotton and wood products are 100%, 95% and 40% cellulose respectively. Since they are highly combustible, solid waste having a high proportion of paper and wood products, are suitable for incineration. The calorific values of ovendried paper products are in the range 12000 – 18000 kcal/kg and of wood about 20000 kcal/kg, which compare with 44200 kcal/kg for fuel oil.

Synthetic organic material (Plastics)

They are highly resistant to biodegradation and, therefore, are objectionable and of special concern in solid waste management. Hence the increasing attention being paid to the recycling of plastics to reduce the proportion of this waste component at disposal sites. Plastics have a high heating value, about 32,000 kJ/kg, which make them very suitable for incineration. But, one should note that polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas. The latter increases corrosion in the combustion system and is responsible for acid rain.

Non-combustibles:

This class includes glass, ceramics, metals, dust and ashes, and accounts for 12 – 25% of dry solids.

Heating value

An evaluation of the potential of waste material for use as fuel for incineration requires a determination of its heating value, expressed as kilojoules per kilogram (kJ/kg). The heating value is determined experimentally using the *Bomb calorimeter test*, in which the heat generated, at a constant temperature of 25°C from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water (100°C), the combustion water remains in the liquid state. However, during combustion, the temperature of the combustion gases reaches above 100°C, and the resultant water is in the vapour form. While evaluating incineration as a means of disposal or energy recovery, one has to consider the heating values of respective constituents.

Ultimate analysis

This refers to an analysis of waste to determine the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur, and it is done to perform mass balance calculation for a chemical or thermal process. Besides, it is necessary to determine ash fraction because of its potentially harmful environmental effects, brought about by the presence of toxic metals such as cadmium, chromium, mercury, nickel, lead, tin and zinc. One should note that other metals (e.g., iron, magnesium, etc.) may also be present but they are non-toxic.

The following table shows an ultimate analysis of a typical municipal solid waste

Element	**Range (% dry weight)**
Carbon	25-30
Hydrogen	2.5-6.0
Oxygen	15-30
Nitrogen	0.25-1.2
Sulphur	0.02-0.12
Ash	12-30

Proximate analysis

This is important in evaluating the combustion properties of wastes or a waste or refuse derived fuel. The fractions of interest are:

- moisture content, which adds weight to the waste without increasing its heating value, and the evaporation of water reduces the heat released from the fuel;
- ash, which adds weight without generating any heat during combustion;

- volatile matter, i.e., that portion of the waste that is converted to gases before and during combustion;
- fixed carbon, which represents the carbon remaining on the surface grates as charcoal. A waste or fuel with a high proportion of fixed carbon requires a longer retention time on the furnace grates to achieve complete combustion than a waste or fuel with a low proportion of fixed carbon.

The following table shows an proximate analysis of a typical municipal solid waste

Components	**Value (%)**	
	Range	Typical
Moisture	15-40	20
Volatile matter	40-60	53
Fixed carbon	5-12	7
Glass, metal, ash	15-30	20

Lesson-27 Solid waste disposal in rural and urban areas

This lesson educates the various methods of disposing solid wastes, explaining their scope, importance and need.

Disposal is the final element in the solid waste mangement system. It is the ultimate fate of all solid wastes, be the residential wastes collected and transported directly to a landfill site, semisolid waste (sludge) from municipal and industrial treatment plants, incinerator residue, compost or other substances from various solid waste processing plants that are of no further use to society. It is, therefore, imperative to have a proper plan in place for safe disposal of solid wastes, which involves appropriate handling of residual matter after solid wastes have been processed and the recovery of conversion products/energy has been achieved.

Problems due to improper disposal of wastes

- health hazards (e.g., residents in the vicinity of wastes inhale dust and smoke when the wastes are burnt; workers and rag pickers come into direct contact with wastes, etc.);
- pollution due to smoke;
- pollution from waste leachate and gas;
- blockage of open drains and sewers.

Hence it is very much imminent that safe disposal of solid wastes is important for safeguarding both public health and the environment.

