Environmental Engineering

About the Author

After obtaining diploma in civil engineering in 1959, Mr Basak joined the Irrigation Department of the Government of West Bengal as an overseer and conducted survey work in hilly areas of Kalimpong sub-division for several minor irrigation schemes. In 1961, he joined the Central Water and Power Commission, Government of India as a Supervisor and conducted the project survey for 'Ganga Brahmaputra Navigation cum Irrigation Project'. Then he was posted as Field in-charge of 'Tista Barrage Site'.

Mr Basak joined Malda Polytechnic in 1963, as a demonstrator and was subsequently promoted as lecturer after obtaining AMIE and continued there till his retirement in 1997. He organised Survey Camps for the final year diploma students many times.

He has authored two other books, *Surveying and Levelling* and *Irrigation Engineering*, both published by Tata McGraw-Hill.

Environmental Engineering

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Dedicated to
my wife ***Bharati***
son ***Niladri****, daughter* ***Subarna****,*
and daughter-in-law ***Manidipa***
as a token of love and memories

Preface

Public Health Engineering or Environmental Engineering was one of the three subjects that I taught at Malda Polytechnic. During my teaching stint, which lasted 34 years, the books that I came across were written verbosely and in a complex manner. The students usually found it difficult to understand the subject through these books.

In this book, I have tried to explain the various topics of the subject concisely and lucidly with self-explanatory illustrations so that it may be easily understood by the students.

The book is divided into four parts. Parts I, II and III, namely, Water Supply, Sanitation and Pollution respectively comprise the subject matter. Part IV contains two appendices comprising Multiple-choice Questions and Model Questions. The book covers the syllabi of polytechnics, technical institutions, AMIE and Engineering Colleges. It will also be useful to the engineers working in the Public Health Department.

Salient features of this book are:

- Self-explanatory sketches for each topic
- Numerous worked out problems
- A chapter on Air Pollution and Control
- Multiple-choice questions (Appendix A) and Model questions (Appendix B).

I heartly acknowledge the useful suggestions made by the reviewers for the improvement of this book. I acknowledge the well-wishes of my students and friends. My heartiest thanks to Mr Swapan Chakraborty of Souvenir Commercial Academy, Malda, for preparing the typed copies of the manuscript.

N N Basak

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1

Introduction

1.1 NECESSITY OF WATER SUPPLY SCHEMES

Water Supply Scheme involves (a) collection (b) conveyance (c) treatment and (d) distribution of water.

In early days, people lived in small isolated areas and their habits were such that they consumed water for drinking, bathing and cooking only, and each family collected water for its own use. This necessary water was collected from surface sources like rivers, lakes and ponds, etc.

But as the population increased, towns and cities developed and the habits of people improved. Trades and industries were established and as a result the demand for water increased considerably. The original small water sources became insufficient and large water sources became inevitable.

A large water source may be far away from the township and the quality of water may not be safe for drinking. The role of water supply scheme, i.e. collection, conveyance, treatment and distribution of water comes in handy here.

For every town or city, an administrative body, either the municipality or corporation, has been established to look after the public health, and to supply potable water to consumers after proper treatment.

Now-a-days, water is required for the following purposes:

(a) Drinking and cooking.
(b) Bathing and washing of clothes and utensils,
(c) Washing of vehicles,
(d) Gardening,
(e) Swimming pools, fountains, etc.
(f) Fire-fighting, and
(g) Trades and industries

At many places water is lifted from deep tube wells by a turbine pump and is supplied directly to the consumers without any treatment. However, in that case also the water supply scheme becomes necessary to create a network for distribution.

1.2 SALIENT FEATURES OF A WATER SUPPLY SCHEME

The following are the salient features of a water supply scheme:

1. Population Forecast Every scheme should be such that it may run satisfactorily at least for three decades. So, the probable population of the town or city should be ascertained for the future decades (According to the design periods).

2. Assessment of Water Demand Depending upon the probable population, the total water requirement for the town or city should be estimated considering the domestic demand, public demand, industrial demand, fire demand, etc.

3. Record of Industry The nature and number of industries in a town or city should be recorded because, the industries require much water for running and maintenance. This record should also be updated from time to time.

4. Record of Public Places The nature and number of public places like markets, cinema halls, auditoriums, parks, swimming pools, schools, colleges, etc. should be recorded for the provision of additional water requirement.

5. Sources of Water The cost of the water supply scheme depends on the selection of the site for the source of water. So, the source of water should be such that the cost of conveyance and water treatment may be reasonable.

6. Quality of Water The water should not be too turbid and there should be no or minimum source of contamination to avoid any excessive treatment.

7. Overhead Reservoir The water, after treatment, is generally stored in overhead reservoir from where it is supplied to the consumers. The location of the reservoir should be such that the water can flow easily to the network of distribution system.

1.3 NEED TO PROTECT WATER SUPPLY

The water supply to the consumers should be protected for the following reasons:

(a) The water available from the *surface sources such as rivers, lakes, reservoirs,* etc. may be polluted by the people residing near the sources. The industrial wastes also may pollute the water. It may carry suspended and/or dissolved impurities and bacteria which may cause water-borne diseases like typhoid, dysentry, cholera, etc.

(b) The *underground water* may be polluted by the percolating water which may carry harmful chemicals. Such pollution may be the cause of skin diseases, and troubles of heart, lungs, kidney, etc.

(c) The source of water may be polluted by radioactive substances which may affect the human organs seriously. The discharges from nuclear power plant, nuclear research centre and nuclear explosion contain such radioactive substances.

1.4 FLOW CHART OF A WATER SUPPLY SCHEME

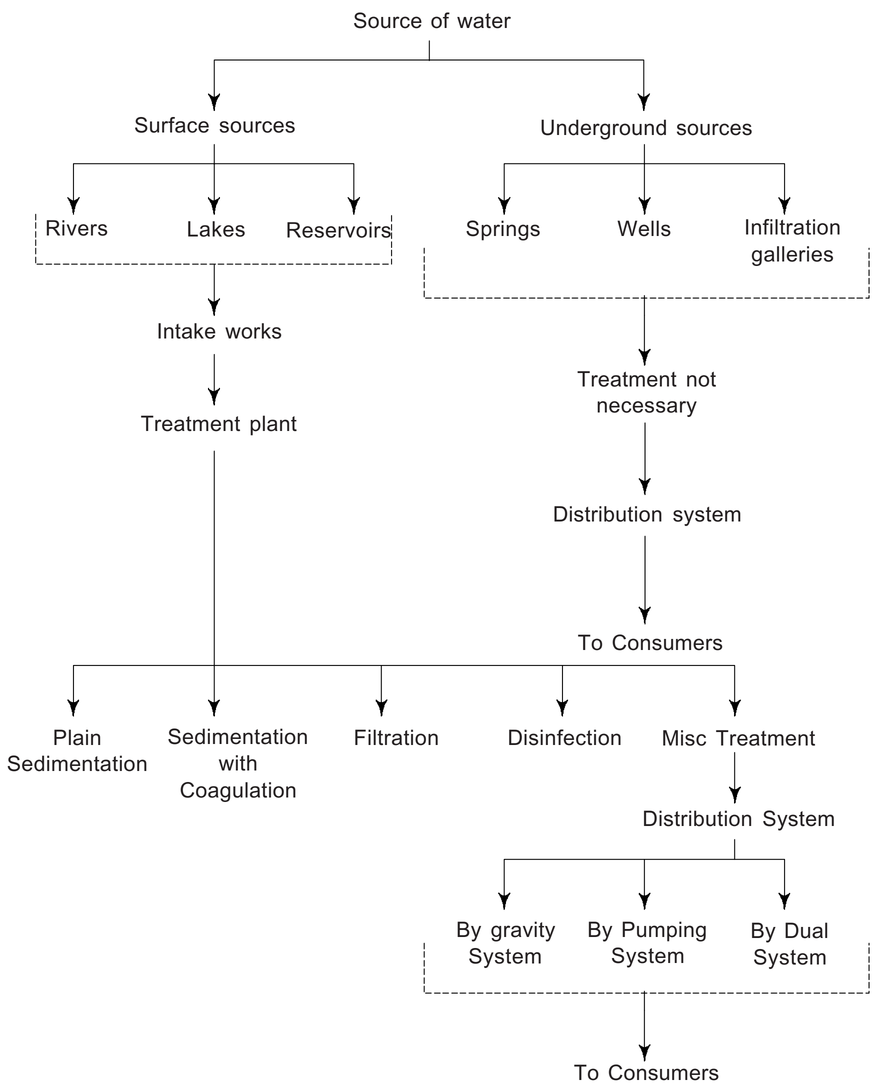

Fig. 1.1 *Flow chart of a water supply scheme*

1.5 DUTIES OF WATER WORKS ENGINEERS

The following are the duties of water works engineers:

(a) The engineer should *have perfect knowledge about planning, designing, construction and maintenance of the structures* required for the water supply system. He has to perform all the above works.

(b) He should be *able to detect the possible causes of contamination of water sources* and should know the methods to be adopted to control the causes of contamination to reduce the load on the treatment plant.

(c) He should *know the laboratory tests* which may be required for the treatment works.

(d) He should *know the account works* related to water supply scheme.

(e) He should *possess the administrative capacity to control the subordinates* so that they are bound to perform their duties sincerely to maintain a regular supply of water to consumers.

Review Questions

1. Explain the necessity of water supply scheme.
2. Enumerate the salient features of water supply scheme.
3. Explain the need to protect water.
4. Give a flow chart of water supply scheme.
5. State the duties of water works engineers.

2

Quantity of Water

2.1 INTRODUCTION

The assessment of the total quantity of water required for a town or a city is the fundamental work in a water supply scheme. The scheme should be designed to run efficiently for at least three future decades (i.e. thirty years). Depending on the total water demand, the suitable source of water should be found out. Sometimes, one source may not be sufficient to supply water throughout the year; in that case, other sources should also be found out.

In the following sections, the factors which govern the demand of water are discussed in detail.

2.2 TYPES OF WATER DEMAND

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

1. Domestic Demand The domestic demand includes the water required in the houses for drinking, cooking, bathing, washing of clothes and utensils, sanitary blocks, private vehicles, gardening, etc. The requirement of water for domestic animals is also included in this demand. In Indian towns or cities, the domestic consumption of water under normal condition is taken as 135 lits/day/capita (as per I.S: 1172–1971). In developed countries, the water demand is very high due to their advanced life style.

2. Commercial Demand It includes the water demand in commercial centres like office buildings, hotels, restaurants, shopping centres, cinema houses, motor garages, laundries, dairies, etc. For this purpose, the demand is assumed as 25 lits to 40 lits. capita/day.

3. Industrial Demand The industrial demand of water depends on the type of industry in the area. The number and type of industries such as cloth mill, paper mill, cotton mill, sugar mill, chemical industry, hume pipe, rolling

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Note: per capita means per head.

mill, etc. should be recorded. The water demand for this purpose is generally assumed as 20% to 25% of the total water demand of the city or town.

4. Public Demand It includes the water requirement for public places such as public sanitary blocks, parks, swimming pools, etc. The water demand for this purpose is considered as 5% of the total consumption of water in the town or city.

5. Fire Demand In case of any outbreak of fire in busy areas of a town or city, sufficient quantity of water may not be available for fire-fighting from the surface sources such as ponds, ditches, open wells, etc. Again these sources may not exist within busy areas of the town or city. Hence, requisite amount of water for fire-fighting should always be kept stored in underground reservoirs in specific places and fire hydrants should be established in main pipe lines at an interval of about 100 m to 150 m. In the event of fire, the fire brigade pump is connected to the fire hydrant and the jet of water is thrown under high pressure over the fire. The water required for fire demand is calculated by the following empirical formulae:

(a) The National Board of Fire underwriters formula,

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

where, Q = lits/min
P = Population in thousand

(b) Freeman's formula,

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

where, Q = lits/min
P = Population in thousand

(c) Buston's formula,

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

where, Q = lits/day
P = Population in thousand

(d) Kuichling's formula,

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

where, Q = lits/min
P = Population in thousand

The calculated amount of water is then converted to lits/capita/day and added to the total water demand. For safety, an additional amount of 10% should be taken into account.

6. Compensate Losses Some portion of water is always wasted due to the following reasons:

(a) Defective pipe joints
(b) Cracks in pipe line
(c) Faulty valves and fittings

(d) Consumers may keep the taps open
(e) Public taps may be damaged
(f) Unauthorised connection

To compensate the water losses due to the above factors, an allowance of about 15% of total water requirement should always be made.

2.3 FACTORS AFFECTING THE RATE OF DEMAND

The following are the various factors that affect the rate of demand:

1. Climatic Condition The demand of water is more in summer and it is less in winter. Again, the demand varies according to hot and cool places. The demand is more on a very hot day, and it is less on a cloudy or a rainy day.

2. Cost of Water If water tax is implemented by providing water meter, then the consumption of water will be less. The consumers will control the wastage of water in their own interest. The rate of tax also will affect the demand. Thus, the higher the cost, the lower will be the consumption and vice versa.

3. Distribution Pressure If the distribution pressure is very high, the water consumption will be more. Maximum water is lost unnecessarily when the tap is opened for bathing, face washing, etc.

4. Habits of People Due to advanced life style water consumption is very high in the high value premises. The rate is average in middle class zone and the rate is low in slum areas.

5. Industry Every industry requires much water for operation and maintenance. So, the presence or absence of industry in a town or city affects the rate of demand.

6. Quality of Water The good quality of water increases the rate of demand, whereas the bad quality decreases the rate.

7. Sewerage System The existence of sewerage system in a town or city increases the rate of demand.

8. System of Supply In a continuous system of supply, the consumption of water is more as there is every chance of misuse or wastage of water. So, the rate of demand is more.

In an intermittent system of supply the water consumption is less, as water is supplied only in some specific periods of the day. There is little chance of misuse. So, the rate of demand is low.

2.4 PER CAPITA DEMAND

The demand of water per person per day is known as per capita demand or per capita consumption. To obtain the per capita demand the total consumption of water in a year is divided by the total population and the number of days in a year.

i.e. $$\text{Per capita demand} = \frac{\text{Yearly water consumption (in lits)}}{\text{Population} \times 365}$$

It is expressed in lits/day.

For an average Indian town, per capita consumption varies from 150 lits to 300 lits per day.

Break Up of Per Capita Demand

1.	Domestic demand	135 lits/capita/day
2.	Public demand	20 lits/capita/day
3.	Industrial demand	40 lits /capita/day
4.	Commercial demand	10 lits/capita/day
5.	Fire demand	15 lits/capita/day
6.	Loss and waste	50 lits/capita/day
	Total	= 270 lits/capita/day

For design purpose the value may be assumed between 250 to 300 lits/capita/day.

2.5 BREAK UP OF DOMESTIC DEMAND AND PUBLIC DEMAND

Domestic Demand

1.	For drinking	5 lits
2.	For cooking	5 lits
3.	For bathing	50 lits
4.	For cloth washing	25 lits
5.	For utensils washing	10 lits
6.	For house washing	10 lits
7.	For latrine and urinal	30 lits
	Total	= 135 lits/capita/day

Public Demand

1.	For factory	30 to 45	lits/capita/day
2.	For hospital	300 to 400	lits/capita/day
3.	For hostel	125 to 135	lits/capita/day
4.	For school & college	40 to 50	lits/capita/day
5.	For office	30 to 45	lits/capita/day
6.	For restaurant	60 to 70	lits/capita/day
7.	For hotel	150 to 175	lits/capita/day
8.	For market & cinema hall	10 to 15	lits/capita/day

2.6 VARIATION OF WATER DEMAND

The average rate of daily demand per capita is not constant. It always varies due to the factors like climatic conditions, habits of people, type of industries in the town or city, etc. Again, the demand varies from season to season, month to month, day to day and even from hour to hour. This fluctuation of demand is also known as variation of demand. (Fig. 2.3)

Peak Hourly Demand

The maximum daily demand is practically consumed in 24 hours in a particular day. But that demand is not uniform throughout the period of 24 hours. It varies according to the hours of the day. As shown in Fig. 2.3 the peak hourly demand occurs in the morning 6 A.M. to 8 A.M. and at the evening 6 P.M. to 8 P.M. During these periods the people use maximum water for washing, bathing, cooking, etc.

The *slack period* occurs early in the morning and late at night.

For design purpose, the values of maximum daily consumption and peak hourly demand are essential for adjusting the speed of the pump.

The values are ascertained as follows:

(a) Average daily demand $= \dfrac{\text{Total yearly consumption in lits}}{365}$

(b) Maximum daily consumption = 180% of average daily demand

(c) Peak hourly demand = 150% of average daily demand.

In order to meet the peak hourly demand the pumps should run at such an average speed so that the surplus water is stored in a service reservoir in slack period. This surplus water is supplied during the peak hours to meet the peak hourly demand.

2.7 POPULATION FORECAST

The following are the general methods of population forecast:

1. Mathematical method
2. Decreasing rate method
3. Simple graphical method
4. Comparative graphical method
5. Master plan method.

1. Mathematical Method

The following are the various mathematical methods of population forecast:

(a) Arithmetical Increase Method In this method, the rate of increase in population is assumed constant. So, the average increase in population is worked out from the record of past decades. Then, this average is added to the present population and the population of successive decades to get the required population.(Example 2.1)

(b) Geometrical Increase Method In this method, it is assumed that the percentage increase in population remains constant. From the available census records this percentage increase is worked out. Then the population of successive future decades is calculated according to the procedure shown in Example 2.1.

(c) Incremental Increase Method In this method, the average increase in population is first worked out as per arithmetical increase method. Then, the average incremental increase is found out. Then both the averages are counted to get the population in future decades as explained in Example 2.1.

Example 2.1

The census records of a town show the population as follows:

(a) Present population = 50,300
(b) Population before one decade = 46,500
(c) Population before two decades = 43,100
(d) Population before three decades = 40,500

Calculate the probable population after one, two and three decades by using (a) Arithmetical increase method (b) Geometrical increase method (c) Incremental increase method.

Solution

(a) Arithmetical Increase Method:

Increase between present and 1st decades = 50,300 – 46,500 = 3800
Increase between 1^{st} and 2^{nd} decades = 46,500 – 43,100 = 3400
Increase between 2^{nd} and 3^{rd} decades = 42,100 – 40,500 = 2600
Total increase = 9800

$$\text{Average increase per decade} = \frac{9800}{3} = 3266.6 = 3267 \text{ (say)}$$

Population after one decade = 50,300 + 3267 = 53,567
Population after two decades = 53,567 + 3267 = 56,834
Population after three decades = 56,834 + 3267 = 60,101

(b) Geometrical Increase Method:

Percentage increase in population:

$$\text{(a) Between present and } 1^{st} \text{ decades} = \frac{50{,}300 - 46{,}500}{46{,}500} \times 100 = 8.17$$

$$\text{(b) Between } 1^{st} \text{ and } 2^{nd} = \frac{46{,}500 - 43{,}100}{43{,}100} \times 100 = 7.89$$

$$\text{(c) Between } 2^{nd} \text{ and } 3^{rd} = \frac{43{,}100 - 40{,}500}{40{,}500} \times 100 = 6.42$$

Total = 22.48

$$\text{Average percentage} = \frac{22.48}{3} = 7.49\%$$

= 7.50% (say)

So, Population after one decade = 50,300 + (50,300 × 0.75) = 54,073
Population after two decades = 54,073 + (54,073 × .075) = 58,128
Population after three decades = 58,128 + (58,128 × .075) = 62,488

(c) Incremental Increase Method:

Ist Step:

Average increase per decade = 3267 (as calculated in arithmetical increase method)

2^{nd} Step:

Period:		*Increase in population*	*Incremental increase*
3^{rd} and 2^{nd}	—	2600	
2^{nd} and 1^{st}	—	3400	+ 800
1^{st} and present	—	3800	+ 400
			Net = + 1200

Average incremental increase = $+\dfrac{1200}{2} = +600$

Note: In the incremental increase column, the sign(+ve or –ve) must be given, so that the net result may come accordingly.

Therefore,

Population after one decade = 50,300 + 3267 + (1 × 600) = 54,167

Population after two decades = 54,167 + 3267 + (2 × 600) = 58,634

Population after three decades = 58,634 + 3267 + (3 × 600) = 63,701

2. Decreasing Rate of Growth Method

It is observed that the growth of life follows a certain limit. It may happen that the early growth may be at an increasing rate and the later growth may be at a decreasing rate. In this method, the average decrease in 'percentage increase' is calculated. This average is deducted from the 'percentage increase' of each successive decades accordingly. Then the population of the successive decades is worked out accordingly.

Example 2.2

The census records of a small town is as follows:

Year		*Population*
1930	—	9,000
1940	—	13,000
1950	—	17,500
1960	—	23,000

Calculate the probable population in 1970, 1980 and 1990 by decreasing growth rate method.

Solution

(a) Increase between 1930 and 1940 = 13,000 – 9,000 = 4000

(b) Increase between 1940 and 1950 = 17,500 – 13,000 = 4500

(c) Increase between 1950 and 1960 = 23,000 – 17,500 = 5500

Percentage increase in Population	Decrease in Percentage increase	Remark
$\frac{4000}{9000} \times 100 = 44.4$	—	Percentage increase in 1940
$\frac{4500}{13000} \times 100 = 34.6$	9.8	Percentage increase in 1950
$\frac{5500}{17,500} \times 100 = 31.4$	3.2	Percentage increase in 1960
	Total decrease = 13.0	

Average decrease = $\frac{13.0}{2} = 6.5\%$

We get percentage increase in 1960 as 31.4%

Therefore,

Net percentage increase in 1970 = 31.4 – 6.5 = 24.9%

Net percentage increase in 1980 = 24.9 – 6.5 = 18.4%

Net percentage increase in 1990 = 18.4 – 6.5 = 11.9%

Now,

$$\text{Population in 1970} = 23,000 + 23,000 \times \frac{24.9}{100} = 28,727$$

$$\text{Population in 1980} = 28,727 + 28,727 \times \frac{18.4}{100} = 34,012$$

$$\text{Population in 1990} = 34,012 + 34,012 \times \frac{11.9}{100} = 38,059$$

3. Simple Graphical Method

The population in the past decades is given as follows:

Year	*Population*
1930	9,000
1940	13,000
1950	17,500
1960	23,000

With the population of the past decades a graph is plotted (population as ordinate and year as abscissa) to any suitable scale and a curve is obtained. This curve is extended upto the required future decades. From the graph the population in the future decades is noted as follows (Fig. 2.1)

Year	*Population*
1970	28,900
1980	34,000
1990	38,000

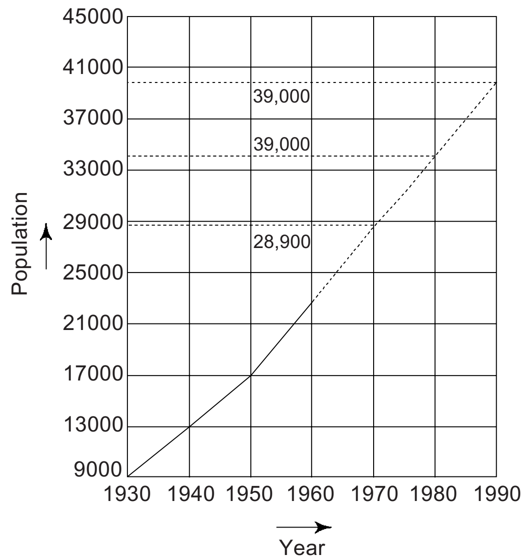


Fig. 2.1 *Population growth curve*

4. Comparative Graphical Method

From the census records, the population growth curves of different cities (*A.B.C* and *D*) are plotted in the graph. The curves will indicate the trend of growth of population in the cities. By comparing the nature of the curves, the curve of the city under consideration is drawn by a dotted line (*Y*). This dotted line shows the expected population of the city under consideration. (Fig. 2.2)

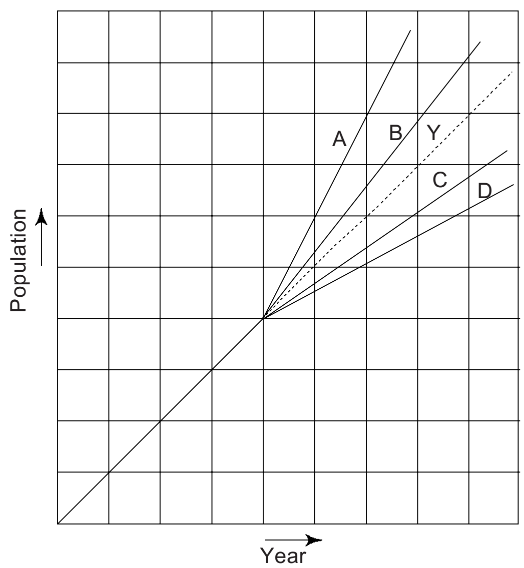


Fig. 2.2 *Comparative growth curve*

5. Master Plan Method

In this method, a master plan of the city should be prepared by dividing the city into various zones such as residential, industrial and commercial zone, etc. The future expansion of the city should also be regulated with the by-laws of the corporation. The population densities of different zones are pre-determined. When the city will be fully developed, the probable population may be forecast by studying the master plan.

2.8 GRAPHICAL REPRESENTATION OF VARIATION OF WATER DEMAND

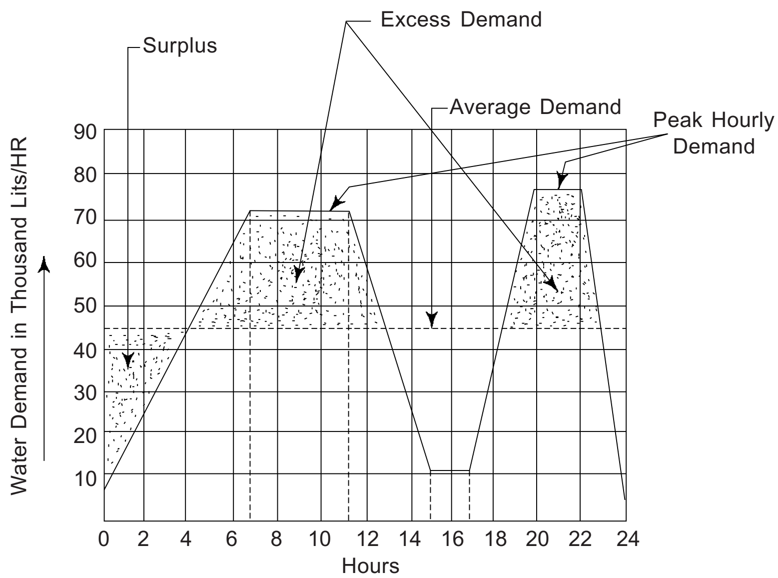


Fig. 2.3 *Variation of demand*

Problem 2.1

Estimate the water demand for a small town having the probable population as 50,000 (after three decades). Assume reasonable data.

Solution: Assumptions

1. Domestic demand—135 lits/capita/day.
2. For school & colleges (5,000 students)—50 lits/capita/day.
3. For hostels (500 boarders)—125 lits/capita/day
4. For factories (1000 workers)— 40 lits/capita/day
5. For hospitals (500 beds)—300 lits/capita/day
6. For offices (2000 employees)—30 lits/capita/day
7. For hotels (2000 persons)—150 lits/capita/day
8. For restaurants (2000 persons)—50 lits/capita/day
9. For markets and cinema halls—15 lits/capita/day

10. For fire demand —15 lits/capita/day
11. For parks and swimming pools—20 lits/capita/day
12. For loss and waste—10 lits/capita/day

Requirement of Total Quantity of Water

1.	Dometic demand	= 50,000 × 135	= 67,50,000 lits/day
2.	Demand for schools and colleges	= 5,000 × 50	= 2,50,000 lits/day
3.	Demand for hostels	= 500 × 125	= 62,500 lits/day
4.	Demand for factories	= 1,000 × 40	= 40,000 lits/day
5.	Demand for hospitals	= 500 × 300	= 1,50,000 lits/day
6.	Demand for offices	= 2,000 × 30	= 60,000 lits/day
7.	Demand for hotels	= 2,000 × 150	= 3,00,000 lits/day
8.	Demand for restaurants	= 2,000 × 50	= 1,00,000 lits/day
9.	Demand for markets & cinema halls	= 50,000 × 15	= 7,50,000 lits/day
10.	Demand for fire	= 50,000 × 15	= 7,50,000 lits/day
11.	Demand for parks & swimming pools	= 50,000 × 20	= 10,00,000 lits/day
12.	Demand for loss and waste	= 50,000 × 10	= 50,000 lits/day
		Total	1,07,12,500 lits/day
		i.e.	107.125×10^5 lits/day

Review Questions

1. What are the various types of water demand?
2. What do you mean by per capita demand and fluctuation of demand?
3. State the factors that affect the rate of water demand.
4. State the methods of population forecast.

3

Sources of Water

3.1 SELECTION OF SOURCES OF WATER

The following points should be considered while selecting the site for the sources of water for a water supply scheme:

1. Location The source should be as near as possible to the town or city to minimise the cost of conveyance.

2. Elevation of Intake Point The reduced level (R.L.) of the intake point should be higher than that of the supply zone so that the water can flow by gravity. Otherwise, pumping unit should be established for the conveyance of water from the intake point to the treatment plant. It will increase the cost of the scheme.

3. Quantity of Water The source should be such that the required quantity of water may be available throughout the year to meet the water demand.

4. Quality of Water The cost of the treatment depends on the quality of water. Bad quality water requires excessive treatment and increases the cost. But the good quality requires less treatment and decreases the cost of the scheme.

3.2 SOURCES OF WATER

The sources of water may be of two types:

A. Surface sources
B. Underground sources.

A. Surface Sources

The following are the different surface sources of water:

(a) River or stream
(b) Ponds or lakes.
(c) Storage reservoir.

1. River or Stream Rivers constitute the principal source of water supply. Some rivers are perennial (water available throughout the year) and some are non perennial or inundation (water available in rainy season only). Perennial rivers should always be selected for the scheme. In case of inundation rivers, the weir or barrage or low dam may be constructed to form a storage reservoir from where water may be drawn by intake works.

The quantity of water from the rivers may be reliable, but the quality may not be reliable.

The streams are suitable for small water supply scheme. Here, the quantity of water may not be sufficient.

2. Pond or Lake The natural or artificial depressions where surface run-off is collected in rainy season are known as ponds or lakes. The catchment area of these sources is small and hence the quantity of water is not reliable. But the quality is reliable and it requires little treatment before use. This source is suitable for small water supply schemes.

3. Storage Reservoir An artificial lake which is formed by constructing dam across a river valley is termed as storage reservoir. The function of such reservoir may be multipurpose such as irrigation, water supply, hydro-electric power generation, fishery, etc. The quantity and quality are both reliable. So, this source is always preferred for large water supply projects.

B. Underground Sources

The following are the underground sources of water:

(a) Infiltration well (b) Infiltration gallery
(c) Springs. (d) Wells.

1. Infiltration Well For tapping water from sandy river beds, the infiltration wells are sunk in series in sandy river beds. These are constructed or brick masonry with open joints. The water percolates through these joints and gets collected in the wells. The top of the wells are covered with R.C.C. slab having manhole for inspection. Again, the water from the infiltration wells gets collected in a jack well. Then the water from the jack well is pumped out and stored in a storage reservoir. The quality of water is good and it requires no treatment. The quantity of water from this source is suitable for small water supply schemes. Figure 3.1 shows an infiltration well and a jack well.

2. Infiltration Gallery For tapping water from sandy river beds sometimes horizontal tunnels are constructed in the beds. The walls of the tunnel are constructed with brick work and its top is covered with R.C.C. slab having manholes at some interval. The perforated pipe lines are connected to the tunnel through which the water gets collected inside the tunnel. This tunnel is known as infiltration gallery. It has been shown in Fig. 3.2. The slope of the gallery is such that the water inside the gallery flows towards a well which is known as sump well. Finally, the water from the sump well is pumped out and stored in a storage reservoir. The quality of water is good

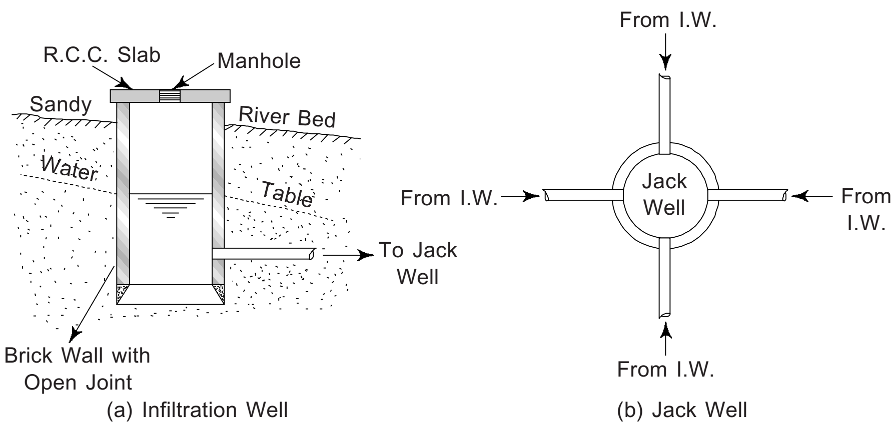


Fig. 3.1 *Infiltration well and jack well*

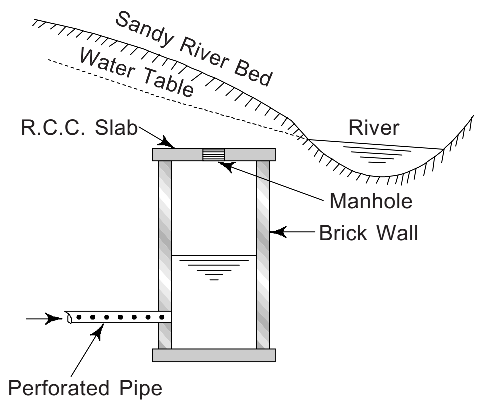


Fig. 3.2 *Infiltration gallery*

and it requires no treatment. The quantity of water from this source is suitable for small water supply schemes.

3. Springs When underground water reappears at the ground surface by percolation or by underground pressure, then it is known as spring. The water of the spring may contain some type of salts or minerals. So, it should be tested before use. If required, the water should be treated to make it suitable for drinking. This source is suitable for water supply in hilly town. The following are the different forms of springs:

(a) Artesian Spring When a pervious layer is sandwiched between two impervious layers in the form of a valley, then the artesian spring comes into existence. Figure 3.3. shows an artesian spring. Some artesian springs discharge hot water. Such springs are termed as 'hot springs'. The water of the hot spring is suitable for bathing to remove diseases such as gout, skin problem, etc.

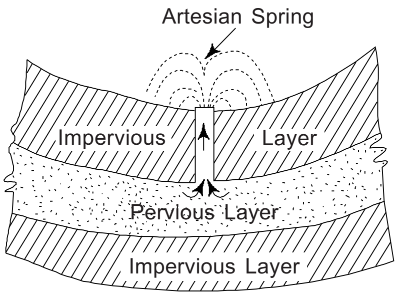


Fig. 3.3 *Artesian spring*

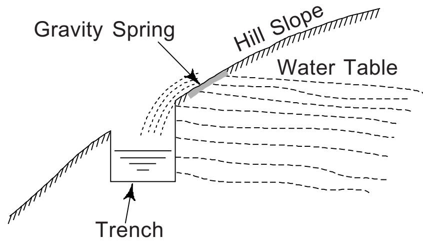


Fig. 3.4 *Gravity spring*

(b) Gravity Spring The gravity spring comes into existence when the water table rises along the hill slope and the water finds a path (i.e. a pervious zone) on the slope through which it rushes out by gravity. The discharge of water from such spring is variable as the water table may rise or fall in different seasons. A trench is constructed just below the spring for tapping water. Figure 3.4 shows a gravity spring.

(c) Surface Spring When subsoil water forms a storage due to the presence of impervious layer in the form of a valley, then the surface spring comes into existence. Figure 3.5 shows a surface spring. A cut-off wall is constructed on the impervious layer to form a reservoir from where water is supplied to the consumers.

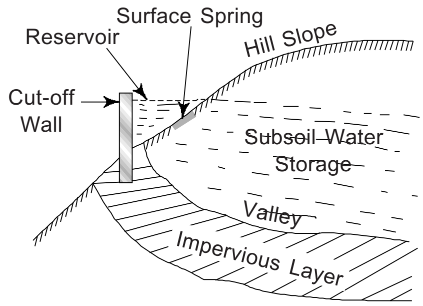


Fig. 3.5 *Surface spring*

4. Wells An artificial hole made into the ground for tapping underground water is known as well. Again, the well may be of two types—open well and tube well.

The open well draws water from the topmost pervious layer. The diameter of this well varies from 1m to 2m and the depth varies from 20 m to 30 m depending upon the nature of soil and the water table. This well may be dried up in summer and the water may be polluted by surface water. The water from this source is not suitable for drinking purpose. This well may be constructed by earthen ware ring, R.C.C. ring or brick work.

The tube well draws water from the deeper most pervious layer. The diameter and the depth of this well vary from 37 mm to 150 mm and 100 m to 200 m respectively, depending upon the nature of soil and suitable water bearing strata. The tube well is constructed by sinking G.I. pipes. Again, such wells may be shallow or deep. The deep tube well is considered the best source of water for any water supply scheme, as the water can be drawn by direct pumping system (by submersible turbine pump) and can be supplied directly to the consumers without any treatment.

3.3 DEFINITION OF TERMS RELATING TO UNDERGROUND SOURCE

1. Porosity It is defined as the ratio of the volume of voids present in a soil mass to the total volume of that soil. It is expressed as percentage.

Thus, $$n = \frac{V}{V_t} \times 100$$

where, n = porosity; V = volume of voids.
V_t = Total volume of soil mass.

2. Coefficient of Permeability It is defined as the rate of flow of water through the aquifer per unit cross-sectional area per unit hydraulic gradient. So, it indicates the velocity of water through the soil and is expressed in cm/sec. It is denoted by k.

3. Water Table It is the surface or a line on the soil below which the soil mass is saturated with water. This surface varies with the change of seasons. In rainy season the water surface is near the ground surface whereas in dry season this surface goes down towards the impervious layer. Figure 3.6 shows the water table.

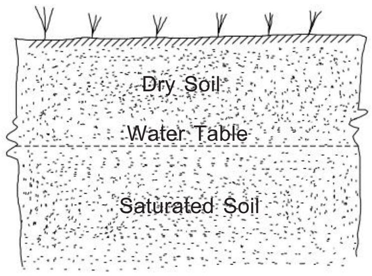


Fig. 3.6 *Water table*

4. Ground Water Yield It is defined as the quantity of water that can be extracted from the saturated aquifer by the force of gravity (i.e. by digging well).

5. Aquifers or Water Bearing Strata The permeable formation of the soil of the earth's crust is known as aquifer. It is also known as water bearing strata because the ground water exists in this strata. The aquifers may be of following types:

(a) Unconfined Aquifer It is the topmost aquifer in which the water table exists on the surface of saturation. It is also known as water table aquifer, as shown in Fig. 3.7. The surface water enters this aquifer through the surface soil.

(b) Confined Aquifer The aquifer which is sandwiched between two impervious strata is known as confined aquifer, as shown in Fig. 3.7.

(c) Perched Aquifer This is also an unconfined aquifer which is separated from the main water table by a shal-

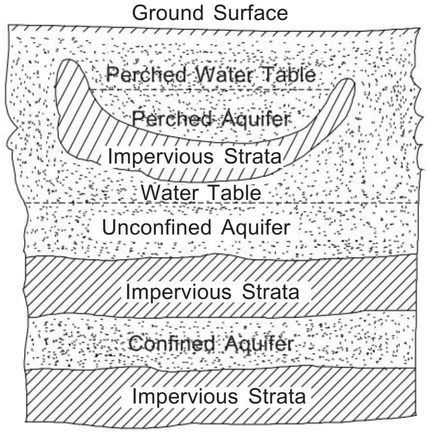


Fig. 3.7 *Aquifer*

low and curved impervious strata. The water table in this aquifer is known as perched water table which may be above the main water table as shown in Fig. 3.7.

6. Specific Yield It is defined as the ratio of the volume of water that can be drained off by gravity to the total volume of soil after attaining the point of saturation. It is expressed as percentage.

Thus, $$S_y = \frac{W_r}{V_t} \times 100$$

Where, S_y = Specific yield
W_r = Volume of water retained
V_t = Total volume of soil

7. Specific Capacity It is defined as the discharge per unit draw down when the water is pumped out from the well. It is expressed in cumec.

Thus, $$\text{specific capacity} = \frac{Q}{S}$$

Where, Q = Total discharge in cumec.
S = Total draw down in m.

8. Yield of a Well The yield of a well is defined as the rate of pumping of water from the well without causing its failure.

9. Spacing of Well The spacing of the well should be such that the circle of influence of the adjacent well may not coincide. Due to the mutual interference, the yield of well may be reduced considerably.

10. Cone of Depression When water is pumped from the well, the original water table is depressed and forms a curved surface in the form of an inverted cone. This cone is known as the cone of depression and is shown in Fig. 3.8. The curved surface is known as the draw down curve.

11. Circle of Influence The base of the cone of depression is known as the circle of influence, as shown in Fig. 3.8. The radius of this circle is known as radius of circle of influence.

12. Draw Down When water is pumped out from a well, then the original head (H) is reduced to a depressed head (h) and the water enters the well

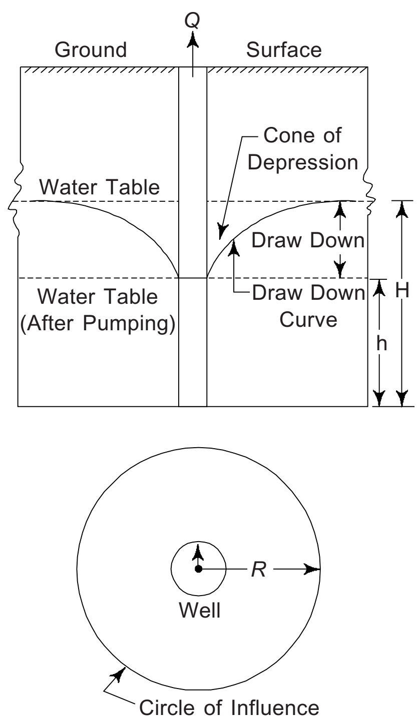


Fig. 3.8 *Cone of depression*

under the influence of the head (*H–h*). This head is known as depression head or percolation head or draw down.

3.4 CLASSIFICATION OF WELL

- Well
  - Open well
  - Tube well
    - Strainer type
    - Cavity type
    - Slotted type

Open Well

An open well is constructed by digging the earth. Its diameter varies from 1 m to 2 m and the depth varies from 10 m to 20 m. This well may be lined or unlined. The lined open well is constructed in loose soil. The lining may be provided by brick masonry, stone masonry, pre-cast R.C.C. ring, earthen ware ring, etc. The unlined open well is constructed in hard soil and in hilly area.

Tube well

A tube well consists of G.I. pipes of diameter varying from 3.75 cm to 15 cm and of length varying from 7 m to 8 m. The tube well is sunk into the ground by boring. The pipes are joined by sockets. It penetrates the number of water bearing strata which are sandwiched between the impervious layers. The tube well may be shallow or deep. The depth of shallow tube well varies from 30 m to 40 m and the depth of deep tube well varies from 200 m to 300 m.

The tube well may be of the following types:

1. Strainer type
2. Cavity type
3. Slotted type

1. Strainer Type In this type of tube well, the G.I. pipes of length 6 m and of required diamer are assembled with socket joints and driven into the ground up to the required depth. A conical shoe is provided at the bottom of the pipe and the strainers (i.e. filters) are fitted in such a way that they exist within the aquifers (i.e. water bearing strata). The portion of the plain pipes which exist within the impermeable strata is known as blind pipe. Figure 3.9 shows a strainer type tube well.

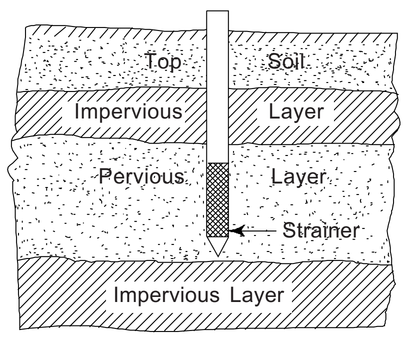


Fig. 3.9 *Strainer type tube well*

2. Cavity Type In this type of tube well, the G.I. pipe of required diameter is driven into the ground up to the depth so that it just penetrates the clay layer and finds a water bearing strata. No strainer is provided in this well. At the beginning when the pumping is started, fine sand comes out with water and consequently a cavity is formed. As the pumping is continued, the cavity finally takes the shape of a hemisphere and no more sand particles enter the well. The cavity thus formed behaves like a clear water pool. Figure 3.10 gives an idea of the cavity type tube well.

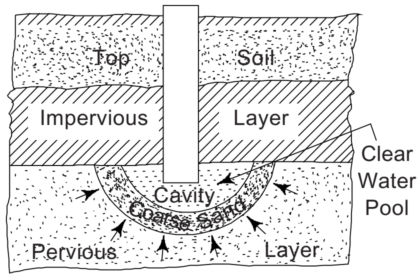


Fig. 3.10 *Cavity type tube well*

3. Slotted Type In this type of tube well, the G.I. casing pipe of bigger diameter (about 30 cm) is first driven into the ground upto the required depth. Then the G.I. well pipe of lesser diameter is inserted into the casing pipe. The lower portion of the well pipe is slotted upto a length of about 3m. The casing pipe is then gradually withdrawn and the annular space between the well pipe and casing pipe is filled up with a mixture of gravel and coarse sand. This is known as shrouding. The shrouding should be such that is cover the slotted portion completely. When the pumping is started, the sandy water comes through the well initially and finally the fine sand is eliminated and clear water comes out. Figure 3.11 shows a slotted type tube well.

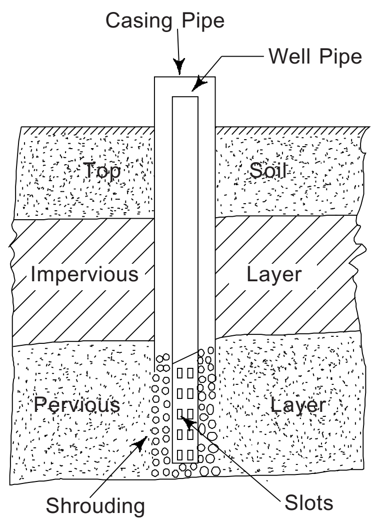


Fig. 3.11 *Slotted type tube well*

3.5 SINKING OF OPEN WELL

Open well may be of two types:

1. Unlined well
2. Lined well.

1. Construction of Unlined Well

This type of open well is constructed in hard soil. In this case, the excavation of the earth is started according to the required diameter of the well. The excavation is continued until the water rushes out from the bottom. Generally, the diameter varies from 1.5 m to 2m and the depth varies from 10 m to 15 m. As lining is not provided in this well, it is very cheap. This type of well is very common in hilly area. Figure 3.12 shows an unlined open well.

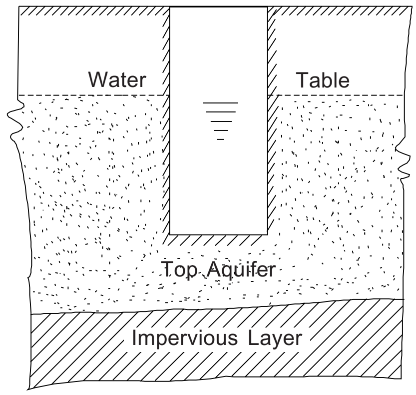


Fig. 3.12 *Unlined open well*

2. Construction of Lined Open Well

The lined of the well may be of two types:

(a) By pre-cast R.C.C. Rings In this case, a pit is first excavated upto a depth of 30 cm, according to the diameter of the R.C.C. rings. Then one ring is placed in position perfectly. Now two more rings are set on it, as shown in Fig. 3.13. The excavation is started and the rings go on sinking gradually due to their weight. More and more rings are set over the previous rings as the excavation proceeds. Finally, the water rushes out from the bottom. In village areas, the earthen-ware rings are generally used. The diameter of this type of well varies from 1 m to 1.5 m and depth varies from 15 m to 18 m. Extreme precaution should be taken for the vertical sinking of the well.

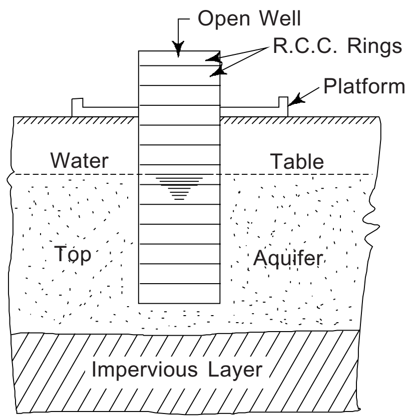


Fig. 3.13 *R.C.C. ring lining*

(b) By Masonry Wall In this case, a pit is first excavated upto a depth of about 30 cm and a well curb (made of steel, wood or R.C.C.) having cutting edge at the bottom is placed in position. The top width of the circular curb is equal to the thickness of the well wall. On the top of well curb the masonry wall is constructed upto a height of 1.5 m, as shown in Fig. 3.14. After proper curing of the wall, the excavation is started inside the well and below the curb. The masonry wall goes on sinking due to its own weight. The masonry wall is constructed step-by-step (1.5 m height at a time) as the excavation proceeds. Thus the well is sunk up to the required depth. The verticality of the well should be maintained by plumb bob.

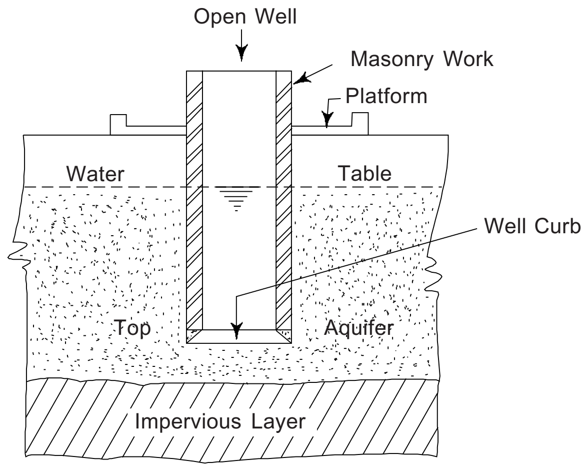


Fig. 3.14 *Masonry lining*

3.6 SINKING OF TUBE WELL

The tube wells may be of two types:
(a) Shallow tube well
(b) Deep tube well

1. Sinking of A Shallow Tube Well

The shallow tube well are generally sunk by two methods

(a) Wash Boring Method In this method, a pit of depth about 1 m and diameter 10 cm is first excavated at the position where the tube well is proposed to be sunk. A G.I. pipe of diameter 3.75 cm and length 6 m is held vertically in the pit by the lever. The pipe is completely filled with water and an operator standing on the bamboo frame covers the upper end of the pipe with palm of his hand, as shown in Fig. 3.15. Sufficient quantity of water is poured continuously on the pit. Now, the pipe is moved up and down with the lever which is operated by a group of labourers. During upward stroke, the end of the pipe is kept tightly closed with palm and during downward stroke it is kept open. Thus, in upward motion suction takes place and in downward motion the slurry rushes out through the upper end of the pipe. In this way, the pipe sinks gradually. When the first pipe reaches the ground level, another pipe is fixed with it by socket joint. The procedure is continued until the required depth is reached. The washing of the pipe is done until

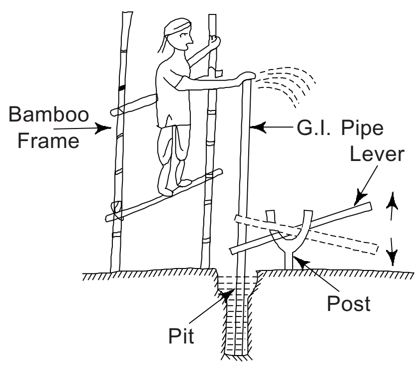


Fig. 3.15 *Wash boring method*

clear water comes out. This method is suitable for sandy and clayey soil. (Fig. 3.15)

(b) Water Jet Method In this method, a pit is first excavated to a depth of about 1 m and diameter slightly larger than the diameter of the casing pipe. The casing pipe is held vertically in the pit. Then a jet pipe with a nozzle at the bottom is lowered inside the casing pipe. Water is forced under high pressure through the jet pipe and it comes out of the nozzle with tremendous force as shown in Fig. 3.16. The soil at the bottom of the casing pipe is loosened and slurry is formed. This slurry comes out through the annular space between the jet pipe and casing pipe. The casing pipe is rotated slowly and it sinks gradually. When the casing pipe comes to the ground level, another pipe is fitted to it by socket joint. This procedure is continued until the required depth is attained. This method is suitable for sandy and clayey soil. Finally, the tube well pipe with strainers is inserted and the casing pipe is withdrawn completely.

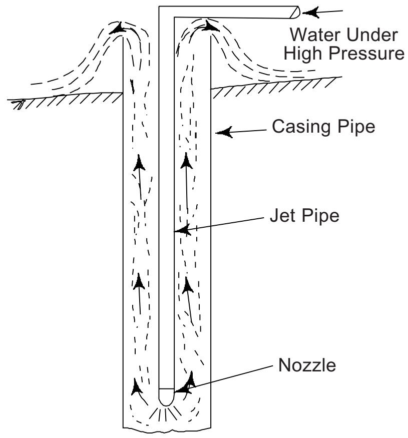


Fig. 3.16 *Water jet method*

2. Sinking of Deep Tube Wells

The deep tube wells are generally sunk by percussion method and rotary method.

(a) Percussion Method In this method, a pit is first excavated to a depth of about 1 m and it is filled up with water. A casing pipe of required diameter having cutting edge at the bottom is placed vertically in the pit. The casing pipe consists of a platform for loading sand bags. A plunger of hollow metal tube is suspended by a rope which passes through a pulley fixed with a wooden tripod as shown in Fig. 3.17. The plunger consists of cutting edge and a ball valve. Now, repeated blows are given with the plunger by stretching the rope up and down. During each down stroke, the ball valve opens and the slurry enters the plunger. Again during the upstroke, the ball valve closes and the slurry is prevented from coming out. When the

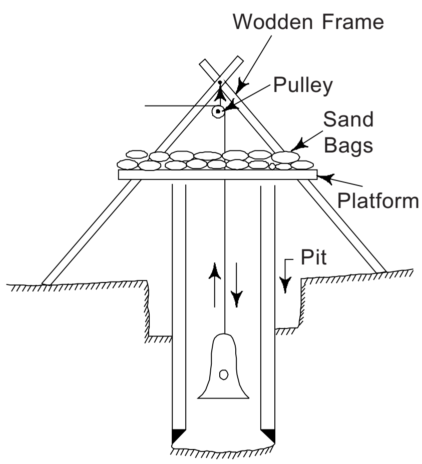


Fig. 3.17 *Percussion method*

plunger is filled up with slurry, it is taken out and the slurry is removed. The plunger is again lowered and the same procedure is repeated. Thus the casing pipe goes on sinking. When the upper end of the casing pipe reaches the ground level, an additional pipe is fixed with it by a socket joint. When the desired depth is attained, the platform is removed and a tube well pipe with strainers (at predetermined aquifers) is inserted within the casing pipe. The casing pipe is then gradually withdrawn step-by-step and the annular space between the casing pipe and the tube well pipe is shrouded with gravel and coarse sand.

(b) Rotary Method This method consists of the following components:

(i) A derrick
(ii) A pump set (with motor)
(iii) Drill pipe and drill bit.
(iv) Rotating device
(v) A platform carrying the derrick and pump set.

The whole arrangement is known as drill rig. The rig is anchored at the site properly. A suitable tank is excavated near the site, and it is filled with muddy water. The rotating device and drill pipe are placed in position as shown in Fig. 3.18. When the rotating device is started, the drill pipe rotates and slides downwards cutting the soil with drill bit. The water is pumped continuously into the hole through the drill pipe and thus slurry is formed. This slurry comes out through the annular space between the drill pipe and the wall of the hole. This slurry is taken again to the mud water tank for recharging. A portion of the slurry is taken to settling tank to determine the type of formation at various layers. When the required depth is attained, the drill pipe is withdrawn and the tube well pipe with strainers at appropriate layers is inserted immediately into the hole. The washing of the well is done properly to get clear water and more yield.

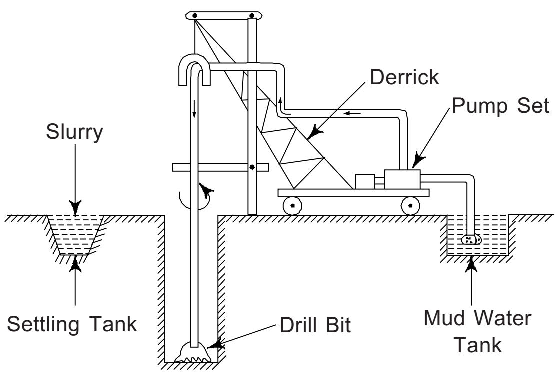


Fig. 3.18 *Rotary method*

3.7 DETERMINATION OF YIELD OF AN OPEN WELL

The yield of an open well can be determined by the following two tests:

1. Constant level test or pumping test
2. Recuperation test

1. Constant Level Test or Pumping Test

In this test, the water from the open well is pumped for some period so that the water level is depressed by some head, (H) which is known as depression head or draw down. Then the rate of pumping is adjusted in such a way that the water level remains constant in the well. At this time, the rate of pumping is equal to the rate of yield from the well as shown in Fig. 3.19. Now, from the rate of pumping, the discharge can be measured by suitable measuring device.

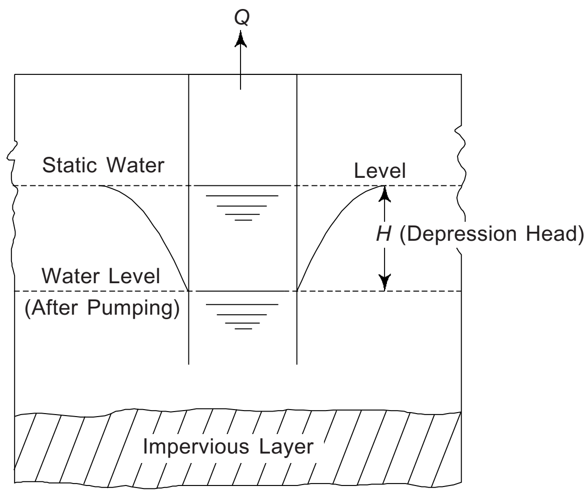


Fig. 3.19 *Constant level test*

From Darcy's Law,

$$Q = K\,A\,i$$

or $$Q = K\,A \times \frac{H}{L} \qquad \left(i = \frac{H}{L}\right)$$

or $$Q = C\,A\,H \qquad \left(C = \frac{K}{L}\right)$$

Where, Q = Discharge
K = Coefficient of permeability
A = Cross-sectional area of permeable layer through which water enters the well.
i = Hydraulic gradient
H = Depression head
L = Length of flow path
C = Percolation intensity coefficient

2. Recuperation Test

As it is very difficult to adjust the rate of pumping to maintain the constant level in the well, the recuperation test is adopted to determine the yield of open well.

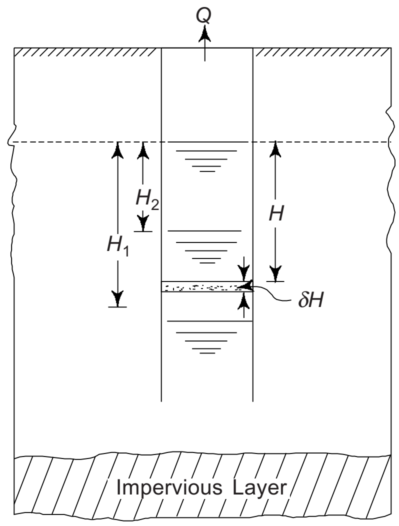


Fig. 3.20 *Recuperation test*

In this test, the water from the well is pumped to a depression head H_1 and the pumping is stopped. The water level rises due to the ground water flow as shown in Fig. 3.20. The total time taken by the water to reach static level is noted. Then the rate of yield may be calculated from the expression deduced below.

Let,

H_1 = Depression head when pumping was stopped

H_2 = Depression head after a certain period

T = Time taken by the water level to rise from H_1 to H_2

H = Depression head at time t

δH = Decrease in depression head in time δt

In time t the water level will recuperate by $(H_1 - H)$ and it will recuperate by δH in time δt.

So, volume of water, $\delta V = A\ \delta\ H.$ (3.1)

Where, A = c/s area of bottom of well

Again, $\delta V = Q.\ \delta t.$

and $Q \propto H$ (where, Q = Rate of recharge at time t under head H)

or $Q = \text{K}.\ H.$

∴ $\delta V = \text{K}.\ H.\ \delta t$ (3.2)

where, K = a constant

from (3.1) and (3.2)

$\text{K}\ H\ \delta t = A\ \delta H.$

or $$\delta t = -\frac{A}{K} \cdot \frac{\delta H}{H} \tag{3.3}$$

[Here the –ve sign indicates that when the time t increase, the depression head H decreases.]

Integrating both sides of the Equation (3.3) within limits,

$T = O$ and T

$H = H_1$ and H_2

We get,

$$\int_0^T \delta t = -\frac{A}{K} \int_{H_1}^{H_2} \frac{\delta H}{H}$$

or $$T = -\frac{A}{K}\ \log_e \left[\frac{H_2}{H_1}\right]$$

or $$T = \frac{A}{K} \log_e \left[\frac{H_1}{H_2}\right]$$

or $$TK = A \log_e \left[\frac{H_1}{H_2}\right]$$

or $$\frac{K}{A} = \frac{1}{T} \text{Log}_e \left[\frac{H_1}{H_2}\right]$$

or $$\frac{K}{A} = \frac{2.303}{T} \log_{10} \left[\frac{H_1}{H_2}\right] \quad (3.4)$$

Here, $\frac{K}{A}$ is known as specific yield of well per unit area. It is expressed as $m^3/hr/m^2$.

Again, $$K = \frac{2.303 \times A}{T} \log_{10} \left[\frac{H_1}{H_2}\right] \quad (3.5)$$

Where K = Specific capacity of well in m^3/hr/unit head

Now, the discharge Q = K. H.

where H = Constant depression head

Problems on Open Well

Problem 3.1

Calculate the specific capacity of an open well from the following data:

Initial depression head	= 5 m.
Final depression head	= 2 m.
Time of recuperation	= 2 hrs.
Diameter of well	= 3 m.

Calculate also the specific yield and yield of the well under head 3m.

Solution

Here, $A = \frac{\pi}{4} \times 3^2 = 7.07 m^2$

$T = 2$ hrs.

$H_1 = 5$ m.

$H_2 = 2$m.

$H = 3$m.

From the relation (Eq. (3.5)

$$K = \frac{2.303 \times A}{T} \log_{10} \left[\frac{H_1}{H_2}\right]$$

$$= \frac{2.303 \times 7.07}{2} \log_{10} \left[\frac{5}{2}\right]$$

$= 3.24\ m^3$/hr/unit head.

So, the specific capacity is 3.24 m^3/hr/unit head.

Specific yield = $\frac{K}{A} = \frac{3.24}{7.07} = 0.458\ m^3/hr/m^2$

Yield of well Q = K × H = 3.24 × 3 = 9.72 m^3/hr.

= 9720 lits/hr.

Problem 3.2

Find the diameter of an open well to give the discharge of 3 lits/sec. The depression head is 3m and specific yield 1 $m^3/hr/m^2$

Solution

We know, $Q = k \cdot H.$

or $Q = \frac{K}{A} \cdot A\ H$ (1)

Here, $\frac{K}{A} = 1\ m^3/hr/m^2$

Assuming the diameter of well as dm.

$$A = \frac{\pi}{4} \cdot d^2$$

$$H = 3m$$

$$Q = 3 \text{ lits/Sec} = \frac{3 \times 60 \times 60}{1000} = 10.8\ m^3/hr.$$

From equation (1)

$$10.8 = 1 \times \frac{\pi}{4} \times d^2 \times 3$$

or $10.8 = 2.356\ d^2$

or $d^2 = \frac{10.8}{2.356}$

$$d = 2.14m.$$

So, the diameter of open well is 2.14 m.

3.8 DETERMINATION OF YIELD OF TUBE WELL

There may be two cases:

Case I. *Yield of tube well in unconfined aquifer.*

Case II. *Yield of tube well in confined aquifer.*

Case I. Yield of Tube Well in Unconfined Aquifer

Let,

H = Height of static water level from impervious layer

h = Depth of water in well from max. draw down to the top of impervious layer

s = Draw down

R = Radius of circle of influence
r = Radius of well
Q = Discharge of well
T = A point taken on drawdown curve with co-ordinate (x, y)
O = A point taken as origin

Considering that a cylindrical surface around the well passes vertically through the point $T(x, y)$, as shown in Fig. 3.21.

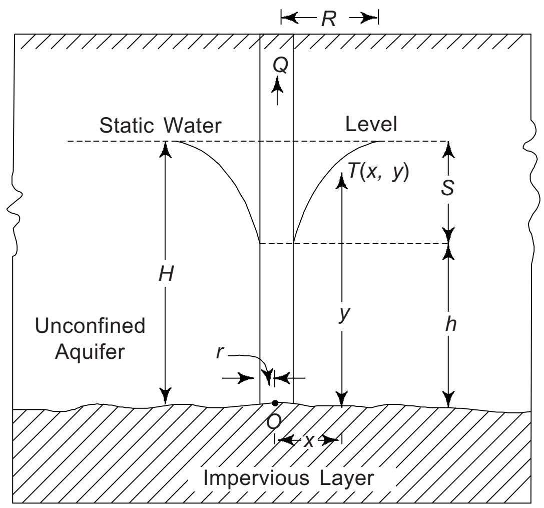


Fig. 3.21 *Unconfined aquifer*

Then, the area of cylindrical surface = $2\pi xy$.

If $\frac{dy}{dx}$ be the hydraulic gradient at point T.

Then, by Darcy's law

$$\text{Rate of flow} = K \cdot \frac{dy}{dx} \cdot (2\pi xy)$$

Where, K = Coeff. of permeability

Again,

Discharge of well = Rate of flow

i.e. $$Q = K \frac{dy}{dx}(2\pi xy)$$

or $$Q \cdot \frac{dx}{x} = 2\pi Ky \cdot dy \qquad (3.6)$$

Integrating both sides of Eqn (3.6)
between limits $x = r$ and R.
$Y = h$ and H.

$$Q \int_{r}^{R} \frac{dx}{x} = 2\,\pi\,K \int_{h}^{H} y\,dy$$

or $$Q \log_e \left[\frac{R}{r}\right] = \pi\,K\,(H^2 - h^2)$$

or $$Q = \frac{\pi K\,(H^2 - h^2)}{Log_e \left(\frac{R}{r}\right)}$$

or $$Q = \frac{\pi K\,(H^2 - h^2)}{2.303\,Log_{10} \left(\frac{R}{r}\right)}$$

or $$Q = \frac{1.36\,K\,(H^2 - h^2)}{Log_{10} \left(\frac{R}{r}\right)} \quad (3.7)$$

The equation can be expressed in terms of drawdown S.

$S = H - h$

or $H = S + h$

And $H + h = S + 2h$

$(H^2 - h^2) = (H + h)\,(H - h)$

$= (S + 2h) \cdot S$

So, the expression in (3.7) may be written as

$$Q = \frac{1.36\,K.S\,(S + 2h)}{Log_{10} \left(\frac{R}{r}\right)} \quad (3.8)$$

Case II. Yield of Tube Well in Confined Aquifer

Let,

H = Height of static water level from bottom of confined aquifer
h = height of max. draw down from bottom of confined aquifer
S = Draw down
R = Radius of circle of influence
r = Radius of well
Q = Discharge of well
T = A point on draw down curve
O = A point taken as origin

Considering that a cylindrical surface around the well passes vertically through the point T (x, y), as shown in Fig. 3.22.

