Water Pollution

Reference: Introduction to Environmental Engineering and Science,

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II. Oxygen-Demanding Wastes

- One of the most important measures of the quality of a water source is the amount of dissolved oxygen (DO) present.
- The saturated value of dissolved oxygen in water is on the order of 8 to 15 mg of oxygen per liter of water, depending on temperature and salinity. The minimum recommended amount of DO for a healthy fish population has often been set at 5 mg/L.
- Oxygen-demanding wastes are **substances that oxidize in the receiving body of water**. As bacteria decompose these wastes, they utilize oxygen dissolved in the water, which reduces the remaining amount of DO.
- As DO drops, fish and other aquatic life are threatened and sometimes killed, undesirable odors, tastes, and colors reduce the acceptability of that water as a domestic supply and reduce its attractiveness for recreational uses.
- Oxygen-demanding wastes are usually **biodegradable organic substances** contained in municipal wastewaters or in effluents from certain industries, such as food processing and paper production.
- The oxidation of **certain inorganic compounds** may contribute to the oxygen demand.
- Even **naturally occurring organic matter**, such as leaves and animal droppings, that finds its way into surface water contributes to oxygen depletion.

- There are several measures of oxygen demand commonly used.
  - The ***chemical oxygen demand*** **(COD)** is the amount of oxygen needed to chemically oxidize the wastes
  - The ***biochemical oxygen demand*** **(BOD)** is the amount of oxygen required by microorganisms to biologically degrade the wastes. BOD has traditionally been the most important measure of the strength of organic pollution, and the amount of BOD reduction in a wastewater treatment plant is a key indicator of process performance.
  - **Theoretical Oxygen Demand (ThOD)**
  - **Total Organic Carbon (TOC)**

Biochemical oxygen demand (BOD)

Aerobic decomposition of organic matter:

$$\text{Organic matter} + O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O + \text{New cells} + \text{Stable products } (NO_3, PO_4, SO_4, \ldots)$$

Anaerobic decomposition of organic matter:

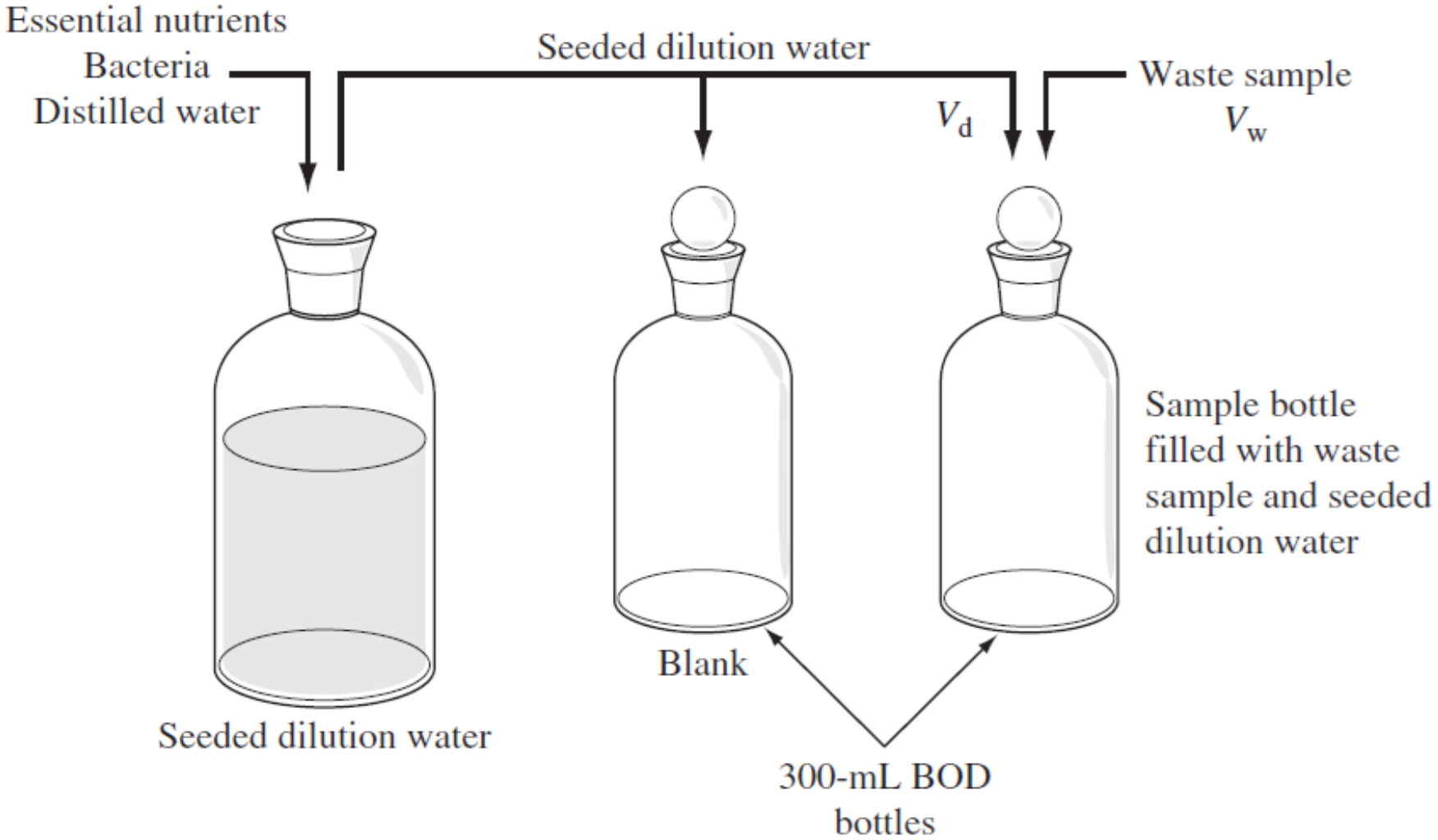
$$\text{Organic matter} \xrightarrow{\text{Microorganisms}} CO_2 + H_2O + \text{New cells} + \text{Unstable products } (H_2S, NH_3, CH_4, \ldots)$$

