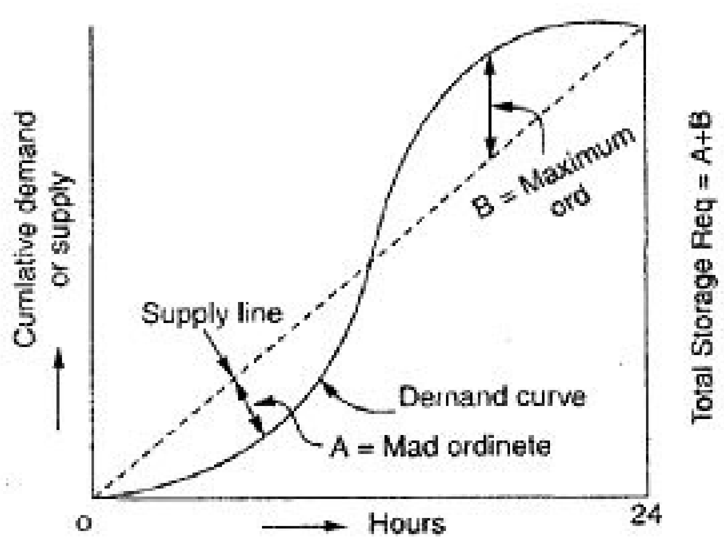
Mass curve method:



QUALITY OF SEWAGE

Characteristics and Quality of sewage must be determined before its disposal because of following :

(*i*) Floating solids of untreated sewage decompose and create unpleasant smells and odour in the river water.

(*ii*) Large amount of organic matter present in untreated sewage starts consuming dissolved oxygen of the river water. Due to less amount of dissolved oxygen in river water, fish start dying.

(*iii*) Untreated sewage is also responsible for contaminating source water with harmful micro-organisms called *pathogenic bacterias.* Pathogens are responsible for causing serious water borne diseases such as cholera, typhoid, dysentry, etc.

Though municipal sewage normally contains 99.9% of water content, it is always desirable to treat the sewage before discharging the same in the river water to safe guard against the above defects.

Factors deciding Extent and Type of treatment required for the Sewage so as not to pollute Source of disposal :

1. Character and quality of sewage
2. Source of disposal

Treatment of Sewage

Out of millions bacterias generally found per litre of untreated sewage, only a small number are harmful to man. These harmful bacterias are called *pathogens.* The remaining large number of bacterias called *non-pathogens* are not only harmless but useful for the process of decomposition of the sewage. The main basis of treatment of sewage is to provide a suitable environment for the action of aerobic and anaerobic bacterias for stabilising organic matter present in sewage either through aerobic or anaerobic decomposition.

Decomposition of Sewage

(*i*) **Aerobic decomposition.** During treatment, in aeration tanks, contact beds, intermittent sand filters, trickling filters and oxidation ponds, it is primarily done by oxidation.

(*ii*) **Anaerobic decomposition.** During treatment, in septic tanks, Imhoff tanks and sludge digestion tanks, it is mainly done by putrefaction alone.

CHARACTERISTICS OF SEWAGE

I. Physical Characteristics

1. **Turbidity.** Degree of turbidity of sewage may be measured either by a turbidity rod or turbid meter. The degree of turbidity increases with the increase of sewage strength.
2. **Colour.** Colour of sewage indicates degree of its freshness. Black or dark brown colours indicate stale and septic sewage.
3. **Odour.** Fresh sewage remains practically odourless. As soon as dissolved oxygen gets exhausted, the sewage first becomes septic and thereafter offensive odours are evolved due to decomposition of sewage. Hydrogen sulfide gas is generally liberated from stale decomposed sewage.
4. **Temperature.** *Temperature of untreated sewage affects following*

   (*i*) Biological activities of the bacterias present in the sewage.

   (*ii*) Solubility of gases in the sewage.

   (*iii*) Viscosity of sewage which ultimately affects the sedimentation process.

   Average temperature of sewage in India is about 20°C which is favourable for the biological activities. At higher temperature, dissolved oxygen gets reduced considerably.
5. **Solids.** It contain 99.9% water and 0.1% solids.

II. Chemical Characteristics

1. **Total Solids**

   Solids may exist in the sewage in any of the following forms :

   (*i*) **Suspended solids :** These solids remain floating in sewage.

   (*ii*) **Dissolved solids :** These solids remain dissolved in sewage.

   (*iii*) **Colloidal solids :** These are finely divided solids which remain either in solution or in suspension.

   (*iv*) **Settleable solids :** These are solid matter which settles at the bottom of the container in case sewage-is kept undisturbed for a period of two hours.

Proportion of different types of Solids per 1000 kg of sewage

Total solids	......	0.45 kg.
Suspended solids	......	0.112 kg.
Dissolved solids	......	0.225kg.
Settleable solids	......	0.112 kg

Proportion of Organic and Inorganic solids in total solids

Organic matter (carbohydrates), fats and nitrogenous compounds	..... 45%
Inorganic matter (generally harmless)	..... 55%

2. pH value

Logarithm of reciprocal of hydrogen ion concentration present in sewage, is called *pH value*. If pH value is less than 7, the sewage is acidic, and if more than 7, the sewage is alkaline. pH value may be determined with the help of a potentiometer.

3. Chloride Contents

Chloride upto 120 mg/ litre is obtained from domestic sewage. Large quantity of chlorides is added from industrial waste. High content of chloride in the sewage indicates presence of industrial waste.

Chloride content in the given sample of sewage may be measured by titrating with standard silver nitrate solution, using potassium chromate as indicator.

Two tests are conducted for chlorine

(*i*) **Chlorine Demand Test:** This test is done to determine amount of chlorine required for proper disinfection. Unstable organic matter present in sewage has a demand for chlorine and the amount of chlorine required for this purpose is called *chlorine demand*. It thus indicates the amount of organic matter present in the sewage.

(*ii*) **Chlorine Residual Test :** After treatment of sewage, it is necessary to chlorinate it to kill any bacteria present. If residual chlorine is present after its application, it indicates that chlorination is sufficient. Residual chlorine test is conducted in the same manner as that for water.

4. Nitrogen contents

Presence of nitrogen in sewage indicates presence of organic matter.

It may occur in one or more of the following forms

(*i*) ***Free ammonia :*** During first stage of decomposition of organic matter, free ammonia is liberated. The amount of free ammonia present in sewage is measured by simply boiling sewage, and measuring the gas thus liberated.

