Characteristics of Water &Wastewater

Environmental Engineering
Unit-I

Definition of Terms

- Before studying the principles for design and construction of house drainage system it is necessary to first understand the basic terms used in subsequent description of topics in this chapter. Important terms are defined as follows:
- **Wastewater**: Water when used for different purpose like domestic commercial, industrial etc., receives impurities and become wastewater. Thus wastewater is used water and it has **physical, chemical, and biological** Impurities in it, wastewater is a general term.
- **Sewage:** The waste water coming from W.C. and containing human excreta is known as sewage.

Definition of Terms

- **Sullage:** The Wastewater coming from bathrooms and kitchens which does not contain fecal matter is known as sullage.
- **Plumbing System:** It is entire system of pipe line for providing water supply to the building or it is a system of pipes for disposal of wastewater from the building.
- **Sewer:** A pipe carrying sewage/ wastewater is called sewer.
- **Soil Pipe**: It is pipe carrying sewage from W.C.
- **Waste Pipe:** It is a pipe carrying sulluge from bathrooms, kitchens, sinks, wash basins, etc.
- **Sewerage System:** A system of sewers of different types and sizes in a town collecting wastewater from the town and carrying it to the wastewater treatment plant.

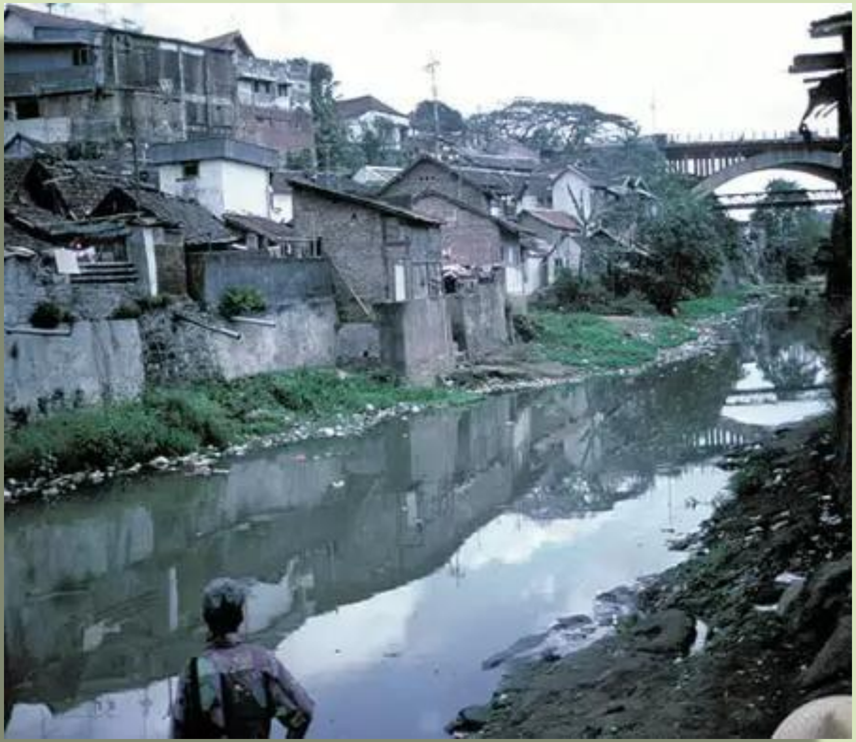
Sewage

- **Waste matter from domestic or industrial establishments that is carried away in sewers or drains for dumping** or conversion into a form that is not toxic.

Introduction

- Wastewaters are usually classified as **industrial wastewater** or the **domestic wastewater** (sewage or muncipile wastewater).
- **Characteristics of industrial wastewater vary greatly from industry to industry and within industries also there are variations in the quality depending upon the processes, for example quality of wastewater coming out from a cooling tower will be quite different then the wastewater coming out from any chemical process** on the other hand there are limited variations in the quality of sewage depending upon season, sewerage system, lifestyle of people etc..
- **Quality of sewage also plays an important role in design and construction of various treatment units.**

Wastewater



Characteristics of Water & Waste Water

- The characteristics of sewage can be classified under following three heads:
- **Physical Characteristics**
- **Chemical Characteristics**
- **Biological Characteristics**

Physical Characteristics

The Physical Characteristics of WATER are determined using the physical method of analysis:

Colour

- The colour of the sewage indicates the freshness of sewage. If it's colour is **greyish brown or yellowish**, it indicates **fresh sewage**. With passage of time, as putrefaction starts it begins to get black. The colour of stale and septic sewage is **black**(When all the oxygen has disappeared from sewage, it becomes septic). Other colors may also be formed due to presence of some specific industrial waste. The color of the sewage can normally be detected by the naked eye.

Odour

- The odour of a fresh sewage is not offensive or practically it can be considered odourless, but as it starts to get stale, it begins to give offensive odour. Within 3 to 4 hours, all oxygen present in the sewage gets exhausted and it starts emitting offensive odour by hydrogen sulphide gas which is formed due to anaerobic decomposition of sewage.

Colour

Physical Characteristics

Temperature

- The temperature has an effect on the biological activity of bacteria present in the sewage and it also affects the solubility of gases in sewage. It also affects the viscosity of sewage (more is the temperature, lesser is the viscosity of sewage).
- The normal temperature, of sewage is slightly higher than the temperature of the water supply because of the additional heat due to utilization of water. Also when the wastewater flows in a closed pipes, its temperature future increases.
- The average temperature of sewage in India is about 20 ^{0} C which is near about ideal temperature of sewage for biological activities. At higher temperature coupled with the lower dissolved oxygen activities can cause serious problems in disposal of waste water.

Physical Characteristics

Turbidity

- Sewage is normally turbid representing dirty dish water or wastewater from baths having other floating matter like fecal matter, pieces of paper, cigarette ends, match sticks, greases, vegetable debris, fruit skins, soaps, etc.. The turbidity depends on the quantity of solid matter present in suspension state. The turbidity depends on the quantity of solid matter present in suspension state. The turbidity can be determined by the turbidity rod or by turbidimeters e.g. Nephlometric

Turbidity

Chemical Characteristics

- The Chemical Characteristics of sewage helps in indicating the stage of sewage decomposition, its strength, and extent and type of treatment required for making it safe the chemical characteristics of sewage includes.

Chemical Characteristics

Solids

- Solids normally contain **99.9 % water and only 0.1 %** of total solids present in the sewage may be in any of the four: **suspended solids, dissolved solids, colloidal solids, and settle able solids.**
- Suspended solids are those solids which remain floating in sewage, dissolved solids are those which remain dissolved in sewage just as a salt in water. Colloidal solids are finely divided solids remaining either in solution or in suspension . Settleable solids are that solids which settles out, if sewage is allowed to remain undisturbed for a period of 2 hrs.

Chemical Characteristics

- The proportion of these different types of solids is generally found to be as given below:
- it has been estimated that about 1000 kg of sewage contains about 0.454 kg of total solids, out of which 0.225 kg in solution, 0.112 kg is in suspension and 0.112 kg is settle able.
- Also solids can be **organic** or **inorganic**. About 45 % of total solids are organic and the remaining 55 % is inorganic
- **Inorganic matter** consists of minerals and salts like sand, gravel, dissolved salts, chlorides, sulphates, etc.

Chemical Characteristics

- **Organic matter** consists of
- **Carbohydrates** like cellulose, cotton, starch, sugar, etc..
- **Fats and oils** received from kitchens garages, etc..
- **Nitrogenous compounds** like protein and their decomposed product, including wastes from animals, urea, fatty acids etc.
- Generally presence of inorganic solids in sewage is not harmful. They can be removed by mechanical units in treatment plants. But the suspended and dissolved organic solids are responsible for creating nuisance if disposed of without treatment.

