Better Plants
U.S. DEPARTMENT OF ENERGY

Biological Wastewater Treatment Training Series
Presentation #1: Wastewater Quality

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Overview

- This series of presentations is designed to help participants understand the basic concepts of biological wastewater treatment.
- There will be 15 presentations, each of which cover a specific area of biological treatment.
- The goal is to prepare participants to visit activated sludge facilities, to assess operating conditions, and to suggest ways to enhance process performance and save energy.
- Each presentation will be about 30 to 40 minutes in length.

Overview – A List of the 15 Presentations

- Wastewater Quality
- Introduction to Biological Wastewater Treatment
- Activated Sludge Microbiology
- Introduction to Activated Sludge Biokinetics
- Activated Sludge Process Modifications – Part I
- Activated Sludge Process Modifications – Part II
- Activated Sludge Process Control
- Introduction to Biological Nitrification-Denitrification

Overview – A List of the 15 Presentations (continued)

- Denitrification
- Introduction to Aerobic Digestion of Sludge
- Understanding Performance of Aeration Equipment
- Optimize Your WWTP, Save Energy, Reduce Nutrient Loads
- Using the Bio-Tiger Model: Input Data and Output Data
- Case Studies: Using Bio-Tiger Model to Save Energy in Conventional Activated Sludge Processes
- Case Studies: Using Bio-Tiger Model to Save Energy in Oxidation Ditches

A. Biochemical Oxygen Demand

- Amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions at 20C for 5 days

$$C_aH_bO_c + O_2 \rightarrow CO_2 + H_2O + \text{biomass} + \text{energy} + \text{OEP}$$

*OEP = other end products

$$y = L\,(1 - 10^{-kt})$$

where: y = BOD at any time t in days
L = ultimate BOD
k = BOD bottle constant

Biochemical Oxygen Demand

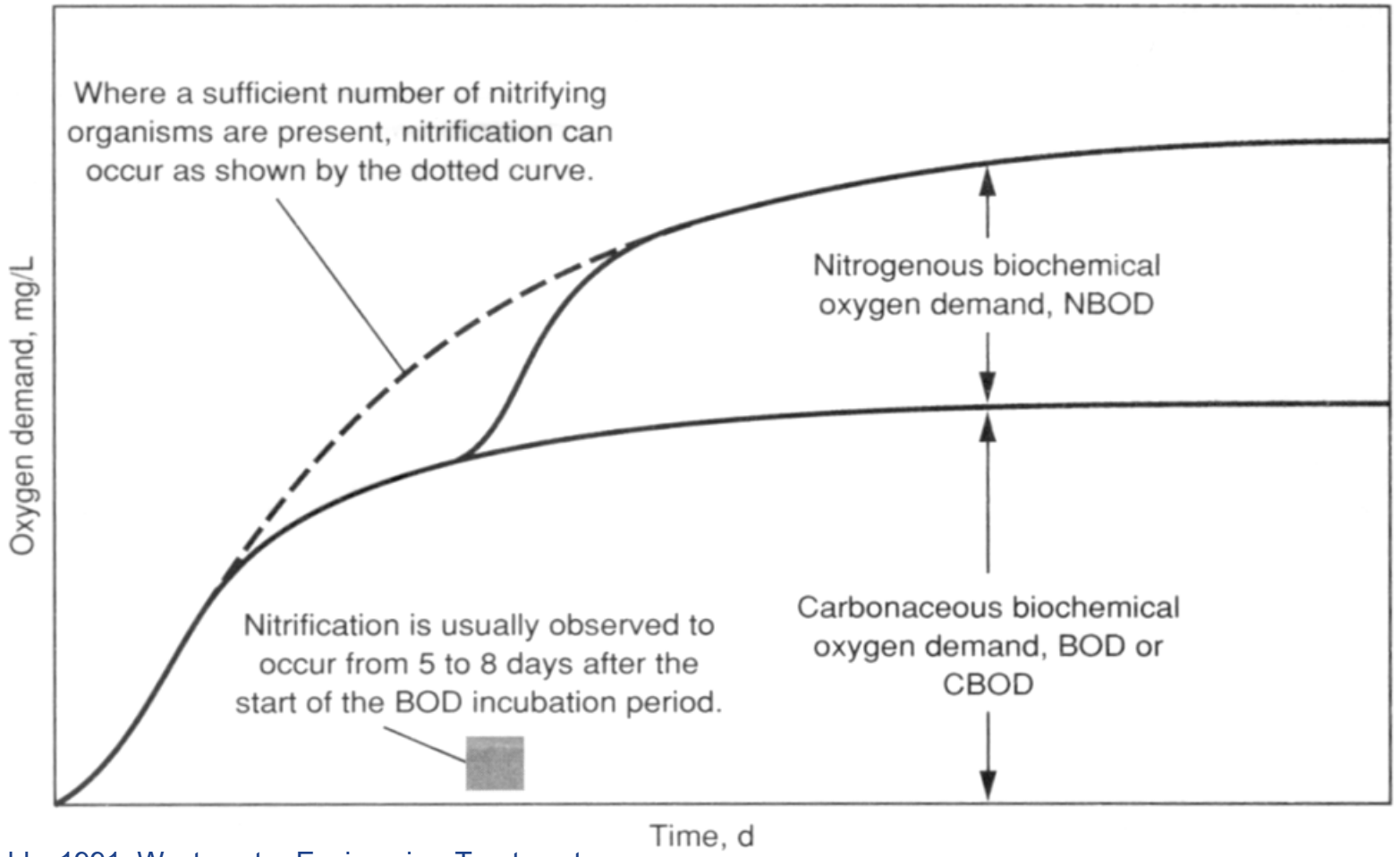
Carbonaceous BOD (CBOD) - Used to quantify the amount of oxygen used by microorganisms to oxidize organic constituents in a wastewater.