(*ii*) ***Albuminoid nitrogen :*** Quality of nitrogen present in sewage before commencement of decomposition of organic matter indicates the albuminoid nitrogen. The amount of albuminoid nitrogen may be measured by adding strong alkaline solution pottasium permaganate ($KMNO_4$) to the already boiled sewage sample and again boiling the same. Ammonia gas thus liberated is required quantity of albuminoid nitrogen in the given sample.

(*iii*) ***Nitrites :*** Presence of nitrites indicates that organic matter in the sewage in only partly decomposed. Quantity of nitrites present in the sewage sample may be measured by colour matching method by adding sulphonorilic acid and naphthamine. The colour developed in the water is compared with standard colour of solution of known concentration.

(*iv*) ***Nitrates :*** Presence of nitrates in the sewage indicates that organic matter is fully oxidised. Amount of nitrates present in the sewage sample may be measured by colour matching method by adding phenol-di-sulphuric acid and potassium hydroxide. Colour developed in the waste water is compared with standard colour of known concentration.

(*v*) ***Presence of Fats and Grease :*** Sources of grease, fats, and oils in the sewage is from the discharges of animal and vegetable matter. These matters forms scum on the top of the sedimentation tanks, and clog voids of the filtering media. To determine amount of fats and grease, sewage sample is first evaporated and the residual solids so left are mixed with either ether or hexane. Thus solution obtained is allowed to evaporate. The residue is of fats and grease.

(*vi*) ***Hydrogen Sulphide gas :*** Presence of hydrogen sulphide gas in sewage indicates anaerobic decomposition. Excess amount of hydrogen sulphide gas may cause corrosion of concrete sewers and may produce bad odours at the treatment plant. To safegaurd against these bad effects, hydrogen sulphide gas (H_2S) is kept below 1 ppm in fresh sewage.

(*vii*) ***Dissolved oxygen (DO) :*** Because of rapid absorption of oxygen from the atmosphere, dissolved oxygen is always present in variable quantities in sewage water. Its content in sewage is dependant upon amount and character of unstable organic matter in it.

The test of dissolved oxygen is carried out before discharging treated sewage into source water to ensure that at least 4 ppm of DO is available in the sewage for the existence of fish life.

DO content of sewage is generally determined by Wrinkler's method which depends on the fact that, in alkaline solution, the dissolved oxygen oxidises magnaneous ion to maganic ion which in turn oxidises iodide to liberate iodine in quantities equivalent to the amount of dissolved oxygen present. The dissolved oxygen is reported as mg/l or as percentage saturation with dissolved oxygen.

If G_s is dissolved oxygen saturation in mg/l, n is salinity of chloride content in mg/l, T is temperature of sewage in centigrade, P is barometric pressure in mm of Hg and P_w is saturated vapour pressure of water in mm of Hg, then

- for temperature between 0°C to 30°C,

$$C_s = 0.678\,(P - P_w)\,(1 - n \times 10^{-5})/(T + 35)$$

- and for temperature between 30°C to 50°C,

$$C_s = 0.827\,(P - P_w)\,(1 - n \times 10^{-5})/(T + 49)$$

5. Presence of fats, greases, and oils

6. Sulphides, sulphates and H_2S gas

Gases, which are generally evolved during aerobic decomposition of sewage are :

$$CO_2 + NH_3 + H_2S$$

Gases, which are generally evolved during anaerobic decomposition of sewage are :

$$CO_2 + NH_3 + H_2S + CH_4.$$

7. Strength of Sewage

It gives an indication of the nuisance value of sewage. *It is generally indicated by following characteristics:*

(i) Total volatile solids, both suspended and dissolved

(ii) Odour

(iii) Chlorine demand

(iv) **Theoretical Oxygen Demand (T.O.D).** Amount of oxygen required for complete oxidation of organic matter into CO_2 is called TOD.

$$C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O$$

(180) (192)

(From Organic matter)

Hence 1 gm of glucose is requiring $\frac{192}{180}$ gms of oxygen. This demand is called *theoretical oxygen demand* (TH.O.D.). It is of academic use only because determination of exact composition of organic matter is difficult.

(v) **Chemical Oxygen Demand (COD).** Amount of oxygen required for chemical oxidation is called COD. It is defined as amount of oxygen absorbed by waste water from a strong oxidising agent like $K_2Cr_2O_7$, $KmnO_4$.

Importance of Chemical Oxygen Demand is due to following reasons :

(*a*) Rapid chemical oxidation.

(*b*) Chemical oxidation does not depend on many variables.

(*c*) Chemical oxidation requires less equipment, hence economical.

(*d*) In highly toxic sewage, chemical procedure is the only method lo determine the organic load.

Method of determination of COD : It is *Refluxing*. COD results although less than T.O.D and depends on composition. Time required for COD test is 3 to 4 hrs.

Advantages of COD test

(*i*) Computation of various parameters are not required

(*ii*) Time required for conducting COD test is less than T.O.D. test

Disadvantages of COD test : This does not defferentiate between biodegradable organic matter and non-biodegradable organic matter.

Total Organic Carbon (TOC)

This test involves oxidation of the sample to convert inorganic carbon to CO_2, which is then stripped. Both COD and TOC measures biodegradable fraction of the organics, but unlike COD it is independent of the oxidation state of the organic matter. CO_2 released in the test can be measured by a infrared analyzer. This test is rapid, accurate and correlates moderately well with BOD.

(vi) **Biochemical Oxygen Demand (BOD)**

BOD is most commonly used parameter to define strength of municipal or organic industrial waste water. It is defined as the amount of oxygen required by micro-organisms for the decomposition of bio-degradable matters under aerobic condition.

Standard BOD test : It determines the amount of oxygen required by micro-organism for decomposition of bio-degradable matter under aerobic condition in 5 days at 20°C.