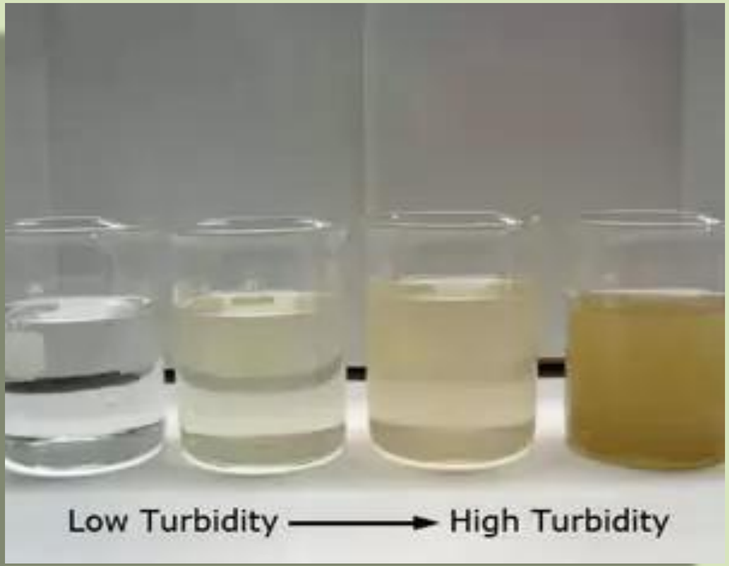
Chemical Characteristics

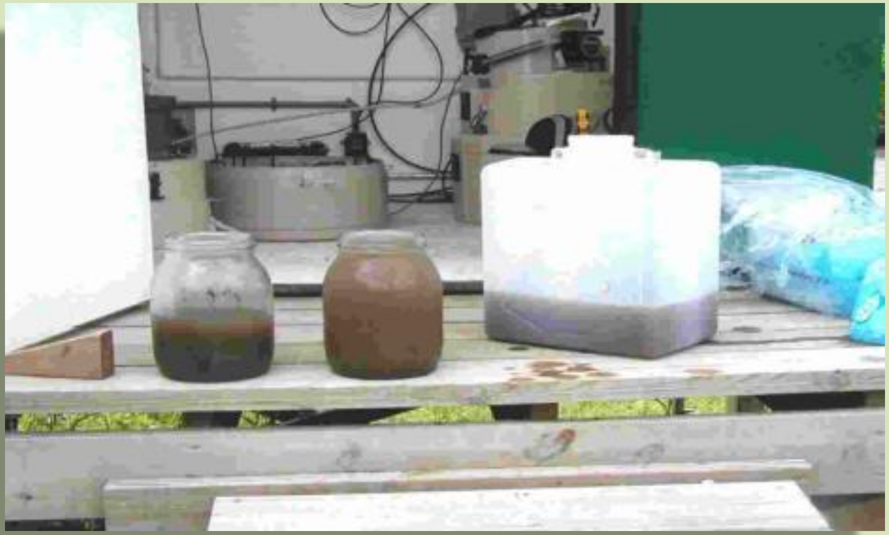
- **The amount of various kinds of solids present in the sewage can be determined as follows:**
- **Total Solids (S_1 in mg/ lit)**
- It can be determined by evaporating a known volume of sewage sample and weighing the dry residue left. The mass of the residue divided by the volume of sample evaporated will give total solids in mg/lit.
- **Suspended Solids (S_2)**
- These are solids which are retained by filter of 1 µm pores. So they are called non filterable solids. Their quantity can be determined by passing a known volume of sewage through a glass filter and weighing the dry residue left. Mass of the residue divided by the volume of the sample will give **S_2 in mg/lit**.
- **Dissolved Solids and colloidal (S_3)**
- Difference between total and suspended solids i.e. **$S_1 - S_2$** represents the dissolved solids and colloidal solids.

Chemical Characteristics

- **Volatile and Fixed Suspended Solids**
- The total suspended solids (S_2) may either be volatile or fixed.
- To determine their proportions, the non filtered residue is burnt and ignited at about 550 ^{0}C in a muffle furnace for about 15 to 20 minutes.
- Loss of weight due to ignition will represent the volatile solids in the sample (S_4) and S_2–S_4 will give the fixed solids (S_5).

Solids

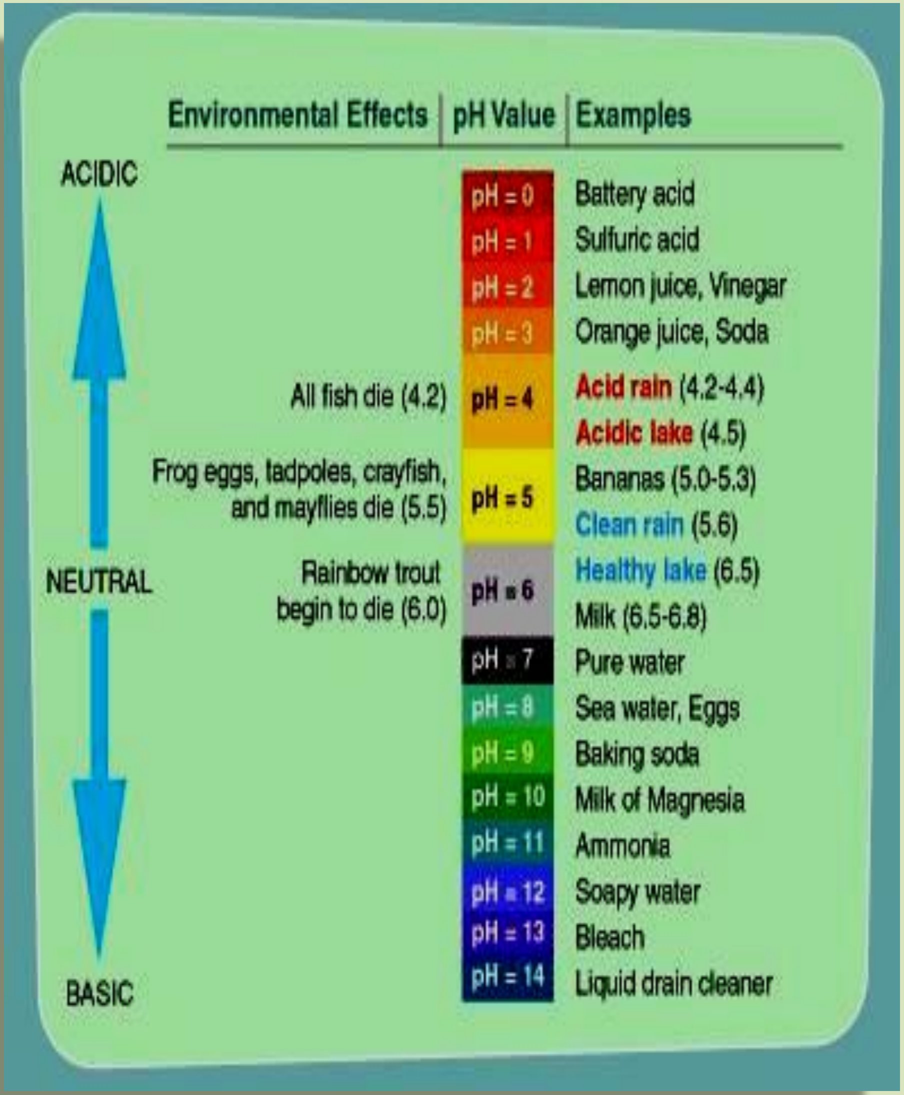


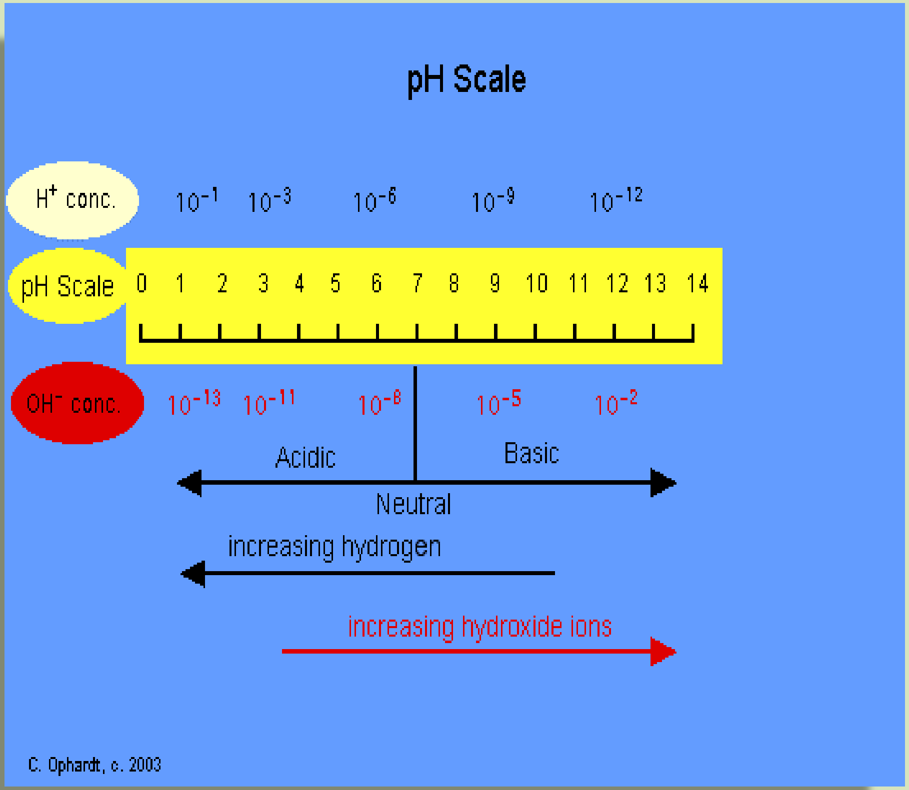


pH

- The pH value of sewage indicates the logarithm of reciprocal of hydrogen ion concentration present in the sewage. It is thus an indicator of the acidity or the alkalinity of sewage. If the pH value is less than 7, the sewage is acidic and if the pH vale is more than 7, the sewage is alkaline.
- The fresh sewage is alkaline, with passed of time pH tends to fall due to production of acid by bacterial action in anaerobic or nitrification processes. However with treatment of sewage the pH tends to rise.
- Determination of pH is important because efficiency of certain treatment methods depends on it. Especially the biological treatment, for better result the pH of sewage should be around 7.0 in biological treatment as microorganisms can flourish in that pH range.
- pH can be determined using pH meter (Potentiometer)