Nitrogenous BOD (NBOD) - The amount of oxygen used by microorganisms to oxidize dissolved nitrogen in a wastewater.

$$2NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + 2H_2O + 4H^+ + \text{new cells}$$

$$2NO_2^- + O_2 \longrightarrow 2NO_3^- + \text{new cells}$$

Biochemical Oxygen Demand



Ref: Metcalf & Eddy, 1991, Wastewater Engineering Treatment, Disposal and Reuse

Uses of BOD Data

- To determine the organic strength of wastewaters
- To evaluate the purification capacity of receiving bodies of water
- To define discharge standards where organic loading must be restricted to maintain desired dissolved oxygen level
- To check on the quality of wastewater effluent

Uses of BOD Data

- To determine the size of wastewater treatment facilities (e.g., aeration tanks)
- To evaluate the efficiency of wastewater treatment units
- To determine sewer user charges for indirect industrial dischargers

B. Chemical Oxygen Demand

Definition: Amount of oxygen that is required to oxidize an organic compound under the influence of a strong oxidant ($K_2Cr_2O_7$) in an acid environment (heat, catalyst)

$$C_aH_bO_c + Cr_2O_7 + H^+ \rightarrow Cr^{3+} + CO_2 + H_2O$$

- Major advantage of COD test: short time required (3 hours)
- If a relationship can be established between BOD and COD, it facilitates a fairly quick estimate of the BOD value.

C. Theoretical Oxygen Demand

- Carbohydrates: glucose
- Fats: stearic acid
- Amino Acids: glycine

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

- 1 mg glucose requires 192/180 = 1.067 mg O_2

D. Solids

- **Settleable Solids** – suspended solids that will settle under quiescent conditions because of the influence of gravity
- **Total Solids** – matter that remains as residue upon evaporation and drying at 103°C
- **Suspended Solids** – solids that are retained by a standard filter pad with an effective retention of 1.2 μm
- **Dissolved Solids** – solids that pass through a standard filter pad with an effective retention of 1.2 μm
- **Volatile Solids** – solids which are combustible at 550 °C; volatile solids are primarily organic matter