Why 5 days 20°C is atdopted as standard BOD

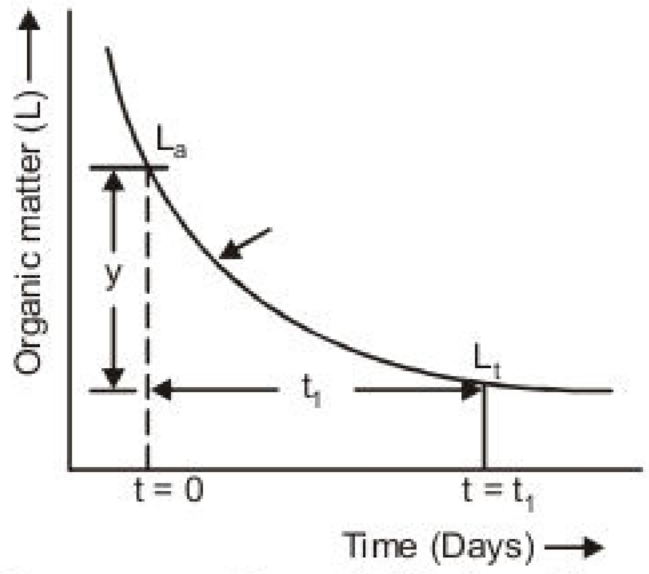
(*i*) All countries have adopted the same, hence to make standards with others, this standard is adopted.

(*ii*) Night defined bacterias are developed at 5^{th} day.

(*iii*) In 5 days about $2/3^{rd}$ organic matters are oxidised, hence ultimate BOD, $BOD_u = \frac{3}{2} BOD_5$

Note : 10 days BOD is about 90% of the total.

BOD by Dilution Technique :



BOD tests consists of diluting the sewage with water containing a known amount of dissolved oxygen and noting the loss of oxygen after a period of storage or incubation. The usual incubating period is 5 days at a temperature of 20°C. The diluting water is aerated, contains a small amount of sodium bicarbonate and has a pH of 7.0 to 7.6.

The rate of biochemical oxidation of organic matter is proportional to remaining concentration of the unoxidized substance that is measured in terms of *oxidizibility*. The relationship is shown graphically.

From the figure, L is the oxygen demand at t = 0 day. It may also be called *first stage demand* though the same relationship applies at the beginning of oxidation period. Then L_t is remaining oxygen demand at the end of any time '*t*' days. K is a constant associated with days and temperature and determinable experimentally.

BOD of to Days

Then oxygen absorbed or used in milligrams per liters in t days,

$$X_t = L\,(1 - 10^{-K_1 t})$$

where, L = first stage demand

K = *de-oxygenation constant* or *BOD rate constant*

Ultimate First Stage BOD

First demand during first 20 days or so, occurs due to oxidation of organic matter, and is called Carbonaceous demand or first stage demand or initial demand. The latter demand occurs due to biological oxidation of ammonia, and is called Nitrogeneous demand or second stage demand.

Ultimate first stage BOD, X_t can be obtained by substituting $t = \infty$ days in the above equation.

Therefore, $$X_u = L\left[1 - 10^{-K_1 \infty}\right]$$

$$= \left[1 - \frac{1}{10^{\infty}}\right] = L[1 - 0] = L$$

Hence ultimate BOD is a fixed quantity equal to initial equivalent of the organic matter present in the sewage and does not depend upon temperature of oxidation.

Constant K_1 varies with temperature as,

$$K_{D\,(t^\circ)} = K_{D(20^\circ)}\,[1.047]^{T-20^\circ}$$

where, $K_D(T)$ = deoxygenation constant at T°C.

Initial BOD or L varies with temperature as,

$$LT = L_{20}(0.02\,T + 0.6)$$

where L_T is value of L at T°C, and L_{20} is its value at 20°C

The 5 day BOD determination at 20°C is generally used as providing a sufficient time to eliminate accidental factors which might affect results and temperature is close to the averages temperature of sewage and plant effluents.

Test for BOD in Sewage

Complete oxidation of the organic matter (both carbonaceous and nitrogenous) takes more than 2 months; however within about 10 days nearly 90 per cent of the biological oxygen demand is satisfied. After that period the rate is very slow. Usually 5 day BOD is tested and within this period nearly 70% of the BOD is satisfied. To carry out this test, sewage of the effluent is diluted with aerated pure water in the ratio of 1 : 100. Then D.O. of the diluted sample is calculated. The diluted sample is incubated for 5 days at 20°C and loss of oxygen in this period is calculated.

B.O.D. in p.p.m (of 5 days)

$$= \text{Loss of oxygen in ppm} \times \frac{100}{\%\ \text{diluted sample}}$$

III. BIOLOGICAL CHARACTERISTICS

Sewage contains living organisms, such as bacteria, algae, fungi and protozoa.

Following two types of bacteria in sewage carry out the process of breaking the complex organic compounds into simple and stable compounds :

1. **Aerobic bacteria :** It live in the presence of oxygen dissolved in water or free oxygen.
2. **Anerobic bacteria :** It live and carry on their activities in the absence of free oxygen.

Decomposition of sewage. It takes place in following two stages:

(*i*) Aerobic Decomposition

Sewage contains organic matter, waster products, water, etc. Aerobic bacteria convert this matter, in the presence of the dissolved oxygen in the sewage water, initially to nitrogeneous, carbonaceous and sulphurous compounds, which are more stable. With the supply of more oxygen, these compounds are further decomposed into more stable nitrites and then to nitrates. Aerobic decomposition is also called *oxidation*, because during this process, organic matter is broken up and oxidised to more stable products.

Aerobic bacteria produce gases which are not offensive in odour. When oxygen supply in the water is exhausted, the aerobic bacteria die.

Following treatment plants work on the oxidation principle : Aeration tanks, Contact beds, Intermittent sand filters, Trickling filters and Oxidation ponds.

(*ii*) Anerobic Decomposition

When aerobic bacteria die, anerobic bacteria start their activity with the oxygen available in the organic matter. These bacteria break up organic compounds to nitrites, nitrates, proteins, etc. The gases produced in the process are very offensive in odour. Anerobic decomposition is also called *putrefaction* and the end products include black residue called *humus*, ammonia, methane, hydrogen sulphides, etc.

Following treatment units work on the principle of putrefaction : Septic tanks, Imhoff tanks, Sludge digestion tanks, etc.

Plants use products of decomposition such as carbon dioxide or nitrates to produce chlorophyll. When plants die they are decomposed by aerobic and anerobic bacteria and so the cycle goes on.

Fresh sewage does not have offensive odour. But after a few hours it becomes stale, septic and foul. Hence in sewage treatment, aerobic decomposition is encouraged by supplying oxygen for its activity by the following ways:

(*a*) Allowing sewage to pass through porous medium, and circulating through the pores as in the case of trickling filters.