pH


Environmental Effects
pH Value
Examples
ACIDIC
NEUTRAL
BASIC
pH = 0
Battery acid
pH = 1
Sulfuric acid
pH = 2
Lemon juice, Vinegar
pH = 3
Orange juice, Soda
All fish die (4.2)
pH = 4
Acid rain (4.2-4.4)
Acidic lake (4.5)
Frog eggs, tadpoles, crayfish, and mayflies die (5.5)
pH = 5
Bananas (5.0-5.3)
Clean rain (5.6)
Rainbow trout begin to die (6.0)
pH = 6
Healthy lake (6.5)
Milk (6.5-6.8)
pH = 7
Pure water
pH = 8
Sea water, Eggs
pH = 9
Baking soda
pH = 10
Milk of Magnesia
pH = 11
Ammonia
pH = 12
Soapy water
pH = 13
Bleach
pH = 14
Liquid drain cleaner


pH Scale
H+ conc.
10-1 10-3 10-6 10-9 10-12
pH Scale
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
OH- conc.
10-13 10-11 10-8 10-5 10-2
Acidic
Basic
Neutral
increasing hydrogen
increasing hydroxide ions
C. Ophardt, c. 2003

Nitrogen Content (Nitrogen Compounds)

- The presence of nitrogen in sewage is an indication of the presence of the organic matter and may occur in one or more of the following forms:
- **Free ammonia called ammonia nitrogen**
- **Albuminoid or Organic Nitrogen**
- **Nitrites**
- **Nitrates**

Nitrogen Content (Nitrogen Compounds)

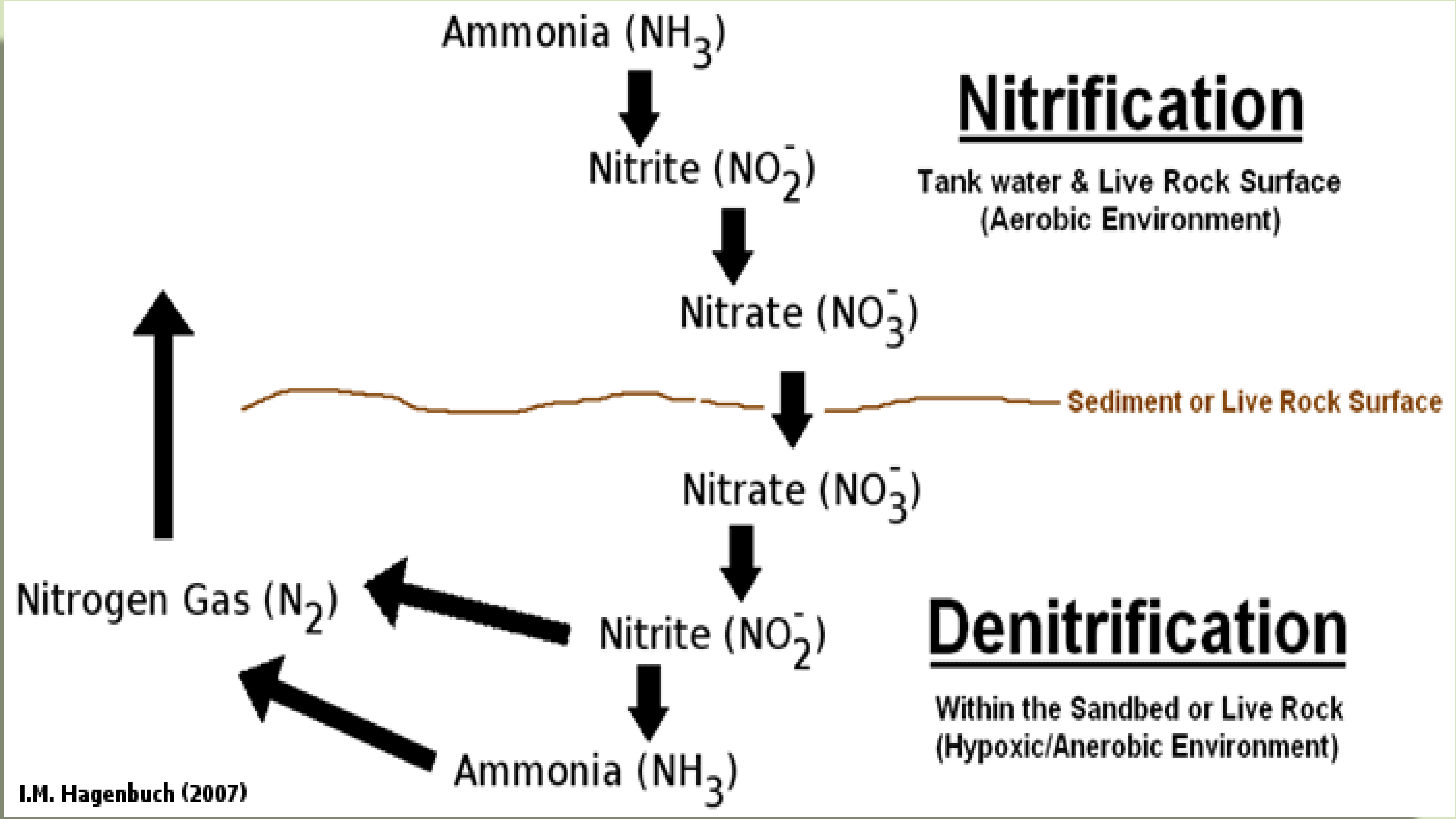
- The free ammonia indicates the very first stage of decomposition of organic matter (thus indicating recent pollution**); albuminoid nitrogen** indicates the quantity of nitrogen in sewage before the decomposition of organic matter. **Nitrates** indicates the presence of fully oxidized organic matter in sewage.
- The **nitrites** thus indicates the intermediate stage of conversion of organic matter of sewage into stable forms, thus indicating the progress of treatment. Their presence shows that the treatment given to the sewage is incomplete, and sewage is stale. Whereas, the presence of nitrates indicates the well oxidized and treated sewage.
- Organic nitrogen can be measured by adding strong alkaline solution of $KMn0_4$ to already boiled water sample and again boiling the same. Ammonia gas thus liberated is measured which gives the quantity of organic nitrogen. The sum total of **ammonia nitrogen** is called **kjedahl nitrogen**.

Nitrogen Content (Nitrogen Compounds)

- Nitrites are dangerous but as oxidation of nitrites to nitrates is vey fast it is generally not find in water bodies.
- As Nitrates represent fully oxidized matter its presence in sewage is not dangerous. But if the sewage contains higher nitrates and if it is disposed of in a water body then the nitrates content in the water body would increase. Higher quantity of nitrates adversely the health of infants, causing a disease called mathemoglobinemia (commonly called as blue baby disease). Children suffering from this disease may vomit; their skin colour may become dark and may die in extreme case.
- Nitrites and Nitrates are measured by colour matching techniques.

Mathemoglobinemia

Nitrogen Content (Nitrogen Compounds)



Chlorides Contents

- Chlorides are generally found in sewage and are derived from kitchen wastes, human feces and urinary discharges. The normal chloride content of sewage is 120 mg/lit, whereas the permissible limit of chloride content in water is 250 mg /lit.
- However, large amount of chlorides may enter from industries like ice cream plants, meat salting etc.. Hence, when the chloride content of a given sewage is found to be high, it indicates the presence of industrial wastes or infiltration of seawater, thereby indicating strength of sewage.
- It can be determined by titrating the wastewater with standard silver nitrate solution using potassium chromate as indicator.

Chlorides Contents

Fats, Oils and Greases

- Fats, oils and greases are derived in sewage from the discharge of animals and vegetable matter, or from the garages, kitchens of hotels and restaurants, etc..
- Such matter form scum on the top of the sedimentation tanks, clogs the voids of the filter media and affects the diffusion of oxygen. They thus interfere with the normal treatment methods. Hence these detection and removal is important.
- Oils and greases are soluble in ether. Hence for their determination, a sample of sewage, sample is first of all evaporated, leaving behind the oil and grease as a residue, which is then weighed.