Some of the disposal methods of solid wastes are

1. Open dumping
2. Composting
3. Land filling
4. Incineration
5. Gasification
6. Refuse-derived fuel
7. Pyrolysis

Open dumping

Open dumping is an illegal process, in which any type of the waste such as household trash, garbage, tires, demolition/construction waste, metal or any other material dump at any location like along the roadside, vacant lots on public or private property even in parks other than a permitted landfill or facility. Open dumping poses a threat to human health and the environment because it causes land pollution. In the developing countries, municipal solid waste is commonly disposed off by discharge the waste in open dumps around 60-90%, which are environmentally unsafe. Open dumping of nondegradable component like burning of plastic waste is added to create air pollution and uncollected waste pose serious health hazards. As a result of illegal dumping, land area such as property value may decrease and also put negative impact on the scarcity of land in future

Composting

Composting is a natural biological process that carried out under controlled aerobic (requires oxygen) or anaerobic conditions (without oxygen). Organic waste is biodegradable and can be processed in the presence of oxygen or in the absence of oxygen using anaerobic digestion. Anaerobic composting is not common because of the slow degradation rate and produce odorous intermediate product. Anaerobic digestion however also produces methane gas which is an important source of bio-energy.

Composting is an efficient method to break down organic materials into an end product which is beneficial for soil and plants. Compost is used as an organic amendment to improve the physical, chemical and biological properties of soil. Adding compost helps to increase the ability of the soil to hold and release essential nutrients.

Composting has a long tradition particularly in rural India. Composting is difficult process because the waste arrives in a mixed form and contains a lot of non-organic material. When mixed waste is composted, the end product is of poor quality. The presence of plastic objects in the waste stream is especially problematic, since these materials do not get recycled or have a secondary market. In the absence of segregation, even the best waste management system or plant will be rendered useless. In India, composting is used around 10-12% because composting needs segregation of waste and sorting is not widely practiced

Landfills

A landfill is an area of land onto or into which waste is deposited. The aim is to avoid any contact between the waste and the surrounding environment, particularly the groundwater.

Landfilling will be done for the following types of waste:

- Mixed waste not found suitable for waste processing;
- Pre-processing and post-processing wastes from waste processing sites;
- Non-hazardous waste not being processed or recycled.

Landfilling will usually not be done for the following waste streams in the municipal solid waste:

- Biowaste/garden waste
- Dry recyclables

Landfills minimise the harmful impact of solid waste on the environment by the following mechanisms:

- Isolation of waste through containment;
- Elimination of polluting pathways;
- Controlled collection and treatment of products of physical, chemical and biological changes within a waste dump – both liquids and gases; and
- Environmental monitoring till the waste becomes stable.

Essential components of municipal solid waste landfill

1. A liner system at the base and sides of the landfill which prevents migration of leachate or gas to the surrounding soil.
2. A leachate collection and control facility which collects and extracts leachate from within and from the base of the landfill and then treats the leachate.
3. A gas collection and control facility (optional for small landfills) which collects and extracts gas from within and from the top of the landfill and then treats it or uses it for energy recovery.
4. A final cover system at the top of the landfill which enhances surface drainage, prevents infiltrating water and supports surface vegetation.
5. A surface water drainage system which collects and removes all surface runoff from the landfill site.
6. An environmental monitoring system which periodically collects and analyses air, surface water, soil-gas and ground water samples around the landfill site.
7. A closure and post-closure plan which lists the steps that must be taken to close and secure a landfill site once the filling operation has been completed and the activities for long-term monitoring, operation and maintenance of the completed landfill.

Incineration

Incineration is one of the waste treatment technologies that involve the combustion of organic materials and other substances. This refers to the controlled burning of wastes, at a high temperature (roughly 1200 – 1500°C), which sterilises and stabilises the waste in addition to reducing its volume. Hence, Incineration waste treatment system is normally described as 'thermal treatment'. Incinerator process converts the waste into bottom ash, particulates and heat, which can be used to generate the electric power. The volume of ash is usually 10% of the original volume of the waste. Finally, the ash is typically disposed off in the landfill site. In developing countries, the use of incineration is in few amounts to around 1-5% respectively.

In India the incineration is a poor option as the waste consists mainly high organic material (40–60%) and high inert content (30–50%) also low calorific value content (800–1100 kcal/kg), high moisture content (40–60%) in MSW and the high costs of setting up and running the plants.

Gasification

This is the partial combustion of carbonaceous material (through combustion) at high temperature (roughly 1000°C) forming a gas, comprising mainly carbon dioxide, carbon monoxide, nitrogen, hydrogen, water vapour and methane, which can be used as fuel. Gasification is the solid waste incineration under oxygen deficient conditions, to produce fuel gas. In India, there are very few gasifiers in operation, but they are mostly for burning of biomass such as agro-residues, sawmill dust, and forest wastes. Gasification can also be used for MSW treatment after drying, removing the inert and shredding for size reduction.