Area of cylindrical surface = $2\,\pi x b$.

If $\frac{dy}{dx}$ be the hydraulic gradient at time T.

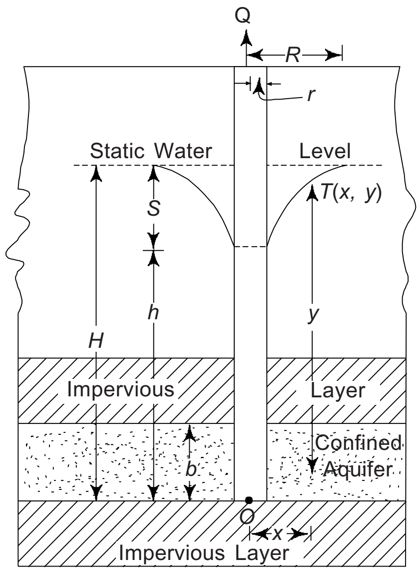


Fig. 3.22 *Confined aquifer*

By Darcy's law.

Rate of flow through cylindrical surface $= K \cdot \dfrac{dy}{dx} \cdot 2\,\pi\,xb$

But, Discharge of well = Rate of flow.

$$Q = K\,\frac{dy}{dx}\,.\,2\,\pi\,xb.$$

or $$Q\,\frac{dy}{x} = 2\,\pi\,K\,b \cdot dy \qquad (3.9)$$

Integrating both sides of Eqn (3.9) between limits

$x = r$ and R.

$y = h$ and H

$$Q\int_r^R \frac{dx}{x} = 2\,\pi\,kb\;\;Kb\int_h^H dy$$

or $$Q\,\log_e\left[\frac{R}{r}\right] = 2\,\pi\,kb\,(H - h)$$

or $$Q = \frac{2\pi Kb(H-h)}{\text{Log}_e\left(\dfrac{R}{r}\right)}$$

or $$Q = \frac{2\pi Kb(H-h)}{2.303\,\text{Log}_{10}\left(\dfrac{R}{r}\right)}$$

or $$Q = \frac{2.72\,Kb\,(H-h)}{\text{Log}_{10}\left(\frac{R}{r}\right)} \tag{3.10}$$

But $S = (\ H - h)$

$$Q = \frac{2.72\ K\ bs}{\text{Log}_{10}\left(\frac{R}{r}\right)} \tag{3.11}$$

For confined aquifer, the coefficient of transmissibility is given by $T = kb$. So, the Eqn (3.11) can be written as

$$Q = \frac{2.72\,Ts}{\text{Log}_{10}\left(\frac{R}{r}\right)} \tag{3.12}$$

Problems on Tube Well

Problem 3.3

A tube well fully penetrates an unconfined aquifer. Calculate the discharge of the well from the following data.

(a) Diameter of well = 15 cm
(b) Draw down = 4m
(c) Length of strainer below draw down = 10 m
(d) Coeff. of permeability = 0.05 cm/sec.
(e) Radius of circle of influence = 200 m

Solution

Here,

K = 0.05 cm/sec = 5 × 10^4 = 4 m/sec.
S = 4 m (Draw down)
h = 10 m (length of strainer)
r = 7.5 cm = 0.075 m.
R = 200 m.

From eqn (3.8)

$$Q = \frac{1.36\,KS\,(S+2h)}{Log_{10}\left(\frac{R}{r}\right)}$$

$$= \frac{1.36\times 5\times 10^{4}\ \times 4\,(4+2\times 10)}{Log_{10}\left(\frac{200}{0.75}\right)}$$

= 0.019 m^3/sec. = 19 lits/sec

Problem 3.4

A tube well of 30 cm diameter penetrates an unconfined aquifer. During the pumping test, the following data was obtained:

(a) Height of static water level from bottom of aquifer = 50 m.
(b) Height of drawdown from bottom of aquifer = 45 m.
(c) Radius of circle of influence = 300 m.
(d) Coeff. of permeability = 50 m/day.

Calculate the discharge of the well.

Solution

Here,

$$R = 300 \text{ m.}$$

$$r = \frac{30}{2} = 15 \text{ cm} = 0.15 \text{ m.}$$

$$H = 50 \text{ m}$$

$$h = 45 \text{ m}$$

$$K = 50 \text{m/day}$$

$$= \frac{50}{24 \times 60 \times 60} = 5.787 \times 10^{-4} \text{m/sec.}$$

From relation, (3.7)

$$Q = \frac{1.36\, K\, (H^2 - h^2)}{\text{Log}_{10} \frac{R}{e}}$$

We get,

$$Q = \frac{1.36 \times 5.787 \times 10^{-4}\, (50^2 - 45^2)}{\text{Log}_{10} \frac{300}{0.15}}$$

$$= 0.1132 \text{ m}^3\text{/sec.}$$

$$= 113.2 \text{ lits/sec.}$$

Problem 3.5

A tube well penetrates fully into a confined aquifer. The following data was collected during observation. Calculate the discharge of the well.

(a) Radius of tube well = 20 cm
(b) Thickness of confined aquifer = 25 m
(c) Drawdown = 4 m
(d) Radius of circle of influence = 300 m.
(e) Coeff. of transmissibility = $125 \times 10^{-4} \text{m}^2\text{/sec.}$

Find also the coeff. of permeability.

Solution

Here,

$R = 300$ m
$r = 20$ cm $= 0.20$ m
$S = 4$ m
$b = 25$ m
$T = 125 \times 10^{-4}$ m^2/sec.

We know,
Coeff. of transmissibility $T = k.b.$

$$K = \frac{T}{b} = \frac{125 \times 10^{-4}}{25} = 5 \times 10^{-4} \text{m/sec.}$$

So, coeff. of permeability is 5×10^{-4}m/sec.
Again, from relation

$$Q = \frac{2.72\ K\ bs}{\text{Log}_{10}\ \frac{R}{r}}$$

Discharge $$Q = \frac{2.72 \times 5 \times 10^{-4} \times 25 \times 4}{\text{Log}_{10}\left(\frac{300}{0.20}\right)}$$

$= 0.0428$ m^3/sec.
$= 42.8$ lits/sec.

Problem 3.6

A tube well penetrates a confined aquifer completely. Determine the diameter of the tube well from the following data.

(a) Required yield = 100 lits/sec.
(b) Radius of circle of influence = 200 m
(c) Thickness of confined aquifer = 30 m.
(d) Draw down = 5 m.
(e) Coeff. of permeability = 60m/day.

Solution

Here,

$Q = 100$ lit/sec $= 0.10$ m^3/sec.
$R = 200$ m
$b = 30$ m.
$S = 5$ m.

$$K = 60 \text{ m/day} = \frac{60}{24 \times 60 \times 60} = 6.944 \times 10^{-4} \text{ m/sec.}$$

Let,

r be the radius of the tube well.

From the relation.

$$Q = \frac{2.72\ Kbs}{\text{Log}_{10}\left(\frac{R}{r}\right)}$$

We get,

$$0.10 = \frac{2.72 \times 6.944 \times 10^{-4} \times 30 \times 5}{\text{Log}_{10}\left(\frac{200}{r}\right)}$$

or $\text{Log}_{10}\left(\frac{200}{r}\right) = \frac{2833.15 \times 10^{-4}}{0.10}$

or $\frac{200}{r} = 680.92$

$r = 0.29$ m = 29 cm = 30 cm (say)

So, the diameter of well is 60 cm.

3.9 DEVELOPMENT OF A WELL

The method of extracting and removing the fine sand particles from the soil around the strainer is termed as development. The development is done for the following reasons:

(a) To prevent sand particles from entering the well;
(b) To increase the specific capacity of the well;
(c) To increase the life of well.

The development is generally done by the following methods:

1. By Pumping In this method, the pumping of the well is done repeatedly. At the beginning, the pumping operation is started and is continued till clear water comes out. Then the pumping is stopped. After a specific interval of time, the pumping is again started and continued until clear water comes out. In this way by successive operation, it is found that the sand particles are completely removed and the maximum discharge capacity has been attained, then the well is said to be completely developed.

2. By Compressed Air An air pipe is introduced into the well pipe and extended upto the zone of strainer. Then the compressed air having pressure 7 kg./cm^2 is sent through the air pipe by opening the air valve. The pressure of the air in the well develops a powerful agitation and the water flows outwards through the strainer and loosens the fine materials. The air valve is then closed. The inside pressure is decreased and consequently the water from outside enters the well with tremendous force bringing the loosened materials with it. The water of the well is then pumped out. Again, the air valve is opened and the same process is followed. This process is repeated several times till clear water comes out.

3. By Back Washing This method consists of an air compressor, a discharge pipe and an air pipe. The discharge pipe and air pipe assembly is introduced into well pipe.

The compressed air is then sent through the air pipe which forces the water in the well carrying the fine sand particles to come out through the discharge pipe. When clear water comes out of the well the air compressor is shut off. The water in the well is allowed to return to the static level. The process is repeated for several times until clear water is discharged.

4. By Chemicals This method involves the use of some chemical compounds like hydrochloric acid and solid carbon dioxide (dry ice). At first hydrochloric acid is poured into the well and the well top is capped. The compressed air is sent into the well through the air pipe which forces the hydrochloric acid to enter the surrounding soil formation. The well cap is removed; dry ice is introduced into it and the well top is capped again. The gaseous carbon dioxide is released suddenly and a high pressure is created in the well. This high pressure forces the muddy water to come out of the well in the form of jet through the spout. The process is repeated for several times. Thus the well is developed to give clear water.

5. By Surging In this method, the sand particles are removed from filter with the help of a plunger. The plunger is inserted in the well and strokes are given up and down vigorously to loosen the sand particles sticking to strainer. Then the water is pumped out. This process is repeated for several times until clear water comes out.

3.10 SHROUDING OF WELL

The method of filling the annular space between the casing pipe and the tube well pipe by an aggregate of gravel and coarse sand is termed as shrouding. It is required for slotted type tube well in sandy and unconsolidated soil. The shrouding is done for the following reasons:

(a) It prevents the finer particles of the soil coming in contact with the strainer.
(b) It prevents chocking of the strainer.
(c) It protects the well pipe from the corrosive effect of surrounding soil.
(d) It increases the effective diameter of well.

Procedure The shrouding materials should be well grades. Shrouding is essential when actual tube well pipe is to be sunk with the help of casing pipe, where an annular space will appear when the casing pipe is withdrawn. Here, the casing pipe is sunk upto the required depth, then the tube well pipe fitted with strainer (slotted pipe) is inserted fully. The casing pipe is then withdrawn to a height of about 60 cm and the hollow space is immediately filled with shrouding materials (mixture of gravel and coarse sand). The casing pipe is again lifted to a height of 30 cm and the space is filled up by the same materials. In this way, the casing pipe is withdrawn stage by stage and the spaces are filled up with the shrouding materials until the slotted strainer is covered completely. The process has been shown in Fig. 3.23.

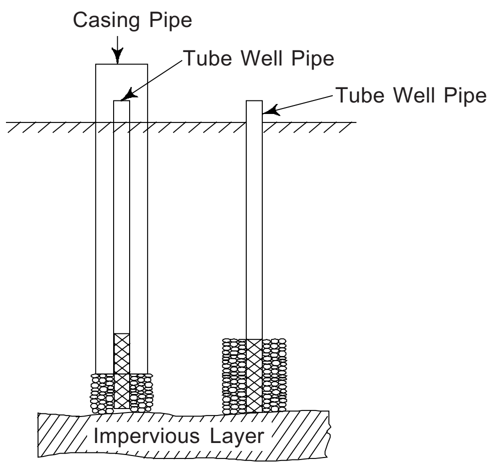


Fig. 3.23 *Shrouding of well*

3.11 MAINTENANCE OF TUBE WELL

The maintenance work involves the method of cleaning or replacing the strainers or tube well pipe to make it workable for longer period. The following measures are generally taken:

(a) If the yield of the well is reduced due to the clogging of strainer, then the strainer may be cleaned by surging.
(b) Sometimes compressed air is forced through the well pipe to remove the clogging.
(c) Dry ice may be dropped into the well pipe and the well top is tightly capped. The pressure of carbon dioxide vapour forces the soil particles away from the strainer.
(d) The internal corrosion of the well pipe or strainer may be removed by sulphuric acid.
(e) If muddy water is discharged through the well, then it is an indication of perforation in the well pipe or damaged strainers. In that case, the resinking of the well should be done by removing the affected pipe and changing the wire net of the strainer.

3.12 FAILURE OF TUBE WELL

A tube well may fail due to the following reasons.

(a) Corrosion The ground water contains acids, chlorides, sulphates, etc. which cause the corrosion of pipes. Again, the corrosion damages the strainers. The following steps may be taken to reduce the corrosion:

(i) Always thick pipes should be used.

(ii) Galvanised pipes or other anti-corrosive coated pipes should be used.
(iii) Periodical washing of the tube well should be done by sulphuric acid.

(b) Incrustation The ground water also contains calcium-bicarbonate, magnesium salts, etc. These compounds get deposited inside the tube well and the diameter of the well is reduced. This is known as incrustation. The incrustation can be arrested by the following steps:

(i) The water of the tube well is tested in the laboratory to determine the presence of alkali salts. The salts which are responsible for incrustation may be removed by titration. The titration may be done by forcing the proper doses of acids to the well. The water of the well is then pumped out.
(ii) The tube well should not be left unused for long period.

Review Questions

1. State the various surface sources of water.
2. State the various underground sources of water.
3. What are the various methods of sinking an open well? Describe any one with sketch.
4. What are the various methods of sinking the tube well? Describe any one with sketch.
5. How can the yield of an open well be determined? Describe the recuperation test for finding the yield of open well.
6. Deduce the expression for finding the yield from an unconfined aquifer.
7. Describe the methods of development of well.
8. What is shrouding? How is shrouding done?
9. State the method of maintenance of tube well.
10. What steps should be taken to avoid the failure of tube well?

4

Intake and Conveyance

4.1 SELECTION OF INTAKE POINT

The method of collecting water from the surface sources for the water supply scheme is termed as 'intake'. The structures which are constanted for this purpose are known as 'intake works'. The following points should be considered while selecting the site for intake works:

(a) The intake point should satisfy the condition for the availability of water throughout the year.
(b) The water at the site should be more or less clear so that excessive treatment is avoided.
(c) The intake site should be easily accessible.
(d) The site should not be on the curve of a river.
(e) The site should not be selected at the zone of heavy current which may damage the structure of intake works.
(f) The site should not be at the zone of the river where pollution of water is suspected.
(g) The site should be selected as near as possible to the treatment plant to reduce the conveyance cost.

4.2 TYPE OF INTAKE WORKS

Intake works may be of various types depending on the avaliable source of surface water. Generally the intake works may be of following types:

A. River intake
B. Lake intake
C. Reservoir intake
D. Canal intake

A. River Intake

A circular or rectangular sump well is constructed with masonry work in the bank of the river in such a way that the water can enter the well in both the conditions such as H.F.L. and L.W.L. The water enters the sump well through the pipes installed at different levels. Screens are provided at the end of the pipes to eliminate suspended matters. A main suction pipe having strainer at the bottom is inserted into the sump well as shown in Fig. 4.1. The main pipe is connected to the pumping unit which delivers water to the treatment plant.

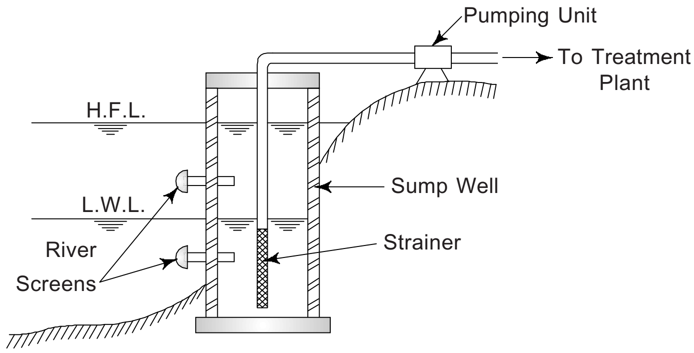


Fig. 4.1 *River intake*

However, there is no hard and fast rule for the type of tapping water from the river. The site condition will guide the type of structure to be constructed. Sometimes intake works may be constructed in the middle of the river. In that case, all precautions should be taken to protect the structure from silting and heavy current of the river.

B. Lake Intake

A submersible rectangular chamber is constructed at the bed of the lake from where water can be available throughout the year. The top cover of the chamber consists of several holes having gratings on it to prevent the entry of debris, weeds, aquatic lives, etc. into the chamber. A bell mouthed pipe is provided in the chamber which contains screen at the top. The bell mouth pipe is connected to the pumping unit through the suction pipe as shown in Fig. 4.2. The pump house draws water from the chamber and delivers that to the treatment plant.

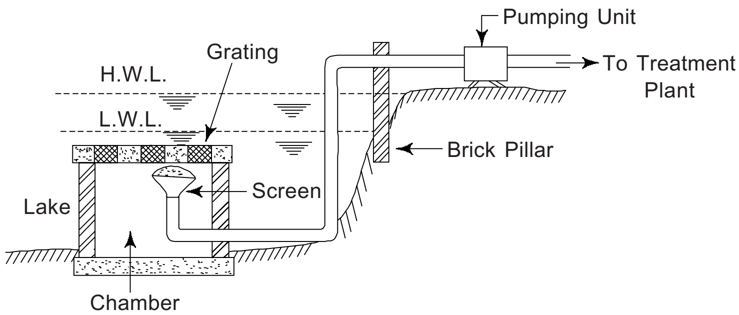


Fig. 4.2 *Lake intake*

C. Reservoir Intake

If an inundation river becomes the only nearby source of water for a town, then weir or low dam may be constructed across the river to form a reservoir. The dam may be earthen or gravity type which depends on the site condition. However, an intake well is constructed on the body of the weir or dam in such a way that the water can be tapped throughout the year. Intake pipes with screens at its ends are fitted at different levels to a vertical pipe which is provided inside the well. The vertical pipe is again connected to the pumping unit as shown in Fig. 4.3. The pumping unit draws water from the reservoir directly and delivers it to the treatment plant.

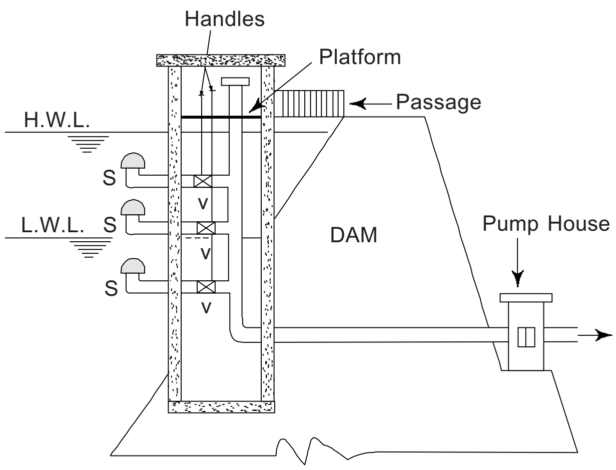


Fig. 4.3 *Reservoir intake*

D. Canal Intake

If a canal becomes the source of water for a town, then an intake well is constructed by the bank of the canal. The well may be circular or rectangular and it is constructed with masonry work. An inlet pipe is inserted into the well for drawing water. On the canal side, the well consists of an opening with screen as shown in Fig. 4.4. The intake pipe is extended below the lowest water level of the canal and it carries a hemispherical screen at the end. A manhole is provided on the well cap for inspection work. The intake pipe is connected to the pumping unit for sending water to the treatment unit.

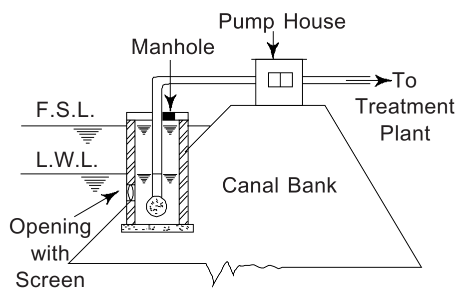


Fig. 4.4 *Canal intake*

4.3 PIPES FOR CONVEYANCE

The following are the pipes that are generally used for the conveyance of water in water supply schemes:

(a) Asbestos cement pipe
(b) Cast-iron pipe
(c) Cement concrete pipe
(d) Galvanised iron pipe
(e) Lead pipe
(f) Steel pipe
(g) Wrought iron pipe
(h) Copper pipe
(i) Plastic pipe

(a) Asbestos Cement Pipes The asbestos cement pipes are manufactured from a mixture of cement and asbestos fibre. These pipes are very light and can be transported easily. But these are very brittle and liable to be broken if handled carelessly. The cutting, drilling, jointing, etc. can be done easily with these pipes. These are smooth and so the carrying capacity is good. The pipes are not affected by salts, acids and corrosive agents. But these are not intended for high internal pressure. So, these pipes are suitable for distribution system where internal pressure is low.

(b) Cast-Iron Pipes The cast-iron pipes are manufactured from pig iron by casting (i.e. moulding). These pipes can resist corrosion and can withstand high internal pressure. But these are very heavy and very difficult to transport. The pipes are brittle in nature and may form cracks if handled carelessly. These are suitable for conveyance where the internal pressure is very high.

(c) Cement Concrete Pipes The pre-cast cement concrete pipes are manufactured in rolling mills and then transported to the site as per requirement. The pipes may be made of plain concrete, re-inforced cement concrete or pre-stressed cement concrete. The plain concrete pipes are used for carrying water at places where there is no internal pressure. The re-inforced cement concrete pipes are manufactured by reinforcing with steel bars and casting the concrete in a framework. These pipes can withstand high internal pressure. Now a days, for very high pressure the pre-stressed cement concrete pipes are used. The concrete pipes are very heavy and thus, very difficult to handle and transport.

(d) Galvanised Iron Pipes These are manufactured by galvanising iron pipe. The pipes are economical, light and easy to handle and transport. They can be easily cut and threaded. The pipes can be easily joined by sockets. But these pipes are liable to be affected by acidic and alkaline water. These pipes are suitable for service connections.

(e) Lead Pipe Lead pipes are not adopted for the conveyance of drinking water, because it may cause lead poisoning. These pipes are generally used

in sanitary fitting and water treatment plant. Sometimes these are used in chemical industries. These are very light and can be easily bent and cut.

(f) Steel Pipes The steel pipes are light and strong to withstand high internal pressure. They can be easily transported. But they cannot withstand external pressure. These pipes are not suitable for distribution system in water supply scheme. The pipes are joined by welding or reveting.

(g) Wrought Iron Pipes The wrought iron pipes can be easily cut and threaded. These are costly and not much durable. The pipes are affected by corrosion and hence these are generally used inside the building. These pipes may be recommended for main pipe line if these are galvanised by zinc.

(h) Copper Pipe These pipes are very costly and are not used for ordinary works. These are not affected by corrosion and can resist acidic action. So, these pipes are generally used in chemical industries and for making gouseneck in house plumbing. Sometimes, these are used in hot water supply line.

(i) Plastic Pipes At present, the plastic pipes are commonly used in water supply systems. They are resistant to corrosion, light in weight and economical. The pipes are available in different forms:

(a) Low density polythene pipes
(b) High density polythene pipes
(c) Rigid PVC (poly vinyl chloride) pipes

Among the three types, the rigid PVC pipes are most favourite in water supply schemes. These are resistant to acids, alkalies and salts. These pipes are safe for carrying potable water. These pipes are strong and can withstand much higher pressure for a smaller wall thickness.

4.4 PIPE JOINTS

The pipes are manufactured in small length varying from 2m to 5m. But at the time of laying, the pipes are joined together to make them continuous. The selection of the type of joint depends on the pipe materials, internal pressure, site condition, etc. For example

(a) For cast iron and wrought iron pipes—Bell and spigot joint.
(b) For steel pipes—Welded or reveted joint.
(c) For R.C.C. and A.C. pipes—Collar joint
(d) For temporary work—Flanged or threaded joint
(e) For temperature change—Expansion joint
(f) For places where settlement is suspected—Flexible joint

Now, the details of the joints are as follows:

(i) Bell and Spigot Joint

The plain end of the pipe is known as spigot end and the expanded end is known as bell end. The yarn of hemp is wound round the spigot end and a rubber gasket is placed tightly over the yarn. The spigot end is now inserted into the bell end in such a way that it is properly set in position. Then the gap of the joint is filled up with molten lead by suitable pouring device as shown in Fig. 4.5. The lead shrinks on cooling. Then it is tightened by means of chalking tool and hammer.

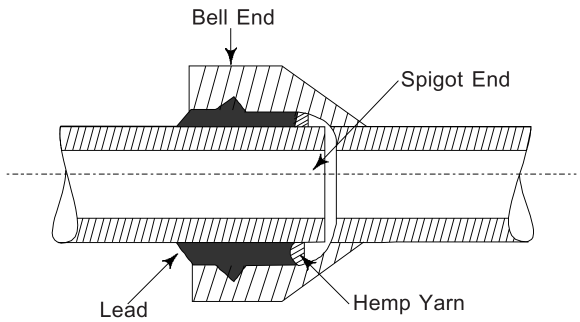


Fig. 4.5 *Bell and spigot joint*

(ii) Collar Joint

Collar joint is recommended for joining the R.C.C. pipes and asbestos cement pipes. Grooves are provided at both ends of these pipes. Before joining, the pipes are brought face to face and at the same level. A gasket or hemp is placed between the grooves of the pipes and a collar (made of concrete) is placed properly at the joint. The position of the collar is checked so that it may have same lap on both the pipes. Then the space between the pipes and the collar is filled up with cement mortar(1:1) (shown in Fig. 4.6) and the surface is finished at an angle of 45°.

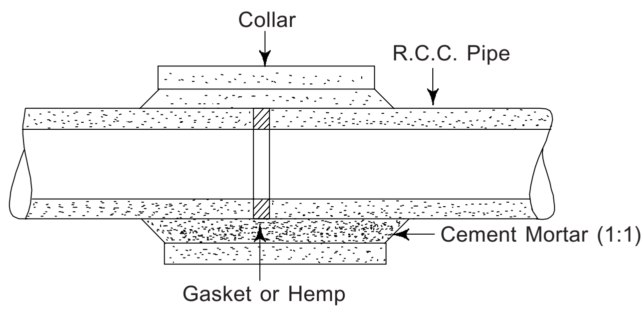


Fig. 4.6 *Collar joint*

(iii) Expansion Joint

The expansion joint is recommended for places where the elongation or shortening of the pipe may happen due to the change of atmospheric temperature. Here, the bell end is projected vertically to some extent for coupling with the flanged ring by nuts and bolts. Before starting the joint, the flanged ring and a rubber gasket is placed in position on the spigot end. Then the spigot end is inserted into the bell end and held in position by checking the level. Then the rubber gasket is pressed tightly between the annular space, by means of nuts and bolts to make the joint water tight as shown in Fig. 4.7. The rubber gasket will absorb the variation of length if caused due to the change of temperature.

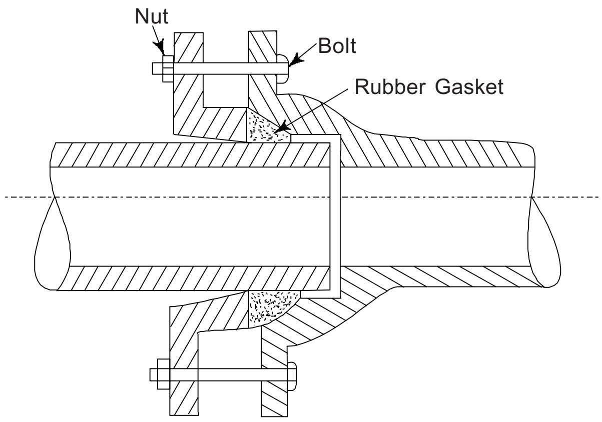


Fig. 4.7 *Expansion joint*

(iv) Flanged Joint

This type of joint is recommended for temporary work where the pipe line may be dismantled after work or it may be shifted. For this joint, the ends of the pipes should be provided with wide flange with several holes for nuts and bolts. While joining the pipes, a rubber gasket is inserted between the flanges and the nuts are tightened to make the joint watertight as shown in Fig. 4.8. This joint is not suitable in places where vibration or deflection is suspected.

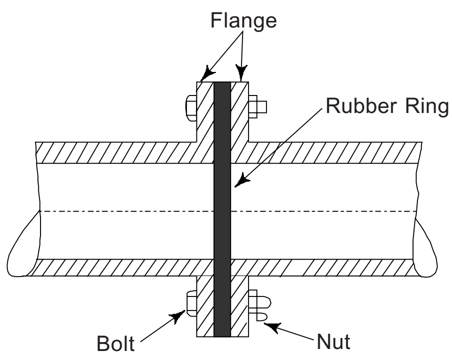


Fig. 4.8 *Flanged joint*

(v) Flexible Joint

This type of joint is recommended for the places where the settlement of the pipe line may occur. For this joint, one pipe has spigot end with a beat and the other pipe has socket end with spherical shape and it consists of several holes for nuts and bolts. During assembling, the spigot end of one pipe is inserted into the socket end of other pipe. A retainer ring is pushed to touch the beat. Then a rubber ring is also pushed to touch the retainer ring (shown in Fig. 4.9). A cast iron gland ring is placed in position and a cast iron follower ring is fixed with the socket end by nuts and bolts.

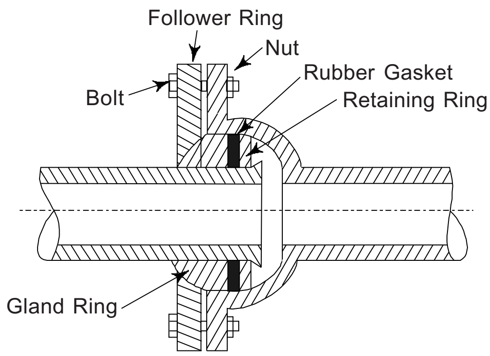


Fig. 4.9 *Flexible joint*

(vi) Threaded Joint

This type of joints are recommended for connecting the G.I. pipes. Here, the ends of the pipes are plain with threads on outside. The joints require sockets which are threaded on inside. To make the joint water-tight, either zinc point or hemp yarn applied on the threads. Then the socket is tightened so that the pipes are held firmly in position (shown in Fig. 4.10).

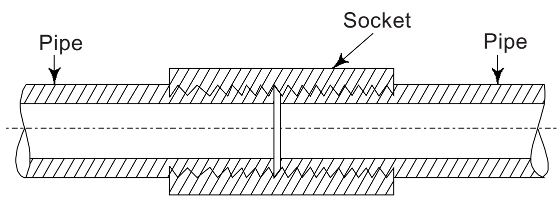


Fig. 4.10 *Threaded joint*

4.5 PIPE CORROSION

If the water flows through the pipe line which has got acidic property, the formation of scales and disintegration of pipe materials may occur. This phenomenon is known as pipe corrosion. The following are the effects of pipe corrosion:

(a) Due to corrosion the cross-sectional area of the pipe may be decreased and hence the discharge through the pipe may be reduced.

(b) If the disintegration is severe due to corrosion, then heavy repair works or replacement of pipes are necessary.

(c) The corrosion is responsible for undesirable colour, taste and odour in the flowing water.
(d) The corrosion damages the joints of the pipe line.

4.6 CORROSION CONTROL

The corrosion may be controlled by taking following measures:-
(a) Cathodic protection
(b) Standard pipe materials
(c) Protective lining
(d) Treatment of water

(a) Cathodic Measure The pipe line is found to act as cathode. The pipe line may be connected to the D.C. generator or to some anodic metal to prevent the pipe corrosion.

(b) Standard Pipe Materials The pipe materials should be standard according to I.S.I. specification.

(c) Protective Lining The pipe surface should be coated with paint, tar, zinc oxide, etc. which protects the pipe line from corrosion.

(d) Treatment of Water The water should be treated to adjust pH value and to eliminate calcium carbonate, carbon dioxide, etc.

4.7 LAYING OF PIPELINE

The laying of pipe line should be done according to the following stages:

Stage 1 Marking of Centre Line and the Width of the Trench

Figure 4.11 shows the marking of trench. The centre line of the proposed pipe line should be marked on the ground by pegs at an interval of 20m with the help of theodolite. The width of general excavation (w_1) should be 30 cm more than the external diameter of the pipe. The excavation width is marked on the ground by a spade. At the places of joints, the width of excavation (w_2) should be 30 cm more than the normal width (w_1). At the joints, the depth of excavation should be 15 cm more than the normal depth. The clear length (L) at joint should be double the length of joint.

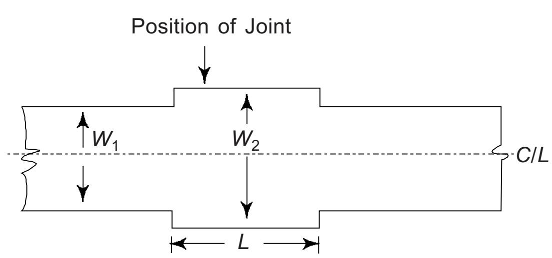


Fig. 4.11 *Marking of trench*

Stage 2 Excavation of Trench

The excavation of the trench is carried out according to the marking on the ground. The excavated earth should be dumped on both sides of the trench. The depth of the trench should not be less than 90 cm to protect the pipe line from being damaged by external loads. The excavation should be done carefully so that the underground cables (telephones or other systems) may not be damaged.

Stage 3 Side Protection of Trench

When the excavation is done along the hard soil, the side protection may not be provided. But, when the excavation runs along the loose soil, the side protection must be provided to against the trench from collapsing. The side protection should be done by sheet piles (wooden planks or iron sheets) which are supported by timber struts, timber blocks and wedges as shown in Fig. 4.12.

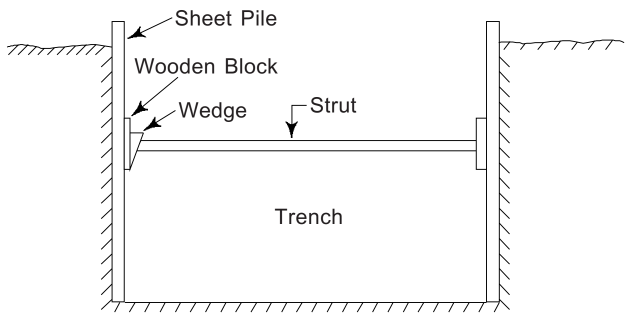


Fig. 4.12 *Side protection*

Stage 4 Preparation of Subgrade

For small diameter pipes the subgrade is prepared by simply ramming a layer of sand or clayey soil or moorum to a thickness of about 15 cm to 30 cm. Sometimes a single layer of brick flat soling may be provided which should be rammed properly (shown in Fig. 4.13).

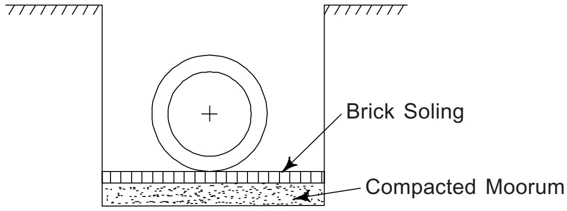


Fig. 4.13 *Small diameter pipe*

For large diameter pipes the subgrade is prepared by cement concrete foundation (1:3:6) over a layer of brick flat soling. Concrete benching should be provided to hold the pipe line in position. Grooves should be provided on concrete foundation or moorum subgrade at the places of joints (as shown in Fig. 4.14).

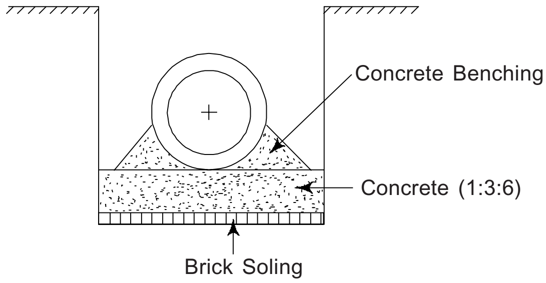


Fig. 4.14 *Large diameter pipe*

Stage 5 Dumping of Materials

The pipes and other joining materials should be dumped on the excavated earth along one side of the trench. While unloading, care should be taken so that the pipes may not be damaged by breaking or cracking.

Stage 6 Laying and Joining of Pipes

When the bed of trench is properly prepared, the pipes are dropped in the trench carefully and placed side by side properly. Small diameter pipes may be placed in the trench by manual labours. But, the large diameter pipes should be placed in the trench by crane or other mechanical device. Then the operations of joining are done according to the recommended joints (as per pipe materials).

Stage 7 Testing

After completion of the work, the pipe line should be tested to detect the leakage (if any) in the pipe line. The following tests are generally carried out:-

(a) Pressure Test A section of the pipe line should be filled with water and pressure should be applied by pump. The pressure is noted on the pressure gauge. If the pressure on the gauge falls gradually, then it indicates the leakage in that section of the pipe line. The leakage should be detected and rectified accordingly.

(b) Leakage Test by Empirical Formula The allowable leakage is given by the relation,

$$L = \frac{ND\sqrt{P}}{3.3}$$

Where

L = allowable leakage in cm^3/hr.
N = Number of joints.

D = Diameter of pipe in mm.

P = Applied pressure in kg/cm^2

If the actual leakage is more than the allowable leakage, then the leakage point should be detected and rectified accordingly.

Stage 8 Filling up the Trench

After testing and rectification (if any), the excavated earth from both sides is dropped in the trench gradually in layers (15 cm) and each layer is tamped lightly by tamping rod. Finally, the top surface is rammed with extra earth in the shape of a ridge which gets levelled in course of time.

REVIEW QUESTIONS

1. Enumerate the points to be considered while selecting the intake point.
2. Describe the different types of intake with a neat sketch.
3. Name the different types of pipes used in water supply schemes. Briefly describe their characteristics.
4. Describe with sketches, the different types of pipe joints.
5. What is pipe corrosion? What are the effects of corrosion?
6. State how corrosion can be prevented.

5

Pumps

5.1 INTRODUCTION

The mechanism by which the water is lifted from the underground source to some height or to some place is known as pump.

Types of Pumps

The pumps may be of the following types:

(a) Centrifugal pump (b) Reciprocating pump

(c) Rotary pump (d) Air lift pump.

Necessity of Pump

The application of pumping unit becomes necessary under the following circumstances:

(a) It is not always possible to carry water by gravity from surface source to the treatment plant. So, pumping unit becomes necessary at this position.

(b) It becomes extremely necessary for drawing water from underground source.

(c) It becomes necessary for lifting water from treatment plant to overhead reservoir.

(d) It becomes necessary at some specific points on the pipe line for boosting up the pressure.

(e) It becomes necessary for supplying water to consumers by direct pumping system from deep tube well.

5.2 LIFTING HEAD OF PUMP

The total lift of a pump consists of the following heads:

(a) Suction Head (H_s) The distance between the static water level and the centre line of pump is known as suction head.

(b) Delivery Head (H_d) The distance between the centre line of pump and the point of delivery is known as delivery head.

(c) Head Loss (H_f) It is the total loss due to friction when the water flows through the pipe line.
Hence, total head = $H_s + H_d + H_f$

5.3 CENTRIFUGAL PUMP

The centrifugal pump involves the principle of centrifugal force. When the water in the chamber (i.e. casing) of a pump is rotated vigorously by the impeller about the central point, a centrifugal force develops which moves the water towards the periphery of the chamber. Thus, the velocity head is converted to pressure head and this head forces the water through the delivery pipe. At the same time, the water from the underground source is lifted up by suction through the suction pipe. Centrifugal pump may be of the following two types:

(a) Volute Type In this type, the chamber is spiral shaped (i.e. volute shaped) and consists of impellers which are rotated by motor.

The suction takes place through the centre of the impeller ring. When the impellers rotate, the water from the centre is forced towards the periphery of the chamber as shown in Fig. 5.1. The velocity of flow in the chamber remains uniform. The velocity head is thus converted to pressure head which causes the water to flow though the delivery pipe.

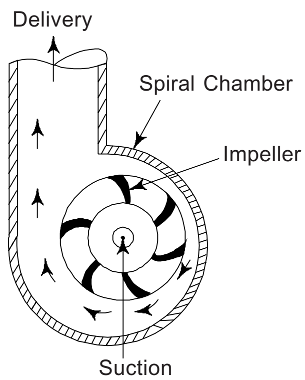


Fig. 5.1 *Volute type*

(b) Turbine Type In this type, a diffusion ring is provided between the impellers and the casing. The ring carries fixed diffusers or guide vanes. It has been shown in Fig. 5.2. There are openings between the diffusers through which the water forces out towards the periphery. In this case also the velocity head is converted to pressure head which causes the water to flow through the delivery pipe.

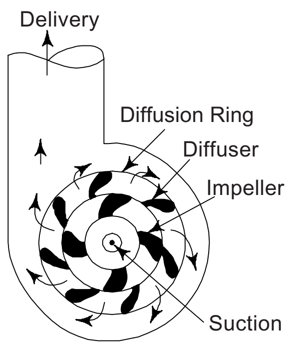


Fig. 5.2 *Turbine type*

Advantages of Centrifugal Pump

1. It requires minimum space for installation as it is compact in design.
2. It can be installed for high speed driving mechanism.
3. The working is simple and there is no valve in the pump, hence it is reliable and durable.

Disadvantages

1. The pump will not work, if the chamber is not full of water. So, the priming should always be done before starting the pump.
2. The pump will not work if there is any leakage in the suction side.

5.4 RECIPROCATING PUMP

This type of pump consists of a closed cylinder in which a piston moves to and fro by a connecting rod. The connecting rod is again hinged with a wheel which is rotated by a motor. During the suction stroke, the suction valve is opened and delivery valve remains closed and water enters the cylinder as shown in Fig. 5.3. During the delivery stroke, the delivery valve is opened and the suction valve remains closed and the water is forced through the delivery pipe. An inlet is provided for priming which is necessary for starting the pump.

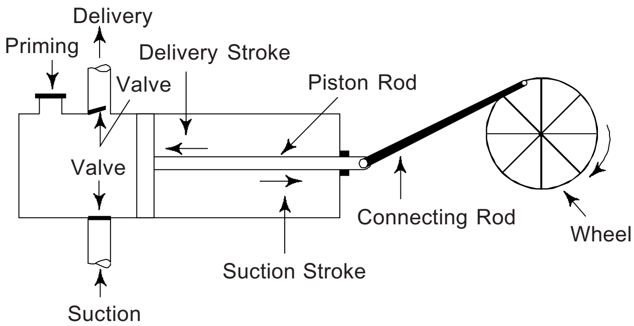


Fig. 5.3 *Reciprocating pump*

5.5 ROTARY PUMP

It consists of two cams that are pivoted in a casing. These cams rotate in opposite directions and thereby the suction takes place through the suction pipe (shown in Fig. 5.4). The rotation of the cams pushes the water in upward direction through the delivery pipe (Fig. 5.4).

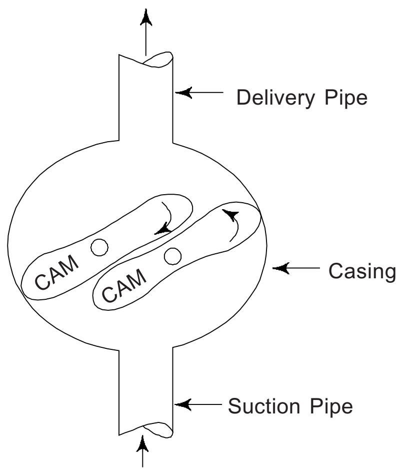


Fig. 5.4 *Rotary pump*

Advantages

1. The flow of water is uniform.
2. No priming is required.
3. It requires no valve and its operation is simple.

Disadvantages

1. It requires replacement of cams frequently and hence it involves more maintenance cost.
2. It cannot be used for pumping water containing high sediment.

5.6 AIR LIFT PUMP

It consists of a casing pipe in which an educator pipe and an air pipe are introduced. The bottom end of the air pipe carries an air diffuser which is introduced into the educator pipe in upward direction. When compressed air is forced through the air pipe as shown in Fig. 5.5, a mixture of air and water is formed and rises up in the form of bubbles. This mixture has low specific gravity than the water in the casing pipe. Thus the pressure of the water in the educator pipe becomes less than the pressure of water in the casing pipe. This pressure difference forces the water to rise through the educator pipe and finally the water is discharged through the outlet. The efficient working of the pump depends on the air pipe's submergence depth. Generally, the depth of submergence should be about two-third of the length of air pipe.

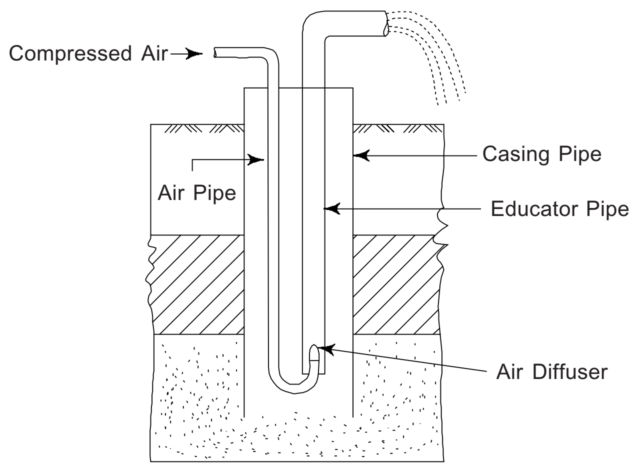


Fig. 5.5 *Air lift pump*

5.7 HORSE POWER OF PUMP

The horse power of a pump is determined by the work done by the pump in raising a particular quantity of water to some height.

Let, W = Quantity of water in kg.

H = total head in m.

Then work done by pump = $WH = wQH$ ($W = w \times Q$) (5.1)

where, w = Density of water 1000 kg/m^3

Q = Discharge in m^3/sec.

Again, total head

$$H = H_s + H_d + H_f$$

where, H_s = Suction head
H_d = Delivery head
H_f = Head lost due to friction

Again, the head lost by friction is given by

(a) $H_f = \dfrac{f1Q^2}{3d^5}$

(b) $H_f = \dfrac{4\,flv^2}{2gd}$

where, f = Coefficient of friction
l = Total length of pipe in m (suction and delivery)
V = Velocity of flow in m/sec.
g = Acceleration due to gravtiy (9.81 m/sec^2)
d = Diameter of pipe in m.

From Eqn. (5.1)

Water Horse Power (W.H.P) = $\dfrac{wQH}{75}$

Considering efficiency of the pump as η

Brake Horse Power (B.H.P.) = $\dfrac{wQH}{75 \times \eta}$

Problems on Horse Power

Problem 5.1

A centrifugal pump is required to lift water at the rate of 150 lits/sec. Calculate the horse power of the engine from the following data:

(i) Suction head = 3 m.
(ii) Delivery head = 3 m.
(iii) Coeff. of friction = 0.01.
(iv) Efficiency of pump = 75%
(v) Diameter of pipe = 15 cm.

Solution

Here, Q = 150 lits/sec = 0.15 m^3/sec.
Suction head = 3m.
Delivery head = 3m.
Coeff. of friction = 0.01.
Diameter of pipe = 15 cm = 0.15 m.
The length of pipe where frictional effect may occur is given by.

$$l = 3 + 3 = 6 \text{ m.}$$

Now, Head lost due to friction,

$$H_f = \frac{flQ^2}{3d^5} = \frac{0.01 \times 6 \times (0.15)^2}{3 \times (0.15)^5} = 5.93 \text{ m.}$$

So, total head, $H = H_s + H_d + H_f$

$= 3 + 3 + 5.93 = 11.93$ m

Here, efficiency, $\eta = 75\% = 0.75$

$$\text{B.H.P} = \frac{1000 \times 0.15 \times 11.93}{75 \times 0.75} = 31.8 = 32 \text{ (say)}$$

Problem 5.2

A town has a population of one lakh. A pumping unit is to be established for supplying water to the town having the following data:

(i) Average water demand = 150 lits/capita/day
(ii) R.L. of water in the sump well = 30 m.
(iii) R.L. of reservoir = 66 m.
(iv) Duration of supply = 8 hrs.
(v) Distance between sump well and reservoir = 1000 m.
(vi) Value of coeff. of friction (f) = 0.0075
(vii) Efficiency of pump = 80%
(viii) Velocity of flow in the pipe = 2 m/sec.

Determine the diameter of main pipe and B.H.P of the pump.

Solution

Average water demand of the town = 100000 × 150 lits/day.

$= 15 \times 10^6$ lits/ day

Assuming maximum demand as 1.5 times the average demand,

Maximum daily demand = $1.5 \times 15 \times 10^6$ lits/day.

As the total demand is supplied in 8 hrs.

$$\text{Required discharge } (Q) = \frac{1.5 \times 15 \times 10^6}{8} \text{ lits/hr.}$$

or $$Q = \frac{22.5 \times 10^6}{8 \times 60 \times 60} \text{ lits/sec.}$$

or $$Q = \frac{22.5 \times 10^6}{8 \times 60 \times 60 \times 10^3} = 0.780 \text{ cumec. (1 cumec} = 10^3 \text{ lits)}$$

$\therefore$ Cross-sectional area of pipe $= \dfrac{Q}{V} = \dfrac{0.780}{2.5}$

$= 0.312 \text{m}^2$

Let, the diameter of pipe be 'd'

$$\frac{\pi}{4} d^2 = 0.312.$$

$\therefore \quad d = \sqrt{\dfrac{0.312 \times 4}{\pi}}$

or $\quad d = 0.63$ m = 0.65 m (say)

Head lost due to friction in length 1000m

$$H_f = \frac{4\,flv^2}{2\,gd} = \frac{4 \times 0.0075 \times 1000 \times (2.5)^2}{2 \times 9.81 \times 0.65}$$

= 14.7 m.

Here $\quad H_s + H_d$ = R.L. of reservoir – R.L. of sump.

= 66.0 – 30.0 = 36 m.

Total head = $H_s + H_d + H_f$

= 36 + 14.7 = 50.7 m.

$$\text{B.H.P} = \frac{WQH}{75 \times \eta} = \frac{1000 \times 0.78 \times 50.7}{75 \times 0.8} = 659. \text{ Ans.}$$

5.8 LIFTING OF WATER FROM DEEP TUBE WELL

Water is lifted from deep tube by two systems:

1. Bowl assembly system
2. Submersible pump system

1. Bowl Assembly System

As shown in Fig. 5.6, the motor is installed at the head of the tube well. The bowl assembly of centrifugal turbine pump is introduced sufficiently below

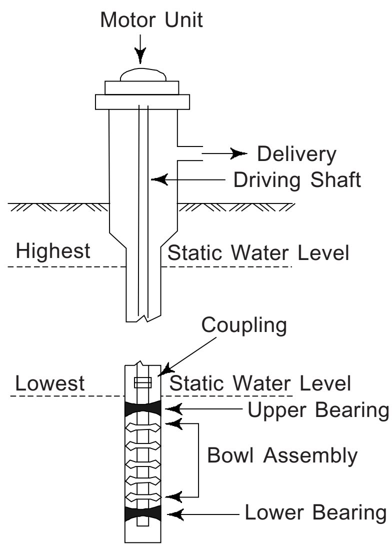


Fig. 5.6 *Bowl assembly system*

the lowest static water level (i.e. in Summer). The motor is connected to the pump by driving shaft. The water is available throughout the year at a constant rate.

2. Submersible Pump System

In this system, a submersible pump set (electric motor and centrifugal turbine pump) is lowered into the tube well by suspended cable (shown in Fig. 5.6). It is placed sufficiently below the lowest static water level. The water is available throughout the year at a constant rate.

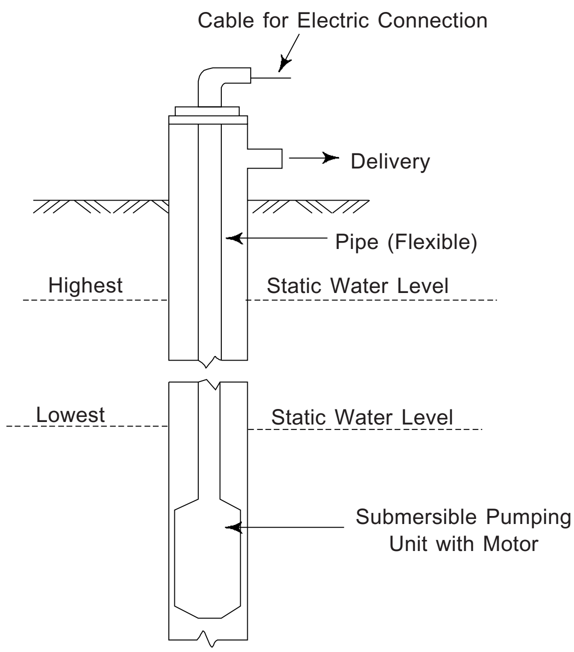


Fig. 5.7 *Submersible pump*

Review Questions

1. State the lifting head of a pump.
2. Describe the volute type of centrifugal pump with sketch.
3. Describe the turbine type of centrifugal pump with sketch.
4. How is B.H.P of a pump determined?
5. Describe, with a sketch, the mechanism of lifting water from deep tube well.

6

Pollution of Water

6.1 INTRODUCTION

Man cannot survive without water. But this water may be the cause of disaster if it is polluted by harmful agencies and used for drinking purpose. Absolutely pure water cannot be expected. When the rainwater flows as run-off, it passes through the ground surface and gets collected in rivers, lakes and ponds. On its way, the water get polluted by harmful salts, acids, minerals, pathogenic bacteria, radioactive substances, etc. Hence, the water may possess undesirable colour, odour, taste and even disease causing microorganisms.

In early days, this type of surface water was consumed by human beings for drinking, bathing, washing, etc. In those days man did not have the technical knowledge for purifying contaminated water. As a result, man had to suffer water-borne diseases like dysentry, cholera, etc. and innumerable villages were destroyed by epidemics.

With the growth of civilisation and development of towns or cities, man began to think over the issues of pure water for drinking, safety of life and healthy environment. Though absolute pure water cannot be available, but it should contain the least amount of impurities which may not be injurious to human health. Such water is known as wholesome water or potable water. The potable water should have the following properties:

(a) It should be very clear (i.e. colourless).
(b) It should not possess any odour.
(c) It should be tasteful.
(d) It should not contain any bacteria.

Now, to obtain the desired quality of potable water, the sample of water from the sources should be collected, tested in laboratory and necessary treatments should be recommended accordingly.

In this chapter, we shall study the nature of impurities, tests for detecting the amount of impurities and finally recommendation for the next step in water treatment.

6.2 SOURCES OF WATER POLLUTION

The following are the sources of pollution of surface water:

1. Washing clothes of persons suffering from diseases like dysentry, cholera, typhoid, etc.
2. Bathing of persons suffering from skin diseases.
3. Bathing cattles.
4. Throwing dead animals in the river.
5. Discharges from industries like tannery, chemical, dying, paper, etc.
6. Intensive use of chemical manure for the growth of crops.
7. Use of insecticides in cultivated land containing arsenic and other harmful ingredients.
8. Radioactive ash which may spread due to nuclear explosion.
9. Discharge from nuclear power plant.
10. Discharge from nuclear research centre.
11. Debris from slips in hilly area containing harmful salts.
12. Discharge of sewage of a town or city into the river without any treatment.

6.3 COMMON IMPURITIES IN WATER

The common impurities in water may be classified into following groups:

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

1. Physical Impurities

Physical impurities may cause the following factors:

(a) Turbidity The turbidity of water indicates the presence of colloidal matters such as fine silt and clay. In some cases the salts of iron and manganese may impart turbidity in water. The colloidal substances and salts may be injurious to human health.

(b) Colour The water gets colour from the discharge of some industries such as tannery, textile industry, paper industry, etc. Those discharges mainly contain lignin, tannin and other waste products which may impart colour.

(c) Taste and Odour The discharges of waste products from some industries and trades contain strong smelling chemical compounds which impart taste and odour to the water. Generally, the smelling compounds are free chlorine, hydrogen sulphide, phenol, etc. Such compounds make the water very unpleasant to consume.

(d) Floating Matters At many places the dumping ground for debris or garbage may be close to the river. In rainy season garbage are carried by rain

water appearing as floating matters in the river or stream. Again, in rainy season different types of debris may come down with rain water from the catchment area in hilly region. These floating matters may pollute water by decomposing.

(e) Unpleasant Gases The presence of gases in water is indicated by the formation of foam in rivers. The foam may be formed by the absorption of gases while the water falls with tremendous velocity from water-falls in hilly area, or due to the whirling motion in rivers which flow with great velocity.

(f) Radioactive Substances The nuclear power plant, nuclear research centre and some industries dealing with radioactive substances may discharge some waste products which may have radioactive property. This property seriously affects the human life and aquatic life.

2. Chemical Impurities

The presence of the following compound results in the chemical impurity of water.

(a) Acids The waste products of some industries such as battery factory, explosives factory, etc. contain acids. If these waste products are directly discharged into river, then it will be harmful to the aquatic life and will destroy the self-purification property of river water.

(b) Alkalies The waste products of some industries contain alkalies also. These alkalies have the same effect as that of acids.

(c) Inorganic Compounds The waste products of some industries such as fertiliser industry, coke oven industry, etc. contain certain inorganic compounds. These compounds mainly consist of chloramines, sulphide, ammonia, etc. which are toxic to a aquatic life.

(d) Organic Compounds The organic compounds may be of the following forms:

(i) The organic compounds may exist in water due to the presence of fats, proteins, carbohydrates, etc.

(ii) The suspended organic compound may develop due to decayed fruits, dead animals, etc. The organic compound like albuminoid ammonia is responsible for developing pathogenic bacteria which is dangerous to public health.

3. Bacteriological Impurities

The development of pathogenic bacteria, fungi, viruses, etc. in water is caused due to the fermentation of dead bodies and also due to the unhygienic discharge of sewage into river without proper treatment. These bacterial loads are responsible for water borne diseases.

6.4 TESTING OF WATER

Before the recommendation of treatment processes to be adopted in a water supply scheme, the sample of water from the source should be collected and tested in laboratory. The necessity of testing is to verify the following factors:

(a) To select the source of water.
(b) To find the number of units to be established in a treatment plant and the type of treatment needed.
(c) To find the cost of treatment.
(d) To find the daily requirement of coagulants, bleaching power, chlorine, etc.

The testing of water involves the following steps:

1. Collection of water sample
2. Physical test
3. Chemical test
4. Bacteriological test.

We shall study the above steps in detail in the following sections.

6.5 COLLECTION OF WATER SAMPLE

The arrangement of treatment plant depends on the laboratory analysis of water. Again, the correctness of laboratory test depends on the method of collection and preservation of sample. The following points should be kept in mind while collecting the sample:

(a) The bottles of the samples should be properly labelled with informations like date, time of collection, type of source, etc.
(b) The bottles should be cleaned properly.
(c) The bottles may be of polythene or glass with airtight corks.
(d) The capacity of bottles should be about 2 to 3 litres.
(e) The bottles should be packed in a wooden box with saw dust.
(f) The samples should be tested as early as possible.
(g) If the water is collected from tap, then the water should be allowed to flow for some time before collection.
(h) If the water is collected from surface sources such as rivers, streams or lakes, then it should be collected from a depth of about 50 cm.

6.6 PHYSICAL TEST

This test is carried out for the following physical characteristics:-

1. Colour
2. Taste and odour
3. Turbidity
4. Temperature

1. Colour

We have mentioned earlier that the coloured discharge from some industries impart colour to water. This colour is undesirable in water as it may stain clothes and this water may be injurious to human health if the colour comes from harmful chemicals.

However, here we shall study the laboratory test for finding the intensity of colour. The colour in water is measured by an instrument called *Tintometer.* The instrument consists of an eye-piece having two holes. One hole is meant for looking a slide of standard coloured water and the other hole is meant for looking a slide of water to be tested. The intensity of colour is measured in a cobalt scale by comparing the two slides. The unit of standard colour is produced by dissolving 1 mg of platinum-cobalt in one lit. of distilled water. The unit of colour is expressed by a number as indicated in the cobalt scale. For potable water this number should be less than 10.

2. Taste and Odour

The taste and odour in water may come due to the presence of strong smelling waste products discharged from industries. It may also be due to dead microorganisms and dissolved gases such as hydrogen sulphide, methane, carbon dioxide, etc.

The odour is generally expressed as fishy, earthy, grassy, etc. It is measured by an instrument known as *osmoscope* which consists of a tube for inhaling the odour of water to be tested by diluting it in odour-free water. The intensity of odour is expressed as *Threshold number*.

Such as, if 4 c.c. of water to be tested is diluted in 100 c.c. odour-free water and odour is detected, then the threshold number is 4.

If 5 c.c. of water is diluted in 100 c.c. of odour-free water and odour is detected, then threshold number is 5.

For potable water, the threshold number should not be more than 3.

3. Turbidity

The colloidal matters like silt and clay impart turbidity to water. It is expressed as part per million (i.e. ppm.). The permissible turbidity for potable water should be 5 to 10 ppm. The turbidity can be measured by

(a) Turbidity rod—Field test
(b) Jackson Turbidimeter—Laboratory test
(c) Baylis Tubidimeter—Laboratory test

(a) Turbidity Rod It consists of an aluminium rod which is graduated. A graduated tape is provided on the top of the rod for marking the position of eye. A hole is provided at the bottom of the rod for inserting a platinum needle as shown in Fig. 6.1. For measuring the turbidity, the rod is gradually lowered in water. Then a position will come when the needle will just disappear under standard light condition. The depth of water at this position is noted from the bar. This reading gives the turbidity of water in ppm.

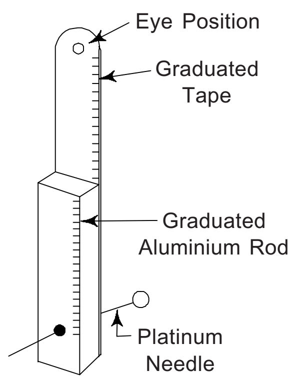


Fig. 6.1 *Turbidity rod*

(b) Jackson Turbidimeter The instrument consists of a stand made of wood or metal on which a container is provided with suitable frame. Again, the container consists of a graduated glass tube. A candle is placed below the stand as shown in Fig. 6.2. The flame of the candle is visible through the glass tube. Now, the water under test is poured gradually and the image of the flame is observed. A time comes when the flame disappears. Just at that moment the reading on the glass tube is noted which indicates the turbidity in ppm. This instrument is suitable for measuring the turbidity above 100 ppm.

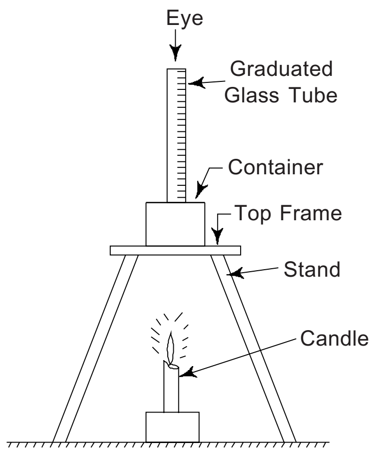


Fig. 6.2 *Jackson turbidimeter*

(c) Baylis Turbidimeter It consists of a metal box. On the left side of the box two glass tubes are mounted vertically. The lower ends of the tubes are surrounded by blue cobalt plates. On the right side, a bulb (high power) is fitted on the base and a reflector is provided on the back as shown in Fig. 6.3. One glass tube is filled with water whose turbidity is to be measured and the other tube is filled with standard solution of known turbidity. When the bulb is lighted, the blue light is seen through the glass tubes from top. If the colour intensity of the tubes differ, then another tube with standard solution of known turbidity is inserted. In this way, the tube with standard solution goes on changing until a stage comes when the colour intensity from both the tubes are nearly same. Then the turbidity of the standard solution is considered as the turbidity of the sample of water. This instrument is suitable for measuring the turbidity below 5 ppm.

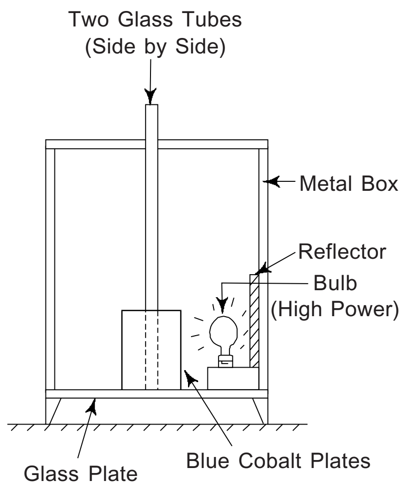


Fig. 6.3 *Baylis turbidimeter*

4. Temperature

Practically, the temperature has no significance as no treatment can be given to control it. But it is seen that the growth rate of bacteria is rapid at high temperature. So, the sample of water should be collected at a temperature below 15°C. The temperature is observed by a thermometer by which the atmospheric temperature is recorded. The temperature of potable water should be about 10°C to 25°C.

6.7 CHEMICAL TEST

The chemical tests are carried out to determine the following factors:

(a) Chlorides
(b) Nitrogen and its compounds
(c) Dissolved gases
(d) pH-value (Hydrogen-ion concentration)
(e) Hardness
(f) Iron and manganese
(g) Total solids
(h) Sulphates
(i) Alkalinity

(a) Chlorides

The presence of sodium chloride in excess is injurious to human health. So, it should be removed or brought down to a permissible limit. In potable water, the permissible limit is 200 mg/lit (i.e. 200 ppm).

The process of determination of sodium chloride content in water is explained below:

(i) A known quantity of sample of water (say 100 C.C) is taken in a porcelain pot.
(ii) Few drops of potassium chromate solution are added to it.
(iii) Then by titrating with silver nitrate solution, the amount of chloride in water is determined.

During titration, various chemical reactions go on and ultimately a reddish precipitate appears. Now, the amount of silver nitrate required to produce that precipitate indicates the amount of chlorides present in water.

(b) Nitrogen and its Compounds

Nitrogen may be present in water in the following forms:

(i) Free ammonia
(ii) Albiminoid ammonia
(iii) Nitrates
(iv) Nitrites

The presence of these forms is detected by the following observations:

Free ammonia is detected by boiling the water, when ammonia gas is liberated. Then the amount of the gas is measured by receiving the gas in a glass jar. The presence of free ammonia in drinking water should not exceed 0.15 ppm.

Albuminoid ammonia is detected by adding a solution of potassium permanganate in water and boiling it. It results in liberation of ammonia gas. The amount of the gas is then ascertained. The presence of albuminoid ammonia in drinking water should not exceed 0.3 ppm.

Nitrites and nitrates are detected by converting these into ammonia and they are measured by comparing with standard colours. The presence of nitrites in drinking water should be nil. But the presence of nitrates may be permissible up to 45 mg. per litre.

(c) Dissolved Gases

The gases like oxygen, carbon dioxide, hydrogen sulphide, methane are present in water in dissolved state.

To detect dissolved oxygen, the sample of water is exposed to atmosphere for 4 hours at 27°C with a solution of potassium permanganate of 10% concentration. The quantity of oxygen absorbed is then ascertained. In potable water the dissolved oxygen should be about 5 to 10 ppm.

The presence of carbon dioxide is detected by mixing a solution of lime in water. If there is carbon dioxide in water it will give a milky white colour.

The presence of other gases is detected by suitable methods in chemical laboratory.

(d) pH-Value (i.e. Hydrogen-ion Concentration)

The term pH-value is used to designate the acidity and alkalinity of water. The acidity is caused due to the presence of mineral acids, free carbon dioxide, sulphates of iron and aluminium, etc. The alkalinity is caused due to the presence of bicarbonates of sodium, calcium, magnesium, etc.

When electric current is passed through the neutral water (i.e. pure water), then it breaks up into positively charged hydrogen-ions (H^+) and negatively charged hydroxyl-ions (OH^-).

i.e. $H_2O = H^+ + (OH)^-$

According to the law of mass action,

Concentration of H^+-ion × concentration of OH^--ion = a constant = 10^{-14}

Neutral Water It is observed that in neutral water

H^+-ion concentration = OH^--ion concentration

So, H^+-ion concentration = 10^{-7}

and OH^--ion concentration = 10^{-7}

Now, the pH-value is defined as the logarithm of reciprocal of H^+-ion concentration.

i.e. $$\text{pH-value} = \text{Log}_{10}\left(\frac{1}{H^+}\right) = \text{Log}_{10}\left(\frac{1}{10^{-7}}\right) = \text{Log}_{10}{}^{7} = 7.$$

So, the pH-value of neutral water is 7.