Fats, Oils and Greases

Toxic

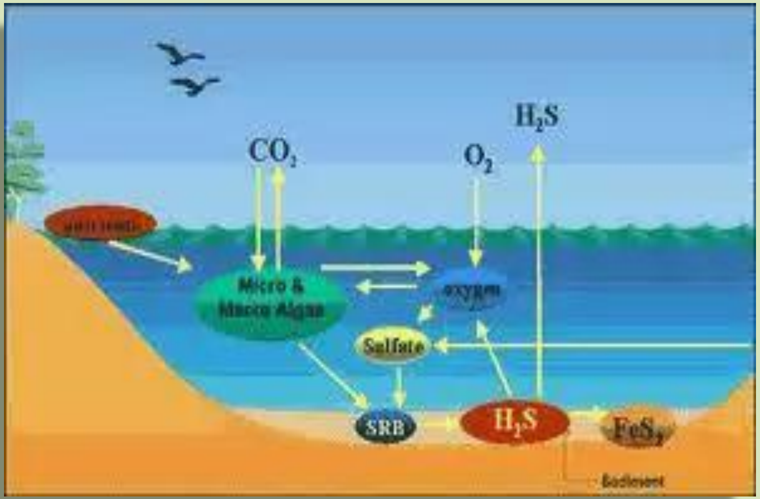
- Copper, lead, silver, chromium, arsenic, phenols, boron, cyanides, etc.. are some of the toxic compounds affecting the microorganisms resulting in malfunctioning from industrial waste.

Toxic Waste

Sulphides, Sulphates and Hydrogen Gas

- Sulphides and sulphates are formed due to the decomposition of various sulphur containing substances in sewage. This decomposition also leads to evolution of hydrogen sulphide gas, causing bad odours, besides causing corrosion of concrete sewer pipes.
- In aerobic digestion of sewage, the aerobic and facultative bacteria oxidizes the sulphur and its compounds present in the sewage to initially form sulphides, which ultimately breakdown to form sulphates ions, which is a stable and unobjectionable end products.
- In an-aerobic digestion of sewage the anaerobic and facultative bacteria reduce the sulphur and its compounds into sulphides, with evolution of H_2S gas along with methane and carbon dioxide, thus causing very obnoxious odours.

Sulphides, Sulphates and Hydrogen Gas



Dissolved Oxygen

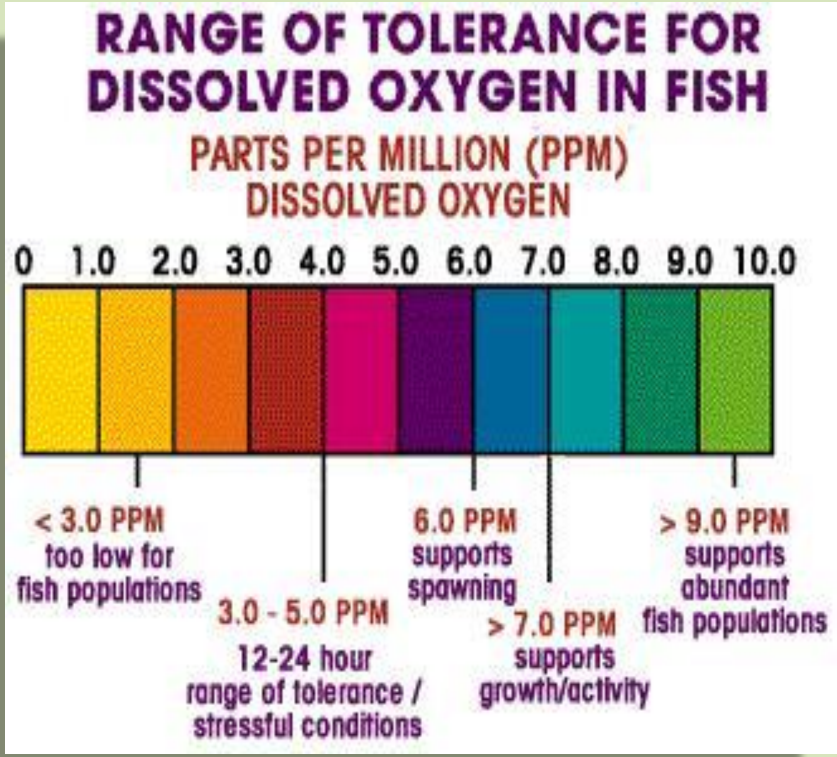
- Dissolved oxygen is the amount of oxygen in the dissolved state in the wastewater. Through the wastewater generally does not have DO, its presence in untreated wastewater indicates that the waste water is fresh. Similarly, its presence in treated wastewater effluent indicates that the considerable oxidation has been accomplished during the treatment stages. While discharging the treated wastewater into receiving waters, it is essential to ensure that at least **4 mg/l** of DO is present in it. If DO is less, the aquatic animals like fish etc. are likely to be killed near the vicinity of disposal. The presence of DO in wastewater is desirable because it prevents the formation of obnoxious odour. DO determination also helps to find the efficiency of biological treatment.

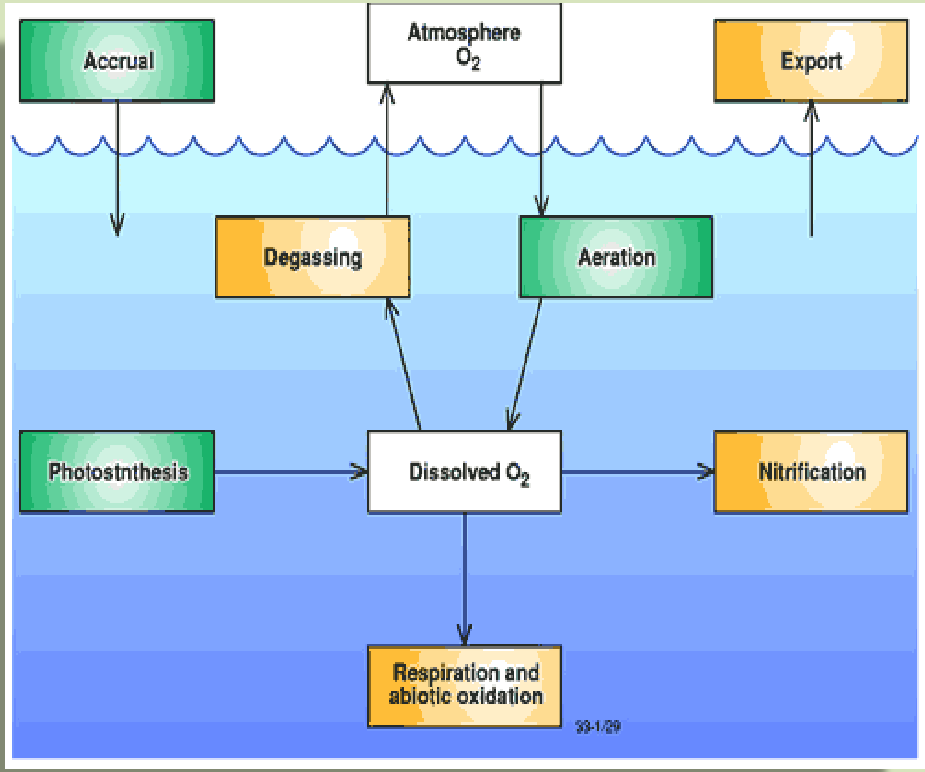
Dissolved Oxygen

The actual quantity of DO is governed by

- Solubility of Oxygen
- Partial Pressure of oxygen in atmosphere.
- Temperature
- Purity (Salinity, suspended solids etc.) of water
- The DO of wastewater decreases as the temperature increases.
- The solubility of sewage in waste. DO content of sewage is determined by winklers method.

Dissolved Oxygen





Biochemical Oxygen Demand

There are two types of organic matter

- (i) Biodegradable or biologically active
- (ii) Non biodegradable or biologically inactive
- Organic matter is often assessed in terms of oxygen required to complete oxidize the organic matter to CO_2, H_2O, and other end products of Oxidation.
- **Biochemical Oxygen Demand (BOD)** is defined as the amount of oxygen required by the microorganisms (mostly bacteria) to carry out decomposition of biodegradable organic matter under aerobic conditions.

Biochemical Oxygen Demand

- The BOD test is widely used to determine the pollution strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into natural watercourses. It is the one of the most important test in stream pollution control activities.
- This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacity of receiving bodies of water.
- It is also useful in design of wastewater treatment plant and also to measure the efficiency of some treatment processes.

Biochemical Oxygen Demand

- The test is of prime importance in regulatory work and in studies designed to evaluate the purification capacity of receiving bodies of water.
- It is also useful in design of wastewater treatment plant and also measure the efficiency of some treatment processes.
- The organic matter present in the wastewater may belong to two groups:
- **Carbonaceous matter**
- **Nitrogenous matter.**
- The ultimate carbonaceous BOD of a waste is the amount of oxygen necessary for microorganisms in the sample to decompose the biodegradable carbonaceous material. This is the first stage of oxidation and the corresponding BOD is called as first stage BOD.

Biochemical Oxygen Demand

- In the second stage the nitrogenous matter is oxidized by autotrophic bacteria, and the corresponding BOD or nitrification demand.
- In fact, polluted water will continue to absorb oxygen for many months, and it is not practically feasible to determine this ultimate oxygen demand.
- Hence the 5 days period is generally chosen for the standard BOD test, during which oxidation is about 60 to 70 % complete, while within 20 days period oxidation is about 95 % to 99 % complete. A constant temperature of 20^0 C is maintained during incubation. The BOD value of 5 Day incubation period is commonly written as BOD 5 or simply as BOD.