(*b*) Adding activated sludge to fresh sewage and blowing air.

In a sewage treatment plant, activity of anerobic bacteria is controlled so that odour is not noticeable.

Biological Tests

Biological tests on sewage are carried out to determine types of bacteria and biological life in them. Sewage is added to culture media and allowed to develop in an incubator at a specified temperature and for a specified time. Bacteria form colonies which can be counted with a microscope and depending on the type and quantity of bacteria present in the sewage, treatment is given.

Micro - Organisms Composition of Sewage : [C HOPKINS, CaFe. Mgr]

C = carbon, H= Hydrogen, O = oxygen, P = Phosphorus, K = Potassium, I = Iodine, N = Nitrogen, S = Sulfer, Ca = Calcium, Fe = Ferrous, Mg = Magenesium.

Thermal Pollution

Discharge of heated waste water into the water body is called *thermal pollution.* It increases metabolic decay of fish and saturation D.O.

Relative Stability of Sewage Effluent

It is the ratio of oxygen available in the effluent (as D.O. nitrite or nitrate) to the total oxygen required to satisfy first state BOD.

Relative Stability

Relative stability (*S*)

$$= \frac{\text{Quantity of D.O. present in waste water}}{\text{Quantity of D.O. required to satisfy its first stage BOD}}$$

$$= \frac{L_0\left(1-10^{-k_D t}\right)}{L_0} \times 100 = [1-10^{-k_D \cdot t}] \times 100$$

$\therefore$ $S = 100\,[1-(0.794)^{t20}]$

$\Rightarrow S = 100\,[1-(0.630)^{t37}]$

where, t_{20} and t_{37} represent the time in days for a sewage sample to decolourise a standard volume of methylene blue solution, when incubated at 20°C or 37°C respectively.

In India, BOD test are generally conducted at 37°C, because here it becomes very costly to maintain the equipments at 20°C.

$= 100\,[1-(0.794)^{t_{20}}]$ or $100\,[1-(0.63)^{t_{37}}]$

where t_{20} and t_{37} represents time in days for a sewage sample to decolourise a standard volume of methylene blue solution when incubated at 20°C or 37°C respectively.

Sewage Disposal Into Streams

By superimposing rates of deoxygenation and reoxygenation mathematically, following equation called *Streeter - Phelps equation* is obtained.

$$D_t = \frac{K_D . L}{K_R - K_D}\left[(10)^{-K_D . t} - (10)^{-K_R . t}\right] + \left[D_0 . (10)^{-K_R . t}\right]$$

where, D_t = D.O. deficit in mg/*l* after t days

L = ultimate first stage B.O.D. at the point of water discharge in mg/*l*

D_0 = initial oxygen deficit in mg/*l* of the water (if any)

K_n = deoxygenation coefficient which can be determined either by laboratory or field tests.

K_D varies with temperature as,

$$K_{D(T)} = K_{D(20°C)} = [1.047]^{T-20}$$

Typical values of $K_{D(20°C)}$ vary between 0.1 and 0.2. generally taken as 0.10.

K_R = Reoxygenation coefficient that can be found out by field tests. K_R varies with temperature as per the equation,

$$K_{R(T)} = K_{R(20°C)} . (1.016)^{T-20}$$

where $K_{R(T)}$ is K_R value at T°C and $K_{R(20°C)}$ is K_R value at 20°C.

Critical time (t_c) at which minimum D.O., occurs can be found from Streeter- Phelps equation as

$$t_c = \left(\frac{1}{K_R - K_D}\right).\log\left(\left\{\frac{K_D.L - K_R.D_0 + K_D.D_0}{K_D.L}\right\}.\frac{K_R}{K_D}\right)$$

and critical or maximum deficit is given by,

$$D_c = \frac{K_D.L}{K_R}(10)^{-K_D.t_c}$$

$\frac{K_D}{K_R}$ is sometimes represented by 'f' and is called *self-purification constant.*

$$t_c = \frac{1}{K_D(f-1)}\log\left[\left\{1-(f-1)\frac{D_o}{L}\right\}f\right]$$

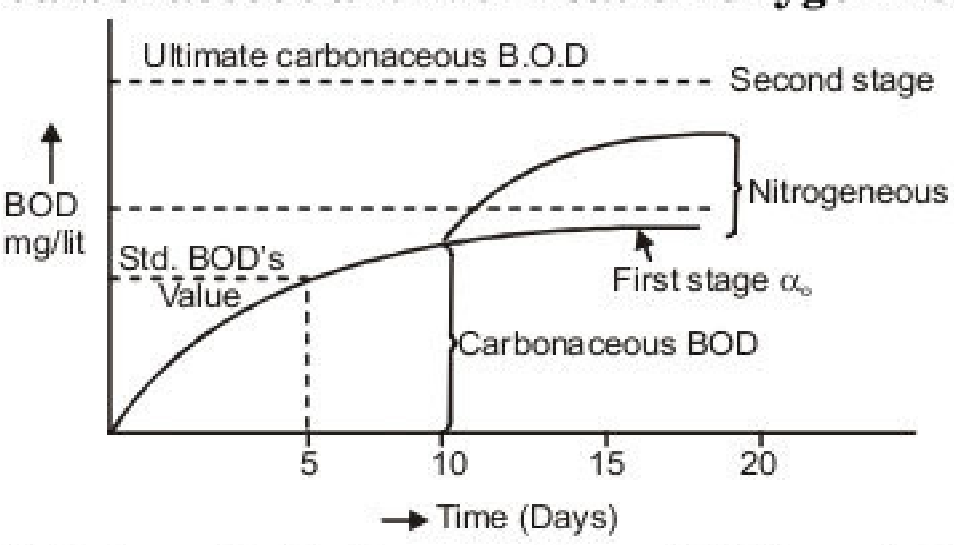
and equation for D_c can be reduced to,

$$\left(\frac{L}{D_c f}\right)^{f-1} = f\left[1-(f-1)\frac{D_o}{L}\right]$$

This is an important first stage equation in which L is B.O.D. of the mixture of sewage and stream.

When initial deficit, D_o is zero, then $\frac{L}{D_c} = [f]^{f/(f-1)}$

Carbonaceous and Nitrification Oxygen Demand



This hypothetical curve shows BOD exerted, D.O. depleted as the biological reactions progresses with time.