Acidic Water When an acid such as hydrochloric acid (Hcl) is added to water, the following dissociation takes place,

$$H_2O = H^+ + (OH)^-$$
$$Hcl = H^+ + Cl^-$$

So, H^+-ion concentration increases, but OH^--ion concentration decreases and consequently pH-value decreases. This is an indication of acidity. The acidity ranges from pH-value 7 to 0. The water is maximum acidic when pH-value is 0.

Alkaline Water When an alkali like sodium hydroxide Na (OH) is added to water, the following dissociation takes place.

$$H_2O = H^+ + (OH)^-$$
$$Na\,(OH) = Na^+ + (OH)^-$$

i.e. OH^--ion increases, but H^+-ion decreases and consequently pH-value increases. This is an indication of alkalinity. The alkalinity ranges from pH-value 7 to 14. The water is maximum alkaline when pH-value is 14.

Thus, from the above observation it is seen that

H^+-ion increases—pH-value—decreases.

H^+-ion decreases—pH-value—increases.

The pH-value of water is determined by the following two methods:

(i) Electrometric Method In this method, a potentiometer is adopted to measure the electrical pressure exerted by the positively charged H^+-ions. The pH-value is directly obtained from a rating table already prepared in laboratory.

(ii) Colourimetric Method In this method, some chemical reagents are added to water to produce a colour. This colour is compared with standard colour of known pH-value. A set of tubes containing coloured water of known pH-value are kept ready in the laboratory. So, by trial the pH-value of sample of water is determined with reference to the standard coloured tubes.

(e) Hardness

Hardness of water may be described as the soap destroying property of water. The hardness may be of two types—temporary hardness and permanent hardness.

The temporary hardness is due to the presence of bicarbonates of calcium and magnesium. The permanent hardness is due to the presence of sulphates, chlorides and nitrates of calcium and magnesium. The hardness is determined in two ways.

(1) EDTA (Ethylene Diamine Tetracetic Acid) Test In this test, the water is titrated against EDTA salt solution with 'Erio chrome Black T' as indicator. During titration the colour changes from red to blue. From the amount of salt solution absorbed in titration, the hardness may be ascertained.

(2) Soap Solution Test In this test, a standard soap solution is added to water and vigorously shaken for about 5 minutes. Then the formation of lather is observed. The difference between the total amount of soap solution and the lather factor will show the hardness.

The hardness of water is generally expressed in degrees. One degree hardness is defined as the soap destroying power which is equivalent to the effect of 14.25 mg of calcium carbonate in one litre of water. It is also expressed in ppm. One degree hardness is equal to 14.25 ppm.

(f) Iron and Manganese

The presence of iron and manganese in water makes the food tasteless and causes stains in clothes. The concentration of iron and manganese should not be more than 3 ppm in potable water. The amount of iron and manganese in water is determined by colour test. Some colouring agents are added to the sample of water. Then, the colour of this solution is compared with the solution of known amount of the metals. Thus, the concentration of iron and manganese will be obtained.

(g) Total Solids

Solid particles may be present in water either in suspended or in dissolved form. The suspended particles are determined by filtering the water through filter. The particles retained on the filter is weighed after drying properly.

The dissolved particles are determined by evaporating the filtered water and by weighing the residue after drying properly.

Two results are added to know the total solids.

6.8 BACTERIOLOGICAL TEST

Water always contains some bacteria which can be detected by microscope only. Again, the bacteria may be of two types—pathogenic bacteria and non-pathogenic bacteria.

The pathogenic bacteria are harmful bacteria. It causes diseases such as typhoid, cholera, dysentry, etc. The non-pathogenic bacteria is not harmful. But it is difficult to isolate the two. The combined group of the two bacteria is termed as B-coli group (i.e. Bacterium and Coli). Sometimes the group is termed as coliform group. The common bacteria in this group is known as E-coli (Escherichia coli). However, both the groups are identified by the following bacteriological tests

1. Total count or Agar Plate count test.
2. B-coli test (or E-coli test)

1. Total Count Test

In this test, the bacteria are cultivated on a medium of agar having different dilutions of sample of water with sterilised water. The diluted sample is placed in an incubator for 24 hours at 37 °C. The bacterial colonies formed after this period are counted with the help of microscope. Again, the diluted sample is placed in the incubator for 48 hours at 20 °C. The bacterial colonies formed in this case are also counted. The two results are added to know the total number of colonies. This is known as *Total counts.* It is then converted to colonies per c.c. For potable water, the total count should be 100 per c.c.

2. B-Coli Test

This test is carried out in three phases:

(a) Presumptive test
(b) Confirmed test
(c) Completed test

(a) Presumptive Test This test is based on the belief that the coliform group can ferment the lactose broth and can produce gas. The procedure of the test is described below:

(i) A known amount of diluted sample of water is taken in a standard fermentation tube containing lactose broth.
(ii) The tube is kept at a temperature of 37 °C for 48 hours.
(iii) After this period, if gas is seen in the tube, then this is an indication of presence of B-coli. This result is positive and the sample of water is unsafe for drinking. If no gas is seen, then the sample of water is free from B-coli. This is a negative result and the water is safe for drinking.

(b) Confirmed Test The test may be carried out by any one of the following two methods:

(i) Method 1 A small quantity of lactose broth showing positive result in presumptive test is taken to another fermentation tube containing green lactose bile and kept for 48 hours. If gas is seen, then the presence of B-coli is confirmed. So, the completed test must be done.

(ii) Method 2 A small quantity of lactose broth showing positive presumptive test is taken on a plate containing Endo or eosin-methylene-blue agar. It is kept for 24 hours at 37 °C. If colonies of bacteria are seen, the positive result is confirmed. So, the completed test must be done.

(c) Completed Test The samples of the previous test are taken into lactose broth fermentation tube and agar tube and both tubes are incubated at 37 °C for 24 to 48 hours. If gas is seen after this period, then it indicates positive result. So, this type of water is unsafe for drinking.

B-coli Index

This is an index or number showing the approximate number of B-coli per c.c. of sample of water. This is found out by the following procedure:

(a) A number of presumptive tests are carried out with different dilution ratios of water sample with sterilised water.
(b) For each test percentage of positive result is recorded.
(c) The difference between the successive percentage is found out.
(d) This difference is multiplied by the reciprocals of quantity of mixture (i.e. water sample and sterilised water).
(e) The sum of such values gives the B-coli index.

The B-coli index should be between 3 and 10, for potable water.

6.9 STANDARDS OF DRINKING WATER

The standards of drinking water are identified by three distinct categories:

1. Standard Considering Physical Characteristics

(a) Colour The number on cobalt scale should not exceed 20.

(b) Taste and Odour The threshold number should not be more than 3.

(c) Temperature The desirable temperature should be 10°C.

(d) Turbidity The permissible turbidity should be 5 to 10 ppm.

2. Standard Considering Chemical Characteristics

(a) Chlorides The amount of chlorides should not exceed 250 mg/lit.

(b) Dissolved Gases The amount of dissolved gases should be 5 to 10 ppm.

(c) Hardness The hardness of water should be between 5 and 8 degrees.

(d) pH-value The pH-value should be between 7 and 8.5.

(e) Nitrogen and its Compounds

(i) The amount of free ammonia should not exceed 0.15 ppm.
(ii) The albuminoid ammonia should not exceed 0.3 ppm.
(iii) The amount of nitrites should be nil.
(iv) The amount of nitrates should not exceed 45 mg/lit.

(f) Total Solids The amount of total solids should be less than 500 ppm.

3. Standard Considering Bacteriological Characteristics

(a) Total Counts The total counts should not exceed 100 per c.c.

(b) B-coli Index The B-coli index should be preferably less than 3. In any case, it should not exceed 10.

6.10 WATER-BORNE DISEASES

The diseases which are carried by water and get entry to human body through drinking water are known as water-borne diseases. Some common diseases are cholera, dysentry, typhoid, etc. Such diseases are mainly caused by pathogenic bacteria. Sometimes the clothes of the patients suffering from those diseases are washed in rivers, ponds, lakes, etc. and the above bacteria are discharged into the surface water. If this surface water is not treated properly, the bacteria may enter the distribution system and thus the water-borne diseases may spread.

6.11 MAINTENANCE OF PURITY OF WATER

The purity of water may be maintained by adopting the following measures:

(a) Development of catchment area
(b) Recycling operation in industrial plants
(c) Development of civic sense
(d) Restriction in drainage system

(a) Development of Catchment Area

The catchment area should be developed by the following ways to arrest the debris carried by the tributaries:

(i) Check dams should be constructed on the tributaries in hilly area.
(ii) Contour bunds should be constructed on the hill slope.
(iii) Cultivation and grazing of cattles should be restricted in the catchment area.

(b) Recycling Operation in Industrial Plants

The quantity of water required for one cycle may be re-used in the next cycle after removing the by-products or waste products. The water lost during one cycle may be replaced by fresh water in next cycle. The waste products should be treated within the plant area and then disposed off to the river. The untreated industrial waste should never be discharged into the river.

(c) Development of Civic Sense

The people residing near the surface sources of water are mainly responsible for the pollution of water. So, their civic sense should be developed by organising meetings at the Panchayat level or block level. The villagers should be educated to perform the following duties:

(i) They should not throw dead bodies of animals into the river.
(ii) They should not wash or throw the clothes of patients into the water of rivers, pond, lake, etc.

(d) Restriction of Drainage System

The drain water from the town or city should not be discharged directly into the river. Necessary treatments should be adopted before discharging.

Review Questions

1. What are the sources of water pollution?
2. State the common impurities in water.
3. State the procedure of collecting sample of water.
4. State the standards of drinking water.
5. State the measures to be taken for the maintenance of purity of water.

7

Primary Treatment of Water

7.1 OBJECT OF WATER TREATMENT

The water from the surface sources may have some characteristics which are unsuitable for human consumption, industrial use, commercial use, etc. The following are some of those characteristics:

(a) It may be turbid.
(b) It may contain colour.
(c) It may contain acids, salts and gases which have corrosive action and may impart hardness of water.
(d) It may contain bacteria which may cause water-borne diseases.

Therefore, the object of treatment of water is to remove those impurities and to make the water suitable for domestic, industrial and commercial uses.

Underground water may be free from the above impurities, but sometimes it may possess the property of hardness which should be removed (see Chapter 11).

7.2 FLOW DIAGRAM OF A TREATMENT PLANT

Sequence of units:

1. Intake point
2. Pump house
3. Plain sedimentation tank
4. Coagulation tank
5. Filtration unit
6. Chlorination unit
7. Water softening plant
8. Overhead reservoir

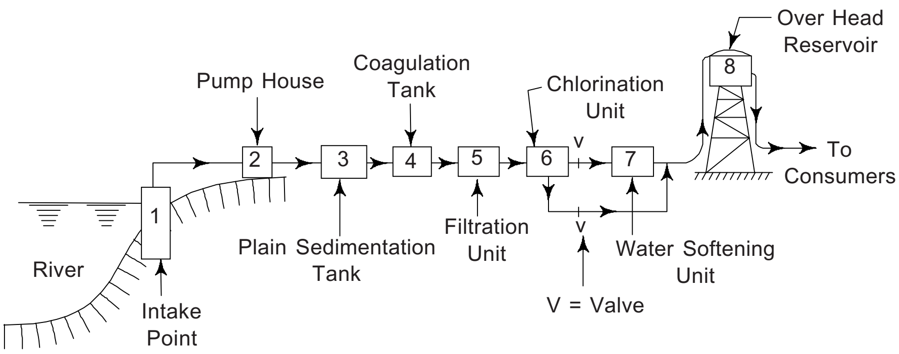


Fig. 7.1 *Flow diagram of treatment plant*

7.3 FUNCTIONS OF UNITS

The function of each unit is stated briefly

1. Intake Point The function of this unit is to collect water in the intake well so that the water can be supplied throughout the year.

2. Pump House The function of this unit is to draw water from the intake well and to supply the same to the treatment plant.

3. Plain Sedimentation Tank The function of this unit is to remove the heavier suspended particles in water. In this tank, the water is detained for some period or allowed to flow at a very low velocity so that the heavier suspended particles are settled down at the bottom of sedimentation tank. But some lighter particles still remain in suspension.

4. Coagulation Tank The function of this unit is to remove the lighter suspended particles by the application of some coagulants. In this tank, some recommended coagulant is mixed with the water and the water is allowed to flow at a very low velocity through the coagulation tank. The coagulant makes the lighter particles to gain settleable size and ultimately settle down at the bottom of the tank. But some finer colloidal particles still remain in suspension.

5. Filtration Unit The function of this unit is to remove the finer collodial particles and some bacteria by filtering media of sand and gravel. But some bacteria still remain in water.

6. Chlorination Unit The function of this unit is to destroy the bacteria by application of chlorine.

7. Water Softening Tank The function of this unit is to remove the hardness of water to make it fit for commercial purpose. This unit is not always necessary.

8. Overhead Reservoir The function of this unit is to store the purified water after the treatment is complete. The water from the reservoir is supplied to the consumers by gravity.

7.4 THEORY OF SEDIMENTATION

The particles which do not change their shape, size and weight while settling down in a fluid are known as *discrete particles*. The suspended impurities in water consists of discrete particles such as inorganic solids having specific gravity about 2.65 and organic solids having specific gravity 1.04. The particles having specific gravity more than 1.20 readily settle down at the bottom of the tank due to the force of gravity. This phenomenon of settlement is known as *hydraulic subsidence*. Every particle has its own hydraulic subsidence value. But the lighter particles cannot settle down due to force of gravity. Such particles are converted to settleable size by the application of some coagulant in water.

The process of settlement depends upon the following factors:

(a) Velocity of flow
(b) Size and shape of particle
(c) Viscosity of water

After long investigation with the nature of discrete particles, Mr G G Stokes developed an expression for the velocity of settlement. The expression is as follows:

$$V = 418(S - S_1)\, d^2 \left(-\frac{3T + 70}{100}\right)$$

where, V = Velocity of flow in mm/sec.
S = Specific gravity of particle
S_1 = Specific gravity of water
d = Diameter of particle
T = Temperature in °C.

The particles are given maximum opportunity to settle down by decreasing the velocity of flow and increasing the length of travel (i.e. by increasing the length of sedimentation tank).

7.5 PURPOSE OF SEDIMENTATION

The following are the purposes of sedimentation:

(a) To reduce the heavy sediment load before the water enters the coagulation tank.
(b) To make the process of coagulation more easy.
(c) To reduce the amount of coagulant.
(d) To reduce the cost of coagulation process.
(e) To make the working of other treatment processes more efficient.

7.6 THEORY OF COAGULATION AND FLOCCULATION

Coagulation

The theory of coagulation can be explained by the following phenomenon:

(a) Floc Formation When some chemicals (known as coagulants) are mixed with water thoroughly, a thick gelatinous precipitate is formed which is known as *floc*. This floc has got the property of attracting the suspended impurities in water and settle down towards the bottom of tank.

(b) Electric Charge It is observed that the ions of floc possess positive electric charge and the colloidal particles possess negative electric charge. So, the floc attracts the colloidal particles while it travels towards the bottom of tank.

Flocculation

The phenomenon of the formation of floc is termed as flocculation. The efficiency of flocculation depends on the following factors:

(a) Dose of Coagulant The dose of coagulant should be ascertained by laboratory test for the sample of water.

(b) Mixing The mixing of coagulant should be perfectly done for the quick formation of floc.

(c) pH-value The pH-value of water should be determined in laboratory to select the type of coagulant.

While settling down, the floc attracts more and more suspended impurities and thus the size of floc goes on increasing and ultimately the surface area of floc becomes sufficiently wide to arrest colloidal matters, organic matters and some amount of bacteria.

7.7 SEDIMENTATION TANK

The sedimentation tanks may be of the following types

(a) Rectangular Tank

In this type of tank, its capacity depends upon the volume of water to be treated. The length depends on the velocity of flow and the detention period. The detention period may vary from 4–6 hours. The width of the tank varies from 10 m–12 m, and the depth of the tank varies from 2 m–4 m. Here, the length of travel of the particles is increased by providing baffle walls. Thus, the velocity of flow is much reduced to maintain the designed detention period. Due to the low velocity of flow the heavier particles are settled down at the bottom of the tank as sludge. At some interval, the sludge is cleared through the sludge removal pipe by opening the valve as shown in Fig. 7.2. If the sludge becomes stiff, it is agitated gently by rakers at the time of removal. It is found that the hydraulic subsidence of the particles is more effective if the velocity of flow is kept within 15 cm to 30 cm per minute. The comparatively clear water is taken to the next unit through the outlet pipe.

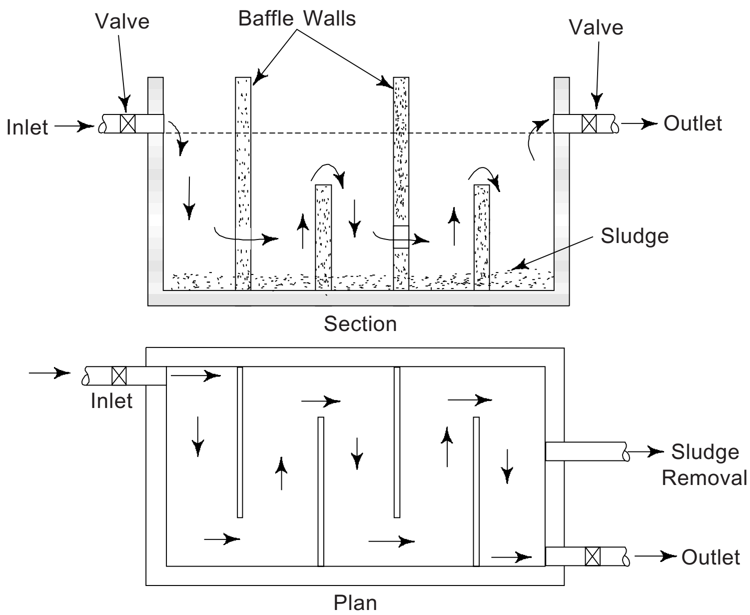


Fig. 7.2 *Rectangular tank*

(b) Circular Tank

The circular sedimentation tank may have radial or spiral flow. But the tank with radial flow is commonly adopted. In this tank, the water is allowed to enter through the pipe which is provided at its centre. The water flows upwards gently through the openings. The water is collected at the circular draw-off channel from where it is taken to next unit through the outlet pipe as shown in Fig. 7.3. The sediments or sludge are settled down at the bottom of the tank. A driving unit is provided for rotating an arm which consists of

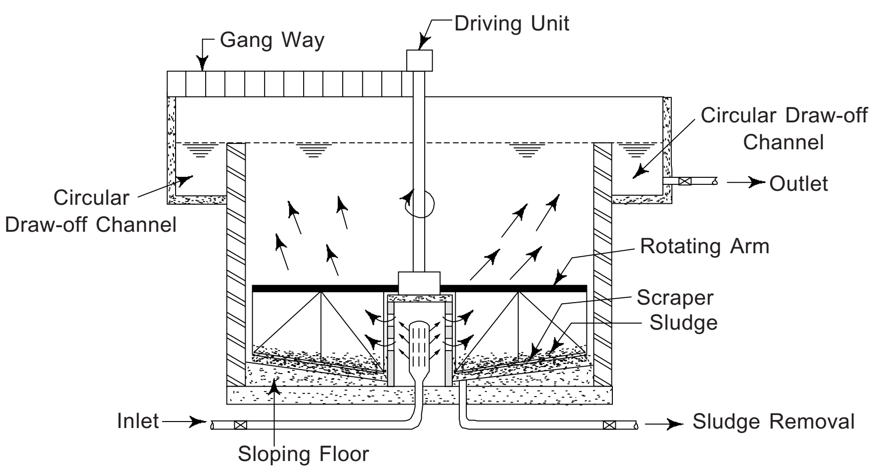


Fig. 7.3 *Circular tank*

scrapper. The circular motion of the scrapper helps the sludge to discharge through the sludge removal pipe.

(c) Hopper Bottom Tank

In this tank, the water is allowed to enter through a deflector box which is provided at the centre. The water flows downwards inside the box and then it rises in upward direction through the opening between the box and the wall of the tank. When the water rises in upward direction, the particles having specific gravity more than 1.00 cannot follow the path and ultimately settle down at the bottom of the tank due to the property of hydraulic subsidence. The sludge is pumped out through the sludge outlet pipe as shown in Fig. 7.4. The comparatively clear water is collected at the draw-off channel provided at the side of the tank from where it is taken to the next unit through the outlet pipe.

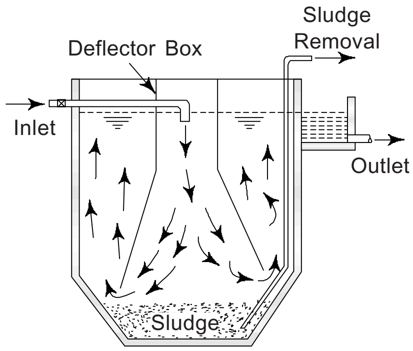


Fig. 7.4 *Hopper bottom tank*

7.8 COAGULATION TANK

Figure 7.5 shows a coagulation tank. It consists of the following components:

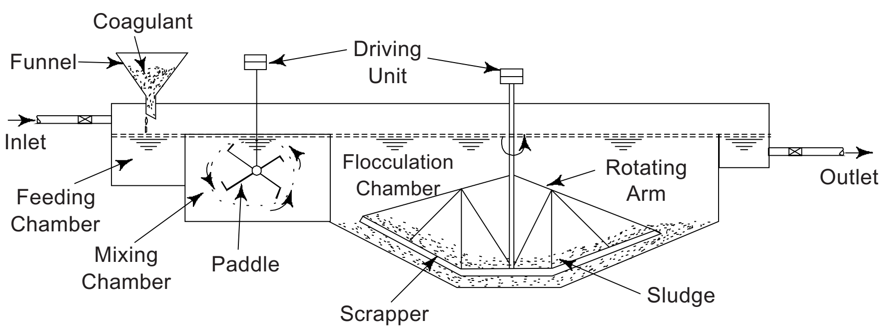


Fig. 7.5 *Coagulation tank*

1. Inlet Chamber The water is allowed to enter the coagulation tank through the inlet chamber. In this chamber, the feeding of coagulant is done by a suitable method.

2. Feeding Device The selected coagulant is added to water by a feeding device. The device consists of a conical container which is filled with the coagulant. A stop cock is provided at the bottom of the container to control the dose of coagulant.

3. Mixing Device There are various types of mixing devices. A suitable type is adopted for mixing operation. Generally, the device consists of paddles which are rotated by a driving unit. The paddles go on rotating continuously, and thus the coagulant is mixed thoroughly with water.

4. Flocculation Chamber In this chamber, the mixture of water and coagulant is detained for some specified period or it is allowed to flow at a very low velocity so that the floc may be formed. The floc goes on settling down by arresting the suspended particles. Thus, sludge is deposited at the bottom of the coagulation chamber.

5. Sludge Removal At the time of removal, the sludge is agitated by scrappers fixed with rotating arms which are operated by a driving unit. The sludge is taken off through the sludge removal pipe by opening the valve.

6. Collection of Clear Water The clear water from the top is collected in a draw-off chamber from where it is taken to the next unit through the outlet pipe.

7.9 FEEDING DEVICES OF COAGULANT

The feeding of coagulant may be of two types:

(a) Dry Feeding

The coagulants which are not hygroscopic or efflorescent and remain dry under various conditions of temperature and pressure are suitable for dry feeding. Aluminium sulphate has got the above characteristics. So, this can be fed in a powder form. Again, the coagulants which are corrosive in nature should also be fed in dry form (i.e. powder form). The dry feeding is done by the device shown in Fig. 7.6. In this device, the coagulant is stored in powder form in a conical hopper. Agitating plates are provided inside the hopper. An agitator constantly goes on agitating the plates so that the coagulant can remain in loose powder form.

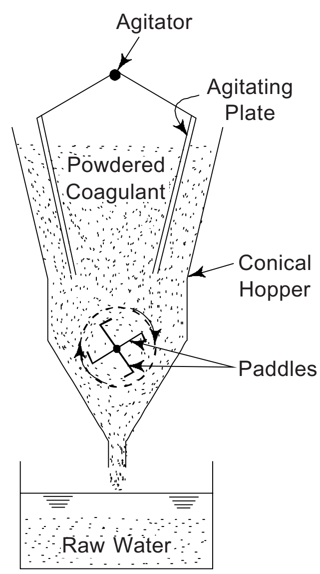


Fig. 7.6 *Dry feeding*

A toothed wheel is provided at the bottom of the hopper. The toothed wheel goes on rotating at an uniform speed and the coagulant also goes on dropping in raw water at a uniform rate. By adjusting the speed of the wheel the dose of coagulant can be adjusted.

(b) Wet Feeding

The coagulant like ferrous sulphate cannot be fed in dry form as its powder form may change to solid form due to the change of temperature. Similarly, the quick lime cannot be used in dry form, as it may be converted to slaked lime by absorbing moisture from air. So, these coagulants are always fed in liquid form. The wet feeding of coagulant is done by a device, shown in Fig. 7.7.

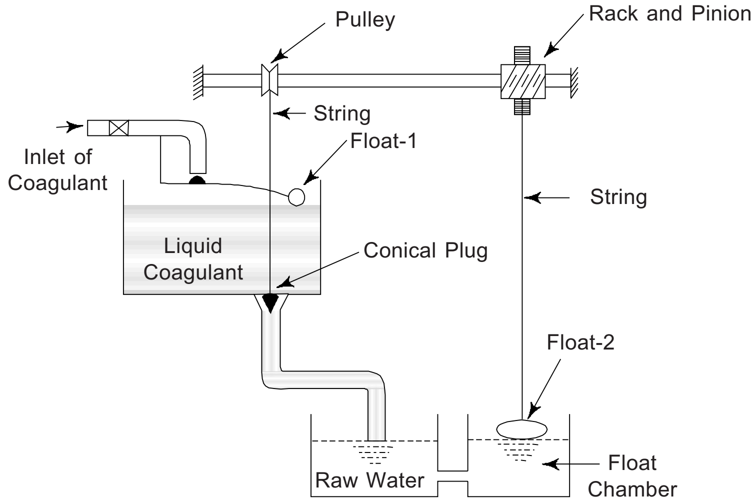


Fig. 7.7 *Wet feeding*

The liquid coagulant from coagulant storage tank is allowed to flow in the coagulant feeding tank through the inlet pipe. The level of solution in feeding tank is kept constant by a ball valve. If the liquid level of this tank rises, float-1 rises up and the curved lever closes the mouth of inlet pipe. Again, when the level goes down, the mouth is opened. A conical plug is provided at the bottom of this tank which controls the flow of coagulant into the raw water chamber. The raw water chamber is connected to the float chamber. If the water level in the raw water chamber rises, the water level in the float chamber will also rise and the float-2 will rise. Thus, the rack and pinion will move in one direction (clockwise or anticlockwise) and the pulley will also move in the same direction. The conical plug will be lifted automatically and more quantity of coagulant solution will enter the raw water chamber. The feeding of coagulant becomes slower when the water level of raw water chamber goes down. Thus, the conical plug controls the rate of feeding according to the volume of raw water.

7.10 MIXING DEVICES OF COAGULANTS

The quick formation of floc depends on the proper mixing of coagulant with the raw water. The following are the common devices which are generally employed:

(a) Flash mixer
(b) Deflector plate mixer
(c) Flocculator

(a) Flash Mixer

The flash mixer consists of a fan which is rotated by an electric motor through a vertical shaft. The inlet pipe releases the coagulant solution just below the fan. Again, the raw water is deflected by a deflecting wall so that it may come in contact with coagulant solution. The rotating fan mixes the solution with the water thoroughly. The mixed water rises upwards and finally comes out through the outlet pipe as shown in Fig. 7.8. A wash out drain is provided at the bottom of the mixer for cleaning when required.

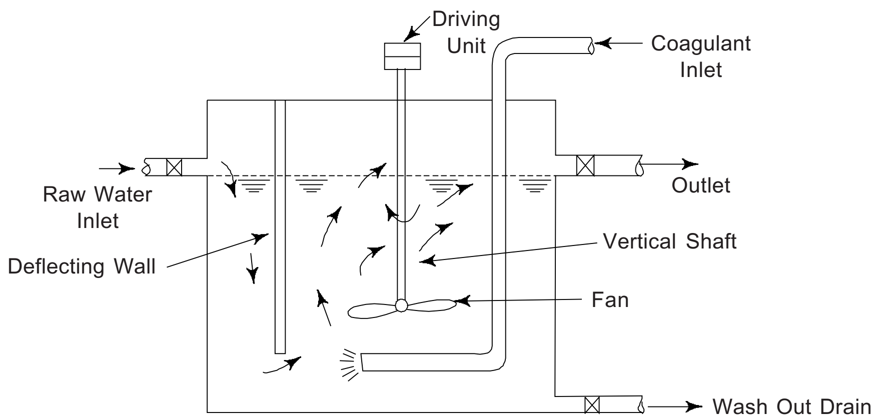


Fig. 7.8 *Flash mixer*

(b) Deflector Plate Mixer

Figure 7.9 shows a deflector plate mixer. In this device, a deflector plate is provided for agitating the raw water. The inlet pipe discharges the solution just above the deflector plate. The raw water, while entering the mixer is deflected by the deflecting wall and rises upwards through the holes provided below the deflector plate. The water comes in contact with the coagulant solution just above the deflector plate. The water is thoroughly mixed with coagulant by the agitation of deflector plate. Finally, the water passes out through the outlet pipe.

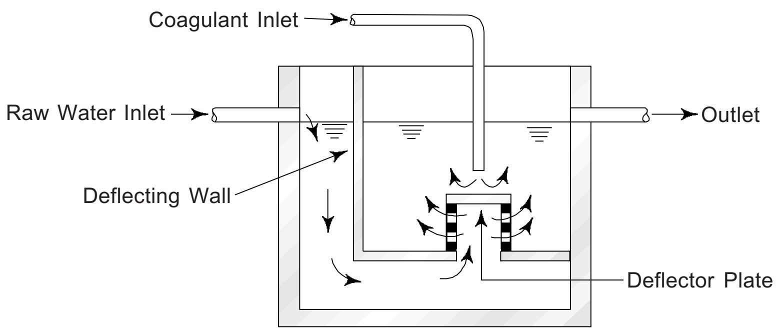


Fig. 7.9 *Deflector plate mixer*

(c) Flocculator

It consists of a vertical shaft which is geared with a horizontal shaft. As shown in Fig. 7.10, the horizontal shaft again consists of several paddles. When the vertical shaft is rotated by driving unit, the horizontal shaft also goes on rotating. With the rotation of the horizontal shaft, the paddles go on revolving at a very slow spend at about 2 to 3 r.p.m. This unit is adopted for stirring the mixture of raw water and coagulant solution very gently so that the formation of floc may occur very quickly. The flocculator is generally provided within the flocculation chamber.

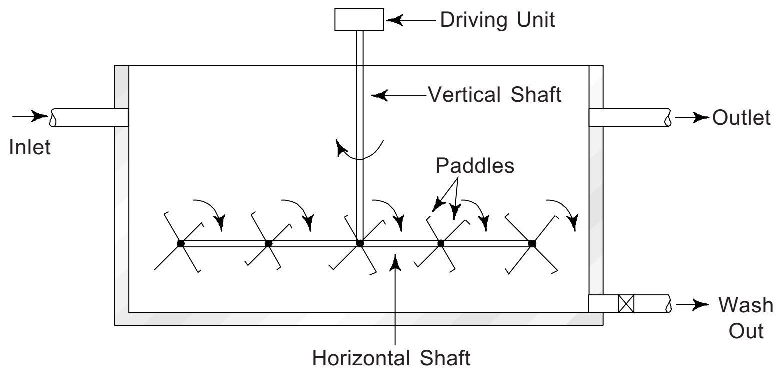


Fig. 7.10 *Flocculator*

7.11 TYPES OF CHEMICALS USED AS COAGULANTS

The following are the usual chemicals which are used for the coagulation:

(a) Aluminium sulphate
(b) Chlorinated copperas
(c) Ferrous sulphate and lime
(d) Magnesium carbonate
(e) Sodium aluminate.

(a) Aluminium Sulphate

The chemical composition of aluminium sulphate is $Al_2(SO_4)_3$, $18H_2O$. It is commonly known as alum. It is available in the form of a solid lump, but applied in a powder or liquid form. It is very effective if bicarbonate alkalinity is present in water. If the water possesses no alkalinity, some amount of lime is to be added to water.

When alum is mixed with water, a chemical reaction takes place and aluminium hydroxide ($Al(OH)_3$), calcium sulphate ($CaSO_4$) and carbon dioxide (CO_2) are formed. The aluminium hydroxide is insoluble in water and it forms the floc. It is effective between pH-value 6.50 and 8.50. The dosage of this coagulant depends on various factors such as turbidity, colour, pH-value, etc. In practice, the dosage of alum varies from 10 to 30 mg per litre.

This coagulant is now universally used in water treatment projects for the following advantages:

(i) It reduces taste and odour.
(ii) It produces very clear water.
(iii) The floc is quite tough.
(iv) The floc is not broken while clearing.
(v) It is very cheap.

(b) Chlorinated Copperas

When chlorine is mixed with the solution of ferrous sulphate, a chemical reaction takes place which forms sulphate [$Fe_2(SO_4)_3$] and ferric chloride [$FeCl_3$]. The combination of these two compounds is known as chlorinated copperas. Both the compounds are effective for the formation of floc. Sometimes, ferric sulphate and ferric chloride may be applied independently with lime. In that case, ferric hydroxide [$Fe(OH)_3$] is formed which is also effective for the formation of floc.

The ferric sulphate is effective for pH-value 4 to 9 and ferric chloride is effective for pH-value 3.5 to 6.5.

(c) Ferrous Sulphate and Lime

The ferrous sulphate and lime when mixed with water, a chemical reaction takes place and ferrous hydroxide [$Fe(OH)_2$] is formed. This compound is again oxided by the dissolved oxygen in water and finally ferric hydroxide is formed. This ferric hydroxide forms the floc.

7.12 JAR TEST FOR FINDING THE DOSE OF COAGULANT

During the process of coagulation and sedimentation, the dose of coagulant is determined in laboratory by jar test. In this test, the apparatus consists of several jars of capacity 1–2 lits. The jars are placed in a base plate (as shown in Fig. 7.11.) Spindles are provided in each jar. The spindles carry paddles at the lower ends. Again, the spindles are geared with a horizontal shaft which is rotated by driving unit (i.e. motor). The raw water is poured into the jars and different quantities of a coagulants are added to the water of each jar. The driving unit is started with initial speed of about 40 r.p.m. with the rotation of the shaft, the paddles are also rotated and the coagulants are mixed thoroughly with water. After 5 mins the speed of the motor is reduced and continued for about 10 mins. Then driving unit is stopped. After about 30 mins the formation of floc in each jar is observed. The amount of coagulant which produces good floc is considered as the required quantity for the treatment of that particular sample of water.

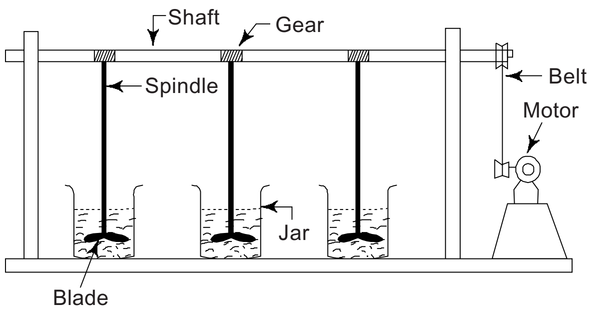


Fig. 7.11 *Jar test*

7.13 DESIGN ASPECTS OF SEDIMENTATION TANK

The following factors should be the main considerations in the design of sedimentation tank:

(a) Velocity of Flow The velocity of flow should be such that it may cause the hydraulic subsidence of the suspended particles. For this phenomenon, the velocity of flow should not be allowed to exceed 15 cm to 30 cm per min.

(b) Detention Period The time taken by a particle to travel the distance between the entrance and exist of the tank is known as detention period. This period should be 3 to 4 hours.

(c) Tank Dimension The minimum depth of tank should be 2.5 m. The width of the rectangular tank should be 10 m to 12 m. The length should be 3 to 4 times the width of the tank.

Problems on Sedimentation Tank

Problem 7.1

A water supply project has to supply water to a town having population of 50,000. Design a suitable sedimentation tank with the following data:

(i) Per capita demand = 150 lits/day
(ii) Peak demand = 1.5 × Average demand
(iii) Velocity of flow = 30 cm/min.
(iv) Detention period = 4 hours.

Solution

Daily average demand of water = $150 \times 50{,}000 = 75 \times 10^5$ lits/day.
Peak demand = $1.5 \times 75 \times 10^5$ lits/day
Here the detention period is 4 hours.

$$\therefore \text{ Quantity of water to be detained } = \frac{1.5 \times 7.5 \times 10^5 \times 4}{24}$$

$$= 1875 \times 10^3 \text{ lits}$$

$$= 1875 \text{ m}^3$$

Capacity of tank = 1875 m^3
Velocity of flow = 30 cm/min.
= 0.30 m/min.
Length of tank = Velocity of flow × detention period
= 0.30 × 4 × 60
= 72 m.

Cross-sectional area of tank = $\frac{\text{Volume}}{\text{length}} = \frac{1875}{72}$ = 20.48 m^2

Assuming effective depth as 3 m.

Width of tank = $\frac{20.48}{3}$ = 6.8 m = 7.0 m (say).

Assuming free board as 0.5 m.

Actual depth = 3.0 + 0.5 = 3.5 m.

Considering 20% extra length for inlet and outlet works,

Extra length = 72 × 0.2 = 14.4 m = 14.5 m. (say)

So, Net length = 72 + 14.5 = 86.5 m.
Therefore, the dimension of the sedimentation tank is 86.5 m × 7 m × 3.5 m.

Problem 7.2

Design a sedimentation tank for a water supply scheme which has to supply 1.5×10^6 litres/day to a town. Assume detention period as 5 hours, velocity of flow as 20 m/min, depth of tank as 3 m, allowance for sludge deposition 50 cm.

Solution

Quantity of water to be treated = 1.5×10^6 lits/day

Quantity of water to be treated during detention period = $\frac{1.5 \times 10^6 \times 5}{24}$
= 0.31×10^6 lits
= 310 m^3

Volume of tank = 310 m^3
Velocity of flow = 20 cm/min
= 0.20 m/min
Required length = velocity × detention period
= 0.20 × 5 × 60
= 60 m.

Cross-sectional area of tank = $\frac{\text{Volume}}{\text{length}}$

= $\frac{310}{60}$ = 5.16 m^2

Depth of tank = 3 m
Sludge depth = 0.5 m

∴ Effective depth = 2.5 m.

So, width of the tank = $\frac{5.16}{2.5}$ = 2.06 m.

= 2.10 (say)

Providing free board of 0.5 m

Actual depth = 3.5 m

Providing 20% allowance in length for inlet and outlet

Extra length required = 60 × 0.2 = 12m

Actual length = 60 + 12 = 72 m

Therefore, the size of sedimentation tank is

72 m × 2.10 m × 3.5 m.

Review Questions

1. State the necessity of water treatment.
2. Give a flow diagram of a treatment plant.
3. State the functions of each unit.
4. Write notes on the theory and purpose of sedimentation.
5. Describe a rectangular type of sedimentation tank with sketch.
6. Enumerate the theory of coagulation and flocculation.
7. Describe a coagulation tank with sketch.
8. What are the common coagulants used in a treatment plant? Describe the functions of the coagulants.
9. Describe the feeding devices of the coagulants.
10. Describe the mixing devices of the coagulants.

8

Filtration of Water

8.1 THEORY OF FILTRATION

The process of filtration consists in allowing the water to pass through the bed of sand. Thus, the colloidal impurities and some of bacteria are removed. The theory of filtration is explained by the following phenomenon:

(a) Mechanical Straining The voids of sand grains behave like a fine sieve. So, when the water is allowed to pass through the sand bed, the suspended particles are arrested by the voids and the clear water is allowed to flow towards the bottom.

(b) Sedimentation The voids of the sand grains act like small sedimentation tanks. The fine suspended particles are arrested in these tanks by the gelatinous film developed during the process of filtration.

(c) Biological Action When the water is allowed to pass through the sand bed, a film of zoological jelly is formed around the sand grains. The bacteria are caught in these voids. The zoological film helps to develop bacterial colonies. The bacteria consume the organic impurities for their survival. Thus, the harmful organic matters are converted to harmless compounds by the biological action.

(d) Electrolytic Action The process of filtration may be explained by the ionic theory, where two opposite electric charges are found to be neutralising each other when they come in contact. It is found by observation that the sand grains of filter and the colloidal suspended particles possess electricity of opposite polarity. Hence, they attract one another and neutralise themselves. Ultimately, the chemical characteristics of water are changed while passing through the bed of sand.

8.2 CLASSIFICATION OF FILTERS

The filters are classified according to the rate of filtration and the force by which the water passes through the filtering media. So, under these conditions, the filters may be of the following types:

(a) Gravity Filters In these types of filters, the water percolates under the force of gravity. Again, these filters may be of two types:

(i) Slow Sand Filter In this filter, the water is allowed to pass slowly through the layer of sand and the sand used is of finer quality (i.e. fine sand).

(ii) Rapid Sand Filter In this filter, the rate of filtration is increased by increasing the size of sand grains (i.e. coarse sand) and the water is allowed to pass under a greater filtration head.

(b) Pressure Filter In this filter, the water is allowed to pass under a pressure greater than atmospheric pressure through a closed cylinder. Here, the force of gravity has no function.

- Filters
  - Gravity filters
    - Slow sand filters
    - Rapid sand filters
  - Pressure filters

8.3 SLOW SAND FILTER

1. Theory

The theory of slow sand filter is based on the principle that if water is allowed to percolate slowly through the filtering media, then the biological, chemical and physical characteristics of water are improved considerably. And it permits sufficient time for those improvements. That's why, the water is allowed to enter the filter bed slowly by suitable inlet arrangement. As the filtration takes much time, it is not suitable for large scale. It is suitable for drinking water only for small towns.

2. Constructional Features

(a) Enclosure Tank It is a rectangular water-tight tank constructed in brick masonry. The inside surface is plastered with rich cement mortar (1:3) accompanied with waterproof compound. The bed slope is about 1 in 100 towards the centre. The depth of the tank varies from 2 m–3.5 m. The surface area depends on the volume of water to be filtered. Generally, the surface area varies from 100 m^2 to 2000 m^2.

(b) Under Drainage System It consists of a central drain and lateral drains. The central drain is a larger diameter pipe which extends from inlet side to outlet side. The lateral drains consist of perforated pipes of smaller diameter which are connected to the central drain from both sides. As shown in Fig. 8.1, the filtered water is first collected in lateral drains and then it flows towards the central drain. The central drain carries it to the outlet chamber.

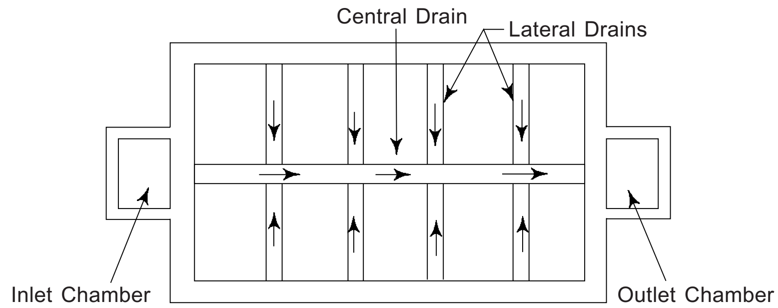


Fig. 8.1 *Under drainage system*

(c) Base Materials The clean gravels of different sizes are used as base materials. It is placed over the under drainage system in four layers. Each layer is of 15 cm thickness. The bottom layer is made of bigger size gravels i.e. 40–65 mm. Two intermediate layers are provided. In first layer, the gravel size is 20–40 mm and in second layer, the gravel size is 6–20 mm. The top layer is made of smaller size gravels—3–6 mm.

(d) Filter Media of Sand The fine sand of effective size of 0.20–0.35 mm and uniformity coefficient 2 to 2.75 is generally used as the filtering media. The depth of the sand layer varies from 60–100 cm.

(e) Appurtenance The following appurtenances are provided:

(i) A vertical air pipe is passed through the filter media for proper functioning of filter.
(ii) A device for measuring loss of head.
(iii) An adjustable telescopic tube to maintain constant discharge.

3. Working of the Filter

As shown in Fig. 8.2, the water from the coagulation tank is brought to the inlet chamber through inlet pipe. Then the water is allowed to stand over the

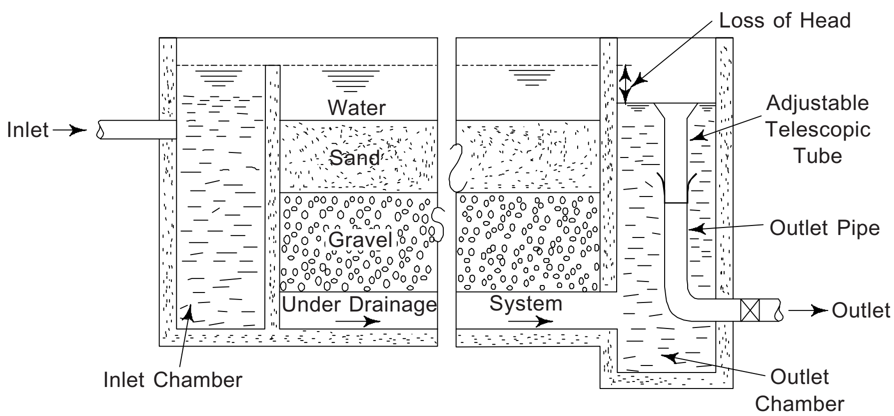


Fig. 8.2 *Slow sand filter*

sand bed to a depth equal to the depth of filter media. This depth is known as filtering head. The water percolates through the sand bed and gets collected in the outlet chamber through the under drainage system. The water from the outlet chamber is then taken to the next unit for further treatment.

4. Cleaning Operation

As the process of filtration goes on, the filtering media gets clogged due to the impurities and the loss of head goes on increasing gradually. When the loss of head reaches a certain limit, the working of filter is stopped. At that time the filter requires cleaning. For the purpose of cleaning, the top layer of sand is scrapped to a depth of about 25 mm and replaced by clean sand before the filter is started again for service.

5. Rate of Filtration

The rate of filtration in a slow sand filter is very low. It is generally 100 lits to 200 lits per hour per square metre of surface area of filter.

6. Efficiency

(a) Turbidity It can remove turbidity to the extent of 50 to 60 ppm

(b) Colour It can remove colour to the extent of about 25 per cent.

(c) Bacteria It can remove bacteria to the extent of about 95 per cent.

8.4 RAPID SAND FILTER

1. Theory

It is observed that the rate of infiltration is more in coarse sand than that in fine sand. So, the theory of rapid sand filter is based on the principle of increasing the rate of filtration by providing coarse sand as filter media. The filtration head is also increased to increase the pressure head and the rate of filtration.

We have seen in slow sand filter that the rate of filtration is very low and it requires more space for installation. To overcome these difficulties, the fine sand in slow sand filter is replaced by coarse sand to achieve greater percolation and to reduce surface area.

2. Constructional Features

(a) Enclosure Tank It consists of a water tight tank constructed with brick masonry. The inside surface is plastered with rich cement mortar (1:3) with water proof compound and finished with neat polish. The depth varies from 2–4 m. The surface area depends on the volume of water to be filtered. However, the surface area varies from 30–60 m^2.

(b) Under Drainage System Figure 8.3 shows a rapid sand filter. The under drainage system consists of a central drain and perforated lateral drains.

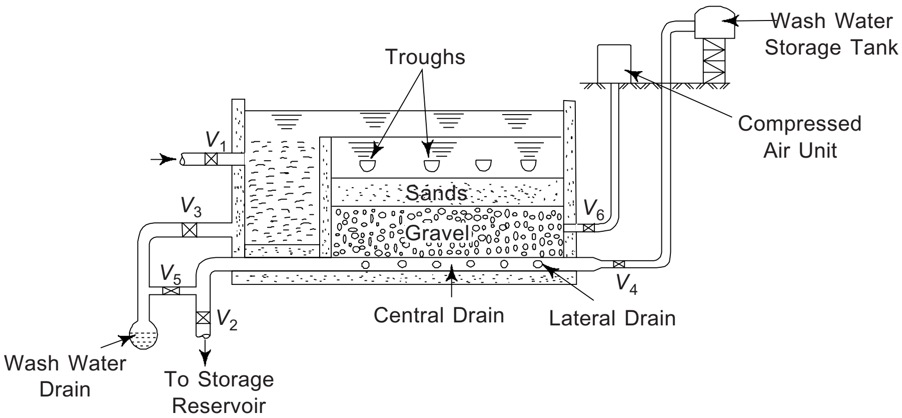


Fig. 8.3 *Rapid sand filter*

The lateral drains are connected to the central drain from both sides and they are placed at a distance of 30 cm centre to centre. Generally, G.I. pipes of required diameter are used in under drainage system.

(c) Base Materials Clean gravels of different sizes are used as base materials. These gravels are placed on the under drainage system in four layers, each layer being 15 cm thick. The bottom layer is made of bigger size gravels—20–40 mm. Two intermediate layers are provided. In first layer, gravel size is 12–20 mm and in second layer, it is 6–12 mm. The top layer is made of small size gravels—3–6 mm.

(d) Filter Media of Sand The coarse sand of effective size of 0.35–0.65 mm and uniformity coefficient 1.20–1.80 is generally used as the filtering media. The depth of sand layer varies from 60–100 cm.

(e) Appurtenance

(i) Air Compressor It is provided for sending the compressed air through the under drainage system at the time of washing the filter.

(ii) Troughs These are provided on the top of sand layer for carrying dirty water at the time of washing the filter.

(iii) Rate Control This is provided to control the rate of flow.

3. Working of Filter

In normal working condition, the valves V_1 and V_2 are kept open and other valves are kept closed. The water from the coagulation tank enters the inlet chamber through the inlet pipe. Then the water uniformly spreads over the filter media. The filtered water is collected in the central drain through the lateral drains. Finally, the water is taken to the storage tank.

When loss of head exceeds some limit, then a negative head is formed. At this time the function of filter is stopped. It requires washing to resume normal working condition.

4. Washing of Filter

(a) During washing period the valves V_1 and V_2 are kept closed.
(b) The valves V_4 and V_6 are opened. The wash water and compressed air are forced through the under drainage system.
(c) After some time, the valve V_6 is closed and valve V_3 is opened so that the dirty water can be removed through the wash water drain.
(d) When washing is over, the valves V_3 and V_4 are closed. But V_1 and V_5 are kept open for some time.
(e) Finally, the valve V_5 is closed, and V_1 remains open.

Now, valve V_2 is opened to start the normal work.

5. Rate of Filtration

The rate of filtration is very high. Generally, the rate of filtration varies from 4000–6000 lits per hour per sqm. of surface area of filter.

6. Efficiency

(i) Turbidity It can remove turbidity to the extent of 30– 45 ppm.

(ii) Colour It is highly efficient in removing the colour.

(iii) Bacteria It is less efficient in removing the bacteria.

8.5 TROUBLES IN RAPID SAND FILTER

The following are the common troubles in rapid sand filter:

1. Loss of Head and Negative Head

Loss of Head The water has to face a frictional resistance when it passes through the filtering media. So, it loses some of its head. If piezometer-1 is inserted in the water above the sand bed and piezometer-2 is fitted with outlet pipe as shown in Fig. 8.4, the two piezometers will show a difference of water level. That difference is known as *loss of head*. Initially, the loss of head is small. But it increases gradually due to the deposition of suspended matters over the sand bed. Ultimately, a stage may come, when the water level in the piezometer-2 goes below the centre line of the under drainage system.

Negative Head When the water level in the piezometer-2 goes below the centre line of under drainage, then the distance between the centre line and the water level in piezometer-2 is known as *Negative head* that is shown in Fig. 8.4. Due to the formation of negative head the lower portion of filter acts as a vacuum and the water is sucked in upward direction through the filter media.

2. Air Binding

When the negative head is formed, it tends to release the dissolved air and gases which may be present in water. Thus bubbles are formed. These bubbles

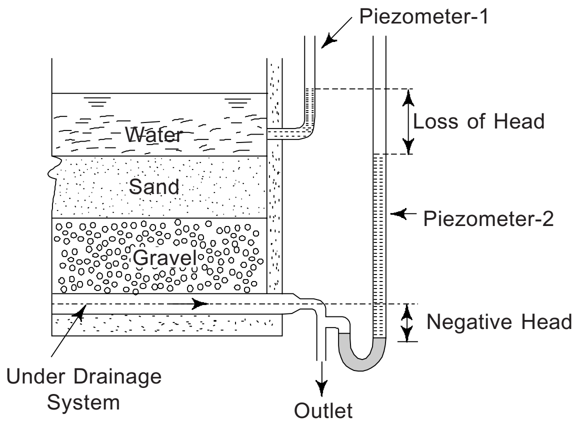


Fig. 8.4 *Loss of head and negative head*

adhere to the sand grains and the process of filtration is stopped. This phenomenon is known as *Air binding*.

3. Mud Balls

If the washing of filter is not done perfectly, then the fine colloidal substances, (i.e. mud) may exist in the sand bed. The existing mud forms nodules all over the sand bed. These nodules are known as *Mud balls*. The mud balls may interfere with the working of filter.

4. Cracking of Filter

If the filter is not washed in proper time, then it is found that the sediments on the sand bed form cracks on the edges of the filter media. This is known as cracking of filter. This trouble is eliminated by breaking the mud balls and washing the filter properly.

8.6 PRESSURE FILTER

1. Theory

The theory is based on the fact that if water is sent under pressure through the filtering media, then the rate of filtration is highly increased. The quality of sand and gravel are kept similar to that of rapid sand filter. As shown in Fig. 8.5, the base materials and filter media are enclosed in a cylinder through which the water is sent under pressure greater than the atmospheric pressure. The pressure is developed by pumping.

2. Construction

It is a closed cylinder made of steel sheets by reveting. The diameter of cylinder varies from 2 m to 4 m and length varies from 4 m to 8 m. Two manholes are provided on top for inspection. It consists of inlet pipe, outlet

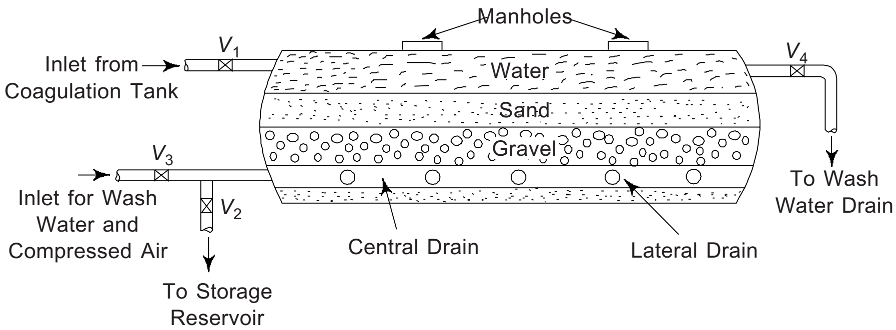


Fig. 8.5 *Pressure filter*

pipe, an inlet for wash water and compressed air and a wash water drain. The gravels and coarse sand are placed over the under drainage system which consists of a central drain and lateral drains. Figure 8.5 shows a pressure filter.

3. Working

In normal working condition, the valves V_1 and V_2 are kept open and the other valves are kept closed. The water enters the chamber through the inlet pipe on the top and passes through the filtering media under pressure. The filtered water is discharged through the outlet pipe and stored in a storage tank.

4. Cleaning

When the rate of filtration is decreased due to the deposition of impurities on the top surface of filter media, it requires cleaning. During cleaning, the valves V_1 and V_2 are closed and the valves V_3 and V_4 are opened. The wash water and compressed air are sent through the base materials in an upward direction. The compressed air agitates the sand grains and the wash water washes the impurities in sand grains. The dirty water is exhausted through the wash water drain.

5. Rate of Filtration

The rate of filtration is very high. It is about 6000 to 15,000 lits per hr. per m^2 of surface area of filter.

6. Efficiency

The pressure filter is less efficient than rapid sand filter in removing turbidity, colour and bacterial load.

It is not suitable for public water supply projects. It is suitable for industrial plants, private estate, small colonies, etc.

8.7 COMPARISON BETWEEN SLOW SAND FILTER AND RAPID SAND FILTER

Table 8.1 compares the properties of Slow Sand Filter and Rapid Sand Filter.

Table 8.1

No.	Particulars	Slow Sand Filter	Rapid Sand Filter
1.	Area	Requires large area for installation	Requires small area for installation
2.	Quality of sand	Fine sand, effective size 0.20–0.35 mm, uniformity coefficient 2 to 2.75	Coarse sand, effective size 0.35–0.65 mm, uniformity coefficient 1.20 to 1.80
3.	Base materials	Gravel size varies from 3–65 mm	Gravel size varies from 3– 40 mm
4.	Method of cleaning	Scraping top layer of sand to a thickness of about 25 mm	Back washing by water and compressed air
5.	Period of cleaning	1 to 3 months	2 to 3 days
6.	Supervision	Skilled supervision not required	Skilled supervision required
7.	Rate of filtration	100 to 200 lits per hr per m^2 of surface area of filter	3000 to 6000 lits per hr per m^2 m^2 of surface area of filter
8.	Efficiency	Highly efficient in removing bacteria	Less efficient in removing bacteria
9.	Economy	It is not economical	It is economical
10.	Suitability	It is suitable for towns	It is suitable for large cities.

REVIEW QUESTIONS

1. Explain the theory of filtration.
2. Describe, with sketch, the construction, working, cleaning, rate of filtration and efficiency of a slow sand filter.
3. Describe, with sketch, the construction, working, cleaning, rate of filtration, and efficiency of a rapid sand filter.
4. Enumerate the troubles that occur during the operation of rapid sand filter.
5. Describe, with sketch, the working and cleaning of pressure filter.
6. Give a comparative details between slow sand filter and rapid sand filter.
7. Distinguish between the following:
   (a) Central drain and lateral drain.
   (b) Loss of head and negative head.
   (c) Gravity filter and pressure filter.

9

Disinfection of Water

9.1 NECESSITY OF DISINFECTION

The process of destroying harmful bacteria from water and making it safe for drinking is known as *disinfection*. The substances used for this purpose are known as disinfectants. The common disinfectants are lime, iodine and bromine, Ozone, potassium permanganate, silver, chlorine, etc. Chlorine is the most important disinfectant which has a wonderful power for killing bacteria in a short span of time with a minimum amount of expenditure. So, this chemical is used in most of the developing countries for the disinfection of water.

The process of destroying all the bacteria (either harmful or harmless) is known as *sterilization*. But in a water supply scheme, we require only the removal of harmful bacteria (i.e. pathogenic bacteria) which may cause water-borne diseases like cholera, dysentry, typhoid, etc.

Now, the necessity of disinfection may be described as follows:

(a) After filtration, the water is found to carry some pathogenic bacteria which are responsible for water-borne diseases. Disinfection is necessary to destroy all such bacteria.

(b) In distribution system, the water may be contaminated by the leakage of pipe line or in some other way. Disinfection is necessary to such degree that the water may remain safe all along the distribution system and up to the point of consumption.

(c) Disinfection is necessary to protect the citizens from health hazard and to assure a healthy atmosphere to all.

9.2 METHODS OF DISINFECTION

The following are the methods of disinfection:

(a) Disinfection by boiling

(b) Disinfection by ultra-violet rays

(c) Disinfection by iodine and bromine
(d) Disinfection by excess lime
(e) Disinfection by ozone
(f) Disinfection by potassium permanganate
(g) Disinfection by silver
(h) Disinfection by chlorine

9.3 DISINFECTION BY BOILING

When water is boiled to boiling temperature (in 100 °C), the bacteria is completely removed. It should be boiled at least for 10–15 mins. Boiling also removes some of the dissolved salts. It is the most effective method of disinfection. But, this method is not suitable on large scale. It is suitable for domestic purpose, i.e. to boil water before its use as drinking water. The water should be cooled down to a comfortable temperature before drinking. In case of an epidemic, the consumers should always boil water to check the water-borne diseases.

9.4 DISINFECTION BY ULTRAVIOLET RAYS

When mercury is enclosed in quartz bulbs and electric current is passed through it, the ultraviolet rays are emitted. These rays are found to be very powerful in killing all types of bacteria. In this method the water is allowed to flow around the bulbs several times. The depth of flow should not exceed 10–15 cm. This method does not impart any taste and colour to water or there is no possibility of overdosing. It is a costly method and suitable for small water supply installations like factories, institutions, training camps, etc.

9.5 DISINFECTION BY IODINE AND BROMINE

The iodine and bromine also have the property of killing bacteria. So, sometimes these are used for disinfection. The dose of iodine or bromine should be 8–10 ppm. These chemicals are available in the form of small pallets. In this method, the water is stored in suitable containers and required number of pallets are dropped in the containers and left for 5 minutes. It becomes safe for drinking.

This method is suitable for small water supply installations like factories, institutions, military or survey camps, etc.

9.6 DISINFECTION BY EXCESS LIME

Normally, lime is added to water to remove some of the dissolved salts. But, when excess lime is added to water, it is found to act as disinfectant. The excess lime increases the pH-value of water (i.e. increases alkalinity) which is detrimental to bacteria because the bacteria cannot resist alkalinity of water. It is found that the pH-value having 9–10 can remove bacteria to the extent of 99 per cent. But, after treatment the residual lime should be removed by the method of recarbonation.

9.7 DISINFECTION BY OZONE

In atmosphere, the molecule of oxygen contains two atoms (O_2). But, it changes to three atoms when electric current under high voltage is passed through a stream of air in a chamber. This triatomic oxygen is known as ozone (O_3). The ozone easily breaks into oxygen (O_2) and nescent atom (O). This third atom is very powerful in killing bacteria. The dose of ozone varies from 2–5 ppm and contact period varies from 5 to 10 minutes. If after treatment some residual ozone is present in water, it is automatically removed. Since ozone is unstable in nature, there is no possibility of any danger to the consumers.

It is a costly method and much care should be taken to avoid any accident due to electrical fault.

9.8 DISINFECTION BY POTASSIUM PERMANGANATE

Potassium permanganate is a powerful oxidising agent. It oxides the organic matters present in water and hence the bacteria are killed. But this is not suitable in large scale for public water supply schemes. This is mostly used for disinfecting the water of wells in village area, swimming pools, ponds, etc. The dose of this chemical is about 2–3 ppm and the contact period is generally 2–3 hours.

9.9 DISINFECTION BY SILVER

Silver is found very effective in killing bacteria. Silver foils are spread over the filter media and water is passed through it. The water absorbs some portion of silver which kills bacteria. The dose of silver varies from 0.5–1 ppm. As silver is costly, it is not suitable for public water supply schemes. It is suitable for domestic use only.

9.10 DISINFECTION BY CHLORINE

Chlorine has got the wonderful power of destroying bacteria. It is the best among all the other disinfectants used for the disinfection of water. It kills bacteria very fast and its effect lasts for such a long time that it even acts in the distribution system. It is cheap and reliable. It some residual chlorine exists in water, it does not cause any harm to consumers.

(The application of chlorine is studied in details in Chapter 10—Chlorination.)

REVIEW QUESTIONS

1. Why is disinfection necessary?
2. What are the methods of disinfection?
3. Write short notes on:
   (a) Ozone treatment

(b) Ultra-violet ray treatment
(c) Boiling treatment
(d) Silver treatment
(e) Iodine and bromine treatment
(f) Excess lime treatment
(g) Potassium permanganate treatment
(h) Chlorination

10

Chlorination

10.1 DEFINITION

The process of disinfection of water by the application of chlorine is known as chlorination. The term chlorination indicates the destruction of bacteria from drinking water and waste water in order to protect the public health from water-borne diseases.

10.2 ACTION OF CHLORINE

The action of chlorine is explained by the following:

(a) When chlorine is added to water, the chemical reaction takes place as follows:

$$Cl_2 + H_2O = HOCl + HCl$$

After some time, the hypochlorous acid is further ionized as follows:

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

The hypochlorous acid (HOCl) and hypochlorite ion (OCl) are very powerful in killing bacteria.

(b) A recent theory states that the free chlorine partly unites with the cell structure of bacteria and forms some products which are poisonous to bacteria. Such products are known as chloro-products.

(c) The action of chlorine is dependent on pH-value. At high pH-value (above 8.5) the chlorine is practically inactive. But at low pH-value (below 7), the chlorine is very effective in killing bacteria.

(d) The dosage of chlorine should also be proper. If the dose of chlorine is insufficient, the disinfection will be incomplete. Again, if the dose is excess, it will create bad smell and taste. The excess residual chlorine may be injurious to human health. So, the proper dose of chlorine should be determined by laboratory test, (i.e. by break point chlorination which is illustrated later on).

10.3 APPLICATION OF CHLORINE

Chlorine may be applied in water in any one of the following forms:

1. Chlorine
2. Chloramines
3. Bleaching powder
4. Chlorine dioxide

1. Chlorine

Chlorine may be applied in two ways—gaseous form or liquid form.

In gaseous way, chlorine gas is dissolved in water and a solution is formed. This solution is mixed with water according to the dose ascertained in laboratory test.

In liquid way, chlorine gas is converted to liquid by applying a pressure of 7 kg. to 11 kg./cm^2 in a cylinder specially made for this purpose. Then the liquid chlorine is added to water by a device which is known as chlorinator. The use of free chlorine is favoured universally for the following advantages:

(i) Chlorine is the most powerful for destroying the bacteria absolutely.
(ii) The process of application is easy.
(iii) It can be stored easily.
(iv) The optimum dose can be easily found out by break point chlorination.

2. Chloramines

The free chlorine is not stable in water. To make is stable , some amount of ammonia is mixed with water along with chlorine. As a result of the chemical reactions some compounds are formed which are known as chloramines. The following chloramines are formed:

(i) Mono-chloramine (NH_2Cl)—It is effective for pH-value above 7.
(ii) Dichloramine ($NHCl_2$)—It is effective for pH-value between 5 and 7.
(iii) Nitrogen trichloride (NCl_3)—It is effective for pH-value below 4.

The ammonia may be mixed with water in gaseous or solution form. The following are the benefits of adding ammonia along with chlorine:

(i) It makes chlorine stable in water.
(ii) It reduces the amount of chlorine necessary for the treatment.
(iii) It becomes more powerful in killing bacteria.
(iv) It reduces the irritating effect of chlorine.

3. Bleaching Powder

Bleaching powder is also known as calcium hypochlorite [$Ca(OCl)_2$]. When it is mixed with water, hypochlorite ions (OCl) are formed. These ions again combine with hydrogen ions (H^+) present in water and, thus, hypochlorous acid (HOCl) is formed. This phenomenon is known as hypo-chlorination. The hypochlorous acid and hypochlorite ions are both responsible for the destruction of bacteria.

The bleaching powder is available in white powder form which contains usually 35 per cent of chlorine. It is very unstable in character and hence it should be stored carefully.

Before application, the bleaching powder is dissolved in water and a solution is prepared. This solution is added to water according to the predetermined dose: Generally, the dose of bleaching powder is about 2 to 4 ppm.

Nowadays, the hypochlorination is done by some commercial compounds like HTH, pittchlor, pittcide, etc.

Bleaching powder is not recommended for public water supply. It is suitable for disinfecting the water of swimming pools, ponds, etc.