Biochemical Oxygen Demand

- Another reason for selecting 5 days as standard duration is to avoid interference of nitrification bacteria. Nitrification starts after 6th or 7th day. Sanitary engineers are generally interested in carbonaceous BOD only, so by selecting 5 days we generally get only the carbonaceous BOD. Interference of Nitrification can be eliminated by pretreatment of sample or by using inhibitory agents like methylene blue.
- Now a day BOD test is also done at 27 ^{0}C and duration of 3 days ($BOD_3\ ^{27}$), results can be obtained faster and it is more nearer to the actual field conditions in INDIA

BOD Test

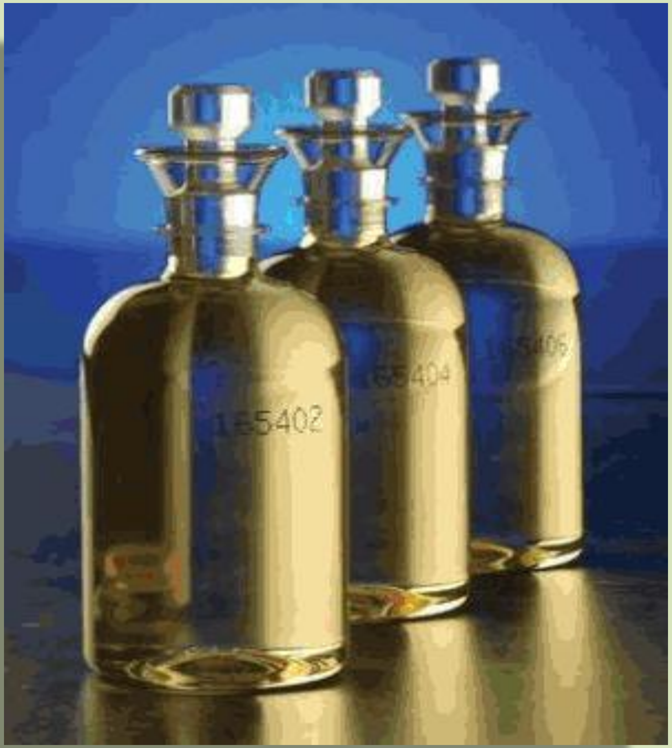
- The sample is first diluted with a known volume of specially prepared dilution water. Dilution water contains salts and nutrients necessary for biological activity and phosphate buffer to maintain pH around 7 to 7.5. diluted water is fully aerated. The initial D.O of the diluted sample is measured. The diluted sample is then incubated for 5 days at 20 ^{0}C. The D.O. of the diluted sample after the incubation period is found out. The difference between the initial D.O. of the diluted sample after the incubation period is found out. The difference between the initial D.O value and the final D.O. Value will indicate the oxygen consumed by the sewage sample in aerobic decomposition in 5 days. The BOD in mg/lit or ppm is then calculated by using the equation:
- **BOD= D.O. consumed in the test by the diluted sample x**

$$\frac{\text{Volume of the diluted sample}}{\text{Volume of undiluted sewage sample}}$$

BOD Test

- The factor on the right hand side is the dilution factor. For ex, 1 % diluted sample means 1 ml of sewage is diluted to make 100 ml of test sample; and hence dilution factor would be 100, as 1 ml has been diluted by 100 times to make 100 ml. Hence, the multiplying factor would be 100.
- In actual practice BOD bottles having 300 ml volume is used for experiment. The given volume of sample, say 5 ml is placed in the bottle and mixed with pure aerated dilution water to make 300 ml diluted sample. This sample is incubated at $20\ ^0$ C for the period of 5 days. Light must be excluded from the incubator to prevent the algal growth that may produce oxygen in the bottle. The D.O. content before and after incubation are determined. The BOD of the sewage is then calculated as
- BOD= DO consumed by the diluted sample x $\left(\frac{300}{5}\right)$

BOD Test



Derive the equation of first stage BOD

- BOD Test is conducted to determine the oxygen demand for the first 5 days on a number of sample, and their average value is taken as the BOD_5 at the test temperature.
- In fact if the oxygen is made available for a period more than 5 days, it is found that the oxygen is consumed rapidly for 6 to 7 days, and then slows down until the end of about 20 days or so. Thereafter, it may again accelerate for sometime, and slow down to a very low rate for an indefinite period. The first demand during the first 20 days or so, in fact 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 Nitrogenous demand or second stage demand.

Derive the Equation of first stage BOD

- Infact the sanitary engineers are more concerned with the first stage demand, since the oxygen consumed in its satisfaction is not recoverable. Hence, the term BOD is usually used to mean the first stage BOD, i.e. the demand due to presence of carbonaceous matter alone.
- The rate at which BOD is satisfied at any time, depends on temperature, and also on the amount and nature of organic matter present in sewage at that time.

Derive the Equation of first stage BOD

The rate at which BOD is satisfied at any time, (*i.e.* the rate of *deoxygenation*) depends on temperature, and also on the amount and nature of organic matter present in sewage at that time.

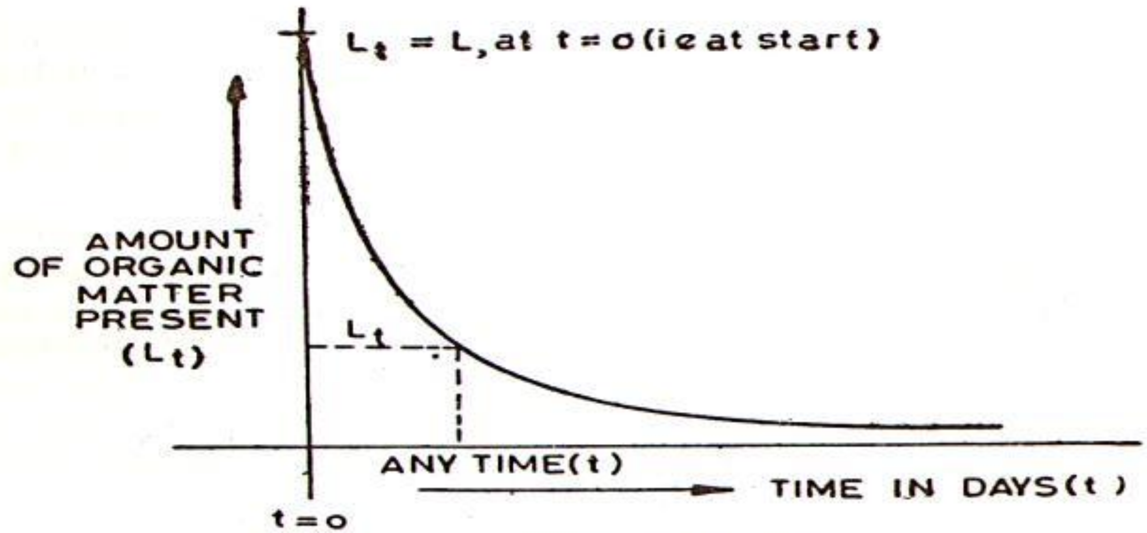


Fig. 7.3. 1st stage BOD curve.

Thus, at a certain temperature, the rate of deoxygenation is assumed to be directly proportional to the amount of organic matter present in sewage at that time ; *i.e.*

$$\frac{dL_t}{dt} = -KL_t^* \quad ...(7.12)$$

where L_t = oxygen equivalent of carbonaceous oxidisable organic matter present in sewage after t days from the start of oxidation, in mg/l.

t = time in days.

K = rate constant signifying the rate of oxidation of organic matter, and it depends upon the nature of organic matter and temperature. Its unit is per day.

Integrating Eq. (7.12), we get

$$\int \frac{dL_t}{L_t} = \int -K \cdot dt$$

or $$\log_e L_t = -K \cdot t + C \qquad ...(7.13)$$

where C is a constant of integration, and can be evaluated from the boundary conditions at the start *i.e.*

when t = zero (0),

i.e. at start $L_t = L$ (say).*

Substituting in Eq. (7.13), we have

$$\therefore \quad \log_e L = K(0) + C$$

or $$C = \log_e L$$

Substituting this value of C in Eq. (7.13), we get

$$\log_e L_t = -K \cdot t + \log_e L$$

or $$\log_e L_t - \log_e L = -K \cdot t$$

or $$\log_e \frac{L_t}{L} = -K \cdot t$$

or $$2.3 \log_{10} \frac{L_t}{L} = -K \cdot t$$

or $$\log_{10} \frac{L_t}{L} = -\frac{K \cdot t}{2.3}$$

$$= -0.434\, K \cdot t$$

Using $$0.434\, K = K_D \qquad ...(7.14)$$

where K_D** is the **De-oxygenation constant** or more strictly, the **BOD rate constant** (on base 10) at the given temperature = $0.434\, K$

We have

$$\log_{10} \frac{L_t}{L} = -K_D \cdot t$$

or $$\frac{L_t}{L} = (10)^{-K_D \cdot t} \quad \text{...(7.15)}$$

Now, L is the organic matter present at the start of BOD reaction, (expressed as oxygen equivalent) and L_t is the organic matter left after t days ; which means that during t days, the quantity of organic matter oxidised = $L - L_t$.