Refuse-derived fuel (RDF)

This is the combustible part of raw waste, separated for burning as fuel. Various physical processes such as screening, size reduction, magnetic separation, etc., are used to separate the combustibles

Pyrolysis

This is the thermal degradation of carbonaceous material to gaseous, liquid and solid fraction in the absence of oxygen. This occurs at a temperature between 200 and 900°C. The product of pyrolysis is a gas of relatively high calorific value of 20,000 joules per gram with oils, tars and solid burned residue

Module 8. INTRODUCTION TO AIR POLLUTION. TYPES OF POLLUTANTS PROPERTIES AND THEIR EFFECTS ON LIVING BEINGS

Lesson-28 Introduction to air pollution

INTRODUCTION

This lesson introduces air pollution, its types and sources.

Introduction to air pollution

As we all know, air is the most essential for our living. A person cannot survive for five minutes without air. The important life controlling element, viz. air, sometimes becomes an enemy when it gets polluted. Air pollution is nothing but a system where presence of any substance (solid, liquid or gas) in the atmosphere in such a concentration that may or may tend to cause injuries to human, crops or property and to the atmosphere itself. The substances which cause air pollution are called as air pollutants.

The polluted air affects not only living beings but also non living things and has a deleterious effect on mankind. Air pollution is a serious problem in many countries of the world. Centre for Science and Environment (CSE) has observed that air pollution is the fifth leading cause of death in India after high blood pressure, indoor air pollution, tobacco smoking and poor nutrition, with about 620,000 premature deaths occurring from air pollution-related diseases. Like China, India faces an unprecedented public health crisis due to air pollution. Half of the urban population breathes air laced with particulate pollution that has exceeded the safety standards. As much as one third of urban population is exposed to critical level of particulate pollution. Smaller cities are among the most polluted in the country.

The green think tank released its own assessment and the global study's India specific data during February 2013 warning that the number of premature deaths due to air pollution had increased six fold over the last 10 years.

Air quality data generated by the Central Pollution Control Board (CPCB) for 2007 under the National Air Quality Monitoring Programme (NAMP) presents deadly facts about air pollution levels in Indian cities. CSE has analysed the official data to assess the state of air quality and trend in Indian cities. The most widely monitored pollutants in India are particulate matter (PM), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and on a limited scale carbon monoxide. Some of the worst forms of air pollutions are found in Indian cities. The Central Pollution Control Board (CPCB) considers air to be 'clean' if the levels are below 50 per cent of the prescribed standards for pollutants. During 2007 only 2 per cent cities have low air pollution on the basis of PM_{10}. In about 80 per cent of cities (of a total of 127 cities/towns monitored under the NAMP) at least one criteria pollutant exceeded the annual average ambient air quality standards. This has serious public health implications. There are very few cities, which can be termed clean keeping PM_{10} levels (respirable particulates) as criteria however over the years SO_2 levels have fallen sharply in many cities but the NO_2 levels are increasing in many cities.

Issues of concern in air pollution

Global warming

In past few decades, there has been a large amount of hue and cry regarding the issue of earth getting hotter and hotter year after year. This concept of global warming is predominantly because of major changes in the human lifestyle. Generally, green house gases viz., Carbon dioxide, methane, etc. in the lower atmosphere act as a shield in trapping some of the heat, as it radiates back to the atmosphere from the Earth. Such gases because of their heat and warmth have made survival for life on our mother Earth. But when the quantities of these green house gases increases, excessive heat is generated and makes living almost impossible.

The reasons for increase in quantity of green house gases :

- Continuous and excessive burning of fossil fuels increases carbon dioxide level
- Excessive deforestation leads to increase in carbon dioxide level
- Large scale decomposition of organic matter in swamps, rice fields, live stock yards has lead to increase in methane level
- Level of Chloro Flouro Carbons (CFCs) increasing due to change in human life style

Acid rain

Rainfall through unpolluted environment is slightly acidic with its pH value ranging just less than 7. However, when the environment is polluted with primary pollutants like SO_x and NO_x gases, the resultant precipitation tends become more acidic. This acidity if because of the formation of secondary pollutants like sulphuric acid and nitric acid due to the reaction of water vapour with SO_x and NO_x gases. It has been specified that when the pH value of rainfall is less than 5.6 or below, then the rain is specifically termed as acidic.