4. Chlorine Dioxide

Sometimes, chlorine dioxide (ClO_2) is used for the removal of bacteria. It is produced by passing chlorine gas through sodium chlorite in a closed container. It is very unstable and should be used very quickly. It can remove taste and odour. It is not suitable for large scale. It may be used for small installations like housing estate, factories, etc.

10.4 FORMS OF CHLORINATION

The following are the different forms of chlorination:

1. Plain chlorination
2. Pre-chlorination
3. Post-chlorination
4. Double chlorination
5. Break point chlorination
6. Super-chlorination
7. Dechlorination

1. Plain Chlorination

When the raw water is supplied to consumers by applying chlorine treatment only, it is termed as plain chlorination. In this case, the raw water is sufficiently clear and it does not require primary treatments like sedimentation, coagutation and filtration. Generally, in case of emergencies, for military camps, training camps, survey camps, etc. the process of plain chlorination is adopted.

2. Pre-chlorination

In rainy season, when the raw water is suspected to be highly contaminated, then a dose of chlorine is added to raw water before it enters the sedimentation tank. This application of chlorine is termed as pre-chlorination. That means, it is an advance dose of chlorine before the actual period of chlorination. The idea of pre-chlorination is as follows:

(i) It reduces bacterial load before it enters the treatment plant.
(ii) It checks the formation of algae in sedimentation tank.
(iii) It controls fermentation in settling tank.

3. Post-Chlorination

When chlorine is added to water after all the treatments are over and just before it enters the distribution system, it is termed as post-chlorination. This dose of chlorine is added to water to control the contamination when it flows through the distribution system. Generally, the dose of chlorine is about 1 to 2 ppm.

4. Double Chlorination

When pre-chlorination and post-chlorination are both adopted in water supply scheme to safeguard the public health from epidemic, then it is termed as double chlorination. This system is urgently needed in case of flood or other natural calamity when the possibility of bacterial contaminations are very high.

5. Break Point Chlorination

The break point chlorination is a method of determining the chlorine demand of raw water.

There is no chlorine demand in pure water. If chlorine is added to such water, the chlorine will come as residual chlorine which is represented by a straight line R_1 (Fig. 10.1).

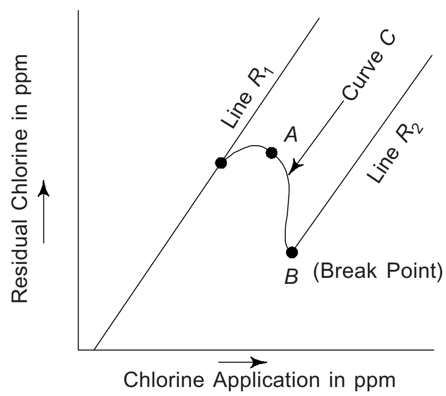


Fig. 10.1 *Break point*

When chlorine is added to contaminated water, it will kill the bacteria and oxidise the organic matters. In the beginning, the chlorine goes on killing bacteria and then it starts accumulating up to a certain point which is shown by A (on curve C) in Fig. 10.1. If the dose of chlorine goes on increasing, it will start emitting bad smell. But after sometime the bad smell suddenly disappears. This critical point is known as *break point* which is indicated by point B. If further chlorine is added, it will come as residual chlorine which is shown by a straight line R_2. During the period of bad smell, the chlorine oxidizes the organic matters.

So, the actual dose of chlorine should be determined by carefully finding the break point formation.

6. Super-Chlorination

The process of application of chlorine beyond the formation of break point, is termed as super-chlorination. This treatment is necessary when there is an epidemic due to some water-borne disease. But, in this treatment much residual chlorine in water may appear which is unpleasant to consumers. To neutralise the residual chlorine to an allowable limit, dechlorination should be done. The amount of residual chlorine in water may be determined by laboratory test.

7. Dechlorination

The process of removal of excess residual chlorine from water is known as dechlorination. The residual chlorine should not be removed completely, but some amount of chlorine about 0.25 to 0.50 ppm should remain in water so that it may not be polluted in the distribution system. For dechlorination, various types of chemicals may be used such as sodium sulphite, activated carbon, potassium permanganate, sulpher dioxide, etc.

10.5 MIXING DEVICE OF CHLORINE

Chlorine is mixed with water with a device which is known as chlorinator. These are various types of chlorinators patented by different manufacturers. A simple type is described below:

It consists of a glass jar containing distilled water in which the chlorine is fed from the chlorine cylinder. An agitator is provided inside the jar as shown in Fig. 10.2. It agitates the distilled water to form a uniform chlorine solution. This solution is fed to the water in the main pipe through injector

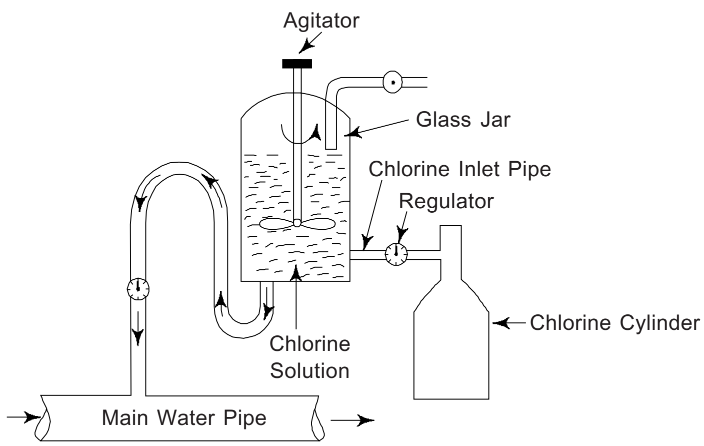


Fig. 10.2 *Chlorinator*

pipe. To control the dose of chlorine a regulator is provided in the injector pipe. One regulator is provided in chlorine inlet pipe and the other is provided in distilled water pipe to regulate the flow of chlorine and distilled water respectively.

10.6 TESTS FOR RESIDUAL CHLORINE

The residual chlorine in water is tested by the following tests:

(a) Orthotolidin test (b) Starch-iodide test.

1. Orthotolidin Test

This test is carried out by the following procedure:

(i) 1 ml of orthotolidin solution is added to 100 ml of sample of water in a test tube.

(ii) A yellow colour will be formed. The intensity of colour will indicate the amount of residual chlorine which should be ascertained by comparing with colour standard. As for example,

Deep yellow—Indicates very high chlorine content.
Medium yellow—Indicates moderately high chlorine content.
Light yellow—Indicates slightly high chlorine content.
Lemon yellow—Indicates safe for potable water.

2. Starch-Iodide Test

This test is carried out by the following procedure:

(i) 10 ml of potassium-iodide is mixed with 1 litre of sample of water. The mixture is agitated thoroughly.

(ii) 5 ml of starch solution is added to the above solution and a blue colour is formed.

(iii) This colour is removed by titration with sodium thiosulphate solution.

(iv) The chlorine content is ascertained as follows:

Chlorine content = 0.3546 × Quantity of thiosulphate solution required.
(in ppm)

REVIEW QUESTIONS

1. Explain the action of chlorine, when mixed with water.
2. How is chlorine applied in water?
3. Explain the different forms of chlorination.
4. How is orthotolidin test carried out?
5. State the procedure of starch-iodide test.
6. Distinguish between the following:
   (a) Pre-chlorination and post-chlorination
   (b) Super-chlorination and dechlorination
   (c) Plain chlorination and break-point chlorination.

11

Water Softening

Water softening may be defined as the removal or reduction of hardness from water.

11.1 DEFINITION OF HARDNESS

The hardness of water is defined as the quality of water which is due to the presence of bicarbonates of calcium and magnesium; sulphates, chlorides and nitrates of calcium and magnesium. Such water is termed as hard water.

11.2 TYPES OF HARDNESS

Hardness may be of two types

(a) Temporary Hardness The presence of bicarbonates of calcium and magnesium in water is known as temporary hardness. It is also known as carbonate hardness.

(b) Permanent Hardness The presence of sulphates, chlorides and nitrates of calcium and magnesium in water is known as permanent hardness. It is also known as non-carbonate hardness.

11.3 EFFECTS OF HARDNESS

The following are the effects of hardness:

(a) It makes the food tasteless.
(b) The vegetables, meat, etc. takes much time to be boiled properly (i.e. soft).
(c) It increases the fuel cost for cooking.
(d) It consumes more soap and so it is uneconomical in washing of clothes.
(e) The working of dying system is highly affected as it causes the change of colour shades in fabrics.
(f) It reduces the life of fabrics.
(g) It forms scales on boilers which reduce the life of steam engines.
(h) It leads to corrosion and incrustation of pipes.

11.4 NECESSITY OF WATER SOFTENING

The softening of water is necessary for the following reasons:
- (a) To improve the taste of food.
- (b) To reduce the consumption of soap in washing of clothes.
- (c) To reduce the formation of scales in boilers.
- (d) To increase the life of fabrics.
- (e) To neutralise the effect on colour in dying system.
- (f) To reduce the corrosive effect on pipes.

11.5 REMOVAL OF TEMPORARY HARDNESS

The temporary hardness may be removed by the following methods:
(a) By boiling (b) By adding lime.

(a) By Boiling When the water is boiling for a long time, the chemical reactions take place as given below:

$$Mg(HCO_3)_2 \rightarrow MgCO_3 + CO_2 + H_2O$$
$$Ca(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$$

After boiling, the magnesium and calcium carbonates are formed which are insoluble in water and they settle down at the bottom of the tank when the water is cooled gradually.

This process is not suitable for large scale. This is applicable in domestic purposes only.

(b) By Adding Lime When lime is added to water having temporary hardness, the following chemical reactions take place:

$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow CaCO_3 + Mg(OH_2) + H_2O$$
$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$$

After reaction, the calcium carbonate and magnesium hydroxide are formed. These are insoluble in water and they settle down at the bottom of the tank.

11.6 REMOVAL OF PERMANENT HARDNESS

The permanent hardness can be removed by the following three processes:
1. Lime-soda process
2. Zeolite process
3. Demineralisation process

1. Lime-Soda Process

Figure 11.1 shows the lime-soda process which involves the following units:

(i) Feeding and Mixing Unit The lime and soda are mixed in an appropriate proportion and a solution is made. The solution is stored in a lime-soda tank. It is then fed to the raw water inlet pipe by suitable device. A regulator is provided to control the dose of lime-soda. The solution flows to the mixing tank where the water and lime-soda are mixed thoroughly by rotating paddles.

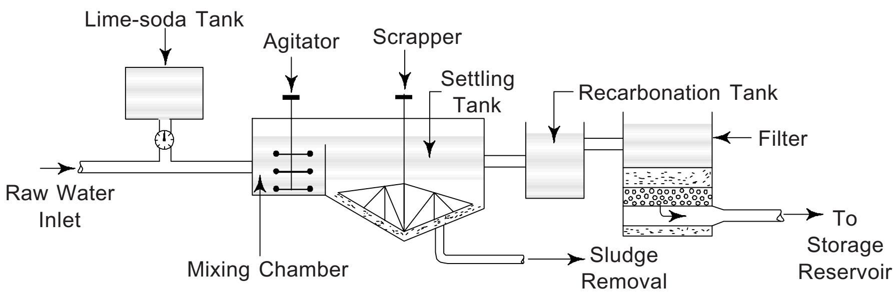


Fig. 11.1 *Lime-soda process*

(ii) Settling Tank This tank is similar to the coagulation tank. Here, the water is detained for some specified period. The sludge is collected at the bottom of the tank which is taken-off through the sludge removal pipe at a regular interval. The water from the top is taken to recarbonation plant.

(iii) Recarbonation Tank The calcium carbonate formed in this process should be removed from water. Otherwise, this will disturb the function of the filtration unit. It is removed by carbon dioxide. The carbon dioxide (CO_2) reacts with calcium carbonate ($CaCO_3$) and thus calcium hydroxide [$Ca(HCO_3)_2$] is formed.

(iv) Filtration Unit The filter may be rapid sand filter or pressure filter. The water from the recarbonation tank is spread over the filter media. The suspended fine particles are arrested by the filter media and clear water passes through the under drainage system. The filtered water is taken to the storage reservoir.

Advantages

(i) The pH-value of water is increased which reduces the corrosion of distribution pipes.
(ii) The alkalinity of water is increased which destroys pathogenic bacteria.
(iii) It removes iron and manganese to some extent.
(iv) It reduces the other mineral contents.
(v) It reduces the quantity of coagulants required for coagulation.

Disadvantages

(i) It is difficult to dispose of the large volume of sludge.
(ii) The calcium carbonate formed in this process is not completely insoluble. It is slightly soluble in water. So, this process cannot remove the hardness completely.
(iii) If recarbonation is not done, a layer of calcium carbonate will be deposited on the filter media. This layer disturbs the process of filtration.

2. Zeolite Process

The zeolite is a compound of aluminium, silica and soda. These chemicals posess the property of interchanging base. Hence, the zeolite process is also known as base-exchange process. The zeolite may be obtained from nature or it may be artificially prepared.

The natural zeolite is green in colour. So, it is also known as green sand. It can remove the hardness of 7000 to 10,000 gms per m^3 of zeolite.

The artificial zeolite is known as permutit. It is a synthetic hydrated silicate of aluminium and sodium. The raw materials from which it is manufactured are felspar, kaolin clay and soda. It is white in colour. It can remove the hardness of 35,000 to 40,000 gms per m^3 of permutit.

The sodium present in zeolite may be exhausted after some period, then it is regenerated by adding a solution of salt in the bed of zeolite.

It is a filter of cylindrical shape in which zeolite bed of thickness 90–180 cm is provided directly over the under drainage system. In this filter, there is no necessity of gravel and sand layer. As shown in Fig.11.2 the hard water is allowed to enter the filter on the top. It passes through the zeolite bed and the soft water is collected below the under drainage from where it is taken to the storage reservoir. The zeolite plant may be gravity filter type or pressure filter type. After softening a considerable amount of hard water, the sodium content in zeolite may be exhausted. It is regenerated by passing a solution of 10% common salt through the zeolite bed. The rate of flow through the zeolite is generally 100–300 lits/min/m^2 of surface area.

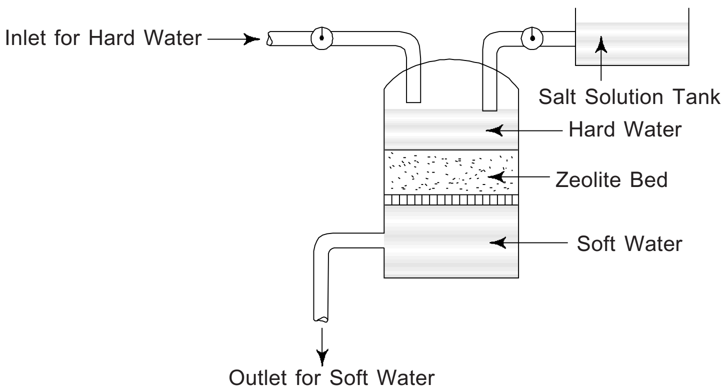


Fig. 11.2 *Zeolite process*

Advantages

(i) The treatment unit is compact.
(ii) No sludge is formed in this process.
(iii) It produces zero hardness of water.
(iv) The desired degree of hardness can be prepared by adding this soft water to any hard water in a to proper proportion.
(v) It is automatic and economical.
(vi) It eliminates the deposition of calcium carbonate in distribution system.

Disadvantages

(i) It is not suitable for turbid water.
(ii) It is unsuitable for water containing iron and manganese.
(iii) Much time is lost at the time of regeneration of exhausted sodium.

3. Demineralisation

In this process, hard water is passed through the bed of carbonaceous matter (i.e. resin) containing hydrogen ions (H) as base. Here, the hydrogen ions are exchanged for metallic ions. So this process is also termed as de-ionisation process. When hard water is allowed to pass through the resineous bed, the chemical reactions take place. Thus, the filtered water contains carbonic acid, sulphuric acid and hydrochloric acid which are removed by mixing required proportion of alkaline water to the treated water.

After some time, the hydrogen ions of the substance are exhausted. These are regenerated by passing a solution of sulphuric acid or hydrochloric acid through the bed of resin. This method is suitable for preparing soft water for industrial purpose.

Review Questions

1. What is hardness of water?
2. What is the necessity of water softening?
3. What are the effects of hardness?
4. What do you mean by temporary hardness and permanent hardness?
5. How is temporary hardness removed?
6. Explain in detail the lime-soda process for the removal of permanent hardness in water.
7. State the advantages and disadvantages of lime-soda process.
8. Describe in detail the zeolite process for the removal of permanent hardness from water.
9. State the advantages and disadvantages of zeolite process.
10. Explain the demineralisation process for the removal of permanent hardness in water.
11. Distinguish between the following:
    (a) Temporary hardness and permanent hardness
    (b) Permutit and green sand
    (c) Zeolite process and demineralisation process.

12

Miscellaneous Water Treatment

12.1 INTRODUCTION

We have already learnt that water treatment plant involves the process of sedimentation, coagulation, filtration, disinfection, water softening, etc. These treatments are necessary for drinking water, water for washing of clothes and for some industrial and commercial uses. But there may be other impurities or some unpleasant conditions which are not directly injurious to human health. The following are the different method for making the water better in every way:

(a) Removal of iron and manganese
(b) Removal of colour, odour and taste
(c) Fluoridation
(d) Defluoridation
(e) Desalination.

12.2 REMOVAL OF IRON AND MANGANESE

Detection The presence of iron and manganese in water is detected by the following observations:

(i) The water containing iron and manganese developes reddish or brownish stains in clothes.
(ii) The reddish tinge is due to the presence of iron and brownish tinge is due to the presence of manganese.
(iii) If water containing iron and manganese is kept in a pot for few hours, then it becomes either red or brown.
(iv) The water may possess metallic taste.
(v) It creates reddish or brownish deposit on the pipe lines.

Removal The presence of iron and manganese in water may be in two forms:

(i) Without any organic matter

(ii) In combination with organic matter.

When iron and manganese exist in water without any organic matter, then they are removed by aeration, sedimentation and filtration. In aeration tank, the water is ejected in the form of spray from a fountain and thus it comes in contact with the oxygen in air as shown in Fig. 12.1. The soluble ferrous and manganese compounds are converted into ferric and manganic compounds which are insoluble in water. These compounds settle down in the settling tank as sludge. Finally, the water is allowed to flow through the filter where the remaining compounds are arrested by the filter media of sand. Clear water is then taken out the outlet pipe.

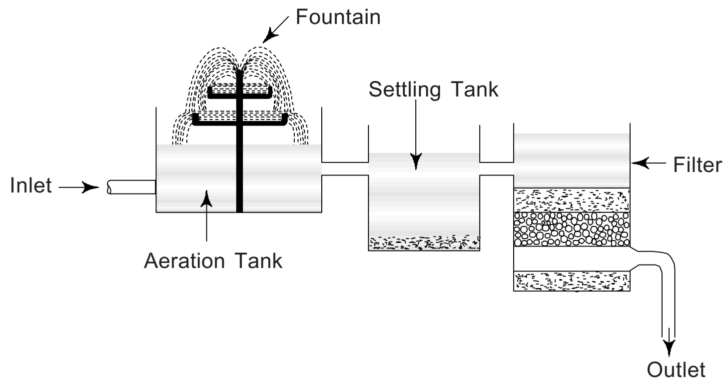


Fig. 12.1 *Iron and manganese removal (without organic matter)*

When iron and manganese exist in water in combination with organic matter, then the bond is broken by adding lime or chlorine or potassium permanganate. As shown in Fig. 12.2, in dosing tank, the requisite proportion of lime or chlorine or potassium permanganate is added. The water is agitated thoroughly to break the bond. The water is then taken to a settling tank

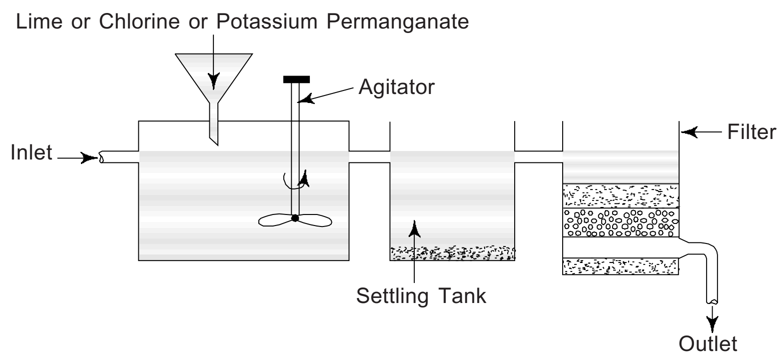


Fig. 12.2 *Iron and manganese removal (with organic matter)*

where some portion of insoluble compounds settle as sludge. The remaining portion is arrested in the filter. Clear water is taken out through the outlet pice.

12.3 REMOVAL OF COLOUR, ODOUR AND TASTE

Properties like colour, odour and taste in water indicate the presence of dissolved gases, organic matters, industrial wastes, etc. These are removed in the following ways:

1. By Aeration

In this process, water is brought in intimate contact with air so that the water can absorb oxygen from air. The aeration can be done by the following methods:

(a) By Air Diffusion: In this method, a perforated pipe is provided at the bottom of the settling tank, in which the raw water is sent through inlet pipe. The compressed air is blown through the perforated pipe, as shown in Fig. 12.3. The air is deflected by the deflector and comes out through the perforations. Thus air bubbles are formed and the water is agitated vigorously. In this way, the water absorbs oxygen from the compressed air and the colour, odour and taste are removed.

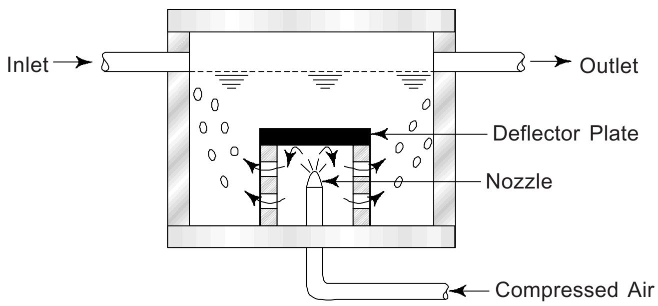


Fig. 12.3 *Air diffusion*

(b) By Trickling Beds: In this method, the water is allowed to flow through the trickling bed prepared with coke. The bed of coke is laid on the perforated plate. The water is spread over the bed by the rotating arm as shown in Fig. 12.4. While flowing through the coke the water becomes free from the dissolved gases and thus the colour, odour and taste are removed.

(c) By Spray Nozzles: As shown in Fig. 12.5 in this method, the water is thrown up in the air like spray through the nozzles. Thus, the water comes in contact with air and the colour, odour and taste are removed.

(d) By Cascades: As shown in Fig. 12.6, in this method, the water is allowed to fall over a series of concrete steps which are known as cascades. The water flows in thin film so that it comes in contact with air, and thus the colour, odour and taste of water are removed.

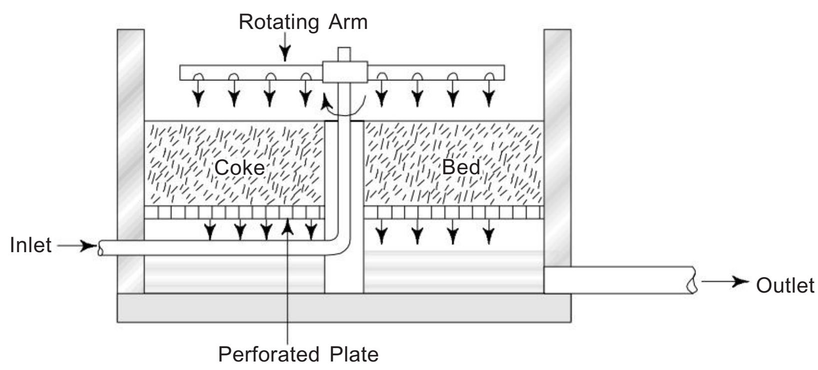


Fig. 12.4 *Trickling bed*

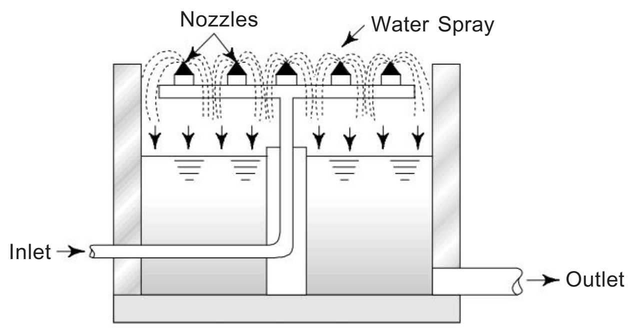


Fig. 12.5 *Spray nozzles*

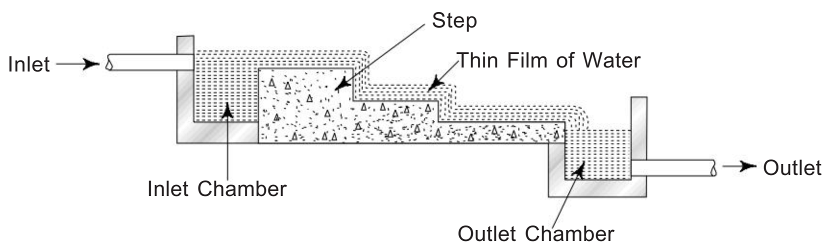


Fig. 12.6 *Cascades*

2. By Activated Carbon

The activated carbon is manufactured by charring the wood, saw dust, etc. at about 500 °C in a closed chamber. Then it is activated by passing air or steam. It is usually available in powder form. As shown in Fig. 12.7, a bed of activated carbon is prepared over a perforated plate and the water is allowed to spread over the bed. While the water flows through the activated carbon, the colour, odour and taste are removed.

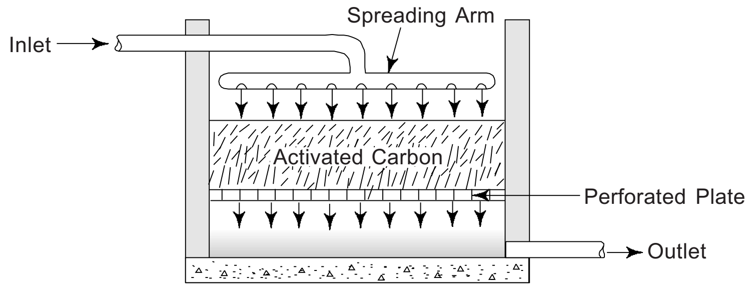


Fig. 12.7 *Activated carbon*

3. By Copper Sulphate

The solution of copper sulphate ($CuSO_4$, $7H_2O$) is prepared and added to water in the reservoir or just at the entry in the distribution system. The dosage of copper sulphate is generally 0.50–0.75 ppm.

4. By Oxidation

The Oxidation of organic matters is done by adding chlorine, potassium permanganate, ozone, etc. to water as oxidising agents. Generally, the excess chlorine is added beyond the break point for oxidising the organic matters.

12.4 FLUORIDATION

The process of adding fluoride in water is termed as fluoridation. It is observed that a fluoride content of about 1 ppm in drinking water reduces the chances of decaying and falling of teeth, formation of cavities in teeth, etc. That's why fluoridation is adopted in water supply scheme in several countries. The common compounds of fluoride which are generally used are sodium fluoride (NaF), sodium silico fluoride ($Na_2Si.F_6$) fluoride can be applied in solution form or powder form. The feeding of fluoride is done after chlorination.

So, it should be noted that *fluoridation* is done to improve the physical comfort by removing the dental complaints. But *chlorination* is done to destroy the bacteria to protect the consumers from water-borne diseases.

12.5 DEFLUORIDATION

If it is found that the water contains fluoride in excess than the permissible quantity, then the excess quantity should be removed by applying some chemicals. This method of reducing the fluoride is termed as *defluoridation*. Defluoridation is done by adding activated carbon, calcium phosphate, etc. in water just before the distribution system.

12.6 DESALINATION OF WATER

In coastal towns or cities or in areas under the saline tract, it is very difficult to obtain suitable water for drinking or other domestic purposes. The suitable source of water may be far away from the towns or cities which may involve enormous cost for conveyance. In those places, there is no other alternative than to accept the process of desalination of available brakish water. The following are common methods of desalination:

1. Distillation
2. Electro-dialysis

1. Distillation

It is the best method of removing the salt from brakish water. There are various methods of distillation. In one of the methods, the saline water is boiled to convert it to vapour stage, and then it is condensed to form water by some cooling device.

The modern evaporators consist of several chambers which are connected by pipe lines. Hot steam is sent through the first chamber which converts the cold saline water into vapour. Then the steam is allowed to pass through the second chamber and the same phenomenon (i.e. Vapourisation) occurs, and so on. Finally, the vapour from all the chambers enters the cooling chamber where it is condensed to form the suitable potable water.

2. Electro-dialysis

It is found that in saline water H_2O molecules are bonded with sodium ions (Na^+) and chlorine ions (Cl^-). The bond is broken by passing electric current through the saline water in a rectangular vessel. Two thin plastic membranes (known as ion exchange resins) are provided, one on the cathode side and the other on the anode side. When electric current is passed through the saline water, the positively charged sodium ions (Na^+) move towards the negative pole (i.e. cathode) and the negatively charged chlorine ions (Cl^-) move towards the positive pole (i.e. anode). Thus the water at the middle portion of the vessel becomes free from salt. The clear water is taken to the clear water tank and the brine water near the poles is taken to the brine water tank. The whole process is shown in Fig. 12.8.

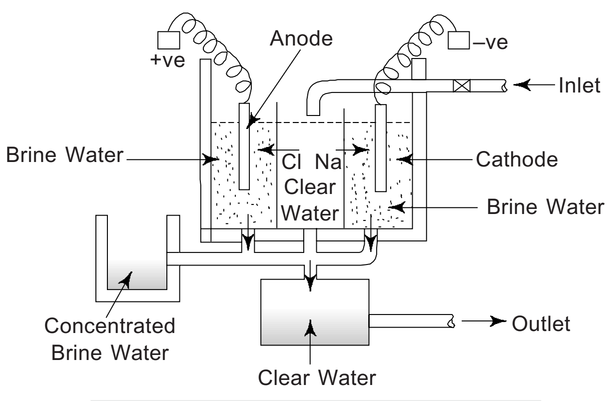


Fig. 12.8 *Electro-dialysis process*

Review Questions

1. Describe the method of the removal of iron and manganese from water.
2. How will you detect the presence of iron and manganese?
3. How is colour, odour and taste removed from water?
4. What do you mean by aeration? Why and how is it done?
5. What is activated carbon? Describe its use.
6. Write short notes on fluoridation and de-fluoridation
7. Enumerate the difference between fluoridation and chlorination.
8. What are desalination and brakish water? Why is desalination necessary?
9. What are the common methods employed in desalination?

13

Distribution System

13.1 INTRODUCTION

The distribution system plays an important role in the water supply scheme. Distribution should be done in such a way so that the water can be supplied evenly to the consumers and it can reach at every corner of various zones. The location of fire hydrant, air relief valve, pressure relief valve, etc. should be so oriented that any accidental situation may be easily overcome. The following points should be kept in mind while designing the distribution system:

(a) The methods of distribution such as gravity method, pumping method and dual method should be carefully decided according to the conditions of intake point and the distribution area.
(b) The layout of distribution such as dead end method, grid iron method, circular method and radial method should be decided according to the nature of supply zones.
(c) The distribution pipe lines should not be taken below the sewer line.
(d) The joints of pipe lines should be perfectly done and tested before filling up the trenches to ensure any leakage of the joints.
(e) The pipes should be anti-corrosive and strong enough to bear the loads of vehicles passing over the pipe lines.
(f) Inspection chambers should be provided at specific points.
(g) Each zone should be separated by sluice valves (i.e. gate valve) so that the repair works in any zone may not disturb the other zones.
(h) The diameters of main line, branch lines, distributory lines should be carefully designed so that ample supply of water to the consumers can be assured.

13.2 METHODS OF DISTRIBUTION

The methods of distribution depends on the topography of the town or city. The following are the different methods of distribution:

1. Gravity System

In this system, the water flows under the force of gravity from the distribution reservoir to the distribution area. This system is suitable when the source of water treatment plant and the distribution reservoir are situated at a high level than the distribution area. As shown in Fig. 13.1, the treated water is stored in the distribution reservoir from where it is supplied to the consumers. It is the most reliable system, as there is no possibility of break of water supply due to any mechanical or electrical failure. But here, much pressure head may not be developed and hence the water may not rise to a considerable height at the consumers end. In case of fire demand, the booster pumps may be installed to develop high pressure.

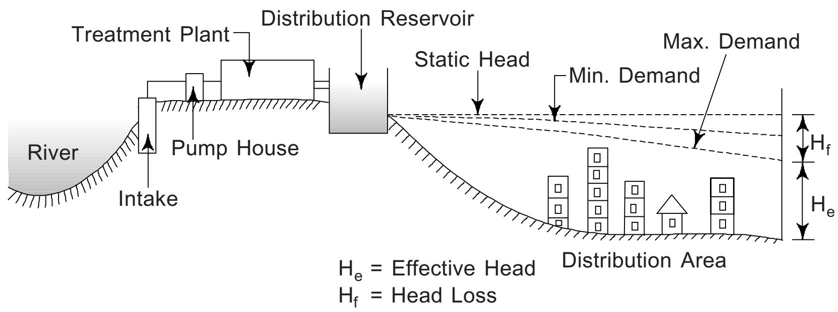


Fig. 13.1 *Gravity system*

2. Pumping System

As shown in Fig. 13.2, in this system, the water is lifted from the deep tube well by submersible pump or bowl assembly and is directly supplied to the consumers. Here, the treatment plant is not necessary. This system is adopted

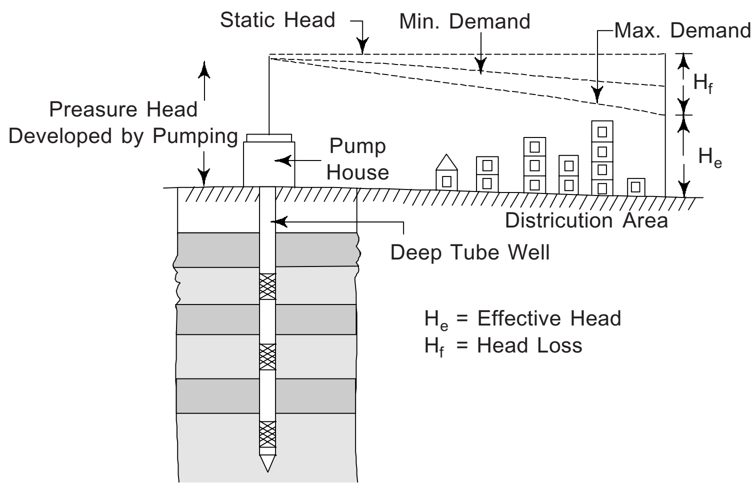


Fig. 13.2 *Pumping system*

when suitable surface source is not available near the town or city. But this system is solely dependent on the mechanical and electrical power. So, in case of any failure of the mechanism, the supply of water is highly disturbed. In this system, the water pressure on the consumer's end is high.

3. Dual System

Figure 13.3 shows the dual system of distribution in which, the pumping and gravity both systems are utilised simultaneously when required. Normally, the pumps are operated at a constant speed to meet the average demand of water. So, during the period of low demand, the excess water is stored in an elevated reservoir. During the period of peak demand, the water is supplied by pumping and from the elevated reservoir simultaneously. This system is fairly reliable, because in case of any failure of pumping mechanism, the water supply can be continued for some period from the reservoir.

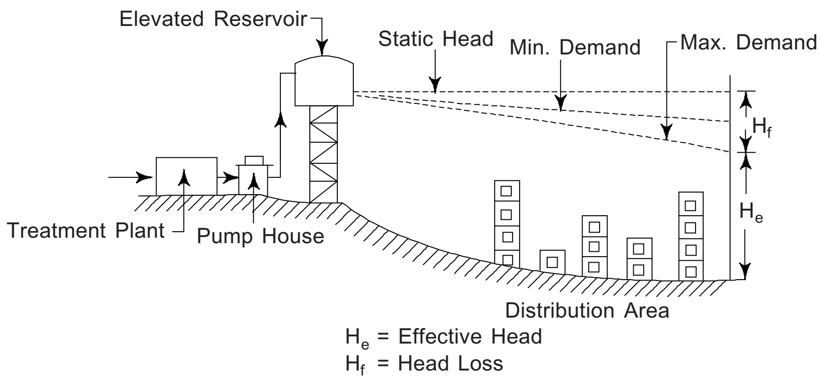


Fig. 13.3 *Dual system*

13.3 SYSTEMS OF WATER SUPPLY

Depending upon the duration of supply, the water supply systems may be divided into the following two groups:

1. Continuous Supply System

In this system, water is supplied to the consumers through out the 24 hours of the day. This system is suitable when plenty of water is available from the source and the cost of water treatment is considerably low. But in this system a considerable amount of water may be wasted due to the lack of civic sense of consumers or any leakage in pipe line or any damage in taps provided along the streets. However, this is an ideal system, because the consumers do not face any water problem during the day and water for fire-fighting may be available at any time.

2. Intermittent Supply System

In this system, water is supplied during some fixed period of the day. The number of times and the duration of supply depend on the water supply authority. Generally, water is supplied three times in a day, such as 5 a.m. to 7 a.m., 9 a.m. to 11 a.m. and 5 p.m. to 7 p.m. But, this system is not ideal, because the consumers may face inconvenience due to the unavailability of water at the time of extreme necessity. Again, at the time of sudden outbreak of fire, the fire-brigade vehicles may not get water for fire-fighting.

13.4 LAYOUT OF DISTRIBUTION PIPES

The following are the four methods of the layout of distribution pipes:

1. Dead-end Method

Figure 13.4 shows the dead-end method of layout of water distribution pipes. In this system, a main line is taken from the reservoir along the main road. The sub-mains are taken suitably from the main line. Cut-off valves are provided at the entry of sub-mains. From the sub-mains, the branch lines are taken from which service connections are given to the consumers through the ferrule. The ends of the sub-mains and branch lines are stopped by scour valves which are known as dead-ends. For washing the pipe lines, the dead-ends (i.e. scour valves) are opened periodically and the stagnant water is allowed to flow out. Due to the dead-ends, there is no free circulation of water and the water remains stagnant within the pipe line. This system is suitable for irregular developing town or city.

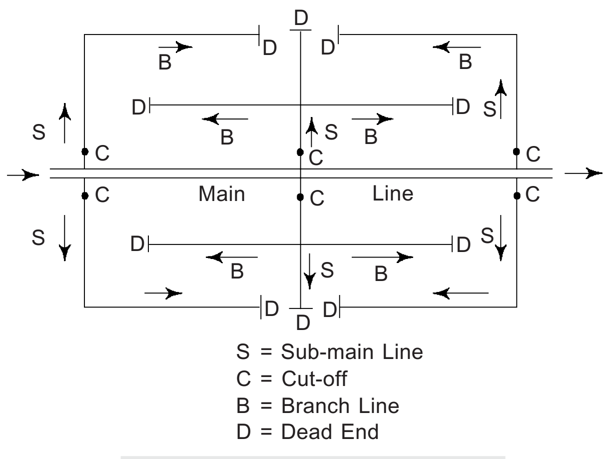


Fig. 13.4 *Dead-end method*

2. Grid-iron Method

Figure 13.5 shows the grid-iron method. It is also known as interlaced system or reticulation system. In this system, the main line, the sub-main lines, and the branch lines are interconnected. So, there is free circulation of water

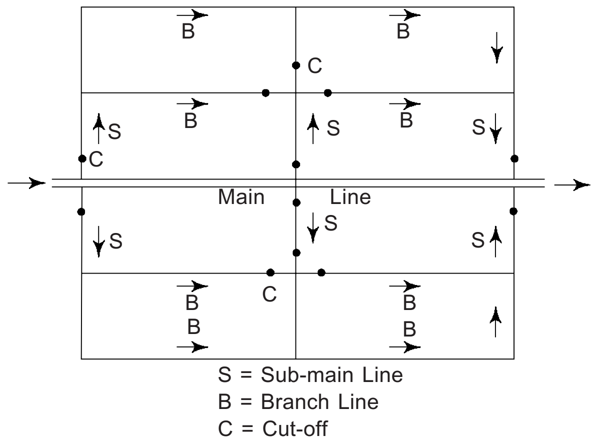


Fig. 13.5 *Grid-iron method*

through the pipe lines. Cut-off valves are provided at each junction point so that the repair works may be conducted at a particular area without disturbing the whole area. In case of fire, plenty of water is available at any zone and at any time. But, in this system the length of pipe lines is too great, and hence it is very costly. This system is suitable for town or city having rectangular layout of roads.

3. Circular Method

In this system, the main water line is divided into two parts; in two directions left and right. As shown in Fig. 13.6, in inlet side, the left and right water mains travel in opposite directions along the periphery of the area and they meet again on the outlet side. This system is also known as ring system. Here, every point gets water supply from both directions and for fire-fighting the water may be available from all the directions. This system is suitable for well planned town or city where the locality can be divided into square or circular blocks and the main water line can be laid around the sides of the square or around the circle. (Fig. 13.6.)

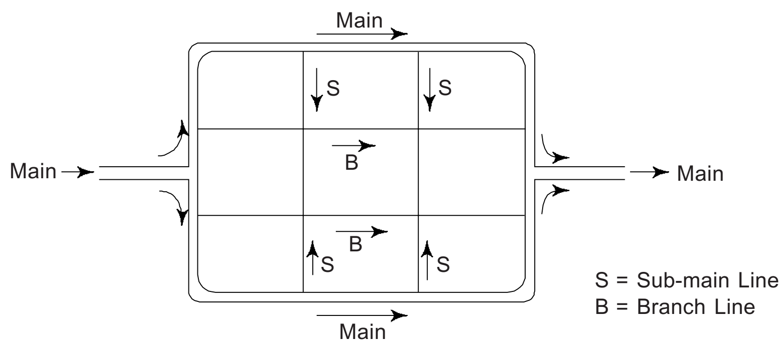


Fig. 13.6 *Circular method*

4. Radial Method

As shown in Fig. 13.7, in radial method, the town or city is divided into various circular or square zones and distribution reservoirs are placed at the centre of each zone. The distributor lines are laid radially from the reservoir towards the periphery of each zone. This system is suitable when the town or city can be oriented with radial roads and streets. In this system, the water from the main reservoir is allowed to flow through the main pipe and sub-main pipe and get collected at the distribution reservoir of each zone. Then the water is supplied to consumers through the distributor pipe lines.

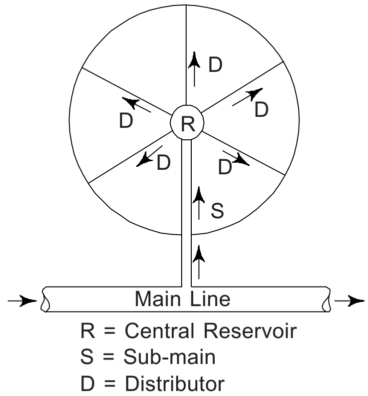


Fig. 13.7 *Radial method*

13.5 WASTAGE OF WATER

The wastage of water has a great impact on the water supply scheme. If the wastage exceeds the permissible limit, then the supply of water to the consumers decreases and they have to suffer for that. So, the causes of wastage should always be investigated and proper steps should be taken accordingly. The following are some of the reasons for water wastage.

(a) Carelessness of Consumers

(i) A tap in the bathroom or basin or kitchen or any other place may be kept open unnecessarily.

(ii) A damaged tap may not be replaced in time.

(iii) The small reservoir in bathroom or in any other place may be allowed to overflow unnecessarily.

(iv) The street taps may be kept open or damaged and the water flows out unnecessarily.

(b) Leakage in Pipe Line

(i) There may be leakage of water through the pipe joints.

(ii) There may be leakage through the pipe line which was damaged at the time of excavation trenches for telephone line, drainage line, sewer line, etc.

13.6 DETECTION OF LEAKAGE OF WATER

The point of leakage of water can be detected by the following tests:

(a) By Hydraulic Gradient: The pressure of water is measured at a regular interval along the pipe line by a pressure gauge. Then, a graph is prepared with the recorded pressure. The graph will show the hydraulic gradient of the flow of water along the pipe line. By studying the nature of hydraulic gradient, the point or leakage can be detected. This is a very effective method.

(b) By Compressed Air: If compressed air is blown through the water pipe, then bubbles will be formed at the point of leakage and ultimately the water will come out by loosening the soil above the pipe line.

(c) By Direct Observation: The point of leakage can be detected by observation. The ground surface at the point of leakage will be moist and soft, and green spot will appear at the surface.

(d) By Sound Test: A metal rod may be inserted into the ground in such a way that it may touch the pipe line. The 'hissing sound' of the escaping water may be heard through the metal rod by some hearing device.

13.7 PREVENTIVE MEASURES TO CONTROL WASTAGE OF WATER

To control the wastage of water the following measures should be taken:

(a) Zoning System: The layout of distribution should be done by dividing the area into a number of small zones. The water is supplied to each zone by a branch line. This will help to locate the point of leakage easily.

(b) Pipe Joints: There are different types of pipe joints. So, the proper joint should be done by considering the pipe materials. Again, the joints should be done perfectly and leakage test should be carried out before filling up the trench.

(c) Installation of Water Meter For Each Zone: Water meters should be installed at the entry of each zone. At mid night, there is practically no consumption of water. If such meters indicate the flow of water during this period, then the leakage of water can be detected.

(d) Water-Tax: If some water-tax is imposed on consumers on the basis of the volume of water consumptions, then they will be cautious about the wastage of water within their house.

(e) Vigilance Team: A vigilance team should be formed by the water supply authority to look after the road side taps and the pipe lines. This team will walk along the roads daily and inspect the conditions of taps. They will also observe the ground surface along the route of the pipe line to detect any sign of leakage.

13.8 TYPES OF DISTRIBUTION RESERVOIRS

The distribution reservoirs may be of the following types:

1. Surface Reservoirs

The surface reservoir is suitable in gravity system of supply. It is constructed below the ground surface or just on the ground surface according to the condition of the site. It is a rectangular tank constructed with brick masonry or R.C.C. The tank is plastered with rich cement mortar and finished with neat cement polish. The storage capacity depends on the water requirement of the scheme. The water from the treatment plant is stored in this tank. As shown in Fig. 13.8, the wash out pipe is provided at the bottom. The outlet pipe is provided about 30 cm above the bottom level of the tank.

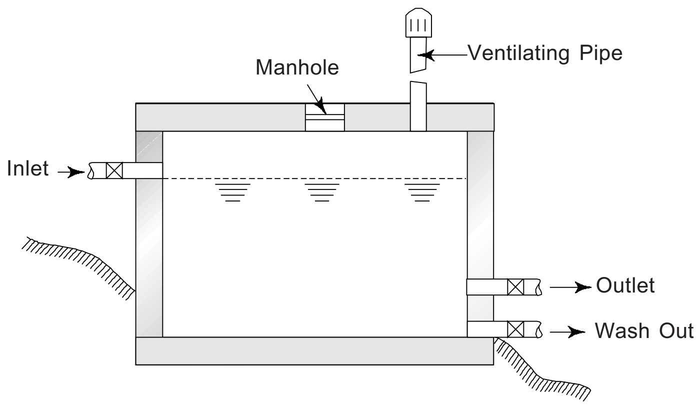


Fig. 13.8 *Surface reservoir*

2. Elevated Reservoirs

The elevated reservoirs are constructed high above the ground. The height of the reservoir depends on the pressure head to be developed to supply water to all points of the distribution zone. The shape of the tank may be circular or elliptical, as shown in Fig. 13.9. Normally, the pumps run at a constant speed to meet the average demand. But in slack period the excess water is stored in the reservoirs. At the period of peak demand, the water is supplied by pumping as well as from the reservoir. So, such types of reservoirs are essential in dual system of water supply.

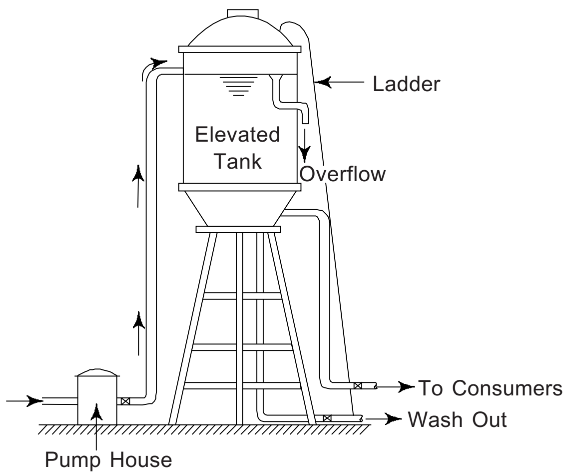


Fig. 13.9 *Elevated tank*

3. Stand Pipe

Figure 13.10 shows a stand pipe distribution reservoir. It is a vertical cylindrical tank constructed of steel or R.C.C. It consists of inlet pipe, overflow pipe, wash out pipe and distribution pipe. The water from the surface sources like natural lake, stream, spring, etc. is stored in this tank by pumping and then distributed to the consumers by the force of gravity. The diameter of stand pipe varies from 8 m–12 m and its height varies from 10–20 m. This system is suitable for hilly area.

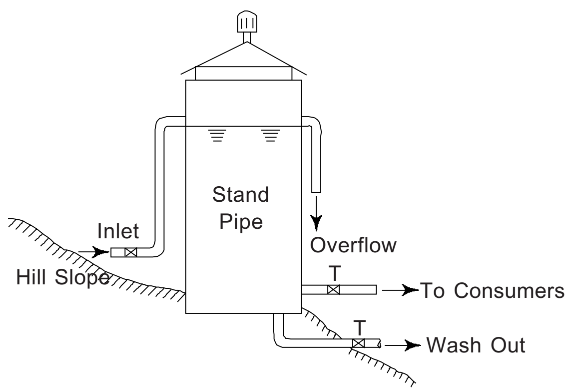


Fig. 13.10 *Stand pipe*

13.9 PRESSURE IN DISTRIBUTION SYSTEM

While flowing through the distribution system, the water loses the pressure due to friction, valves, bends, etc. Therefore, the pressure available at the consumer's end is much lower than the pressure at the entrance of the distribution system. The pressure is usually designated by pressure head. When the pressure head is not sufficient to raise the water in the upper storey, the consumers have to install booster pumps to lift water.

The pressure in the distribution system depends on the following factors:

(a) The height of the highest building in the extreme end of the distant zone.

(b) Distance of the extreme end of the distant zone from the reservoir or supply point.

(c) The pressure required for fire hydrant.

In practise, the residual pressure head at the extreme end of supply zone should be as follows:

Single storey building—7 m of water

Double storey building—12 m of water

Three storey building—17 m of water

The residual pressure head should not exceed 22 m.

13.10 MAINTENANCE OF DISTRIBUTION PRESSURE

The distribution pressure can be maintained by adopting the following measures:

(a) The service reservoir should be constructed at the centre of supply zone.
(b) A surge tank (i.e. balancing tank) should be provided on the main water line at a suitable place. When the rate of supply is more than water demand, the excess water is stored in this tank. Again, when the water demand is more than the rate of supply, the water from the surge tank flows to the distribution system to meet the excess demand.
(c) To supply water to distant zones, booster pumps may be installed at required points.

13.11 REQUIREMENTS OF DISTRIBUTION SYSTEM

The following are the requirements of a distribution system:

(a) The main pipe line should carry water three times the average demand.
(b) The branch lines should carry water twice the average demand.
(c) The water demand at the various zones should be recorded.
(d) The length and diameter of pipes at various sections should be marked on site plan with the positions of fire hydrants, valves, junctions, etc.
(e) The pressure drops at different sections of main pipe line should be recorded.
(f) The pipe lines should be cleared periodically.

REVIEW QUESTIONS

1. Describe, with sketches, the methods of distribution system.
2. Describe the systems of water supply with their merits and demerits.
3. Describe, with sketches, the layout of distribution system.
4. What are the causes of wastage of water?
5. How can leakage of water be detected and prevented?

14

Valves and Pipe Fittings

14.1 INTRODUCTION

In water works, the various types of pipe apparatus such as valves, sluices, sockets, elbows, etc. are needed to control the flow of water, to release the excessive pressure in the pipe line, to eliminate the accumulation of air in the summits of the pipe line. Again, in house plumbing various types of pipe fitting such as taps, sockets, elbows, nipples, stop cocks, gate valves, checkvalves, tees, etc. are required. The following are the important appurtenances in pipe lines:

1. Air valves
2. Reflux valves
3. Relief valves
4. Sluice valves or Gate valves
5. Scour valves
6. Stop cocks
7. Bib cocks
8. Fire hydrants
9. Ferrule
10. Water-meter

14.2 AIR VALVES

Air valves are also known as air relief valves. The water flowing through the pipe line always carries some air with it. This air tends to accumulate at the summits of the pipe line. Due to the accumulation of air, a backward pressure is created which causes a blockage to the flow of water. Thus the discharge through the pipe is suddenly decreased and ultimately it may be stopped. So, the air relief valve is provided at the summit to release the air pressure. The air valve consists of a cast-iron chamber in which a float, lever and a poppet valve are provided, as shown in Fig. 14.1.

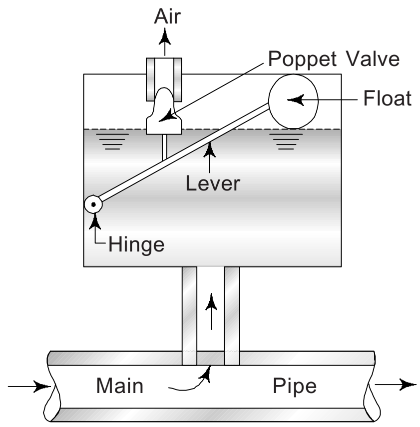


Fig. 14.1 *Air valve*

The function of air valve is as follows:

(a) In normal condition, the chamber remains full of water. The float touches the roof of the chamber and the poppet valve remains in closed position.
(b) As the air goes on accumulating on the top of the chamber, a pressure goes on developing there.
(c) This pressure causes the water level to go down and hence the float moves downward which pulls the lever down. Thus the poppet valve is opened and the air is allowed to escape.
(d) When the air is released completely, the water level rises again and the normal working condition revives.

14.3 REFLUX VALVES

Reflux valves are also known as check valves or non-return valves. These possess some automatic device which allows the water to flow in one direction only. These are made of brass or gun metal. As shown in Fig. 14.2, a valve is pivoted at one end and it can rest on a projection on the other end. This valve is provided in the pipe line which draws water from the pump. When the pump is operated, the valve is opened and the water flows through the pipe (as indicated by arrow). But, when the pump is suddenly stopped or it fails due to power failure, the valve is automatically closed and the water is prevented from returning to the pump.

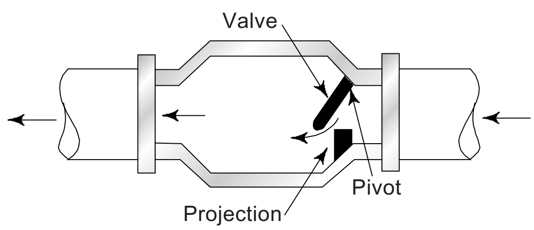


Fig. 14.2 *Reflux valve*

14.4 RELIEF VALVES

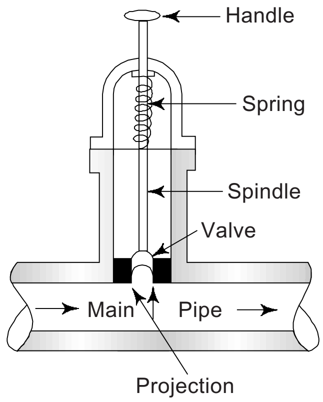


Fig. 14.3 *Relief valve*

Figure 14.3 shows a relief valve. The relief valves are also known as pressure relief valves or cut-off valves or safety valve. The power of the spring of the valve is so adjusted that the valve always remains in closed position up to some permissible water pressure in the pipe line. When the pressure of the water suddenly exceeds the permissible pressure due to water hammer phenomenon, then the valve is opened automatically and the excess pressure is released instantaneously. Thus the pipe line is protected from bursting. These valves are provided along the pipe lines at some specific points where the pressure is likely to increase.

14.5 SLUICE VALVES

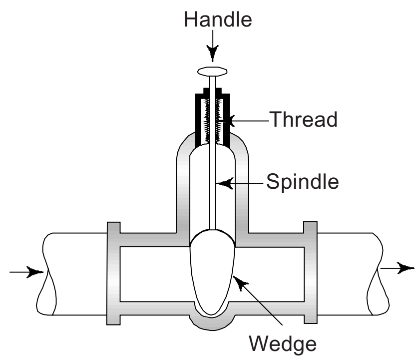


Fig. 14.4 *Sluice valve*

Sluice valves are also known as gate valves or shut-off valves. These valves are provided to stop the flow of water through the pipe and are essential to divide the main line into several sections. Moreover, in branch lines or at some specific points on the distribution system these valves are provided to perform the repair works without disturbing the water supply in the other sections. As shown in Fig. 14.4, it consists of a spindle which carries a wedge at the bottom and a handle at the top. The spindle is threaded and can be moved up and down. When the spindle is rotated anti-clockwise, the wedge is lifted up and the water flows through the pipe. When it is turned clockwise, the wedge closes the opening and the flow of water is stopped.

14.6 SCOUR VALVES

Scour valves are also known as wash-out valves. These are similar to the sluice valves, but the function is different. The scour valves are provided at the dead-end of the pipe line. The function of this valve is to remove the sand, silt, etc. from the pipe line. The valve is opened by turning the spindle and the muddy water is allowed to flow out. When the washing is completed, the valve is closed by turning the spindle.

14.7 STOP COCKS

The stop cocks are practically sluice valve of small sizes. These are provided on the pipe line leading to wash basins, water tanks, flushing tanks, etc. to stop or open the flow of water when necessary. These are made of brass or gunmetal. As shown in Fig. 14.5 the stem of the stop cock is threaded. So, the valve can be moved up and down by turning the handle.

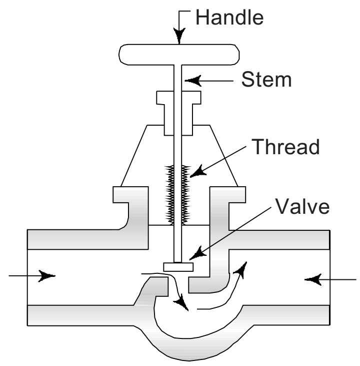


Fig. 14.5 *Stop cock*

14.8 BIB COCKS

Bib cocks are small size water taps which are fixed on the pipe line in wash basins, bathrooms, kitchens, etc. from where the consumers obtain water. It is operated by a handle. Figure 14.6 shows a bib cock. The stem of the handle is threaded. So, the valve can be moved up and down by turning the handle. The clockwise turning of handle stops the flow of water and anticlockwise turning opens the flow of water. These are generally made of brass or gun metal or plastic.

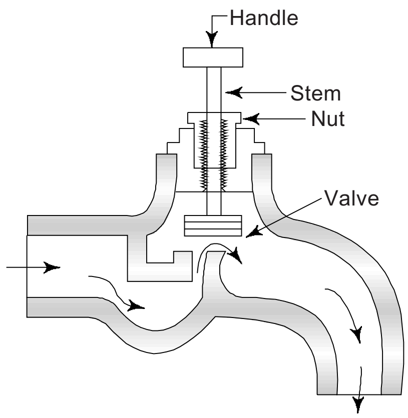


Fig. 14.6 *Bib cock*

14.9 FIRE HYDRANT

Fire hydrant is an outlet provided in the main water line for tapping water in case of fire. When fire occurs in some place, the fire brigade vehicles run to the spot and connect the hose pipe to the spout by removing the cap. Then the valve is opened by turning the handle. After finishing the work, the cap is replaced and the valve is closed. The hydrants are provided on the main line at important points. The location of the fire-hydrant should be marked on a map by the fire-brigade authority. The hydrants may be of two types:

(a) Post hydrant.
(b) Flush hydrant

The post hydrant (shown in Fig. 14.7 (a)) is projected above the road level. This type of hydrant is prominent and can be located easily. But, it is liable to be damaged by the miscreants.

The flush hydrant is provided below the road level. It is protected by cast iron box or brick masonry. A cast iron cover is placed over the box (Fig. 14.7 (b)). But, it is difficult to locate the position of the hydrant easily. However, some signal should be provided above the ground level to detect the hydrant easily.

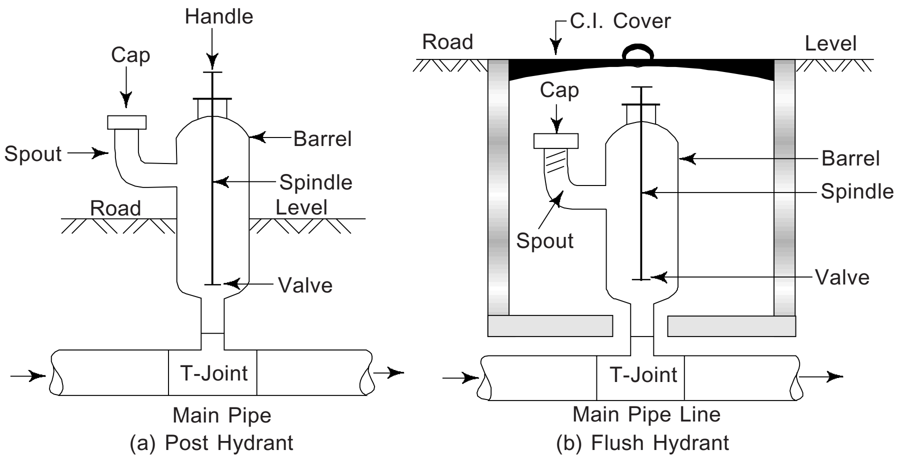


Fig. 14.7 *Fire Hydrant*

14.10 FERRULE

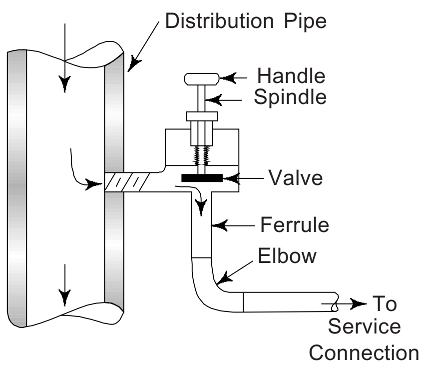


Fig. 14.8 *Ferrule*

Ferrule is a device by which water connection is given to the consumers. It is connected between the distribution pipe and service connection. It controls the quantity of water to be supplied to the consumers. In case of any dispute, the water supply to a house is disconnected by operating the ferrule. It is manufactured of brass or gunmetal in the shape of a 'T'. As shown in Fig. 14.8, the open ends of the ferrule are threaded. One end is connected to the distribution pipe by making a hole and the other end is connected to service connection pipe with the help of an 'Elbow'. The valve is moved up and down by rotating the handle.

14.11 WATER METER

The device by which the quantity of water flowing through a particular point is measured is known as water meter. It helps directly to compute the volume of water used by a consumer from the reading on the meter. The water-tax is charged according to the volume of water consumed. Figure 14.9 shows a rotary water meter. The meters may be of following types:

(a) Displacement type
(b) Velocity type

The displacement type meter records the number of times a container of known volume is filled up and emptied by the flowing water. From the reading, the volume of water can be worked out.

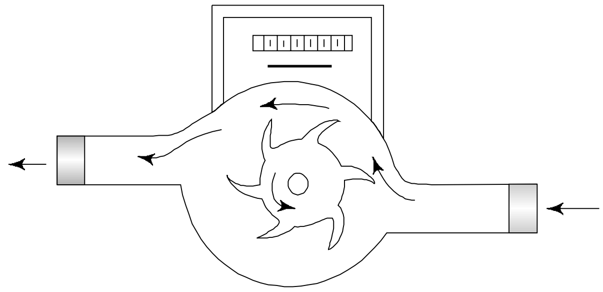


Fig. 14.9 *Rotary water meter*

The velocity type meter gives a reading on the dial according to the velocity of flow of water. From the reading, the volume of water can be worked outn from the manufacturer's rating table.

REVIEW QUESTIONS

1. Why is it necessary to remove the air from the water pipe? Describe a suitable device to remove the air from the pipe time.
2. What is the function of fire-hydrant? Describe the fire hydrant with a neat sketch.
3. Write short notes on the following with neat sketch:
   (a) Air valve
   (b) Reflux valve
   (c) Relief valve
   (d) Sluice valve
4. Distinguish between the following:
   (a) Stop cock and bib cock
   (b) Sluice valve and scour valve
   (c) Reflux valve and relief valve
   (d) Flush hydrant and post hydrant
5. How is the water consumed by a consumer measured? Describe the device meant for it.

15

Preparation of Water Supply Scheme or Project

When a water supply scheme is to be prepared for a newly developed town or city or an already existing scheme has to be expanded, following investigations should be conducted for the preparation of project report.

15.1 RECONNAISSANCE

During reconnaissance survey the following points should be noted:

(a) Total area to be covered
(b) Existing population, habits of the people, type of industries, etc.
(c) Existing source of water
(d) An index map is to be prepared showing the population densities at different zones
(e) Trend of development of the town or city
(f) Intensity of public demand for the water supply scheme

15.2 DEMAND OF WATER

A water supply scheme should be designed to serve the probable population for at least three decade. So, the total demand of water for the next three decades should be ascertained. For this purpose, the following points should be considered:

(a) Depending upon the present population, the probable population for the next three decades is estimated by the usual methods (generally by mathematical method).
(b) The daily rate of demand per capita is worked out depending on the habits of the people.
(c) The demand of water for industries, sewerage system, fire demand, public demand, etc. should also be worked out.

(d) The total water demand for the peak hours is estimated considering the system of water supply (i.e. continuous or intermittent).

15.3 SOURCES OF WATER

The sources of water may be in two forms:

1. Surface source
2. Underground source

1. Surface Source

The surface source may be of following types:

(a) A Perennial River In this source, the quantity of water may be adequate. But the quality should be examined in order to ascertain the treatment units to be adopted.

(b) An Inundation River In this source, the quantity of water may not be adequate. In this case, an artificial reservoir has to be prepared by constructing weir across the river.

(c) A Large Lake In this source, this quantity of water may be reliable. But requisite quantity of water may not be available in summer.

2. Underground Source

The underground source is very reliable in respect of quality. If the quantity of water is found to be adequate by studying the highest and lowest water table, then deep tube wells should be sunk at suitable points in different zones. In such a case, the water is supplied by direct pumping through a pump house.

15.4 PREPARATION OF TOPOGRAPHICAL MAP

A topographical map of the town or city has to be prepared. It should indicate the location of roads, streets, lanes, houses, playground, parks, etc.

15.5 LAYOUT MAP OF THE SCHEME

On the topographical map, the layout of the scheme is marked by using different colour convention or any suitable convention so that the work can be conducted in different phases. The layout should indicate the following informations:

(a) Position of intake work
(b) Position of treatment plant
(c) Conveyance route from intake point to treatment plant
(d) Position of storage reservoir or pump house
(e) Network of main and distribution pipe lines
(f) The specific points such as position of check valve, fire hydrant, inspection chamber, junction points, etc.

15.6 MAPS AND DRAWINGS TO BE PREPARED

The following maps should accompany the scheme:

(a) A topograpahial map (to suitable scale)
(b) A layout map of the scheme (to suitable scale)
(c) Detailed drawings of intake work, pump house, deep tube well (if necessary), overhead reservoir, etc. after design. The designs should accompany the drawings.

15.7 OFFICE WORK

The office work includes the design, drawing and detailed estimate of the scheme or project for the following items:

(a) Intake work
(b) Purification plant
(c) Conveyance pipe line
(d) Sinking of deep tube well (if necessary)
(e) Construction of pump house (if necessary)
(f) Overhead reservoir
(g) Distribution network of pipe lines
(h) Compensation payable (if required)
(i) Other allied expenditure
(j) Total cost of the scheme including all the above items and 20% provision for future extension.