Carbonaceous oxygen demand : It progresses at a decreasing rate with time, since rate of biological activity decreases as the available food supply diminishes. Shape of the hypothetical curve is best expressed mathematically by first order kinetics, *i.e.*

BOD at any time, t = ultimate BOD $(1 - 10^{-Kt})$

Nitrification oxygen demand : Nitrifying Bacteria can exert on oxygen demand in the BOD test, fortunately growth of nitrifying bacteria lags behind that of the micro-organisms performing carbonaceous reaction. Nitrification generally does not occur untill several days after the standard 5 day incubation period for BOD test.

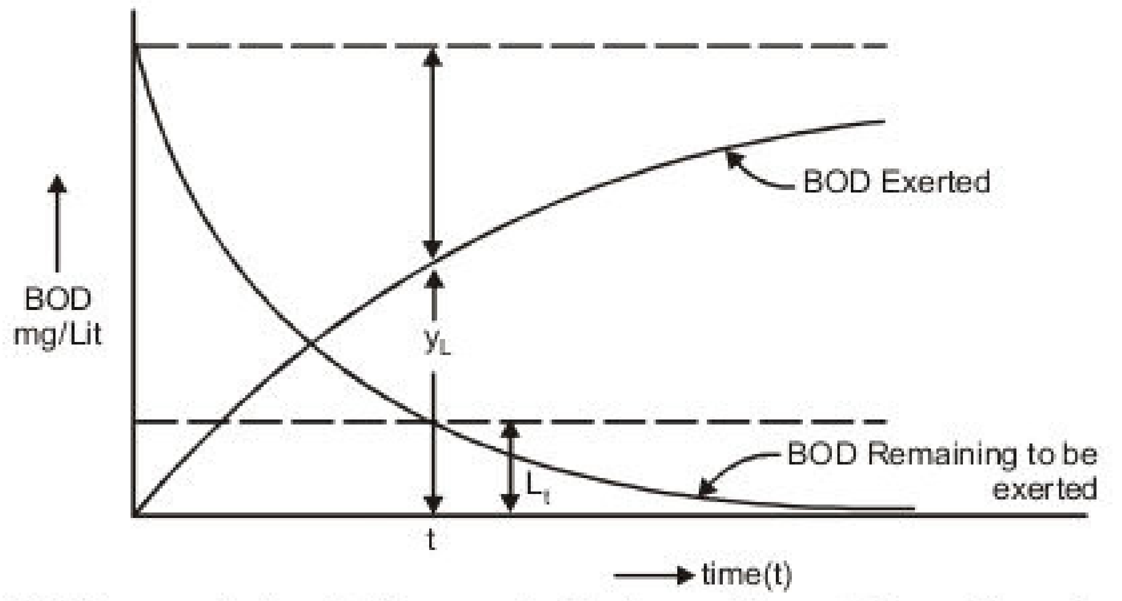
Also, Carbonaceous demand – first stage demand

Nitrification demand – second stage demand

BOD and Oxygen Equivalent Relationship

The rate at which organics are utilized by micro organisms is assumed to be a first order action, i.e. the rate at which organics utilized is proportional to amount available.

Therefore, if y_t is BOD exerted in time t, and L is BOD of sewage at starting, i.e. oxygen equivalent of organic matter present in sewage at start, then



BOD remaining to be exerted at any time t, $L_t = (L - y_t)$

$$\frac{dL_t}{dt} \propto L_t$$

$$\Rightarrow \quad \frac{dL_t}{dt} = -K.L_t$$

$$\Rightarrow \quad \frac{dL_t}{L_t} = -K.dt$$

$$\Rightarrow \quad \text{Log } L_t = -K.t + c$$

At $t = 0$, $\quad L_t = L$

$$\Rightarrow \quad c = \log L$$

$$\Rightarrow \quad \log L_t = -K.t + \log L$$

$$\Rightarrow \quad \log L_t - \log L = -K.t$$

$$\Rightarrow \quad \log\frac{L_t}{L} = -K.t$$

$$\Rightarrow \quad \frac{L_t}{L} = e^{-Kt}$$

$$\Rightarrow \quad L_t = L.e^{-Kt}$$

as $\quad L_t = L - y_t$

$$\Rightarrow \quad L - y_t = L.e^{-Kt}$$

$$\Rightarrow \quad y_t = L - L.e^{-Kt} = L(1 - e^{-Kt})$$

$$\Rightarrow \quad \boxed{y_t = L(1 - e^{-K.t})}$$

or $\quad \boxed{y_t = L.(1 - 10^{-K_D.t})}$

where $K_D = 0.434$ K

Temperature Dependance of Rate Constant

Ultimate BOD is independent of temperature but the rate constant (K or K_D) are dependent on temperature. Higher the temperature, higher will be the value of rate constant and vice-versa.

Relation of temperature dependence is given by,

$$K_T = K_{20}(\theta)^{T-20}$$

In most cases, $\theta = 1.047$, therefore

$$K_T = K_{20}(1.047)^{T-20}$$

From laboratory determination, K_{20} has been found to be 0.1/day (base '10') or 0.23 (base 'e').

Unit of rate constant is $(\text{Day})^{-1}$.

SEWAGE AND SEWERAGE TREATMENT

Sewage

Types of Sanitary Sewage

1. Domestic sewage
2. Industrial sewage
3. Storm sewage

System of Sanitation

1. Old conservancy system
2. Modern water carriage system

Sewerage System

Types of Sewerage System

1. Combined system
2. Separate system
3. Partially separate system

Components of Sewage System

1. House sewers
2. Lateral sewers
3. Branch sewers
4. Main sewers (Trunk sewers)
5. Outfall sewers
6. Manholes

Quantity of Discharge in Sewers

In the design of sewers, it will be necessary to determine quantity of sewage which will be conveyed through them.

Quantity of sewage consists of following :

1. Infiltration.

It is the water that enters sewers through poor joints, cracks, manhole covers, etc. During dry weather, there will be no infiltration and hence only domestic sewage and industrial waste will be conveyed. During rains, infiltration will be due to rise in ground water table and from roofs.

Infiltration depends on the following factors :

(*i*) Height of ground water level

(*ii*) Type of soil in which sewers are laid

(*iii*) Workmanship of laying pipes

2. Dry Weather Flow

Minimum sewage discharge through combined seweage system during non-monsoon period is called *dry weather flow* (*D.W.F*).

