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New Scheme Based On AICTE Flexible Curricula

Civil Engineering, VI-Semester

CE602- Environmental Engineering-I

Environmental Engineering-I

Unit – I

Estimation of ground and surface water resources. quality of water from different sources, demand & quantity of water, fire demand, water requirement for various uses, fluctuations in demand, forecast of population.

Unit – II

Impurities of water and their significance, water-borne diseases, physical, chemical and bacteriological analysis of water, water standards for different uses. Intake structure, conveyance of water, pipe materials, pumps - operation & pumping stations.

Unit – III

Water Treatment methods-theory and design of sedimentation, coagulation, filtration, disinfection, aeration & water softening, modern trends in sedimentation & filtration, miscellaneous methods of treatment.

Unit – IV

Sewerage schemes and their importance, collection & conveyance of sewage, storm water quantity, fluctuation in sewage flow, flow through sewer, design of sewer, construction & maintenance of sewer, sewer appurtenances, pumps & pumping stations.

Unit – V

Characteristics and analysis of waste water, recycles of decomposition, physical, chemical & biological parameters. Oxygen demand i.e. BOD & COD, TOC, TOD, Th OD, Relative Stability, population equivalent, instrumentation involved in analysis, natural methods of waste water disposal i.e. by land treatment & by dilution, self purification capacity of stream, Oxygen sag analysis.

Reference Books: -

1. Water Supply Engineering by B.C. Punmia - Laxmi Publications (P) Ltd. New Delhi
2. Water Supply & Sanitary Engg. by G.S. Birdi - Laxmi Publications (P) Ltd. New Delhi
3. Water & Waste Water Technology by Mark J.Hammer - Prentice - Hall of India, New Delhi
4. Environmental Engineering - H.S. Peavy & D.R.Rowe-Mc Graw Hill Book Company,New Delhi
5. Water Supply & Sanitary Engg. by S.K. Husain
6. Water & Waste Water Technology - G.M. Fair & J.C. Geyer
7. Relevant IS

List of Experiments:

1. To study the various standards for water
2. To study of sampling techniques for water
3. Measurement of turbidity
4. To determine the coagulant dose required to treat the given turbid water sample
5. To determine the conc. of chlorides in a given water samples
6. Determination of hardness of the given sample
7. Determination of residual chlorine by “Chloroscope”
8. Determination of Alkalinity in a water samples
9. Determination of Acidity in a water samples
10. Determination of Dissolved Oxygen (DO) in the water sample.

Unit – I

Estimation of ground and surface water resources. Quality of water from different sources, demand & quantity of water, fire demand, water requirement for various uses, fluctuations in demand, forecast of population.

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1. **Raw Water Source**

The various sources of water can be classified into two categories:

1. **Surface sources, such as**
   a. **Ponds and lakes;**
   b. **Streams and rivers;**
   c. **Storage reservoirs; and**
   d. **Oceans, generally not used for water supplies, at present.**
2. **Sub-surface sources or underground sources, such as**
   a. **Springs;**
   b. **Infiltration wells ; and**
   c. **Wells and Tube-wells.**

Water Quality

The raw or treated water is analysed by testing their physical, chemical and bacteriological characteristics:

Physical Characteristics:

- **Turbidity**
- **Color**
- **Taste and Odour**
- **Temperature.**

Chemical Characteristics:

- **pH**
- **Acidity**
- **Alkalinity**
- **Hardness**
- **Chlorides**
- **Sulphates**
- **Iron**
- **Solids**
- **Nitrates**

Bacteriological Characteristics:

Bacterial examination of water is very important, since it indicates the degree of pollution. Water polluted by sewage contains one or more species of disease producing pathogenic bacteria. Pathogenic organisms cause water borne diseases, and many non pathogenic bacteria such as *E.Coli*, a member of coliform group, also live in the intestinal tract of human beings. *Coliform* itself is not a harmful group but it has more resistance to adverse condition than any other group. So, if it is ensured to minimize the number of coliforms, the harmful species will be very less. So, coliform group serves as indicator of contamination of water with sewage and presence of pathogens.

The methods to estimate the bacterial quality of water are:

- Standard Plate Count Test
  Most Probable Number
  Membrane Filter Technique

Water Quantity Estimation

The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data:

1. Water consumption rate (Per Capita Demand in litres per day per head)
2. Population to be served.

Quantity= Per capita demand x Population

Water Consumption Rate

It is very difficult to precisely assess the quantity of water demanded by the public, since there are many variable factors affecting water consumption. The various types of water demands, which a city may have, may be broken into following classes:

Water Consumption for Various Purposes:

S.No	Types of Consumption	Normal Range (lit/capita/day)	Average	%
1	Domestic Consumption	65-300	160	35
2	Industrial and Commercial Demand	45-450	135	30
3	Public Uses including Fire Demand	20-90	45	10

4	Losses and Waste	45-150	62	25

Fire Fighting Demand:

The per capita fire demand is very less on an average basis but the rate at which the water is required is very large. The rate of fire demand is sometimes traeted as a function of population and is worked out from following empirical formulae:

	Authority	Formulae (P in thousand)	Q for 1 lakh Population)
1	American Insurance Association	Q (L/min)=4637 √P (1-0.01 √P)	41760
2	Kuchling's Formula	Q (L/min)=3182 √P	31800
3	Freeman's Formula	Q (L/min)= 1136.5(P/5+10)	35050
4	Ministry of Urban Development Manual Formula	Q (kilo liters/d)=100 √P for P>50000	31623

Factors affecting per capita demand:

a. **Size of the city: Per capita demand for big cities is generally large as compared to that for smaller towns as big cities have sewered houses.**
b. **Presence of industries.**
c. **Climatic conditions.**
d. **Habits of people and their economic status.**
e. **Quality of water: If water is aesthetically $ medically safe, the consumption will increase as people will not resort to private wells, etc.**
f. **Pressure in the distribution system.**
g. **Efficiency of water works administration: Leaks in water mains and services; and unauthorised use of water can be kept to a minimum by surveys.**
h. **Cost of water.**
i. **Policy of metering and charging method: Water tax is charged in two different ways: on the basis of meter reading and on the basis of certain fixed monthly rate.**

Fluctuations in Rate of Demand

Average Daily Per Capita Demand
= Quantity Required in 12 Months/ (365 x Population)

If this average demand is supplied at all the times, it will not be sufficient to meet the fluctuations.

- ***Seasonal variation*: The demand peaks during summer. Firebreak outs are generally more in summer, increasing demand. So, there is seasonal variation .**
- ***Daily variation* depends on the activity. People draw out more water on Sundays and Festival days, thus increasing demand on these days.**
- ***Hourly variations* are very important as they have a wide range. During active household working hours i.e. from six to ten in the morning and four to eight in the evening, the bulk of the daily requirement is taken. During other hours the requirement is negligible. Moreover, if a fire breaks out, a huge quantity of water is required to be supplied during short duration, necessitating the need for a maximum rate of hourly supply.**

So, an adequate quantity of water must be available to meet the peak demand. To meet all the fluctuations, the supply pipes, service reservoirs and distribution pipes must be properly proportioned. The water is supplied by pumping directly and the pumps and distribution system must be designed to meet the peak demand. The effect of monthly variation influences the design of storage reservoirs and the hourly variations influences the design of pumps and service reservoirs. As the population decreases, the fluctuation rate increases.

To estimate water demand, following parameters must be determined or calculated.

To determine the maximum water demand during a fire, the required fir flow must be added to the maximum daily consumption rate. The shortage is fulfilled by elevated storage tanks which have been filled during lower demand in usual days

1. **Average daily water consumption: It is based on complete one year supply of water. It is the total consumption during one year, divided by the population. q = (Q / P x 365) lpcd (liters per capita per day)**
2. **Maximum daily consumption: It is the maximum amount of water used during one day in the year. This amount is 180% of the average daily consumption MDC = 1.8 x Avg. daily consumption. It is usually a working day (Monday) of summer season.**
3. **Maximum weekly demand: The amount of water used by a population during a whole single week in a study span of 1 year.**
   Maximum weekly demand = 1.48 x Avg. D. C
   Maximum monthly demand = 1.28 x Avg. D. C

Maximum hourly demand = 1.5 x Avg. D. C
Maximum daily demand = 1.8 x Avg. D. C

4. **Fire water demand | Fire Demand: The amount of water used for firefighting is termed as fire demand. Although, the amount of water used in firefighting is a negligible part of the combine uses of water but the rate of flow and the volume required may be so high during fire that it is a deciding factor for pumps, reservoirs and distribution mains.**
   Minimum fire flow should be 500 gpm (1890 L/m)
   Minimum fire flow should be 8000 gpm (32, 400 L/m)
   Additional flow may be required to protect adjacent buildings.

Maximum daily demand *= 1.8 x average daily demand*
Maximum hourly demand of maximum day *i.e. Peak demand*
= 1.5 x average hourly demand
= 1.5 x Maximum daily demand/24
= 1.5 x (1.8 x average daily demand)/24
= 2.7 x average daily demand/24
= 2.7 x annual average hourly demand

<u>Design Periods & Population Forecast</u>

This quantity should be worked out with due provision for the estimated requirements of the future . The future period for which a provision is made in the water supply scheme is known as the design period

Design period is estimated based on the following:

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

Population Forecasting Methods

The various methods adopted for estimating future populations are given below. The particular method to be adopted for a particular case or for a particular city depends largely on the factors discussed in the methods, and the selection is left to the discrection and intelligence of the designer.

1. **Arithmetic Increase Method**

   This method is based on the assumption that the population increases at a constant rate; i.e. $dP/dt=constant=k$; $P_t= P_0+kt$. This method is most applicable to large and established cities.

2. **Geometric Increase Method**

   This method is based on the assumption that percentage growth rate is constant i.e. $dP/dt=kP$; $\ln P= \ln P_0+kt$. This method must be used with caution, for when applied it may produce too large results for rapidly grown cities in comparatively short time. This would apply to cities with unlimited scope of expansion. As cities grow large, there is a tendency to decrease in the rate of growth.

3. **Incremental Increase Method**

   Growth rate is assumed to be progressively increasing or decreasing, depending upon whether the average of the incremental increases in the past is positive or negative. The population for a future decade is worked out by adding the mean arithmetic increase to the last known population as in the arithmetic increase method, and to this is added the average of incremental increases, once for first decade, twice for second and so on.

4. **Decreasing Rate of Growth Method**

   In this method, the average decrease in the percentage increase is worked out, and is then subtracted from the latest percentage increase to get the percentage increase of next decade.

5. **Simple Graphical Method**
   In this method, a graph is plotted from the available data, between time and population. The curve is then smoothly extended upto the desired year. This method gives very approximate results and should be used along with other forecasting methods.
6. **Comparative Graphical Method**
   In this method, the cities having conditions and characteristics similar to the city whose future population is to be estimated are selected. It is then assumed that the

city under consideration will develop, as the selected similar cities have developed in the past

7. Ratio Method

In this method, the local population and the country's population for the last four to five decades is obtained from the census records. The ratios of the local population to national population are then worked out for these decades. A graph is then plotted between time and these ratios, and extended upto the design period to extrapolate the ratio corresponding to future design year. This ratio is then multiplied by the expected national population at the end of the design period, so as to obtain the required city's future population.

Drawbacks:

1. Depends on accuracy of national population estimate.
2. Does not consider the abnormal or special conditions which can lead to population shifts from one city to another.

3. Logistic Curve Method

The three factors responsible for changes in population are:
(i)Births, (ii) Deaths and (iii) Migrations.

Logistic curve method is based on the hypothesis that when these varying influences do not produce extraordinary changes, the population would probably follow the growth curve characteristics of living things within limited space and with limited economic opportunity. The curve is *S-shaped* and is known as *logistic curve*.

Que. Population Forecast by Different Methods

Problem: Predict the population for the years 1981, 1991, 1994, and 2001 from the following census figures of a town by different methods

Year	1901	1911	1921	1931	1941	1951	1961	1971
Population: (thousands)	60	65	63	72	79	89	97	120

Solution:

Year	Population: (thousands)	Increment per Decade	Incremental Increase	Percentage Increment per Decade
1901	60	-	-	-

1911	65	+5	-	(5+60) x100=+8.33
1921	63	-2	-3	(2+65) x100=-3.07
1931	72	+9	+7	(9+63) x100=+14.28
1941	79	+7	-2	(7+72) x100=+9.72
1951	89	+10	+3	(10+79) x100=+12.66
1961	97	+8	-2	(8+89) x100=8.98
1971	120	+23	+15	(23+97) x100=+23.71
Net values	1	+60	+18	+74.61
Averages	-	8.57	3.0	10.66

+=increase; - = decrease

Arithmetical Progression Method:

$$P_n = P + ni$$

Average increases per decade = i = 8.57

Population for the years,

1981= population 1971 + ni, here n=1 decade

= 120 + 8.57 = 128.57

1991= population 1971 + ni, here n=2 decade

= 120 + 2 x 8.57 = 137.14

2001= population 1971 + ni, here n=3 decade

= 120 + 3 x 8.57 = 145.71

1994= population 1991 + (population 2001 - 1991) x 3/10

= 137.14 + (8.57) x 3/10 = 139.71

Incremental Increase Method:

Population for the years,

1981= population 1971 + average increase per decade + average incremental increase

= 120 + 8.57 + 3.0 = 131.57

1991= population 1981 + 11.57

= 131.57 + 11.57 = 143.14

2001= population 1991 + 11.57

= 143.14 + 11.57 = 154.71

1994= population 1991 + 11.57 x 3/10

= 143.14 + 3.47 = 146.61

Geometric Progression Method:

Average percentage increase per decade = 10.66

$$P_n = P (1+i/100)^n$$

Population for 1981 = Population 1971 x $(1+i/100)^n$

= 120 x (1+10.66/100), i = 10.66, n = 1

= 120 x 110.66/100 = 132.8

Population for 1991 = Population 1971 x $(1+i/100)^n$

= 120 x $(1+10.66/100)^2$ **, i = 10.66, n = 2**

= 120 x 1.2245 = 146.95

Population for 2001 = Population 1971 x $(1+i/100)^n$

= 120 x $(1+10.66/100)^3$ **, i = 10.66, n = 3**

= 120 x 1.355 = 162.60

Population for 1994 = 146.95 + (15.84 x 3/10) = 151.70

Sedimentation Tank Design

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

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

Volume of tank = Flow x Detention period = $2.4 \times 10^3 \times 3/24 = 300\ m^3$

Assume depth of tank = 3.0 m.