15.8 PROJECT REPORT

When all the investigation works, design, drawing, estimation, etc. have been completed, a report should be prepared and submitted to higher authorities for approval. The report should contain following information:

(a) Introduction
(b) Necessity and background
(c) Justification of taking up the present scheme
(d) Procedure adopted for land acquisition
(e) The compensation statement which should include the nature of property, name of owner, amount of property, amount of compensation according to present market price, etc.
(f) Detailed estimate of the scheme
(g) Detailed specification for constructional work
(h) Conclusion and recommendations

16

Water Supply Arrangements in Buildings

16.1 INTRODUCTION

The method of fitting the accessories in water supply system in a building is known as plumbing:

The following accessories are required for the plumbing work:

1. Stop cock
2. Bib cock
3. Check valve or gate valve or sluice valve
4. Sockets
5. Nipple (short and long)
6. Union
7. Elbow
8. Tee
9. Wash basin
10. Sink
11. Shower
12. Bathtub (if necessary)
13. G.I. Pipes—12 mmϕ, 19 mm ϕ, 25 mm ϕ, etc.

16.2 POSITIONS AND FUNCTIONS OF DIFFERENT ACCESSORIES

1. Stop Cock: It may be made of steel or brass and is fitted to the pipe line leading to wash basin, sink, shower, bathtub, etc. to stop the flow of water when necessary.

2. Bib Cock: It may be made of steel, brass or plastic. It is provided to the wash basins, sinks, bathrooms and at places where it is necessary for tapping water for washing hands and faces, utensils, clothes, etc.

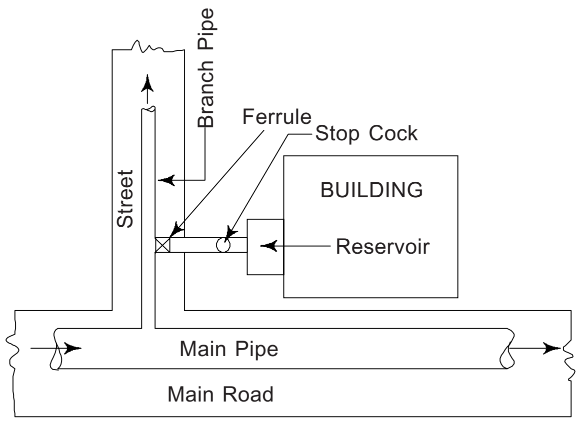


Fig. 16.1 *Layout of municipal supply*

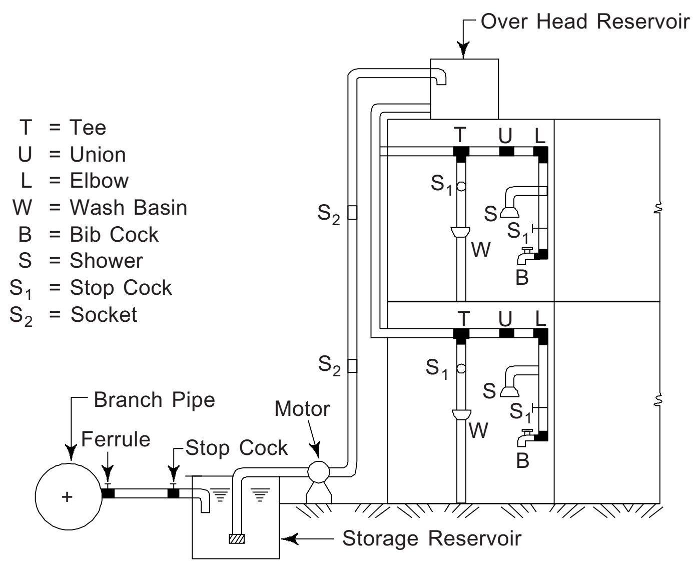


Fig. 16.2 *Plumbing work in building*

3. Check Valve: It may be made of steel or brass. It is provided to the pipe line to check the flow of water. It is also known as gate valve or sluice valve. The non-return check valve is provided on the vertical pipe line leading to the overhead tank to check the back flow of water.

4. Socket: It is made of galvanised iron pipe of different diameters. Sockets may be of two types—plain socket and reducing socket.

The plain socket is used to connect two pipes of same diameter. The reducing socket is used to connect two pipes of different diameters.

5. Nipple: It is made of galvanised iron pipe of different diameters. Nipples may be of two types—short and long. The length of short nipple is 25 mm and is used for fixing bib cocks or at some other necessary points. The length of long nipple may be 150 mm, 225 mm, 300 mm, etc. and of different diameters. It is used for short extension of pipe line when necessary.

6. Union: It may be made of brass or cast iron. It is used to connect two pipes of same diameter so that the pipe line may be opened easily for the purpose of washing or for carrying out repair works.

7. Elbow: It is made of galvanised iron in the shape of 'L'. It is used at the points where two pipes are to be joined in right angles.

8. Tee: It is made of galvanised iron in the shape of 'T'. It is used at the point where a vertical pipe line is to be taken from a horizontal pipe line.

9. Wash Basin: It is made of porcelain in various shapes and sizes. It is fixed with the wall at a suitable place in a building for washing hands, face, etc.

10. Sink: It may be made of concrete or porcelain or P.V.C. in the shape of rectangular trough and fitted with the wall of kitchen.

11. Shower: It may be made of steel or plastic in different types. It is provided in the bathroom for bathing.

12. Bath Tub: It is installed in the bathroom for bathing by immersing the whole body in water. It is an essential fitting in houses abroad, also popular in rich urban societies, specially in the metropolitan cities.

13. G.I. Pipe: It is made of galvanised iron of different diameters (12 mm, 19 mm, 25 mm.......). The length of the pipe varies from 6 m to 7 m.

16.3 PROCEDURE OF DOMESTIC WATER CONNECTION

The domestic water connection is obtained according to the following procedure:

(a) Requisite amount of money should be submitted to the water supply section of municipality or corporation.
(b) The water connection to the consumers is made from the distributory pipe line with the help of ferrule.
(c) The connecting pipe from the ferrule is extended up to the premises of the consumer. The consumer then extends the connecting pipe up to the reservoir. A stop cock should be provided on the extension pipe line.
(d) An authorised plumber should be appointed for the internal plumbing work of the building.

17

Water Supply Arrangement in Rural Area

17.1 INTRODUCTION

The major portion (about 70 per cent) of the Indian population lives in villages. They live in unhygienic conditions and are mostly bound to drink river water or pond water which may be polluted in many ways (i.e. by bathing, washing of clothes of patients, etc). Hence, they suffer from water-borne diseases frequently. So, proper arrangement should be made by the government agency to supply potable water to villagers.

17.2 ARRANGEMENT OF WATER SUPPLY

The arrangement of the supply of potable water in the rural area may be achieved by the following ways:

1. By Protecting the Water of a Pond

A suitable pond should be selected for a particular village for drinking water only. The pond should be protected by fencing and a ghat should be provided for drawing water. Requisite amount of alum solution should be spread near the ghat area. Then chlorine solution should also be applied in that area once in a week. The application of alum and chlorine should be done at night so that water can be drawn in the morning. This sterilising work should be done by local panchayat.

2. By Digging Big Open Wells

Large diameter (1.5 m ϕ to 2 m ϕ) open wells may be dug at suitable places in a village so that every body can get water. The depth of well should be such that water can be available throughout the year. The well water may be disinfected by lime when required.

3. By Sinking Tube Wells

Tube wells (by G.I. Pipe or P.V.C. Pipe) may be sunk at suitable places in a village so that everybody can get water. The depth of tube well should be such that the water can be available throughout the year.

4. By Overhead Reservoir

A water supply scheme may be prepared for several villages. A suitable site should be selected for deep tube well, pump house and overhead reservoir. According to the total population of the village, the capacity of the reservoir should be ascertained. The water of the well is stored in reservoir by pumping and then supplied to consumers by the network of pipe line.

PART II

SANITATION

1

Introduction

1.1 DEFINITION OF DIFFERENT TERMS

1. Refuse: The rejected materials which are collected in dustbins and the foul discharges which are carried by underground drains are termed as refuse. Refuse may be of two types:

(a) Dry Refuse It includes grass, leaves, paper pieces, sweepings, decayed fruits and vegetables, cloth pieces, waste cotton, rejected plasters from hospitals, etc.

(b) Wet Refuse It includes the discharge from latrines, urinals, bathrooms, kitchens and stables.

2. Garbage: The dry refuse is also termed as garbage. It includes the sweepings from markets, public places, and streets. The rejected materials from residential area such as vegetable peel, paper pieces, ash, decayed fruits and vegetables, etc. are also included in garbage.

3. Sewage: The liquid waste from a community is termed as sewage. It mainly includes the discharges from latrines, urinals and stables. The discharges from bathrooms, and the storm water (i.e. rain water) are also included in sewage. The human excreta is termed as night soil. The sewage may be of the following types:

(a) Sanitary Sewage The foul discharges from residential area are known as sanitary sewage. It includes mainly the discharge from latrines and urinals.

(b) Industrial Sewage The discharges from the industries (i.e. industrial waste) are known as industrial sewage.

(c) Combined Sewage The combination of sanitary sewage and storm water is known as combined sewage.

(d) Fresh Sewage The sewage which is produced at the moment is termed as fresh sewage.

(e) Raw Sewage The sewage which is not yet treated is termed as raw sewage.

(f) Septic Sewage The sewage which is undergoing treatment process is termed as septic sewage. After the completion of the process of decomposition, it is termed as stale sewage.

(g) Weak Sewage The sewage which is diluted with water and contains less amount of suspended matters is termed as weak sewage.

4. Dry Weather Flow (D.W.F.): The flow of sewage during the dry season of the year is termed as dry weather flow.

5. Wet Weather Flow (W.W.F): The flow of sewage during the rainy season of the year is termed as wet weather flow.

6. Storm Water: The surface run-off during the rainfall at any place is termed as storm water.

7. Sullage: The discharge from the bathrooms and kitchens is termed as sullage. It is not a foul discharge and it does not cause bad smell.

8. Sewer: The underground conduits or drains which carry the sewage are known as sewers. The sewers may be of the following types:

(a) Main Sewer The sewer which carries the whole sewage coming from the branch lines is termed as main sewer.

(b) Branch Sewer The sewer which carries the sewage from the lateral sewers and delivers the same to the main sewer is termed as branch sewer.

(c) Combined Sewer The sewer which carries the domestic sewage and storm water is termed as combined sewer.

(d) Intercepting Sewer The sewer which carries the discharges from a number of main sewers and delivers the same to the point of treatment is known as intercepting sewer.

(e) Lateral Sewer The sewer which obtains the sewage directly from the residential buildings is known as lateral sewer.

(f) Relief Sewer The sewer which carries the excess discharge from an existing sewer is termed as relief sewer.

9. Sewerage: The network of collecting and conveying sewage by water carriage system through the underground sewers is known as sewerage.

10. Manhole: The opening or hole through which a man can enter the sewer line or other closed structure for inspection and cleaning is termed as manhole.

11. Soil Pipe: The pipe which carries the discharges from the urinals, water closets, etc. is known as soil pipe.

12. Vent Pipe: The pipe which is installed for the purpose of escaping the foul gases from the septic tanks, digesting tanks, etc. is known as vent pipe.

13. Anti-siphonage Pipe: The pipe which is installed with water closet to preserve the water seal in the trap is known as anti-siphonage pipe. This pipe maintains the ventilation properly and it prevents the siphonic action in the water seal of the trap.

14. Waste Pipe: The pipe which carries the discharge from the bath-rooms, kitchen sinks, etc. is termed as waste pipe.

1.2 FEATURES OF SANITARY WORKS

The features of the sanitary works are as follows:

1. Collection
2. Conveyance
3. Treatment
4. Disposal

1. Collection

The dry refuse (i.e. garbage) and liquid refuse (i.e. sewage or night soil) should be collected in a planned way to protect the town from insanitary conditions. The following steps should be taken for the collection work:

(a) Market is the main source of garbage. The refuse like decayed vegetable and fruits, ash, mud, fish scales, etc. should be collected by labours and dumped in a particular place for removal.
(b) The swept refuse from public places should be dumped in dust-bins.
(c) The refuse from the domestic houses should be thrown in road side dust-bins.
(d) The refuse from hospitals should be collected in some particular place.
(e) If a town is under conservancy system, the night soil should be removed by the sweepers from the latrines of individual houses before dawn and collected in covered bullock carts or trailors.
(f) In water carriage system, the collection of sewage does not arise as it is conveyed through the network of pipe lines.

2. Conveyance

After collection of the garbage and night soil, they should be removed to the dumping ground by suitable conveyance. Generally, the trucks or trailors are employed for the conveyance of those refuse. The night soil carts or trailors should move to the trenching ground early in the morning.

3. Treatment

In Conservancy system, the night soil is left for natural treatment by sunshine. The garbage is separated in two groups combustible and non-combustible. The combustible garbage is burnt to ashes and non-combustible garbage is laid in low-lying areas.

In water carriage system, the sewage is carried to the treatment plant by underground sewer line for necessary treatment.

4. Disposal

There are various methods of sewage disposal (Ch. 11) and sludge disposal (Ch. 13). The effluent is discharged into the river and the sludge is digested to convert it to manure.

1.3 PURPOSE OF SANITATION

The waste products like garbage, sewage, sullage, etc. are produced every-day in towns and cities. The garbage is produced in domestic area, markets, public places, streets, etc. and the liquid waste is produced from latrines, urinals, stables, bathrooms, etc. If the garbage is not collected and disposed of regularly, then it will go on accumulating in the dust-bins. This will cause insanitary conditions by producing bad small, fly nuisance, bacteria, etc. The sources of water may also be polluted which may cause water-borne diseases. Again, if the sewage and sludge are not disposed of properly, they will also cause insanitary condition.

Under these circumstances, it is most necessary to establish the sanitation systems in towns or cities.

1.4 PRINCIPLES OF SANITATION

The following are the principles of sanitation:

(a) The waste matters like garbage and sewage should be removed as early as possible after its formation.

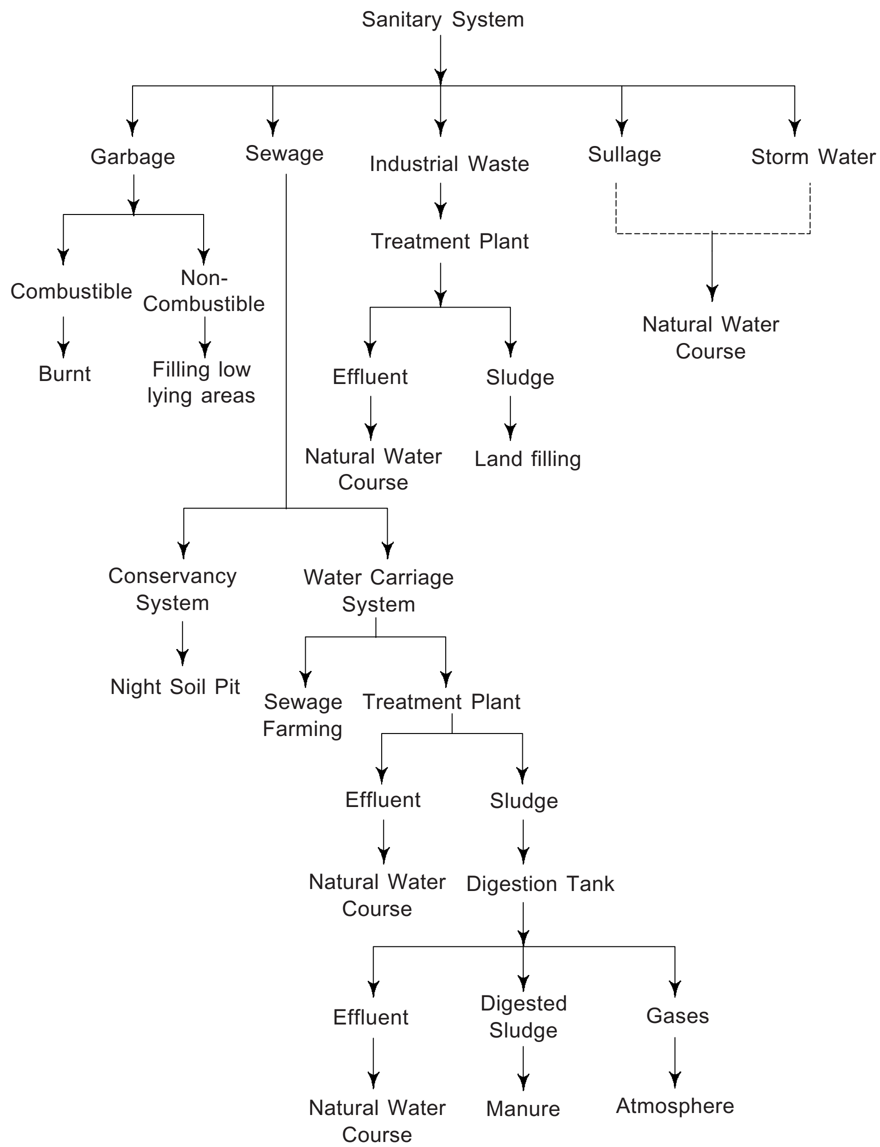
(b) The waste matters after collection should be treated within four hours and the effluent should be disposed of immediately.

(c) The floors and furnitures in a house should be cleaned regularly.

(d) The buildings should be made damp-proof.

(e) Water supply should be regular and sufficient so that the flushing of the lavatories may be done properly.

1.5 FLOW CHART OF SANITARY SYSTEM



REVIEW QUESTIONS

1. State the features of the sanitary works.
2. Define the following:
   (a) Refuse
   (b) Garbage

(c) Sewage
(d) Sullage
(e) Dry weather flow
(f) Wet weather flow
(g) Sewerage

3. Distinguish between the following:
   (a) Sewage and sullage
   (b) Dry weather flow and wet weather flow
   (c) Sanitary sewage and industrial sewage
   (d) Raw sewage and septic sewage
   (e) Lateral sewer and intercepting sewer
   (f) Vent pipe and waste pipe.

2

Solid Waste Collection, Disposal and Rural Sanitation

2.1 SOURCES OF SOLID WASTE

The solid waste (i.e. garbage) includes the dry refuse like street sweepings, ash, mud, decayed vegetables and fruits, grass, leaves, paper pieces, cloth pieces, etc. The following are the sources of such solid waste:

(a) Market The market is the chief source of solid waste. Huge amount of garbage is found to be deposited every day in the market. Here, the refuse includes decayed vegetables and fruits, ash, mud, fish scales, rejected matters from meat shops, paper pieces, etc.

(b) Road Side Dustbins The rejected materials from the houses along the roads or streets are thrown in the road side dustbins. The refuse includes vegetable and fruit peel, paper and cloth pieces, fish scales, house sweepings, ash, etc.

(c) Residential Area From the residential areas like housing estates, colonies, etc. the dry refuse is thrown in dustbins or dumped at a particular place alloted for the purpose.

(d) Street Sweepings The sweepings of main roads are collected in dustbins and the sweepings of the streets of colonies, housing estates, factories, plants, etc. and carried away every morning. The sweeping of main roads should be done early in the morning when there are less vehicles on the roads. The refuse mainly includes dust, grass, leaves, plants, paper pieces, etc.

(e) Cinema and Theatre Halls The sweepings from the cinema and theatre halls mainly include dust, nutshells, paper pieces, etc. The refuse are dumped in nearby dustbins.

(f) Schools and Colleges The sweepings of schools and colleges mainly include dust and paper pieces. The refuse is collected in the nearby dustbins.

(g) Hospitals The refuse of hospitals includes rotten clothes and plasters, paper pieces, waste cotton, dust, broken glass, rejected bottles of medicine, disposable syringes, injection samples, etc. These are collected and dumped in suitable place in front of the hospitals.

2.2 COLLECTION AND REMOVAL OF SOLID WASTE

The solid wastes should be collected and removed in a planned way so that unhygienic condition do not arise and the people do not feel any inconvenience due to bad odour and ugly situation. The wastes are collected and removed in the following ways:

(a) The refuse from the markets is collected by the sweeper from all corners or zones and dumped in a suitable place in front of the market. Then the materials are loaded to the truck or trailer and removed immediately to the place of dumping. The collection should be done daily in the early morning.
(b) From the road side dustbins, the refuse is collected by the vehicles and removed to the dumping ground.
(c) The refuse from the hospitals is collected by trucks and removed to the dumping areas every morning.
(d) The refuse from the schools and colleges, cinema halls, etc. is collected in small hand-driven wheel baskets and finally thrown to the receiving vehicles standing on the main road or any suitable place.

The following vehicles are employed for the removal of solid waste.

1. Rickshaw-vans: These are three-wheeled small vehicles with cover on four sides, almost like a box. The capacity of these vehicles varies from 8 to 10 cubic ft. These are suitable for narrow lanes and *kachcha* roads where heavy vehicles cannot enter. They carry the refuse up to the dumping place by the side of main roads from where heavy vehicles remove the materials to the dumping ground.

2. Wheeled Baskets: These are rectangular baskets with two-wheels on the front and a support at the back. There are two handles on the top by which they can be pushed or pulled. The capacity of such baskets varies from 3 to 5 cft. These are meant for removing the refuse from the narrow lanes and *kachcha* roads and dumping the materials by the side of main roads from where the heavy vehicles remove them to the dumping ground.

3. Trailors: The trailors may be two-wheeled or four-wheeled. They are drawn by tractors. The capacity of trailor varies from 100 to 150 cft. These vehicles remove the refuse from main roads and carry them to the dumping ground. The loading and unloading is done by manual labours.

4. Trucks: The trucks are four-wheeled heavy vehicles. The capacity of the trucks varies from 200 to 250 cft. These vehicles are employed to remove the refuse from the markets and main roads and carry them to the dumping ground. The loading and unloading is done by manual labours or by mechanical device.

2.3 DISPOSAL OF SOLID WASTE

The disposal of the solid waste (i.e. garbage) should be done very carefully so that it may not cause any unhygienic condition. After removal of the refuse, it is taken to the dumping ground. Then suitable method is adopted for the safe disposal. The following are the general methods of disposal:

(a) By trenching
(b) By land filling
(c) By incineration
(d) By pulverisation
(e) By composting
(f) By disposal to sea

(a) By Trenching In this method, trenches are excavated in barren lands far away from the town. The size of the trench may be 12m × 3m × 2m. The garbage is dumped into the trench and levelled properly. The top surface is covered by the excavated earth or by ash (if available). The process of fermentation goes on by the anaerobic bacteria. After about six months the garbage is converted into manure. It is then taken off for use in cultivation. Again, the trench is filled up with fresh garbage. The number of trenches should be such that the process can be continued throughout the year.

(b) By Land Filling This method is very suitable if low-lying areas are available in the locality. In this method, the garbage is dumped in low-lying area phase by phase. The garbage is levelled and the top surface is covered by a blanket of earth or ash. After a considerable time, the garbage is converted into compost soil. Though this soil has got the manurial value; such soil is not taken for cultivation because the garbage is dumped for the purpose of land filling only.

(c) By incineration The process of burning the garbage into ash is known as incineration. The garbage collected from the hospitals may contain bacteria of various diseases. So, such garbage should be burnt in the incinerator (i.e. burning plant) and converted to ash so that the bacteria are completely destroyed. This is a costly method. So, this method is applicable for the towns where sufficient land may not be available for the other methods of disposal.

Again, the garbage collected from other sources may be sorted into two groups—combustible and non-combustible. The combustible garbage may be burnt in incinerator and the non-combustible garbage is buried into the ground.

(d) By Pulverisation The method of grinding the garbage into powder is known as pulverisation. In this method, the garbage is first dried in the sun

for few days by spreading uniformly in the dumping ground. Then the grinding of the dried garbage is done in grinders to convert it to powder. This powder may be used as manure. This is a costly method. So, this method may be adopted in rich countries.

(e) By Composting In this method, the garbage is converted to manure in a mechanical compost plant. This is a hygienic method of garbage disposal. Here, the worthless materials may be obtained as useful materials like fertiliser. The mechanical compost is done in the following way:

(i) Primarily, the materials like paper pieces, cloth pieces, plastic, card board, etc. are separated by any suitable method.
(ii) The ferrous materials are separated by magnetic separator.
(iii) The remaining materials are pulverised.
(iv) The pulverised materials are subjected to fermentation in a mechanical compost plant for about 7 days.
(v) After this period, the materials are converted to compost manure.

(f) By Disposal into Sea In coastal towns, the disposal of garbage into the sea may be applicable. But the garbage should be discharged into the deep sea by studying the current and wave action of the sea so that it may not return to the shore again. This is an easy and cheap method of garbage disposal.

2.4 RECLAMATION OF LAND

Sometimes the garbage may be utilised for the reclamation of land such as filling of ponds, ditches, etc. for the purpose of construction of housing estate, multi-stories buildings, etc. But the filling of the ponds or ditches should be done in scientific way. The following procedure should be adopted for the reclamation of such low-lying areas:

(i) The raw garbage should never be discharged into the ponds or such area because it may create unhealthy situation in the neighbouring area.
(ii) The garbage should be dumped by the banks of the pond and left for about six months.
(iii) During this period, the garbage is converted into soil.
(iv) This soil is levelled gradually towards the centre of the pond.
(v) Stage by stage the pond is filled up from the bank towards the centre.
(vi) When the complete filling is done, the area is left for several years for proper consolidation of the soil.
(vii) After some years, the area may be depressed to some extent. Then, that depression may be filled up by fresh earth or by the soil converted from the garbage.
(viii) The process of reclamation of land may take several years.

2.5 RURAL SANITATION

In village area, the disposal of human excreta is generally done by temporary arrangements such as:

1. Aqua privy
2. Bore-hole privy
3. Tub or pail privy
4. Pit privy
5. Trench privy

   Now-a-days, different types of development works for rural sanitation are taken up by the Block Development Authority. Some developments are as follows:

6. Low-cost latrine with septic tank
7. Cesspool

1. Aqua Privy

As shown in Fig. 2.1, the aqua privy consists of three chambers constructed of brick masonry. The pan is placed over the top of first chamber. The pipe of the pan is extended up to 30 cm below the scum (i.e. floating night soil) level. The night soil directly falls to the first chamber. Here, the night soil is decomposed under anaerobic condition. The foul gas passes to second chamber through the opening at the top and finally escapes to the atmosphere by vent pipe. The liquid passes to the second chamber through a large opening at the bottom. In the second chamber, further decomposition takes place by aerobic bacteria. Then the effluent passes to the third chamber through a bent pipe. The third chamber is filled up with clinkers. Finally, the effluent is discharged through the effluent channel. The size of the chambers depends on the number of users.

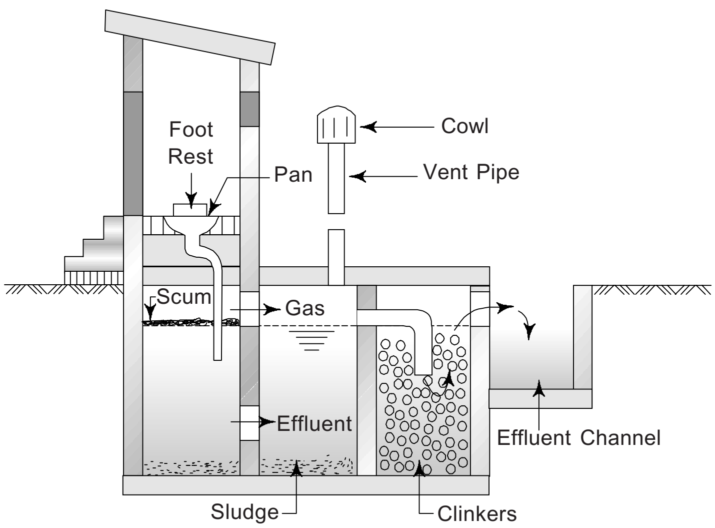


Fig. 2.1 *Aqua privy*

2. Bore-hole Privy

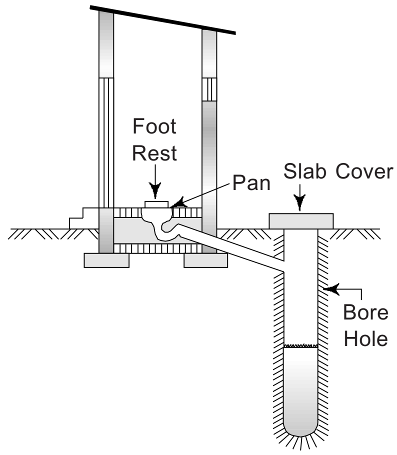


Fig 2.2 *Bore hole privy*

In this type of privy, the latrine is constructed with brick masonry having top cover with asbestos sheet or corrugated tin sheet. A hole is bored outside the latrine by auger. The diameter of the hole is generally 50 cm and depth 5 m. The pan of the latrine is connected to the bore hole by pipe line, as shown in Fig. 2.2. The top of the bore is covered by a slab. The excreta falls to the bore through the pipe. The water is absorbed by the surrounding soil and the excreta accumulated at the bottom. When the bore is nearly filled up, it is closed by dumping earth over it. A new hole is bored by the side of old one and the pipe line is connected to the new bore. After several months, the contents of the old bore may be taken out and the bore may be reused.

3. Tub or Pail Privy

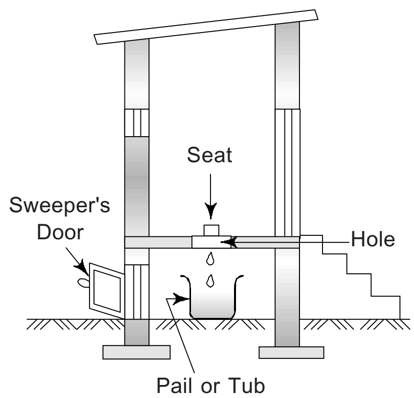


Fig. 2.3 *Tub or pail privy*

In this type of privy, a pail or tub is placed below the seat of the latrine. The night soil is collected in the pail. The pail is made of iron sheet in the shape of a box. As shown in Fig. 2.3, a door is provided behind the latrine for the sweepers to remove the contents of the pail every morning. This system entirely depends on the mercy of the sweepers. So, it may cause unhygienic conditions and fly nuisance, if the sweepers go on strike for any reason or there may be some other troubles.

4. Pit Privy

As shown in Fig 2.4, in this type of privy, a pit is excavated of suitable size. Two planks are placed over the pit. A temporary shed with bamboo post and bamboo hedge is constructed over the pit. In front of the privy, the screens of jute cloth are hanged for privacy. To reduce the bad odour, lime and ash are thrown in the pit from time to time. When the pit is nearly filled up, it is closed by earth or ash and a new pit is excavated. The temporary shed may be shifted over the new pit or constructed newly.

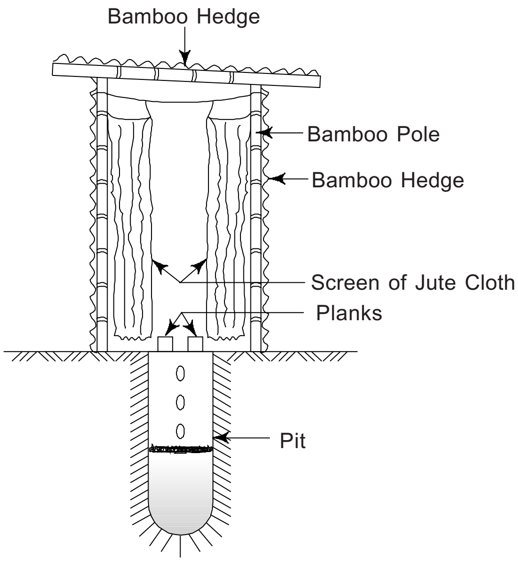


Fig. 2.4 *Pit privy*

5. Trench Privy

In this type of privy, a long trench of required width, depth and length is excavated. The three sides of the trench are covered with bamboo hedge supported by bamboo posts, as shown in Fig. 2.5. Then it is divided into several compartments. The fronts of the compartments are covered by screens of jute cloth for privacy. The top may be open or may be covered by bamboo hedge. The pairs of bamboo pieces are placed side by side as foot rest. These types of privies are purely temporary and mainly provided in fairs or festivals. However, the single privy of same type may also be provided in the house of villagers.

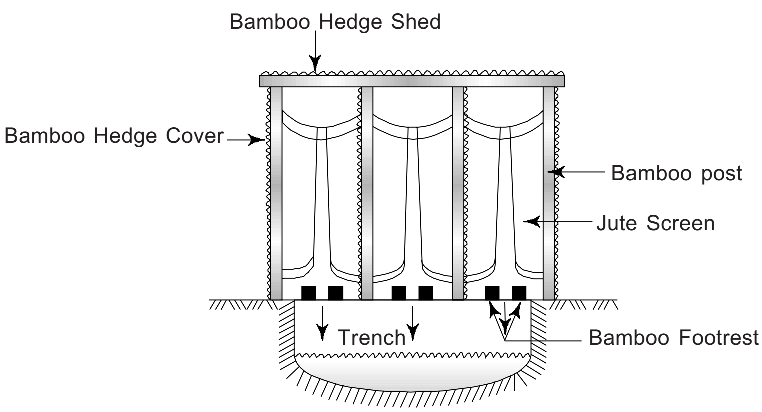


Fig. 2.5 *Trench privy*

6. Low-Cost Latrine with Septic Tank

In this types of latrine, a rectangular tank is constructed which is divided into two compartments by a baffle wall. A latrine is constructed over the first compartment, as shown in Fig. 2.6. A pan is set up suitably in the latrine. The outlet pipe of the pan should immerse to a depth of 30 cm below the scum level. The baffle wall consists of two openings, one at the top for the removal of foul gas and the other at the bottom for the flow of liquid from first chamber to second chamber. A manhole and a vent pipe with cowl are provided over the second chamber. The size of the rectangular tank depends on the number of users. The latrine may be constructed with brick masonry. But the top cover is usually given by asbestos sheet.

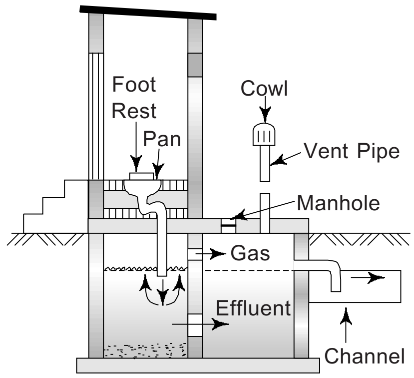


Fig. 2.6 *Low-cost latrine*

7. CessPool

The cesspool is a rectangular or circular chamber which is lined with brick masonry. The pan of the latrine is connected to the cesspool by waste pipe. As shown in Fig 2.7, the wall of the cesspool consists of several zigzag holes so that the water can be absorbed by the surrounding soil. The cesspool is covered with a slab which consists of a small hole for the removal of foul

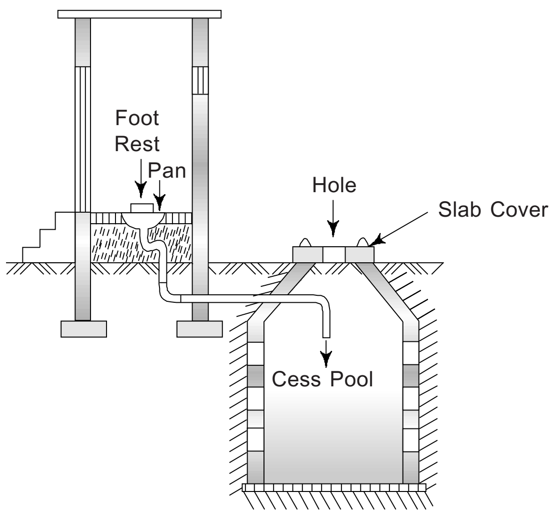


Fig. 2.7 *Cess pool*

gas. The top slab consists of hooks for its removal at the time of cleaning. When the cesspool is filled up, it can be emptied by manual labours or by pumping.

Review Questions

1. Enumerate the sources of solid waste.
2. Describe, how the solid waste is collected and removed.
3. What are the vehicles used for the removal of garbage?
4. Describe the process of disposal of solid waste.
5. What do you mean by reclamation of land? State the procedure adopted for the reclamation of land.
6. What are the different types of privies that exist in village area? Describe any two with sketch.
7. Write short notes on the following:
   (a) Aqua privy
   (b) Bore-hole privy
   (c) Pit privy
   (d) Pail privy
   (e) Trench privy
   (f) Cesspool.

3

Systems of Sanitation

3.1 INTRODUCTION

The system of sanitation involves the collection and disposal work of the solid waste (garbage) and liquid waste (sewage) in a systematic way so that the town or city may remain neat and clean and no insanitary condition may arise. Again, the purpose of well planned sanitations is to protect the people from infectious diseases. The refuse should be removed quickly from the town area so that the bad odour, fly nuisance and ugly environment may not arise. The following are the methods of collection and disposal of refuse:

1. Conservancy system
2. Water carriage system

The conservancy system is an old system and is employed in undeveloped towns. But, in modern developed cities the water carriage system is always adopted. Again, the water carriage system may be of three types:

(a) Separate system
(b) Combined system
(c) Partially separate system.

We shall study all the above topics in the followings sections.

3.2 CONSERVANCY SYSTEM

In this system, the garbage, sewage and storm water are collected and disposed of separately by the following ways:

(a) Garbage: The garbage is removed by the wheeled baskets from road side dust-bins, markets, cinema halls, hospitals, etc. and collected in heavy vehicles like trailors or trucks. And then it is conveyed to the dumping ground which should be far away from the town. At the dumping ground, the garbage is separated in two categories—flammable and inflammable. The flammable garbage should be burnt and the inflammable garbage should be dumped in ditches or low-lying areas.

(b) Sewage (i.e. Night Soil): The night soil which is collected in pans at the service latrines of individual houses is removed by the sweepers every day before dawn. The contents of the pans are collected in closed tankers which are drawn by tractors. When the tankers are filled up, they are taken to the night soil trenching ground which should be far away from the town area. The tankers discharge its contents to the night soil pits which are excavated in zig zag manner. Here, the night soil is left for natural treatment by sunshine. It takes too much time for complete decomposition and too much area for disposal.

(c) Storm Water and Sullage: The storm water and sullage are allowed to flow through the open drains and finally allowed to discharge into the river or stream. They do not require any treatment before disposal to natural watercourse.

Disadvantages

The following are the disadvantages of conservancy system:

(i) The compact design of building is not possible, because the lavatory must be constructed separately and away from the main building.

(ii) The decomposition of night soil starts after five hours from the time of production. But the night soil is normally removed after twenty four hours. So, it creates bad odour and fly nuisance around the building.

(iii) The night soil trenching ground requires large area for disposal.

(iv) This system extremely depends on the mercy of sweepers. If the sweepers go on strike for any reason, then the public health will be in danger.

(v) The movement of the night soil vehicles through the main roads or residential area is highly undesirable.

(vi) In rainy season or in floods, the night soil trenching ground may be submerged and it may cause water pollution and may lead to epidemic.

(vii) Initially it seems to be cheap, but the maintenance cost is very high.

The conservancy system has no advantage.

3.3 WATER CARRIAGE SYSTEM

The system in which water is used as a medium for conveying the sewage to the treatment plant and final disposal is known as water carriage system. Plenty of water is required to run this system satisfactorily. Here, the use of human power for collection and disposal of sewage is completely eliminated. The following works are involved in water carriage system:

1. Storm Water: The storm water may be carried separately or may be carried along with sewage through the underground conduits or sewers.

2. Sewage and Sullage: The sewage and sullage are carried by water through the underground sewers. Plenty of water is required for flushing the lavatories and urinals for easy conveyance. The quantity of water should be such that the dilution ratio between solid matters and water becomes very high and the mixture behaves like water. If the water supply remains suspended for a considerable time due to electrical or mechanical failure, then this system is highly affected. Due to lack of water, the sewer line may be choked or some other troubles may arise.

The installation of water carriage system is very costly, but still it is a scientific and hygienic method of sewage disposal. So, this system is always recommended for modern towns or cities.

Advantages

The following are the advantages of this system:

(i) This system permits compact design of building by accommodating the lavatories in a suitable part of it.
(ii) This is hygienic in nature, as the sewage is carried by underground sewers.
(iii) Less area is required for treatment works.
(iv) The water supplied to the consumers as per demand (i.e. per capita demand) is sufficient for flushing and carrying the sewage. No extra water is required for the sewerage system.
(v) It does not depend on the manual labours except in the case of cleaning of sewers when required.
(vi) There is no chance of any nuisance on the streets.
(vii) The self-cleaning velocity is effective in cleaning the sewers.
(viii) The sludge obtained from sewage treatment plant may be used as manure after proper digestion.

Disadvantages

The following are the disadvantages of this system:

(i) The system is very costly.
(ii) In rainy season, the large volume of sewage flows to the treatment plant which may exceed the normal capacity of the plant.
(iii) In case of any break of water supply, the system is highly affected.

3.4 COMPARISON BETWEEN CONSERVANCY SYSTEM AND WATER CARRIAGE SYSTEM

Table 3.1 lists down the differences between Conservancy and Water Carriage System.

Table 3.1

Sl. No.	*Conservancy System*	*Water Carriage System*
1.	Compact design of building is not possible.	Compact design of building is possible.
2.	Collection and disposal works are done above the ground.	Collection and disposal works are carried out by underground sewers.
3.	It is non-hygienic.	It is hygienic.
4.	It requires no water for conveyance.	It requires large amount of water for conveyance.

(*Contd.*)

Table 3.1 (*Contd.*)

Sl. No.	*Conservancy System*	*Water Carriage System*
5.	The sewage is disposed of without treatment.	The sewage is disposed of after treatment.
6.	Underground sources of water may be polluted.	There is no risk of pollution of underground water.
7.	Large number of labours are required for running the system.	Less number of labours are required for running the system.
8.	It depends on the mercy of sweepers.	It does not depend on the mercy of sweepers.
9.	No skilled labours are required for the maintenance of this system.	Highly skilled labours are required for the maintenance of this system.
10.	Initial cost is low but maintenance cost is high.	Initial cost is high, but maintenance cost is low.
11.	This system is applicable for undeveloped towns.	This system is applicable for developed cities.
12.	Large area is required for treatment and disposal.	Less area is required for treatment and disposal.

3.5 SYSTEMS OF SEWERAGE

The three systems of sewerage have been discussed below:

1. Separate System

This system consists of two sewer lines. One is meant for carrying the sewage to the treatment plant and the other is meant for carrying the storm water. The storm water is directly discharged into the river. After sewage treatment the effluent is also discharged into the river through separate sewer line.

The following are the advantages of this system:

(i) The storm water can be discharged into river directly without any treatment.
(ii) It reduces the load on the treatment plant.
(iii) There is no chance of pollution of river water, as the storm water is not foul in nature.
(iv) If due to change of grade or other inconvenience the sewage is required to pumped, it will impart less load to pumping unit.

The following are the disadvantages of this system:

(i) As two sets of sewer lines are required, it becomes costly.
(ii) The sewer line carrying the storm water remains idle in dry period. So, it may be clogged by garbage in that period.

2. Combined System

This system consists of a single sewer line of large diameter through which the sewage and storm water are allowed to flow and are carried to the treatment plant.

The following are the advantages of this system:

(i) The storm water dilutes the sewage and hence its strength is reduced.

(ii) The self-cleansing velocity is easily achieved.

(iii) Due to larger diameter of sewer, it can be easily cleaned.

(iv) As the single sewer line serves the double function, it becomes economical.

The following are the disadvantages of this system:

(i) The treatment plant is unnecessarily loaded with the combined volume of sewage and storm water. It may exceed the normal capacity of the plant.

(ii) During a heavy storm, the combined sewer may be overflown and it may create trouble for the people at large.

(iii) It creates unnecessary pollution of storm water.

3. Partially Separate System

This system consists of two sewer lines—one is of large diameter for carrying sewage and the other is of smaller diameter for carrying storm water only. When it rains, the storm water, at the beginning, is allowed to flow with the sewage through the larger sewer line. When the rain continues for a long time or it rains heavily, then the excess storm water is diverted to the smaller sewer line to discharge in the river directly. Thus, the load on the treatment plant is controlled and kept within the permissible capacity of the plant.

The following are the advantages of this system:

(i) It reduces the load on the treatment plant and the excess storm water may be safely discharged in the river.

(ii) It helps to maintain the self cleansing velocity in the larger sewer as the storm water is allowed partly.

(iii) The storm water from individual houses may be safely disposed of to the larger sewer.

The following are disadvantages of this system:

(i) The smaller sewer remains idle in dry season.

(ii) If the diversion of storm water is not done at proper time, then it may create unnecessary trouble both in the treatment plant and in the streets.

Review Questions

1. Describe the conservancy system and water carriage system.
2. State the advantages and disadvantages of conservancy system.
3. State the advantages and disadvantages of water carriage system.
4. Compare between the conservancy and water carriage system.
5. What are the various systems of sewerage? Describe the merits and demerits of each.

4

Quantity of Sewage and Storm Water

4.1 INTRODUCTION

The design the suitable section of sewers, it is always necessary to determine the quantity of sewage. The sewage consists of two categories—(a) Domestic or sanitary sewage, (b) Storm water.

The sanitary sewage which flows in dry season is known as dry weather flow (D.W.F.).

The combined flow of sanitary sewage and storm water in rainy season is known as wet weather flow (W.W.F.).

We shall study the methods of determination of dry weather flow and storm water in the following sections.

4.2 FACTORS AFFECTING THE QUANTITY OF SEWAGE OR D.W.F.

The following factors affect the quantity of D.W.F:

1. Rate of Water Supply

The quantity of sewage varies with the rate of water supply. The water supply is not constant throughout the day. It varies with the hours of the day. Again, it varies from day to day and even from season to season. So, to estimate the quantity of sewage, the rate of water supply should be taken into account. Generally, the rate of sewage is assumed equal to the rate of water supply. But, in practice, the rate of sewage should be slightly less than the rate of water supply due to evaporation loss and absorption loss. It is found that the rate of sewage is about 60 to 70 per cent of the rate of water supply.

2. Population

The quantity of sewage depends on the population of the town or city. With the increase in population, the quantity of water also increases. So, the population of the town or city after two or three decades should be ascertained by the suitable method of population forecast.

3. Nature of Area

The quantity of sewage depends on the area of the town such as residential area, industrial area, commercial area, etc. In residential area, the quantity of sewage is taken equal to the quantity of water supplied to consumers. In industrial area, the quantity of water varies with the types of industry. So, the quantity should be determined by actual survey of industry.

4. Infiltration

The subsoil water may percolate in the sewer through the defective joints or cracks in it. The joints may be defective due to poor materials and inferior workmanship. The cracks in the sewer may be formed due to careless handling during conveyances. Cracks may also be formed by the roots of the trees existing along the sewer line. However, it is very difficult to determine the quantity of water infiltrated to sewer. For design purpose, the quantity of water entering the sewer is assumed by considering the length of sewer, number of joints and the diameter of sewer.

4.3 DETERMINATION OF DRY WEATHER FLOW

The quantity of sewage (i.e. D.W.F.) is determined by considering the following three factors:

(i) The total quantity of sewage is taken equal to the quantity of water supply.

(ii) An additional quantity of water is considered for infiltration, private water supply arrangements, commercial and industrial water supply. It is determined by field inspection.

(iii) A subtraction should be made for leakage in pipe line, water consumption in drinking, cooking, washing, etc.

Thus,

Quantity of D.W.F. = (Total quantity of water supply)
+ (Addition due to infiltration etc.)
– (Subtraction due to leakage and consumption)

But, it is found by experiment that the quantity of D.W.F. is equal to 70 to 80 % of the total quantity of water supplied to consumers.

4.4 VARIATION OF FLOW OF SEWAGE

The flow of sewage is directly related to the flow of water supply. As water supply varies from hour to hour, day to day, month to month and season to season, the flow of sewage also varies accordingly. In designing the section of sewer, the maximum rate of flow is required. The maximum flow occurs early in the morning, i.e. 05–00 hrs. to 07–00 hrs., at noon 12–00 hrs to 14–00 hrs, at evening 18–00 hrs to 20–00 hrs. However, the peak flow of sewage should be ascertained by different observations.

4.5 FACTORS AFFECTING STORM WATER

The following are the factors affecting storm water:

(a) Intensity of Rainfall: If the intensity of rainfall is more, the corresponding storm water (run-off) will be more. Again, if this intensity is low, the corresponding storm water will also be low.

(b) Soil Characteristics: If the catchment area consists of rocky or clayey soil, the storm water will be more. Again, if the soil is sandy, the storm water will be low.

(c) Topography: If the ground slope of the area is steep, the storm water will be more. If the ground is flat and consists of depressions, the storm water will be low.

(d) Shape and Size of Catchment: If the catchment area is large and fan-shaped, the storm-water will be low.

(e) Geological Condition: It the catchment area consists of fissures, cracks, etc. the water losses will be more and hence the storm water will be low.

(f) Vegetative Cover in the Area: If the catchment area consists of plantation, forest area, etc., the storm water will be low.

(g) Weather Condition: If the temperature in the area is high, the evaporation loss will be high and hence the storm water will be low and vice versa.

4.6 DETERMINATION OF RAINFALL INTENSITY

When rainfall records are non-available, the intensity of rainfall is ascertained by the following empirical formulae.

(a) $i = \dfrac{672}{t+10}$ (For storm duration 5 to 20 mins)

(b) $i = \dfrac{1020}{t+10}$ (For storm duration 20 to 100 mins)

(c) $i = \dfrac{3430}{t+18}$ (Where rainfall is frequent, and more than 100 mins)

Here, i = intensity of rainfall in mm/hr.
t = storm duration in mins.

4.7 DETERMINATION OF RUN-OFF COEFFICIENT (K)

When the run-off coefficient is not given, but the nature of surface and impermeability factors of the area are known, then the value of K may be determined. Table 4.1 shows the nature of surface and impermeability factors (p).

Table 4.1

	Surface	Value of P
1.	Residential area with many buildings	0.70 – 0.90
2.	Residential area with detached houses	0.25 – 0.50
3.	Areas with few buildings	0.20 – 0.25
4.	Cultivated areas	0.15 – 0.20
5.	Forest areas	0.10 – 0.20
6.	Rough pasture and barren lands	0.10 – 0.20
7.	Gardens, lawn, parks, etc.	0.05 – 0.10

Now, the run-off coefficient (K) is given by the following expression:

$$K = \frac{a_1 p_1 + a_2 p_2 + ...}{A}$$

where, a_1, a_2 .... = Area of different surfaces.

p_1, p_2 .... = Impermeability factors of those surfaces.

A = Total surface area (a_1, a_2, a_3 ......)

Example 4.1

A catchment area consists of the following surfaces,

(a) Cultivated area = 50 hectares (p = 0.20)

(b) Forest area = 30 hectares (p = 0.10)

(c) Garden = 5 hectares (p = 0.05)

(d) Residential area = 15 hectares (p = 0.50)

Find the run-off coefficient of the area.

Solution

Here, total area = 50 + 30 + 5 + 15 = 100 hectares

From, expression, $$K = \frac{a_1 p_1 + a_2 p_2 + ...}{A}$$

$$= \frac{50 \times 0.20 + 30 \times 0.10 + 5 \times 0.05 + 15 \times 0.50}{100}$$

$$= \frac{20.75}{100}$$

$$= 0.2075.$$

Table 4.2 *Table Showing the Values of K for Different Surfaces*

	Nature of Surface	Value of K
1.	*Urban area*	
	30% impervious	0.40 – 0.50
	50% impervious	0.55 – 0.65
	70% impervious	0.65 – 0.30
	Residential area	0.30 – 0.40

(*Contd.*)

Table 4.2 (*Contd.*)

	Nature of Surface	*Value of K*
2.	*Rural area*	
	Cultivated area	0.30 – 0.60
	Rough pasture	0.10 – 0.40
	Forest area	0.10 – 0.40
	Area covered by huts	0.20 – 0.30

4.8 COMPUTATION OF STORM WATER

The storm water may be computed by

1. Rational method
2. Empirical formulae

1. Rational Method

In this method, the quantity of storm water is given by the expression,

$$Q = \frac{K \cdot i \cdot A}{360}$$

where, Q = storm water in cumec,
K = Run-off coefficient or impermeability factor
i = Intensity of rainfall in mm/hr.
A = Catchment area in hectares

Example 4.2

A catchment area of 20 sq km. consists of two-third rural and one-third urban area. The rainfall in the area is recorded as 25 mm/hr. Find the quantity of storm water in the area.

Solution:

Total area = 20 sq km = 20 × 1000 × 1000 sqm.
= 2000 hectares (1 hectare = 10,000 m^2)
Rural area = 2000 × 2/3 = 1333.33 hectares
Urban area = 2000 × 1/3 = 666.67 hectares
Intensity of rainfall, i = 25 mm/hr (given)
Assuming run-off coefficient,
K for rural area = 0.30
K for urban area = 0.50

Storm water, $$Q = \frac{K \cdot i \cdot A}{360}$$

or $$Q = \frac{0.30 \times 25 \times 1333.33 + 0.50 \times 25 \times 666.67}{360}$$

= 50.925 m^3/sec.
= 50925 lits/sec. ($1 m^3$ = 1000 lits)

2. Empirical Formulae

The empirical formulae are based on the experiences and experiments on various conditions, such as nature of surface area, intensity of rainfall, impermeability and the topography of the area concerned. The following are the empirical formulae that are generally adopted:

1. Inglis formula,

$$Q = \frac{123100\,A}{\sqrt{A + 10.36}}$$

where, Q = Storm water in lits.sec.
A = Area in km^2

2. Fanning's formula,

$$Q = 3125\ A^{5/8}$$

3. Talbot's formula,

$$Q = 87000\ A^{1/4}$$

4. Ryve's formula,

$$Q = 15\ CA^{2/3}$$

(C = A constant, its value varies from 450 to 675.)

5. Dicken's formula,

$$Q = 14\ CA^{3/4}$$

(C = A constant, its value is 250 for large area and 1600 for small area)

Review Questions

1. What are the factors which are considered in determining the quantity of dry weather flow?
2. Describe the procedure of determining the quantity of dry weather flow.
3. Explain the rational method of determining storm water.
4. State some empirical formulae for calculating the intensity of rainfall.
5. State some empirical formulae which are adopted for calculating the quantity of storm water.
6. How is impermeability factor determined?

5

Design of Sewers

5.1 INTRODUCTION

In sanitary engineering, the design of sewer is most important, because the success of sewerage system depends on it. After estimating the quantity of sewage and storm water, the diameter of main sewer, branch sewer, intercepting sewer, etc. should be designed properly. The design period should be taken as 30 years according to the population forecast for that period. The minimum and maximum velocities of flow of sewage should be maintained by providing suitable gradient so that the conditions of non-silting and non-scouring may be achieved.

In this chapter, we shall study all the topics relating to sewer such as section of sewer, materials of sewer, joints in sewer, ventilation of sewer, laying of sewer, etc.

5.2 MINIMUM AND MAXIMUM VELOCITY

The sewage contains suspended particles to a considerable amount. So, the minimum velocity should be such that the silting of those particles in sewer may not occur. Such minimum velocity is known as self-cleansing velocity. The self-cleansing velocity depends on the amount and size of suspended particles. Again, the amount of suspended particles depends on dilution factor. Considering the above factors, the minimum velocity should be achieved by providing suitable gradient in the sewer. Generally, the self-cleansing velocity varies from 70–100 cm per sec.

The maximum velocity should also be taken into account. The suspended particles may impart scouring action to the inner surface of sewer and may damage the sewer section. So, the maximum permissible velocity should be such that no scouring action may taken place. Such maximum velocity is known as non-scouring velocity. The non-scouring velocities for some sewer material are given on next page.

Table 5.1

Materials	*Non-scouring Velocity in cm/sec.*
Brick lined sewer	150 to 250
Cement concrete sewer	250 to 300
Stone ware sewer	300 to 450

5.3 EMPIRICAL FORMULAE FOR THE DESIGN OF SEWERS

1. Mean velocity by Chezy's formula.

   Velocity, $V = C\sqrt{mi}$ m/sec.

   where, V = mean velocity in m/sec.
   C = Chezy's constant.
   m = hydraulic mean depth in m.
   i = longitudinal slope or hydraulic gradient.

   The Chezy's constant (C) can be obtained by Bazin's formula or Kutter's formula.

2. Bazin's formula.

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

or

$$C = \frac{87}{1 + \dfrac{K}{\sqrt{m}}}$$

   where C, m = as above
   K = Bazin's constant.

Table 5.2 *Bazin's Constant*

Surface	*Value of K*
Very smooth surface	0.109
Brick and concrete surface	0.290
Rubble masonry surface	0.833

3. Kutter's Formula.

$$C = \frac{23 + \dfrac{0.00155}{i} + \dfrac{1}{N}}{1 + \left(23 + \dfrac{0.00155}{i}\right)\dfrac{N}{\sqrt{m}}}$$

   where, C, m, i = As above.
   N = Roughness coefficient or rugosity factor or Kutter's constant.

Table 5.3 *Rugosity Factor (N)*

Surface	*Value of N*
Smooth surface	0.010
Concrete surface	0.012
Stone ware pipe	0.013
Brick or stone masonry	0.017
Earthen channel	0.025

4. Mean velocity by Manning's formula.

   Velocity, $V = \frac{1}{N} \times m^{2/3} \times i^{1/2}$

   where, V, N, m and i = As above
5. Mean Velocity by crimp and Bruge's formula.

   Velocity, $V = 83.50 \times m^{2/3} \times i^{½}$

   where, V, m, i = As above.
6. Mean velocity by Hazen and Willian's formula.

   Velocity, $V = 0.85 \times C \times m^{0.63} \times i^{0.54}$

   where, V, m, i = As above,

   C = a coefficient. (given in Table 5.4)

Table 5.4 *Value of Coefficient C*

Type of Materials	*Value of C*
Cast-iron pipe	100
Brick sewer	100
Stone ware pipe	110
Cement lined pipe	110
Pipes with very smooth inside surface	140

Problem 5.1

Calculate the velocity of flow and the discharge through a sewer of diameter 1 m laid at a gradient of 1 in 500. Assume the sewer running full. Use Manning's formula with N = 0.012.

Solution

We know, Manning's formula

$$V = \frac{1}{N} \times m^{2/3} \times i^{1/2}$$

Given, Coefficient of rugosity, $N = 0.012$

Gradient, $i = \frac{1}{500}$, diameter $d = 1$ m.

Now, Area $A = \frac{\pi d^2}{4}$

Wetted perimeter, $P = \pi d$ (running full)

Hydraulic mean depth, $m = \dfrac{A}{P} = \dfrac{\pi d^2}{4 \times \pi d} = \dfrac{d}{4}$.

$\therefore \quad m = \dfrac{1}{4} = 0.25$ m

Velocity by Manning's formula

$$V = \frac{1}{0.012} \times (0.25)^{2/3} \times \left(\frac{1}{500}\right)^{1/2}$$

$= 1.479$ m/sec.

Discharge, $Q = A \times V$

$$= \frac{\pi \times (1)^2}{4} \times 1.479$$

$= 1.16\ m^3$/sec.

Problem 5.2

Design the diameter of combined sewer having the following data:

1. Area = 500 hectares
2. Population = 1,00,000
3. Water supply = 150 lits/capita/day
4. Intensity of rainfall = 15 mm/hr
5. Impermeability factor = 0.50
6. Maximum permissible velocity = 2.0 m/sec.

Assume reasonable data if necessary.

Solution

Assuming 80% of water supply appears as sewage.

Average discharge $= \dfrac{1,00,000 \times 150 \times 0.80}{24 \times 60 \times 60} = 139$ lits/sec.

Assuming maximum discharge as 1.5 times, the average discharge.

Max. discharge = 139 × 1.5 = 208.5 lits/sec,

$\therefore$ D.W.F = 208.5 lits/sec

Storm water is given by

$$Q = \frac{K\,i\,A}{360}$$

$$= \frac{0.50 \times 15 \times 500}{360}$$

$= 10.41\ m^3$/sec

= 10410 lits/sec.

where K = 0.50

i = 15 mm/sec

A = 1000 hectares

Combined discharge = 208.5 + 10410

= 10618.5 lits/sec.

i.e. $Q = 10.618\ m^3/sec.\ (1m^3 = 1000\ lits)$

Assuming, the sewer running full at maximum velocity

$$Q = A \times V, \qquad A = \frac{Q}{V} = \frac{10.618}{2} = 5.309\ m^2$$

where A = C/s area of sewer

V = 2m/sec. permissible Velocity

Let, d = diameter of sewer

So, $$\frac{\pi d^2}{4} = 5.309$$

or $$d = \frac{\sqrt{5.309 \times 4}}{\pi}$$

$\therefore$ $d = 2.6$ m.

Problem 5.3

A sewer of diameter 1m is to be laid along a road with self-cleaning velocity as 90 cm/sec. Find the gradient of the sewer line to achieve the said velocity considering the sewer running half filled. Assume Bazin's constant = 0.30.

Solution

Given diameter = 1 m

Bazin's constant = 0.30

$$\text{C/s Area} = \frac{\pi d^2}{4}$$

$$\text{Wetted perimeter } p = \frac{\pi d}{2}$$

$$\text{Hydraulic mean depth} = m = \frac{\pi d^2}{4} \times \frac{2}{\pi d}$$

$$= \frac{d}{2} = \frac{1}{2} = 0.5 \text{ m.}$$

Value of Chezy's constant, C is found out by Bazin's formula.

$$C = \frac{157.6}{1.81 \times \frac{K}{\sqrt{m}}} = \frac{157.6}{1.81 \times \frac{0.30}{\sqrt{0.50}}} = 70.54$$

From Chezy's formula,

$$V = C\sqrt{mi}$$

$$0.90 = 70.54 \times \sqrt{0.50} \times \sqrt{i} \text{ (Self-cleaning velocity = 0.90 cm/sec)}$$

or $$\sqrt{i} = \frac{0.90}{70.54 \times \sqrt{0.50}} = 0.018$$

$\therefore$ $$i = .0003 = \frac{1}{3333.3}$$

So, the gradient is 1 in 3333.33.

5.4 SECTION OF SEWER

Generally, the circular shaped sewers are adopted, the advantages of circular sewers are:

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

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

(i) They can be constructed in such a convenient size and shape so that a man can enter the sewer for cleaning, repairing, etc.
(ii) The process of construction is easy.
(iii) The structural strength is more.
(iv) The cost of construction is low.

The following are the non-circular sewers that are commonly adopted:

(a) Basket-Handle Section: In this sewer, the outer surface is circular. The inner surface is divided into two portions. As shown in Fig. 5.1, 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.

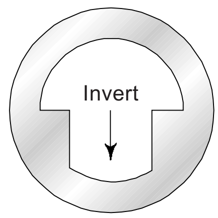


Fig. 5.1 *Basket-handle section*

(b) Egg-shaped Section: The egg-shaped section sewers may be of two types—normal egg-shaped and inverted egg-shaped. Both the sections are suitable for carrying D.W.F. and combined sewage. Figure 5.2 shows both types of egg-shaped section.

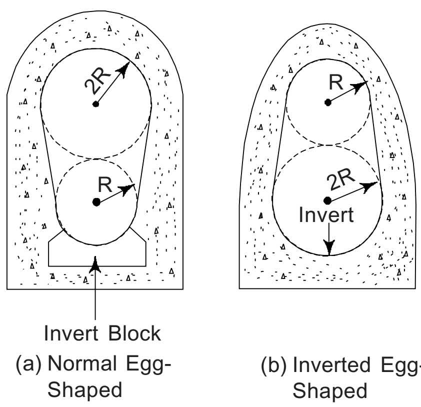


Fig. 5.2 *Egg-shaped section*

(c) Horse-Shoe Section: This type of sewer is constructed for carrying heavy discharge. This is like a tunnel and resembles a horse-shoe, as shown in Fig. 5.3. The size is so large that the maintenance works within the sewer are very easy.

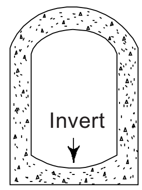


Fig. 5.3 *Horse-shoe section*

(d) Parabolic Section: As shown in Fig. 5.4, the upper surface of the sewer is in the shape of a parabola and the invert is in the shape of an ellipse. This type of sewer is suitable for carrying small discharge.

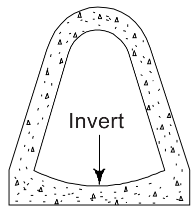


Fig. 5.4 *Parabolic section*

(e) Rectangular 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. Figure 5.5 shows a rectangular section.

(f) U-shaped Section: As shown in Fig. 5.6, this type of sewer resembles the letter 'U'. This sewer is suitable for carrying heavy discharge. The maintenance works are easy in this section. (Fig. 5.6).

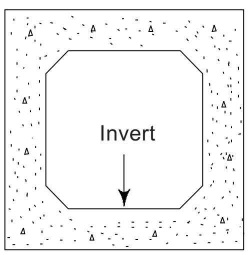


Fig. 5.5 *Rectangular section*

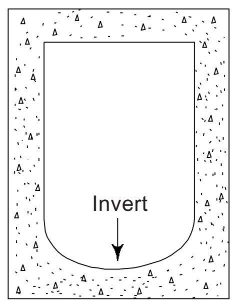


Fig. 5.6 *U-shaped section*

5.5 MATERIAL OF SEWER

The following material are used for sewers:

(a) Asbestos Cement Asbestos cement is a mixture of cement and asbestos fibre. Pipes are manufactured from this mixture over a rotating mandrel in uniform thickness. The diameter of the pipes varies from 5 cm to 100 cm. These pipes are very light and can be handled and transported easily and they are not affected by salts, acid and corrosive materials. The cutting, drilling, fitting and joining of the pipes can be done easily. These pipes are suitable for domestic sanitary fittings.

(b) Bricks The bricks are used for constructing large size sewers. The brick work should be done by cement mortar (1:5) and the inner surface is

plastered by rich cement morter (1:3) accompanied by neat cement polish. To prevent infiltration, the outer surface should also be plastered. The brick work can be done easily as bricks are available at all places at a cheap price. But, the sewer section should always be rectangular.

(c) Cast-iron The cast-iron can withstand high internal pressure and can bear external load. These are very heavy and difficult to transport. These pipes should be handled carefully, otherwise cracks may be formed due to sudden shock. These are resistant to corrosion, but if the sewage contains sulphates, then they may be affected by corrosion. However, the cast-iron pipes are suitable for city roads and in places where high external loads are suspected. The C.I. pipes are suitable for the following conditions:

(i) When the sewage is conveyed under high pressure.
(ii) When the sewer line is to be laid in exposed position or in suspension.
(iii) When heavy load is suspected to come over the sewer due to the movement of heavy vehicles.

(d) Cement Concrete The pre-cast cement concrete pipes are extensively used in the construction of sewers. The pre-cast pipes are manufactured with mild steel re-inforcement by centrifugal process. These are known as 'Hume pipes'. The diameter of hume pipes varies from 10 cm to 200 cm and length varies from 1m to 3m. These are strong and smooth. But these are very heavy and difficult to transport. The pipes are joined by collar joints.

(e) Plastic Previously, the plastic pipes were not used for carrying sewage. Now, the P.V.C. pipes are used for sewer lines for carrying industrial sewage and in domestic sanitary fitting. These are resistant to corrosion. These pipes may be available in diameter varying from 5–15 cm and of longer length. They are light in weight and can be bent easily.

(f) Stone Ware The stone ware pipes are manufactured from vitrified clay by moulding and burning to a temperature of about 1200°C in a kiln. During the process of burning, sodium chloride is spread on the surface of the pipe so that a glass-like appearance comes on the pipes. This is known as glazing. The diameter of the pipe varies from 10–60 cm and the length varies from 90–120 cm. These are resistant to corrosion and abrasion. But these are brittle and may be damaged if handled carelessly. These are generally used in domestic sanitary fittings.