*D*rainage discharge, which is produced during monsoon season is generally very high, say 20 to 25 times that of the sewage discharge called dry weather flow (D.W.F).

Quantity of dry weather flow depends on following factors

(*i*) Population : As in a water-supply project, probable life of the sewage system has to be fixed according to the life of different components, say 40 or 50 years. The population to be served at the end of the period will have to be determined to fix size of sewers and other components of the system.

(*ii*) Rate of Water Supplied : Quantity of domestic sewage entering the sewer depend on the water-supply. However, all the water supplied may not reach the sewer as part of it may have been used for a purpose such as watering gardens, which may not return to the sewer. It may also happen that industries may have their own supply of water which may be led into sewers. Thus it is usually assumed that average rate of sewage flow equals average rate of consumption of water.

Thus following two factors should be closely checked before deciding proportion of water-supply appearing as sewage:

(*a*) Purpose for which water is being used has to be carefully studied.

(*b*) Intensity of pressure in the pipelines has to be checked. More the pressure, more the wastage of water and leakage and so quantity reaching consumers will be less than that supplied.

(*iii*) Nature of Industries : Quantity of industrial waste depends on the type of industry. Hence, each industry has to be carefully studied before estimating quantity of industrial sewage.

Variation in Rate of Sewage

In the design of sewers, it is necessary to determine maximum rate of sewage discharge that will be flowing in them. They should be large enough to allow flow at the maximum rate. Otherwise there may be backing up of sewage into plumbing fixtures of buildings. Peak discharge occurs much after the peak water consumption as sewers take time to fill to high-point flow before it starts travelling.

3. Storm Water

Storm water is that water which runs-off after a rainfall.

LAYING OF SEWERS

It consists of following operations:

1. Setting out Alignment

Centre line is marked starting from the outfall (lowest point) and proceeds upwards. Generally, sewer is laid along the middle of the street and existing underground structures like water-mains should be avoided. Setting out is done by a theodolite and chain.

Centre line is marked by an offset line parallel to the proposed alignment which will not be disturbed during construction. Temporary B. Ms are established at 200-400 m intervals. Reduced levels of these bench marks are fixed with reference to a GTS benchmark. Pegs or spikes are also driven at 10 m intervals. Position of appurtenances are marked as per plan. This method is suitable when inconvenience to traffic should be caused only for a short duration of time.

Another method of marking centre line is by driving two vertical posts into the ground on either side of the centre of the trench. A horizontal rail called *sight rail* is fixed between these two posts at a convenient height from the ground level. A suitable vertical height is added to the levels of the invert (bottom) of pipe given on the plan and top of sight rail is adjusted to the modified level and the levels are marked on nails driven into sight rails. A string is stretched between the rails. Thus an imaginary line parallel to the sewer line on the ground is obtained at the level of the string.

2. Excavation of Trenches

First the pavement is removed. Width of trench to be excavated is 150 mm more than the external diameter of the sewer. A minimum trench width of 600 -1000 mm has to be provided to enable the pipes to be laid and jointed. Sometimes even for small diameter pipes, width is made 150 mm more than the diameter but at the ends where joints are situated, the trench is made larger.

3. Bracing and Dewatering

In rocky and hard soils, sides of the trenches will remain in the cut position. However, in loose soil as well as made-up soil, the sides will collapse and hence shoring and strutting is necessary. This is also necessary to prevent caving to reduce danger to workmen. When sides of trenches are of depth more than 1.5m, they are held securely by shoring and bracing or sloped to the angle of repose of the soil.

If trench has to be excavated below the ground water table, then water flows into it and causes difficulty in laying pipes. The common method adopted is to allow the water to flow into a sump from where it is pumped out. As the water will contain gritty materials, only centrifugal pumps are suitable.

However, if soil encountered is sandy material, then moving water separates grains of sand and undermines side walls, in such a condition, that the problem is overcome by using well points. These are pipes 50 - 75 mm in diameter, pointed at the lower ends, with perforations just above the point. These pipes are driven into the ground on one or both sides of the trench about 2 m from centre line, 1 m apart, and driven well below the watertable. 150-203 mm header pipes parallel to the trench are fixed to the well pipes and connected to a pump. Water is pumped out and keeps the trench dry.

For large sewers, an underground tiled drain with open joints with gravel around is provided below the sewer. The drain discharges into a sump from where it is pumped. The advantage is that water will not enter the trench and damage bottom and sides. Drain can be left after the work is completed but should be closed to prevent continuous drainage of the soil.

4. Laying of Pipe

Pipe should be inspected to ensure that it has no cracks or defects. Pipe lengths are placed in line and grade after the trench has been completely dewatered.

Small-sized pipes can be laid by the pipe-layers manually, but heavier pipes are lowered into the trenches by means of ropes. Pipes are laid with their socket end on the upgrade for easy jointing. Pipes are lowered and spigot-end of one pipe is placed in the socket of the one before it.

Levels of the invert of the sewers are checked by means of a boning rod or traveller. Boning rod has a shoe at the bottom. Length of the boning rod is adjusted so that its level at the top coincides with the line of sight. Verticality of the boning rod is checked by a plumb bob. Boning rod is placed with its shoe touching invert of the sewer. Level of the invert is then adjusted.

Sewers are generally laid on a concrete bedding so that weight of the pipe is distributed uniformly.

5. Jointing

In ordinary bell-and-spigot pipes, cement mortar (1 : 1) or bitumen joints are adopted. A gasket is inserted with a caulking tool and the joint is filled with mortar or bitumen. The cement-mortar joint is finished by applying cement mortar at an angle of 45° on the outer face.

Cement-mortar joints have the disadvantage that they are rigid and any settlement of pipe will produce cracks, which will cause infiltration. When ground water table is above the sewer, special precautions are necessary. In such situations it is preferable to adopt bituminous materials. Bitumen is poured at 200°C and a jute gasket is caulked in place to prevent the bitumen from entering the pipe.

6. Testing of Sewers

Testing is carried out in sections of sewer lines between manholes. Lower end of the pipe is provided with a plug. Pipe is filled with water and allowed to stand for a week before commencing application of pressure.