Surface area = 300/3 = 100 m^2

L/B = 3 (assumed). L = 3B.

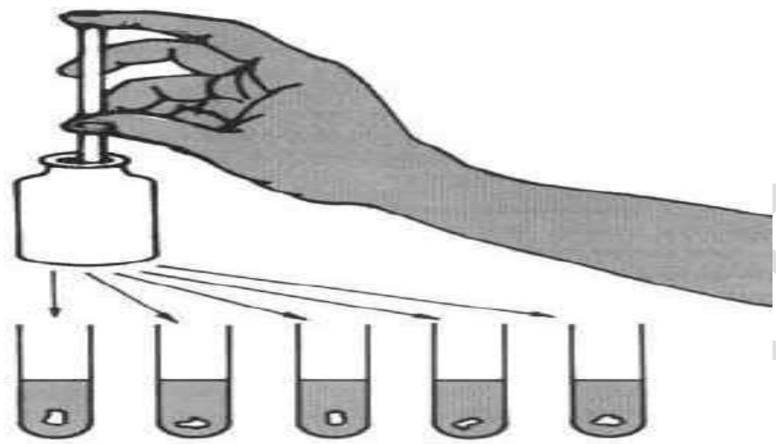
$3B^2 = 100\ m^2$ i.e. B = 5.8 m

L = 3B = 5.8 X 3 = 17.4 m

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

Unit – II

Impurities of water and their significance, water-borne diseases, physical, chemical and bacteriological analysis of water, water standards for different uses. Intake structure, conveyance of water, pipe materials, pumps - operation & pumping stations.



Qualitative and quantitative measurements are needed from time to time to constantly monitor the quality of water from the various sources of supply. The harbour-master should then ensure appropriate water treatment within the fishery harbour complex as well as initiate remedial measures with the suppliers when water supply from outside is polluted.

2.1.1 Borewells

Contamination may arise from pollutants entering the water table some distance from the port or from sewage entering the borehole itself in the port area through cracked or corroded casings. In cases where overdrawing is evident (water is brackish), tests should be conducted at least monthly.

2.1.2 Municipal mains

Supply could be contaminated at source or through corroded pipelines leading to the fishery harbour. Mixing with sewage lines due to defective piping has been known to occur often. Complete tests should be carried out every half year, and the authorities should be informed when results indicate contamination.

2.1.3 Water tanks and reservoirs

Both types of structure are prone to bacterial growth if the residual chlorine levels in them are low or non-existent. Testing may not be necessary if periodic scrubbing is carried out. Bacteriological tests should be done at least half-yearly.

2.1.4 Harbour basin water

Typically, harbour basins are tested yearly. However, in areas where monsoons are very active, it may be advisable to test at the peak of the dry season when effluent point discharges tend to remain concentrated in the water body and again during the wet season when agriculture run-off may be considerable. Another critical period for harbours is the peak of the fishing season when the harbour is at its busiest and vessel-generated pollution is likely to be at its peak.

- **Testing procedures and parameters may be grouped into physical, chemical, bacteriological and microscopic categories.**
  - **Physical tests indicate properties detectable by the senses.**
  - **Chemical tests determine the amounts of mineral and organic substances that affect water quality.**
  - **Bacteriological tests show the presence of bacteria, characteristic of faecal pollution.**

Physical tests

Colour, turbidity, total solids, dissolved solids, suspended solids, odour and taste are recorded.

- **Colour in water may be caused by the presence of minerals such as iron and manganese or by substances of vegetable origin such as algae and weeds. Colour tests indicate the efficacy of the water treatment system.**
- **Turbidity in water is because of suspended solids and colloidal matter. It may be due to eroded soil caused by dredging or due to the growth of micro-organisms. High turbidity makes filtration expensive. If sewage solids are present, pathogens may be encased in the particles and escape the action of chlorine during disinfection.**
- **Odour and taste are associated with the presence of living microscopic organisms; or decaying organic matter including weeds, algae; or industrial wastes containing ammonia, phenols, halogens, hydrocarbons. This taste is imparted to fish, rendering them unpalatable. While chlorination dilutes odour and taste caused by some contaminants, it generates a foul odour itself when added to waters polluted with detergents, algae and some other wastes.**

Intake Structure

The basic function of the intake structure is to help in safely withdrawing water from the source over predetermined pool levels and then to discharge this water into the withdrawal conduit (normally called intake conduit), through which it flows up to water treatment plant.

Factors Governing Location of Intake

1. **As far as possible, the site should be near the treatment plant so that the cost of conveying water to the city is less.**
2. **The intake must be located in the purer zone of the source to draw best quality water from the source, thereby reducing load on the treatment plant.**
3. **The intake must never be located at the downstream or in the vicinity of the point of disposal of wastewater.**
4. **The site should be such as to permit greater withdrawal of water, if required at a future date.**
5. **The intake must be located at a place from where it can draw water even during the driest period of the year.**
6. **The intake site should remain easily accessible during floods and should noy get flooded. Moreover, the flood waters should not be concentrated in the vicinity of the intake.**

Design Considerations

1. **sufficient factor of safety against external forces such as heavy currents, floating materials, submerged bodies, ice pressure, etc.**
2. **should have sufficient self-weight so that it does not float by upthrust of water.**

Types of Intake

Depending on the source of water, the intake works are classified as follows:

Pumping

A pump is a device which converts mechanical energy into hydraulic energy. It lifts water from a lower to a higher level and delivers it at high pressure. Pumps are employed in water supply projects at various stages for following purposes:

1. **To lift raw water from wells.**
2. **To deliver treated water to the consumer at desired pressure.**
3. **To supply pressured water for fire hydrants.**
4. **To boost up pressure in water mains.**
5. **To fill elevated overhead water tanks.**

6. To back-wash filters.
7. To pump chemical solutions, needed for water treatment.

Classification of Pumps

Based on principle of operation, pumps may be classified as follows:

1. Displacement pumps (reciprocating, rotary)
2. Velocity pumps (centrifugal, turbine and jet pumps)
3. Buoyancy pumps (air lift pumps)
4. Impulse pumps (hydraulic rams)

Capacity of Pumps

Work done by the pump,

H.P.=gQH/75

where, g= specific weight of water kg/m^3, Q= discharge of pump, m^3/s; and H= total head against which pump has to work.

H= H_s + H_d + H_f + (losses due to exit, entrance, bends, valves, and so on)

where, H_s=suction head, H_d = delivery head, and H_f = friction loss.

Efficiency of pump (E) = gQH/Brake H.P.

Total brake horse power required = gQH/E

Provide even number of motors say 2,4,... with their total capacity being equal to the total BHP and provide half of the motors required as stand-by.

Conveyance

There are two stages in the transportation of water:

1. Conveyance of water from the source to the treatment plant.
2. Conveyance of treated water from treatment plant to the distribution system.

In the first stage water is transported by gravity or by pumping or by the combined action of both, depending upon the relative elevations of the treatment plant and the source of supply. In the second stage water transmission may be either by pumping into an overhead tank and then supplying by gravity or by pumping directly into the water-main for distribution.

Free Flow System

In this system, the surface of water in the conveying section flows freely due to gravity. In such a conduit the hydraulic gradient line coincide with the water surface and is parallel to the bed of the conduit. It is often necessary to construct very long conveying sections, to suit the slope of the existing ground. The sections used for free-flow are: Canals, flumes, grade aqueducts and grade tunnels.

Pressure System

In pressure conduits, which are closed conduits, the water flows under pressure above the atmospheric pressure. The bed or invert of the conduit in pressure flows is thus independant of the grade of the hydraulic gradient line and can, therefore, follow the natural available ground surface thus requiring lesser length of conduit. The pressure aqueducts may be in the form of closed pipes or closed aqueducts and tunnels called *pressure aqueducts or pressure tunnels* designed for the pressure likely to come on them. Due to their circular shapes, every pressure conduit is generally termed as a *pressure pipe*. When a pressure pipe drops beneath a valley, stream, or some other depression, it is called a depressed pipe or an *inverted siphon*. Depending upon the construction material, the pressure pipes are of following types: Cast iron, steel, R.C.C, hume steel, vitrified clay, asbestos cement, wrought iron, copper, brass and lead, plastic, and glass reinforced plastic pipes.

Hydraulic Design

The design of water supply conduits depends on the resistance to flow, available pressure or head, and allowable velocities of flow. Generally, Hazen-William's formula for pressure conduits and Manning's formula for freeflow conduits are used.

Hazen-William's formula

$$U=0.85\ C\ r_H^{0.63}S^{0.54}$$

Manning's formula

$$U=\frac{1}{n}\ r_H^{2/3}S^{1/2}$$

where, U= velocity, m/s; r_H= hydraulic radius,m; S= slope, C= Hazen-William's coefficient, and n = Manning's coefficient.

Darcy-Weisbach formula

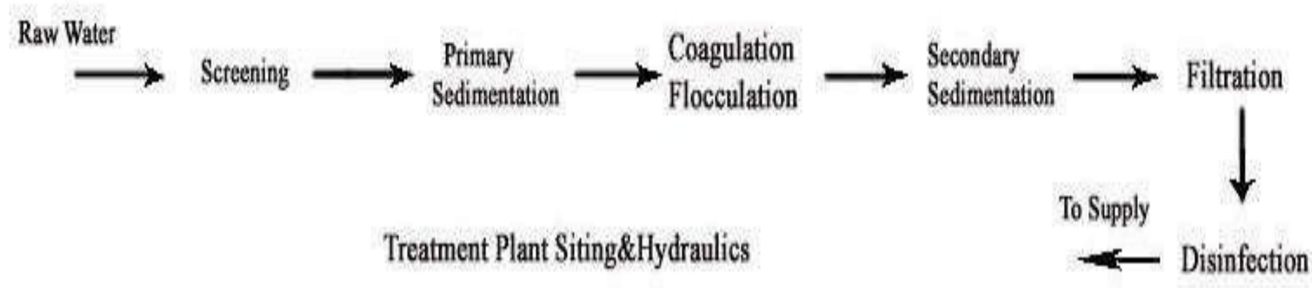
$$h_L=(fLU^2)/(2gd)$$

Unit – III

Water Treatment methods-theory and design of sedimentation, coagulation, filtration, disinfection, aeration & water softening, modern trends in sedimentation & filtration, miscellaneous methods of treatment.

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

The layout of conventional water treatment plant is as follows:



Depending upon the magnitude of treatment required, proper unit operations are selected and arranged in the proper sequential order for the purpose of modifying the quality of raw water to meet the desired standards. Indian Standards for drinking water are given in the table below.

Indian Standards for drinking water

Parameter	Desirable-Tolerable	*If no alternative source available, limit extended upto*
Physical		
Turbidity (NTU unit)	< 10	25
Colour (Hazen scale)	< 10	50
Taste and Odour	Un-objectionable	Un-objectionable
Chemical		
pH	7.0-8.5	6.5-9.2
Total Dissolved Solids mg/l	500-1500	3000

Total Hardness mg/l (as $CaCO_3$)	**200-300**	**600**
Chlorides mg/l (as Cl)	**200-250**	**1000**
Sulphates mg/l (as SO_4)	**150-200**	**400**
Fluorides mg/l (as F)	**0.6-1.2**	**1.5**
Nitrates mg/l (as NO_3)	**45**	**45**
Calcium mg/l (as Ca)	**75**	**200**
Iron mg/l (as Fe)	**0.1-0.3**	**1.0**

The typical functions of each unit operations are given in the following table:

Aeration

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

Types of Aerators

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

1. **Gravity Aerators (Cascades): In gravity aerators, water is allowed to fall by gravity such that a large area of water is exposed to atmosphere, sometimes aided by turbulence.**
2. **Fountain Aerators : These are also known as spray aerators with special nozzles to produce a fine spray. Each nozzle is 2.5 to 4 cm diameter discharging about 18 to 36 l/h. Nozzle spacing should be such that each m3 of water has aerator area of 0.03 to 0.09 m2 for one hour.**
3. **Injection or Diffused Aerators : It consists of a tank with perforated pipes, tubes or diffuser plates, fixed at the bottom to release fine air bubbles from compressor unit. The tank depth is kept as 3 to 4 m and tank width is within 1.5 times its depth. If**

depth is more, the diffusers must be placed at 3 to 4 m depth below water surface. Time of aeration is 10 to 30 min and 0.2 to 0.4 litres of air is required for 1 litre of water.

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

Settling

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

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

Purpose of Settling

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

Principle of Settling

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

Types of Settling

Type I:

Discrete particle settling - Particles settle individually without interaction with neighboring particles.

Type II:

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

Type III:

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

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

Type I Settling

- **Size, shape and specific gravity of the particles do not change with time.**
- **Settling velocity remains constant.**

If a particle is suspended in water, it initially has two forces acting upon it:
(1) force of gravity: $F_g=\rho_p g V_p$
(2) the buoyant force quantified by Archimedes as: $F_b=\rho g V_p$
If the density of the particle differs from that of the water, a net force is exerted and the particle is accelaratd in the direction of the force: $F_{net}=(\rho_p-\rho)gV_p$
This net force becomes the driving force.
Once the motion has been initiated, a third force is created due to viscous friction. This force, called the *drag force*, is quantified by:
$F_d=C_D A_p r v^2/2$
C_D= **drag coefficient.**
A_p = **projected area of the particle.**
Because the drag force acts in the opposite direction to the driving force and increases as the square of the velocity, acceleration occurs at a decreasing rate until a steady velocity is reached at a point where the drag force equals the driving force:

$$(\rho_p-\rho)gV_p = C_D A_p \rho v^2/2$$

For spherical particles,

$$V_p=\pi d^3/6 \text{ and } A_p=\pi d^2/4$$

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

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

$C_D = \frac{24}{R_e}$ **(laminar)**

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

$C_D= 0.4$ **(turbulent)**

where Re is the Reynolds number:

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

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

Stokes Flow

For laminar flow, terminal settling velocity equation becomes:

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

which is known as the *stokes equation*.

