Wastewater Treatment Lecture 3

Wastewater Engineering – Biological Oxygen Demand (BOD)

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Dissolved Oxygen

1 Fresh Wastewater

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 wastewater is fresh.

2 Receiving Waters

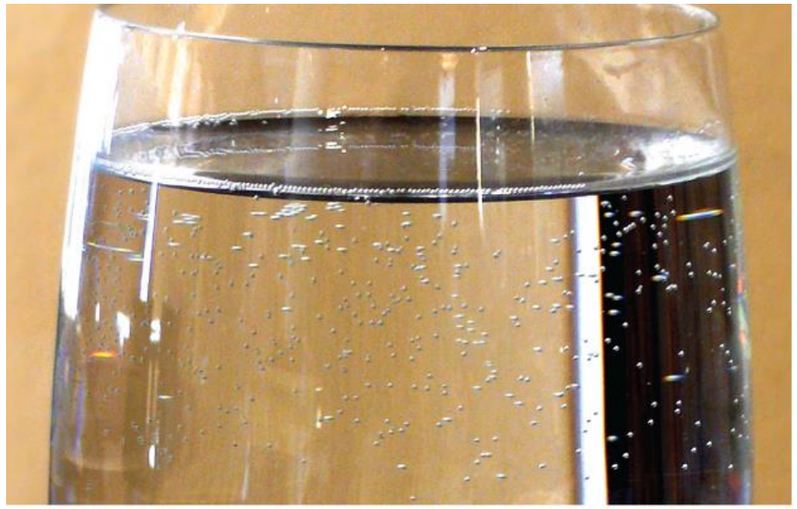
While discharging the treated wastewater into receiving waters, it is essential to ensure that at least 4.5 mg/l of DO is present. If DO is less, aquatic animals like fish, etc. are likely to be killed near the vicinity of disposal.

3 Odour Prevention

DO helps prevent the formation of unpleasant odours by limiting the growth of anaerobic bacteria that produce foul smells.

4 Treatment Efficiency

Monitoring DO levels is important for assessing the effectiveness of biological treatment processes.



Factors Affecting Dissolved Oxygen

Solubility of Oxygen

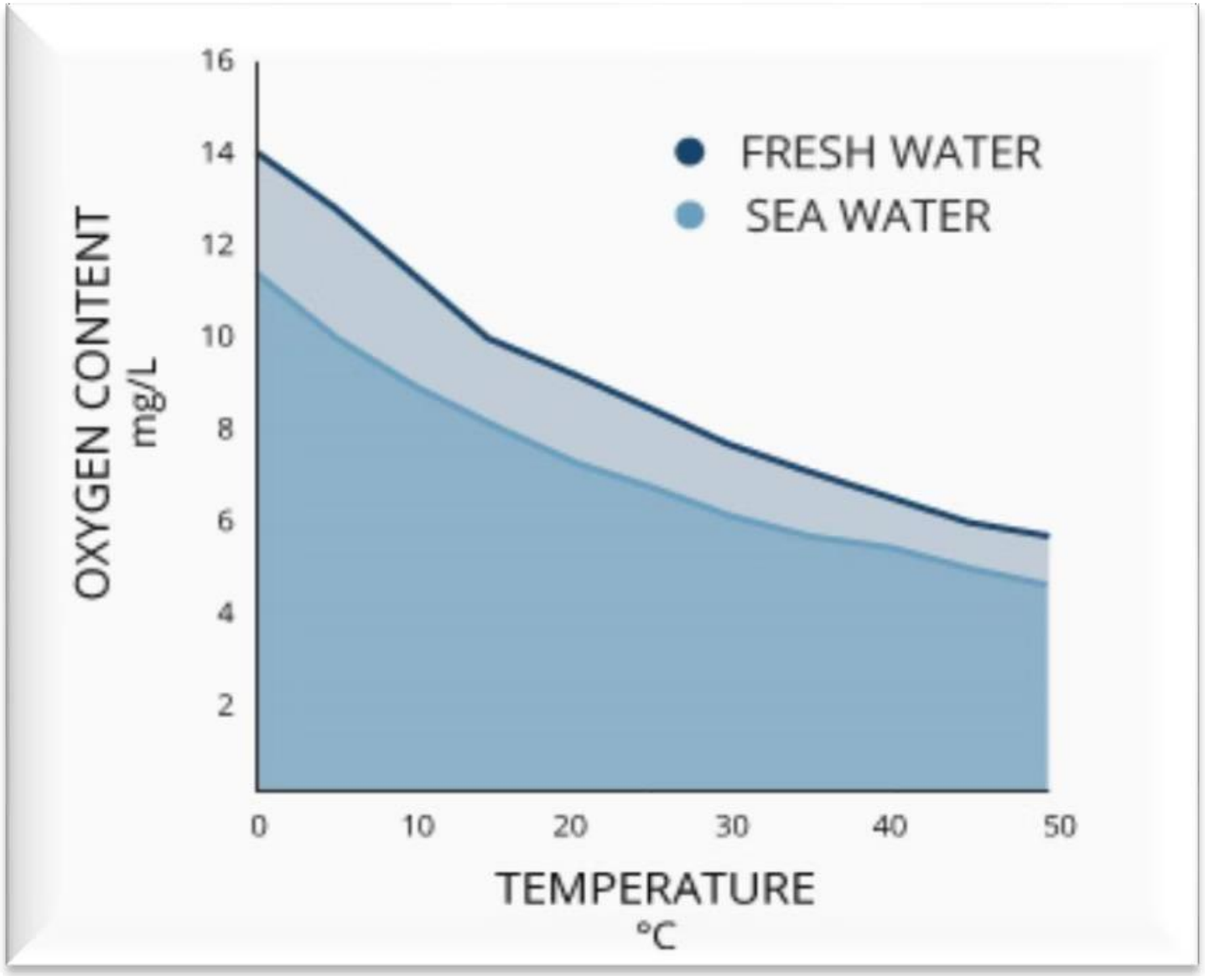
The solubility of oxygen in water is influenced by factors such as temperature, pressure, and salinity.