Photochemical smog

Photochemical smog is a unique type of air pollution which is caused by reactions between sunlight and pollutants like hydrocarbons and nitrogen dioxide. Although photochemical smog is often invisible, it can be extremely harmful, leading to irritations of the respiratory tract and eyes. In regions of the world with high concentrations of photochemical smog, elevated rates of death and respiratory illnesses have been observed.

Ozone depletion

Ozone depletion is the most dreaded aspect of air pollution, having wide spread implications, extending over the entire atmosphere. This problem is caused by the reduction of naturally available ozone layer in the atmosphere. Scientists are also becoming aware of the possible connection between ozone depletion and climate change due to global warming.

The increased concentrations of green house gases leading to warmer climate at the Earth's surface, infact causes cooling effect at altitudes where the ozone layer is found. This cooling of the stratosphere enhances the chemical reaction that destroys the ozone, leading to further ozone depletion.

Chlorofluoro carbons (CFCs) are the chief agents of ozone destruction. They are largely used and subsequently released in modern world, in refrigeration, air-conditioning, fire extinguishers. These inert CFCs do not disintegrate in the lower atmosphere and do rise several kilometers up into the stratosphere, where they release chlorine atoms in the presence of sunlight. Each chlorine atom from CFCs then reacts with an ozone molecule forming Chlorine monoxide. The Chlorine monoxide thus formed, reacts with another oxygen atom to form a new oxygen molecule and a chlorine atom. The chlorine atoms, thus replenished can go on to break apart thousands and thousands of more ozone molecules, leading to large scale ozone deficits. It has been estimated that each atom of chlorine can destroy up to 1 lakh ozone molecules at a faster rate than the gas is replenished naturally.

Types of air pollution

Personal air exposure

It refers to exposure to dust, fumes and gases to which an individual exposes himself when he indulge himself in smoking

Occupational air exposure

It represents the type of exposure of individuals to potentially harmful concentration of aerosols, vapors, and gases in their working environment.

Community air exposure

This is most serious, complex, consists of varieties of assortment of pollution sources, meteorological factors, and wide variety of adverse social, economical, and health effects.

- Natural Sources –Volcano, forest fire, dust storms, oceans, plants and trees
- Anthropogenic Sources - created by human beings

Classification of sources of Air pollution

Air pollutants may be classified by sources as stationary or mobile

-Stationary sources

- Point sources (Industrial processing, power plants, fuels combustion etc.)
- Area sources (Residential heating coal gas oil, on site incineration, open burning etc.)

- Mobile sources

- Line sources (Highway vehicles, railroad locomotives, channel vessels etc.)

Lesson-29 Types of primary air pollutants and their properties

INTRODUCTION

The agent causing pollution in air is termed as air pollutant. Air pollutants are broadly classified into primary and secondary pollutants. This lesson deals with primary pollutants and their properties.

Primary air pollutants

The atmosphere has hundreds of air pollutants from natural or from anthropogenic sources. All such pollutants are called as primary pollutants

The important primary pollutants are:

1. Sulphur oxides, specifically sulphur dioxide
2. Carbon monoxide
3. Nitrogen oxides
4. Lead
5. Hydrocarbons
6. Radioactive substances
7. Hydrogen sulphide

Sulphur dioxide

Sulphur dioxide is an irritant gas, and when inhaled, affects our mucous membranes. It increases the breathing rate and causes oxygen deficits in the body, leading to bronchial spasms. Patients of asthma are very badly affected by this pollutant. Sulphur dioxide is also responsible for causing acidity in fogs, smokes and in rains and hence is the major source of corrosion of buildings and metal objects.

Major sources of Sulphur dioxide

- Burning of fuels
- Thermal power plants
- Oil refineries and chemical plants
- Open burning of garbage

Carbon monoxide

Carbon monoxide possesses about 200 times affinity for blood haemoglobin than oxygen. Eventually, then inhaled, CO replaces O_2 from the haemoglobin and form what is known as carboxy-haemoglobin. This carboxy-haemoglobin is of no use for respiratory purposes, and hence when about half of the haemoglobin of the blood is used up in forming carboxy-haemoglobin, death becomes a certainty. Persons dying of carbon monoxide inhalations exhibit characteristics bright pink colour of the flesh due to the presence of pink coloured carboxy-haemoglobin in their bloods.