Transition Flow
Need to solve non-linear equations:

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

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

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

- **Calculate velocity using Stokes law or turbulent expression.**
- **Calculate and check Reynolds number.**
- **Calculate C_D.**
- **Use general formula.**
- **Repeat from step 2 until convergence.**

Types of Settling Tanks

- **Sedimentation tanks may function either intermittently or continuously.The intermittent tanks also called quiescent type tanks are those which store water for a certain period and keep it in complete rest. In a continuous flow type tank, the flow velocity is only reduced and the water is not brought to complete rest as is done in an intermittent type.**

- Settling basins may be either long rectangular or circular in plan. Long narrow rectangular tanks with horizontal flow are generally preferred to the circular tanks with radial or spiral flow.

Long Rectangular Settling Basin

- Long rectangular basins are hydraulically more stable, and flow control for large volumes is easier with this configuration.
- A typical long rectangular tank have length ranging from 2 to 4 times their width. The bottom is slightly sloped to facilitate sludge scraping. A slow moving mechanical sludge scraper continuously pulls the settled material into a sludge hopper from where it is pumped out periodically.

A long rectangular settling tank can be divided into four different functional zones:
Inlet zone: **Region in which the flow is uniformly distributed over the cross section such that the flow through settling zone follows horizontal path.**
Settling zone: **Settling occurs under quiescent conditions.**
Outlet zone: **Clarified effluent is collected and discharge through outlet weir.**
Sludge zone: **For collection of sludge below settling zone.**

Inlet and Outlet Arrangement

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

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

Weir Overflow Rates

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

Circular Basins

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

Settling Operations

- **Particles falling through the settling basin have two components of velocity:**

1. **Vertical component:** $v_t = \frac{(\rho_p - \rho) g d^2}{18\mu}$
2. **Horizontal component: vh=Q/A**

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

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

$$t = \frac{V}{Q} = \frac{L Z_0 W}{Q}$$

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

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

$$\text{or } v_0 = \frac{Q}{A_s}$$

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

Design Details

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

General Properties of Colloids

1. Colloidal particles are so small that their surface area in relation to mass is very large.
2. Electrical properties: All colloidal particles are electrically charged. If electrodes from a D.C. source are placed in a colloidal dispersion, the particles migrate towards the pole of opposite charge.
3. Colloidal particles are in constant motion because of bombardment by molecules of dispersion medium. This motion is called Brownian motion (named after Robert Brown who first noticed it).
4. Tyndall effect: Colloidal particles have dimensioThese are reversible upon heating. e.g. organics in water.
5. Adsorption: Colloids have high surface area and hence have a lot of active surface for adsorption to occur. The stability of colloids is mainly due to preferential adsorption of ions. There are two types of colloids:
   i. Lyophobic colloids: that are solvent hating. These are irreversible upon heating. e.g. inorganic colloids, metal halides.
   ii. Lyophilic colloids: that are solvent loving. These are reversible upon heating. e.g. organics in water.

Coagulation and Flocculation

- **Colloidal particles are difficult to separate from water because they do not settle by gravity and are so small that they pass through the pores of filtration media.**
- **To be removed, the individual colloids must aggregate and grow in size.**
- **The aggregation of colloidal particles can be considered as involving two separate and distinct steps:**
- **Particle transport to effect interparticle collision.**
- **Particle destabilization to permit attachment when contact occurs.**

Transport step is known as flocculation whereas coagulation is the overall process involving destabilization and transport.

Flocculation

Flocculation is stimulation by mechanical means to agglomerate destabilised particles into compact, fast settleable particles (or flocs). Flocculation or gentle agitation results from velocity differences or gradients in the coagulated water, which causes the fine moving, destabilized particles to come into contact and become large, readily settleable flocs. It is a common practice to provide an initial rapid (or) flash mix for the dispersal of the coagulant or other chemicals into the water. Slow mixing is then done, during which the growth of the floc takes place..

Rapid or Flash mixing is the process by which a coagulant is rapidly and uniformly dispersed through the mass of water. This process usually occurs in a small basin immediately preceding or at the head of the coagulation basin. Generally, the detention period is 30 to 60 seconds and the head loss is 20 to 60 cms of water. Here colloids are destabilised and the nucleus for the floc is formed.

Slow mixing brings the contacts between the finely divided destabilised matter formed during rapid mixing.

Perikinetic and Orthokinetic Flocculation

The flocculation process can be broadly classified into two types, perikinetic and orthokinetic.

Perikinetic flocculation refers to flocculation (contact or collisions of colloidal particles) due to Brownian motion of colloidal particles. The random motion of colloidal particles results from their rapid and random bombardment by the molecules of the fluid.

Orthokinetic flocculation refers to contacts or collisions of colloidal particles resulting from bulk fluid motion, such as stirring. In systems of stirring, the velocity of the fluid varies both spatially (from point to point) and temporally (from time to time). The spatial changes in

velocity are identified by a velocity gradient, G. G is estimated as $G=(P/hV)^{1/2}$, where P=Power, V=channel volume, and h= Absolute viscosity.

Mechanism of Flocculation

Gravitational flocculation: Baffle type mixing basins are examples of gravitational flocculation. Water flows by gravity and baffles are provided in the basins which induce the required velocity gradients for achieving floc formation.

Mechanical flocculation: Mechanical flocculators consists of revolving paddles with horizontal or vertical shafts or paddles suspended from horizontal oscillating beams, moving up and down.

Coagulation in Water Treatment

- **Salts of Al(III) and Fe(III) are commonly used as coagulants in water and wastewater treatment.**
- **When a salt of Al(III) and Fe(III) is added to water, it dissociates to yield trivalent ions, which hydrate to form aquometal complexes $Al(H_2O)_6^{3+}$ and $Fe(H_2O)_6^{3+}$. These complexes then pass through a series of hydrolytic reactions in which H_2O molecules in the hydration shell are replaced by OH^- ions to form a variety of soluble species such as $Al(OH)^{2+}$ and $Al(OH)^{2+}$. These products are quite effective as coagulants as they adsorb very strongly onto the surface of most negative colloids.**

Destabilization using Al(III) and Fe(III) Salts

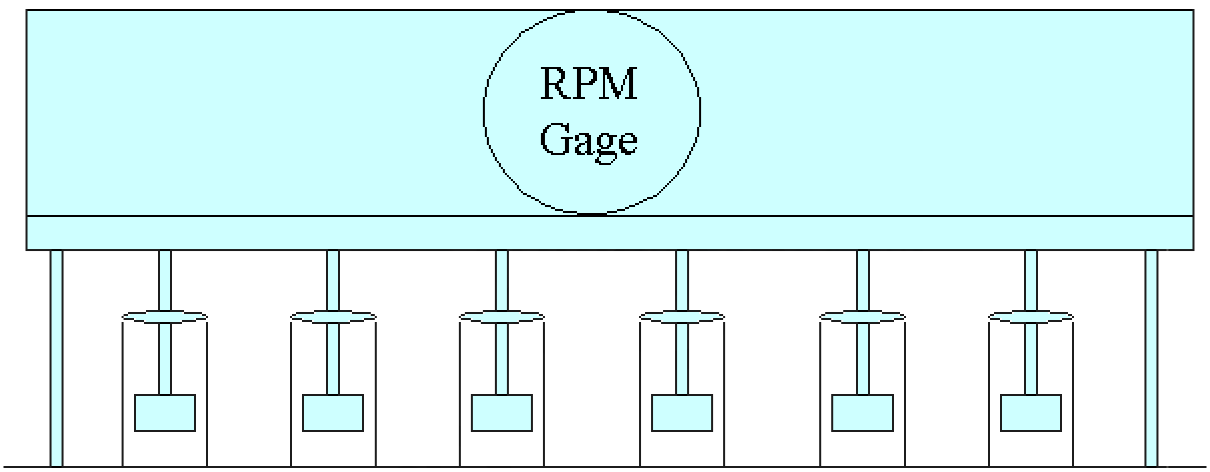
- **Al(III) and Fe(III) accomplish destabilization by two mechanisms:**
  (1) Adsorption and charge neutralization.
  (2) Enmeshment in a sweep floc.
- **Interrelations between pH, coagulant dosage, and colloid concentration determine mechanism responsible for coagulation.**
- **Charge on hydrolysis products and precipitation of metal hydroxides are both controlled by pH. The hydrolysis products possess a positive charge at pH values below iso-electric point of the metal hydroxide. Negatively charged species which predominate above iso-electric point, are ineffective for the destabilization of negatively charged colloids.**
- **Precipitation of amorphous metal hydroxide is necessary for sweep-floc coagulation.**
- **The solubility of $Al(OH)_3(s)$ and $Fe(OH)_3(s)$ is minimal at a particular pH and increases as the pH increases or decreases from that value. Thus, pH must be controlled to establish optimum conditions for coagulation.**
- **Alum and Ferric Chloride reacts with natural alkalinity in water as follows:**
  $Al_2(SO_4)_3.14H_2O + 6\ HCO^{3-} \longrightarrow 2\ Al(OH)_3(s) + 6CO_2 + 14\ H_2O + 3\ SO_4^{2-}$
  $FeCl_3 + 3\ HCO^{3-} \longrightarrow Fe(OH)_3(S) + 3\ CO_2 + 3\ Cl^-$

Jar Test

- **The jar test is a common laboratory procedure used to determine the optimum operating conditions for water or wastewater treatment. This method allows adjustments in pH, variations in coagulant or polymer dose, alternating mixing speeds, or testing of different coagulant or polymer types, on a small scale in order to predict the functioning of a large scale treatment operation.**

Jar Testing Apparatus

- **The jar testing apparatus consists of six paddles which stir the contents of six 1 liter containers. One container acts as a control while the operating conditions can be varied among the remaining five containers. A rpm gage at the top-center of the device allows for the uniform control of the mixing speed in all of the containers.**



Jar Test Procedure

- **The jar test procedures involves the following steps:**
  Fill the jar testing apparatus containers with sample water. One container will be used as a control while the other 5 containers can be adjusted depending on what conditions are being tested. For example, the pH of the jars can be adjusted or variations of coagulant dosages can be added to determine optimum operating conditions.
- **Add the coagulant to each container and stir at approximately 100 rpm for 1 minute. The rapid mix stage helps to disperse the coagulant throughout each container.**
- **Turn off the mixers and allow the containers to settle for 30 to 45 minutes. Then measure the final turbidity in each container.**

- **Reduce the stirring speed to 25 to 35 rpm and continue mixing for 15 to 20 minutes. This slower mixing speed helps promote floc formation by enhancing particle collisions which lead to larger flocs.**
- **Residual turbidity vs. coagulant dose is then plotted and optimal conditions are determined. The values that are obtained through the experiment are correlated and adjusted in order to account for the actual treatment system.**

Filtration

- **The resultant water after sedimentation will not be pure, and may contain some very fine suspended particles and bacteria in it. To remove or to reduce the remaining impurities still further, the water is filtered through the beds of fine granular material, such as sand, etc. The process of passing the water through the beds of such granular materials is known as Filtration.**

How Filters Work: Filtration Mechanisms

There are four basic filtration mechanisms:

SEDIMENTATION : The mechanism of sedimentation is due to force of gravity and the associate settling velocity of the particle, which causes it to cross the streamlines and reach the collector.
INTERCEPTION : Interception of particles is common for large particles. If a large enough particle follows the streamline, that lies very close to the media surface it will hit the media grain and be captured.
BROWNIAN DIFFUSION : Diffusion towards media granules occurs for very small particles, such as viruses. Particles move randomly about within the fluid, due to thermal gradients. This mechanism is only important for particles with diameters < 1 micron.
INERTIA : Attachment by inertia occurs when larger particles move fast enough to travel off their streamlines and bump into media grains.

Filter Materials

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

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

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

Types of Filter

Slow sand filter: **They consist of fine sand, supported by gravel. They capture particles near the surface of the bed and are usually cleaned by scraping away the top layer of sand that contains the particles.**

Rapid-sand filter: **They consist of larger sand grains supported by gravel and capture particles throughout the bed. They are cleaned by backwashing water through the bed to 'lift out' the particles.**

Multimedia filters: They consist of two or more layers of different granular materials, with different densities. Usually, anthracite coal, sand, and gravel are used. The different layers combined may provide more versatile collection than a single sand layer. Because of the differences in densities, the layers stay neatly separated, even after backwashing.

Principles of Slow Sand Filtration

- **In a slow sand filter impurities in the water are removed by a combination of processes: sedimentation, straining, adsorption, and chemical and bacteriological action.**
- **During the first few days, water is purified mainly by mechanical and physical-chemical processes. The resulting accumulation of sediment and organic matter forms a thin layer on the sand surface, which remains permeable and retains particles even smaller than the spaces between the sand grains.**
- **As this layer (referred to as "Schmutzdecke") develops, it becomes living quarters of vast numbers of micro-organisms which break down organic material retained from the water, converting it into water, carbon dioxide and other oxides.**
- **Most impurities, including bacteria and viruses, are removed from the raw water as it passes through the filter skin and the layer of filter bed sand just below. The purification mechanisms extend from the filter skin to approx. 0.3-0.4 m below the surface of the filter bed, gradually decreasing in activity at lower levels as the water becomes purified and contains less organic material.**
- **When the micro-organisms become well established, the filter will work efficiently and produce high quality effluent which is virtually free of disease carrying organisms and biodegradable organic matter.**

They are suitable for treating waters with low colors, low turbidities and low bacterial contents.