Temperature

DO levels decrease as the temperature of water increases, as warmer water holds less dissolved oxygen.

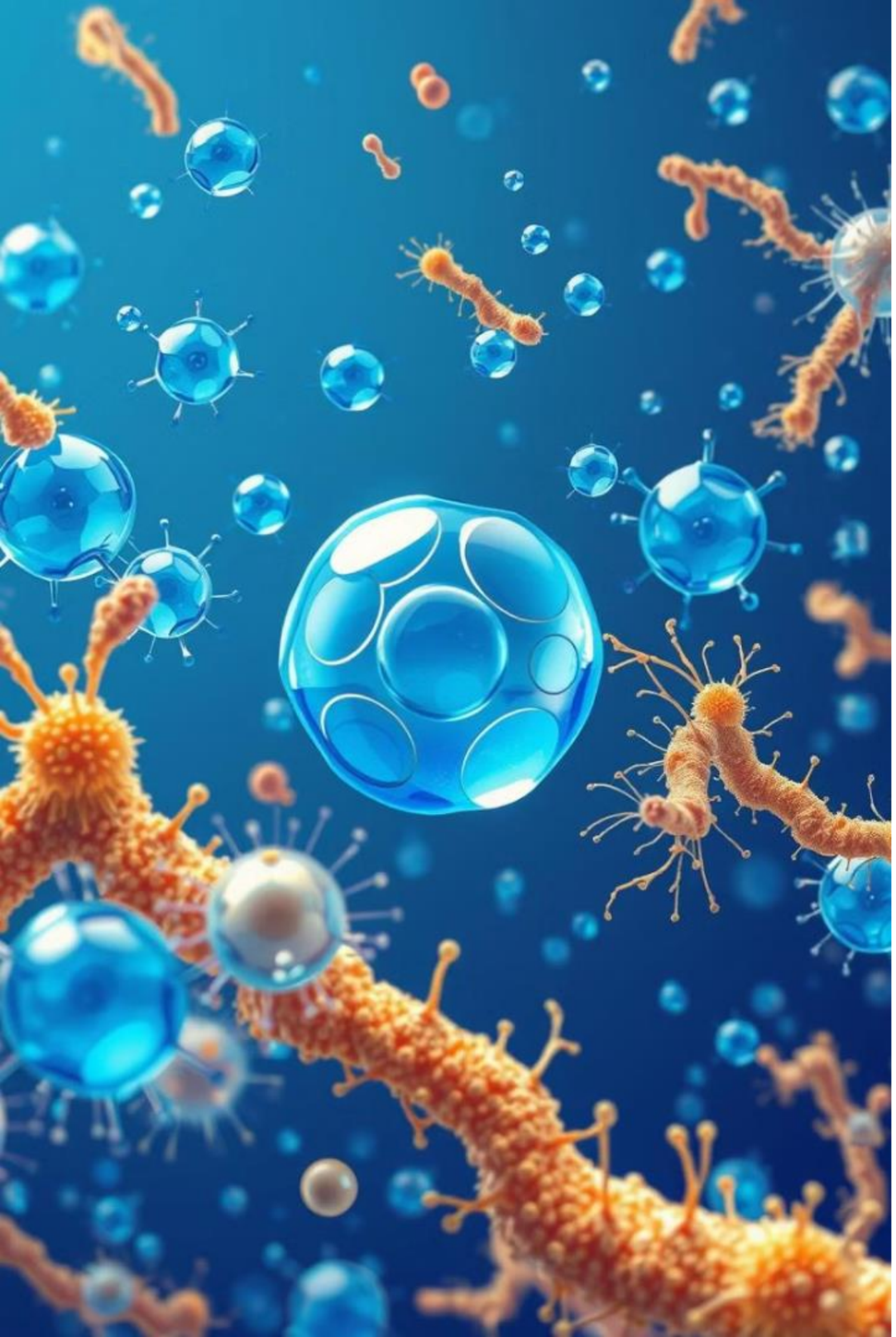
Purity

The presence of impurities like salinity and suspended solids reduces the solubility of oxygen in water.



DO Level and Water Quality

Water Quality	DO Level (ppm (mg/L) O2 at 20°C Sea Level)
Good Quality	8-9
Moderate Pollution	4-5
Highly Polluted	<4.5



Biological Oxygen Demand (BOD)

Biodegradable Organic Matter

Organic matter that can be decomposed by microorganisms.

Non-biodegradable Organic Matter

Organic matter that cannot be decomposed by microorganisms.

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.

$$\{CH_2O\} + O_2 \rightarrow CO_2 + H_2O$$

Biological Oxygen Demand (BOD)

1 BOD Definition

BOD measures the amount of oxygen consumed by microorganisms decomposing organic matter in water.

2 BOD Test

The BOD test is conducted over 5 days at 20°C, mimicking the natural decomposition process.

BOD and Water Quality

Low BOD

Indicates clean water with minimal organic matter, supporting healthy aquatic life.

High BOD

Indicates high organic matter content, leading to oxygen depletion and stress for aquatic organisms.

BOD Test Applications

1 Pollution Strength

The BOD test is used to determine the polluting strength of domestic and industrial wastewater.

2 Stream Pollution Control

BOD measurements are crucial for evaluating the purification capacity of rivers and streams.

3 Treatment Plant Design

BOD data helps in the design and optimisation of wastewater treatment plants.

4 Treatment Process Efficiency

BOD measurements are used to assess the effectiveness of specific treatment processes.

Standard BOD Test

Incubation Period

The standard BOD test is conducted for a duration of 5 days at a constant temperature of 20°C.

Oxidation Completion

During the 5-day incubation period, about 70-80% of the ultimate BOD is typically achieved.

Temperature Control

Maintaining a constant temperature of 20°C is crucial for consistent and accurate BOD measurements.

BOD Test Procedure

1. ## Sample Collection

   Collect 2-3 ml water samples from the desired location.

2. ## Initial DO Measurement

   Measure DO level immediately using a dissolved oxygen test kit.

3. ## Incubation

   Place one sample in a dark incubator at 20°C for 5 days.