Carbon monoxide also affects the central nervous system, and is even responsible for heart attacks, and high mortality rates.

Carbon monoxide chiefly originates from automobile exhausts, and is caused by incomplete combustion of organic matter.

Oxides of Nitrogen

Nitric oxide and Nitrogen dioxide are found to be injurious to human health. Nitrogen dioxide is more injurious than nitric oxide.

Eye and nasal irritations are the common problems caused by nitrogen dioxide. Also respiratory discomfort occurs with brief exposure to NO_2.

Hydrogen sulphide

It is a foul smelling gas with a typical odour of rotten egg. Exposure to hydrogen sulphide for short periods may lead to loss of smell sense . This gas may also cause headaches, conjunctivitis, sleepnessness and pain in the eyes. Its higher concentration may block oxygen transfer and damage the nerve tissues. However, hydrogen sulphide is generally not found in any trouble some concentrations in our atmosphere mainly because it is not emitted in automobile exhausts.

Lead

Lead is mainly injected into the atmosphere through the exhausts of automobiles, particularly, by automobiles running on petrol. The concentrations of lead in inhaled air, may cause irritation of mucous membranes of nose, throat and lungs. Lead poisoning may also cause damage to gastro-intestinal tracts, liver and kidney. It may also cause abnormalities in preganancy and fertility. Lead poisoning is also found to be responsible for retarding mental growth in children.

Hydrocarbons

The compounds containing only hydrogen and carbon are hydrocarbons. Hydrocarbons are chiefly released into the atmosphere by automobile exhausts. Substances like formaldehyde cause irritation of eyes, skins and lungs and hence may be quite injurious to health

Radioactive isotopes

The radioactive isotopes viz., Strontium-90, Cesium-137 and Iodine-131 have been the main products of atomic explosives and accidental discharges from atomic and nuclear reactors; although, however, other isotopes may also be present. The serious health hazards caused by such radioactive emissions are anemia, cancers, shortening of life spans and above all the genetic effects, like sterility, embroyo defects, congenital malformations, etc. Radioactivity is notorious for its delayed and long term evil effects on human health.

Lesson-30 Types of secondary air pollutants and their properties

INTRODUCTION

This lesson deals with secondary air pollutants and their properties.

The primary pollutants often react with one another or with water vapour, in the presence of sunlight to form entirely a new type of pollutants called / termed as secondary air pollutants. These types of pollutants are the chemical substances, which are produced from the chemical reactions of natural or anthropogenic air pollutants or due to their oxidation caused by the energy of the sun.

There are two main reasons for making distinction between primary and secondary air pollutants. First, in order to perform and interpret atmospheric chemical research, one must distinguish between primary and secondary air pollutants. The second reason is that emission controls can only be effectively treated at primary anthropogenic air pollutants, their formation process must be understood and somehow interrupted. Controlling the air concentrations of primary anthropogenic pollutants is much easier than controlling the concentrations of secondary pollutants. The distinction between primary and secondary air contaminants is not always clear, as the same chemical can either be directly emitted into or formed by reactions in the air.

As secondary air pollutants are mainly formed by chemical reactions, and chemical reactions usually produce products that are less reactive than their reactants, it would be convenient to assume that secondary pollutants are more inert than primary pollutants. In many cases, it is true. However, as sunlight drives many atmospheric reactions, additional energy can be found in some secondary pollutants.

The most important secondary air pollutants are:

- Sulphuric acid
- Ozone
- Formaldehyde
- Peroxy-acetyl-nitrate (PAN)

Sulphuric acid

It is formed by the simple chemical reaction between sulphur dioxide and water vapour, and is much more toxic pollutant than sulphur dioxide having far reaching effects on environment since it causes acid rain.

Ozone

Ozone is a primary example of a very reactive secondary air pollutant. Thus photoactivation can produce highly reactive products. The peak concentration of ozone is built late in the day, after the sun has had time to drive their formation.

Since ozone has been generally found to occur in the highly motorized areas, particularly during day time, it is believed that it is produced by the photochemical reaction of hydrocarbons and nitrogen oxide. Possibility of formation of such photochemical smog is quite high in places where number of plying automobiles is too high and where inversion smog conditions prevail in the atmosphere.

The presence of ozone gas in the air may cause irritation in the respiratory tract, reaching much deeper into the lungs than the oxides of sulphur.