Sand Filters vs. Rapid Sand Filters

- Base material: In SSF it varies from 3 to 65 mm in size and 30 to 75 cm in depth while in RSF it varies from 3 to 40 mm in size and its depth is slightly more, i.e. about 60 to 90 cm.
- Filter sand: In SSF the effective size ranges between 0.2 to 0.4 mm and uniformity coefficient between 1.8 to 2.5 or 3.0. In RSF the effective size ranges between 0.35 to 0.55 and uniformity coefficient between 1.2 to 1.8.
- Rate of filtration: In SSF it is small, such as 100 to 200 L/h/sq.m. of filter area while in RSF it is large, such as 3000 to 6000 L/h/sq.m. of filter area.
- Flexibility: SSF are not flexible for meeting variation in demand whereas RSF are quite flexible for meeting reasonable variations in demand.
- Post treatment required: Almost pure water is obtained from SSF. However, water may be disinfected slightly to make it completely safe. Disinfection is a must after RSF.
- Method of cleaning: Scrapping and removing of the top 1.5 to 3 cm thick layer is done to clean SSF. To clean RSF, sand is agitated and backwashed with or without compressed air.
- Loss of head: In case of SSF approx. 10 cm is the initial loss, and 0.8 to 1.2m is the final limit when cleaning is required. For RSF 0.3m is the initial loss, and 2.5 to 3.5m is the final limit when cleaning is required.

Backwashing of Rapid Sand Filter

- For a filter to operate efficiently, it must be cleaned before the next filter run. If the water applied to a filter is of very good quality, the filter runs can be very long. Some filters can operate longer than one week before needing to be backwashed. However, this is not recommended as long filter runs can cause the filter media to pack down so that it is difficult to expand the bed during the backwash.
- Treated water from storage is used for the backwash cycle. This treated water is generally taken from elevated storage tanks or pumped in from the clear well.
- The filter backwash rate has to be great enough to expand and agitate the filter media and suspend the floc in the water for removal. However, if the filter backwash rate is too high, media will be washed from the filter into the troughs and out of the filter.

When is Backwashing Needed

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

- The head loss is so high that the filter no longer produces water at the desired rate; and/or

- **Floc starts to break through the filter and the turbidity in the filter effluent increases; and/or**
- **A filter run reaches a given hour of operation.**

Operational Troubles in Rapid Gravity Filters

Air Binding:

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

Formation of Mud Balls :

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

Cracking of Filters :

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

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

- **Breaking the top fine mud layer with rakes and washing off the particles.**
- **Washing the filter with a solution of caustic soda.**
- **Removing, cleaning and replacing the damaged filter sand.**

Standard design practice of Rapid Sand filter: Maximum length of lateral = not less than 60 times its diameter. Spacing of holes = 6 mm holes at 7.5 cm c/c or 13 at 15 c/c. C.S area of lateral = not less than 2 times area of perforations. C.S area of manifold = 2 times total area of

laterals. Maximum loss of head = 2 to 5 m. Spacing of laterals = 15 to 30 cm c/c. Pressure of wash water at perforations = not greater than 1.05 kg/cm^2. Velocity of flow in lateral = 2 m/s. Velocity of flow in manifold = 2.25 m/s. Velocity of flow in manifold for washwater= 1.8 to 2.5 m/s. Velocity of rising washwater= 0.5 to 1.0 m/min. Amount of washwater = 0.2 to 0.4% of total filtered water. Time of backwashing = 10 to 15 min. Head of water over the filter = 1.5 to 2.5 m. Free board = 60 cm. Bottom slope = 1 to 60 towards manifold.

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

where Q is in m^3/s, b is in m, h is in m. L:B = 1.25 to 1.33:1

<u>Disinfection</u>

The filtered water may normally contain some harmful disease producing bacteria in it. These bacteria must be killed in order to make the water safe for drinking. The process of killing these bacteria is known as Disinfection or Sterilization.

<u>Disinfection Kinetics</u>

When a single unit of microorganisms is exposed to a single unit of disinfectant, the reduction in microorganisms follows a first-order reaction.

$dN/dt=-kN$ $\qquad$ $N=N_0e^{-kt}$

This equation is known as Chick's Law:-

N = number of microorganism (N_0 is initial number)
k = disinfection constant
t = contact time

<u>Methods of Disinfection</u>

1. ***Boiling:*** **The bacteria present in water can be destroyed by boiling it for a long time. However it is not practically possible to boil huge amounts of water. Moreover it cannot take care of future possible contaminations.**
2. ***Treatment with Excess Lime:*** **Lime is used in water treatment plant for softening. But if excess lime is added to the water, it can in addition, kill the bacteria also. Lime when added raises the pH value o water making it extremely alkaline. This extreme alkalinity has been found detrimental to the survival of bacteria. This method needs the removal of excess lime from the water before it can be supplied to the general public. Treatment like recarbonation for lime removal should be used after disinfection.**

3. ***Treament with Ozone:*** **Ozone readily breaks down into normal oxygen, and releases nascent oxygen. The nascent oxygen is a powerful oxidising agent and removes the organic matter as well as the bacteria from the water.**
4. ***Chlorination:*** **The germicidal action of chlorine is explained by the recent theory of *Enzymatic hypothesis*, according to which the chlorine enters the cell walls of bacteria and kill the enzymes which are essential for the metabolic processes of living organisms.**

Chlorine Chemistry

Chlorine is added to the water supply in two ways. It is most often added as a gas, $Cl_2(g)$. However, it also can be added as a salt, such as sodium hypochlorite (NaOCl) or bleach. Chlorine gas dissolves in water following Henry's Law.

$$Cl_{2(g)} \longrightarrow Cl_{2(aq)} \quad K_H = 6.2 \times 10^{-2}$$

Once dissolved, the following reaction occurs forming hypochlorous acid (HOCl):

$$Cl_{2(aq)} + H_2O \longrightarrow HOCl + H^+ + Cl^-$$

Hypochlorous acid is a weak acid that dissociates to form hypochlorite ion (OCl-).

$$HOCl \longrightarrow OCl^- + H^+ \quad Ka = 3.2 \times 10^{-8}$$

All forms of chlorine are measured as mg/L of Cl_2 (MW = 2 x 35.45 = 70.9 g/mol) Hypochlorous acid and hypochlorite ion compose what is called the free chlorine residual. These free chlorine compounds can react with many organic and inorganic compounds to form chlorinated compounds. If the products of these reactions posses oxidizing potential, they are considered the combined chlorine residual. A common compound in drinking water systems that reacts with chlorine to form combined residual is ammonia. Reactions between ammonia and chlorine form chloramines, which is mainly monochloramine (NH_2Cl), although some dichloramine ($NHCl_2$) and trichloramine (NCl_3) also can form. Many drinking water utilities use monochloramine as a disinfectant. If excess free chlorine exits once all ammonia nitrogen has been converted to monochloramine, chloramine species are oxidized through what is termed the breakpoint reactions. The overall reactions of free chlorine and nitrogen can be represented by two simplified reactions as follows:

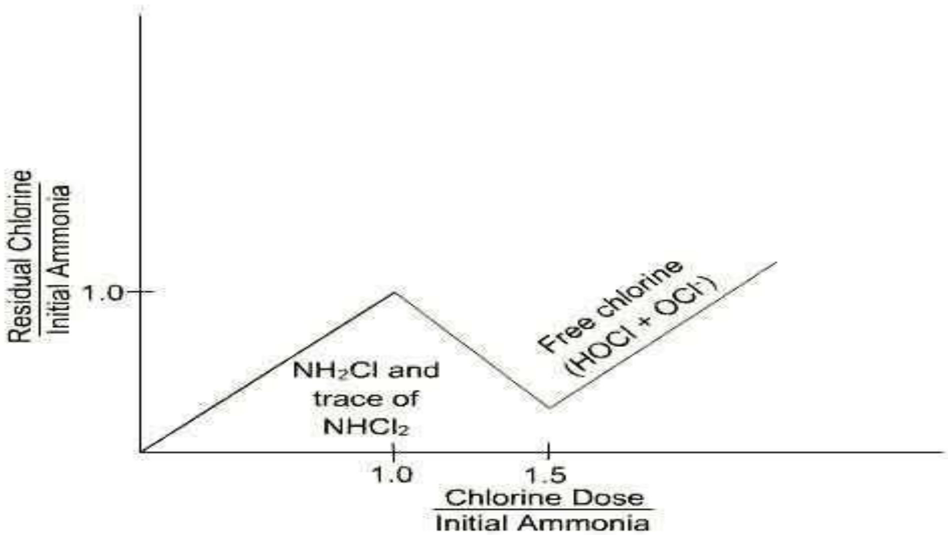
Monochloramine Formation Reaction. This reaction occurs rapidly when ammonia nitrogen is combined with free chlorine up to a molar ratio of 1:1.

$$HOCl + NH_3 \longrightarrow NH_2Cl + HOCl$$

Breakpoint Reaction: When excess free chlorine is added beyond the 1:1 initial molar ratio, monochloramine is removed as follows:

$$2NH_2Cl + HOCl \longrightarrow N_{2(g)} + 3H^+ + 3Cl^- + H_2O$$

The formation of chloramines and the breakpoint reaction create a unique relationship between chlorine dose and the amount and form of chlorine as illustrated below.



Free Chlorine, Chloramine, and Ammonia Nitrogen Reactions

Chlorine Demand

Free chlorine and chloramines readily react with a variety compounds, including organic substances, and inorganic substances like iron and manganese. The stoichiometry of chlorine reactions with organics can be represented as shown below:

HOCl:

$$1/10C_5H_7O_2N + HOCl \longrightarrow 4/10CO_2 + 1/10HCO^{3-} + 1/10NH^{4+} + H^+ + Cl^- + 1/10H_2O$$

OCl⁻:

$$1/10C_5H_7O_2N + OCl^- \longrightarrow 4/10CO_2 + 1/10HCO^{3-} + 1/10NH^{4+} + Cl^- + 1/10H_2O$$

NH_2Cl:

$$1/10C_5H_7O_2N + NH_2Cl + 9/10H_2O \longrightarrow 4/10CO_2 + 1/10HCO^{3-} + 11/10NH^{4+} + Cl^-$$

Chlorine demand can be increased by oxidation reactions with inorganics, such as reduced iron at corrosion sites at the pipe wall. Possible reactions with all forms of chlorine and iron are as follows:

Treatment Plant Layout and Siting

Plant layout **is the arrangement of designed treatment units on the selected site.** ***Siting*** **is the selection of site for treatment plant based on features as character, topography, and shoreline. Site development should take the advantage of the existing site topography. The following principles are important to consider:**

1. **A site on a side-hill can facilitate gravity flow that will reduce pumping requirements and locate normal sequence of units without excessive excavation or fill.**
2. **When landscaping is utilized it should reflect the character of the surrounding area. Site development should alter existing naturally stabilized site contours and drainage as little as possible.**
3. **The developed site should be compatible with the existing land uses and the comprehensive development plan.**

Treatment Plant Hydraulics

Hydraulic profile **is the graphical representation of the hydraulic grade line through the treatment plant. The head loss computations are started in the direction of flow using water surface in the influent of first treatment unit as the reference level. The total available head at the treatment plant is the difference in water surface elevations in the influent of first treatment unit and that in the effluent of last treatment unit. If the total available head is less than the head loss through the plant, flow by gravity cannot be achieved. In such cases pumping is needed to raise the head so that flow by gravity can occur.**

There are many basic principles that must be considered when preparing the hydraulic profile through the plant. Some are listed below:

1. **The hydraulic profiles are prepared at peak and average design flows and at minimum initial flow.**
2. **The hydraulic profile is generally prepared for all main paths of flow through the plant.**
3. **The head loss through the treatment plant is the sum of head losses in the treatment units and the connecting piping and appurtenances.**
4. **The head losses through the treatment unit include the following:**
    a. **Head losses at the influent structure.**
    b. **Head losses at the effluent structure.**
    c. **Head losses through the unit.**

   d. Miscellaneous and free fall surface allowance.

5. The total loss through the connecting pipings, channels and appurtenances is the sum of following:
   a. Head loss due to entrance.
   b. Head loss due to exit.
   c. Head loss due to contraction and enlargement.
   d. Head loss due to friction.
   e. Head loss due to bends, fittings, gates, valves, and meters.
   f. Head required over weir and other hydraulic controls.
   g. Free-fall surface allowance.

Water Distribution Systems

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

Requirements of Good Distribution System

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

Layouts of Distribution Network

The distribution pipes are generally laid below the road pavements, and as such their layouts generally follow the layouts of roads. There are, in general, four different types of pipe networks; any one of which either singly or in combinations, can be used for a particular place. They are

- **Dead End System**
- **Grid Iron System**
- **Ring System**
- **Radial System**

Distribution Reservoirs

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

Functions of Distribution Reservoirs:

- **to absorb the hourly variations in demand.**
- **to maintain constant pressure in the distribution mains.**
- **water stored can be supplied during emergencies.**

Location and Height of Distribution Reservoirs:

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

Types of Reservoirs

1. **Underground reservoirs.**
2. **Small ground level reservoirs.**
3. **Large ground level reservoirs.**
4. **Overhead tanks.**

Storage Capacity of Distribution Reservoirs

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

1. **Balancing Storage: The quantity of water required to be stored in the reservoir for equalising or balancing fluctuating demand against constant supply is known as the balancing storage (or equalising or operating storage). The balance storage can be worked out by mass curve method.**
2. **Breakdown Storage: The breakdown storage or often called emergency storage is the storage preserved in order to tide over the emergencies posed by the failure of pumps, electricity, or any othe mechanism driving the pumps. A value of about 25% of the total storage capacity of reservoirs, or 1.5 to 2 times of the average hourly supply, may be considered as enough provision for accounting this storage.**
3. **Fire Storage: The third component of the total reservoir storage is the fire storage. This provision takes care of the requirements of water for extinguishing fires. A provision of 1 to 4 per person per day is sufficient to meet the requirement.**

The total reservoir storage can finally be worked out by adding all the three storages.