4. ## Final DO Measurement

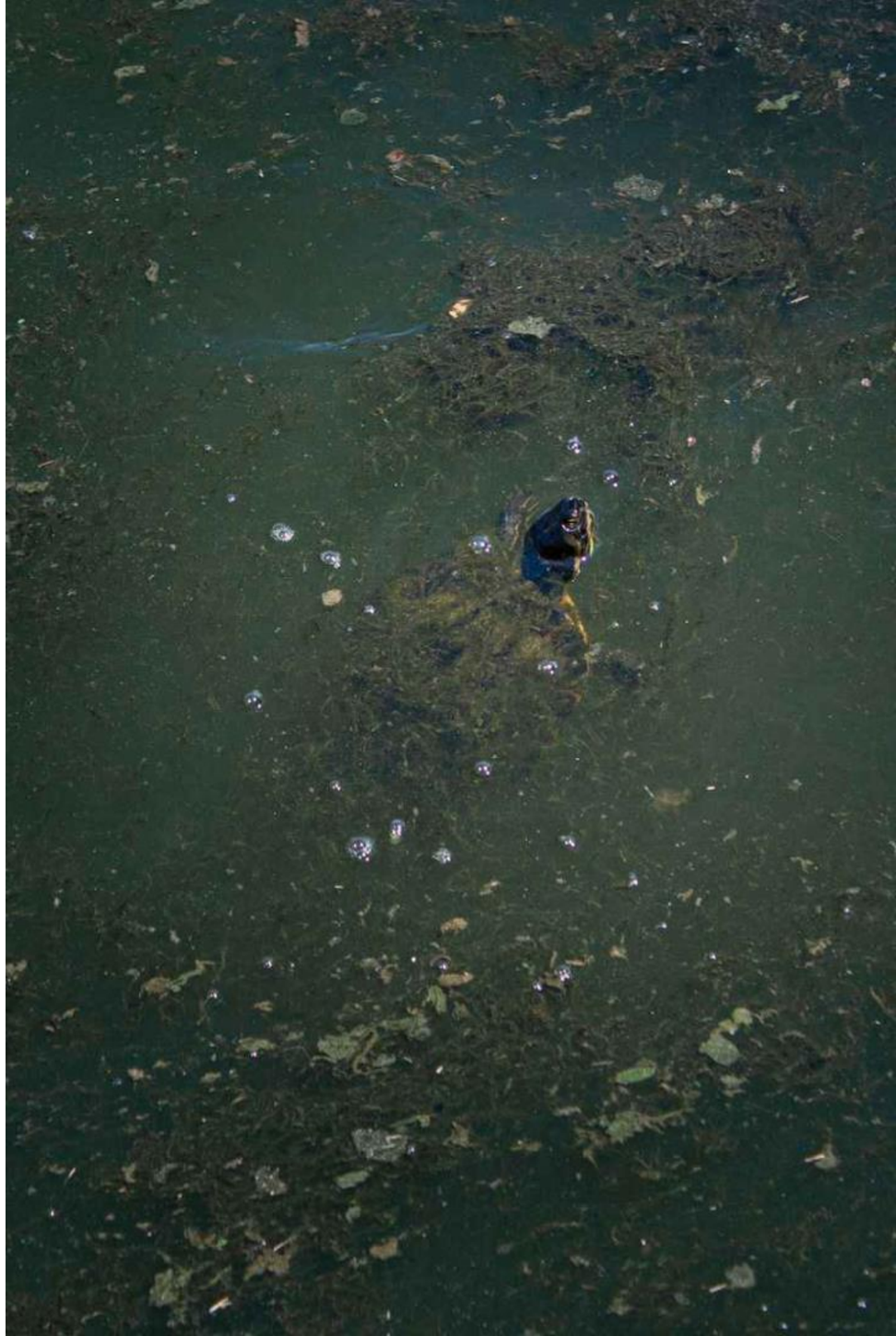
   After 5 days, measure DO level again using the test kit.

5. ## BOD Calculation

   Subtract the day 5 DO reading from the day 1 reading to determine BOD.

BOD Levels and their Implications

BOD Level (mg/l)	Remarks
1	Very Clean
2	Clean
3	Fairly Clean
5	Doubtful
10	Contaminated



BOD Levels in Different Sources

Normal Water

BOD values range from 0-3 mg/l, indicating a high quality of water with minimal organic matter.