Formaldehyde

Formaldehyde is an organic chemical that is very prevalent in our environment. It has colorless gas with a pungent odor from a family of gases called aldehydes. Commonly known as a preservative in medical laboratories and mortuaries, formaldehyde is also found in other products such as chemicals, particle board, household products, glues, permanent press fabrics, paper product coatings, fiberboard and plywood. It is a sensitizing agent that can cause an immune system response upon initial exposure. It is also a suspected human carcinogen that is linked to nasal cancer and lung cancer. Formaldehyde exposure is most common through gas-phase inhalation.

Peroxy-acetyl-nitrate (PAN)

It is a secondary pollutant present in photochemical smog. It is thermally unstable and decomposes into peroxyethanoyl radicals and nitrogen dioxide gas. It is a lachrymatory substance.

Peroxyacetyl nitrate, or PAN, is an oxidant more stable than ozone. Hence, it is better capable of long-range transport than ozone. It serves as a carrier for oxides of nitrogen (NOx) into rural regions and causes ozone formation in the global troposphere.

The formation of PAN on a secondary scale becomes an issue when ethanol is used as an automotive fuel. Acetaldehyde emissions increase, which subsequently react in the atmosphere to form smog. Whereas ethanol policies solve domestic oil supply problems, they drastically exacerbate air quality conditions

Peroxy acetyl nitrate irritates the eyes resulting in blurred vision and eye fatigue. It decreases vital capacity due to decrease in both inspiratory capacity and expiratory reserve volume.

Lesson-31 Effects of air pollutants on living beings

INTRODUCTION

Air pollutants have a deleterious impact on both living and non-living beings. In this lesson, you will be learning about the effects of air pollution on living and non-living beings

Effect of Acid rain

When an air pollutant, such as sulphuric acid combines with the water droplets that make up clouds, the water droplets become acidic. When those droplets fall to the ground as rain or snow, the acidity of the water can have damaging effects on the environment. When acid rain falls over an area, it can kill trees and harm animals, fish, and other wildlife. Acid rain destroys the leaves of plants. When acid rain infiltrates into soils, it changes the chemistry of the soil making it unfit for many living things that rely on soil as a habitat or for nutrition. Acid rain also changes the chemical properties of the lakes and streams that the rainwater flows into, harming fish and other aquatic life.

Ozone layer depletion

Air pollutants called chlorofluorocarbons (or CFCs) destroy ozone molecules in the stratosphere. This has left places in the layer where the ozone is thin. These areas of thin ozone are called ozone holes. The ozone layer, located in the stratosphere layer of Earth’s atmosphere, shields our planet from the Sun’s ultraviolet radiation. Ultraviolet radiation causes skin cancer and damages plants and wildlife.

Tropospheric ozone harms living things

Ozone molecules in the troposphere damage lung tissues of animals and prevent plant respiration by blocking the openings in leaves, called stomata, where respiration occurs. Without sufficient respiration, a plant is not able to photosynthesize at a high rate and will not be able to grow. Ozone is also able to enter the stomata and decay plant cells directly.

Global warming harms living things

Our planet is currently warming much more rapidly than expected because of additional greenhouse gasses that are released into the atmosphere from air pollution. When fuels are burned, some of the pollutants released, such as carbon dioxide, are greenhouses gasses. Through the process of photosynthesis, plants convert carbon dioxide into oxygen and use the carbon to grow larger. However, the amount of carbon dioxide released by burning fuels is far greater than plants can convert. Cutting down forests exacerbates the problem

Human health effects

- Exposure to air pollution is associated with numerous effects on human health, including pulmonary, cardiac, vascular, and neurological impairments.
- The health effects vary greatly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution.
- Exposure to air pollution can cause both acute (short-term) and chronic (long-term) health effects.
- Acute effects are usually immediate and often reversible when exposure to the pollutant ends. Some acute health effects include eye irritation, headaches, and nausea.
- Chronic effects are usually not immediate and tend not to be reversible when exposure to the pollutant ends. Some chronic health effects include decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants.

Effects on human respiratory system

- Both gaseous and particulate air pollutants can have negative effects on the lungs.
- Solid particles can settle on the walls of the trachea, bronchi, and bronchioles.
- Continuous breathing of polluted air can slow the normal cleansing action of the lungs and result in more particles reaching the lower portions of the lung.
- Damage to the lungs from air pollution can inhibit this process and contribute to the occurrence of respiratory diseases such as bronchitis, emphysema, and cancer.

