11. WATER QUALITY AND ESTIMATION OF ORGANIC CONTENT

11.1 Surface Water Quality: Rivers and Streams

Surface water is highly susceptible to contamination due to sewage, industrial waste discharge, and agricultural run-off apart from the recreational activities. The objective of the water quality management is to control the discharge of pollutants so that water quality is not degraded to an unacceptable extent below the acceptable level. To achieve this quantitative analysis of pollutants is must. It is necessary to understand the background water quality which would be present without human interventions, and decide the levels of pollutants acceptable for intended uses of the water. The impact of different pollutants joining the water body should be understood well for this purpose. The impact of the pollution on a river depends both on the nature of the pollutant and the characteristics of the individual river. Some of the important characteristics include velocity of water flowing in the river, depth of flow, type of river bottom, and surrounding vegetation. The other factors include, climate of the region, geological characteristics of the watershed, land used pattern, and aquatic life in the rivers. All these parameters must be considered in water quality management in the river.

It is understood that the water quality in the rivers will not remain same throughout the stretch of river i.e. from origin to the point where it meet to the sea. The water quality is best near the origin of the river and goes on deteriorating as the river flows and goes on assimilating the pollutant discharged in it. Proper management is necessary if the water quality is to remain usable for intended purpose. Oxygen demanding wastes and nutrients are among the common pollutant having profound impact on almost all types of rivers, hence they deserve special emphasis.

11.2 Effect of Oxygen Demanding Wastes on Rivers

Depletion of dissolved oxygen is a major problem due discharge of oxygen demanding organic or inorganic pollutant in the surface water. This poses threat to higher forms of aquatic life, if the concentration of oxygen falls below a critical point. To quantify how much oxygen will be depleted, it is necessary to know the quantity of oxygen demanding waste and how much oxygen will be required to degrade the waste. Although, oxygen is getting depleted for the degradation of organic matter, it is continuously being replenished from the atmosphere and through photosynthesis. The net concentration of oxygen in the water body is determined by the relative rates of these competing processes i.e. deoxygenation and reoxygenation.

11.3 Estimation of organic content of the wastewater

The organic matter present in the water body can be analyzed in laboratory by determining Boichemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and by determination of Total Organic Carbon (TOC). These test procedure and relevance of these tests are discussed below.

11.3.1 Biochemical Oxygen Demand (BOD)

The BOD can be defined as the oxygen required for biochemical oxidation of organic matter present in the water under aerobic conditions. This test is based on the premise that all the biodegradable organic matter contained in a water sample will be oxidized to CO_2 and H_2O by microorganisms using molecular oxygen. For example, the general overall oxidation reaction for glucose is

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

Thus, the theoretical oxygen demand would then be:

Oxygen demand = (Gram of oxygen used) / (Gram of carbon oxidized)

= 192 / 72 = 2.67 g/g of carbon

The actual BOD will be less than theoretical oxygen demand due to incorporation of some of the carbon into newly synthesized bacterial cells. The test is performed under the conditions similar to those in actual natural water to measure indirectly the amount of biodegradable organic matter present. A water sample is inoculated with bacteria (1 to 2 mL of sewage per liter) that consume the biodegradable organic matter to obtain energy for their life processes. The organisms also utilizes oxygen in the process of consuming the organic matter, the process is called as ‘aerobic’ decomposition. This oxygen consumption is measured; more is the organic matter concentration more is the amount of oxygen utilized. Thus, the BOD test is the indirect measurement of organic matter in terms of the oxygen requirement to convert them into stable end product. Although, not all organic matter is biodegradable within the stipulated incubation period, and the actual test procedure lack in precision, due to different inoculum seed and many fold dilution required, it is still the most widely used method of quantifying organic matter because of the direct conceptual relationship between BOD and oxygen depletion in receiving waters.

The BOD test is performed for the following:

- To determine quantity of oxygen required for biochemical stabilization of organic matter.
- To determine suitability of biological treatment method, depending on COD/BOD ratio, and sizing the treatment units. For COD/BOD ratio less than 2 the wastewater is most suitable for biological treatment; for COD/BOD ratio between 2 to 6 acclimation of the inoculum is required for effective biological treatment; and for higher COD/BOD ratio biological treatment of such wastewater may not be suitable option.
- To monitor efficiency of the process.
- To determine compliance with wastewater discharge permits.

During the BOD test the organic matter will be converted into stable end product such as CO_2, sulphate (SO_4), orthophosphate (PO_4) and nitrate (NO_3).