River Water

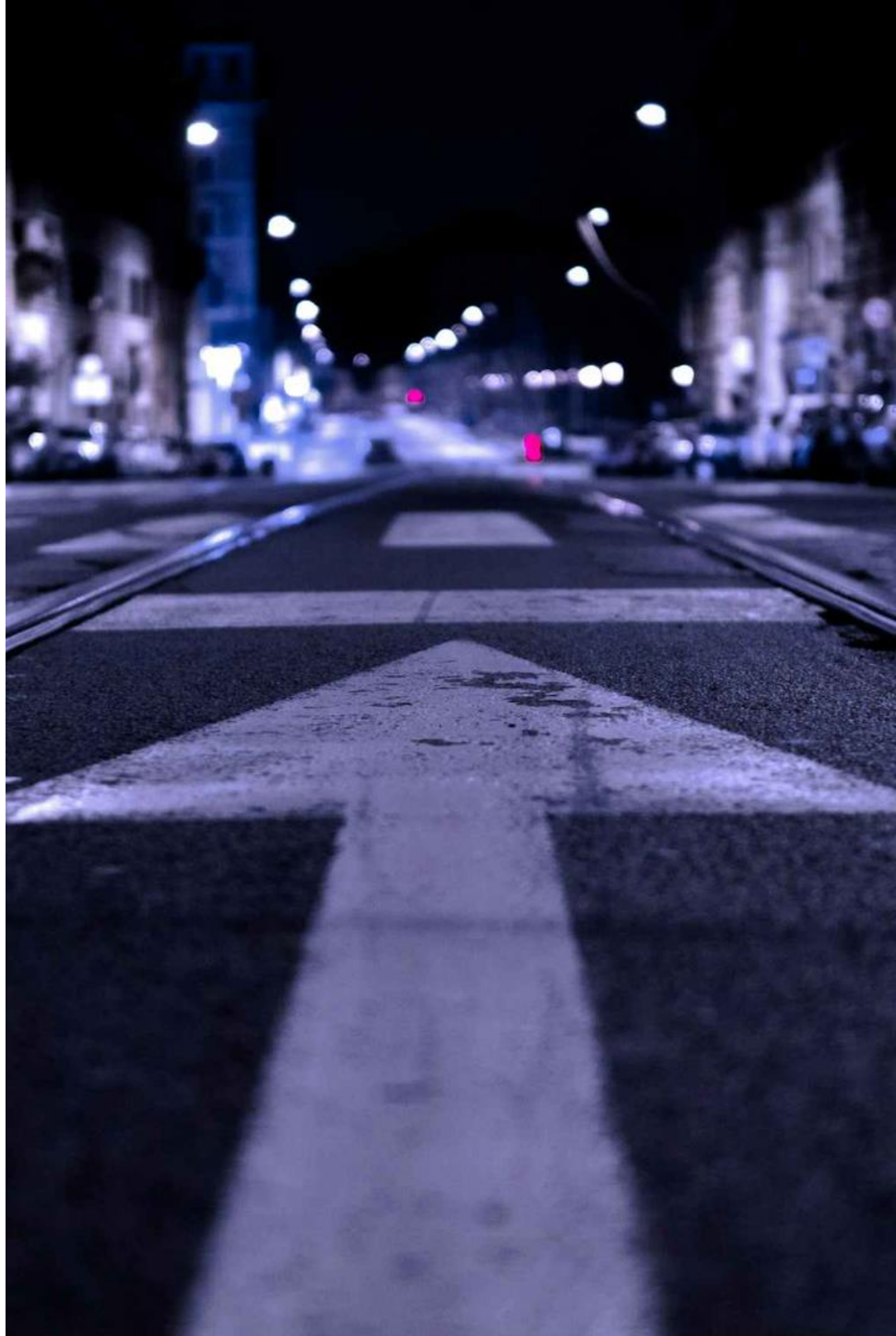
BOD values typically range from 5-20 mg/l, indicating a moderate level of organic matter.

Sewerage Water

BOD values usually fall between 50-100 mg/l, indicating a high level of organic matter from domestic waste.