Unit 4

Sewerage schemes and their importance, collection & conveyance of sewage, storm water quantity, fluctuation in sewage flow, flow through sewer, design of sewer, construction & Maintenance of sewer, sewer appurtenances, pumps & pumping station

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Some Important Definitions

- **Industrial wastewater: It is the wastewater generated from the industrial and commercial areas. This wastewater contains objectionable organic and inorganic compounds that may not be amenable to conventional treatment processes.**
- **Night Soil: It is a term used to indicate the human and animal excreta.**
- **Sanitary sewage: Sewage originated from the residential buildings comes under this category. This is very foul in nature. It is the wastewater generated from the lavatory basins, urinals and water closets of residential buildings, office building, theatre and other institutions. It is also referred as domestic wastewater.**
- **Sewage: It indicates the liquid waste originating from the domestic uses of water. It includes sullage, discharge from toilets, urinals, wastewater generated from commercial establishments, institutions, industrial establishments and also the groundwater and stormwater that may enter into the sewers. Its decomposition produces large quantities of malodorous gases, and it contains numerous pathogenic or disease producing bacteria, along with high concentration of organic matter and suspended solids.**
- **Sewage Treatment Plant is a facility designed to receive the waste from domestic, commercial and industrial sources and to remove materials that damage water quality and compromise public health and safety when discharged into water receiving systems or land. It is combination of unit operations and unit processes developed to treat the sewage to desirable standards to suit effluent norms defined by regulating authority.**
- **Sewer: It is an underground conduit or drain through which sewage is carried to a point of discharge or disposal.**
- **Sewerage: The term sewerage refers the infrastructure which includes device, equipment and appurtenances for the collection, transportation and pumping of sewage, but excluding works for the treatment of sewage. Basically it is a water carriage system designed and constructed for collecting and carrying of sewage through sewers.**
- **Subsoil water: Groundwater that enters into the sewers through leakages is called subsoil water.**
- **Sullage: This refers to the wastewater generated from bathrooms, kitchens, washing place and wash basins, etc. Composition of this waste does not involve higher concentration of organic matter and it is less polluted water as compared to sewage.**

Wastewater: The term wastewater includes both organic and inorganic constituents, in soluble or suspended form, and mineral content of liquid waste carried through liquid media. Generally the organic portion of the wastewater undergoes biological decompositions and the mineral matter may combine with water to form dissolved solids.

Wastewater Quantity Estimation

The flow of sanitary sewage alone in the absence of storms in dry season is known as dry weather flow (DWF).

Quantity= Per capita sewage contributed per day x Population

Sanitary sewage is mostly the spent water of the community draining into the sewer system. It has been observed that a small portion of spent water is lost in evaporation, seepage in ground, leakage, etc. Usually 80% of the water supply may be expected to reach the sewers.

Fluctuations in Dry Weather Flow

Since dry weather flow depends on the quantity of water used, and as there are fluctuations in rate of water consumption, there will be fluctuations in dry weather flow also. In general, it can be assumed that

(i) Maximum daily flow = 2 x average daily flow and
(ii) Minimum daily flow = 2/3 x (average daily flow).

Collection & conveyance of sewage-

For the disposal of waste products of towns two works are required

- Collection Works
- Disposal Works

- The disposal works mainly consist of treatment works which are essential to treat waste water and dispose it off in such a way that it may not cause any harm to the health of public nor pollute the nearby water sources. The collection works are the works which are done to collect the waste products. In olden days it was done by conservancy method, but in modern cities it is done by water- carriage method.

Methods of Collection

The sanitation of town or city is done by two methods:

- Conservancy System
- Water-Carriage System

The collection system is meant for collection of the sewage generated from individual houses and transporting it to a common point where it can be treated as per the needs before disposal. In olden days, waste generated from water closets was collected by conservancy methods and other liquid waste was transported through open drain to finally join natural drains. Since, the excreta was carried through carts, it was not hygienic method for transportation to the disposal point. Now, collection and conveyance of sewage is done in water carriage system, where it is transported in closed conduit using water as a medium.

Collection of Sewage

Mainly it is divided into two waste disposal methods.

1. Conservancy System
2. Water Carriage System

1. Conservancy System

This type of waste disposal / refuse are collected separately and disposed of.

A. Garbage is collected separately in dustbins and conveyed by covered carts or Lorries to suitable place. The combustible and non-combustible garbage is sorted out. The former is burnt and the later is buried in low lying areas.

B. The human and animal waste (feces and urine) are collected in pans from lavatories and is then carried by labors in carts or Lorries for disposal outside the city where it is buried for manure. The human and animal waste are also called night-soil.

C. The storm water is conveyed separately by close and open channels and discharge into natural streams. This system is obsolete now and can be used in rural areas where there is scarcity of water.

This system has the following disadvantages.

a. Cost- The system has less initial cost but the maintenance cost is high because of working labors.

b. Design of building- The lavatory has to be built away from the residential building which causes inconvenience.

c. Insanitary condition- The night soil is carried once in 24 hours while it becomes insanitary after 5-6 hours causing bad smell and fly nuisance.

d. Labor problem- If the labour goes on strike the system totally fails.

e. Land requirements- The night soil trenching ground required large areas of disposal.

f. Foul appearance- It is highly undesirable to allow night soil carts to pass through roads of the city.

i. Open drains- Storm water following in open drains cause unhygienic condition in the area.

j. Pollution of water-The liquid wastes from lavatories may seep into the ground polluting groundwater.

k. Risk of epidemic- The sewage is conveyed openly and is not properly disposed of causing risk of epidemic.

2. Water Carriage System

In this system water is used as a medium to carry wastes to the point of final disposal. The quantity of water is so high (99.9%) that wastes becomes liquid which is carried by the sewers. The garbage is collected separately as in conservancy system. The storm water may be disposed of separately or combined with sanitary sewage.

This system is universally used nowadays because of the following advantages.

a) Cost- Though the initial cost of the system is high but the maintenance cost is less.

b) Compact design- The lavatories can be accommodated inside the building which causes compact design of building and also convenience.

c) Hygienic conditions- The sewage is carried in covered drains thus the risk of epidemic are reduced.

d) Land requirement- Less land is required for treatment and disposal thus making the system economical.

e) Treatment- Proper treatment of sewage is possible to make the sewage suitable for disposal.

The only disadvantage of this system is the wastage of water (99.9% of water).

Merits of Conservancy System

The following are the merits of Conservancy System

- **It is cheaper in Initial cost because storm water can pass in open drains and conservancy latrines are much economical.**
- **The quantity of sewage reaching at the treatment plant before disposal is low.**
- **As the storm water goes in open drains, the sewer section will be small and will run full for the major portion of the year, due to which there will be no silting and deposits in sewer-lines.**
- **In floods if the water level of river rises at the out-fall, it will not be costly to pump the sewage for disposal**

Demerits

- **It is possible that storm water may go in sewer causing heavy load on treatment plants, therefore it is to be watched.**
- **In crowded lanes it is very difficult to lay two sewers or construct road side drains, causing great inconvenience to the traffic.**
- **Buildings cannot be designed as compact unit, because latrines are to be designed away from the living rooms due to foul smell, which are also inconvenient.**
- **In the presence of conservancy system, the aesthetic appearance of the city cannot be increased.**
- **Decomposition of sewage causes insanitary conditions which are dangerous to public health.**
- **This system completely depends on the mercy of sweepers.**

Water Carriage System

With the development and advantages of the cities, urgent need was felt to replace conservancy system with some more improved types of system in which human agencies should not be used for the collection and conveyance of the sewage. After a large number of trials it was found that the water is the only cheapest substance, which can be easily used for collection and conveyance of sewage. Therefore it is called Water-Carriage System. In this system the excremental matters are

mixed up in large quantity of water and are disposed off after necessary treatment in a satisfactory manner.

Merits & Demerits of Water Carriage System

Merits

- **It is hygienic method, because all the excremental matters are collected and conveyed by water only and no human agency is employed for it.**
- **There is no nuisance in the street of the town due to offensive matters, because all the sewage goes in closed sewers under the ground. The risk of epidemic is reduced.**
- **As only one sewer is laid, therefore it occupies less space in crowded lane.**
- **Due to more quantity of sewage, self-cleansing velocity can be obtained even at less gradients.**
- **Buildings can be designed as compact one unit.**
- **The land required for the disposal work is less as compared with conservancy system in which more area is required.**
- **The usual water supply is sufficient and no additional water is required in water carriage system**
- **This system does not depend on the manual labour**
- **Sewage after proper treatment can be used for various purposes.**

Demerits

- **The following are the demerits of water carriage System**
- **This system is very costly in initial cost. • The maintenance of this system is also costly.**
- **During monsoon large volume of sewage is to be treated whereas very small volume is to be treated in the remaining period of the year.**

Sewerage System

- **The Sewerage System are classified as follows:**

1. **Combined System**
2. **Separate System**
3. **Partially Separate System**

When only one set of sewer is laid, carrying both the sanitary sewage and storm water it is called combined system. In the separate system, if a portion of storm water is allowed to enter in the sewers carrying sewage and the remaining storm water flows in separate set of sewers it is called partially separate system. The combined system is most suited in areas having small rainfall which is evenly distributed throughout the area, because at such places self-cleaning velocity will be available in every season. As only one sewer is laid in this system, therefore it can also be used in crowded areas, where it is very difficult to lay two sewers. If rainfall is heavy and it is for short time, it is better to provide separate system, because in combined system self-cleaning velocity will not be available for most of the period of the year.

Sewerage System Merits and Demerits of Separate System

Followings are the merits of Separate System.

- **The sewage flows in separate sewer; therefore the quantity to be treated is small which results in economical design of treatment works.**

- **Separate system is cheaper than combined system, because only sanitary sewage flows in closed sewer and the storm water which is unfold in nature can be taken through open gutter or drains, whereas both types of sewage is to be carried in closed sewer in case of combined system**

- **During disposal if the sewage is to be pumped, the separate system is cheaper.**

- **There is no fear of stream pollution**

o **Sewerage System Followings are the demerits of separate System**

o **Generally self-cleaning velocity is not available, due to small quantity of sewage, therefore flushing is required at various points.**

- **There is always a risk that storm water may enter the sanitary sewer and cause over flowing of sewer and heavy load on the treatment plant.**

- **As two sets of sewer are laid, therefore its maintenance cost is more.**

- **In busy lanes laying of two sewers is difficult which also causes great inconvenience to the traffic during repairs.**

Sewerage System Merits and Demerits of Combined System

Merits of Combined System

- **There is no need of flushing, because self-cleansing velocity is easily available at every place due to more quantity of sewage.**

- **Rain water dilutes the sewage, therefore it can be easily and economically treated.**

- **House plumbing can be done easily because only one set of pipes will be required**

- **The following are the demerits of Combined System**

- **Initial cost is high as compared with separate System**

- **It is not suitable for areas having rainfall for small period of the year, because the dry weather flow will be small due to which self-cleaning velocities will not be available resulting in silting up of the sewers.**

- **If the whole sewage is to be disposed of by pumping, it is uneconomical**

- **During heavy rains, the overflowing of sewers will endanger the public health.**

Rational method

For hydraulic designs on very small watersheds, a complete hydrograph of runoff is not always required. The maximum, or peak, of the hydrograph is sufficient for design of the structure in question. Therefore, a number of methods for estimating a design discharge, that is, the maximum value of the flood runoff hydrograph, have been developed. The rational method is a simple technique for estimating a design discharge from a small watershed. It was developed by Kuching (1889) for small drainage basins in urban areas. The rational method is the basis for design of many small structures. In particular, the size of the drainage basin is limited to a few tens of acres.

Storm water quantity can be estimated by rational method as below:

Storm water quantity, Q = C.I.A / 360

Where,

Q = Quantity of storm water, m3/sec.

C = Coefficient of runoff

I = intensity of rainfall (mm/hour) for the duration equal to time of concentration, and

A = Drainage area in hectares

Minimum Velocity: Self-Cleansing Velocity

The velocity that would not permit the solids to settle down and even scour the deposited particles of a given size is called as self-cleansing velocity. This minimum velocity should at least develop once in a day so as not to allow any deposition in the sewers. Otherwise, if such deposition takes place, it will obstruct free flow causing further deposition and finally leading to the complete blocking of the sewers. This minimum velocity or self-cleansing velocity can

Will be worked out as below:

Vs = 8k (Ss-1) g.d'/f'

K= constant, for clean inorganic solids = 0.04 and for organic solids = 0.06

f' = Darcy Weisbach friction factor (for sewers = 0.03)

Ss = Specific gravity of sediments

g = gravity acceleration

d' = diameter of grain, m

- **Hence, for removing the impurities present in sewage i.e., sand up to 1 mm diameter with specific gravity 2.65 and organic particles up to 5 mm diameter with specific gravity of 1.2, it is necessary that a minimum velocity of about 0.45 m/sec and an average velocity of about 0.9 m/sec should be developed in sewers.**

- **Hence, while finalizing the sizes and gradients of the sewers, they must be checked for the minimum velocity that would be generated at minimum discharge, i.e., about 1/3 of the average** discharge. While designing the sewers the flow velocity at full depth is generally kept at about 0.8 m/sec or so. Since, sewers are generally designed for ½ to ¾ full, the velocity at 'designed discharge' (i.e., ½ to ¾ full) will even be more than 0.8 m/sec. Thus, the

Pattern of sewerage system

The network of sewers consists of house sewers discharging the sewage to laterals. The lateral discharges the sewage into branch sewers or sub-mains and sub-mains discharge it into main sewer or trunk sewer. The trunk sewer carries sewage to the common point where adequate treatment is given to the sewage and then it is discharged. The patterns of collection system depend upon:

- The topographical and hydro-logical features of the area.
- The location and methods of treatment and disposal works.
- The type of sewerage system employed, and extent of area to be served.