If Y_t represents the total amount of organic matter oxidised in t days (*i.e.* the BOD of t days), then we have

$$Y_t = L - L_t$$

Taking L out of bracket on R.H.S.

we have $$Y_t = L\left[1 - \frac{L_t}{L}\right]$$

or $$\frac{Y_t}{L} = 1 - \frac{L_t}{L}$$

or $$\frac{L_t}{L} = 1 - \frac{Y_t}{L}$$

Substituting this value of $\frac{L_t}{L}$ in equation (7.15), we get

$$1 - \frac{Y_t}{L} = (10)^{-K_D \cdot t}$$

or $$\frac{Y_t}{L} = 1 - (10)^{-K_D \cdot t}$$

or $$\boxed{Y_t = L\left[1 - (10)^{-K_D \cdot t}\right]} \quad \text{...(7.16)}$$

This is an important equation. Y_t is the oxygen absorbed in t days, *i.e.* *BOD* of t days.

The ultimate first stage *BOD* (Y_u) would be obtained from the above equation, when we substitute $t = \infty$ days in it.

Hence $$Y_u = L\left[1 - (10)^{-K_D \cdot \infty}\right]$$

or $$Y_u = L\left[1 - \frac{1}{(10)^{\infty}}\right]$$

$$= L[1 - 0]$$

or $$Y_u = L. \quad \text{...(7.17)}$$

Hence, the ultimate first state *BOD* (Y_u) of a given sewage is equal to the initial oxygen equivalent of the organic matter present in this sewage (L). *This is a fixed quantity, and does not depend upon the temperature of oxidation.*

The value of K_D however, determines the speed of the BOD reaction, without influencing the ultimate BOD, as shown in Fig. 7.4.

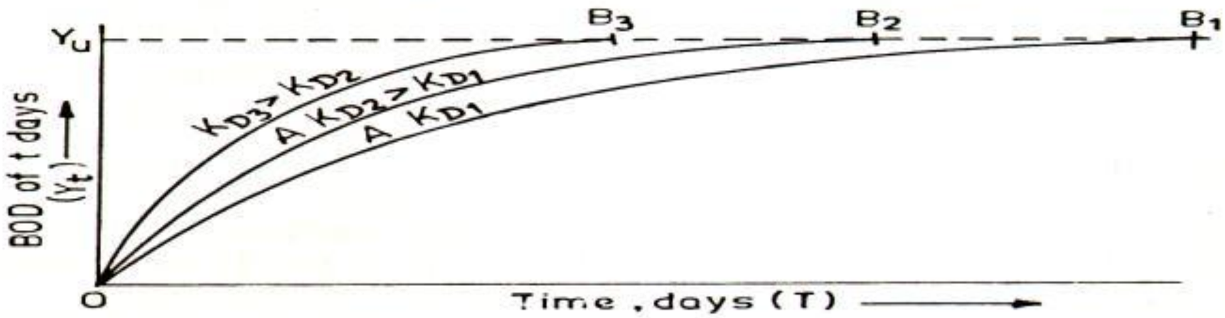


Fig. 7.4. BOD exertion as a function of K_D.

It is found to vary with temperature of sewage, and this relationship is approximately given by the equation

$$K_{D\,(T^\circ)} = K_{D\,(20^\circ)} \left[1.047 \right]^{T - 20^\circ} \qquad \ldots(7.18)$$

where $K_{D\,(20^\circ)}$ = Deoxygenation constant at 20°C. Its numerical value varies between 0.05 to 0.2 per day, depending upon the nature of the organic matter present in sewage. Simple compounds such as sugars and starches are easily utilised by the micro-organisms, and have a high K_D rate, while complex molecules such as phenols are difficult to assimilate and hence have low K_D values. Some typical K_D values are given in Table 7.2.

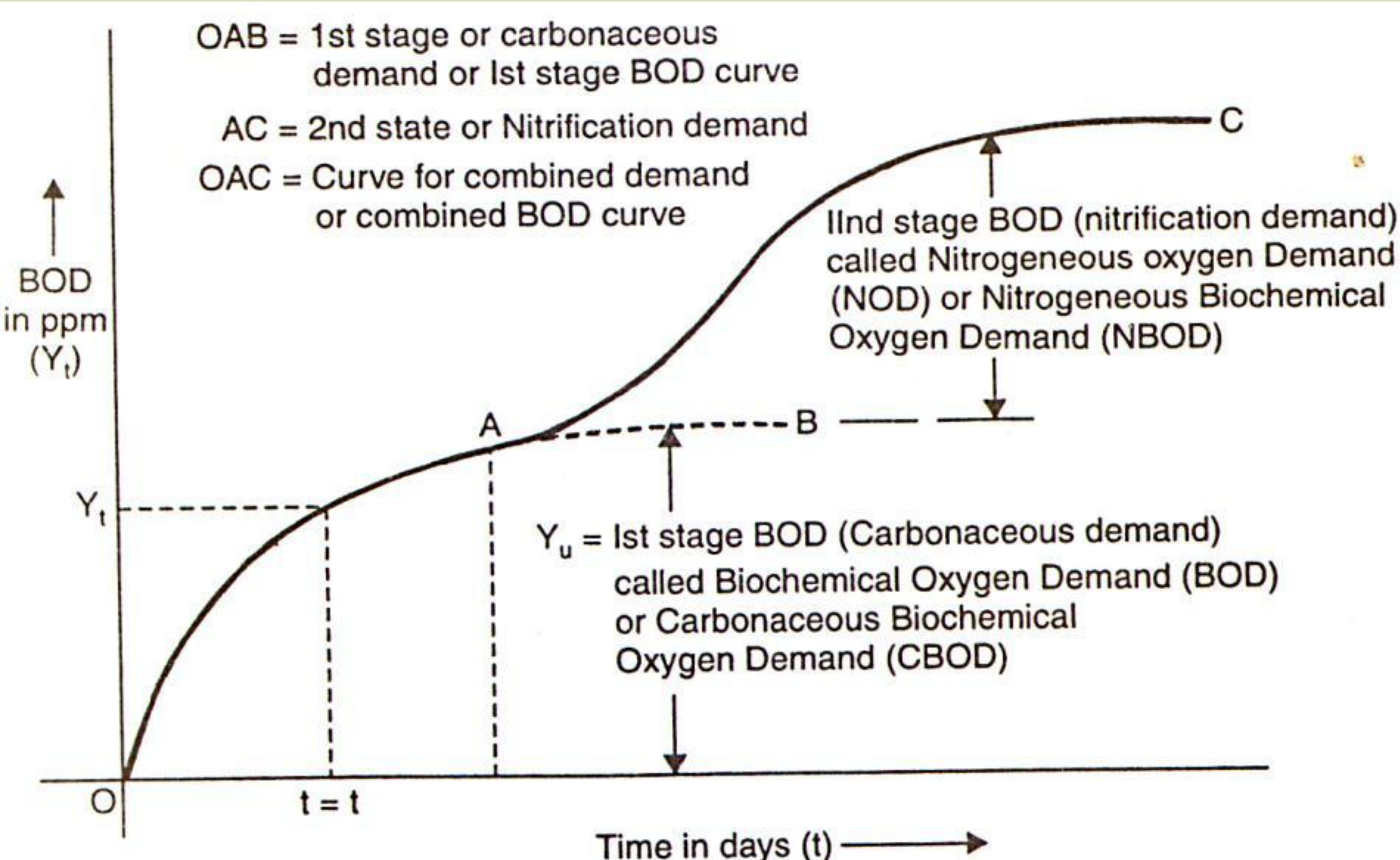
$K_{D\,(T^\circ)}$ = Deoxygenation constant at temperature T°C.