7. Backfilling of Trenches

After testing and removing defects in the pipeline, trenches are refilled with the excavated soil. Soil is laid in layers of 150 mm thickness and is watered and rammed well. When height of backfilled earth reaches 600 mm above the crown of the pipe, then backfilling is stopped for a weak. Then trench is filled 150 mm above the ground level.

SEWER APPURTENANCES

For efficient operation and maintenance of the sewer system, some additional structures called *appurtenances are provided. Sewer appurtenances include following :*

1. Manholes

These are masonry or R.C.C chambers, constructed at suitable intervals and at every change in gradient along the sewer lines for providing access into the sewers, help in joining sewer lengths, and also help in their inspection, leaning & maintenance.

The spacing of manholes is more on large sized sewers, because they can be entered more easily by men for inspection.

Components : *Manhole has following components :*

(*i*) Working chamber

(*ii*) Access shaft

(*iii*) Cover and rungs

(*iv*) Channels

2. Drop Manholes

When a sewer connects with another sewer which is at a materially different level, drop manhole is adopted. A vertical drop pipe from the higher to the lower sewer is provided.

If drop pipe is outside the shaft, the sewer should be continued through the shaft wall to enable inspection and rodding.

3. Street Inlet (or Gullies)

An opening through which storm water from a street is allowed to enter a storm sewer or a combined sewer is called *street inlet*. Inlets are placed on street gutters generally at street intersections where level is low.

4. Catch Basins or Pits

These are small chambers constructed to prevent entry of grit, sand debris, etc. into the sewer lines. When storm water enters the pit, the grit, sand, etc. settle down at the bottom.

Catchpits are used in the following situations :

(*i*) When sewers are laid at a flat gradient and self-cleaning velocity is not developed, then solids present in the sewage accumulate in the sewer which requires frequent cleaning. However, if a catchpit is provided, the solids accumulate in the pit, and can be periodically removed.

(*ii*) When sewer passes through areas where lot of debris is likely to get into the sewer, such as market places, it is likely to be blocked. In such places, catchpits are provided under street inlets.

5. Flushing Tank

Where it is not practicable to obtain a gradient in the sewers to give a self cleaning velocity of 0.75 m/s, it should be flushed occasionally to prevent deposition and clogging.

Methods used for flushing

(*i*) Construction of special flushing tanks at suitable points in the sewer line.

(*ii*) Admission of a limited amount of surface water into sewer line at required point.

(*iii*) Provision of gates at the outlet side of an ordinary manhole. Closing the gate will permit sewage to accumulate and opening it will allow a rush of sewage to pass down the pipe.

6. Inverted Syphon

It is a portion of a sewer constructed lower than the adjacent stretch, to pass beneath a valley, water course, or other obstruction. It runs full at greater than atmospheric pressure because its crown is depressed below hydraulic grade line. Generally, velocity should not be less than 1.2 m/s.

7. Stormregulators

Combined system of sewer is designed to convey dry weather flow and a certain quantity of storm water. When rainfall is unusually heavy, the storm water is also high and this excess water is disposed of from the sewers by means of storm relief works or regulators. Extra quantity of sewage from the main sewer flows over a weir and enters another overflow sewer which conveys the water directly to a stream. Top of the weir is fixed in such a way that extra quantity over and above a predetermined amount of sewage is disposed off. Overflow weir may overflow on one side and is called *single-acting*.

8. Pumping Stations

IS: 4111—1968 gives guidance for design and construction of pumping stations and pumping mains.

Following considerations should be taken into account while locating pumping stations :

(*i*) The site should be above the highest recorded flood level. When construction on ground liable to flood is unavoidable, it should be designed so that motors are well above the highest recorded flood level.

(*ii*) In the event of power failure any overflow which occurs should be able to find its way into a water course without causing flooding or serious damage to property.

(*iii*) Pumping station should be located as far as possible from the residential areas to avoid bad smell.

SEWAGE TREATMENT

Sewage, before being disposed off either in river streams or an land, has generally to be treated, so as to make it safe.

Sewage has to be treated for the following reasons:

(1) To prevent pollution of water into which the sewage is let off, as water may be used downstream for drinking water supply. This causes a health hazard as sewage contains pathogenic bacteria.

(2) To prevent offensive odour in the water if water is used for swimming, boating, etc., and to the people living near the water or land where sewage is disposed off as it causes health hazard.

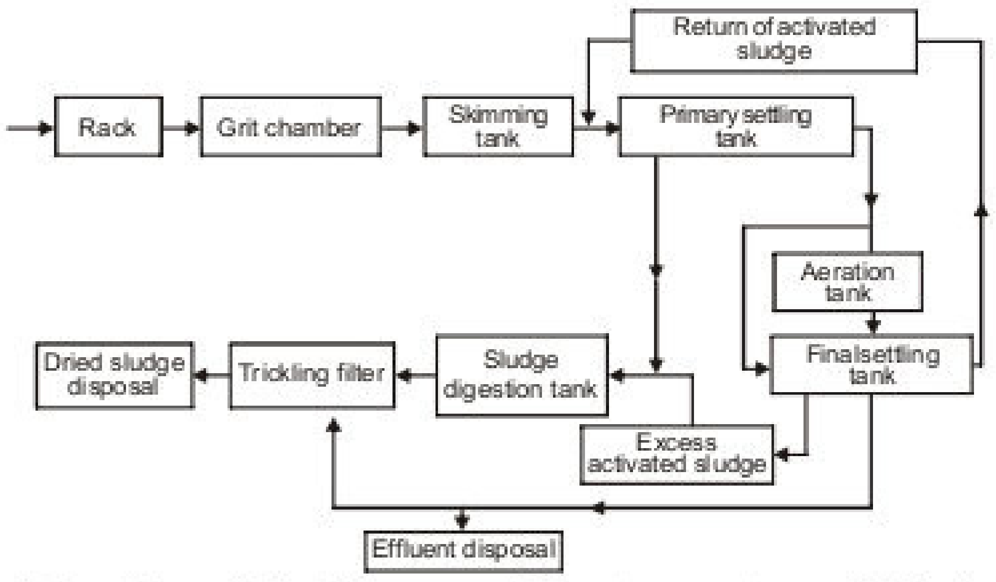
(3) To prevent destruction of fish and other aquatic life.

(4) If sewage has to be disposed of on land, soil will become sewage sick after some time and cannot take any more sewage. This creates a very messy scene at the site and produces offensive odour polluting the entire atmosphere and affecting the neighbourhood.