5.6 JOINTS IN SEWERS

The following are the common joints in sewers:

(a) *Bell and Spigot Joints:* See Part-I, Section 4.8 (i)
(b) *Collar Joints:* See Part-I, Section 4.8 (ii)
(c) *Flexible Joint:* See Part-I, Section 4.8 (v)
(d) *Expansion Joint:* See Part-I, Section 4.8 (iii)
(e) *Flanged Joint:* See Part-I, Section 4.8 (iv)

5.7 SECTION OF SURFACE DRAINS

The following sections are adopted for the construction of surface drains:

1. Rectangular section
2. Semi-circular section
3. U-shaped section
4. V-shaped section.

1. Rectangular Section

In this type, two vertical walls are constructed on a concrete foundation. The thickness of the walls depends on the size of the drain. Again, the depth and width of the drain depends on its required carrying capacity. The inner surface is plastered with rich cement mortar (1:3) and finished with neat cement polish. The bottom edges are rounded-off for smooth running of the sewage as shown in Fig. 5.7. This section is suitable for carrying high discharge.

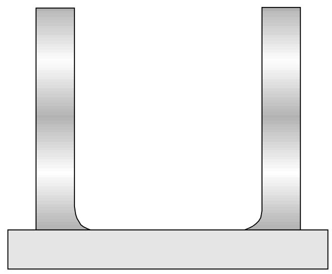


Fig. 5.7 *Rectangular section*

2. Semi-circular Section

Figure 5.8 shows the semi-circular section. It is constructed by casting plain cement concrete (1:3:6) in the shape of a semi-circle. The inner surface is finished with neat cement polish over a rich cement plaster (1:3). The radius (*r*) of the drain depends on the carrying capacity. These are suitable for low discharge.

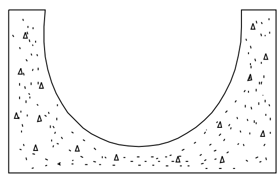


Fig. 5.8 *Semi-circular section*

3. U-Shaped Section

In this type of drain, the bottom surface is made curved and it is constructed with plain cement concrete (1:3:6). The two sides are constructed with brick work. As shown in Fig. 5.9, the sides are vertical and the bottom is curved. So, it resembles the letter 'U'. This is practically a combination of rectangular and semi-circular section. The inner surface is finished with neat cement polish. This is suitable for medium discharge.

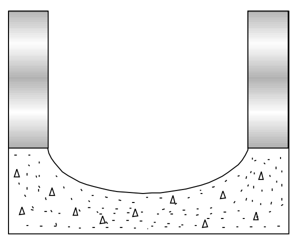


Fig. 5.9 *U-shaped section*

4. V-shaped Section

In this type of drain, the bed block is constructed with plain cement concrete. The sides are made sloping and the brick soling is done according to the slope. Then thick cement mortar (1:6) is laid and levelled properly to form a bed. On this prepared bed, concrete blocks of size 50 cm × 50 cm are set with rich cement mortar (1:3) as shown in Fig. 5.10. The inner surface is finished with neat cement polish. The shape of this drain resembles letter '*V*'. This section is suitable for low discharge.

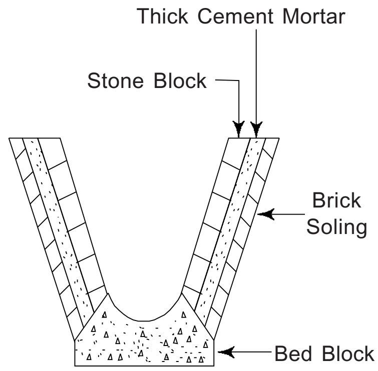


Fig. 5.10 *V-shaped section*

5.8 LAYING OF SEWER

The laying of the sewer consists of the following steps:

1. Marking of the Alignment

The alignment (i.e. centre line) of the sewer is marked along the road with a theodolite and inver tape. The centre line may be marked according to the following two methods:

(a) By reference line
(b) By sight rail

(a) By Reference Line: Figure 5.11 explains the method of reference line. In this method, a reference line is marked along any side of the busy roads by theodolite and inver tape. The points F_1F_2 …. are on the reference line. The starting point (P_1) of the centre line is marked with a peg. Then the distance F_1P_1 is measured by inver tape. Now the other points P_2, P_3, P_4 …. etc. are marked pegs by taking as $F_1P_1 = F_2P_2 = F_3P_3$ …. etc. Thus, the points P_1, P_2, P_3 … etc. will represent the centre line of the sewer. This centre line may be checked by the theodolite.

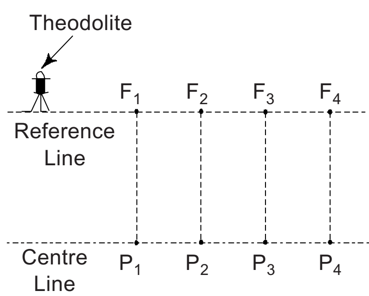


Fig. 5.11 *Reference line*

(b) By Sight Rail: As shown in Fig. 5.12, in this method, two vertical posts are driven at suitable distance apart. Then by ranging through a theodolite the centre line is marked with nail on a sight rail which is fixed on the vertical posts. The sight rail should be fixed in such a way so that its upper edge just coincides with the line of sight. The centre line of the sewer is transferred to the ground by plumb bob with respect to the nail. The

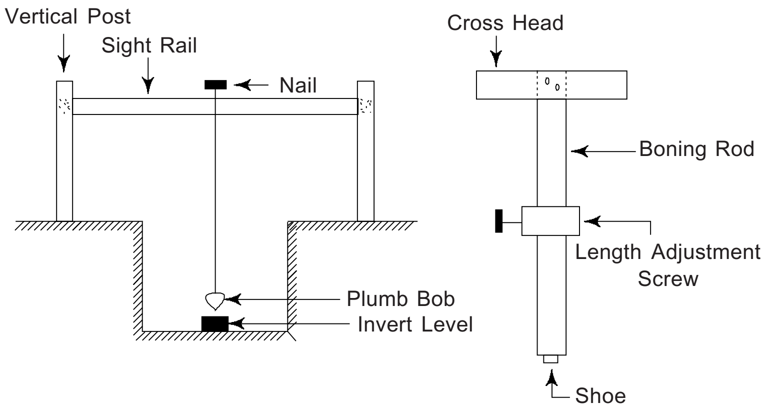


Fig. 5.12 *Sight rail*

distance between the upper edge of sight rail and the invert level is determined and noted on the sight rail for finding the exact invert level by boning rod. The length of boning rod is adjusted according to the height as noted in sight rail. The cross-head is levelled with the upper edge of sight rail and the bottom edge indicates the invert level.

2. Excavation of Trench

Figure 5.13 explains the way of marking for the excavation of trench. The width of the trench (W) is marked on the road which is about 15 cm more than the external diameter or external dimension of sewer. At the probable point of joining, the width of the trench (W_1) is made 60 cm more than the external diameter and a length (L) of about 60 cm is kept clear for the operation of joining. The position of manhole is also marked according to its dimension.

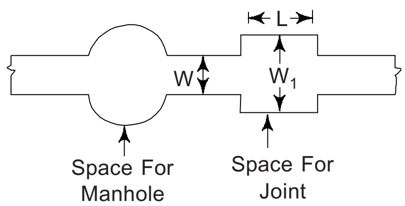


Fig. 5.13 *Excavation of trench*

Now, the excavation is started according to the marking. The invert level is fixed by boning rod, which is adjusted according to the height written in sight rail. The cross-head of boning rod is levelled with the upper edge of sight rail and the verticality of rod is maintained by plump bob. The bottom edge of the shoe will indicate the invert level. In this way, the excavation is continued.

3. Bracing of the Trench

Timber bracings or sheet piling should be provided on both sides of the trench so that it may not collapse due to rain or any reason during the process of laying and joining.

4. Dewatering of Trench

Due to percolation of subsoil water or sudden rainfall, the trench may be filled up with water. So, the dewatering of the trench should be done by pumping before the laying of sewer pipes or construction of sewers.

5. Laying and Joining of Pipes

The bed of the sewer lines is prepared by plain cement concrete (1:3:6). The thickness of concrete varies from 15–20 cm. After proper curing, the pipes are laid along the trench very carefully to avoid cracking or breaking of pipes. Then the operation of joining is performed according to the recommended joint as per the type of pipe material. After completion of joining, both sides of the pipe are finished with concrete, as shown in Fig. 5.14.

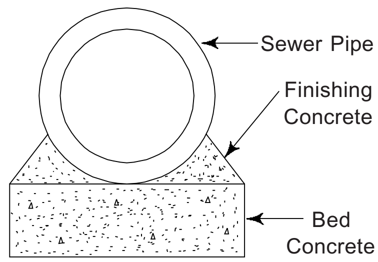


Fig. 5.14 *Concrete bed*

6. Testing of Leakage

The leakage in the pipe joints or any point in the pipe line is tested by the following two methods:

(a) By Water Test: This test is carried out between two manholes. In the lower manhole, the end of the sewer is plugged and in the upper manhole, the other end is kept open. The pipe end of previous section is kept plugged. It has been shown in Fig. 5.15. Then the water is allowed to flow in the sewer line from the upper manhole until the sewer is completely filled up. The depth of water in the upper manhole is raised up to 1 m above the sewer. The water is allowed to stay in the sewer for a week. Then the sewer line is inspected to detect the leakage by observing any sweating. If the leakage is detected, it is rectified immediately.

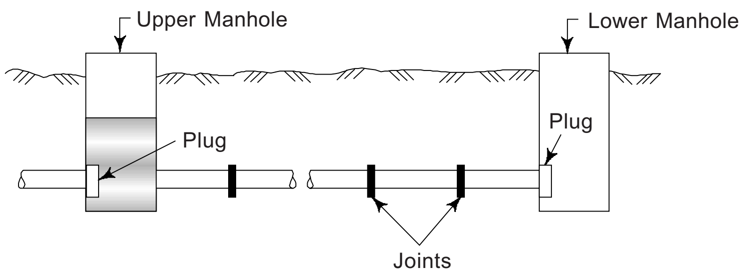


Fig. 5.15 *Water test*

(b) By Air Test: Figure 5.16 explains the procedure of air test. This test is carried out for large diameter sewer. The pipe ends of both the manholes are

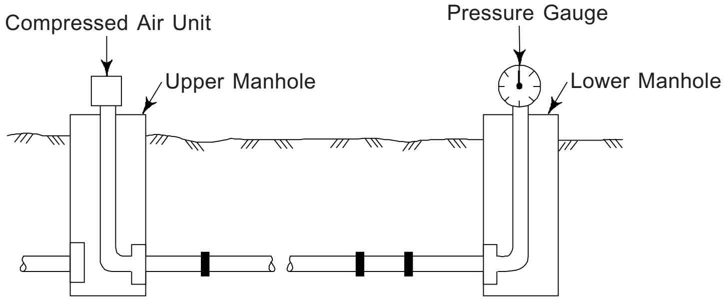


Fig. 5.16 *Air test*

plugged. An air compressor is connected to the plug of upper manhole and pressure gauge is attached with the plug of lower manhole. The pressure exerted by the compressed air is recorded in the pressure gauge. It is left for few hours. If the pressure drops below the permissible limit, then it is an indication of leakage. The exact point of leakage is found out by applying soap solution which will show bubbles at the point of leakage. If leakage is detected, it should be removed immediately.

7. Back Filling

After the completion of testing and removal of leakage (if any), the trenches are filled up with the excavated earth. The earth filling is done in stages. At first, the earth is laid to a thickness of 15 cm above the sewer and it is watered and rammed gently. Then, further layer of earth of thickness 15 cm is laid and rammed properly. Then the back filling is stopped for about 7 days. Finally, the trench is filled up completely with a projection of about 15 cm above the ground level.

5.9 RELATION BETWEEN DIAMETER, GRADIENT, VELOCITY AND DISCHARGE

Table 5.5 *Table Prepared Based on Crimp's Formula*

Diameter in mm	*Gradient for velocity = 0.75 m/sec.*	*Gradient for velocity = 0.90 m/sec.*	*Gradient for velocity = 1.05 m/sec.*
150	1 in 150	1 in 150	1 in 78
225	1 in 265	1 in 180	1 in 135
300	1 in 385	1 in 270	1 in 195
375	1 in 520	1 in 355	1 in 265
450	1 in 660	1 in 460	1 in 340
525	1 in 820	1 in 570	1 in 415
600	1 in 970	1 in 680	1 in 500
675	1 in 1100	1 in 790	1 in 580
750	1 in 1300	1 in 910	1 in 670
900	1 in 1650	1 in 1200	1 in 850
1050	1 in 2100	1 in 1450	1 in 1050
1200	1 in 2500	1 in 1700	1 in 1250

Table 5.6 *Relation between Diameter, Gradient and Discharge (As per I.S.–1742–1983)*

Diameter in mm	*Gradient*	*Discharge in m^3/min*	*Remark*
100	1 in 57	0.18	Table prepared
150	1 in 100	0.42	based on
200	1 in 145	0.73	Manning's
230	1 in 175	0.93	formula taking
250	1 in 195	1.10	Self cleansing velocity as
300	1 in 250	1.70	0.75 m/sec.

Table 5.7 *Relation between Diameter, Gradient and Discharge (As per I.S.–1742–1983)*

Diameter in mm	*Gradient*	*Discharge in m^3/min*	*Remark*
100	1 in 5.6	0.59	Table prepared
150	1 in 9.7	1.32	based on
200	1 in 14	2.40	Manning's formula
230	1 in 17	2.98	where it is not possible
250	1 in 19	3.68	to provide ruling gradient
300	1 in 24.5	5.30	and self-cleansing velocity

5.10 REQUIREMENTS OF SURFACE DRAIN

The following should be the requirement of surface drain:

(a) The self-cleansing velocity should be developed with minimum discharge.
(b) Sufficient free board should be adopted.
(c) The surface should be smooth so that it can be cleaned easily.
(d) It should be strong to resist scouring action.

5.11 CONSTRUCTION OF SURFACE DRAIN

The construction of surface drain should be done according to the following stages:

Stage 1. Marking the Centre Line of Drain

The centre line of the surface drain is marked on the ground on both sides of the road. The width of the drain is marked by spade.

Stage 2. Excavation of Trench

The trench is excavated according to the width and depth. The excavated earth is heaped on one side of excavation leaving sufficient space between the heaps for supplying materials of construction.

Stage 3. Protection of Sides of Trench

Sometimes the construction may not start immediately after the excavation. In that case, the side protection should be done. In loose soil, the side protection is a must but, in hard soil, the side protection can be avoided. The side protection is done by sheet piling with timber planks or iron sheets which may be supported by struts, wooden blocks and timber wedges as shown in Fig. 5.17.

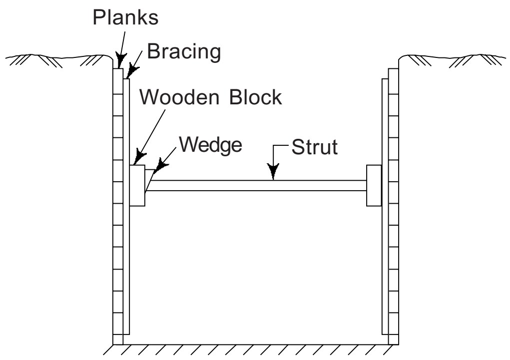


Fig. 5.17 *Side protection of trench*

Stage 4. Preparation of Subgrade

The subgrade is prepared by ramming a layer of sand (about 15 cm). Then a layer of brick bats (15 cm) is laid over the sand layer and rammed perfectly to make the surface compact and levelled.

Stage 5. Construction

Over the compact subgrade a layer of cement concrete (1:3:6) is laid to a thickness of 15 cm. The sides of the drain may be constructed with brick masonry with cement mortar (1:6) or may be constructed with re-inforced cement concrete (1:2:4). The inside surface of the drain should be plastered with rich cement mortar and finished with neat cement polish. Curing should be done for 7 days.

Stage 6. Earth Filling

After proper curing, the hollow spaces on both sides of the drain are filled with excavated earth and rammed lightly.

Review Questions

1. How is the centre line of sewer marked on the ground?
2. How is the leakage of sewer tested?

3. Write short notes on:
   (a) Bucket-handle section
   (b) Egg-shaped section
   (c) U-shaped section
   (d) Horse-shoe section
4. What are the different types of surface drains? Describe them with sketches.
5. Describe the sewer joints with sketch.
6. Describe the characteristics of different types of sewer materials.

6

Sewer Appurtenance

6.1 INTRODUCTION

For the efficient working, cleaning and repairing of the sewer, some structures are constructed along the sewer line at some specific points which are known as sewer appurtenance. The following are the important structures:

1. Manhole
2. Drop manhole
3. Lamp hole
4. Catch basin
5. Street inlet
6. Grease and oil trap
7. Flushing tanks
8. Inverted siphon
9. Ventilating shaft
10. Storm regulator

6.2 MANHOLE

A hole which is made from the ground level to the underground sewer for the entrance of men for inspection, cleaning and repairing works, is known as a manhole. The manholes are provided at specified interval, change of direction, change of grade, junction points, etc.

Depending upon the depth, the manholes may be shallow, normal and deep. The depth below 1 m is considered as normal manhole and the depth above 1.5 m is considered as deep manhole.

As shown in Fig. 6.1, the deep manhole is constructed with brick masonry over a concrete foundation. The bottom portion is wider which is known as working chamber and the upper portion is narrower which is known as access shaft. The access shaft is made narrow by corbelling or by providing R.C.C. slab as offset.

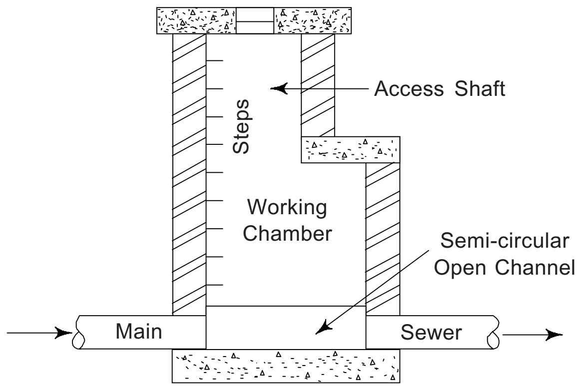


Fig. 6.1 *Manhole*

The following are the components of a deep manhole:

(a) Access Shaft The access shaft may be rectangular or circular. The minimum size of the rectangular shaft should be 90 cm × 100 cm and minimum diameter of circular shaft should be 90 cm. The height of the shaft depends on the height of the working chamber. The shaft serves the purpose of removing the debris from the sewer and acts as a passage for the workers to conduct the maintenance works.

(b) Working Chamber The purpose of working chamber is to provide sufficient space for the workers for cleaning the sewer and for conducting maintenance works. The height of the working chamber should be 2 m so that a worker can work comfortably. The size of rectangular chamber should be 120 cm × 150 cm and diameter of circular chamber should be 120 cm.

(c) Steps The steps are provided on the wall of the manhole for the entry and exit of the workers. The steps may be made of cast iron which are embedded in the wall in zig-zag manner. If the manhole is too deep, then it is better to provide a ladder instead of steps.

(d) Invert The main sewer just ends at both sides of the manhole. A semi-circular section channel is constructed to connect the two ends so that there is an open channel within the manhole. The sides of the channel are made sloping with concrete. This is known as benching. The sediments or obstructions in the sewer are pushed towards the manhole and these are collected in the open channel from where those are taken out through the access shaft.

(e) Manhole Cover Generally, the manhole cover is circular and made of cast-iron. The cover should be thick and heavy and stable enough to resist the wear and tear caused by moving vehicles. The diameter of the cover should be 60 cm to 75 cm so that a man can enter the manhole easily. The frame of the cover is embedded in road pavement and the cover is placed on the groove firmly.

6.3 DROP MANHOLE

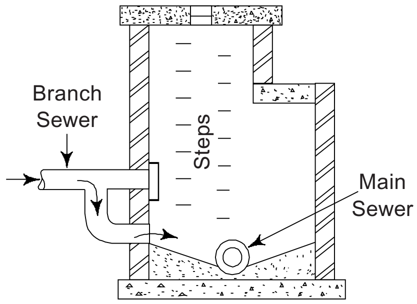


Fig. 6.2 *Drop manhole*

A manhole which is constructed to connect the high level branch sewer to the low level main sewer by vertical dropping pipe is known as drop manhole. As shown in Fig 6.2 a branch sewer passes at higher level and the main sewer runs at lower level. So the sewage will fall in the main sewer in the form of a spring. This will cause much inconvenience to the workers at the working chamber. So, the end of the branch pipe is plugged and a vertical dropping pipe is taken from the branch pipe and connected to the manhole near the bottom to allow the sewage to fall in main sewer smoothly. Steps are provided in zigzag manner for the entry and exit of the workers.

6.4 LAMP HOLE

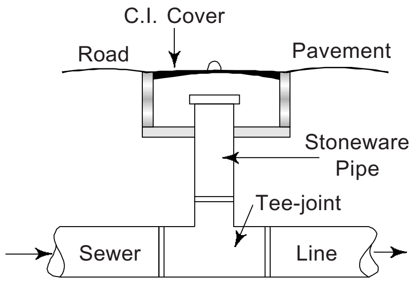


Fig. 6.3 *Lamp hole*

A hole or opening which is provided in a sewer line for lowering a lamp inside is known as Lamp hole. It is a vertical pipe made of stoneware which is connected to the sewer by a Tee-joint. At the top a box-line compartment is made which carries a cast-iron cover. The cover may be solid or perforated as shown in Fig. 6.3.

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

(i) When the spacings of regular manholes are at longer interval.
(ii) When it is difficult to construct a regular manhole.
(iii) When a change of direction or change of grade comes in the sewer line.

The following are the functions of lamp hole:

(i) By removing the C.I. cover, an electric lamp is inserted into the sewer. If the sewer is clear, the light will be visible from the adjacent manholes. If there is any obstruction, the light will not be visible from the manholes. Then the operation of clearing will be done accordingly.
(ii) For clearing the obstruction, the flushing devices may be applied through the lampholes.
(iii) If the C.I. cover is made perforated, then it will serve the purpose of ventilation of sewer or the removal of sewer gases.

6.5 CATCH BASIN

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

The basin is constructed with brick masonry with a perforated C.I. cover at the top. The storm water on the pavement directly enters the basin through the C.I. cover. Moreover, the road curb is provided with grating for the entry of storm water into the basin. The basin is connected to the sewer by a pipe having its hood within the basin as shown in Fig. 6.4. This prevents the sewer gas to escape to atmosphere through the basin. The clear storm water is allowed to enter the sewer and the sediments are arrested at the bottom of the basin which is cleared at a regular interval or when required.

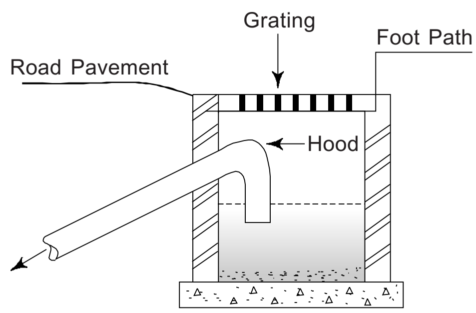


Fig. 6.4 *Catch basin*

6.6 STREET INLET

The street inlets are the openings provided by the side of roads to allow the storm water to enter the sewer directly without accumulating on the road pavement. The spacing of inlets should be 20 m and should be provided on both sides of the road.

The inlets may be vertical or horizontal. A box-like compartment is constructed with brick masonry. In vertical type, a grating is provided on the road curb just at the edge of foot path, as shown in Fig. 6.5(a). In horizontal types, a perforated cover is placed on the top of the chamber, as shown in Fig. 6.5(b).

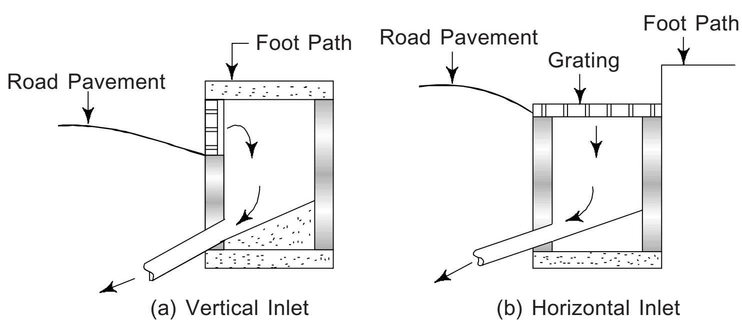


Fig. 6.5 *Street inlet*

6.7 GREASE AND OIL TRAP

The traps or chambers which are constructed on the sewer line for excluding grease and oil from the sewage are known as grease and oil traps. If sewage contains grease and oil, it sticks to the interior surface of the sewer and ultimately get hardened. This decreases the carrying capacity of sewer gradually. So, those oily materials must be removed. The sources of those materials are automobile repairing workshops, kitchens of hotels and restaurants, oil manufacturing industries, etc. The traps should be provided by surveying the location of those areas.

Figure 6.6 shows the grease and oil trap. The trap is a rectangular chamber having baffle walls at the middle. The sewage containing grease and oil enters the chamber through the inlet grating. The sand, grit, etc. are accumulated at the bottom of the first chamber. The grease and oil floats over the second chamber. The sediments and the floating substances (grease and oil) should be removed from time to time.

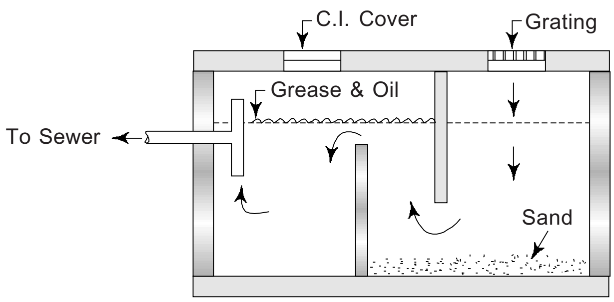


Fig. 6.6 *Grease and oil trap*

6.8 FLUSHING TANK

The flushing tank is a device by which the water is released automatically at some interval for flushing the sewer line. This device is required at places where self-cleansing velocity in the sewer cannot be obtained due to some reason. Figure 6.7 shows a flushing tank. It consists of a U-tube encased in a compartment. The longer arm is extended in the water tank and a bell or hood is placed over the free end. The shorter arm is connected to the sewer line through a straight pipe. Initially, the water level in the U-tube stands at a-a′. The water is supplied to the tank through a flow regulator.

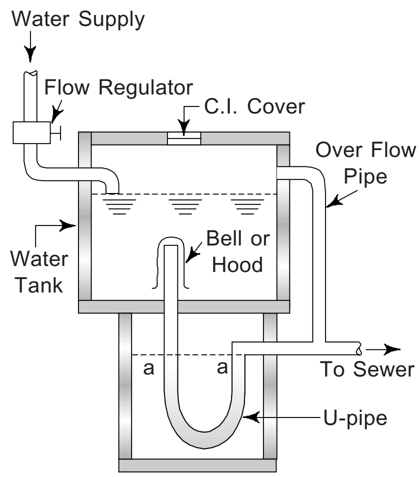


Fig. 6.7 *Flushing tank*

When the water level in the tank increases, the water level in the bell also increases. Ultimately, a stage comes when the siphonic action starts and the water rushes through the sewer clearing all the sediments. The water supply is so regulated that the siphonic action starts at some interval. The siphonic action stops when the water level comes below the bell mouth. After discharging water the level in the U-tube stands again at the line 'a-a'. The capacity of the tank should be quite adequate for flushing the sewer line properly.

6.9 INVERTED SIPHON

During the laying of sewer line, a position may come when it is not possible to maintain the same gradient due to some obstructions such as crossing of railway line, roads, etc. In that case, the inverted siphon should be provided. The condition of siphonic action is that the pipe or tunnel should run full all the time. But in dry season the discharge may not be sufficient to run the inverted siphon full. So, instead of one single line, three single lines, i.e. three lines (S_1, S_2 and S_3) are provided. The flow of sewage is guided by the weirs (W_1, W_2 and W_3), as shown in Fig. 6.8. In dry period, the sewage spills over the weir W_1 and flows through the pipe S_1 only. When the level rises above the weir W_2, the sewage flows through the pipes S_1 and S_2. In rainy season, when the storm water increases the volume of sewage and the level rises above the weir W_3, then the sewage flows through the pipes S_1, S_2 and S_3 simultaneously.

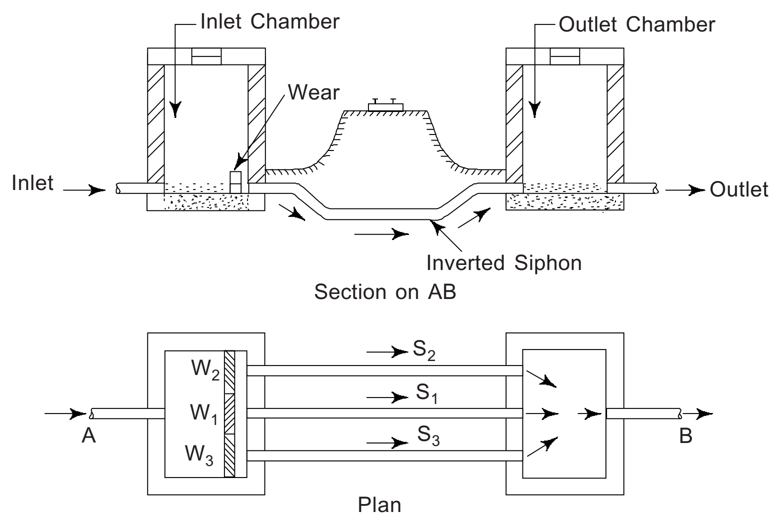


Fig. 6.8 *Inverted siphon*

The inverted siphon may be constructed by cast-iron pipes or hume pipes. If the length of siphon is too great, a vent pipe should be provided in the siphon to prevent air locking.

6.10 VENTILATING SHAFT

The ventilating shaft is provided for the ventilation of sewer. Various gases are produced in the sewer due to the decomposition of organic matters. Some gases may be harmful to workers. Some gases may be highly explosive and may cause explosion in the sewer; some gases may be corrosive and may cause corrosion to sewer pipes. So, by constructing ventilating shaft in the sewer line, these gases are removed. The shaft may be provided at an interval of 100 m. The shaft may be made of C.I. pipes or hume pipes of diameter 15 cm. A cowl is provided on the top. The base of the shaft is wide and secured in concrete foundation. The shaft is directly connected to the sewer or manhole. The height of the shaft should be such that the foul gases may not cause any danger to human health. Figure 6.9 shows a ventilating shaft.

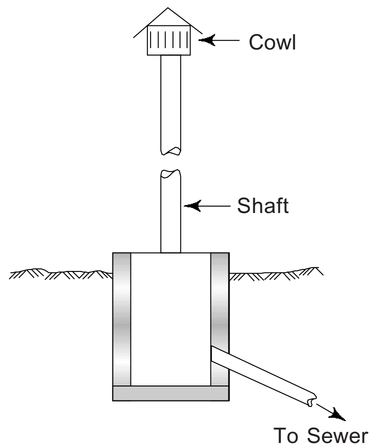


Fig. 6.9 *Ventilating shaft*

6.11 STORM REGULATOR

In dry season, the combined sewer has to carry small discharge of sewage (i.e. dry weather flow). But in rainy season the discharge increases due to storm water. Sometimes, the intensity of rainfall becomes so great that the quantity of storm water is enormously increased. During that period, the discharge may exceed the normal capacity of the combined sewer and it may even exceed the permissible capacity of the treatment plant. So, some devices are adopted for the diversion of the excess storm water to the river or stream. The following are the common devices:

(a) Leaping Weir This arrangement is done within a manhole. It consists of an adjustable weir and lip which are adjusted in such a way so that the permissible discharge of sewage is allowed to flow over the crest of the weir and directly fall in the sanitary sewer. When the discharge is increased enormously due to heavy rainfall, the excess storm water jumps over the crest of the weir and falls on the lip which carries the storm water to the river or stream. Figure 6.10 explains the working of leaping weir.

(b) Overflow Weir In a manhole, the combined sewer is made as an open channel. The channel consists of a weir on one side. Sometimes, weirs may be provided on both sides. In normal condition, the combined sewage flows through the open channel. But, when the quantity of storm water is increased due to heavy rainfall, it exceeds the normal capacity of the combined sewer. In that case the excess water spills over the weir and falls on the storm water sewer which carries the water to the outfall, as shown in Fig. 6.11.

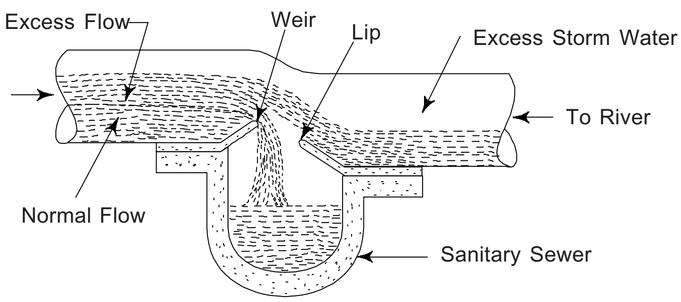


Fig. 6.10 *Leaping weir*

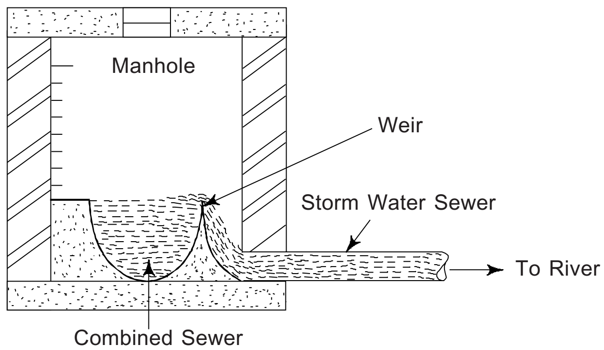


Fig. 6.11 *Over flow weir*

(c) Siphon Spillway In this system, the upper end of the siphon is connected to the combined sewer and the lower end is connected to the storm water sewer. As shown in Fig. 6.12, a priming pipe is connected between the combined sewer and the throat of the siphon. The function of the siphon spillway is as follows:

(i) The throat of the siphon is kept at the maximum permissible level in the combined sewer.

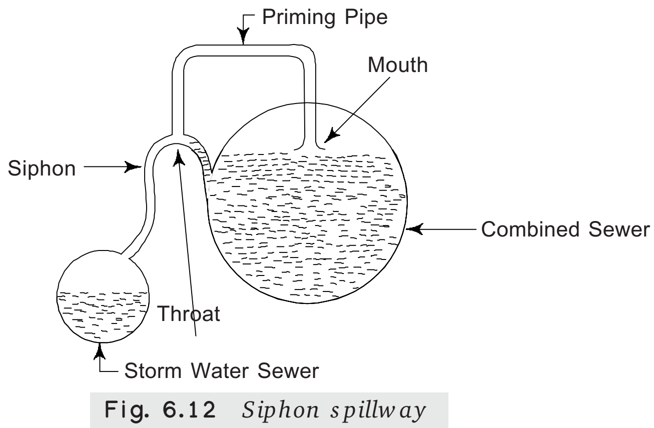


Fig. 6.12 *Siphon spillway*

(ii) The siphonic action does not start when the level of the combined sewage is just below the maximum level.
(iii) When the level in the combined sewer goes above the throat of siphon and the mouth of priming pipe is submerged, the air in the pipe is sucked by the flowing water and suddenly siphonic action starts. Then the excess water starts flowing to the storm water sewer.
(iv) The siphonic action continues till the mouth of the priming pipe remains under water.
(v) After discharging the excess water, the mouth of the pipe gets exposed and air enters the pipe. Then the siphonic action is stopped. This process is repeated when the above condition comes again.

6.12 NECESSITY OF SEWAGE PUMPING

The pumping of sewage is necessary in the following conditions:
(a) The whole portion of a town or city may not be situated in a level ground. Some portion of sewer line may be constructed in low level areas. In that condition, pumping is necessary to lift the sewage from the lower sewer line to higher sewer line;
(b) When the general slope of a town or city is such that the required gradient cannot be maintained;
(c) In case of underground shopping complex or when basement is provided in a building;
(d) When the treatment plant is constructed at a site which is higher than the level of main sewer line.

6.13 SEWAGE PUMPS

The following types of pumps are provided for the pumping of sewage:
(a) Centrifugal Pump.
(b) Reciprocating Pump
(c) Air Pressure Pump or Ejector.

The centrifugal and reciprocating pumps are described in Chapter 5 of Part-I—Water Supply.

Air Pressure Pump or Ejector

There are many ejectors manufactured by different companies out of which 'Shone's Air Ejector' is commonly used which is described below:

Components Figure 6.13 shows a Shone's ejector. It consists of the following components:
(a) A cast iron cylindrical chamber in which a spindle is provided. The spindle again carries two cups—upper and lower.
(b) Two reflux valves are provided, one at the entrance side and other at the exit side.
(c) A lever is pivoted at a suitable point and it carries a counter-weight at one end.

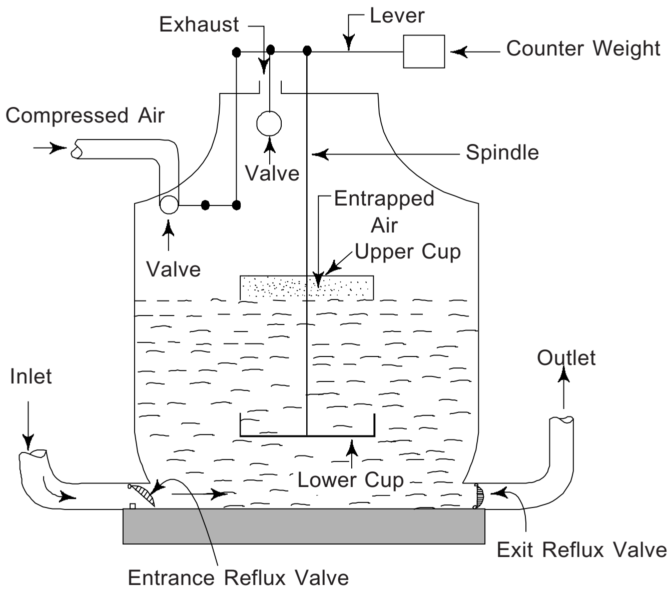


Fig. 6.13 *Shone's ejector*

(d) Two ball valves are attached with the lever—one at the mouth of air compressor and the other at the mouth of exhaust pipe. The valves are adjusted in such a way that when one valve closes, the other valve opens simultaneously during the up and down motion of the spindle.

Working: The working principle is as follows:

(a) At the beginning, the compressed air valve and exit reflux valve remain closed and the entrance reflux valve and exhaust valve remain open.

(b) The sewage enters the chamber through the entrance valve and the air inside the chamber escapes through the exhaust pipe. The level of sewage goes on increasing gradually.

(c) When the level of sewage reaches the bottom of upper cup, the air inside the cup is entrapped. On further increase in sewage level the entrapped air exerts pressure on the spindle. The spindle is lifted up and the lever action starts.

(d) The lever is pivoted in such a way that the exhaust valve is closed and compressed air valve is opened simultaneously.

(e) The compressed air forces the sewage to flow through the outlet pipe by opening the exit reflux valve.

(f) The flow of sewage continues until the sewage level falls below the bottom of upper cup.

(g) The pressure on the spindle is released and by lever action the exhaust valve is opened and compressed air valve is closed. The sewage again flows to the chamber. This process is repeated automatically.

Advantages The advantages of an Air Pressure Pump or ejector are:

(a) The operation of the ejector is automatic and hence no supervision is required.
(b) The primary treatment of sewage is not necessary.
(c) There is no chance of clogging.
(d) No pumping station is required.

Disadvantages The only disadvantage of this system is that it is not suitable for high discharge and its efficiency is low.

Review Questions

1. Describe the component parts of a manhole.
2. What is drop manhole? What are its objects? How is it constructed?
3. What is a flushing tank? Describe with a sketch.
4. Describe a grease and oil trap with sketch.
5. What is a inverted siphon? Describe its function with sketch.
6. What is a lamphole? Mention its objects. Describe a lamp hole with sketch.
7. Mention the objects of storm regulator. Name the types of storm regulators.
8. Explain the working of leaping weir with a neat sketch.
9. Describe an overflow weir with sketch.
10. Explain the working of siphon spillway with sketch.
11. Write short notes on:
    (a) Street inlets
    (b) Automatic flushing tank
    (c) Inverted siphon
    (d) Leaping weir
    (e) Drop manhole
    (f) Grease and oil trap

7

Characteristics of Sewage

7.1 INTRODUCTION

The study of characteristics of sewage plays an important role in sanitary engineering, because the process of treatment should be determined according to the characteristics. Again, the treatment should be such that the effluent can be disposed of to the natural water sources safely. The characteristics are divided into three categories:

1. Physical characteristics
2. Chemical characteristics
3. Biological characteristics

Before carrying out the testing of sewage, the sampling should be done properly. The testing involves the following:

1. Physical tests
2. Chemical tests
3. Biological tests

Again, the treatment of sewage involves the determination of following factors:

1. Biochemical oxygen demand (B.O.D.)
2. Chemical oxygen demand (C.O.D.)

In this chapter, the characteristics and examinations are described stage by stage.

7.2 DEFINITION OF SOME TERMS

1. Algae The unicellular plants which contain chlorophyll are known as Algae. The algae absorb carbon-dioxide and release oxygen by the process of photosynthesis.

2. Fungi The fungi are also unicellular plants, but they do not contain chlorophyll. They are colourless and can decompose starch, sugar, cellulose, fats, proteins etc. The yeast is a kind of fungi.

3. Protozoa These are unicellular worms. They can destroy pathogenic bacteria, but they survive by eating other bacteria.

4. Bacteria The microscopic unicellular organisms are known as bacteria. The bacteria may be harmful or harmless to human being. But the presence of bacteria is essential for the decomposition of sewage.

5. Pathogenic Bacteria The bacteria which are responsible for waterborne diseases like cholera, dysentry, typhoid, etc. are known as pathogenic bacteria.

6. Non-pathogenic Bacteria The bacteria which are harmless to human being are known as non-pathogenic bacteria.

7. Aerobic Bacteria The bacteria which require light and free oxygen for their survival are known as aerobic bacteria.

8. Anaerobic Bacteria The bacteria which do not require light and free oxygen for their survival are known as anaerobic bacteria.

9. Facultative Bacteria The bacteria which can survive with or without the presence of light and free oxygen are known as facultative bacteria.

10. B-coli The pathogenic and non-pathogenic bacteria form a group which is known as bacillus coli group. This group is briefly known as B-coli. This group of bacteria is present in the intestines of all living animals.

11. E-coli The most common type of coliform group is Escherichia coli which is briefly known as E-coli. The germs of E-coli are discharged from the faeces (i.e. stool) of human being.

7.3 PHYSICAL CHARACTERISTICS

The following are the physical characteristics of sewage:

1. Specific Gravity The specific gravity of sewage is slightly more than that of water.

2. Colour The fresh sewage has yellowish grey colour. As the decomposition goes on, the colour also goes on changing. It becomes black when the sewage attains the septic stage. The colour of the industrial sewage depends on the waste products.

3. Odour The fresh sewage has soapy or oily odour. But the stale or septic sewage has offensive odour due to hydrogen sulphide and other gases.

4. Temperature The temperature of sewage is slightly higher than the temperature of water supplied. While passing through the conduits the temperature rises and the bacterial activities start.

5. Turbidity The turbidity of sewage is due to the suspended particles.

6. Solids The sewage contains 0.1% of solid matters and 99.9% of water. The solid matters may be suspended, dissolved or in colloidal states. Again, the solids may be inorganic or organic. The inorganic solids are grits, sand, etc. and organic solids are cellulose, sugar, starch, etc.

7.4 CHEMICAL CHARACTERISTICS

The following are the chemical characteristics of sewage:
1. The fresh sewage is alkaline in nature, and the septic sewage is acidic in nature.

2. Organic Compounds

(i) Nitrogeneous compounds: It include urea, proteins, amino acids, etc.
(ii) Non-nitrogeneous compounds: It include fats, soaps, carbohydrates, etc.

3. Inorganic Compounds It include sand, gravel, grit, etc.

4. Colloidal Matters It include silt, clay, etc.

7.5 BIOLOGICAL CHARACTERISTICS

The sewage contains the following bacteria and microorganisms:

1. Bacteria The bacteria may be of the following types:

(i) Pathogenic Bacteria: This is the root of all water-borne diseases.

(ii) Non-pathogenic Bacteria: This is practically harmless to human being.

(iii) Aerobic Bacteria: It helps the decomposition of sewage in oxidation ponds, lagoons, etc.

(iv) Anaerobic Bacteria: It helps the decomposition of sewage in septic tank, cesspool, etc.

(v) Facultative Bacteria: This bacteria has no function in sewage treatment.

2. Microorganisms The microorganism like algae, fungi and protozoa help the process of decomposition of sewage by photosynthesis or by breaking the organic compounds.

7.6 SAMPLING OF SEWAGE

The following are the procedures of collecting the sample of sewage for the various laboratory tests:

(i) The samples of sewage are collected at an interval of one hour during the day.
(ii) The sampling bottles should be of capacity 100 c.c. to 150 c.c.
(iii) The bottles should be cleaned properly before taking the samples.
(iv) The bottle should be closed tightly by stopper as soon as it is filled up.
(v) The bottle should be kept in a cool place.
(vi) The samples should be collected from different points of the sewer.
(vii) The analysis of sewage should be started within two hours from the time of collection.
(viii) The date, time and place of collection of sample should be noted on the bottles.

7.7 NECESSITY OF TESTING OF SEWAGE

The following points may be considered as the reasons for the necessity of testing of sewage:

(i) To determine the strength, character and the stage of sewage for adopting proper treatment of sewage and the method of disposal.
(ii) To regulate the treatment plant according to variation in the nature of sewage.
(iii) To recommend the type of treatment to be adopted for the particular sample of sewage.
(iv) To adopt optimum treatment to sewage to obtain the effluent of high quality.

7.8 PHYSICAL TESTS

The physical tests include the following observations:

1. Colour The colour indicates the nature of sewage whether it is fresh or septic. The light brown colour indicates fresh sewage. The dark or black colour indicates septic. The colour of industrial sewage depends on the discharge of industrial wastes. The colour of the sewage can be easily identified by naked eye. So, the shade of colour should be properly observed and designated accordingly and noted against the sample. However, to designate the colour the platinum cobalt scale may be used.

2. Turbidity The turbidity of sewage is due to the suspension of fine particles. It is measured by turbidity rod or jackson's turbidimeter. Turbidity is expressed as ppm (i.e. part per million). It is also expressed as mg/lit. Practically, turbidity is phenomenon of resistance offered by water or liquid to the passage of light. The standard unit of turbidity is given by one part of finely divided silica in million parts of distilled water.

3. Temperature The temperature cannot be controlled by any treatment. So, the test for the temperature has no significance in sewage analysis. Still, the temperature of the sample of sewage should be noted as the biological activities depend on the temperature. At greater temperature the biological activities are high and viscosity is low. When viscosity is low, the efficiency of treatment plant is more.

4. Odour The odour indicates whether the sewage is fresh or septic. Some industrial wastes also impart odour to the sewage. However, the odour may be tested in laboratory in terms of threshold number and noted against the sample. The number may be helpful to know the stage of sewage and necessary treatment may be given accordingly.

7.9 CHEMICAL TESTS

The chemical tests involve the determination of following factors:

1. Total solids
2. Chlorine demand

3. Dissolved oxygen
4. Biochemical oxygen demand
5. Chemical oxygen demand
6. Nitrogen
7. pH-value
8. Grease, oil and fats.

1. Total Solids

It is very essential to know the quantity of total solids in sewage. Because, it helps to know the rate of deposition of sludge in the primary sedimentation tank and at the same time it is possible to indicate the organic and inorganic substances in sewage which help in the sewage treatment. The amount of total solids are found out as follows:

A known amount of sewage (say 1 lit) is taken and the water is evaporated at 100°C. The residue is dried properly and weighed. The weight of the dry residue represents the total solids. Again, the total solids may be of two types:

(i) Volatile solids.
(ii) Suspended solids.

(a) Volatile solids The dried total solids (as obtained previously) are heated or ignited in electric furnace. After ignition, the remaining solids are weighed. The loss of weight will indicate the volatile solids present in sewage. The volatile solids are due to the presence of organic matters.

(b) Suspended Solids The solids which settle down due to the phenomenon of hydraulic subsidence are known as suspended or settleable solids. The amount of settleable solids are found out as follows:

A conical glass vessel, known as Imhoff cone, is taken. Figure 7.1 shows an Imhoff cone. The capacity of the cone is 1 lit and it is graduated in ml from the bottom. The sample of sewage of quantity 1 lit is taken in the cone and it is allowed to rest for about two hours. The amount of solids settled at the bottom of the cone is read from the graduation. Now to know the exact amount of settleable solids the moisture from the sediment is removed and weighed.

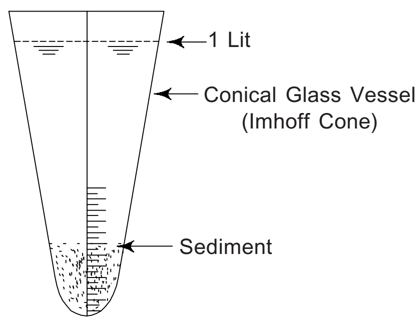


Fig. 7.1 *Imhoff cone*

2. Chlorine Demand

A requisite amount of chlorine is required to break up the organic matters present in sewage and for killing the pathogenic bacteria. The necessity of this chlorine is known as chlorine demand. It is found out by the process of break-point chlorination (as described in chapter—Chlorination).

3. Dissolved Oxygen

The oxygen in dissolved state in sewage is required for the living organisms to perform their metabolic process. Again, it is very essential in precipitating and oxidising inorganic substances. The amount of dissolved oxygen depends on the temperature of sewage. However, the determination of dissolved oxygen in sewage is a very complicated process. It may be determined in the laboratory by using the reagents manganese sulphate, concentrated sulphuric acid, starch indicator, sodium thiosulphate, etc.

4. Biochemical Oxygen Demand (B.O.D.)

The function of oxygen is to oxidise the inorganic and organic matters in sewage. Again, the presence of oxygen is required for the survival of organisms. These organisms are responsible for the aerobic decomposition of organic matters. When the oxygen is exhausted, the anaerobic decomposition starts which is indicated by foul smell. Now, the quantity of oxygen required for the biological decomposition of sewage under aerobic condition should be worked out. This demand of oxygen is known as biochemical oxygen demand or B.O.D. (Details of B.O.D. is given in art. 7.13)

5. Chemical Oxygen Demand (C.O.D.)

The amount of oxygen which is required for the chemical decomposition of organic matters in sewage is known as chemical oxygen demand (C.O.D.). The tests for C.O.D. is required to know the contents of organic matters which should be oxidised by chemical oxidising agents. (Details of C.O.D. is given in art 7.14)

6. Nitrogen

Nitrogen may be present in sewage in the forms of free ammonia, albuminoid ammonia, nitrates or nitrites. The various forms of nitrogen indicate the following stages:

(i) The presence of free ammonia indicates that the sewage is stale.
(ii) The presence of albuminoid ammonia indicates the undecomposed nitrogenous matters.
(iii) Nitrites indicate the stage of conversion of organic matters to stable form.
(iv) Nitrates indicate the stable form of nitrogenous matters. The determination of all the above factors are the guidelines for the results achieved by the sewage treatment plant.

7. pH-value

The pH-value of sewage is to be determined to know its nature—whether it is acidic or alkaline. The treatment methods depend on the pH-value. At the beginning, the fresh sewage is alkaline in nature, but it is converted to acidic nature after few hours. The bacteria cannot survive in acidic sewage. However, the pH-value of sewage is determined by electrometric method or colourimetric method. (As described in Chapter 6—Part-I)

8. Grease, Fat and Oil

The presence of grease, fat and oil are undesirable in sewage, as it may disturb the working of trickling filter and may form some deposits in sewers and treatment plants. Initially, these are eliminated by traps and prevented from entering the sewer. But, still some traces may remain in sewage. The quantity of oily substances is determined by evaporating the sample of sewage. Then the remaining substances are dissolved in ether. When ether is evaporated, it gives the quantity of grease, fat and oil present in sewage.

7.10 BIOLOGICAL TESTS

The biological tests are carried out to know the presence of bacteria, fungi, algae, protozoa, etc. The presence of some bacteria is essential for the decomposition of sewage. But, the presence of pathogenic bacteria indicates the degree of pollution in sewage. So, necessary measure should be taken to kill the pathogenic bacteria. The presence of fungi, algae and protozoa is necessary for the treatment of sewage. The biological tests are carried out by microscope and by studying the biological character of the bacteria. The helpful bacteria are allowed to develop under the favourable conditions. They form colonies and help to decompose the organic substances present in sewage.

7.11 DECOMPOSITION OF SEWAGE

The function of bacteria in sewage is to break up the complex organic compounds into simple and stable compounds. The decomposition of sewage by bacteria may be of the following two types:

1. Aerobic Decomposition

Aerobic decomposition is caused by the aerobic bacteria in presence of plenty of oxygen. This type of bacteria cannot survive without oxygen. This decomposition is also known as oxidation. In this process, the aerobic bacteria break up the organic matters and the organic matters are oxidised to form stable compounds. After oxidation the compounds like carbon dioxide, nitrates, sulphates etc. are formed. The aerobic decomposition occurs in contact beds, oxidation ponds, trickling filters, etc.

2. Anaerobic Decomposition

Anaerobic decomposition is caused by the anaerobic bacteria in absence of oxygen. This type of bacteria can survive without oxygen. This decomposition is also known as putrefaction. The anaerobic bacteria break up the complex organic compounds and convert them into solids, liquids and gases. After putrefaction, the compounds like humas (black residue), ammonia methane, hydrogen sulphide, etc. are formed. The anaerobic decomposition occurs in septic tanks, Imhoff tanks and sludge digestion tanks.

7.12 CYCLES OF DECOMPOSITION

As per universal law, the matters remain constant, only the change of state occurs. Similarly, in biochemical reactions some cycles of decomposition are developed like an endless chain. As for example, organic matters are broken up by biochemical reactions and simple compounds are formed. The plants consume those compounds for their growth and formation of food grains. Again, the animals or human beings consume those plants or food grains for their growth. Ultimately, the organic matters return from the waste products of animals or human beings. It is found that the cycles of decomposition may be of three types:

1. Carbon cycle
2. Nitrogen cycle
3. Sulphur cycle

1. Carbon Cycle

The decomposition of organic carbonaceous matters forms carbon dioxide. The plants consume the carbon dioxide by the process of photosynthesis. Thus plant carbohydrates, fats and proteins are formed. Animals consume the plants and thus the animal fats and proteins are formed. Again, the waste products of animals form the organic carbonaceous matters. In this way, the cycle of carbon is completed. The carbon cycle is also shown in Fig. 7.2.

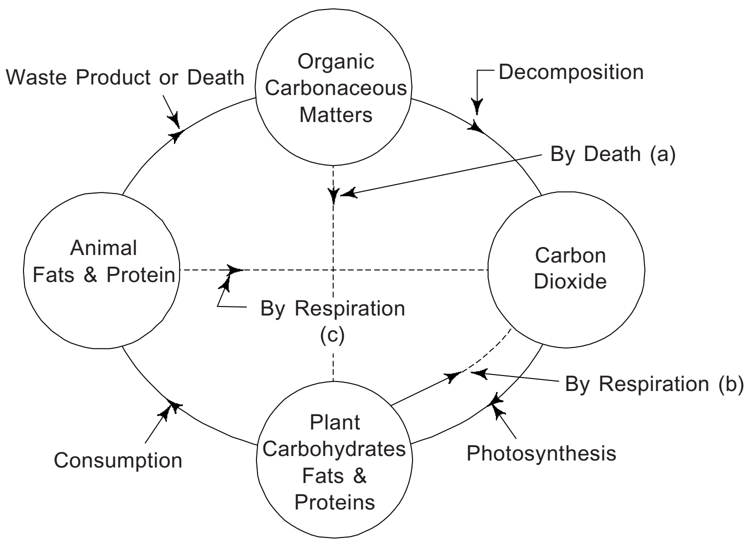


Fig. 7.2 *Carbon cycle*

The actual cycle is shown by firm line and the dotted lines show the subsidiary cycle of carbon as for example

(a) Death of plants may be converted to organic carbonaceous matters.
(b) The plants exhaust carbon dioxide at night by respiration.
(c) The animals also exhaust carbon dioxide by respiration.

2. Nitrogen Cycle

As shown in Fig. 7.3 the decomposition of organic nitrogeneous matters forms ammonia and nitrogen. Then by the process of nitrification, ammonia and nitrogen are transformed into nitrite, nitrate and free nitrogen. Plants consume these products and plant proteins are formed. Animals consume the plants and thus animal proteins are formed. The waste products or death of animals form the organic nitrogeneous matters again. Thus the nitrogen cycle is completed. The following are the subsidiary cycles:

(a) Death of plants forms organic nitrogeneous matters.
(b) Nitrate nitrogen may be converted to ammonia and nitrogen by denitrification.

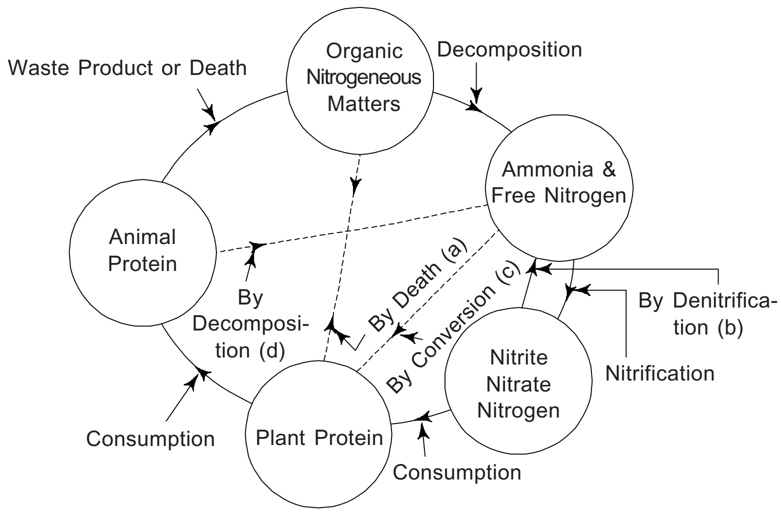


Fig. 7.3 *Nitrogen cycle*

(c) The plant proteins may also be obtained by conversion from nitrogen due to some bacteria.
(d) Ammonia and nitrogen may also be obtained by the decomposition of the waste products of animals.

3. Sulphur Cycle

Hydrogen sulphide is formed by the decomposition of organic sulphurous matters. Sulphates are formed by the oxidation of hydrogen sulphide. As shown in Fig. 7.4, plants consume the sulphates and thus plant proteins are formed. Animals consume the plants and thus animal proteins are formed.

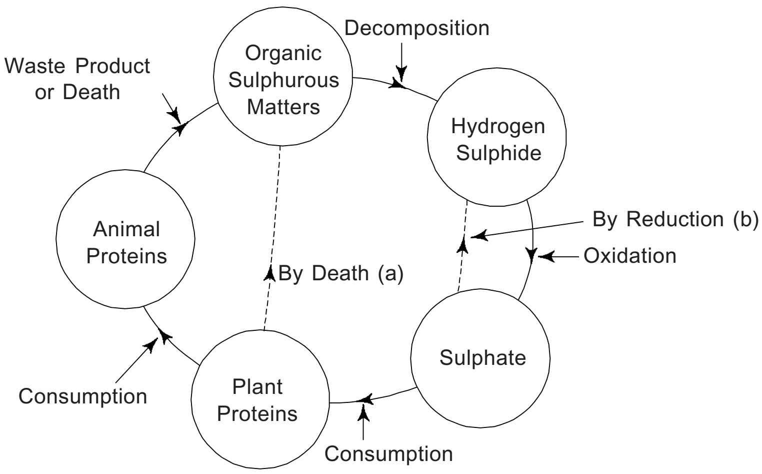


Fig. 7.4 *Sulphur cycle*

Again, the waste products or death of animal form the organic sulphurous matters to complete the cycle. This cycle is known as sulphur cycle. There are two subsidiary cycles:

(a) The death of plants may be converted to organic sulphurous matters.
(b) The sulphates may be transformed to hydrogen sulphide by the process of reduction.

7.13 DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND (B.O.D.)

The demand of oxygen for the biochemical decomposition of organic matters in sewage is known as biochemical oxygen demand (B.O.D.).

The B.O.D. test is necessary to know the amount of oxygen, required by the bacteria for oxidising the organic matters under aerobic condition for 5 days or 10 days at standard temperature of 20°C. This test helps to know the strength of sewage and to know the amount of clear water necessary for the disposal of sewage by dilution.

The B.O.D. test is carried out by the dilution method. In this method, the following procedure is adopted:

(a) The dissolved oxygen in clear water is first found out and noted.
(b) The sample of sewage is diluted by this water and the dilution ratio is noted. Generally, the dilution ratio is 1:100.
(c) The diluted sewage is then kept in an airtight glass bottle for 5 days at 20°C for incubation. During this period, some amount of dissolved oxygen is consumed by bacteria.
(d) After this period, the amount of dissolved oxygen remaining in the glass bottle is worked out.
(e) Then the loss of oxygen is determined which is the difference between the dissolved oxygen at the beginning and dissolved oxygen remaining at the end.

(f) The B.O.D. is then calculated by the following relation: 5-days B.O.D. = (Loss of oxygen × dilution ratio) in ppm.

7.14 DETERMINATION OF CHEMICAL OXYGEN DEMAND (C.O.D.)

The demand of oxygen for the chemical oxidation of organic matters in sewage by using strong chemical oxidant is known as chemical oxygen demand (C.O.D.).

The C.O.D. test is necessary for the industrial sewage and it takes only 5 hours, for the decomposition of organic matters. Whereas B.O.D. test is necessary for domestic sewage only and it takes at least 5 days for the decomposition of organic matters. Again, C.O.D. can be achieved by controlling the amount of chemical oxidising agents while in B.O.D. huge quantity of clear water is required to perform the oxidation of organic matters.

The C.O.D. test is carried out by the following procedure:

(a) A known amount of sample of sewage is taken in a pot.
(b) A known amount of potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4) are added to the sample.
(c) The mixture is kept for about three hours.
(d) During this period, a chemical reaction takes place to produce CO_2 and H_2O.
(e) After the reaction, the remaining amount of potassium dichromate is determined by titration with ferrous ammonia sulphate $Fe(NH_4)_2\ (SO_4)_2$ solution.
(f) The consumption of dichromate indicates the amount of oxygen required for the oxidation of organic matters.

Review Questions

1. Describe the physical properties of sewage.
2. Why is the analysis of sewage necessary? Describe the method of collecting sample of sewage.
3. Discuss the physical tests of sewage.
4. Discuss the chemical tests of sewage.
5. (a) Define B.O.D.
   (b) Discuss how it is determined.
   (c) What is its importance in sewage analysis?
6. What is C.O.D? How is it determined? What is the difference between C.O.D. and B.O.D.?
7. Write short notes on:
   (a) Aerobic decomposition
   (b) Anaerobic decomposition
   (c) Carbon cycle
   (d) Nitrogen cycle

(e) Sulphur cycle
(f) Chlorine demand

8. Differentiate between the following:
(a) Aerobic bacteria and anaerobic bacteria
(b) Inorganic solids and organic solids
(c) Grey sewage and dark sewage
(d) B.O.D. and C.O.D.
(e) Photosynthesis and respiration

8

Primary Treatment of Sewage

8.1 INTRODUCTION

The sewage contains various suspended, floating and oily substances. By primary treatments these substances are removed from the sewage so that the working of the sedimentary treatment units may be easy and there is no disturbances in the operation of those units. The units of the primary treatments are as follows:

(a) Screens
(b) Grit chamber
(c) Detritus tank
(d) Skimming tank
(e) Primary sedimentation tank.

8.2 FLOW DIAGRAM OF PRIMARY TREATMENT

The units in Fig. 8.1. are arranged according to the sequence of primary treatment.

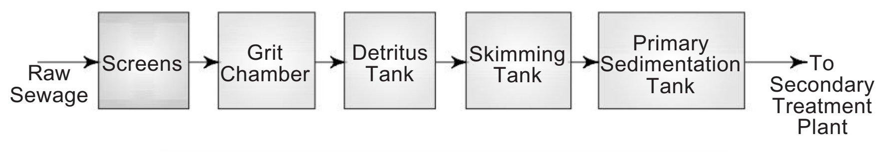


Fig. 8.1 *Flow diagram of primary treatment*

Functions of Units

1. Screens To eliminate large floating matters.

2. Grit Chamber To eliminate large size organic and inorganic matters.

3. Detritus Tank To eliminate finer organic and inorganic matters.

4. Skimming Tank To eliminate grease, oil, soap, etc.

5. Primary Sedimentation Tank To eliminate fine colloidal particles.

8.3 SCREENS

The screen is the first unit of primary treatment plant. The function of screen is to remove all the floating debris like wood pieces, cloth and paper pieces, decayed fruits and vegetables, etc. If these floating matters are not eliminated, it may choke the pipe lines or it may cause damage to the pumping unit.

Construction The screens may be constructed of M.S. bars or rods, gratings, wire meshes or perforated plates. The M.S. bar screen is made by placing parallel bars with spacings according to the following types:

(a) Coarse Screen The spacings of bars are more than 40 mm centre to centre.

(b) Medium Screen The spacing are less than 40mm.

(c) Fine Screen The spacings vary from 1.5 mm to 6 mm.

The screens may be fixed or movable. As shown in Fig. 8.2, the inclination of the screen varies from 30° to 60°. The screens are placed at designed inclination in an oblong rectangular chamber. The ends of the chamber are tapered. It is constructed with brick masonry. The inner surfaces are plastered and finished with neat cement polish. A perforated rectangular channel is provided at the top of the screen for the collection of floating debrises.

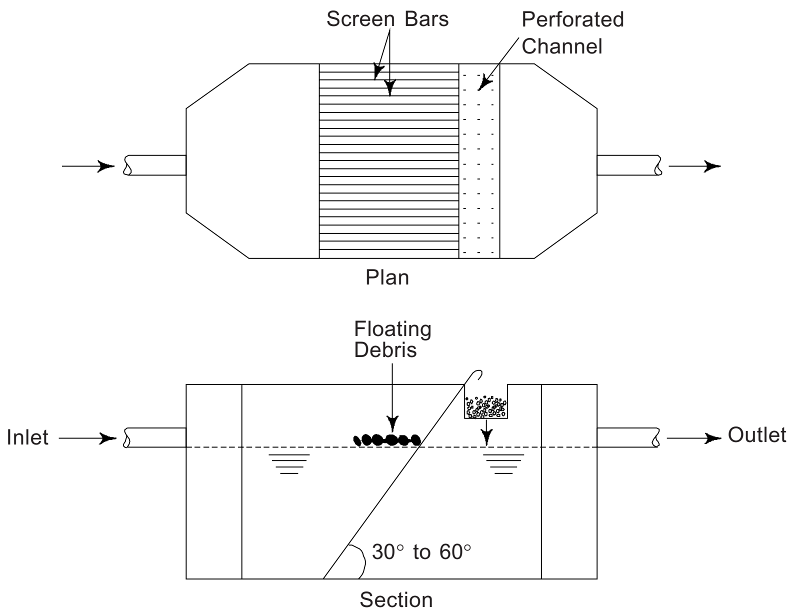


Fig. 8.2 *Screen*

Working The raw sewage is allowed to enter the chamber through the inlet pipe. The floating debris are obstructed by the screen and collected near it. The sewage containing the other suspended materials passes through the screen and is taken to the next unit (i.e. grit chamber).

Cleaning The debris may be cleaned by manual labours or mechanical device. In manual system, the debris are raked by rakers and collected in the perforated channel from where these are disposed of. In mechanical device system, a raking arm (like crane) is provided which collects the debris at regular interval and throws in a collecting basin from where these are disposed of.

Disposal The debris may be disposed of by the following way:

(a) Dumping The debris are dumped in low-lying areas far away from the locality.

(b) Burning After drying, the debris are burnt to ashes.