De-Oxygenation Constant (K_D)

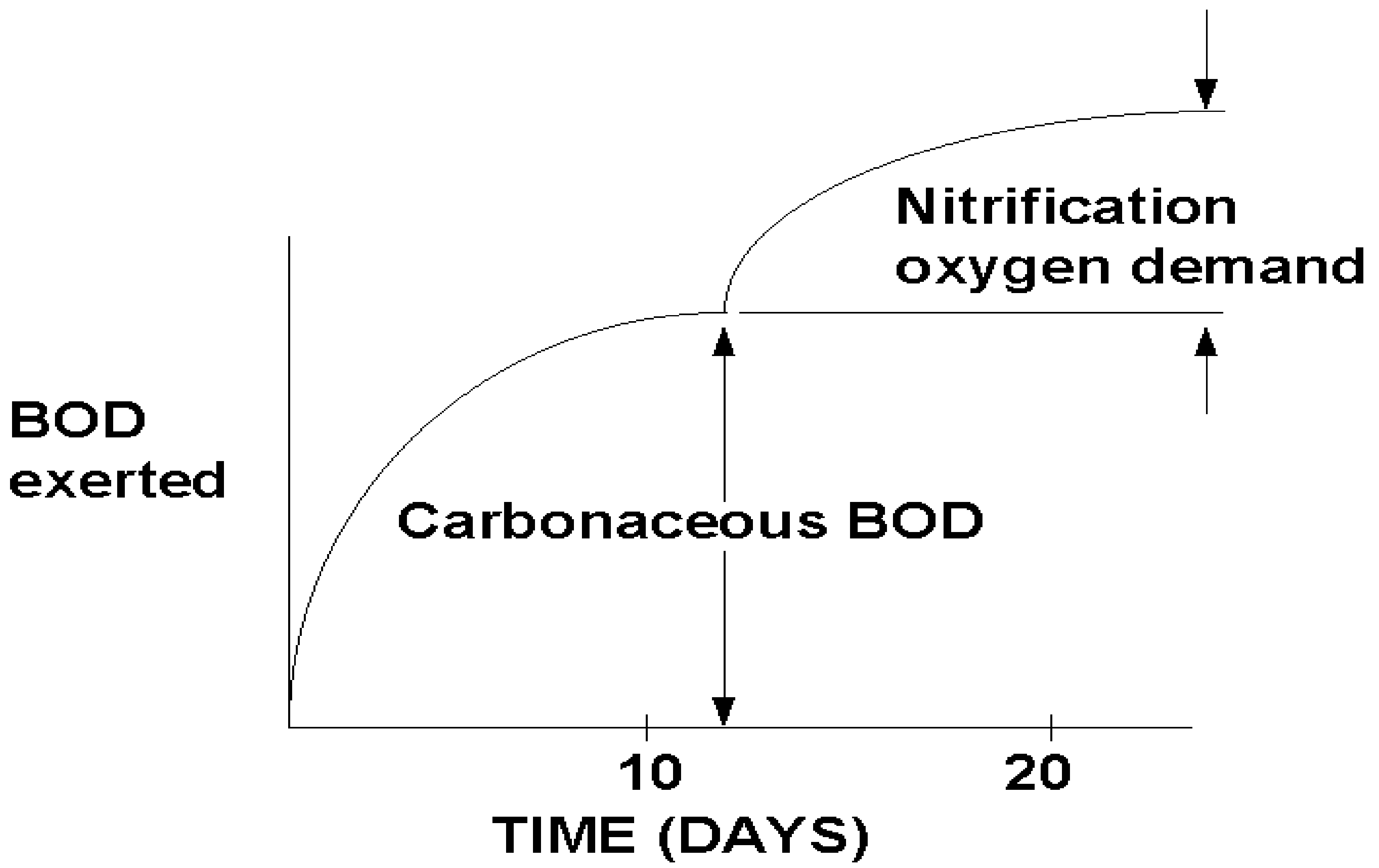
Table 7.2. Typical Values of K_D at 20°C for Various Types of Waters and WasteWaters

Water Type	*K_D value per day*
Tap waters	< 0.05
Surface waters	0.05—0.1
Municipal wastewaters	0.1—0.15
Treated sewage effluents	0.05—0.1

BOD Curve


OAB = 1st stage or carbonaceous demand or Ist stage BOD curve
AC = 2nd state or Nitrification demand
OAC = Curve for combined demand or combined BOD curve
C
IInd stage BOD (nitrification demand) called Nitrogeneous oxygen Demand (NOD) or Nitrogeneous Biochemical Oxygen Demand (NBOD)
BOD in ppm (Y_t)
A
B
Y_t
Y_u = Ist stage BOD (Carbonaceous demand) called Biochemical Oxygen Demand (BOD) or Carbonaceous Biochemical Oxygen Demand (CBOD)
O
t = t
Time in days (t)

BOD Curve



Nitrification
oxygen demand
BOD
exerted
Carbonaceous BOD
10
20
TIME (DAYS)

Limitation of BOD Test

Following are the imitation of BOD Test:

- It measures only the biodegradable organic matter.
- Time duration of the test is very long i.e. 5 days, so if quick results are needed it is not useful.
- Pretreatment is needed if the sample contains toxic waste.
- Nitrifying bacteria can cause interferences and could give higher results. To avoid them proper care must be taken.
- It is essential, to have high concentration of active bacteria present in the sample.

Chemical Oxygen Demand

- The BOD test takes minimum 5 days time and due to this it is not very useful in control of treatment processes. An alternative test is COD test. It is widely used as a means of measuring the amount of organic matter in the waste. It can be used to measure both biodegradable and non biodegradable organic matter. COD test, takes 3 hours in comparison to 5 days for BOD test, In COD test, a strong chemical oxidizing agent like potassium dichromate is used in acidic medium to oxidize the organic matter present in the waste. Almost all type of organic matter with a few exceptions can be oxidized by the action of strong oxidizing agents under acidic conditions. COD can be defined as amount of oxygen required to chemically oxidize organic matter using a strong oxidizing agent like potassium dichromate under acidic condition.

Chemical Oxygen Demand

Total Organic Carbon

- TOC test consists of acidification of the wastewater sample to convert inorganic carbon to CO_2 which is then stripped. The sample is then injected into high temperature furnace where it is oxidized in presence of a catalyst. The CO_2 that is produced is measured by means of infrared analyzer and converted instrumentally to original organic carbon content. The test is accurate and correlates to BOD well. Certain types of organic matter are oxidizing in TOC test so its valve is less than BOD test. For a typical domestic wastewater BOD_5 / TOC ratio varies from 1.0 to 1.6. TOC is not widely used because of the cost of the instrument and the skill necessary in its operation.

Total Organic Carbon

Theoretical Oxygen Demand

- The oxygen required to oxidize the organic matter present in a given wastewater can be theoretically computed. If the organics present in the wastewater are known. Thus if the chemical formulas and the concentrations of chemical compounds present are known to us, we can easily calculate the theoretical oxygen demand of each of these compounds by writing the balance reaction for the compound with the oxygen to produce CO_2 and H_2O and oxidized in organic compounds.
- But in actual practice it is virtually impossible to know the details of the compounds present in any natural raw water or wastewater.

Biological Characteristics

- The sewage contains many microorganisms like bacteria, algae, fungi, protozoa, etc. bacteria being the most predominant. Most of the bacteria found in the sewage are harmless non-pathogenic bacteria. They are helpful in oxidation and decomposition of sewage. A little no of bacteria, however, are disease producing pathogens, which are the real danger to the health of the public.
- In case of sewage samples, the routine bacteriological tests, as performed for water samples, are generally not performed, because of the high concentration of bacteria present in it. But at the time of outbreak of epidemics, certain tests may be done to find the type of pathogens

Population Equivalent

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

  [Standard BOD_5 of industrial Sewage]=

  [Standard BOD_5 of domestic sewage per person per day] x [Population equivalent]

Population Equivalent

- The average standard BOD_5 of domestic sewage is worked out to be about 0.08 kg/day/ person. Hence, if the BOD_5 of the sewage coming from an industries is worked out to be 350 kg/ day, then

Population Equivalent $= \dfrac{\text{Total BOD 5 of the industry in kg/day}}{\text{0.08 kg/day/person}}$

$$= \frac{350}{0.08}$$

$$= 4375$$

Population Equivalent

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

Relative Stability

- Relative Stability of sewage effluent may be defined as the ratio of oxygen available in the effluent (as DO, nitrite or nitrate) to the total oxygen required to satisfy its first stage BOD demand. It is expressed as percentage of the total oxygen required, and can be expressed by the equation:
- **Relative Stability**
- **$S = 100 [\ 1-(0795)^{t}{}_{20}]$**
- or
- **$S = 100 [\ 1-(0.630)^{t}{}_{37}]$**
- Where, S= the relative stability, t_{20} and t_{37} represent the time in days for a sewage sample to decolorize a standard methylene blue solution, when incubated at 20 ^{0}C and 37 ^{0} C respectively.

Relative Stability

- The decolouration caused by enzymes produced by anaerobic bacteria, in fact, is an indication of the available oxygen in oxidizing the unstable organic matter.
- The sooner the decolonization takes place, the earlier the anaerobic condition develops, which means lesser availability of oxygen. Hence if the decolourization takes place sooner (within 4 days), the effluent sample may be taken as relative unstable, But samples which do not decolorize in 4 days can be taken as relative stable, and thus can be discharged into streams without any troubles.

Examples

If the period of incubation is 10 days at 20 ^0C in the relative conductivity test on sewage, calculate the percentage of relative stability.