The simple representation of carbonaceous BOD can be explained as below:

$$\text{Organic matter} + O_2 \xrightarrow{\text{microorganisms}} CO_2 + H_2O + \text{New Cells} + \text{Stable products}$$

This reaction continues till sufficient DO is available in the water. When DO is not available condition becomes anaerobic decomposition (fermentative reduction). The reaction under anaerobic conditions is as under:

$$\text{Organic matter} \xrightarrow{\text{microorganisms}} CO_2 + CH_4 + \text{New Cells} + \text{Other products } (NH_3, H_2S)$$

BOD Test

Biochemical oxidation is slow process and theoretically takes an infinite time to go to completion i.e. complete oxidation of organic matter. During the first few days the rate of oxygen depletion is rapid because of the high concentration of organic matter present. As the concentration of organic matter decreases, so does the rate of oxygen consumption. During the last part of the BOD curve, oxygen consumption is mostly associated with the decay of the bacteria that grew during the early part of the test. The oxygen consumption typically follows the pattern as shown in Figure 11.1. For wastewater like sewage, within 20 day period, the oxidation of carbonaceous organic matter is about 95 to 99% complete, and in the first five days, the period used for BOD determination, 60 to 70% oxidation is complete. The 20 ^{o}C temperature used is an average temperature value typically for slow moving streams in temperate climates. Different results would be obtained at different temperatures because biochemical reaction rates are temperature dependent.

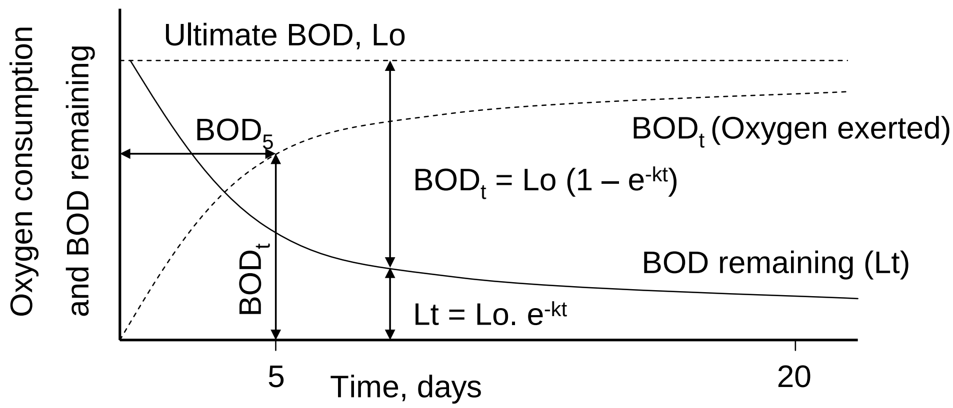

Figure 11.1 Variation in DO Profile during BOD test with duration of incubation

The biochemical oxygen demand is represented as BOD_5 20^{o}C, which indicate the total amount of oxygen consumed for biochemical oxidation of organic matter for first five days at 20^{o}C incubation temperature. Under Indian conditions the BOD values are acceptable for 3 days incubation at 27 ^{o}C.

Since, the saturation value of DO for water at 20^{o}C is only 9.1 mg/L, it is usually necessary to dilute the samples to keep final DO level, at the end of incubation period, above 1.5 mg/L. Hence, according to BOD values expected for that wastewater appropriate dilution should be carried out. Thus, the actual BOD of the unseeded sample can be worked out as

The 5 day BOD of sample $= \dfrac{DO_i - DO_f}{p}$

Where, DO_i and DO_f are initial and final DO of diluted wastewater sample

p is the dilution fraction = $\dfrac{\text{Volume of wastewater}}{\text{Volume of wastewater + volume dilution water}}$

The total volume of the BOD bottle used for test is usually 300 mL. The dilution water (distilled water) is aerated for sufficient time to correct DO close to the saturation value.

Nutrients and buffer solutions are added to the dilution water to provide nutrient for bacterial growth and maintain pH near neutral. Sufficient amount of seed is added to the BOD bottle to ensure adequate concentration of bacterial population to carry out the biodegradation. Usually 1 to 2 mL of sewage per liter is considered as sufficient to act as a seed. In such case it is necessary to subtract the oxygen demand of the seed from the mixed sample. Thus, the BOD of the wastewater with seeded sample can be worked out as below. The DO drop in blank is multiplied by (1- *p*) because this volume of blank is only present in the sample.

$$\text{BODw} = \frac{(DO_i - DO_f) - (B_i - B_f)(1 - p)}{p}$$

Where,

DO_i an DO_f = DO of mixture, initial and final values, respectively.

B_i and B_f = DO of blank, initial and final values, respectively

p = V_w/V_m = Volume of wastewater in mixture / Total volume of mixture

Example:1

1. Dilution water requirement:

A wastewater is expected to have BOD_5 of about 200 mg/L. The initial DO of dilution water is 8.0 mg/L. Calculate the dilution requirement for BOD determination.

Solution

BOD = 200 mg/L; DOi = 8.0 mg/L,

Minimum DO that should be left after five days of incubation is 1.5 – 2.0 mg/L,

Say final DO = 2.0 mg/L

Hence, dilution required = 200 / (8.0 – 2.0) = 33.33 say 35 to 40 times.

Comments: To have accurate test result, the total DO drop during five days incubation should be 2.0 mg/L.

Example: 2. BOD determination

A test bottle containing only seeded dilution water has its DO level drop by 1.0 mg/L in a 5-day incubation. A 300 mL BOD bottle filled with 10 mL of wastewater and the rest seeded dilution water experiences a drop of 6.2 mg/L in the same time period. What would be five day BOD of the wastewater?

Solution:

Dilution factor p = 10/300

Therefore, BOD_5 = [6.2 – 1.0 (1 – (10/300))] / (10/300) = 157 mg/L