Single treatment plant is required in this pattern.

- The drawback in this pattern is that larger diameter sewer is required near to the treatment plant as entire sewage is collected at a common point.
- In addition, with new development of the city the load on existing treatment plant increases.

Figure: Fan pattern of collection system Zone Pattern

- More numbers of interceptors are provided in this pattern.
- This pattern is suitable for sloping area than flat areas.

Water Carriage System

In this system water is used as a medium to carry wastes to the point of final disposal. The quantity of water is so high (99.9%) that wastes becomes liquid which is carried by the sewers. The garbage is collected separately as in conservancy system. The storm water may be disposed of separately or combined with sanitary sewage.

This system is universally used nowadays because of the following advantages.

1. Cost. Though the initial cost of the system is high but the maintenance cost is less.

2. Compact design. The lavatories can be accommodated inside the building which causes compact design of building and also convenience.

3. Hygienic conditions. The sewage is carried in covered drains thus the risk of epidemic are reduced.

4. Land requirement. Less land is required for treatment and disposal thus making the system economical.

5. Treatment. Proper treatment of sewage is possible to make the sewage suit

Disposal of the sewage generated from a locality efficient collection, conveyance, adequate treatment and proper disposal of treated sewage is necessary. To achieve this, following conditions should be satisfied:

1. Sewage should not pollute the drinking water source, either surface or groundwater, or water bodies that are used for bathing or recreational purposes.

2. The untreated sewage during conveyance should not be exposed so as to have access to human being or animals and should not give unsightly appearances or odor nuisance, and should not become a place for breeding flies.

3. It should not cause harm to public health and adversely affect the receiving environment.

Fluctuation in sewage flow:

Where possible, gauging of flow in existing sewers should be made in order to determine actual variations. Recording gauges are available or can be devised that will give depths of sewage in the outfall sewer or in the main leading from a district. In order to design a system for a previously unseward town or section of a city, an estimate must be made of the fluctuations to be expected in the flow. This is of importance, as the sewers must be large enough to accommodate the maximum rate, or there may be a backing up of sewage into the lower plumbing fixtures of buildings.

As in water consumption, the rate of sewage production will vary according to the season of the year, weather conditions, day of the week, and time of day. The variations do not depart so far from the average as for water because of the storage space in the sewers and because of the time required for the sewage to run to the point of gauging. That is, the peaks are flattened because it requires considerable sewage to fill the sewers to the high flow point, and the high from various sections will reach the gauging point after various time of flow. When the peak occurs will depend upon the flow time in the sewers and the type of district served.

- **Sewage flow rates vary by source and with time (time of the day, day of the week, season of the year, weather conditions)**
- **In most municipalities, the sources may be residences institutions such as hospital and school, commercial establishments and industries.**
- **It is thus necessary for the designers and managers to determine the mix of these elements and to estimate their contributions.**

- A case-by-case assessment should always be made before sewers are sized or treatment plant capacities set.
- For institutions, flows may vary as low as 10 gpcd (Gallons Per Capita Daily) (40 lpcd (Litres per Capita per Day)) for schools to 175 gpcd (700 lpcd) for hospitals.
- Hotels may produce flows of about 100 gpcd (400 lpcd) while small business may generally only about 2060 gpcd (8,240 lpcd) per employee.
- Sewage flow patterns in residential areas resemble water use pattern for those areas, with the exception of time lag, as shown in figure.
- The magnitude of this lay varies with the situation, but it is usually on the order of a few hours, where infiltration from rainfall hydrographs produced in the sewers, the hydrographs produced in the sewers may vary considerably during dry periods.
- Otherwise, the variation in daily flow pattern for most residential areas is quite small.
- Where sewers receive significant quantities of wastes from industrial operations, the amount and timing of flows are affected by prevailing industrial practices.
- Table (below) gives an indication of the variation in residential waste water flows as ratios to the average.
- In the absence of site-specific data, such figures may be used to estimate high and low flows.

Description	Ratio to the average
Max daily	2.25:1
Max hourly / peak hourly	3:1
Max daily	0.67:1
Min hourly	Min hourly0.33:1

Residential waste water flows at ratio to the average:

- Data on the ratio of peak flows and min flows to the average daily flow summarized by Gupta show that the peak to average daily flow ratio ranges from about 3.0 for cities of about 10,000 to about 1.5 for cities of 10,00,000 (one million)

* If less population, so less peeking factor and vice versa because less population has less sewage and water consumption.

Flow through sewer

A sanitary sewer or "foul sewer" is an underground carriage system specifically for transporting sewage from houses and commercial buildings through pipes to treatment facilities or disposal. Sanitary sewers are part of an overall system called a sewage system or sewerage.

Sewage may be treated to control water pollution before discharge to surface waters.[1][2] Sanitary sewers serving industrial areas also carry industrial wastewater.

Separate sanitary sewer systems are designed to transport sewage alone. In municipalities served by sanitary sewers, separate drains may convey surface runoff directly to surface waters. Sanitary sewers are distinguished from combined sewers, which combine sewage with storm water runoff in one pipe. Sanitary sewer systems are beneficial because they avoid combined sewer overflows.

Types

Conventional gravity sewers

In the developed world, sewers are pipes from buildings to one or more levels of larger underground trunk mains, which transport the sewage to sewage treatment facilities. Vertical pipes, usually made of precast concrete, called manholes, connect the mains to the surface. Depending upon site application and use, these vertical pipes can be cylindrical, eccentric or concentric. The manholes are used for access to the sewer pipes for inspection and maintenance, and as a means to vent sewer gases. They also facilitate vertical and horizontal angles in otherwise straight pipelines.

Pipes conveying sewage from an individual building to a common gravity sewer line are called laterals. Branch sewers typically run under streets receiving laterals from buildings along that street and discharge by gravity into trunk sewers at manholes. Larger cities may have sewers called interceptors receiving flow from multiple trunk sewers.[6]

Design and sizing of sanitary sewers considers the population to be served over the anticipated life of the sewer, per capita wastewater production, and flow peaking from timing of daily routines. Minimum sewer diameters are often specified to prevent blockage by solid materials flushed down toilets; and gradients may be selected to maintain flow velocities generating sufficient turbulence to minimize solids deposition within the sewer. Commercial and industrial wastewater flows are also considered, but diversion of surface runoff to storm drains eliminates wet weather flow peaks of inefficient combined sewers.[7]

Force mains

Pumps may be necessary where gravity sewers serve areas at lower elevations than the sewage treatment plant, or distant areas at similar elevations. A lift station is a sewer sump that lifts accumulated sewage to a higher elevation. The pump may discharge to another gravity sewer at that location or may discharge through a pressurized force main to some distant location

Effluent sewer

Effluent sewer systems, also called septic tank effluent drainage (STED) or solids-free sewer (SFS) systems, have septic tanks that collect sewage from residences and businesses, and the effluent that comes out of the tank is sent to either a centralized sewage treatment plant or a distributed treatment system for further treatment. Most of the solids are removed by the septic tanks, so the treatment plant can be much smaller than a typical plant. In addition, because of the vast reduction in solid waste, a pumping system can be used to move the wastewater rather than a gravity system. The pipes have small diameters, typically 1.5 to 4 inches, or 4 to 10 cm. Because the waste stream is pressurized, they can be laid just below the ground surface along the land's contour.

Design of Sewer System Sewer system plays a vital role in the economic development of a country. Sewers are must for the drainage of waste water. In order to have an effective sewage system the sewers should be properly designed and more care should be taken in finding the invert levels

otherwise whole design may get wrong. Design of Sewer System. Sewers are designed for the drainage of waste water coming from houses, industries, streets, runoff etc to protect the environment and people from serious diseases, as more than 50 diseases spread from sewage. So for a good living, the sewers should be properly designed and the sewage should be treated properly before discharging it into the river.

Design of Sewers

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

- **The sewage contain particles in suspension, the heavier of which may settle down at the bottom of the sewers, as and when the flow velocity reduces, resulting in the clogging of sewers. To avoid silting of sewers, it is necessary that the sewer pipes be laid at such a gradient, as to generate self-cleansing velocities at different possible discharges.**

- **The sewer pipes carry sewage as gravity conduits, and are therefore laid at a continuous gradient in the downward direction upto the outfall point, from where it will be lifted up, treated and disposed of.**

Hazen-William's formula

$$U = 0.85\, C\, r_H^{0.63} S^{0.54}$$

Manning's formula

$$U = \frac{1}{n} r_H^{2/3} S^{1/2}$$

Where, U= velocity, m/s; rH= hydraulic radius, m; S= slope, C= Hazen-William's coefficient, and n = Manning's coefficient.

Darcy-Weisbach formula

$$h_L = \frac{f L U^2}{2 g d}$$

Minimum Velocity

The flow velocity in the sewers should be such that the suspended materials in sewage do not get silted up; i.e. the velocity should be such as to cause automatic self-cleansing effect. The generation of such a minimum self-cleansing velocity in the sewer, atleast once a day, is important, because if certain deposition takes place and is not removed, it will obstruct free flow, causing further deposition and finally leading to the complete blocking of the sewer.

Maximum Velocity

The smooth interior surface of a sewer pipe gets scoured due to continuous abrasion caused by the suspended solids present in sewage. It is, therefore, necessary to limit the maximum velocity in the sewer pipe. This limiting or non-scouring velocity will mainly depend upon the material of the sewer.

Effects of Flow Variation on Velocity in a Sewer

Due to variation in discharge, the depth of flow varies, and hence the hydraulic mean depth (r) varies. Due to the change in the hydraulic mean depth, the flow velocity (which depends directly on r2/3) gets affected from time to time. It is necessary to check the sewer for maintaining a minimum velocity of about 0.45 m/s at the time of minimum flow (assumed to be 1/3rd of average flow). The designer should also ensure that a velocity of 0.9 m/s is developed atleast at the time of maximum flow and preferably during the average flow periods also. Moreover, care should be taken to see that at the time of maximum flow, the velocity generated does not exceed the scouring value.

Sewer Appurtenances

Sewer appurtenances are the various accessories on the sewerage system and are necessary for the efficient operation of the system. They include man holes, lamp holes, street inlets, catch basins, inverted siphons, and so on.

Man-holes: Man holes are the openings of either circular or rectangular in shape constructed on the alignment of a sewer line to enable a person to enter the sewer for inspection, cleaning and flushing. They serve as ventilators for sewers, by the provisions of perforated man-hole covers. Also they facilitate the laying of sewer lines in convenient length.

Man-holes are provided at all junctions of two or more sewers, whenever diameter of sewer changes, whenever direction of sewer line changes and when sewers of different elevations join together.

Special Man-holes:

Junction chambers: Man-hole constructed at the intersection of two large sewers.

Drop man-hole: When the difference in elevation of the invert levels of the incoming and outgoing sewers of the man-hole is more than 60 cm, the interception is made by dropping the incoming sewer vertically outside and then it is jointed to the man-hole chamber.

Flushing man-holes: They are located at the head of a sewer to flush out the deposits in the sewer with water.

Lamp-holes: Lamp holes are the openings constructed on the straight sewer lines between two man-holes which are far apart and permit the insertion of a lamp into the sewer to find out obstructions if any inside the sewers from the next man-hole.

Street inlets: Street inlets are the openings through which storm water is admitted and conveyed to the storm sewer or combined sewer. The inlets are located by the sides of pavement with maximum spacing of 30 m.

Catch Basins: Catch basins are small settling chambers of diameter 60 - 90 cm and 60 - 75 cm deep, which are constructed below the street inlets. They interrupt the velocity of storm water entering through the inlets and allow grit, sand, debris and so on to settle in the basin, instead of allowing them to enter into the sewers.

Inverted siphons: These are depressed portions of sewers, which flow full under pressure more than the atmospheric pressure due to flow line being below the hydraulic grade line. They are constructed when a sewer crosses a stream or deep cut or road or railway line. To clean the siphon pipe sluice valve is opened, thus increasing the head causing flow. Due to increased velocity deposits of siphon pipe are washed into the sump, from where they are removed.

Pumping of Sewage

Pumping of sewage is required when it is not possible to have a gravitational flow for the entire sewerage project.

Sufficient pumping capacity has to be provided to meet the peak flow, at least 50% as stand by.

Types of pumps:

1. Centrifugal pumps either axial, mixed or radial flow.

2. Pneumatic ejector pumps.

3. Centrifugal pumps are a sub-class of dynamic axisymmetric work-absorbing turbo machinery Centrifugal pumps are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits.

4. Common uses include water, sewage, petroleum and petrochemical pumping; a centrifugal fan is commonly used to implement a vacuum cleaner. The reverse function of the centrifugal pump is a water turbine converting potential energy of water pressure into mechanical rotational energy.

Axial Flow Pumps

Axial-flow pumps differ from radial-flow in that the fluid enters and exits along the same direction parallel to the rotating shaft. The fluid is not accelerated but instead "lifted" by the action of the impeller. They may be likened to a propeller spinning in a length of tube. Axial-flow pumps operate at much lower pressures and higher flow rates than radial-flow pumps.

Mixed/Radial Flow Pumps

Often simply referred to as centrifugal pumps. The fluid enters along the axial plane, is accelerated by the impeller and exits at right angles to the shaft(radially). Radial-flow pumps operate at higher pressures and lower flow rates than axial and mixed-flow pumps.

Mixed-flow pumps function as a compromise between radial and axial-flow pumps. The fluid experiences both radial acceleration and lift and exits the impeller somewhere between 0 and 90 degrees from the axial direction. As a consequence mixed-flow pumps operate at higher pressures than axial-flow pumps while delivering higher discharges than radial-flow pumps. The exit angle of the flow dictates the pressure head-discharge characteristic in relation to radial and mixed-flow.