(c) Composting Good quality manure may be obtained by composting the debris in compost plant.

8.4 GRIT CHAMBER

The function of grit chamber is to remove the inorganic substances like grit, sand and other suspended materials. The velocity of flow in the grit chamber is kept low so that a detention period is available for the settlement of the above substances.

Construction The grit chamber is an oblong rectangular chamber and constructed with brick masonry. As shown in Fig. 8.3, the floor of the chamber is made sloping for the collection of grits at a particular zone. The inner surfaces are plastered and finished with neat cement polish. It consists of an agitator for agitating the deposited grits at the time of cleaning. A pipe line with valve is provided at the bottom of the chamber for periodical removal of the grits. The length, width and depth are designed according to the volume of sewage.

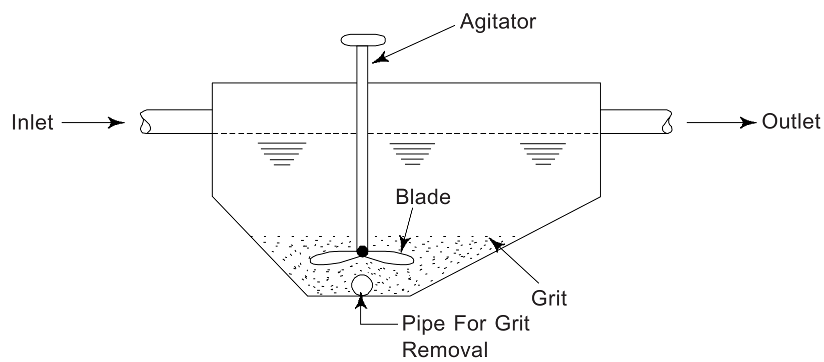


Fig. 8.3 *Grit chamber*

Working The sewage from the screen chamber is allowed to enter the grit chamber and flow at a low velocity of 20 cm to 30 cm per sec. Due to the low velocity, the grits, sands, etc. are settled down at the bottom of the grit chamber.

Cleaning At the time of cleaning, the deposited grits are agitated by agitator and the muddy water comes out through the removal pipe. The grits may also be cleared from top by manual labours with the help of buckets.

Disposal The grits are generally dumped in low-lying areas for the reclamation of land.

8.5 DETRITUS TANK

The function of detritus tank is to remove finer organic and inorganic particles. Practically, the detritus tank is similar to grit chamber. The only difference is that the grit chamber is meant for removing the larger particles and detritus tank is meant for removing finer particles.

Construction Figure 8.4 shows a detritus tank. It is a rectangular tank with vertical sides and tappered bottom and constructed with brick masonry. The depth of the tank varies from 2–3 m and the length varies from 20–40 m. The width depends on the volume of sewage to be treated. The velocity of flow varies from 15–20 cm per second and the detention period varies from 2 to 3 minutes.

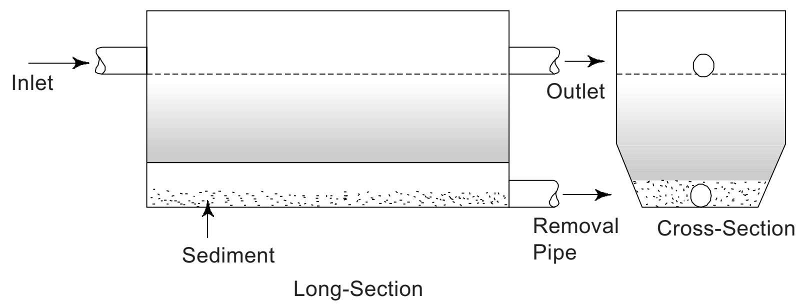


Fig. 8.4 *Detritus tank*

Working The sewage from the grit chamber is allowed to enter the detritus tank through inlet pipe. The sewage flows through the tank with low velocity. The finer suspended particles are settled down at the bottom of the tank.

Cleaning The deposited sediments are cleaned periodically through the removal pipe provided at the bottom of the tank. The sediments are agitated by scrappers, at the time of cleaning.

Disposal The sediments may be disposed of by dumping in low-lying areas for the reclamation of land.

8.6 SKIMMING TANK

Normally, the grease and oil are arrested by the grease and oil trap before the sewage enters the sewer line. But, these elements cannot be completely eliminated by the trap. The skimming tank is provided to remove the remaining portion of grease and oil from the sewage. Otherwise, these oily substances will cause disturbances in activated sludge process and tricking filter.

Construction It is a rectangular tank constructed with brick masonry. Air diffusers are provided at the bottom of the tank through which compressed air is sent to form bubbles in the sewage, as shown in Fig. 8.5. Bent pipes are provided at the inlet and outlet sides. C.I. covers are provided at the top for the removal of scum of grease and oil.

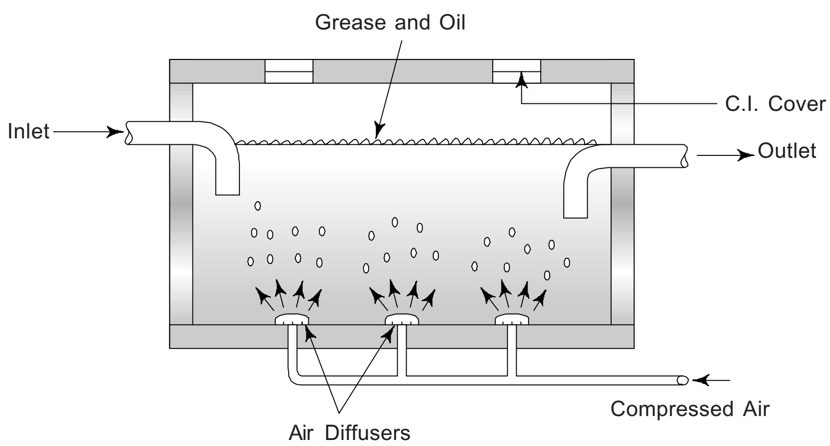


Fig. 8.5 *Skimming tank*

Working The sewage from the detritus tank enters the skimming tank through the bent pipe. The compressed air is sent through the diffusers which forms air bubbles and rises in upward direction. Thus the grease and oil are collected at the surface.

Cleaning By opening the C.I. covers the scum of the oily substances are removed periodically.

Disposal The oily substances are disposed of by burning.

8.7 PRIMARY SEDIMENTATION TANK

The primary sedimentation tank is also known as primary clarifier or primary settling tank. The purpose of this unit is to remove colloidal particles like silt and clay and some organic substance. Moreover, it reduces the load on the secondary treatment. Coagulants may be used, if necessary.

Construction Figure 8.6 shows the primary sedimentation tank. It is a rectangular tank constructed with brick masonry. Baffle walls are provided

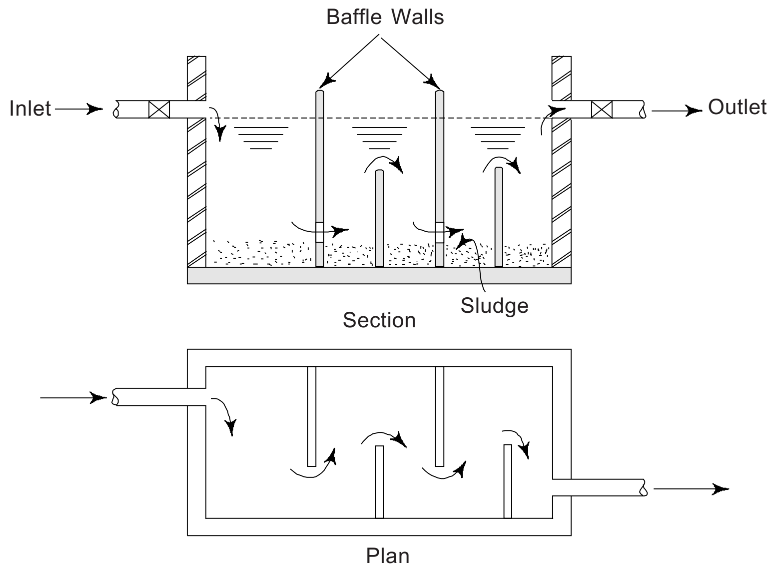


Fig. 8.6 *Primary sedimentation tank*

in zig zag way so as to lengthen the path of the flow of sewage. Inlet and outlet pipes are provided on opposite corners and these are provided with valves. A sludge removal pipe is provided at the bottom of the tank.

Working The sewage enters the tank through the inlet pipe and flows along the zig zag path and hence the velocity of flow is reduced. Thus the sewage is detained for a considerable period in the tank. The colloidal particles and organic substances are settled down at the bottom of the tank. The comparatively clear water passes out through the outlet pipe.

Cleaning The sludge is cleaned periodically through the removal pipe by opening the valve. (not shown in the fig.)

Disposal The sludge may be disposed of by dumping in ditches or low-lying areas or may be dried in sludge drying beds and can be used as manure.

Review Questions

1. Why are screens provided in primary treatment? Describe the method of screening with sketch.
2. Describe a grit chamber with sketch.
3. Describe a detritus tank with sketch.
4. Describe a skimming tank with sketch.
5. State the functions of each unit provided in primary treatment.

9

Secondary Treatment of Sewage

9.1 INTRODUCTION

In the primary treatment, the larger solids in sewage are removed. But the effluent still contains organic matters, bacteria, colloidal matters, etc. Such effluent cannot be discharged into the natural water coarse. So secondary treatments are given to the effluent of primary treatment to make it safe in all respects and suitable for discharging into the river. The most important units in this stage are: (a) Activated sludge process and (b) Filtration of sewage.

There are some other units which are allied with these main treatments. The sequence of the secondary treatment is shown in the next section.

9.2 FLOW DIAGRAM OF SECONDARY TREATMENT

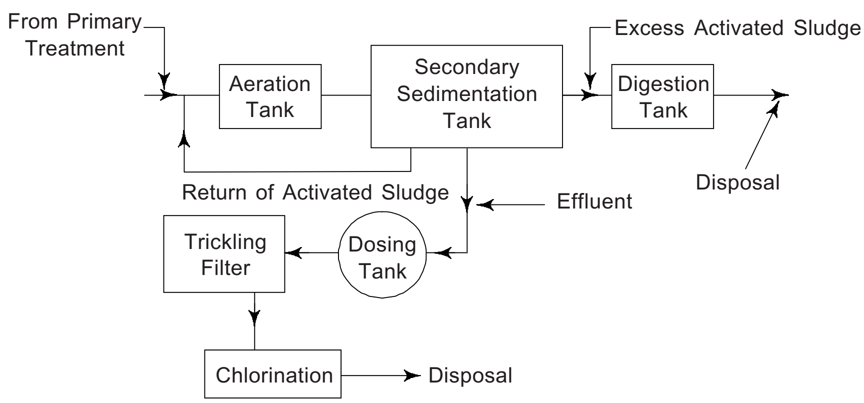


Fig. 9.1 *Flow diagram of seconday treatment*

Functions of the Units of Secondary Treatment

(a) Aeration Tank

(i) It brings the sewage in intimate contact with air.
(ii) It helps to absorb oxygen from air.
(iii) It helps the bacteria to break up the organic matters quickly.

(b) Secondary Sedimentation Tank

(i) It removes the very fine suspended particles with the help of coagulants.
(ii) It produces activated sludge which is very effective in oxidising the organic matters.

(c) Sludge Digestion Tank

(i) It breaks the organic matters into liquid and simple compounds.
(ii) It reduces the volume of sludge.
(iii) It reduces the moisture content of sludge.
(iv) It converts the sludge into fertiliser.
(v) It produces some gases which may be used as fuel.

(d) Dosing Tank

(i) It provides uniform spreading arrangement of sewage over the trickling filter.
(ii) It provides intermittent dosing of sewage by automatic siphonic device.

(e) Trickling Filter

(i) It removes the total solids of sewage.
(ii) It reduces the B.O.D.
(iii) It gives clear effluent.

(f) Chlorination of Sewage

(i) It disinfects the sewage by chlorine.
(ii) It prevents the corrosion of sewers.
(iii) It prevents the growth of algae and other plants life in sewer.

9.3 AERATION TANK

The process of absorbing oxygen from air is known as aeration. The aeration of sewage is the most vital operation in activated sludge process. Due to aeration, the sludge containing bacteria becomes more powerful in decomposing the sewage quickly. Hence, the aeration is the first step of secondary treatment.

The aeration is achieved by providing air diffusers in aeration tank. The air diffusers may be of the following three types:

(a) Jet Diffuser In this method, the compressed air is thrown with high velocity over a metal bowl through the nozzle as shown in Fig 9.2. The jet of air

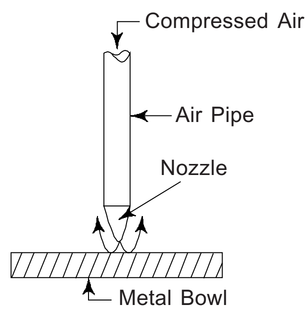


Fig. 9.2 *Jet diffuser*

strikes the surface of bowl and reflects upwards in the form of bubbles. Thus the sewage is agitated and it absorbs oxygen from the air.

(b) Plate Diffuser In this method, the compressed air is blown through a perforated diffuser plate. The air rushes out through the holes of the diffuser plate and rises upwards in the form of bubbles, as shown in Fig 9.3. Thus, the sewage absorbs oxygen from air.

(c) Tube Diffuser Figure 9.4 shows a tube diffuser. It is about 60 cm long and internal diameter is about 7.5 cm. The end of the tube is sealed with a cap. The tube is perforated with oblong holes around its surface. It is fixed in the air pipe and submerged in water up to the required depth. The compressed air is sent through the tube. The air comes out through the holes with great force and agitate the water or sewage.

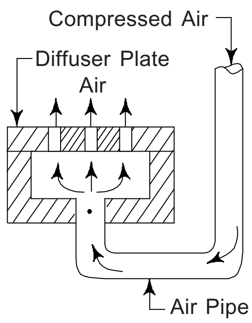


Fig. 9.3 *Plate diffuser*

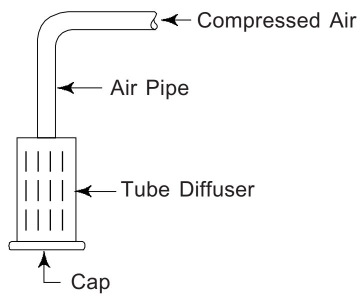


Fig. 9.4 *Tube diffuser*

Types of Aeration Tank

The aeration tanks may be of the following types:

(a) Ridge and furrow type tank
(b) Spiral flow type tank

(a) Ridge and Furrow Type Tank Figure 9.5 shows the ridge and furrow type tank. It is a rectangular tank with ridges and furrows at the

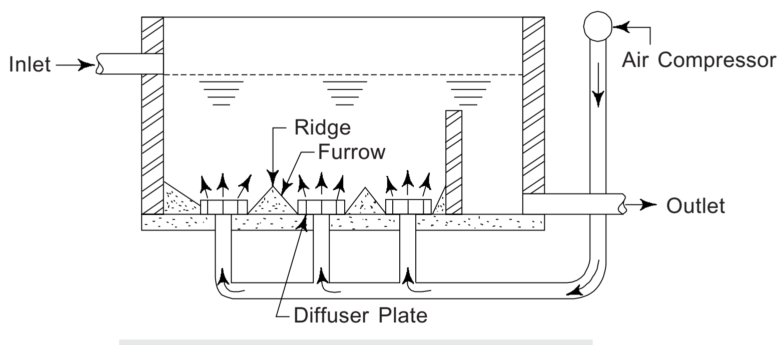


Fig. 9.5 *Ridge and furrow type tank*

bottom. The plate diffusers are provided at the furrows. The sewage is allowed to enter the tank through the inlet pipe at the top and after aeration it is discharged through the outlet pipe at the bottom. The size of the tank depends on the volume of sewage to be treated. In general, the size is 10 m long, 5 m wide and 3 m deep. An air compressor is provided for supplying air to the diffuser plates through the air distributing pipe. The compressed air comes out of the holes of the diffuser and rises up in the form of bubbles.

(b) Spiral Flow Type Tank It is a rectangular tank constructed with brick masonry. A series of tube diffusers are submerged in sewage by air pipes which are connected to the air distribution pipe. A curved baffle wall is provided in front of the diffusers, as shown in Fig. 9.6. When the compressed air is sent through the diffusers, the air bubbles pass over the curved surface of the baffle and gain a spiral motion within the tank. The size of the tank depends on the volume of sewage to be treated.

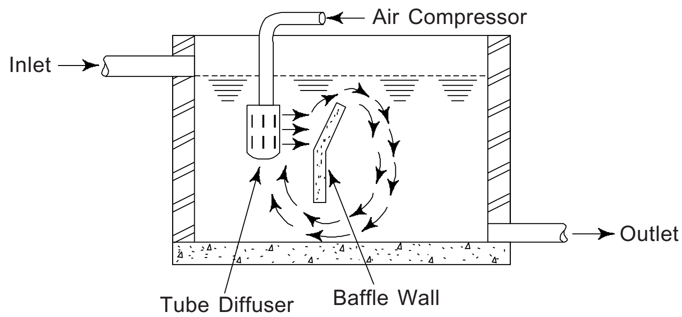


Fig. 9.6 *Spiral flow type tank*

9.4 SECONDARY SEDIMENTATION TANK

The secondary sedimentation tank is also known as secondary clarifier or secondary settling tank. The following are salient features of the tank:

Construction It is a rectangular tank constructed with brick masonry. A baffle wall is provided in the tank to divide it into two zones. The floor of each zone is made sloping towards the side as shown in Fig. 9.7. The inlet and outlet arrangements are made through the chambers and the sludge re-

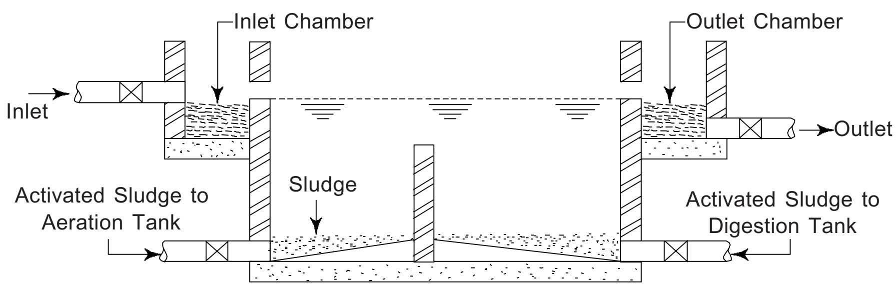


Fig. 9.7 *Secondary sedimentation tank*

moval pipes are provided on both sides. Generally, the length of the tank is three times the width. The detention period is generally 1 hour.

Working The aerated sewage is allowed to enter the tank through the inlet chamber and it is detained for one hour in the tank. The sludge is deposited at the bottom of the tank. This sludge becomes activated due to aeration. The effluent is discharged through the outlet chamber and taken to the trickling filter.

Recirculation of Sludge Some portion of the activated sludge is recirculated to the aeration tank by pumping.

Disposal of Excess Sludge The excess sludge is taken to the sludge digestion tank for digestion and final disposal.

9.5 ACTIVATED SLUDGE PROCESS

Definition

The sludge which is made powerful by the process of aeration is known as activated sludge. It contains high content of oxygen and high number of aerobic bacteria. It possesses unusual property to oxidise the organic matters.

Action

The following are the actions of activated sludge:

(i) The activated sludge when mixed with sewage, the microorganisms multiply rapidly.
(ii) The activated sludge oxidises the organic substances rapidly.
(iii) It converts the colloidal matters to settleable size rapidly.

Operational Features

Figure 9.8 shows the various stages of activated sludge process. The activated sludge process consists of the following operations:

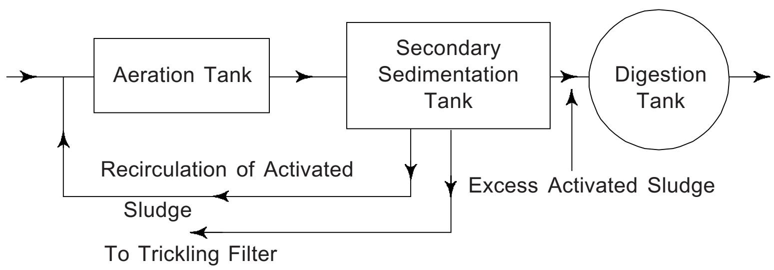


Fig. 9.8 *Activated sludge process*

1. Mixing of Activated Sludge Some portion of the activated sludge settled at the bottom of the secondary settling tank is recirculated and mixed with the effluent of primary settling tank just before its entry to the aeration tank.

2. Aeration Aeration tank is the first unit of the activated sludge process. Here, the effluent of primary settling tank and air are brought in intimate contact by agitating with some mechanical devices. The devices are as follows:

(a) Air diffuser system
(b) Mechanical aeration system
(c) Combination of air diffuser and mechanical aeration.

Generally, air diffuser system is adopted for aeration. This system may be achieved by (i) Jet diffuser, (ii) Plate diffuser or (iii) Tube diffuser. These systems are described in Section 9.3.

Sludge Settlement The secondary sedimentation tank is the second unit. After agitation in aeration tank, the effluent is taken to the secondary settling tank and detained for a specified period (generally, 1 hour). During this detention period, the sludge is settled at the bottom of the tank. This sludge is termed as activated sludge. Some portion of this sludge is recirculated to aeration tank and the remaining portion is sent to digestion tank. Thus, the cycle of activated sludge process goes on working.

9.6 SLUDGE DIGESTION TANK

The activated sludge is taken to this tank for proper digestion and disposal. (The details of digestion tank will be studied in Chapter 12)

9.7 DOSING TANK

The sewage is not applied on the trickling filter continuously. It is applied by automatic siphonic device provided with the dosing tank. As shown in Fig. 9.9, it consists of a U-pipe with its vertical end inserted into the tank. A hood is provided over the free end of the pipe. The other end of U-pipe is connected to the inlet pipe of trickling filter. When the level of sewage remains on the line b – b, there will be no siphonic action. When the level rises and reaches the line a – a, the siphonic action starts. The siphonic action continues until the level reaches to b – b. The rate of flow is adjusted in such a way that the dosing of the filter is achieved at every 10 minutes.

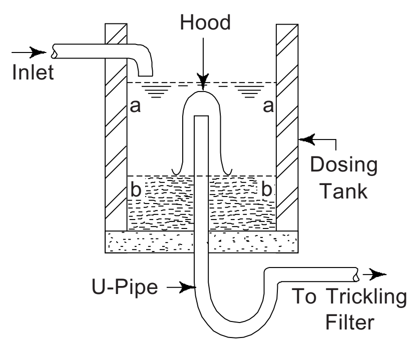


Fig. 9.9 *Dosing tank*

9.8 TRICKLING FILTER

Theory

The theory of trickling filter is based on the principle that the bacterial film (known as bio-film) which is formed around the filtering media, is the source of formation of the bacterial colonies. These bacteria decompose the organic matters for their survival. So, the trickling filter serves the purpose of breaking the complex organic matter by fertilising the bacteria.

Elements of Trickling Filter

The following are the elements of trickling filter:

(a) Construction of Filter Figure 9.10 shows a trickling filter. Generally, the trickling filter is circular in shape. It consists of four numbers of rotary distributing arms which have perforations at the bottom. The arms are fitted with a central support which is rotated by a suitable device. The floor of the filter is made of concrete and its slope is made towards the periphery.

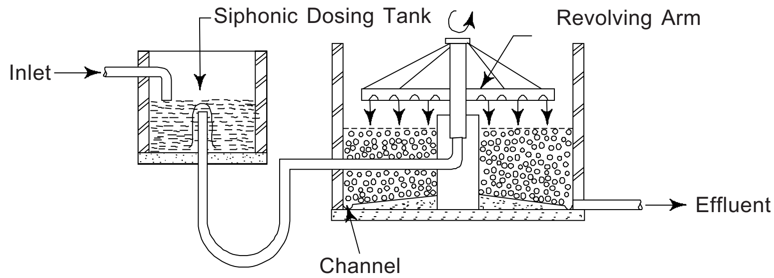


Fig. 9.10 *Trickling filter*

(b) Dosing of Filter A siphonic dosing tank is provided with the trickling filter for intermittent supply of effluent over the filtering media.

(c) Filter Media The filter media consists of broken stones, clinkers, etc. with their size varying from 20 – 50 mm. The larger size stones are placed at the bottom layer and the smaller size stones are arranged towards the top. The stones or clinkers should be of good quality.

(d) Underdrainage System The underdrainage system consists of a channel along the periphery of the filter. The channel again is connected to the outlet pipe.

(e) Ventilation The ventilation of filter is necessary for the smooth working of the filter. The ventilation is achieved by providing vent pipes at the periphery. (not shown in fig.)

(f) Working The effluent is spread over the filtering media of broken stones by rotary arms. The effluent trickles down the media and gets collected in the channel. The channel carries the effluent to the outlet pipe through which the effluent is taken for chlorination.

(g) Cleaning After working for long period, the upper surface of the media may be clogged by sediments. The rate of filtration may be decreased or stopped due to this. At that time, the upper layer of stones are scrapped off and fresh layer of stones of same size are replaced properly.

9.9 CHLORINATION OF SEWAGE

Necessity

The chlorination of sewage is done for the following reasons:
(a) It prevents the growth of algae and other plant life in sewers.
(b) It prevents the corrosion of sewers.
(c) It protects the aquatic life.
(d) It eliminates the odour from effluent.

Chlorination Tank

The chlorination tank is a rectangular chamber constructed of brick masonry. It consists of a vertical shaft and horizontal shaft. The horizontal shaft consists of several paddles which are rotated by a driving unit. The dosing of chlorine is done in a dosing chamber through a funnel, as shown in Fig. 9.11. Generally, the dose varies from 10 to 20 ppm and the contact period is 15 minutes.

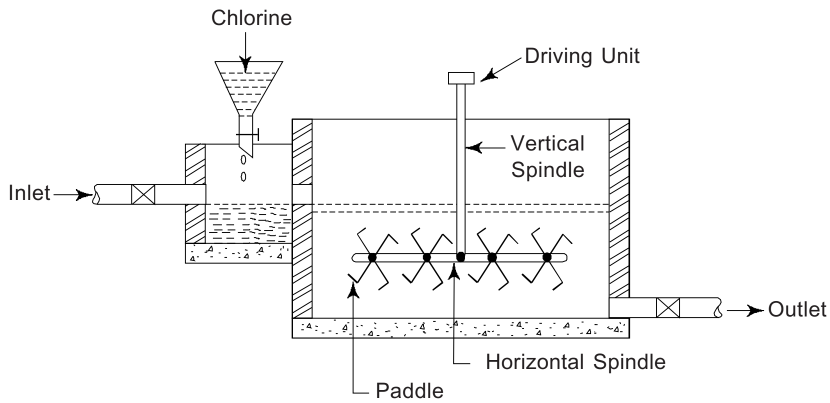


Fig. 9.11 *Chlorination tank*

The requisite amount of chlorine is added to the effluent in dosing chamber and then it flows to the chlorination tank. In chlorination tank, the effluent is thoroughly mixed with chlorine by rotating the paddles. After 15 minutes of detention period, the effluent is allowed to flow to the natural water course.

9.10 CONTACT BED

Like trickling filter the contact bed is a method of filtration of sewage. But, the rate of filtration is low in comparison with trickling filter.

Theory In contact bed, the sewage is brought in contact with the filtering media for some specified period. During this period, a biological film is formed around the particles of the filter media and the bacterial colonies are formed in the film. These bacteria are responsible for the oxidation of organic matters. Again, when the bed is kept empty for some period, the filter gets oxygen from atmosphere and oxides the organic matters if they remain unoxidised.

Construction It is a rectangular tank which is divided into several beds (i.e. sectors). The depth of bed varies from 1m to 2m. Each bed is filled up with filtering media of gravel, ballast or broken stones, as shown in Fig. 9.12. The effective size of ballast varies from 15 mm to 50 mm. A siphonic dosing tank is provided for the supply of sewage to all the beds simultaneously. Generally, the rate of filtration is 500 lits per m^3 of filter media.

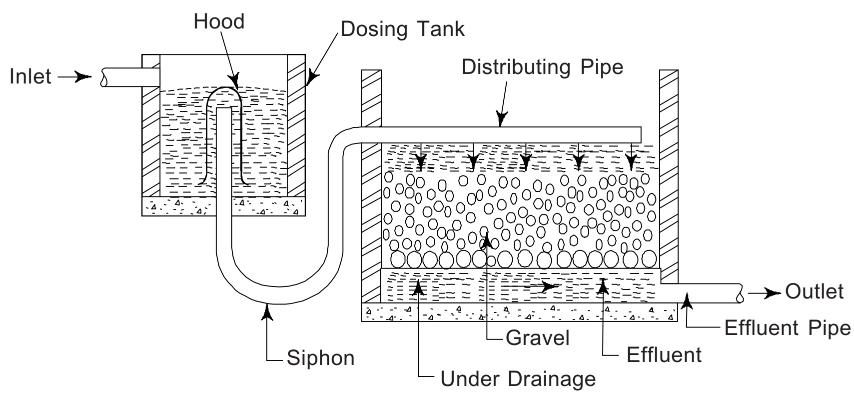


Fig. 9.12 *Contact bed*

Working The contact bed is operated according to the following stages:

Stage 1 The bed is filled with sewage through the siphonic dosing tank and it may take about 2 hours.

Stage 2 The sewage is allowed to stay in the filter media for about 2 hours.

Stage 3 The effluent is allowed to flow through the effluent pipe for the disposal to natural water course. This may take about 2 hours.

Stage 4 The bed is allowed to stay empty for about 4 hours. Thus, the cycle of operation continues during the working period.

Disadvantages

(a) The effluent is turbid.
(b) The removal of bacteria is low.
(c) Rate of filtration is low.
(d) It requires long time.
(e) It is suitable for small establishment.

9.11 INTERMITTENT SAND FILTER

Theory In intermittent sand filter the sewage is purified by the phenomenon of mechanical straining through the sand bed and by bacterial colonies formed in the sand voids.

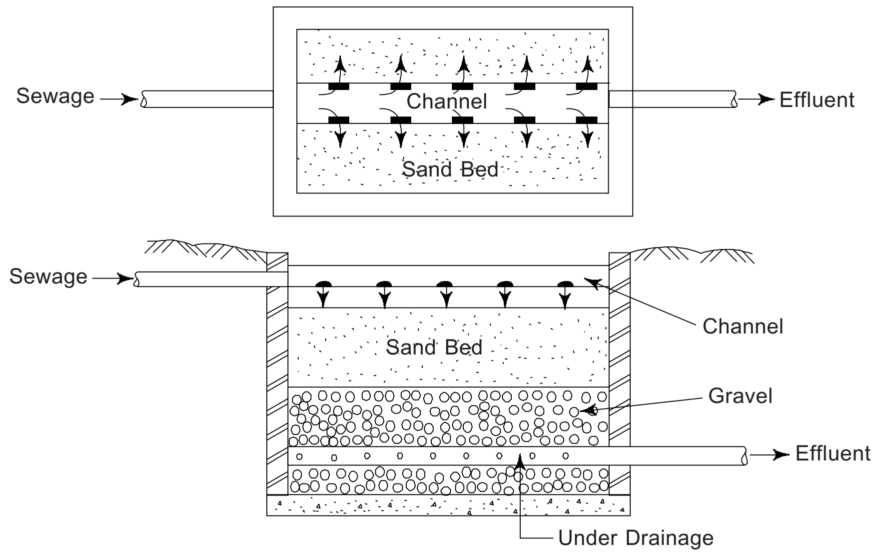


Fig. 9.13 *Intermittent sand filter*

Constructional Features Following are the constructional features of an intermittent sand filter:

(a) It is a rectangular chamber constructed below the ground level with brick masonry. The length, width and depth depends on the volume of sewage to be treated and the area of land available.
(b) Under drainage system with perforated pipe is provided below the chamber to collect the effluent. The pipe is covered with a layer of gravel of thickness which varies from 30–50 cm as shown in Fig. 9.13.
(c) A sand layer of thickness, varying from 100–150 cm, is provided over the layer of gravel. The effective size of sand bed varies from 0.20–0.50 mm and uniformity coefficient varies from 2–5.

Working

(a) The sewage is allowed to flow through the distribution channel and spread over the sand bed. When the depth of sewage is about 10 – 20 cm, the supply is cut-off and left for several days.
(b) The process of filtration goes on and the effluent passes through the underdrainage system. The sludge is retained over the sand bed.
(c) The top layer of sand should be raked properly before starting the next operation.
(d) When the process of filtration is highly disturbed due to the formation of thick scale over the sand bed, the top layer of sand should be removed and a fresh layer of sand should be spread evenly.

Efficiency

(a) The effluent is very clear.
(b) Removes suspended solids to about 90%.
(c) Free from odour.

Review Questions

1. What is meant by secondary treatment of sewage? Give the flow diagram of secondary treatment.
2. Explain the theory, construction and working of contact bed.
3. Describe a trickling filter with sketch.
4. What is the purpose of secondary clarifier? Describe a secondary clarifier with sketch.
5. What is activated sludge? Describe activated sludge process with sketch.

10

Miscellaneous Treatment of Sewage

10.1 OXIDATION POND

Theory The oxidation pond is an excavation of rectangular ditch of shallow depth. The sewage is stored in this pond for a considerable time. During this period, the sewage is decomposed by the action of aerobic bacteria, algae and sunshine. That means, it is a natural method of sewage treatment. The aerobic bacteria absorbs oxygen from the atmosphere for their survival and break up the organic matters in sewage to simple stable compounds.

Construction and Operation The oxidation pond is constructed by excavating a rectangular ditch of shallow depth. The length varies from 50–100 m, the width from 30–50 m and the depth varies from 0.9–1.5 m. The pond is divided into several compartments by small levees in a zig-zag manner, as shown in Fig. 10.1. The sewage is allowed to enter the pond through the inlet channel at one corner. The sewage flows in a zig-zag manner until the whole pond is filled up. The detention period varies from 7–14 days. The decomposition of sewage is achieved by the aerobic bacteria. After complete decomposition a black humus (i.e. sludge) is obtained which may be used as manure. (Fig. 10.1)

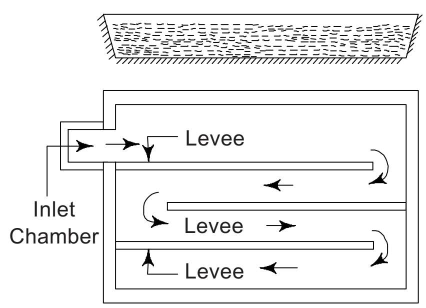


Fig. 10.1 *Oxidation pond*

Advantages

(a) It is a natural method of decomposition, so it is cheap.
(b) Its operation and maintenance is simple.
(c) It is highly efficient in removing B.O.D.

Disadvantages

(a) Large area is required for treatment.
(b) It creates bad smell and mosquito nuisance.
(c) In rainy season or cloudy weather, the sewage becomes septic and this may cause insanitary condition.

Use

This system is suitable for small towns having tropical climate.

10.2 CESSPOOL

The cesspool is an isolated method of sewage treatment for individual house, housing estates, etc. It is not suitable for large scale treatment.

Construction It is a rectangular or circular structure constructed with brick work below the ground level. The brick wall is constructed with cement mortar and inner surface is plastered. Sometimes, several holes are provided on the wall in zigzag manner. The depth varies from 3–4 m and it should not go below the water table. An R.C.C. cover is placed over the top of cesspool. The volume of cesspool depends on the number of users. Generally, the capacity varies from 2000 to 5000 lits. The inlet pipes are connected to it with 'T' pipe, as shown in Fig. 10.2. A vent pipe is provided with it for the removal of foul gases. It should be located far away from the locality. The latrines are connected by underground pipe line. (Fig. 10.2)

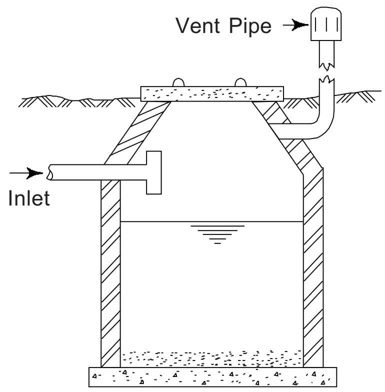


Fig. 10.2 *Cesspool*

Function and Cleaning In cesspool, the decomposition of sewage is achieved by anaerobic bacteria. After decomposition, the sludge is deposited at the bottom and effluent is collected at the top. When the cesspool is filled up, it is removed by pumping and collected in tanker, and disposed of in low-lying barren lands far away from the locality.

10.3 SEPTIC TANK

Theory The theory of septic tank is based on the principle of sedimentation of sewage and digestion of sludge. In this tank, the sewage is detained for some period. During this detention period, the sewage is decomposed by anaerobic bacteria and the sludge is deposited at the bottom (as sedimentation tank). The digestion of sludge is carried out by the anaerobic bacteria (as digestion tank). The effluent is clear and it is discharged into the soak pit constructed at a suitable place.

Use The septic tank is suitable for the towns where it is not possible to establish the water carriage system. It is provided in residential buildings, hostels, hotels, hospitals, schools, colleges, etc.

Constructional Features Figure 10.3 shows a septic tank. The following are the constructional features of septic tank:

(i) It is a rectangular tank constructed with brick masonry over concrete foundation. The length is usually 3 times the breadth.

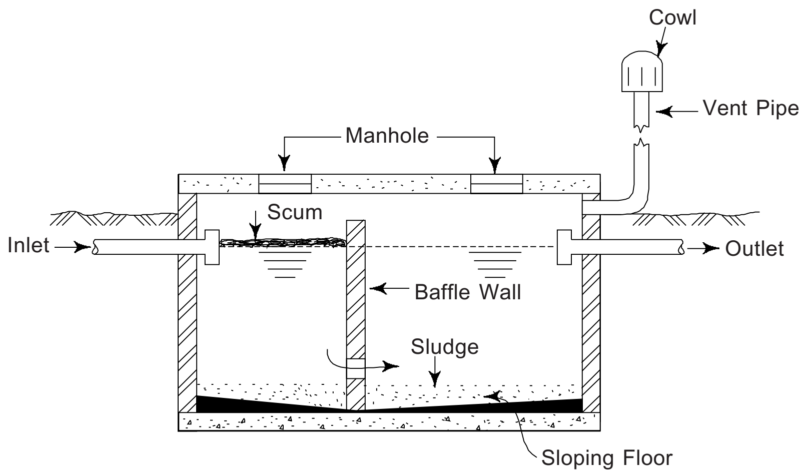


Fig. 10.3 *Septic tank*

(ii) The liquid depth varies from 100–180 cm.
(iii) A free board of 30–50 cm is provided above the liquid level.
(iv) The inlet pipe and outlet pipe consist of 'T' or 'elbow' which are submerged to a depth of about 25 cm below the liquid level.
(v) The outlet level is about 15 cm lower than the inlet level.
(vi) The inside surface of the tank should be plastered and finished with neat cement polish to make it complete watertight.
(vii) For smaller tank single baffle wall should be provided. But for larger tank two baffles should be provided near both the ends.
(viii) The top of the baffle should be at least 15 cm above the liquid level.
(ix) Openings should be provided near the bottom of the baffle for the flow of effluent from first chamber to second chamber. Sometimes, hanging baffles may be provided.
(x) R.C.C. slab with manholes is provided at the top of the tank.
(xi) Ventilation pipe is provided for the removal of foul gases.

Working of Septic Tank The fresh sewage from the latrines enters the first chamber directly where the scum start floating at the beginning. Within few days, the anaerobic bacteria decompose the scum and sludge is formed which is settled down at the bottom of the tank, and it is digested further by those bacteria. The effluent from the first chamber flows to the second chamber through the openings in the baffle wall and finally disposed of to the soak pit. During the decomposition, the gases like carbon dioxide, methane and hydrogen sulphide are formed which are released through the vent pipe.

Due to the deposition of sludge, the capacity of the tank goes on reducing gradually. So, the tank should be cleared every year, or at some reasonable period.

10.4 SOAK PIT OR SOAK WELL

Function The function of soak pit is to receive effluent from the septic tank and disperse the liquid to the surrounding soil through the openings provided at the wall and through the bottom. The soak pit should not be constructed very near to an open well or tube well.

Constructional Features The following are the constructional features of the soak pit:

(i) The soak pit is constructed with brick masonry in the shape of a square or circle. The depth varies from 3–5 m. But the depth depends on the water table of the locality. It should be remembered that the depth should not be taken below the water table.

(ii) The diameter of the pit depends on the volume of effluent and number of users. However, the diameter varies from 1–2 m.

(iii) Openings are provided on the wall of the pit, as shown in Fig. 10.4. The bottom is kept open so that the water can be absorbed by the surrounding soil.

(iv) The pit may be hollow or filled up with brick bats and brick khoa.

(v) Sometimes, a packing of coarse sand (15 cm thick) is provided around the pit to increase the percolating capacity of the soil.

(vi) If the soaking capacity of the pit is destroyed, it should be cleaned and filling materials may be replaced. (Fig. 10.4).

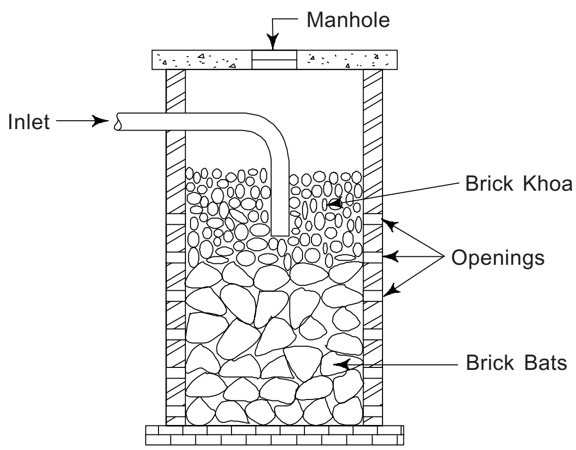


Fig. 10.4 *Soak pit*

10.5 DESIGN OF SEPTIC TANK AND SOAK PIT

Problem 10.1

Design a septic tank having the following data:

(i) Number of users—200

(ii) Rate of water supply—150 lit/head/day

(iii) Detention period—18 hours.

(iv) Percolating capacity of filter media = 1250 lits/m^3

Also find the diameter of the soak well. Assume reasonable data, if required.

Solution

Considering that the whole quantity of water comes as sewage,

Flow of sewage per day = 200 × 150
= 30000 lits.

Detention period is 18 hours.

So, Tank capacity = $\dfrac{30,000 \times 18}{24}$ = 22,500 lits

Assuming sludge storage capacity at the rate of 20 lits/person/year.

Volume of sludge = 200 × 20
= 4000 lits.

∴ Tank capacity = 22,500 + 4000
= 26,500 lits.

Considering 20% provision for future extension.

Extra Volume = 26,500 × .2 = 5,300 lits.

Total Volume of tank = 26,500 + 5,300
= 31,800 lits.
= 32,000 lits (say).
= 32 m^3 [1 m^3 = 1000 lits]

Considering, the effective depth of liquid as 1.5 m.

Cross-sectional area = $\dfrac{32}{1.5}$ = 20.6 m^2.

Let, width = b.

and Length = $3b$.

$b \times 3b = 20.6$

or $3b^2 = 20.6$

∴ b = 3.0 m (say)

∴ Length = 3 × 3 = 9 m.

Considering free board as 0.5 m.

Overall depth = 1.5 + 0.5 = 2m.

Therefore, the size of septic tank is 9m × 3m × 2m.

Size of Soak Well

Volume of soak well = $\dfrac{32 \times 1000}{1250}$ = 25.6 m^3

[As Percolation Capacity = 1250 lits/m^3]

Considering the depth of soak well 3 m.

$$\text{Cross-sectional area} = \frac{25.6}{3} = 8.5 \text{ m}^2.$$

Let d be the diameter of well.

$$\frac{\pi d^2}{4} = 8.5$$

or
$$d = \sqrt{\frac{8.5 \times 4}{\pi}}$$

$\therefore$
$$d = 3.2\text{m}.$$

Therefore, the diameter of soak well is 3.2 m and depth 3 m.

Note: The septic tank and soak pit should always be designed as per the permissible data. But for general constructions some recommended measurements may be adopted.

No. of users	*Length (m)*	*Width (m)*	*Effective depth (m)*
5	1.5	0.75	1.0
10	2.0	0.90	1.0
20	2.25	1.20	1.25
50	5.0	2.0	1.50
100	7.5	2.75	1.50

Review Questions

1. What is the theory of oxidation pond? Describe the construction and working of oxidation pond.
2. Describe a cesspool with sketch.
3. What is the theory of septic tanks? Describe a septic tank with sketch.
4. Describe a soak pit with sketch.

11

Natural Methods of Sewage Disposal

11.1 INTRODUCTION

The sewage can be disposed of by two ways:

(a) By artificial method
(b) By natural method.

In artificial method, the sewage is conveyed through the underground sewer line and taken to the treatment plant where it undergoes primary treatment and secondary treatment. Then the effluent is discharged into the natural water course.

In natural method, the sewage is conveyed through the underground sewer line and it is simply disposed of to the natural water course or some other way. The following are the natural methods of sewage disposal:

(a) Dilution method
(b) Sewage farming method

In this chapter, we shall study the natural methods of sewage disposal.

11.2 DILUTION METHOD

The term dilution is meant by the fact that the disposal of sewage is done by discharging it into the natural water courses such as river, stream, lake or sea. By dilution, the sewage is purified by the self-purification capacity of the natural water. Again, success of self-purification depends on the dilution factor and the nature of sewage at the time of disposal—whether it is fresh or stale. The dilution factor is defined as the ratio of the amount of diluting water to that of the sewage. The dilution factor should be ascertained by measuring the discharge of the river throughout the year. At the dilution factor above 500, the sewage requires no treatment. It can be discharged directly into the river. If the dilution factor becomes less than 500, primary treatments should be given to the sewage before discharging.

The following points should be remembered while adopting the dilution method:

(i) The city or town should be situated near the sea or large river.
(ii) The river should be perennial and plenty of water should be available throughout the year.
(iii) The current of the river should be considerable so that the sewage is carried quickly towards the downstream.
(iv) The sewage should be fresh at the time of disposal or it should be discharged within 3 hours of its formation.
(v) During the period of flood or heavy rainfall, the natural water course should not exert back pressure towards the sewer.
(vi) Laboratory test should be carried out with the sample of water at the down stream side of the point of disposal to verify the quality—whether the water is fit for bathing, washing, irrigation, etc. or not.
(vii) If the sewage contains industrial wastes, then it should be verified to ascertain the quality of water so that it may not be detrimental to aquatic life.

11.3 SEWAGE FARMING METHOD

Definition When sewage is applied on agricultural land for the growth of crops, then it is termed as sewage farming.

The sewage contains much fertilising elements such as nitrates, sulphates and phosphates. These elements are extracted from the soil by the roots of the plants.

Conditions of Sewage Forming The following conditions should be remembered while providing the method of sewage farming:

(i) The farm should be located far away from the locality, because it may create bad smell and insanitary condition.
(ii) The hygienic safety of the workers should always be observed to protect them from the bad effect of pathogenic bacteria.
(iii) The raw sewage should never be supplied to the farm.
(iv) It is better to apply the sewage after primary treatment.
(v) The working of the farm should run on constant supervision, so that insanitary condition may not arise due to over irrigation.
(vi) Precautions should be taken to avoid sewage sickness.

Application of Sewage

The sewage may be applied on the land by the following methods:

(a) Surface irrigation system
(b) Sub-surface irrigation system
(c) Sprinkler irrigation system

(a) Surface Irrigation System This system may be of following types:

(i) Basin Method: This method is employed for supplying water to orchards. In this method, each tree or group of trees are enclosed by circular channel through which sewage flows. This circular channel is known as basin. The basins are connected to the supply channel, as shown in Fig. 11.1. When the basins are filled up, the supply is cut-off.

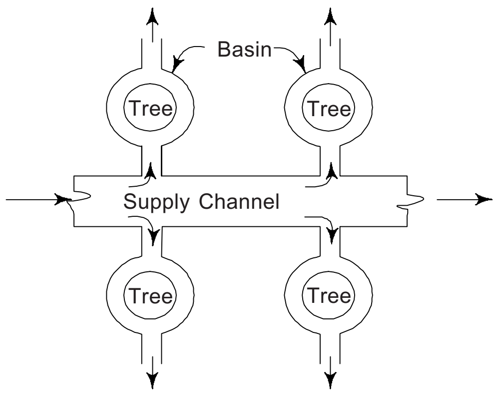


Fig. 11.1 *Basin method*

(ii) Furrow Method: As shown in Fig. 11.2, in this method the sewage is supplied to the land through narrow channels, which are known as furrows. This method is suitable for the crops which are sown in rows. The crops are potato, ground nut, tobacco, sugar cane, etc.

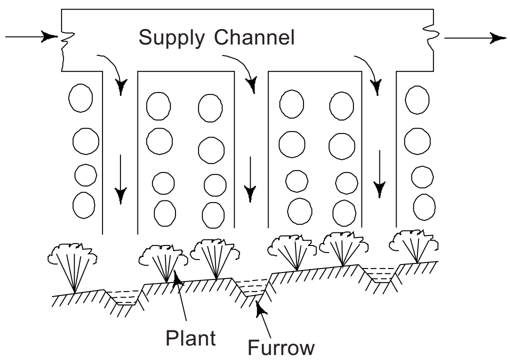


Fig. 11.2 *Furrow method*

(iii) Flooding Method: In this method, the agricultural land is divided into small plots by levees (i.e. low bunds). The sewage is supplied to the plots through the supply channel. The sewage covers the entire area by flowing in zigzag way, as shown in Fig. 11.3.

(b) Sub-surface Irrigation System In this method, the sewage is applied to root zone of crops by underground network of pipes. It consists of

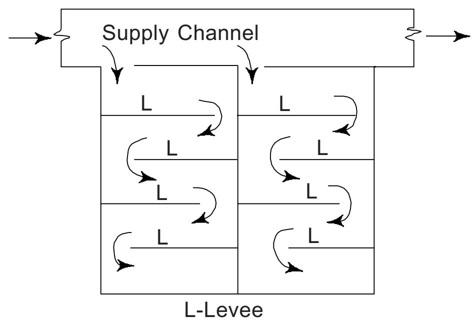


Fig. 11.3 *Flooding method*

lateral perforated pipes which are connected to sub-main pipe line, as shown in Fig. 11.4. The perforated pipes allow the sewage to drip out slowly and the soil below the root zone absorbs the sewage continuously.

(c) Sprinker Irrigation System In this method, the sewage is applied to the land in the form of spray (like rain). The system is achieved by the network of main pipe, branch pipes and lateral pipes. The lateral pipes are perforated through which the sewage comes out, as shown in Fig. 11.5.

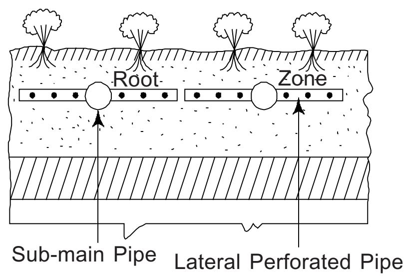


Fig. 11.4 *Sub-surface system*

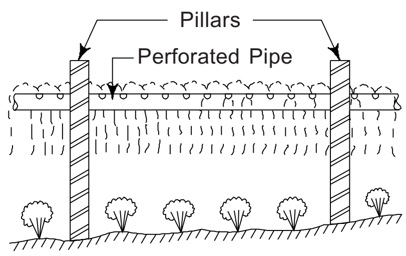


Fig. 11.5 *Sprinkler system*

Advantages and Disadvantages of Sewage Farming

Advantages The following are the advantages of sewage farming:

(i) The fertility of land is increased. So, the yield of crop will be more.
(ii) It is a cheap method.
(iii) No costly equipments are required in this method.
(iv) Where the sewage disposal by dilution is not possible, this method becomes useful.
(v) This method is also suitable in places where irrigation water may not be available.

Disadvantages The following are the disadvantages of sewage farming:

(i) Over-irrigation by sewage may lead to bad odour, fly-nuisance and may be dangerous to human health.
(ii) This method is not suitable in monsoon.

(iii) Limited types of crops can be grown.
(iv) Public may dislike the crops grown by this method.

11.4 SELF PURIFICATION THEORY

If the sewage is discharged into natural water course, then the organic compounds are oxidised by the dissolved oxygen in water and the water gets purified. Thus, a deficiency of dissolved oxygen is created in flowing water. But, that deficiency is immediately replenished by the atmospheric oxygen. This phenomenon of deoxygenation (i.e. loss of oxygen) and reoxygenation (i.e.) gain of oxygen)for maintaining the purification process is known as self-purification property of natural water.

The process of self-purification occurs in the following ways:

(i) When sewage is discharged into natural water course, the water gets polluted in the beginning.
(ii) After some time, the organic matters are decomposed by aerobic bacteria present in sewage. The dissolved oxygen is consumed by bacteria and a deficiency in oxygen is created.
(iii) The deficiency is immediately replenished by atmospheric oxygen.
(iv) Algae and other organisms consume the mineral foods and supply oxygen to the water to maintain the aerobic condition.
(v) The protozoa eat bacteria for survival.
(vi) Again, fish and other aquatic life eat the protozoa.
(vii) Thus, the natural water becomes free from bacteria and protozoa.
(viii) In this way, the decomposition of organic matters and the process of purification go on in natural water.

Graphical Representation

At the beginning, the oxygen demand of sewage is satisfied by dissolved oxygen in water which is represented by deoxygenation curve in Fig. 11.6. Immediately, the deficit of oxygen is filled up by aeration(i.e. by atmospheric oxygen) which is represented by reoxygenation curve. Finally, the rate of deoxygenation becomes equal to that of reoxygenation.

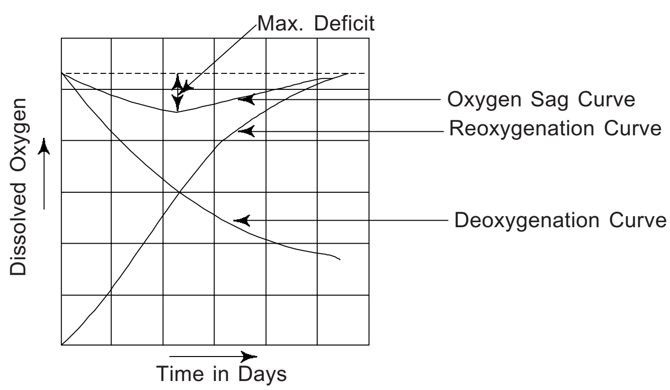


Fig. 11.6 *Self purification process*

By combining both the curves the oxygen sag curve is obtained. When the rates of both the curves are equal, the critical point of maximum deficit is obtained which is indicated by *p*.

11.5 SEWAGE SICKNESS

In sewage farming, when sewage is applied continuously on the agricultural land, the voids of soil go on clogging gradually. A time comes, when the soil voids get completely clogged, air circulation through the soil is totally stopped and sediments get deposited on the surface. An anaerobic condition is developed. At this stage, the soil is unable to absorb further sewage load. An insanitary condition is developed by liberating bad smell. Such condition is termed as sewage sickness.

The following measures may be taken to prevent sewage sickness:

(i) The primary treatment should be given to sewage to eliminate the suspended solids.
(ii) The intermittent supply of sewage should be adopted considering the nature of soil.
(iii) Crop rotation system should be followed so that the different crops may consume different fertilising elements.
(iv) The sub-soil drainage system should be provided to drain out the sub-soil effluent.
(v) Deep ploughing by tractor should be adopted to increase the soaking capacity of soil.
(vi) Time to time, a thin layer of surface soil should be removed by scrapping.

Review Questions

1. What is meant by 'sewage disposal by dilution'? State the conditions to be remembered while applying this method.
2. Discuss the process of self-purification of natural water. Show the graphical representation of this process.
3. What are the advantages and disadvantages of sewage farming?
4. What is meant by sewage sickness? State the measures to be taken to precent sewage sickness.
5. Describe the methods of applying sewage to agricultural land.

12

Sludge Digestion

12.1 INTRODUCTION

The decomposition of complex organic matters in sludge by the bio-chemical reactions created by anaerobic bacteria is termed as sludge digestion.

Necessity of Digestion

The following are the necessity of sludge digestion:

(i) To destroy pathogenic bacteria.
(ii) To reduce the volume of sludge so that it can be disposed of easily.
(iii) To obtain combustible gases.
(iv) To obtain good fertiliser.
(v) To reduce the moisture content for the facility of handling and transporting.

Methods of Sludge Digestion

The sludge can be digested by the following methods:

(i) Sludge digestion tank
(ii) Imhoff tank

12.2 SLUDGE DIGESTION TANK

Constructional Features

1. Enclosure Tank The enclosure tank is generally circular in shape and is constructed with R.C.C. The diameter of tank varies from 5–20 m and depth varies from 3–5 m. However, the actual size depends on the volume of sludge to be treated. The floor of the tank is made sloping like hopper (as shown in Fig. 12.1) and the slope is generally 1 : 2 or 1 : 3.

2. Gas Dome A gas dome is provided with the floating roof for the collection of gas formed during the process of digestion.

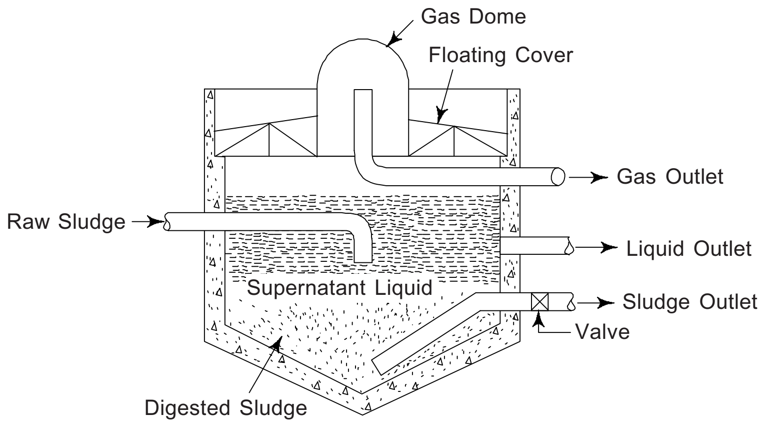


Fig. 12.1 *Sludge digestion tank*

3. Inlet and Outlet An inlet pipe is provided for the entry of raw sludge. A sludge outlet pipe is provided at the bottom. Supernatant liquid outlets are provided at different levels. A gas outlet pipe is provided at the top for drawing the gases from the dome.

4. Mixing Device A suitable mixing device should be provided for mixing the incoming raw sludge with the digested sludge.

5. Scum Breaking Device Some devices should be provided to break up the scum which may form at the top surface.

Working Principles

The following are the working principles of sludge digestion tank:

(a) The raw sludge is allowed to enter the tank through the inlet pipe and is thrown at the centre of the tank.

(b) The sludge is digested by the decomposition of complex organic matters by anaerobic bacteria.

(c) The digested sludge is settled at the bottom of the tank which is withdrawn through the outlet valve and left for drying. The gases (mainly methane) are collected at the dome. The gases are withdrawn through the outlet pipe and are used as fuel.

(d) The supernatant liquid is collected at the space between the digested sludge zone and the gas dome. This liquid is withdrawn from different levels and disposed of in the natural water course.

12.3 IMHOFF TANK

In Imhoff tank, the sedimentation and digestion are carried out simultaneously. The following are the parts and working of Imhoff tank.

(a) Shape It is circular in shape with hopper like bottom and constructed in R.C.C.

(b) Sedimentation Chamber As shown in Fig. 12.2 it is the central zone of Imhoff tank. The sewage containing heavy sludge from the secondary clarifier is allowed to enter this chamber and is detained for specified period.

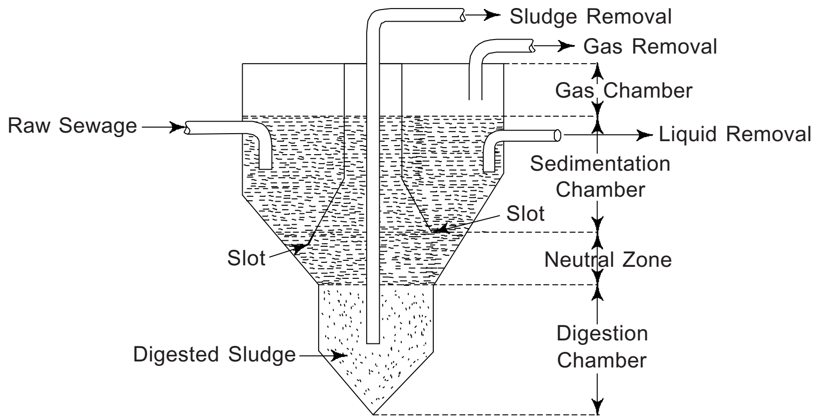


Fig. 12.2 *Imhoff tank*

(c) Baffle Plates and Slots The tank consists of baffle plates with hopper like bottom. Slots are provided between the baffle plates and the body of the tank. The sludge is gradually settled down through the slots and deposited in the digestion chamber.

(d) Digestion Chamber This is the lower part of the Imhoff tank. In this chamber, the sludge is digested under anaerobic condition.

(e) Neutral Zone The space between the slot and the top of digestion chamber is known as neutral zone. The depth of this zone is generally 30 m. This zone prevents the entry of digested sludge into the sedimentation chamber.

(f) Gas Chamber It is the upper zone of the Imhoff tank. In this chamber, the gases (mainly methane) are collected which are withdrawn and used as fuel.

(g) Sludge Removal The digested sludge from the digestion tank is withdrawn through the sludge removal pipe and taken to the drying bed.

Review Questions

1. What is meant by digestion of sludge? State the necessity of digestion of sludge.
2. Describe the method of digestion by digestion tank with a sketch.
3. Describe the method of digestion by Imhoff tank with a sketch.

13

Sludge Disposal

13.1 INTRODUCTION

The sludge (i.e. the settleable part of the sewage) has an objectionable odour and it possesses the property of pollution if not properly disposed of. But, if it is dried and properly stored, then it can be used as a good manure. The sludge may be of various types, such as:

(a) Sludge from primary settling tank
(b) Sludge from secondary settling tank
(c) Sludge from trickling filter
(d) Sludge from digestion tank

The sludge obtained from all the sources may not possess same characteristics. So, the unwanted sludge should be disposed of. The following are the various methods of sludge-disposal:

(a) Disposal by drying bed
(b) Disposal on land
(c) Disposal by throwing into sea
(d) Disposal by lagooning
(e) Disposal by incineration.

13.2 DISPOSAL BY DRYING BED

It is a rectangular pit excavated to the required depth. It is divided into several beds. The beds are filled with gravel and coarse sand as filter. The depth of gravel is 30 cm. The bottom layer of 15 cm consists of 40 mm gravel and the top layer consists of 6 mm gravel. The depth of coarse sand is 15 cm. The underdrainage system consists of a pipe line perforated at the top, as shown in Fig. 13.1. The working principle of drying bed is stated below:

(a) The sludge is spread evenly over the sand bed to a thickness of 30 cm.
(b) After 7 days, the surface of sludge cracks which indicates that the sludge is ready for removal.

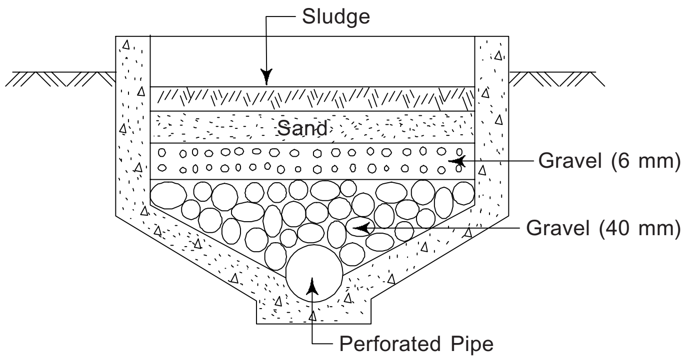


Fig. 13.1 *Drying bed*

(c) The sludge cakes are removed by a spade and stored suitably for the use as manure.
(d) This method is generally recommended for the black sludge (i.e. humus) which has good manurial value.

13.3 DISPOSAL ON LAND

The sludge may be disposed of to the barren lands to make it fertile in due course. The sludge may be applied in barren lands in the following ways:

(a) By Ploughing The sludge is spread over the land and ploughed by tractor. It is then left for several months. Again, the land is ploughed by spreading a fresh layer of sludge. Thus the barren land may be converted to fertile land.

(b) By Trenching Trenches may be excavated in parallel rows at an interval of 1 m on the barren land. The trenches are filled up with sludge and a thin layer of excavated earth is spread over it. After one month, new trenches are excavated perpendicular to the previous trenches and these are filled up with sludge as previous method. Thus the barren land is converted to fertile land where plenty of crops may be grown.

13.4 DISPOSAL BY THROWING INTO SEA

In coastal towns or cities, the sludge may be directly thrown into the sea. Because, there is no utility of sludge, not even as manure or for land treatment. It is a very easy and cheap method of sludge disposal. While dumping into the sea, the following points should be remembered:

(a) The sludge should be thrown into the deep sea far away from the shore.
(b) The direction of wind and wave should be carefully studied so that the sludge may not return to the shore.
(c) The sludge should not be thrown in the zone where the fishermen catch sea-fishes.

13.5 DISPOSAL BY LAGOONING

A lagoon is an artificial pond of shallow depth of about 1 m. The surface area of lagoon depends on the volume of sludge and the availability of land. Embankments are constructed with the excavated earth as shown in Fig. 13.2. A layer of sand of thickness 15 cm is laid at the bottom of the trench.

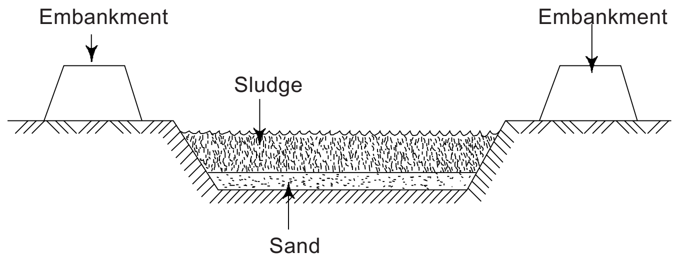


Fig. 13.2 *Lagoon*

The lagoon is filled up with wet sludge and left for few months. The sludge is dried gradually and cracks are formed on the surface. Then the dried sludge is removed and used as manure. Thus is a very cheap method, if sufficient land is available.

13.6 DISPOSAL BY INCINERATION

The term incinerator indicates the process of burning to ashes. The sludge is burnt in incinerator which may be of the following types:

(a) Flash Type This type of incinerator consists of a tower. The tower is first heated by fuel (generally coal) and then the wet sludge is thrown from the top of the tower. The hot gases and the moisture are removed through the top of tower. The burnt sludge is collected at the bottom. It is then disposed of by dumping in ditches or low-lying areas.

(b) Multiple Hearth Type This type of incinerator consists of a furnace. The furnace consists of a series of hearths placed in successive layers. The wet sludge is placed over the top hearth. Then the sludge rolls over the successive hearths towards the bottom hearth. The gases and moisture are removed and the burnt sludge is collected at the bottom. It is then disposed of by dumping in ditches or low-lying areas.

REVIEW QUESTIONS

1. What is the necessity of sludge disposal?
2. Enumerate the various methods of sludge disposal.
3. How are drying beds constructed?
4. Explain the process of drying the sludge in drying bed.
5. How is the sludge disposed of by incineration?
6. Explain the lagooning method of sludge disposal.

14

Sanitary Fittings

14.1 DEFINITIONS

(a) Trap The device which is connected to the soil pipe to stop the entrance of foul gases inside the building is known as trap. It is a bent pipe in the shape of 'U' which always remains full of water.

(b) Water Seal The vertical distance between the crown and the dip of the trap is known as water seal. This portion always remains full of water. The efficiency of trap depends on the depth of water seal. Generally, the water seal varies from 75 mm to 100 mm.