Effect of different air pollutants on living beings

Carbon monoxide

CO (carbon monoxide) combines with haemoglobin to lessen the amount of oxygen that enters our blood through our lungs. The effect of carbon monoxide leads to headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death.

Sulphur dioxide

It can oxidize and form sulphuric acid mist. Thus, presence of sulphur dioxide is responsible for causing acidity in rains and hence causes corrosion of metal objects and buildings. SO_2 in the air leads to diseases of the lung and other lung disorders such as wheezing and shortness of breath. Sulphur dioxide also causes eye irritation, chest tightness.

Nitrogen dioxide

Eye and nasal irritations are the common problems caused by nitrogen dioxide. Nitrogen dioxide also results in respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).

Ozone

Exposure to Ozone leads to eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.

Lead

Lead is responsible to anemia, high blood pressure, brain and kidney damage and neurological disorders. Prolonged exposure can cause damage to the nervous system, digestive problems, and in some cases cause cancer. It is especially hazardous to small children.

Particulate matter

Presence of particulate matter leads to eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.

Volatile organic compounds.

Volatile compounds can cause irritation of the eye, nose and throat. In severe cases there may be headaches, nausea, and loss of coordination. In the longer run, some of them are suspected to cause damage to the liver and other parts of the body.

Formaldehyde

Exposure to formaldehyde causes irritation to the eyes, nose and may cause allergies

Module 9. ISI STANDARDS FOR POLLUTANTS IN AIR AND THEIR ABATEMENTS

Lesson-32 ISI standards for air pollutants and their abatements

This chapter deals with the Indian standards for Air quality and their abatements

National Ambient Air Quality Standards (Source: Central Pollution Control Board)

Pollutants	Time Weighted average	Concentration in ambient air	
		Industrial areas, Residential, Rural and other areas	Sensitive areas
Sulphur Dioxide (SO_2), µg/m^3	Annual Average*	50	20
	24 hours**	80	80
Oxides of Nitrogen as (NO_2) , µg/m^3	Annual Average*	40	30
	24 hours**	80	80
Particulate Matter (RSPM) (size less than 10 microns), µg/m^3	Annual Average*	60	60
	24 hours**	100	100
Particulate Matter (RSPM) (size less than 2.5 microns), µg/m^3	Annual Average*	40	40
	24 hours**	60	60
Ozone (O_3), µg/m^3	8 hours	100	100
	1 hour	180	180
Lead (Pb), µg/m^3	Annual Average*	0.5	0.5
	24 hours**	1.0	1.0
Carbon Monoxide (CO) , mg/m^3	8 hours	2	2
	1 hour	4	4
Ammonia, µg/m^3	Annual Average*	100	100
	24 hours**	400	400
Benzene	Annual Average*	5	5

Benzo Pyrene – particulate phase only, ng/m^3	Annual Average*	1	1
Arsenic, ng/m^3	Annual Average*	6	6
Nickel, ng/m^3	Annual Average*	20	20

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals

** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be compiled with 98 % of the time in a year, 2 % of the time, they may exceed the limits but not on two.

Abatement of air pollution

The air pollution and the resultant air quality can be attributed to emissions from vehicular, industrial and domestic activities. The air quality has been, therefore, an issue of social concern in the backdrop of various developmental activities. The norms for ambient air quality and industry specific emissions have been notified. For control of air pollution, with a view to initiate policy measures and to prepare ambient air quality management plans, 321 Air Quality Monitoring Stations are operational covering twenty five States and four Union Territories.

The CPCB has evolved a format for preparation of action plans, which has been circulated to all State Pollution Control Boards/Committees. The action plans emphasize identification of sources of air pollution, assessment of pollution load and adoption of abatement measures for identified sources. Setting up interdepartmental task force for implementation of city specific action plan has also been suggested.

In order to control vehicular pollution, a road map has been adopted as per the schedule proposed in Auto Fuel Policy, which includes use of cleaner fuels, automobile technologies and enforcement measures for in use vehicles through improved Pollution Under control (PUC) certification system. As per the Auto Fuel Policy, Bharat Stage-II norms for new vehicles have been introduced through out the country from first April, 2005. However, EURO-III equivalent emission norms for all new vehicles, except 2-3 wheelers, have been introduced in 11 major cities from April 1, 2005. To meet Bharat Stage-II, EURO-III and EUROIV emission norms, matching quality of petrol and diesel is being made available.