- The amount of oxygen required by microorganisms to oxidize organic wastes aerobically is called the **biochemical oxygen demand (BOD)**.
- BOD is expressed in milligrams of oxygen required per liter of wastewater (**mg/L**).

Five-Day BOD Test

- The total amount of oxygen that will be required for biodegradation is an important measure of the impact that a given waste will have on the receiving body of water.
- While we could imagine a test in which the oxygen required to degrade *completely* a sample of waste would be measured, for routine purposes, such a test would take too long to be practical (at least several weeks would be required).
- As a result, it has become standard practice simply to measure and report the oxygen demand over a shorter, **restricted period of five days**, realizing that the ultimate demand may be considerably higher.

- The five-day BOD (BOD_5), is the total amount of oxygen consumed by microorganisms during the first five days of biodegradation.
- The test involves putting a sample of waste into a stoppered bottle and measuring the concentration of dissolved oxygen (DO) in the sample at the beginning of the test and again five days later.
- The difference in DO divided by the volume of waste would be the five-day BOD.
- **Light must be kept out of the bottle to keep algae from adding oxygen by photosynthesis, and the bottle is sealed to keep air from replenishing DO that has been removed by biodegradation**.
- To standardize the procedure, the test is run at a fixed temperature of 20°C.
- Since the oxygen demand of typical waste is several hundred milligrams per liter, and the saturated value of DO for water at 20°C is only 9.1 mg/L, it is usually necessary to dilute the sample to keep the final DO above zero. If during the five days, the DO drops to zero, the test is invalid because more oxygen would have been removed had more been available.



Laboratory test for BOD using seeded dilution water.

The five-day BOD of a diluted sample is given by

$$BOD_5 = \frac{DO_i - DO_f}{P}$$

where

DO_i = the initial dissolved oxygen (DO) of the diluted wastewater
DO_f = the DO of the diluted wastewater, 5 days later

$$P = \text{the dilution fraction} = \frac{\text{volume of wastewater}}{\text{volume of wastewater plus dilution water}}$$

A standard BOD bottle holds 300 mL, so P is just the volume of wastewater divided by 300 mL.

EXAMPLE 1 Unseeded Five-Day BOD Test

A 10.0-mL sample of sewage mixed with enough water to fill a 300-mL bottle has an initial DO of 9.0 mg/L. To help assure an accurate test, it is desirable to have at least a 2.0-mg/L drop in DO during the five-day run, and the final DO should be at least 2.0 mg/L. For what range of BOD_5 would this dilution produce the desired results?

Solution The dilution fraction is $P = 10/300$. To get at least a 2.0-mg/L drop in DO, the minimum BOD needs to be

$$BOD_5 \geq \frac{DO_i - DO_f}{P} = \frac{2.0 \text{ mg/L}}{(10/300)} = 60 \text{ mg/L}$$

To assure at least 2.0 mg/L of DO remains after five days requires that

$$BOD_5 \leq \frac{(9.0 - 2.0) \text{ mg/L}}{(10/300)} = 210 \text{ mg/L}$$

This dilution will be satisfactory for BOD_5 values between 60 and 210 mg/L.