(c) Breaking of Water Seal The water seal of a trap may be broken by siphonic action which is known as siphonage. This phenomenon occurs when the sanitary fitting of different floors are connected by a common soil pipe. When the discharge from the upper floors comes down by sucking the air from the connecting pipes of the lower floors, the siphonic action starts and the water seal of the trap may be broken if necessary arrangement is not provided.

(d) Anti-siphonage To protect the water seal in the trap a small diameter pipe is connected to the trap and it is extended vertically. This system is known as anti-siphonage and the pipe is known as anti-siphonage pipe. This pipe contains a cowl at the top.

(e) Inspection Chamber It is a rectangular chamber constructed between the gully trap and main sewer line. The sewage from the gully trap is allowed to fall directly to this chamber to arrest the suspended and floating particles, so that the main sewer may not be clogged. The chamber contains a top slab with a manhole for inspection and clearance.

14.2 GULLY TRAP

The gully trap is constructed of stoneware. It is a device for connecting the house drain to the underground sewer line. Generally, it is placed outside the building wall. The water seal of the trap prevents the foul gases from entering the houses. Figure 14.1 shows a gully trap. It is placed on a concrete foundation and secured in position by brick work. A C.I. grating is provided on the top of the trap for the entry of water from the house drains. A C.I. cover is also provided on the top of the gully for cleaning. The gully traps are generally provided just ahead of the inspection chambers or sewer lines.

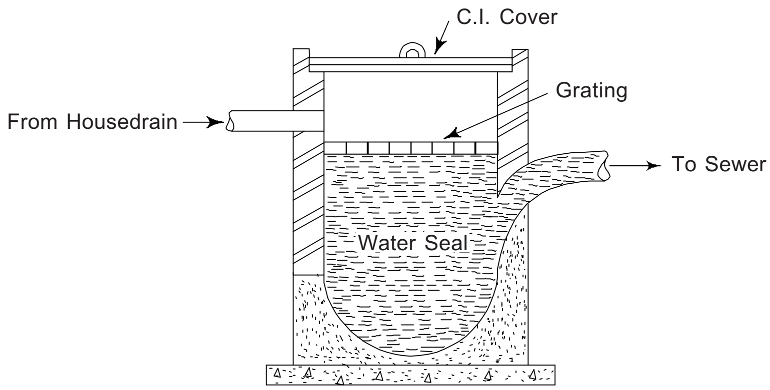


Fig. 14.1 *Gully trap*

14.3 FLOOR TRAP

Figure 14.2 shows a floor trap. The floor trap is generally made of cast-iron and placed in the floor of bath rooms, kitchens, etc. A removable C.I. grating is provided on the top of the trap to prevent the floating matters from entering the pipe line. In multi-storied buildings the floor traps should always be provided for the easy discharge of sullage. The water seal of the trap prevents the foul gases of sewer line from entering the bathrooms or kitchens.

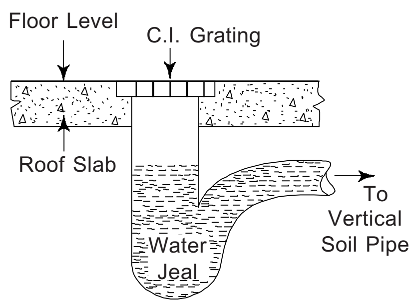


Fig. 14.2 *Floor trap*

14.4 INTERCEPTING TRAP

The intercepting trap is also known as interceptor. It is provided with the manhole of the domestic drainage line. The domestic sewage is carried by the pipe line and allowed to fall in the semicircular open channel within the manhole, as shown in Fig. 14.3. Then the sewage flows to the main sewer through the interceptor. The interceptor consists of water seal so that the foul gases from the sewer may not enter the manhole and the domestic drainage line. It also has an inspection arm which is kept closed by plug. The plug is opened for cleaning the pipe line.

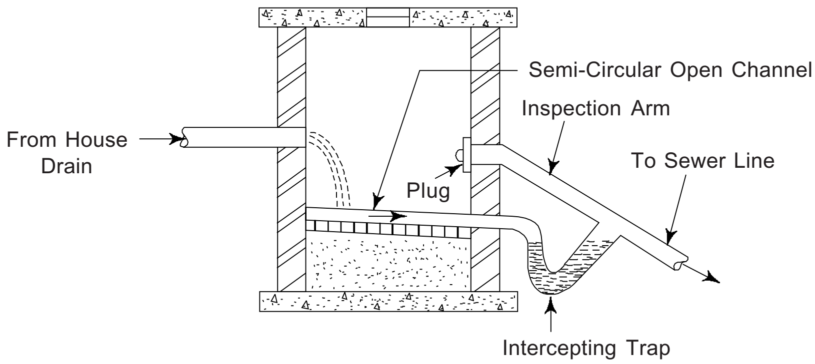


Fig. 14.3 *Intercepting trap*

14.5 P-TRAP

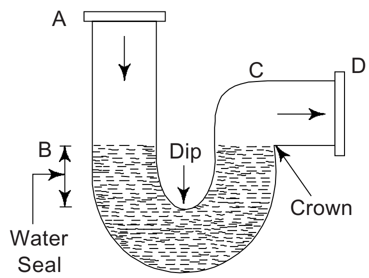


Fig. 14.4 *P-trap*

Figure 14.4 shows a P-trap. This trap is manufactured with stoneware in the shape of the letter 'P'. Here, the arm AB is vertical and the arm CD is horizontal. The water seal varies from 50–100 mm. This trap is provided with the pipe line from urinals, latrines or bathrooms to prevent the foul gases from entering the house.

14.6 Q-TRAP

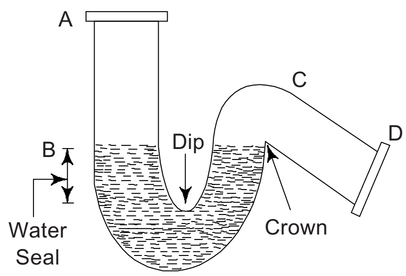


Fig. 14.5 *Q-trap*

This trap is also manufactured with stoneware in the shape of the letter 'Q'. The arm AB is vertical and the arm CD is inclined at 45° with the vertical, as shown in Fig. 14.5. The water seal in this trap also varies from 50–100 mm. This trap is provided with the domestic drainage line according to the position of the site. In this case also the water seal prevents the sewer gases from entering the domestic sewer line.

14.7 S-TRAP

This trap is also manufactured with stoneware in the shape of the letter 'S'. The arms AB and CD are parallel, as shown in Fig. 14.6. The water seal varies from 50–100 mm and it prevents the sewer gases from entering the house. This trap also is required in domestic drainage line according to site condition.

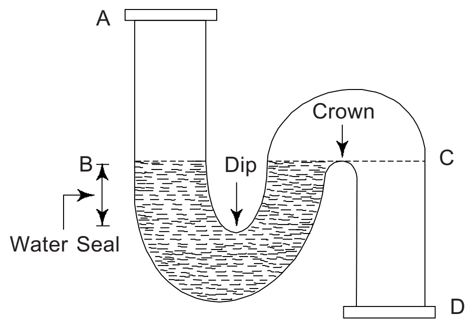


Fig. 14.6 *S-trap*

14.8 WATER CLOSET

The sanitary fittings in which the human excreta is discharged and conveyed to the septic tank or underground sewer through a trap is known as water closet. The water closet may be of two types:

1. Indian Types Water Closet

In this type of closet, the pan and the trap are made of porcelain. These two are assembled properly at the time of laying. The closet is set up at the floor level and a pair of foot rests are provided on both sides of the pan. The trap consists of a hole on the top for the connection to anti-siphonage pipe. The length of the pan varies from 450 mm to 675 mm and the water seal varies from 50 mm to 75 mm. As shown in Fig. 14.7, flushing rim is provided on the top interior surface for flushing the closet with water which is supplied from the flushing tank or cisterns. The water closet is connected to the septic tank or underground sewer according to the system of sanitation.

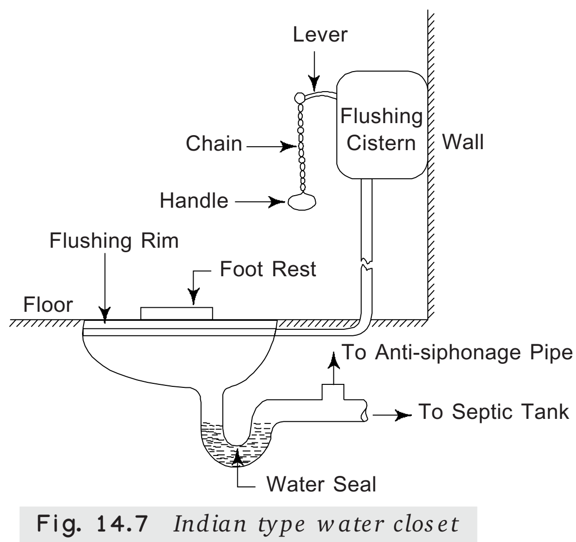


Fig. 14.7 *Indian type water closet*

2. European Type Water Closet

The European type water closet is known as commode system. This closet also is made of porcelain and the shape is somewhat oval. The trap is placed in such a way so that the excreta is directly discharged on the water seal. The length of pan varies from 500 mm to 600 mm and the depth varies from 350 mm to 400 mm. The pan is set up on a pedestal of comfortable height. The flushing rim is provided on the top inner surface. The flushing cistern is placed very near to the pan, as shown in Fig. 14.8. A hole is provided on the leg of the trap for the connection to anti-siphonage pipe. This closet also is connected to the septic tank at the underground sewer line according to the system of sanitation.

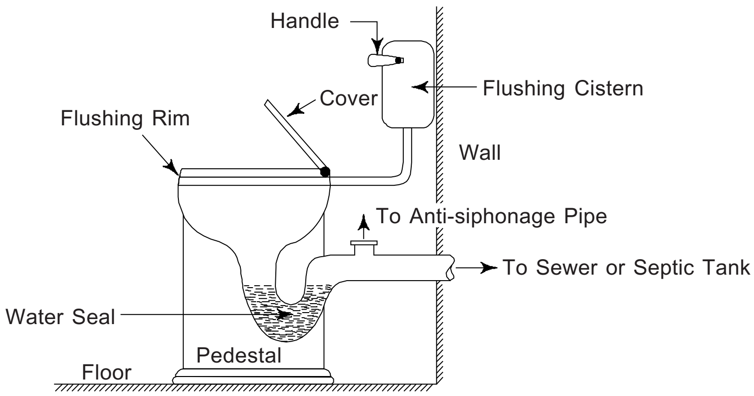


Fig. 14.8 *European type water closet*

14.9 FLUSHING CISTERN

The cistern or tank which is installed above the latrine or urinal for flushing water is known as flushing cistern. In case of Indian water closet, the cistern is made of cast iron and in case of European water closet it is made of porcelain. The C.I. cistern is operated by chain and handle and the porcelain cistern is operated by small handle. The capacity of cistern varies from 5 to 10 lits. The flushing cistern works on the principle of siphon. Figure 14.9 shows a flushing cistern. The flushing cistern consists of the following components: (Now a days plastic flushing cistern is available)

(a) A Bell It is provided over the flushing pipe. It is connected to a lever which is operated by the chain and handle.

(b) A Lever A lever is provided inside the cistern, one end of which consists of a float and the other end consists of a plug.

(c) Overflow Pipe It is provided to maintain the discharge level in the cistern.

(d) Inlet Pipe The mouth of the inlet pipe should be such that it can be closed and opened by a plug which moves up and down with the movement of the float.

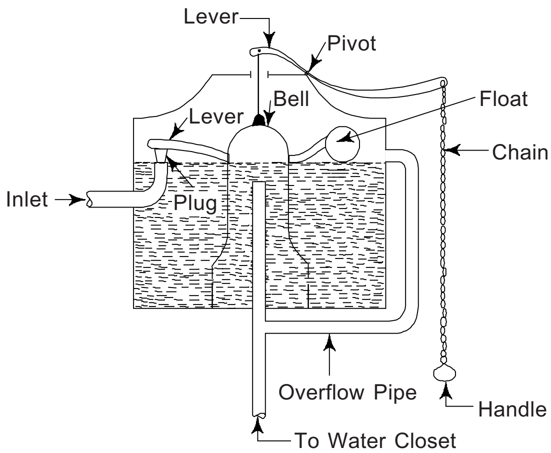


Fig. 14.9 *Flushing cistern*

Working of Flushing Cistern

(a) When the water level in the cistern comes to the discharge level, the float is on the top position. At this time, the plug closes the mouth of inlet pipe by the action of lever.
(b) When the chain is pulled up and down very quickly, the bell is lifted up and down and a partial vacuum is created at the crown of the bell and hence the siphonic action starts.
(c) When the water is discharged completely, the float comes down and the plug is lifted up to open the mouth of inlet pipe and then the water enters the cistern again.
(d) When the cistern is filled up completely, the mouth of the inlet pipe is closed automatically. The function of overflow pipe is to maintain the discharge level in the cistern.

14.10 URINALS

The system for collection and disposal of urine is known as urinal. The bowl-type urinal is commonly used which is shown in Fig. 14.10. It is an oval shaped bowl made of porcelain. It is fixed on the wall at a comfortable height with the help of screws on both sides. A hole is provided on the top for connecting the flushing pipe with the flushing rim. Another hole is provided at the bottom for connecting with the surface drain or underground sewer. The common size of the bowl type urinal is 45 cm × 37 cm.

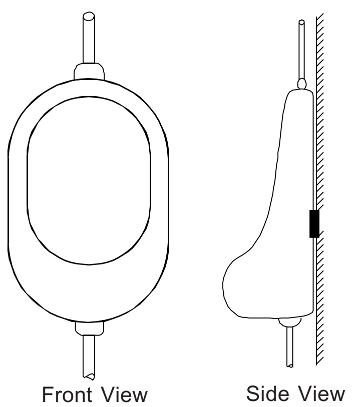


Fig. 14.10 *Bowl type urinal*

14.11 BATH TUB

It is a rectangular basin made of R.C.C., finished with marble chips or marble blocks or any other type according to the choice of the users. The size depends on the individual choice. The sides of the basin are made sloping, as shown in Fig. 14.11. The bath tub is placed on the floor supported by four legs. The water is supplied to the tub through the water tap provided on the top of the tub. The tub consists of a washout pipe and an overflow pipe. Both the pipes are connected to the soil pipe. The washout pipe consists of a trap having water seal so that the foul smell from soil pipe may not enter the bath tub. After bathing, the whole water is discharged and fresh water is stored for further use.

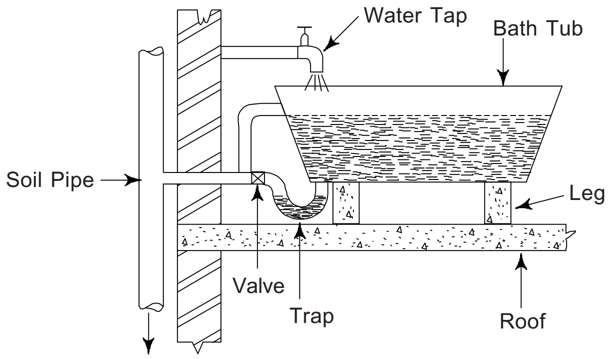


Fig. 14.11 *Bath tub*

14.12 WASH BASIN

Figure 14.12 shows a wash basin. A wash basin is made of porcelain having different sizes and colour shades. The taps may be provided in one side or both sides. It is fixed on the wall at a comfortable height with C.I. brackets and screws. The mouth of the outlet pipe consists of brass or nickel grating. The wash basins are provided in kitchens, bathrooms or some suitable place for washing faces, mouth, hands, etc. The pedestal type wash basin rests directly on the floor.

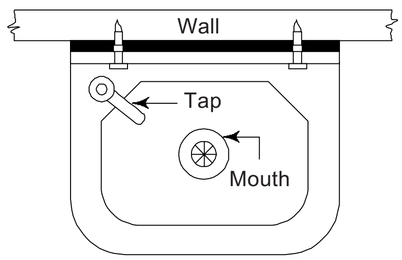


Fig. 14.12 *Wash basin*

14.13 INSPECTION, TESTING AND MAINTENANCE

Inspection

The following inspection should be done:

(a) The traps, closets, etc. should be carefully inspected before installation. Any crack or leakage found in the sanitary connecting parts should be rejected.

(b) Sanitary pipes should be inspected by knocking with a mallet (i.e. wooden hammer). The pipes having ringing sound indicate that they are perfect.
(c) Minor defects in C.I. pipes may be rectified by painting. But major defects in the pipes should not be allowed.

Testing

(a) Smoke Test To detect the leakage in soil pipe, waste pipe, vent pipe etc. smoke is introduced into the pipe by closing the end. The leakage in the pipe may be detected by the emission of smoke through the point of leakage.

(b) Water Test The lower end of the pipe is plugged and water is poured from the upper end with a funnel until the pipe is filled completely. Then the pipe should be examined thoroughly—whether water drops are found on the body of the pipe.

Maintenance

(a) Proper flushing should be done in the lavatory, urinal etc. to keep them in good working condition.
(b) Substances like paper, pieces of clothes, etc. should not be thrown in places from where they may easily enter the pipe line, water closet, etc.
(c) The sanitary fittings should be inspected regularly. Any damage found should be rectified immediately.
(d) To maintain good hygienic condition in building, the disinfectants should be applied regularly in lavatory, urinal, bathroom, etc.
(e) The surface drains should be kept clean by flushing water regularly.

Review Questions

1. Describe a gully trap with sketch.
2. Describe a floor trap with sketch.
3. Describe an interceptor with sketch.
4. Describe P-trap, Q-trap, and S-trap with sketches.
5. Describe urinals and water closets with sketches.
6. Describe a flushing cistern with sketch.
7. Describe a bath tub with sketch.

15

Preparation of Sanitary Scheme or Project

15.1 RECONNAISSANCE

When a sanitary project or scheme is to be prepared for a newly developing town or city, a reconnaissance survey should be conducted to collect the following data:

(a) The total area to be covered under the scheme.
(b) The present population of the area.
(c) Habits of the people according to the nature of residential area.
(d) Types and numbers of public places.
(e) An index map to be prepared showing the different residential zones, trend of development, industrial and commercial zones, etc.
(f) Probable population for the next three decades (i.e. thirty years) should be worked out.

15.2 TOPOGRAPHICAL MAP

The topographical map of the town or city should be prepared showing the colonies, housing estate, high value premises, public places, roads, etc. using different colour shades or symbols.

15.3 DIVISION INTO DIFFERENT ZONES

For successful implementation of the scheme, the area of the town is divided into several zones. This is done because the method of garbage collection and sewerage system may vary from zone to zone.

15.4 SKELETON MAP FOR GARBAGE COLLECTION

To ensure easy disposal of garbage, the positions of garbage collection centres, dustbins, etc. should be marked on the topographical map, so that the vehicles employed for collection and disposal may move easily without causing any inconvenience to the public.

The location of the dumping place should be marked on the skeleton map at a suitable area far away from the locality. A specific route should be indicated for the transport of garbage.

15.5 SKELETON MAP OF UNDERGROUND SEWER LINE

Nowadays, the water carriage system is considered essential for the disposal of sewage, for reasons of hygiene and convenience. Therefore, a sewerage system has to be implemented for which a skeleton map of underground sewer line has to be prepared. The following points should be included in the map:

(a) In the main sewer line, the specific points like manholes, lampholes, inspection chamber, etc. should be marked.
(b) In branch sewer line the specific points of importance should be marked.
(c) The point of change of grade and the position of pump house should be marked.
(d) The position of treatment plant should be shown.
(e) The points of disposal of effluent and the area of sludge disposal should also be marked.

15.6 OFFICE WORK

The office work involves the preparation of the following:

(a) Design of sewers and allied works
(b) Design of treatment plant
(c) Detailed estimate of sewer line and treatment plant
(d) Compensation payable (if required)
(e) Detailed estimate of other allied works
(f) Purpose of vehicles and other machinaries
(g) Total cost of the scheme

15.7 SUPPORTING MAPS AND DRAWINGS

(a) Topographical map
(b) Skeleton map of garbage collection
(c) Skeleton map of underground sewer line
(d) Drawing of treatment plant
(e) Drawing of pump house

15.8 PROJECT REPORT

After completion of all investigation works, design works, estimates, etc. a report has to be prepared and submitted to the competent authority for approval. The report should include the following

(a) Introduction
(b) Necessity

(c) Justification of considering the present scheme
(d) Estimate of the scheme
(e) Specification for the construction and the materials
(f) Conclusion and recommendation

16

Sanitation and Plumbing in Buildings

16.1 SANITATION

Sanitation in a building should be maintained by the owner of the house. The owner should keep in mind the following points:

(a) The sewer or drainage line should be laid outside the building and inspection pit or chamber should be provided at a suitable point so that the sewer line may not be clogged.
(b) Intercepting trap should be provided just ahead of the main sewer to prevent the sewer gases from entering the building.
(c) Anti-siphonage pipe should be extended above the roof level to escape the foul gases to atmosphere.
(d) Flushing of the lavatories and urinals should be done properly.
(e) Disinfecting substances such as phenyl, naphthalene, etc. should be applied in bathrooms and urinals.
(f) The waste matters such as cotton waste, vegetable and fruit peel, cloth pieces, paper, sweepings, fish scales, etc. should be collected in a basket and thrown to roadside dustbins.
(g) The surface drain of the house should be kept clean.

16.2 PLUMBING WORK

Figure 16.1 shows the sanitary plumbing work required in a building. The positions and functions of different attachments are noted below:

(a) Main Soil Pipe It is a vertical pipe provided outside the wall of the building to carry the discharge from water closets, urinals, bathrooms, etc. and to dispose of to main sewer. The pipe may be made of asbestos, cast-iron or P.V.C. The diameter of the pipe varies from 10 cm to 15 cm.

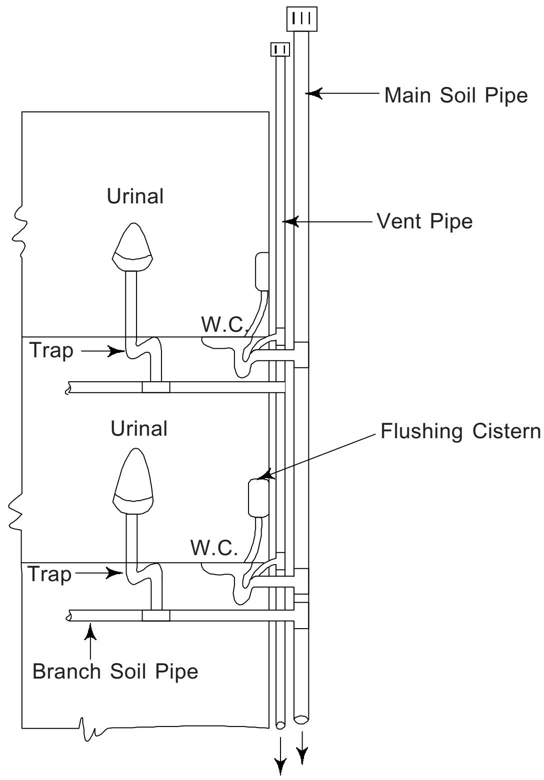


Fig. 16.1 *Sanitary plumbing work*

(b) Branch Soil Pipe It is a small diameter pipe which receives the discharge from the urinals, bathrooms, and kitchen through an 'S-trap'.

It may also be made of asbestos, cast-iron or P.V.C. The diameter may vary from 5 cm to 10 cm.

(c) Vent Pipe It is also made of asbestos or cast-iron or P.V.C and provided vertically on outside of the wall and is connected to the trap to protect the water seal. It is also known as anti-siphonage pipe.

(d) Rain water Pipe It is provided on the outer wall of a building to discharge the rainwater from the roof. This pipe also may be made of asbestos or cast-iron or P.V.C. The diameter of the pipe varies from 10 cm to 15 cm.

The positions of other sanitary fittings such as trap, water closet, wash basin, flushing cistern, etc. are shown in Fig. 16.1 and the particulars of those fittings are described in Chapter 14.

17

Bio-gas Plant

17.1 INTRODUCTION

Due to the gradual diminishing of conventional energy, the production and sources of non-conventional energy is becoming popular, especially in the rural areas. Traditionally, cattle dung has been used as fuel by making dried cakes. For the past few decades, its use for the production of bio-gas has gained popularity as it is more beneficial than its use as dried cakes for fuel. The bio-gas serves the purpose of cooking, lighting, etc.

Bio-gas is obtained by anaerobic decomposition of substances like cattle dung, cattle urine, perishable vegetables, etc. After decomposition the following gases are produced:

(a) Methane (CH_4)
(b) Carbon-dioxide (CO_2)
(c) Nitrogen (N)
(d) Sulphurreted hydrogen (H_2S).

Here, Methane is highly combustible and produces flame and heat energy. It is a source of energy at low cost one cubic metre of gas contains 6000 calories of heat. Again, 6000 calories of heat is equivalent to:

(a) 0.8 lit of petrol
(b) 0.6 lit of crude oil
(c) 1.5 m^3 of cooking gas
(d) 2.2 kWH of electrical energy

17.2 DETAILS OF BIO-GAS PLANT

Components

Figure 17.1 shows the important components of a bio-gas plant.

(a) Intake Tank It is a small tank constructed with brick masonry where cattle dung and other wastes are mixed thoroughly with water in the proportion

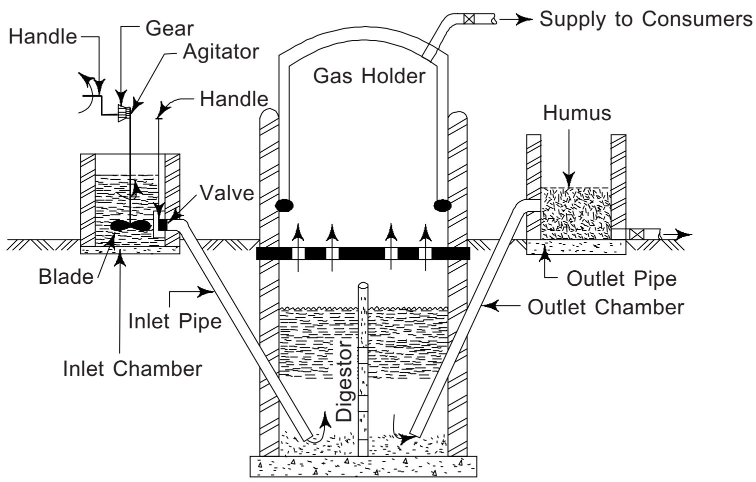


Fig. 17.1 *Bio-gas plant*

of 4 : 5 to form a thick paste. This tank is also known as mixing chamber. The size of the tank depends on the volume of dung available per day.

(b) Outlet Tank It is also a small chamber constructed with brick masonry. After digestion, the humus is collected in this tank.

(c) Digestor It is an underground well constructed with brick masonry. The depth of the well varies from 4–6 m and the diameter varies from 2– 4 m. The prepared paste from the intake tank is fed to the digestor for anaerobic decomposition.

(d) Gas-holder It is like a dome where the gas is collected. The gas-holder is provided with rollers at the bottom so that it can rise or fall according to the pressure of the gas. An outlet pipe, with regulator, is provided on the dome to control the supply of gas.

Working

The working of the bio-gas plant is as follows:

(a) The cow dung and water is mixed in the intake tank as per the recommended proportion (generally 4 : 5). Then by agitator the mixture is converted to a thick paste.

(b) The valve of the inlet chamber is opened and the paste is allowed to enter the digestor.

(c) The mixture is retained in this chamber (i.e. digestor) for several days for anaerobic decomposition. After decomposition gases and humus are produced. The gases are collected in the gas holder and humus is collected at the bottom of digestor.

(d) The gas is supplied to the consumers through the outlet pipe which consists of a regulator.

(e) The humus is taken to the outlet tank from where it is further taken to drying bed to convert is to manure.

PART III

POLLUTION

1

Air Pollution and Control

1.1 INTRODUCTION

The atmospheric air contains about 79% of nitrogen and 21% of oxygen and the negligible traces of other sixteen elements such as carbon dioxide, methane, carbon monoxide, ammonia, sulphur dioxide, etc. are found, which have practically no adverse effect. This air is considered as pure or healthy and is always desirable for human life, animal life and plant life. But due to various factors the balance of nitrogen and oxygen is getting disturbed gradually and is causing adverse effects on human health, animal life, plant life and other materials of the universe.

So, the accumulation of destructive elements in the air from the natural or unnatural sources is termed as air pollution.

1.2 CAUSES OF AIR POLLUTION

The following are the causes of air pollution:

1. Increase in population and traffic
2. Development of industries
3. Development of automobile engineering
4. Development of agriculture
5. World wide arms race
6. Thermal and nuclear power generation

1. Increase in Population

Due to the increase in population, the residential areas of a town or city are being enlarged by destroying the forest areas, trees, jungles, etc. which have the property of absorbing carbon dioxide and releasing oxygen. Due to the growth in population the systems of sanitation have also become a matter of grave concern in a town or city. Again, the manufacturing units of house construction materials such as bricks, cement, stone chips, etc. impart much pollutants in air.

2. Development of Industries

The development of industries such as fertilizer industry, chemical industry, metallurgical industry, petroleum industry, tanning industry, paper industry, etc. discharge poisonous gases and waste products.

3. Development of Automobile Engineering

Due to the development of automobile engineering, the vehicles of petrol and diesel engines are going on increasing in urban areas. The towns and cities are crowded with buses, minibuses, cars, taxies, etc. which are releasing much carbon monoxide in the air regularly.

4. Development of Agriculture

Due to the development of agriculture, improving the yield of crop has become easier. So, the application of chemical fertilizer and insecticides have become a trend. Such things are also responsible for air pollution.

5. World Wide Arms Race

All the countries in the world have a tendency to obtain more power than the others by creating nuclear weapons and other explosives. The nuclear explosions are carried out on the surface of the earth for the purpose. The radioactive substances from such explosions are polluting the atmospheric air.

6. Thermal and Nuclear Power Generation

Due to the development of civilisation, the demand of electric power has increased many folds for running refrigerators, televisions sets, washing machines, pump sets, lights, fans, etc. To meet the excessive demand of power, the thermal and nuclear power generation plants have become an urgent need. The fly ashes and radioactive ashes generated from such plants are polluting the atmospheric air.

1.3 FORMS OF AIR POLLUTANTS

(a) Smoke It is produced chiefly due to the incomplete combustion of fuel such as coal, oil, petroleum, etc. It contains carbon monoxide, carbondioxide, etc.

(b) Dust It is finely divided powder-like matters generated by crushing or grinding of stones, disintegration of stones or other inorganic substances.

(c) Gases These are formless fluids which can be transformed to liquid state by the change of temperature and pressure. These are formed by the decomposition of organic matters or burning of fuels.

(d) Aerosol The dispersion of microscopic solids or liquids in the atmosphere is termed as aerosol.

(e) Particulate Matter The matter which is generated from the sources such as industries, power generation plants, road-way dust, etc. and exist in atmosphere in suspension is known as particulate.

(f) Pollen The fertilizing or reproductive matters of flowers to form seeds is known as pollen. The pollen can float in air or it can be transferred from flower to flower by bees or butterflies.

(g) Sulphur Dioxide (SO_2) It is generated from thermal power plants petroleum industries, oil refineries, acid manufacturing plants, etc. It causes respiratory diseases, irritation of throat and eyes, etc.

(h) Hydrogen Sulphide (H_2S) It is generated from sewage treatment plants, tanning industries, dye manufacturing, etc. It causes irritation and disorder of respiratory organ, etc.

(i) Nitrogen Oxide (NO) and Nitrogen Dioxide (NO_2) These are generated from explosive manufacturing industry, automobile workshop, acid manufacturing plant, etc. It causes bronchitis and oedema of lungs, etc.

(j) Hydrogen Fluoride (HF) It is generated from chemical industry, fertilizer industry, aluminium industry, etc. It causes skin diseases and bone fluorisis, etc.

(k) Hydrogen Peroxide (H_2O_2) It is generated from photo chemical smog products. It causes lungs irritation.

(l) Carbon Monoxide (CO) and Carbon Dioxide (CO_2) It is generated from automobile exhaust, blast furnace, fuel gases, etc. It is a poisonous gas and causes damage to the respiratory organ.

(m) Hydrocarbon It is generated from automobile exhaust. It causes disease of respiratory organ.

(n) Arsenic It is generated from detergents, pesticides, etc. It causes skin diseases.

1.4 SOURCES OF AIR POLLUTION

The sources of air pollution may be classified in two groups:

1. Natural sources
2. Man made sources

1. Natural Sources

The following are the different forms of natural sources:

(a) Atmospheric Reactions In the atmosphere, different types of chemical reactions are always going on. In the lower atmosphere, the gases or vapours are always converted into solids or liquids by condensation or oxidation. In upper atmosphere, the photo-chemical reactions are going on

by the absorption of ultra-violet solar radiation. It breaks the complex molecules of organic matters. The products of atmospheric reactions come down to earth by rain, snowfall, etc.

(b) Dust and Aerosol The dust and aerosol which are present in atmosphere consist of salt particles from sea water, air-borne particles, bacteria, etc. The particles remain in suspension in air.

(c) Microorganisms These are in the form of algae, fungi, bacteria, yeast, etc. These organism can be transported by wind to far distances and can affect plants, animals and human beings.

(d) Pollen These may enter the atmosphere from the flowers of trees, grasses and weeds and may be transported from place to place by wind.

(e) Radioactive Substances The radioactivity of the atmosphere is caused by the radioactive minerals present in the crust of the earth and the action of cosmic rays. The radioactive substances such as radium, uranium, thorium, etc. are responsible for imparting the radioactivity of air.

2. Man-made Sources

The following are the man-made sources of air pollution:

(a) Combustion of Fuel In domestic areas, the burning of coal, wood, oil and LPG forms harmful gases which pollute the air.

(b) Thermal and Nuclear Power Plants The thermal power plants contribute sulphur dioxide and nuclear power plants contribute radioactive fly ashes to the atmospheric air.

(c) Industries The industries like iron and steel manufacturing, oil refinery, chemical factories, petro-chemical plants, pulp and paper, etc. cause serious air pollution. The smelting and refining of non-ferrous metals also impart much air pollutants.

(d) Vehicular Pollution The towns and cities are crowded with trucks, buses, minibuses, cars, taxies, etc. which exhaust carbon monoxide in large scale. This gas is very dangerous to human health.

(e) Construction Materials The manufacture of bricks, cement, stone chips, etc. pollute the atmosphere by discharging smoke, gases and dusts.

(f) System of Sanitation The unscientific disposal of garbage produces foul gases, bad odour and insanitary condition. In towns where the conservancy system is followed, the system of disposal of night soil produces foul gases, fly nuisance, etc.

(g) Nuclear Combustion The experimental combustion of nuclear weapons pollutes the atmosphere by radioactive ashes. Again, the combustion in nuclear research centre, also develops radioactive substances which pollute the atmosphere.

1.5 EFFECTS OF AIR POLLUTION

The following are the effects of air pollution:

1. Effect on Human Health

The inhalation of different gases causes various harmful effects on the human health as listed in Table 1.1:

Table 1.1

Air Pollutants	Effect on human health
(i) Sulphur dioxide	It causes suffocation, respiratory diseases, irritation of eyes and throat.
(ii) Hydrogen sulphide	Danger of respiratory paralysis.
(iii) Nitrogen Oxide	It causes bronchitis, oedema of lungs.
(iv) Hydrogen fluoride	It causes skin disease, bone fluorosis.
(v) Carbon monoxide	It causes lungs disease and slow poisoning leading to death.
(vi) Oxidants	It causes lungs diseases.
(vii) Arsenic	It causes skin disease.

2. Effect on Material

Some of the harmful effects of air pollution has on various material are as follows:

(i) It causes deterioration of building material.
(ii) It causes corrosion and incrustation of metals.
(iii) It causes discolouration of paints, cement colour, etc.
(iv) It causes reduction of strength of materials.

3. Effect on Vegetation

The concentration of nitrogen dioxide, sulphur dioxide and ozone may damage plants, vegetables, fruit trees, and forest areas. Some of the typical effect on vegetation are as follows:

(i) Plants may be dried up, the yield of crop may decrease, the quality of crops may decline or may be affected by diseases.
(ii) The growth of vegetables may stop, the quality may be inferior or may be affected by diseases.
(iii) The quality of fruits may become inferior or the quantity may also decrease.
(iv) The forest area may get destroyed gradually. The growth of trees may become stunted or they may dry up completely.

1.6 CONTROL OF AIR POLLUTION

The following steps should be taken to control air pollution:

1. Control by Zoning

The area of the town or city should be divided into different zones such as residential zone, industrial zone, trade zone, etc. The industrial zone should be far from the residential zone. The planning of the zones should be such that the future development will follow the rules and provisions made for that zone.

2. Control by Afforestation

It is found that the plants can reduce air pollution to a great extent. So, plantation of trees should be encouraged all around the town or city. New forest area should be developed. Trees should be planted at parks and public places.

3. Control by Vehicle Rules

The "vehicle act" should be strictly followed. The design of vehicles should be such that complete combustion of fuel takes place in the engine. The exhaust constituents of the motor vehicles should be within the prescribed safety limit.

4. Control by Increasing the Height of Chimney

The height of chimneys of thermal plants, nuclear plant, brick manufacturing plants, etc. should be increased up to the permissible limit so that the smoke, fly ash or rubbish does not spread over the residential area.

5. Control by Ventilation

Suitable ventilation system should be provided in the kitchen of every house so that the gases produced by burning of wood, coal, oil, etc. may be exhausted very quickly.

6. Control by Mechanical Device

Any one of the following devices should be adopted in industry for controlling the atmospheric pollution.

(a) Bag filters of Fabric filters
(b) Cyclone collectors
(c) Cyclonic scrubbers
(d) Venturi scrubbers.

(a) Bag Filters or Fabric Filters The bag filter is also known as fabric filter. It consists of the fabrics of nylon, dacron, teflon, cotton, wool, etc. enclosed in a hopper bottomed box. The dust laden gas is sent through the bottom of the box, which passes upwards through the fibres as shown in Fig. 1.1. The heavier particles settle down at the bottom of the hopper due to the force of gravity. The finer particles adhere to the fabrics due to the electrostatic charges. The filtered gas passes through the outlet pipe at the

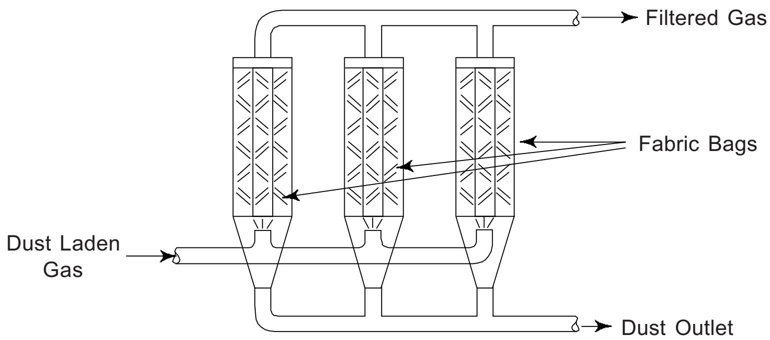


Fig. 1.1 *Bag filter*

top. The dust is taken out through the outlet pipe at the bottom. To clean the finer particles, compressed air is blown through the bags in downward direction.

(b) Cyclone Collector A cyclone is a long tapered cylinder in which an arrangement is made so that the dust laden gas after entering the cylinder, moves downwards along the outer vortex. After reaching a certain distance, it changes its direction and rises up along the inner vortex, as shown in Fig. 1.2. Due to inertia the dust particles are separated and settle down at the bottom. The clean gas comes out through the outlet pipe at the top and the dust particles are taken out through the outlet pipe at the bottom.

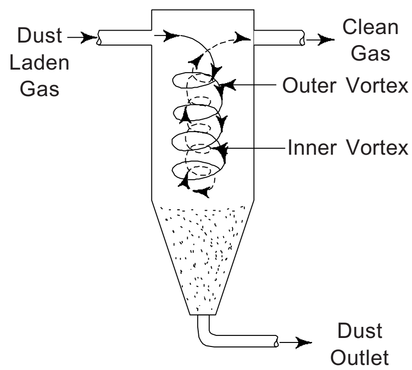


Fig. 1.2 *A cyclone*

(c) Cyclonic Scrubbers This is a chamber having a plate at the centre which is kept moist by water injected through the nozzles. The dust laden gas is forced in the chamber with a centrifugal motion, as shown in Fig. 1.3. The aerosol and particulate matters are arrested by the moist plate. The clean gas is allowed to pass through the outlet pipe. The moisture of the plate is then eliminated by some suitable device and the aerosol and particulate matters are collected at the bottom and are removed through the outlet pipe.

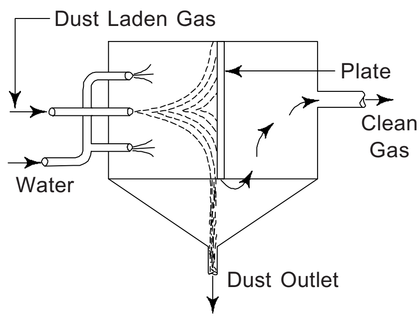


Fig. 1.3 *Cyclonic scrubber*

(d) Venturi Scrubber In this device, a venturimeter is fitted at the bottom of a cylindrical vessel. The dust laden gas and water are allowed to enter

the venturimeter from the top. The gas comes in contact with the water at the throat. The descending water absorbs the aerosol and particulate on its way. Thus, the dirty droplets are formed which are collected in the collection chamber, as shown in Fig. 1.4. The clean gas rises up and finally it is released in the atmosphere through the outlet.

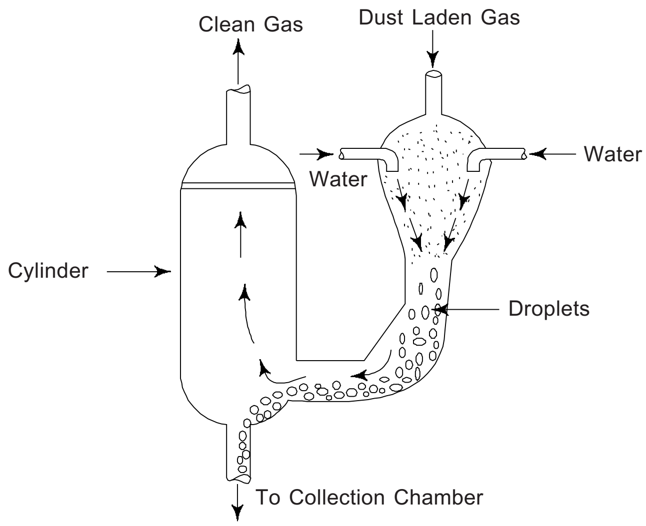


Fig. 1.4 *Venturi scrubber*

Review Questions

1. What are the causes of air pollution?
2. State the different forms of air pollutants.
3. Enumerate the sources of air pollution.
4. Describe the effects of air pollution.
5. Describe the different methods of controlling air pollution.

2

Noise Pollution and Control

2.1 INTRODUCTION

The sound which gives pleasure and comfort to the listener is called sweet sound. But, the sound which is uncomfortable and causes mental strain is called noise.

The noise is measured in terms of decibel. The ratio of the sound produced to the sound distinguishable (i.e very very feeble) by the ear is designated as decibel.

For example, if the ratio of two sounds is 10 : 1 (i.e. $10^1 : 1$), then it is known as 10 decibel. If the ratio is 100 : 1 (i.e. $10^2 : 1$), then it is known as 20 decibel and if the ratio is 1000 : 1 (i.e. $10^3 : 1$), then it is known as 30 decibel and so on.

That means, the common logarithm of the sound intensity ratio multiplied by 10 gives the required decibel. The noise level should be between 40 to 60 decibel for the comfort to human ear. The decibel is denoted by dB.

2.2 ADVERSE EFFECT OF NOISE

The following are the adverse effect of noise:

(i) The continuous noise of intensity 120 dB to 150 dB may cause permanent deafness.
(ii) The noise above 60 dB may cause nausea, headache, etc.
(iii) It may cause loss of sleep.
(iv) It may increase blood pressure.
(v) It may cause irritation of mind.
(vi) It may cause digestive disorder.
(vii) It may develop hypertension.
(viii) Sudden loud noise may cause heart failure.

2.3 SOURCES OF NOISE

The sources of noise may be divided into following groups:

(a) Domestic Noise It includes the operation of radio, television, record player, etc. with high volume. It may also include the use of vacuum cleaner for a long time.

(b) Public Noise It includes the operation of loud speakers with high volume during the festivals, social functions, religious functions, etc.

(c) Traffic Noise It includes the movements and horns of vehicle like buses, trucks, cars, etc. with high speed, along the roads of the towns or cities.

(d) Construction Noise It includes the sound created by the concrete mixer machine, mosaic polishing machine, vibrator, etc.

(e) Industrial Noise It includes the sound created by stone crushing factory, glass factory, aluminium factory, motor garage, etc.

2.4 NOISE ABATEMENT

The noise pollution may be controlled to a large extent by taking the following measures.

(i) The domestic noise may be controlled by operating radios, television, etc. at low volume (i.e. below 60 dB).

(ii) During festivals or other functions the loud-speakers should be operated within permissible limit and the time of operation should also be maintained.

(iii) To control the noise caused by traffic, the speed limit should be strictly imposed. The vehicles which create loud noise due to automobile fault should be rejected.

(iv) The industrial noise may be avoided by keeping the industries far from residential area.

PART IV

APPENDICES

A. Objective Type Questions with Answers

B. Model Questions

Appendix-A

Objective Type Questions with Answers

1. Hard water contains:
   (a) Calcium carbonate (b) Magnesium carbonate
   (c) Magnesium sulphate (d) All the above
2. The largest source of water for public water supply is:
   (a) Lakes (b) Ponds (c) Streams (d) Rivers
3. Maximum permissible colour for domestic supplies, based on cobalt scale is:
   (a) 5 (b) 10 (c) 20 (d) 25
4. On pH scale, maximum alkaline has the value of:
   (a) 5 (b) 7 (c) 14 (d) 21
5. Disinfection of drinking water is done to remove:
   (a) Turbidity (b) Odour (c) Colour (d) Bacteria
6. The disadvantages of hard water is:
   (a) Too much soap consumption
   (b) Making food tasteless
   (c) Scaling of boilers
   (d) Corrosion and incrustation of pipes
   (e) All the above
7. The temporary hardness of water can be removed by:
   (a) Boiling (b) Adding lime
   (c) Addding alum (d) Filtration
8. The pH-value of neutral water is:
   (a) 0 (b) 5 (c) 7 (d) 14
9. The hardness limit of potable water ranges between:
   (a) 50 to 75 ppm (b) 75 to 115 ppm
   (c) 115 to 150 ppm (d) 150 to 200 ppm
10. The permissible nitrites in public water supplies should be:
    (a) Nil (b) 0.5 ppm (c) 1 ppm (d) 1.5 ppm

11. The B.O.D. for safe drinking water must be:
    (a) Nil (b) 5 (c) 10 (d) 15
12. The bacteria which can survive with or without free oxygen is known as:
    (a) Aerobic bacteria (b) Anaerobic bacteria
    (c) Facultative bacteria (d) Pathogenic bacteria
13. For controlling algae, the most common chemical used is:
    (a) Copper sulphate (b) Alum
    (c) Lime (d) Bleaching powder
14. The permissible pH value of drinking water should be between:
    (a) 4.5 to 5.5 (b) 5.5 to 6.5 (c) 6.5 to 8.5 (d) 8.5 to 10.5
15. Aeration is done to remove:
    (a) Odour (b) Colour (c) Hardness (d) Turbidity
16. A plain sedimentation tank can remove suspended impurities upto:
    (a) 60% (b) 70% (c) 80% (d) 90%
17. Detention period for plain sedimentation tank usually ranges from:
    (a) 2 to 4 hrs (b) 4 to 8 hrs (c) 8 to 12 hrs (d) 12 to 14 hrs
18. The most common coagulant is:
    (a) Chlorine (b) Alum
    (c) Lime (d) Bleaching powder
19. To remove very fine suspended particles from water, the method adopted is:
    (a) Screening (b) Sedimentation
    (c) Titration (d) Filtration
20. The maximum permissible loss of head in rapid sand filter is:
    (a) 1 m (b) 2 m (c) 3 m (d) 4 m
21. In rapid sand filter, air binding is caused due to:
    (a) Negative pressure (b) Water pressure
    (c) Vacuum pressure (d) Atmospheric pressure
22. Rapid gravity sand filter can remove bacteria up to:
    (a) 50% (b) 60% (c) 70% (d) 80%
23. Rapid gravity filter can remove turbidity upto:
    (a) 15 gms/lit (b) 20gms/lit (c) 30gms/lit (d) 40gms/lit
24. Disinfection of water is done by:
    (a) Alum (b) Potassium permanganate
    (c) Lime (d) Zinc oxide
    (e) Chlorine
25. The chlorine gas is converted to liquid when subjected to a pressure of:
    (a) $5kg/cm^2$ (b) $6kg/cm^2$ (c) $7kg/cm^2$ (d) $8kg/cm^2$
26. Raw water when treated with only chlorine is known as:
    (a) Plain chorination (b) Pre-chlorination
    (c) Post-chlorination (d) Super-clorination
27. In plain chlorination the quantity of chlorine added is:
    (a) 0.25 m/lit (b) 0.30 mg/lit (c) 0.45 mg/lit (d) 0.50 mg/lit
    (e) 1.00 mg/lit

28. Hardness of water can be removed by boiling if it contains:
    (a) Calcium bicarbonate (b) Calcium sulphate
    (c) Calcium chloride (d) Calcium fluoride
29. One degree hardness means when water has the salt of amount:
    (a) 10.25 mg/lit (b) 12.25 mg/lit
    (c) 14.25 mg/lit (d) 16.25 mg/lit
30. The maximum permissible hardness for public consumption is:
    (a) 95 mg/lit (b) 105 mg/lit (c) 115 mg/lit (d) 125 mg/lit
31. Permanent hardness of water can be removed by:
    (a) Coagulation process (b) Chlorination process
    (c) Filtration process (d) Zeolite process
32. The growth of algae in reservoir is generally controlled by:
    (a) Bleaching powder (b) Copper sulphate
    (c) Lime solution (d) Alum solution
33. The quantity of fluoride permitted in drinking water is:
    (a) 1 mg/lit (b) 2 mg/lit (c) 3 mg/lit (d) 4 mg/lit
34. The liquid waste from kitchen and bathroom is called:
    (a) Sewage (b) Sullage
    (c) Storm water (d) Waste water
35. The gas which may cause explosion in sewers is:
    (a) Carbon dioxide (b) Methane
    (c) Carbon monoxide (d) Hydrogen sulphide
36. Oxidation of sewage results in the formation of:
    (a) Carbon dioxide (b) Nitrates
    (c) Sulphates (d) All the above
37. Fresh sewage becomes stale in:
    (a) One hour (b) Two hours (c) Four hours (d) Six hours
38. In suldge digestion tank, the gas produced is:
    (a) Oxygen (b) Nitrogen (c) Carbon dioxide (d) Methane
39. The removal of oil and grease from sewage is known as:
    (a) Screening (b) Skimming (c) Filtration (d) Sedimentation
40. In septic tank the decomposition of organic matters is done by:
    (a) Aerobic bacteria (b) Anaerobic bacteria
    (c) Pathogenic bacteria (d) Facultative bacteria
41. The water having pH-value 5, is known as:
    (a) Alkaline (b) Acidic (c) Neutral (d) All the above
42. Recuperation test is carried out to determine:
    (a) Watertable in well (b) Depth of water in well
    (c) Yield of well
43. The presence of bicarbonates in water produce:
    (a) Permanent hardness (b) Temporary hardness
    (c) Acidity (d) Alkalinity
44. The presence of carbonates in water produce:
    (a) Acidity (b) Permanent hardness
    (c) Alkalinity (d) Temporary hardness

45. Chlorination is done for the removal of:
(a) Bacteria (b) Hardness (c) Turbidity (d) Colour
46. Alum is a good:
(a) Disinfectant (b) Coagulant (c) Catalyst (d) Oxidant
47. Pathogenic bacteria in water may cause:
(a) Typhoid (b) Cholera (c) Dysentry (d) All the above
48. The physical characteristics of sewage is determined by:
(a) Turbidity (b) Colour (c) Odour (d) Temperature
(e) All the above
49. The amount of oxgen consumed by the aerobic bacteria is known as:
(a) B.O.D. (b) C.O.D. (c) D.O. (d) None of these
50. The standard B.O.D. of water is taken for:
(a) 1 day (b) 2 days (c) 3 days (d) 5 days
51. The detention period in plain sedimentation tank is provided for the removal of:
(a) Heavy suspended particles (b) Very fine suspended particles
(c) Floating matters (d) Bacteria
52. The sludge from septic tank should be removed after a maximum period of:
(a) 2 years (b) 3 years (c) 4 years (d) 5 years
53. The rate of accumulation of sludge per person per year is taken as:
(a) 5 lits (b) 10 lits (c) 15 lits (d) 20 lits
54. The coagulant widely used in sewage treatment is:
(a) Alum (b) Ferric chloride
(c) Ferric sulphate (d) Ferric sulphate
55. The average domestic consumption of water per capita per day is taken as:
(a) 115 lits (b) 125 lits (c) 135 lits (d) 150 lits
56. The ratio of maximum daily demand to average demand is taken as:
(a) 1 : 2 (b) 1 : 5 (c) 1 : 7 (d) 1 : 8
57. The maximum hourly consumption of water is generally taken as:
(a) 110 % of average consumption
(b) 120 % of average consumption
(c) 140 % of average consumption
(d) 150 % of average consumption
58. The evaporation from reservoir surface may be minimised by spraying:
(a) Spirit (b) Hydrochloric acid
(c) Acetyl alcohol (d) Methane
59. The maximum internal pressure in cast iron pipes should be kept at:
(a) $3 kg/cm^2$ (b) $5 kg/cm^2$ (c) $7 kg/cm^2$ (d) $10 kg/cm^2$
60. Air valve in main water supply pipe should be provided at:
(a) Summit (b) Valley (c) Junction (d) Bend
61. The maximum permissible colour for domestic water supply should be:
(a) 5 ppm (b) 10 ppm (c) 15 ppm (d) 20 ppm

62. The permissible amount of nitrites present in potable water is:
    (a) 10 ppm (b) 15 ppm (c) 20 ppm (d) Nil
63. B.O.D. of treated water should be:
    (a) Nil (b) 10 ppm (c) 20 ppm (d) 30 ppm
64. The standard B.O.D. at 20° C is taken for:
    (a) 2 days (b) 3 days (c) 5 days (d) 10 days
65. Pick up the correct statement from the following:
    (a) It is called self cleansing velocity when no silting or scouring takes place.
    (b) It is called self cleansing velocity when scouring takes place.
    (c) It is called self cleansing velocity when silting and scouring may occur simultaneously.
66. Pick up the correct statement from the following:
    (a) A manhole may be provided anywhere in the sewer line.
    (b) A manhole is provided only at the summit point in the sewer line.
    (c) A manhole is generally provided at each junction, bend and change of grade.
67. Pick up the correct statement from the following:
    (a) The sewer gases are nitrogen, carbon monoxide and ozone.
    (b) The sewer gases are hydrogen sulphide, carbon dioxide or methane.
    (c) The sewer gases are hydrogen fluoride, ether and nitrogen dioxide.
68. Pick up the correct statement from the following:
    (a) If the flame of safety lamp extinguishes within five minutes, it indicates the presence of carbon dioxide.
    (b) If the flame of safety lamp extinguishes within five minutes it indicates the presence of carbon monoxide.
    (c) If the flame of safety lamp extinguishes within five minutes, it indicates the presence of nitrogen.
69. Pick up the correct statement from the following:
    (a) Cowl is provided at the base of ventilating shaft.
    (b) Cowl is not provided at the ventilating shaft.
    (c) Cowl is provided at the upper end of ventilating shaft.
70. Pick up the correct statement from the following:
    (a) Pathogenic bacteria in potable water causes bronchitis, jaundice and hay fever.
    (b) Pathogenic bacteria in potable water causes typhoid, cholera and dysentry.
    (c) Pathogenic bacteria in potable water causes cancer, tuberculosis and arthiritis.
71. Pick up the correct statement from the following:
    (a) Free ammonia in sewage is detected by boiling.
    (b) Free ammonia in sewage is detected by adding lime.
    (c) Free ammonia in sewage is detected by adding alum.

72. Pick up the correct statement from the following:
    (a) The standard B.O.D. is taken for 3 days.
    (b) The standard B.O.D. is taken for 5 days.
    (c) The standard B.O.D. is taken for 7 days.
73. Pick up the correct statement from the following:
    (a) The photosynthesis is carried out in presence of moonlight.
    (b) The photosynthesis is carried out in cloudy day.
    (c) The photosynthesis is carried out in presence of sunlight.
74. Pick up the correct statement from the following:
    (a) The process of burning the garbage is known as incineration.
    (b) The process of burning the garbage is known as digestion.
    (c) The process of burning the garbage is known as decomposition.
75. Pick up the correct statement from the following:
    (a) Air valve is provided at the valley of the pipe line.
    (b) Air valve is provided at the summit of the pipe line.
    (c) Air valve is provided at the bend of the pipe line.
76. Pick up the correct statement from the following:
    (a) Temporary hardness is removed by boiling or adding lime.
    (b) Temporary hardness is removed by adding chlorine.
    (c) Temporary hardness is removed by adding zeolite.
77. Pick up the correct statement from the following:
    (a) Permanent hardness is removed by break point chlorination.
    (b) Permanent hardness is removed by coagulation process.
    (c) Permanent hardness is removed by lime-soda or zeolite process.
78. Pick up the correct statement from the following:
    (a) Hard water is detected by its soap consumption.
    (b) Hard water is detected by its specific gravity.
    (c) Hard water is detected by its turbidity.
79. Pick up the correct statement from the following:
    (a) Alum is a good disinfectant.
    (b) Alum is a good oxidant.
    (c) Alum is a good coagulant.
80. Pick up the correct statement from the following:
    (a) Per capita demand is denoted by lits/per person/day.
    (b) Per capita demand is denoted by gallons/per person/day.
    (c) Per capita demand is denoted by lits/per person/hr.

Answers

1. (d)	2. (d)	3. (c)	4. (c)	5. (d)
6. (e)	7. (a)	8. (c)	9. (b)	10. (a)
11. (a)	12. (c)	13. (c)	14. (c)	15. (a)
16. (b)	17. (b)	18. (b)	19. (d)	20. (c)
21. (a)	22. (d)	23. (d)	24. (e)	25. (c)
26. (a)	27. (d)	28. (a)	29. (c)	30. (c)
31. (d)	32. (c)	33. (a)	34. (b)	35. (b)

36. (d)	37. (c)	38. (c)	39. (b)	40. (b)
41. (b)	42. (c)	43. (b)	44. (b)	45. (a)
46. (b)	47. (d)	48. (e)	49. (a)	50. (d)
51. (a)	52. (b)	53. (c)	54. (b)	55. (c)
56. (d)	57. (d)	58. (c)	59. (c)	60. (a)
61. (d)	62. (d)	63. (a)	64. (c)	65. (a)
66. (c)	67. (b)	68. (a)	69. (c)	70. (b)
71. (a)	72. (b)	73. (c)	74. (a)	75. (b)
76. (a)	77. (c)	78. (a)	79. (c)	80. (a)

Appendix-B

Model Questions

1. From the following groups of sentences, choose the correct one:
   (a) (i) For all life water is necessary.
   (ii) For all life water is not necessary.
   (b) (i) Hard water is not suitable for the use in boilers, laundries and textile plants.
   (ii) Hard water is suitable for the use in boilers, laundries and textile plants.
   (c) (i) Sunlight is an agent in self-purification.
   (ii) Moonlight is an agent in self-purification.
   (d) (i) Asiatic cholera is an example of water-borne disease.
   (ii) TB is an example of water-borne disease.
   (e) (i) Chlorination is a method of disinfection of water.
   (ii) Chlorination is a method of softening of water.
   (f) (i) Water having pH-value of 7, is known as neutral water.
   (ii) Water having pH-value of zero is known as neutral water.
   (g) (i) Dysentry is an example of water-borne disease.
   (ii) Leprosy is an example of water-borne disease.
2. (a) Describe the methods of removing taste and odour from water.
   (b) Describe the methods of removing permanent hardness of water.
3. (a) What is meant by the development of a tube well? Describe the different methods of development.
   (b) Describe the different methods of tube well boring.
4. (a) Draw a flow diagram of water treatment plant with river as a source. State the function of each unit.
   (b) Describe a coagulation tank with sketch.
5. (a) What is a hydrological cycle?
   (b) Draw a neat sketch of hydrological cycle.

6. Write short notes on:
   (a) pH-value (b) Hardness of water
   (c) Break point chlorination
7. (a) What is the difference between separate and combined system of sewerage?
   (b) Enumerate the classification of waste.
8. Write short notes on:
   (a) Gully traps (b) Intercepting traps
   (c) Urinals (d) Water closet
9. (a) What is a design period?
   (b) Why is design period necessary?
   (c) What are the objects of sewage treatment?
   (d) What are the principles of biological method of sewage treatment?
10. (a) What are the causes of air pollution?
    (b) What are the sources of air pollution?
11. (a) What is solid waste?
    (b) What is liquid waste?
    (c) What are the sources of solid and liquid waste?
12. (a) What are the different types of latrines in rural area?
    (b) Describe an aqua privy with neat sketch.
13. (a) What is meant by population forecast?
    (b) Estimate the population of a town for the year 2031 whose census records are given below:

Year		Population
1961	–	10,450
1971	–	10,950
1981	–	11,400
1991	–	11,950

14. (a) Describe the function of chlorine as disinfectant.
    (b) Explain briefly what do you mean by break point chlorination.
15. (a) Design a septic tank and soak pit for a hostel of 300 boarders assuming reasonable data.
    (b) Draw the neat sketches of the designed septic tank and soak pit.
16. (a) Describe a borehole privy with neat sketch.
    (b) What are the advantages and disadvantages of borehole privy?
17. (a) Draw a flow diagram of sewage treatment plant.
    (b) Mention the functions of each unit.
18. (a) Describe how garbage is collected and transported.
    (b) What are the sources of solid waste?
19. (a) What are the different types of air pollutants?
    (b) Discuss the effects of air pollution.
20. (a) What is a water table?
    (b) What is the difference between shallow well and deep well?
    (c) Describe how springs are formed.
21. (a) Name the different methods of tube well boring.
    (b) Describe with sketch the jetting system of boring.

22. (a) Describe the function of rapid sand filter.
    (b) State the troubles that may come during the operation of rapid sand filter.
23. Write short notes on:
    (a) Ventilation shaft (b) Air diffuser
    (c) Negative head (d) Cracking of filter
    (e) Air binding (f) Mud balls
24. (a) Describe conservancy system and water carriage system.
    (b) State the merits and demerits of these systems.
25. Write short notes on:
    (a) Grit chamber (b) Screen
    (c) Detritus tank (d) Skimming tank
26. (a) State the importance of water table in pubic health engineering.
    (b) Describe with sketch the infiltration gallery.
27. (a) What is hardness of water?
    (b) What are the causes of hardness?
    (c) What are the processes of removal of permanent hardness? Describe any one method.
28. (a) What is the object of disinfection of water?
    (b) What is chlorination? State the different types of chlorination.
29. (a) State the principle of trickling filter.
    (b) Describe a trickling filter with sketch.
30. (a) Draw the flow diagram of activated sludge process.
    (b) Describe the working principle of activated sludge process.
31. Distinguish between the following:
    (a) Pre-chlorination and post chlorination
    (b) Plain chlorination and super chlorination
    (c) Chlorination and fluoridation
    (d) Sedimentation and coagulation
    (e) Gully trap and floor trap
    (f) P-trap and Q-trap
    (g) Gravity spring and artesian spring
    (h) Shallow well and deep well
32. (a) Name the materials used for the pipes in distribution system.
    (b) Briefly describe the function of service reservoir.
    (c) Draw neat sketches of—
        (i) Sprigot and socket joint
        (ii) Flanged joint
33. Match the names of the following treatments with the names of the impurities which are removed from water.

Treatment	Impurity
(a) Sedimentation	1. Dissolved gas
(b) Filtration	2. Bacteria
(c) Chlorination	3. Dissolved calcium and magnesium
(d) Lime-soda process	4. Heavy suspended particles
(e) Aeration	5. Fine suspended particles

34. Distinguish between the conservancy system and water carriage system.
35. (a) Draw the different types of sewer sections.
    (b) Describe the procedure of laying the sewer lime.
36. Write short notes on:
    (a) Variation of demand of water (b) Canal intake
    (c) Air valve (d) Manhole
    (e) Oxidation pond
37. Describe with sketches the methods of night soil disposal in rural area.
38. (a) Describe with neat sketch the construction, function and use of septic tank.
    (b) Describe a soakpit with sketch.
39. (a) What are the objects of sewage treatment?
    (b) What is achieved in primary treatment?
    (c) What is sludge?
    (d) What are the objects of sludge digestion?
    (e) What is sewage farming?
    (f) What is sewage sickness?
40. What are the salient features to be considered for the preparation of water supply scheme?
41. (a) What is per capita demand?
    (b) Give a table showing the break up of per capita demand.
    (c) Give the break up of domestic use and public use.
42. (a) What are the different forms of water demand?
    (b) What are fluctuation of demand and peak demand?
43. (a) What are the factors that affect the demand of water?
    (b) State the mathematical methods of population forecast.
44. (a) Enumerate the different sources of water.
    (b) Describe with neat sketch the different types of intake of water.
45. (a) What are the common methods of disinfection?
    (b) What are the common disinfectants?
    (c) State the action of chlorination .
    (d) Describe the methods of application of chlorine in water.
    (e) What are the different forms of chlorination?
    (f) What are fluoridation and defluoridation?
46. (a) What do you mean by coagulation and flocculation?
    (b) What is the principle of coagulation?
    (c) What are the different types of coagulants? Mention their uses.
47. (a) What is meant by hardness?
    (b) How can hardness be removed?
    (c) State the effects of hardness.
    (d) How will you detect hard water?
48. (a) How will you detect the presence of iron and manganese in water?
    (b) How are they removed?
49. (a) What is pipe corrosion?
    (b) What are the effects of corrosion?
    (c) How can corrosion be prevented?

50. (a) How can leakage in pipe line be detected?
(b) What are the precautions to be taken to prevent the wastage of water?
51. (a) Name the different types of pipes used for transmitting water in water supply scheme.
(b) Describe their characteristics.
(c) State when and why you would use that pipes.
52. (a) What are the different types of valves used in water supply scheme?
(b) Describe the valves with sketch.
53. (a) What are the common impurities in water?
(b) What should be the standard of drinking water?
54. (a) What is the principle of filtration?
(b) What do you mean by negative head and back washing?
(c) What do you mean by water-borne diseases.
55. (a) What is air diffuser? Describe its function with sketch.
(b) Why does water get colour, odour and taste?
(c) Enumerate the methods adopted for the removal of those.
56. Describe with neat sketch the different types of layout of distribution system.
57. (a) What do you mean by gravity sand filter?
(b) Describe briefly with sketch the construction and function of rapid sand filter.
58. (a) Draw the flow diagram of sewage treatment plant.
(b) Describe the function of each unit.
59. (a) What is activated sludge?
(b) State the action of activated sludge.
(c) Draw the flow diagram of activated sludge process.
(d) Enumerate the salient features of activated sludge process.
60. (a) What are the sources of air pollution?
(b) How can air pollution be controlled?
61. Write short notes on:
(a) Back washing
(b) B-coli index
(c) pH-value
(d) Water-borne diseases
(e) C.O.D.
(f) Ferrule
(g) Hypo-chlorination
(h) Chloro-products
(i) Self-cleansing velocity
(j) Orthotolidin test
(k) Starch-irodide test
(l) Imhoff tank
(m) Digestion tank

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