Peripheral Pumps

A peripheral pump is also called a turbine, or regenerative, pump. The impeller has vanes on both sides of the rim that rotate in a ring like channel in the pump's casing. The fluid does not discharge freely from the tip of the impeller but is recirculated back to a lower point on the impeller diameter. This recirculation, or regeneration, increases the head developed.

The Pneumatic Ejector Pump:-

The pneumatic ejector is a extremely simple yet reliable mechanism. Fundamentally, it consists of a receiver or "pot' that allows liquids and solids to enter without restriction. When the pot becomes filled, compressed air is introduced to displace the contents up to a higher discharge line. The Pneumatic Ejector is unique as a pumping mechanism because no mechanical parts are involved in the actual pumping of the material... and it has no practical limitations on head. Under normal flow conditions, the equipment is designed to operate with a one minute cycle. The cycle consists of two phases. Filling the pot, and then the discharging of its contents. Operation is fully automatic with a choice of electric or mechanical control systems.

Unit – V

Characteristics and analysis of waste water, recycles of decomposition, physical, chemical & biological parameters. Oxygen demand i.e. BOD & COD, TOC, TOD, Th OD, Relative Stability, population equivalent, instrumentation involved in analysis, natural methods of waste water disposal i.e. by land treatment & by dilution, self-purification capacity of stream, Oxygen sag analysis.

Wastewater is simply that part of the water supply to the community or to the industry which has been used for different purposes and has been mixed with solids either suspended or dissolved. Wastewater is 99.9% water and 0.1% solids. The main task in treating the wastewater is simply to remove most or all of this 0.1% of solids.

Type of wastewater from household

Gray water washing water from the kitchen, bathroom, laundry (without feces and urine)

Black water from flush toilet (feces and urine with flush water)

Yellow water Urine from separated toilets and urinals

Brown water Black water without urine or yellow water

The process of decomposition — the breakdown of raw organic materials to a finished compost — is a gradual complex process, one in which both chemical and biological processes must occur in order for organic matter to change into compost.

Recycles of decomposition

The decomposition (stabilization) of organic matter by biological action has been taking place in nature since life first appeared on our planet. In recent times, man has attempted to control and directly utilize the process for sanitary recycling and reclamation of organic waste material. Such organic materials as vegetable matter, animal manure and other organic refuse can be converted from otherwise wasted materials to a more stable form for use as a soil amendment by this process. This process is called "composting" and the final product of composting is called "compost". Generally speaking there are two processes that yield compost:

1. ANAEROBIC (without oxygen) decomposition.
2. AEROBIC (with oxygen) decomposition and stabilization.

In these processes, bacteria, fungi, molds, protozoa, actinomycetes, and other saprophytic organisms feed upon decaying organic materials initially, while in the later stages of decomposition mites, millipedes, centipedes, springtails, beetles and earthworms further breakdown and enrich the composting materials. The organisms will vary in the pile due to temperature conditions, but the goal in composting is to create the most favorable environment possible for the desired organisms. Differences between aerobic and anaerobic composting are discussed below.

Anaerobic Decomposition (Fermentation)

Anaerobic decomposition takes place in nature, as in the decomposition of the organic muds at the bottom of marshes and in buried organic materials to which oxygen does not have access. Intensive reduction of organic matter by putrefaction is usually accompanied by disagreeable odors of hydrogen sulfide and reduced organic compounds which contain sulfur, such as mercaptans (any sulfur-containing organic compound).

Putrefactive breakdown of organic material takes place anaerobically. Organic compounds break down by the action of living organisms that do not require air in the normal sense. These organisms use nitrogen, phosphorus, and other nutrients to live and to develop cell protoplasm, but they reduce the organic nitrogen to organic acids and ammonia. The carbon from the organic compounds which is not utilized in the cell protein is liberated mainly in the reduced form of methane (CH_4). A small portion of carbon may be respired as carbon dioxide ($C0_2$).

Since anaerobic destruction of organic matter is a reduction process, the final product, humus, is subject to some aerobic oxidation when put on the soil, that is, it may appear to decompose further after being exposed to air. This oxidation is minor, takes place rapidly, and is of no consequence in the utilization of the material on the soil. In other words, much less heat is generated in anaerobic decomposition than in aerobic decomposition. The lack of heat generated in the anaerobic destruction of organic matter is a definite disadvantage if contaminated materials are used for composting. High temperatures are needed for the destruction of pathogens and parasites. In anaerobic decomposition the pathogenic organisms do eventually disappear in the organic mass, as a result of the unfavorable environment and biological antagonisms. The disappearance is slow, and the material must be held for periods of six months to a year to ensure relatively complete destruction of pathogens, such as the eggs of Ascaris, nematodes which are among the most resistant of the fecal-borne disease parasites in wastes. Therefore, make compost this year and use it next year. However, organic material can be decomposed anaerobically to produce compost. For instance, a heavy plastic bag can be used to decompose grass clippings or other high nitrogen materials, shredded leaves, kitchen trimmings, a small amount of stable manure or other compostable materials. However, as anaerobic compost can have a strong odor (and may need to be aired prior to using), it is not usually the first choice for home owners. For more details see Structures.

Aerobic Decomposition

When organic materials decompose in the presence of oxygen, the process is called “aerobic.” The aerobic process is most common in nature. For example, it takes place on ground surfaces such as the forest floor, where droppings from trees and animals are converted into a relatively stable humus. There is no accompanying bad smell when there is adequate oxygen present.

In aerobic decomposition, living organisms, which use oxygen, feed upon the organic matter. They use the nitrogen, phosphorus, some of the carbon, and other required nutrients. Much of the carbon serves as a source of energy for the organisms and is burned up and respired as carbon dioxide (C02). Since carbon serves both as a source of energy and as an element in the cell protoplasm, much more carbon than nitrogen is needed. Generally about two-thirds of carbon is respired as C02, while the other third is combined with nitrogen in the living cells. However, if the excess of carbon over nitrogen (C:N ratio) in organic materials being decomposed is too great, biological activity diminishes. Several cycles of organisms are then required to burn most of the carbon.

When some of the organisms die, their stored nitrogen and carbon becomes available to other organisms. As other organisms use the nitrogen from the dead cells to form new cell material, once more excess carbon is converted to C02. Thus, the amount of carbon is reduced and the limited amount of nitrogen is recycled. Finally, when the ratio of available carbon to available nitrogen is in sufficient balance, nitrogen is released as ammonia. Under favorable conditions, some ammonia may oxidize to nitrate. Phosphorus, potash, and various micro-nutrients are also essential for biological growth. These are normally present in more than adequate amounts in compostable materials and present no problem.

During composting a great deal of energy is released in the form of heat in the oxidation of the carbon to C02. For example, if a gram-molecule of glucose is dissimilated under aerobic conditions, 484 to 674 kilogram calories (kcal) of heat may be released. If the organic material is in a pile or is otherwise arranged to provide some insulation, the temperature of the material during decomposition will rise to over 170°F. If the temperature exceeds 162°F to 172°F, however, the bacterial activity is decreased and stabilization is slowed down. Initially, mesophilic organisms, which live in temperatures of 50°F to 115°F, colonize in the materials. When the temperature exceeds about 120°F, Thermophilic organisms, which grow and thrive in the temperature range 115°F to 160°F., develop and replace the mesophilic bacteria in the decomposition material. Only a few groups of thermophiles carry on any activity above 160°F. Oxidation at Thermophilic temperatures takes place more rapidly than at mesophilic temperatures and, hence, a shorter time is required for decomposition (stabilization). The high temperatures will destroy pathogenic bacteria, protozoa (microscopic one-celled animals), and weed seeds, which are detrimental to health or agriculture when the final compost is used. Aerobic oxidation of organic matter produces no objectionable odor. If odors are noticeable, either the process is not entirely aerobic or there are some special conditions or materials present which are creating an odor. Aerobic decomposition or composting can be accomplished in pits, bins, stacks, or piles, if adequate oxygen is provided. Turning the material at intervals or other techniques for adding oxygen is useful in maintaining aerobic conditions.

Compost piles under aerobic conditions attain a temperature of 140°F to 160°F in one to five days depending upon the material and the condition of the composting operation. This temperature can also be maintained for several days before further aeration. The heat necessary to produce and maintain this temperature must come from aerobic decomposition which requires oxygen. After a period of time, the material will become anaerobic unless it is aerated. In this manual the term "aerobic composting" will be used in its commonly accepted meaning of that process. It requires a

considerable amount of oxygen and produces none of the characteristic features of anaerobic putrefaction. In its modern sense, aerobic composting can be defined as a process in which, under suitable environmental conditions, aerobic organisms, principally Thermophilic, utilize considerable amounts of oxygen in decomposing organic matter to a fairly stable humus.

Biochemical oxygen demand

(BOD, also called biological oxygen demand) is the amount of dissolved oxygen needed (i.e., demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water.

OR

The BOD test is used to measure waste loads to treatment plants, determine plant efficiency (in terms of BOD removal), and control plant processes. It is also used to determine the effects of discharges on receiving waters. A major disadvantage of the BOD test is the amount of time (5 days) required to obtain the results.

When a measurement is made of all oxygen consuming materials in a sample, the result is termed "Total Biochemical Oxygen Demand" (TBOD), or often just simply "Biochemical Oxygen Demand" (BOD). Because the test is performed over a five day period, it is often referred to as a "Five Day BOD", or a BOD5.

In many biological treatment plants, the facility effluent contains large numbers of nitrifying organisms which are developed during the treatment process. These organisms can exert an oxygen demand as they convert nitrogenous compounds (ammonia and organic nitrogen) to more stable forms (nitrites and nitrates). At least part of this oxygen demand is normally measured in a five day BOD.

Typical values

Most pristine rivers will have a 5-day carbonaceous BOD below 1 mg/L. Moderately polluted rivers may have a BOD value in the range of 2 to 8 mg/L. Rivers may be considered severely polluted when BOD values exceed 8 mg/L.[7] Municipal sewage that is efficiently treated by a three-stage process would have a value of about 20 mg/L or less. Untreated sewage varies, but averages around 600 mg/L in Europe and as low as 200 mg/L in the U.S., or where there is severe groundwater or surface water Infiltration/Inflow. The generally lower values in the U.S. derive from the much greater water use per capita than in other parts of the world.

Methods

There are two commonly recognized methods for the measurement of BOD.

Dilution method

This standard method is recognized by U.S. EPA, which is labeled Method 5210B in the Standard Methods for the Examination of Water and Wastewater. In order to obtain BOD5, dissolved oxygen (DO) concentrations in a sample must be measured before and after the incubation period, and appropriately adjusted by the sample corresponding dilution factor. This analysis is performed using 300 ml incubation bottles in which buffered dilution water is dosed with seed microorganisms and stored for 5 days in the dark room at 20 °C to prevent DO production via photosynthesis. In addition to the various dilutions of BOD samples, this procedure requires dilution water blanks, glucose glutamic acid (GGA) controls, and seed controls. The dilution water blank is used to confirm the quality of the dilution water that is used to dilute the other samples. This is necessary because impurities in the dilution water may cause significant alterations in the results. The GGA control is a standardized solution to determine the quality of the seed, where its recommended BOD5 concentration is 198 mg/l ± 30.5 mg/l. For measurement of carbonaceous BOD (cBOD), a nitrification inhibitor is added after the dilution water has been added to the sample. The inhibitor hinders the oxidation of ammonia nitrogen, which supplies the nitrogenous BOD (nBOD). When performing the BOD5 test, it is conventional practice to measure only cBOD because nitrogenous demand does not reflect the oxygen demand from organic matter. This is because nBOD is generated by the breakdown of proteins, whereas cBOD is produced by the breakdown of organic molecules.

BOD5 is calculated by:

- **Seeded**
- **Unseeded**

To determine the value of the BOD in mg/L, use the following formula:

BOD, mg/L = [(Initial DO Final DO) x 300]/mL sample

For example:

Initial DO = 8.2 mg/L

Final DO = 4.4 mg/L

Sample size = 5 mL

BOD mg/L = [(8.2 4.4) x 300]/5 = (3.8 x 300)/5 = 1140/5 = 228 mg/L

Manometric method

This method is limited to the measurement of the oxygen consumption due only to carbonaceous oxidation. Ammonia oxidation is inhibited.

The sample is kept in a sealed container fitted with a pressure sensor. A substance that absorbs carbon dioxide (typically lithium hydroxide) is added in the container above the sample level. The sample is stored in conditions identical to the dilution method. Oxygen is consumed and, as ammonia oxidation is inhibited, carbon dioxide is released. The total amount of gas, and thus the pressure, decreases because carbon dioxide is absorbed. From the drop of pressure, the sensor electronics computes and displays the consumed quantity of oxygen.

The main advantages of this method compared to the dilution method are:

- **Simplicity: no dilution of sample required, no seeding, no blank sample.**
- **Direct reading of BOD value.**
- **Continuous display of BOD value at the current incubation time.**

Alternative methods

1. Biosensor: An alternative to measure BOD is the development of biosensors, which are devices for the detection of an analyte that combines a biological component with a physicochemical detector component. Enzymes are the most widely used biological sensing elements in the fabrication of biosensors. Their application in biosensor construction is limited by the tedious, time consuming and costly enzyme purification methods. Microorganisms provide an ideal alternative to these bottlenecks.

The vast variety of microorganisms are relatively easy to maintain in pure cultures, grow and harvest at low cost. Moreover, the use of microbes in biosensor field has opened up new possibilities and advantages such as ease of handling, preparation and low cost of device. A number of pure cultures, e.g. Trichosporon cutaneous, Bacillus cereus, Klebsiella oxytoca, Pseudomonas sp. etc. individually, have been used by many workers for the construction of BOD biosensor. On the other hand, many workers have immobilized activated sludge, or a mixture of two or three bacterial species and on various membranes for the construction of BOD biosensor. The most commonly used membranes were polyvinyl alcohol, porous hydrophilic membranes etc.