Sol:

Relative stability= S

$S= 100 [1-(0795)^{t_{20}}]$

Where, t_{20} = 10 days (given)

$S= 100 [1-(0795)^{10}]$

$S= 100 [1- 0.0995875]$

S= 90.04 %

Examples

Calculate the population equivalent of a city

(i) The average sewage from the city is 95×10^{6} l/day, and

(ii) The average 5 day BOD is 300 mg/l

Sol:

Average 5 day BOD = 300 mg/l

Average sewage flow= 95×10^{6} l/day

Therefore total BOD in sewage

= $300 \times 95 \times 10^{6}$ mg/day

= 300 x 95 kg/day

= 28500 kg/day

$$\text{Population equivalent} = \frac{\text{Total 5 day BOD in kg /day}}{0.08}$$

$$\frac{28500}{0.08}$$

3,56,250

Industrial Waste Water

Characteristics of Industrial Waste Water

- The characteristics of the industrial wastewater usually vary from industry to industry and it also varies from process to process. In general Industrial effluent differs widely from normal domestic sewage obtained from the residences and commercial establishments. They have too high a proportion of suspended solids, dissolved organics and inorganic solids, BOD, alkalinity or acidity, and the different parameters will not be in the normal domestic sewage. The Pollutants in the industrial wastewater includes the raw materials, process chemicals, final products, process intermediates, process by products, oils, and impurities in raw material and process chemicals. Such industrial wastewaters cannot always be treated easily by the normal method of treating domestic wastewater and specially designed methods or sequence of methods may be necessary.

Pollutants in industrial Waste Water and their effects

- **Organic Substances:** These deplete DO of stream and impose great load on secondary treatment unit.
- **Inorganic substances:** These includes carbonates, chlorides, nitrogen, phosphorous etc.. They cause eutrophication of water bodies, increases dissolved solids content and can also be harmful to aquatic life.
- **Acids and alkalies**: These generally affects the aquatic life of receiving water body. They also cause serious problem in operation of treatment units.
- **Toxic Substances**: These includes cyanides, Sulphides, acetylene, phenols, heavy metals, ammonia etc. due to which flora and fauna of receiving waters is greatly affected. The may cause problems in the biological treatments.
- **Colour producing substances**:
- They impart objectionable color in the receiving water bodies.
- **Oils**: They hinder self purification as they remains floating on the surface and cause problem in oxygen diffusion

Organic Pollutants

They Include oils, fats, phenols, organic acids grease and several other organic compounds

Inorganic Pollutants

- They include fine particles of different metals, chlorides, sulphates, oxides of iron, cadmium, acids and alkalis

Inorganic Pollutants

Marine Pollution

The Characteristics of Waste water of Some Industries

The Characteristics of Waste water of Some Industries

- **Dairy Industry**
- Various operations in a dairy industry may include, pasteurization, bottling, preparation of butter, cheese, milk powder etc. Wastewater from dairy industry consists primarily of dilution of milk and its products which impart a **very high BOD**, some times up to **1000 mg/l**. The wastewater may also contain **detergents, germicides, and other chemicals**.

Dairy Industry

Standards for Discharge of Sewage and Industrial Effluents

Table 3.16 BIS (ISI) Standards for Discharge of Sewage and Industria' Effluents in Surface Water Sources* and Public Sewers

Sr. No. (1)	Characteristic of the Effluent (2)	Tolerance limit for Sewage Effluent discharged into Surface Water Sources, as per IS 4764–1973 (3)	Tolerance Limit far Industrial effluents discharged into: Inland surface waters, as per IS 1490–1974 (4)	Public sewers as per IS 3306–1974 (5)
1.	BOD_5	20 mg/l	30 mg/l	500** mg/l
2.	COD	–	250 mg/l	–
3.	pH value	–	5.5 to 9.0	5.5 to 9.0
4.	Total Suspended Solids (TSS)	30 mg/l	100 mg/l	600 mg/l
5.	Temperature	–	40°C	45°C
6.	Oil and grease	–	10 mg/l	100 mg/l
7.	Phenolic compounds (as Phenol)	–	1 mg/l	5 mg/l
8.	Cyanides (as CN)	–	0.2 mg/l	2 mg/l
9.	Sulphides (as S)	–	2 mg/l	–
10.	Fluorides (as F)	–	2 mg/l	–
11.	Total residual chlorine	–	1 mg/l	–
12.	Insecticides	–	Zero	–
13.	Arsenic (as As)	–	0.2 mg/l	–
14.	Cadmium (as Cd)	–	2 mg/l	–
15.	Chromium, hexavalent (as Cr)	–	0.1 mg/l	2 mg/l
16.	Copper	–	3 mg/l	3 mg/l
17.	Lead	–	0.1 mg/l	1 mg/l
18.	Mercury	–	0.01 mg/l	–
19.	Nickel	–	3 mg/l	2 mg/l
20.	Selenium	–	0.05 mg/l	–
21.	Zinc	–	5 mg/l	15 mg/l
22.	Chlorides (as Cl)	–	–	600 mg/l
23.	Sodium	–	–	60%
24.	Ammoniacal nitrogen (as N)	–	50 mg/l	50 mg/l
25.	Radioactive meterials	–		
	(i) α–emitters		10^{-7} μC/ml (micro curie/ml)	–
	(ii) β–emitters		10^{-6} μC/ml	–

*Includes Rivers, Estuaries, Streams, Lakes and Reservoirs.
**subject to relaxation or tightening by the local authorities.

Effluent Discharge Standards

General Standards for Discharge of Environment Pollutants : Effluent
(Gazette Notification of MoEF, May 1993)

S. No.	Parameter	Standards			
		Inland surface water	Public sewers	Land for irrigation	Marine coastal areas
		(a)	(b)	(c)	(d)
1.	Colour and odour	—	—	—	—
2.	Suspended solids mg/l, Max.	100	600	200	a) For process waste water-100 b) For cooling water effluent 10 percent above total suspended matter of influent
3.	Particular size of suspended solids	Shall pass 850 micron IS Sieve	—		a) Floatable solids, max. 3 mm b) Settleable solids, max 850 microns
4.	***	*	—	***	—
5.	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
6.	Temperature	Shall not exceed 5°C above the receiving water temperature	—	—	Shall not exceed 5°C above the receiving water temperature
7.	Oil and grease mg/l Max.	10	20	10	20
8.	Total residual chlorine mg/l Max.	1.0	—	—	1.0
9.	Ammonical nitrogen (as N), mg/l Max.	50	50	—	50

S. No.	Parameter	Standards			
		Inland surface water (a)	Public sewers (b)	Land for irrigation (c)	Marine coastal areas (d)
10.	Total Kjeldahl nitrogen (as NH_3) mg/l, Max	100	-	-	100
11.	Free ammonia (as NH_3) mg/l, Max	5.0	-	-	5.0
12.	Biochemical Oxygen demand (5 days at 20°C) mg/l Max.	30	350	100	100
13.	Chemical Oxygen demand, mg/l Max.	250	-	-	250
14.	Arsenic (as As), mg/l Max.	0.2	0.2	0.2	0.2
15.	Mercury (As Hg.) mg/l Max.	0.01	0.01	-	0.01
16.	Lead (as Pb) mg/l, Max.	0.1	1.0	-	2.0
17.	Cadmium (as Cd) mg/l, Max.	2.0	1.0	-	2.0
18.	Hexavalent chromium (as Cr^{+6}), mg/l, Max.	0.1	2.0	-	2.0
19.	Total chromium (as Cr) mg/l, Max.	2.0	2.0	-	2.0
20.	Copper (as Cu) mg/l, Max.	3.0	3.0	-	3.0
21.	Zinc (as Zn.) mg/l Max.	5.0	15	-	15
22.	Selenium (as Se.) mg/l, Max.	0.05	0.05	-	0.05

S. No.	Parameter	Standards			
		Inland surface water	Public sewers	Land for irrigation	Marine coastal areas
		(a)	(b)	(c)	(d)
23.	Nickel (as Ni) mg/l, Max.	3.0	3.0	-	5.0
[2]24.	***	*	*	*	*
[2]25.	***	*	*	*	*
[2]26.	***	*	*	*	*
27.	Cyanide (as CN) mg/l Max.	0.2	2.0	0.2	0.2
[2]28.	***	*	*	*	*
29.	Fluoride (as F) mg/l Max.	2.0	15	-	15
30.	Dissolved phosphates (as P), mg/l Max.	5.0	-	-	-
[2]31.	***	*	*	*	*
32.	Sulphide (as S) mg/l Max.	2.0	-	-	5.0
33.	Phenolic compounds (as C_6H_5OH) mg/l Max.	1.0	5.0	-	5.0
34.	Radioactive materials (a) Alpha emitter micro curie/ml	10^{-7}	10^{-7}	10^{-8}	10^{-7}
	(b) Beta emitter micro curie/ml	10^{-6}	10^{-6}	10^{-7}	10^{-6}
35.	Bio-assay test	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent

S. No.	Parameter	Standards			
		Inland surface water	Public sewers	Land for irrigation	Marine coastal areas
		(a)	(b)	(c)	(d)
36.	Manganese (as Mn.) mg/l	2	2	-	2
37.	Iron (as Fe) mg/l	3	3	-	3
38.	Vanadium (as V)	0.2	0.2	-	0.2
39.	Nitrate Nitrogen mg/l	10	-	-	20
[2]40.	***	*	*	*	*

2. Omitted by Rule 2(d)(i) of the Environment (Protection) Third Amendment Rules, 1993 vide Notification No. G.S.R. 801 (E) dated 31.12.1993