Industrial Water

BOD values can be significantly higher, ranging from 150-1000 mg/l, reflecting the impact of industrial effluent.



BOD Test

BOD Calculation

$$BOD\ \left(\frac{mg}{L}\right) = \frac{(D1 - D2)}{V}$$

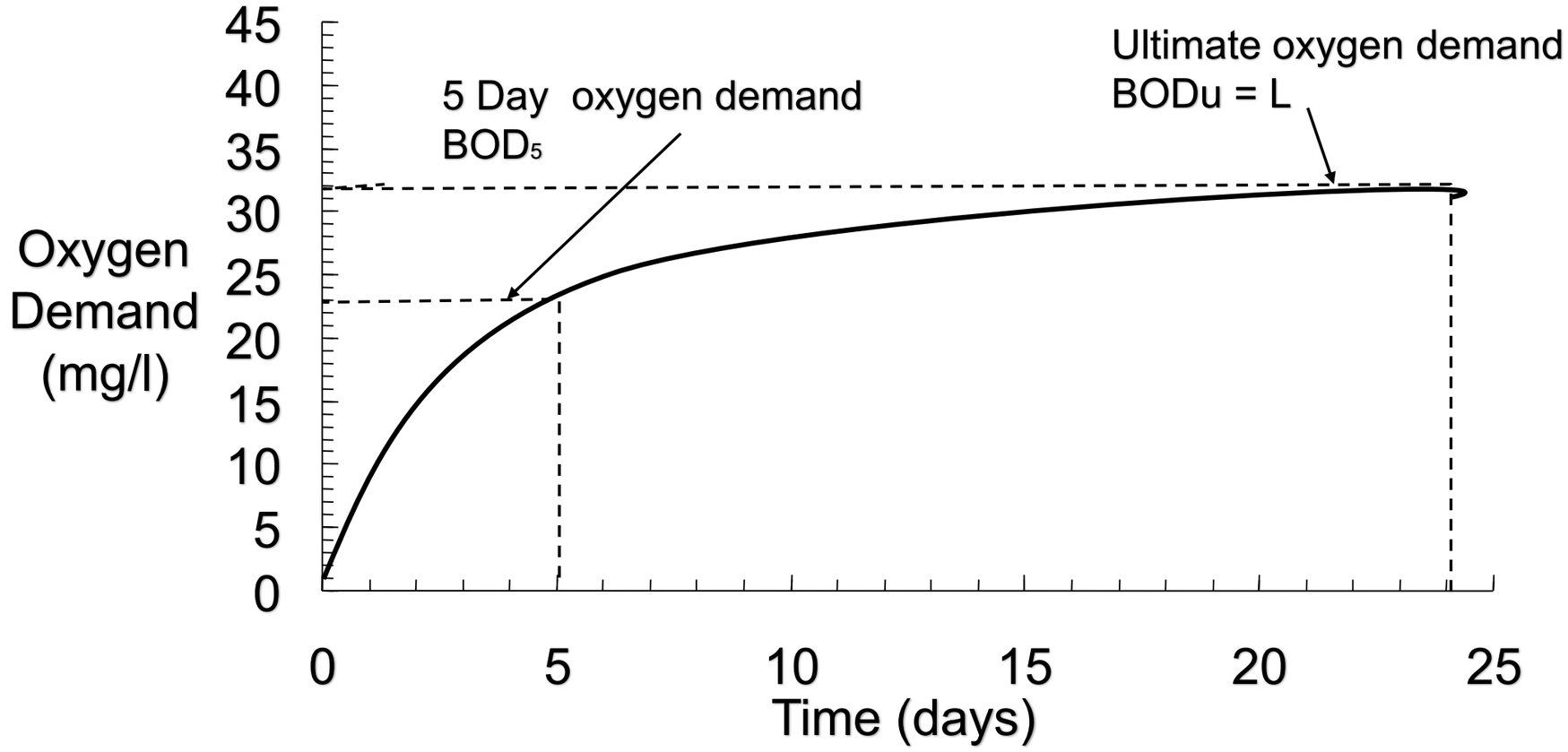
D_1: Initial DO

D2: Final DO

V : The sample's volume (x/300)