SEWAGE TREATMENT PROCESS.

It can be classified into the following four categories :

I. Preliminary treatment II. Primary treatment



Types of Treatment Units Employed in Sewage Treatment, and Their Functions

Type of Treatment	Purification effected	Process or unit employed	BOD removal as% of original	Removal bacteria as% of original	Disposal of residuals
1. Preliminary treatment	(*i*) Removal of floating materials like dead animals, tree branches etc.	Coarse and fine screens of different designs.	5-10	10-20	Screenings can be disposed off, easily, either by burials or burnings
	(*ii*) Removal of heavy settleable inorganic solids	Grit chamber or detritus tanks	10-20	10-20	Grit can be easily disposed off eitehr by burials or burning
	(*iii*) Removal of fats and greases Removals of suspended settleable organic solids.	Skimming tanks or Vacuators	20-30	10-20	Skimmings wasunstable volatile materials, and to disposed off by stablising them in tanks by anaerobic decomposition.
2. Primary treatment	Removal of fine suspended nonsettleable solids and colloidals, including dissolved organic matter	(*i*) Sedimentation tank	30-35	25-75	Sludge containing organic materials has to be stabilised
		(*ii*) Septic tank	20-30	25-75	Stabilised first, in disgestion tank and the digested materials is then used as a
		(*iii*) Imhoff tanks	30-40	25-75	manure or soil builder Effluents are disposed off for sewage farming on lands. These unitssludge digestional along with sedimentation tanks.
3. Secondary or Biological treatment	Removal of pathogens and the remaining very fine dissolved organic matter	(*i*) Chemical flocculations and sedimentation	50-85	40-80	Sludge containing organic materials has to be stabilised in digestion tanks and residue is used as manure or soil builder.
		or			
		(*ii*) Intermittent sand filters, followed and proceeded by sedimentation	90-95	95-98	same as above
		or			
		(*iii*) Conventional low rate tricking filters followed and proceeded by sedimentation	90-95	95-95	same as above
		(*iv*) Modern high rate trickling fitter followed and proceded by sedimentation	75-95	90-98	Effluents are generally disposed off by using them for irrigation
		(*v*) Activated sludge treatment in aeration tank and secondary settling tank			
		or			
		(*vi*) Oxidation ponds	85-90	90-98	
4. Final or tertiary treatment		Chlorinotion	100%	100%	

I. Preliminary Treatment

It consists solely in separating floating materials and heavy settleable inorganic solids. This treatment reduces BOD of the waste water by about 15 to 30%.

Main operations. It consist of following main operations:

1. Screening

Sewage admitted to sewage treatment plant and pumping stations should be effectively screened to protect the machinery in the plant and to avoid difficulties in subsequent stages of treatment. Screens are also necessary when raw sewage is discharged into a water-course without treatment to prevent unsightly and repulsive floating matter being discharged.

Screening device consists of flats placed vertically, inclined or curved (at 45° to 60° to the horizontal) and spaced at close and equal intervals across a channel through which sewage flows. It is used for removal of certain materials such as pieces of wood, floating debris, rags etc. found in sewage.

Depending on the clear spacing between flats, screens are classified as follows :

Coarse screens	. . Above 50 mm
Medium screens	. . 20 to 50 mm
Fine screens	. . Less than 20 mm

Types of Screens : *These are mechanically or manually operated.*

(*i*) Manually cleaned Screens : In these a perforated platform is provided from which an operator may rake the screenings from the screen. A hand-rake is provided. Screen is placed inclined between 45° and 60° to the horizontal.

While designing the screens, clear openings should have sufficient total area, so that velocity through them is not more than 0.8 to 1m/s

Head loss through the screen = $0.0729 (V^2 - v^2)$

where, V = velocity through screen

= 0.8 to 1m/s.

v = velocity above screen

= 0.8 or 5/6 m/s

(*ii*) Mechanically cleaned Screens : In these a mechanical raking device is provided. Inclination of the screen should be between 60 and 90° with the horizontal. Raking mechanism cleans the screens and lifts up screenings and empties into a trough.

2. Grit Removal

Sewage contains inorganic matter such as sand, broken crockery etc., which can create problem in sludge digestion as it combines with other organic matter in the sludge. It also causes wear and tear on pumps.

(*i*) Grit Chamber : It removes grit. It is a tank in which velocity of flow of sewage is reduced. Sand being heavier than organic matter, settles down on the bottom. Chamber may be horizontal or vertical type. Grit chamber is provided after screening operation.

In grit chambers, flow velocity should neither be too low so as to cause setting of lighter organic matter, nor should be too high so as to cause setting of entire silt in the sewage.

For grit chamber, critical scour velocity,

$$V_H = 0.3 \text{ to } 0.45 \text{ m/s}$$

In practice, a flow velocity of about 0.25 to 0.3 m/s is adopted for design of grit basins.

Detention time of about 40 to 60 seconds is generally sufficient for a water depth of about 1 to 1.8 m.

$$\text{Detention time (D.T)} = \frac{\text{Depth of the tank}}{\text{Settling velocity}}$$

or

$$\text{D.T.} = \frac{\text{Length of the tank}}{\text{Horizontal velocity}}$$

$$V_s = d\,(3T + 70)$$

Grit chambers of sewage treatment plant is normally cleaned periodically at about 3 week interwale.

(*ii*) Detritus tank : It remove finer particles but is meant to remove finer particles including some organic matter. For this, velocity is reduced more than that in the grit chamber and detention period is longer. This causes part of the organic matter also to settle down. Detritus is was hed mechanically and the organic matter is returned to sewage. Sometimes compressed air is blown through the chamber to lift up organic matter which is lighter, and to make it flow forward.

3. Removal of Oil, Grease, etc.

Grease and oil creates following difficulties :

(*i*) Produce foul odour when sewage has to be directly discharged into water. Aeration is also retarded that causes anaerobic conditions.

(*ii*) Clogging of trickling filters.

(*iii*) Interfere with the working of bacteria.

(*iv*) Not easily digested in sludge digestion tanks.

Skimming Tanks

Tanks for removing oils and grease is called *skimming tanks*. These are narrow rectangular tanks. Air diffusers are provided at the bottom and compressed air is blown through them. Oil and greasy substances are changed to a soapy mixture by the air and are lifted to the surface. Floating substance