A defined microbial consortium can be formed by conducting a systematic study, i.e. pre-testing of selected micro-organisms for use as a seeding material in BOD analysis of a wide variety of industrial effluents. Such a formulated consortium can be immobilized on suitable membrane, i.e. charged nylon membrane useful for BOD estimation. Suitability of charges nylon membrane lies in the specific binding between negatively charged bacterial cell and positively charged nylon membrane. So the advantages of the nylon membrane over the other membranes are: The dual binding, i.e. Adsorption as well as entrapment, thus resulting in a more stable immobilized membrane. Such specific Microbial consortium based BOD analytical devices, may find great application in monitoring of the degree of pollution strength, in a wide variety of Industrial waste water within a very short time.

Biosensors can be used to indirectly measure BOD via a fast (usually <30 min) to be determined BOD substitute and a corresponding calibration curve method (pioneered by Karube et al., 1977). Consequently, biosensors are now commercially available, but they do have several limitations such as their high maintenance costs, limited run lengths due to the need for reactivation, and the inability to respond to changing quality characteristics as would normally occur in wastewater treatment streams; e.g. diffusion processes of the biodegradable organic matter into the membrane and different responses by different microbial species which lead to problems with the reproducibility of result (Praet et al., 1995). Another important limitation is the uncertainty associated with the calibration function for translating the BOD substitute into the real BOD

OR

Aerobic: A condition in which "free" or dissolved oxygen is present in an aquatic environment.

Anaerobic: A condition in which "free" or dissolved oxygen is not present in an aquatic environment.

Blank: A preliminary analysis omitting only the sample to provide an unbiased reference point or baseline for comparison.

Nitrification: An aerobic process in which bacteria change ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage". (The first stage is called the "carbonaceous stage".)

Nutrient: Any substance used by living things that promotes growth.

Respiration: The process in which an organism uses oxygen for its life processes and gives off carbon dioxide.

Seeding: The process of adding live bacteria to a sample.

COD

In environmental chemistry, the chemical oxygen demand (COD) is an indicative measure of the amount of oxygen that can be consumed by reactions in a measured solution. It is commonly expressed in mass of oxygen consumed over volume of solution which in SI units is milligrams per liter (mg/L). A COD test can be used to easily quantify the amount of organics in water. The most common application of COD is in quantifying the amount of oxidizable pollutants found in surface water (e.g. lakes and rivers) or wastewater. COD is useful in terms of water quality by providing a metric to determine the effect an effluent will have on the receiving body much like biochemical oxygen demand (BOD).

Total organic carbon (TOC)

It is the amount of carbon found in an organic compound and is often used as a non-specific indicator of water quality or cleanliness of pharmaceutical manufacturing equipment. TOC may also refer to the amount of organic carbon in soil, or in a geological formation, particularly the source rock for a petroleum play; 2% is a rough minimum. For marine surface sediments, average TOC content is 0.5% in the deep ocean, and 2% along the eastern margins.

A typical analysis for TOC measures both the total carbon present and the so-called "inorganic carbon" (IC), the latter representing the content of dissolved carbon dioxide and carbonic acid salts. Subtracting the inorganic carbon from the total carbon yields TOC. Another common variant of TOC analysis involves removing the IC portion first and then measuring the leftover carbon. This method involves purging an acidified sample with carbon-free air or nitrogen prior to measurement, and so is more accurately called non-purge able organic carbon (NPOC.

Total Oxygen Demand

TOD is based on the same idea as COD, which is that all organic compounds shall be oxidized completely in order to determine the oxygen demand required. However, using thermal oxidation at 1,200 degrees C guarantees complete oxidation of all organic compounds and no chloride disturbances where the dichromate method is detectable. Table 1 shows a comparison of the different methods for the determination of oxygen demand in wastewater. Non-catalytic, high-temperature methods not only provide accurate results, they are also safer for the operator and environment.

For the determination of TOD, the sample is thermally oxidized at high temperature in a reactor of high-purity alumina and the oxygen consumption of this reaction is measured directly in the gas phase. Until this point, the sample is fed into a combustion furnace, similar to TOC analysis. The furnace has to be continuously pervaded by an oxygen-containing carrier gas in a “closed” system. During the sample injection, a gas exchange with the environment has to be prevented to avoid measurement failures. After cleaning the measuring gas, the oxygen content is measured directly with a zirconium oxide-based detector, and the reduction of the oxygen content is directly an extent for the oxygen consumption.

Within the furnace, the water of the injected sample will evaporate immediately and all organic compounds contained will be oxidized completely at the temperature of 1,200 degrees C. The used reactor is filled with inert ceramic material, which is not affected by ingredients of the sample water. No catalyst is necessary at the temperature used for the oxidizing process, and thus the risk of poisoning of the catalyst that may cause a malfunction of the oxidation process is avoided. The process takes only about one to two minutes, which allows the measurement frequency to be three to five minutes, depending on the application.

This is a clean and fast method of analysis to define oxygen demand of a water sample. Demanding developments of new, improved, and environmentally friendlier methods of COD measurements, as

done in previous professional journals, is not necessary since this method has existed for decades already and is available on the market.

Wastewater treatment is a process used to convert wastewater which is water no longer needed or suitable for its most recent use - into an effluent that can be either returned to the water cycle with minimal environmental issues or reused. The latter is called water reclamation: instead of disposing of treated wastewater it is reused for various purposes. During the treatment process, pollutants are removed or broken down. The infrastructure used for wastewater treatment is called a wastewater treatment plant (WWTP), or a sewage treatment plant in the case of municipal wastewater (households and small industries).The treatment of wastewater belongs to the overarching field of sanitation, which also includes the management of human waste, solid waste and storm water (drainage) management. By-products from wastewater treatment plants, such as screenings, grit and sewage sludge may also be treated in a wastewater treatment plant.

The self-purification of natural water systems

It is a complex process that often involves physical, chemical, and biological processes working simultaneously. The amount of Dissolved Oxygen (DO) in water is one of the most commonly used indicators of a river health. As DO drops below 4 or 5 mg/L the forms of life that can survive begin to be reduced. A minimum of about 2.0 mg/L of dissolved oxygen is required to maintain higher life forms. A number of factors affect the amount of DO available in a river. Oxygen demanding wastes remove DO; plants add DO during day but remove it at night; respiration of organisms removes oxygen. In summer, rising temperature reduces solubility of oxygen, while lower flows reduce the rate at which oxygen enters the water from atmosphere. 12.1 Factors Affecting Self-Purification.

1. Dilution: When sufficient dilution water is available in the receiving water body, where the wastewater is discharged, the DO level in the receiving stream may not reach to zero or critical DO due to availability of sufficient DO initially in the river water before receiving discharge of wastewater.

2. Current: When strong water current is available, the discharged wastewater will be thoroughly mixed with stream water preventing deposition of solids. In small current, the solid matter from the wastewater will get deposited at the bed following decomposition and reduction in DO.

3. Temperature: The quantity of DO available in stream water is more in cold temperature than in hot temperature. Also, as the activity of microorganisms is more at the higher temperature, hence, the self-purification will take less time at hot temperature than in winter.

4. Sunlight: Algae produces oxygen in presence of sunlight due to photosynthesis. Therefore, sunlight helps in purification of stream by adding oxygen through photosynthesis.

5. Rate of Oxidation: Due to oxidation of organic matter discharged in the river DO depletion occurs. This rate is faster at higher temperature and low at lower temperature. The rate of oxidation of organic matter depends on the chemical composition of organic matter.

(i) Dilution:

In the beginning of twentieth century, waste water disposal practices were based on the premise that "the solution to pollution is dilution". Dilution was consid¬ered as the most economical means of waste water disposal. In this method relatively small quantities of waste are discharged into large bodies of water.'

Although dilution is a powerful adjunct to self-cleaning mechanism of surface waters, its success depends upon discharging relatively small quantities of waste into large bodies of water. Growth in population and industrial activity, with increases in water demand and wastewater quantities, precludes the use of many streams for dilution of raw or poorly treated wastewaters.

(ii) Sedimentation and Re-suspension:

Sources of suspended solids, one of the most common water pollutants, include domestic and industrial wastewater and runoff from agricultural or urban ac¬tivities. These solids may be inorganic or organic materials and/or live organ¬isms, and they may vary in size from large organic particles to tiny, almost invisible, colloids. In suspension, solids increase turbidity and the reduced light penetration may restrict the photosynthetic activity of plants, inhibit the vision of aquatic animals, interfere with feeding of aquatic animals that obtain food by filtration, and be abrasive to respiratory structures such as gills offish. Settling out or sedimentation, is nature's method of removing suspended parti¬cles from a watercourse, and most large solids will settle out readily in quies¬cent water. Particles in the colloidal size range can stay in suspension for long periods of time, though eventually most of these will also settle out. Re-suspension of solids is common in times of flooding or heavy runoff. In such cases, increased turbulence may resuspend solids formerly deposited along nor¬mally quiescent areas of a stream and carry them for considerable distances down¬stream. Eventually they will again settle out, but not before their presence has increased the turbidity of the waters into which they have been introduced.

(iii) Filtration:

As large bits of debris wash along a stream bed, they often lodge on reeds or stones where they remain caught until high waters wash them into the main¬stream again. Small bits of organic matter or inorganic clays and other sediments may be filtered out by pebbles or rocks along the stream bed.

(iv) Gas Transfer:

The transfer of gases into and out of water is an important part of the natural purification process. The replenishment of oxygen lost to bacterial degradation of organic waste is accomplished by the transfer of oxygen from the air into the water. Conversely, gases evolved in the water by chemical and biological proc¬esses may be transferred from the water to the atmosphere.

Oxygen sag analysis

Oxygen Sag Analysis The oxygen sag or oxygen deficit in the stream at any point of time during self-purification process is the difference between the saturation DO content and actual DO content at that time. Oxygen deficit, D = Saturation DO – Actual DO The saturation DO value for fresh water depends upon the temperature and total dissolved salts present in it; and its value varies from 14.62 mg/L at 0o C to 7.63 mg/L at 30o C, and lower DO at higher temperatures. The DO in the stream may not be at saturation level and there may be initial oxygen deficit 'Do'. At this stage, when the effluent with initial BOD load Lo, is discharged in to stream, the DO content of the stream starts depleting and the oxygen deficit (D) increases. The variation of oxygen deficit (D) with the distance along the stream, and hence with the time of flow from the point of pollution is depicted by the 'Oxygen Sag Curve' The major point in sag analysis is point of minimum DO, i.e., maximum deficit. The maximum or critical deficit (Dc) occurs at the inflexion points of the oxygen sag curve.

A water tank is a container for storing water. Water tanks are used to provide storage of water for use in many applications, drinking water, irrigation agriculture, fire suppression, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other uses. Water tank parameters include the general design of the tank, and choice of construction materials, linings. Various materials are used for making a water tank: plastics (polyethylene, polypropylene), fiberglass, concrete, stone, steel (welded or bolted, carbon, or stainless). Earthen pots also function as water storages. Water tanks are an efficient way to help developing countries to store clean water.

Types

Chemical contact tank of FDA and NSF polyethylene construction, allows for retention time for chemical treatment chemicals to "contact" (chemically treat) with product water.

The Tanka is used in Rajasthan as a traditional form of rainwater harvesting

Ground water tank, made of lined carbon steel, may receive water from a water well or from surface water, allowing a large volume of water to be placed in inventory and used during peak demand cycles.

Elevated water tank, also known as a water tower, will create a pressure at the ground-level outlet of 1 kPa per 10.2 cm or 1 psi per 2.31 feet of elevation. Thus a tank elevated to 20 metres creates about

200 kPa and a tank elevated to 70 feet creates about 30 psi of discharge pressure, sufficient for most domestic and industrial requirements.

Vertical cylindrical dome top tanks may hold from 200 litres or fifty gallons to several million gallons. Horizontal cylindrical tanks are typically used for transport because their low-profile creates a low center of gravity helping to maintain equilibrium for the transport vehicle, trailer or truck.

A Hydro-pneumatic tank is typically a horizontal pressurized storage tank. Pressurizing this reservoir of water creates a surge free delivery of stored water into the distribution system.

Design

By design a water tank or container should do no harm to the water. Water is susceptible to a number of ambient negative influences, including bacteria, viruses, algae, changes in pH, and accumulation of minerals, accumulated gas. The contamination can come from a variety of origins including piping, tank construction materials, animal and bird feces, mineral and gas intrusion. A correctly designed water tank works to address and mitigate these negative effects.

A safety based news article linked copper poisoning as originating from a plastic tank. The article indicated that rainwater was collected and stored in a plastic tank and that the tank did nothing to mitigate the low pH. The water was then brought into homes with copper piping, the copper was released by the high acid rainwater and caused poisoning in humans. It is important to note that since the plastic tank is an inert container, it has no effect on the incoming water. Good practice would be to analyze any water source periodically and treat accordingly, in this case the collected acid rain should be analyzed, and pH adjusted before being brought into a domestic water supply system.

The release of copper due to acidic water is monitored may be accomplished with a variety of technology, beginning with pH strips and going to more sophisticated pH monitors, indicate pH which when acidic or caustic, some with output communication capabilities. There is no "linkage" between the plastic tank and copper poisoning, a solution to the problem is easy, monitor 'stored rainwater' with 'swimming pool strips' cheap and available at, swimming pool supply outlets. If the water is too acidic, contact state/county/local health officials to obtain advice and precise solutions and pH limits and guidelines as to what should be used to treat rainwater to be used as domestic drinking water.

Articles and specifications for water tank applications and design considerations, the AWWA (American Water Works Association) provides details as required by many states to complete a certification process to insure the quality of water being consumed.

The American Water Works Association is a reservoir of water tank knowledge; the association provides specifications for a variety of water storage tank applications as well as design. The AWWA's site provides scientific resources with which the reader will be able to develop an informed perspective on which to make decisions regarding their water tank requirements.