Ultimate Biological Oxygen Demand (BOD)

"Amount of oxygen required by bacteria to break down decomposable organic matter under aerobic conditions"



Example 1:

A 30 ml concentration of sample diluted in a 300 ml BOD Bottle Yields these:

Initial DO = 8.5 mg/L

Final DO = 6 mg/L

$$BOD\ \left(\frac{mg}{L}\right) = \frac{(D1 - D2)}{V}$$

$$BOD\ \left(\frac{mg}{L}\right) = \frac{(8.5\ \frac{mg}{l} - 6\ \frac{mg}{l})}{30/300}$$

$$BOD\ \left(\frac{mg}{L}\right) = 25\ \frac{mg}{L}$$

Example 2:

A series of dilutions were prepared in 300 mL BOD bottles using settled raw sewage and dilution water. The dilution range, initial DO, final DO, and depletions (using formula #1) are given in Table 1.

Bottle #	mL WW	Initial DO	Final DO	Depletion
1	3	7.95	5.20	2.75
2	6	7.95	3.85	4.10
3	9	7.90	2.40	5.50
4	12	7.85	1.35	6.50

Calculating BOD

1

Step 1: Calculate BOD for each dilution

$$BOD\ \left(\frac{mg}{L}\right) = \frac{(D1 - D2)}{V}$$

BOD for Bottle 1= (7.95 - 5.20) / (3/300) = 275 mg/L

BOD for Bottle 2 = (7.95 - 3.85) / (6/300) = 205 mg/L

BOD for Bottle 3 = (7.90 - 2.40) / (9/300) = 183 mg/L

BOD for Bottle 4 = (7.85 - 1.35) / (12 / 300) = 162 mg/L

2

Step 2: Calculate the average BOD

Average seed BOD = (275 + 205 + 183 + 162)/4

= 206 mg/L

Ultimate BOD

1

Definition

The ultimate BOD is the amount of oxygen required to decompose all of the organic material after infinite time.

This is usually simply calculated by conducting the experiment over a 20thday period.

2

Calculation

$$BOD_t = BOD_u * (1 - e^{-k*t})$$

where BOD_t is BOD at time t

BOD_u is ultimate BOD

k is the deoxygenation rate constant in days-1 or 1/days

t is time.

Example 3:

The BOD5 of a wastewater is determined to be 150 mg/L. The k value is known to be 0.23 per day. What would be the ultimate BOD value?

$$BOD_t = BOD_u * \left(1 - e^{-k*t}\right)$$

$$150 = BOD_u * \left(1 - e^{-0.23*5}\right)$$

$$BOD_u = 220 \frac{mg}{l}$$

Example 4:

The BOD3 of a wastewater is determined to be 120 mg/L. The k value is known to be 0.21 per day. What would be the ultimate BOD value and BOD5?

1) Determine the ultimate BOD

$$BOD_t = BOD_u * (1 - e^{-k*t})$$

$$120 = BOD_u * (1 - e^{-0.21*3})$$

$$BOD_u = 257\ mg/L$$

2) Determine the BOD5

$$BOD_5 = BOD_u * (1 - e^{-k*t})$$

$$BOD_5 = 257\ mg/L * (1 - e^{-0.21*5})$$

$$BOD_5 = 167\ mg/L$$

Chemical Oxygen Demand (COD)

1

Definition

COD measures the oxygen required to chemically oxidise organic matter using a strong oxidising agent, typically potassium dichromate.

2

Advantages over BOD

The COD test is faster, taking approximately 3 hours compared to the 5-day BOD test, making it more suitable for process control.

3

Scope of Measurement

COD measures both biodegradable and non-biodegradable organic matter, providing a more comprehensive indication of organic pollution.

COD Test Visuals

Sample Preparation

A known volume of wastewater sample is mixed with a strong oxidising agent, potassium dichromate, and a catalyst.

Oxidation

The mixture is heated to a specific temperature, causing the oxidising agent to react with the organic matter.

Titration

The remaining oxidising agent is titrated with a standard solution to determine the amount consumed by the organic matter.