Application of Solids Data

- To determine the need for and design of settling tanks
- To determine the efficiency of sedimentation units
- To evaluate the strength of wastewaters
- To determine the solids loading on wastewater treatment units
- To control the biomass in the activated sludge process
- To determine the design and operation of sludge digestion and dewatering units

E. Total Organic Carbon

- A carbon analyzer uses the concept of complete combustion of all organic matter to CO_2 and H_2O; gas stream passes through an infrared analyzer; known carbon standards are used for calibration.

$$BOD_5/TOC \cong O_2/C \cong \frac{32}{12}\ (0.7)\ (0.77) = 1.44$$

(0.7): 70% biodegradable

(0.77): % of ultimate BOD

F. Specific Organic Compounds

- Surfactants –
  - Surface-active agents which are large polar molecules that are slightly soluble in water and may cause foaming;
  - Detergents contain surfactants

- Phenol –
  - The monohydroxy derivative of benzene;
  - Is toxic to bacteria in concentrated solution;
  - Occurs as a natural component of coal-gas; coal-coking, and petroleum industry wastewaters;
  - Biological treatment of phenol at concentrations up to 1,000 mg/l is possible if the bacteria are acclimated.

Specific Organic Compounds (continued)

- Fats, Oil and Grease –
  - Fats and oils are glycerides of fatty acids;
  - They serve as food for humans as well as bacteria, since they can be hydrolyzed to fatty acids and alcohols;
  - FOG are found in high concentrations in food processing, petroleum, and other industrial wastes.

Comments on FOG

- May obstruct sanitary sewers
- Petroleum oils are degraded slowly by bacteria
- May cause slug loading of biotreatment facilities
- May prevent or reduce oxygen transfer and degradation in biotreatment facilities
- Animal/vegetable oil in a dispersed state is metabolized and removed readily in a biological WWTP

Comments on FOG

- High FOG may interfere with monitoring equipment (DO probes, pH probes, etc.)
- Petroleum FOG may present fire/explosion hazards in WWTP
- May cause problems with dewatering of raw and digested primary sludge
- Petroleum FOG may pass thru WWTP

Pesticides

- Pesticides –
  - Trace organic compounds which are toxic to most life forms;
  - Includes insecticides, algicides, fungicides, herbicides, etc.;
  - Major types are chlorinated pesticides (DDT, lindane, endrin, etc.), organic phosphorus pesticides (methyl parathion, malathion, etc.), and carbamate pesticides (general formula = RHNCOOR')

Comments on Pesticides

- May contaminate ground and surface water supplies
- May concentrate in aquatic plants and animals
- Chlorinated pesticides are most resistant to biodegradation and may persist for months or years following application
- Are highly toxic to aquatic life or birds which feed on aquatic life
- Organic phosphorus pesticides generally are less toxic to fish life

G. Nitrogen

- Nitrogen is important to life processes of all plants and animals
- Nitrogen may exist in several forms (organic-N, ammonia-N, nitrite-N, and nitrate-N)
- Nitrogen fertilizes plant life:

$$NO_3^- + CO_2 + \text{green plants} + \text{sunlight} \rightarrow \text{protein}$$

$$NH_3 + CO_2 + \text{green plants} + \text{sunlight} \rightarrow \text{protein}$$

Nitrogen (continued)

- Organic-N may be hydrolyzed to ammonia by bacteria (some types of organic-N are difficult to biodegrade, may pass thru POTW and interfere with chlorine disinfection)
- Ammonia-N is toxic to fish (free ammonia at concentrations ≥ 0.2 mg/l can cause fatalities in several species of fish), O_2 demand (NBOD), an may cause eutrophication
- Ammonia-N reacts with chlorine, forming chloramines
- Nitrite-N and nitrate-N may stimulate algal and aquatic plant growth

Nitrogen (continued)

- Nitrogen is required by microbes in biotreatment systems (BOD/N/P ratio ≅ 100/5/1 to satisfy the N and P requirements of bacteria)
- Under anoxic conditions nitrate and nitrite are reduced to nitrogen gas (denitrification)
- Nitrogen may be important in the design and operation of WWTPs
- N content of sludges is important in determining their fertilizing value

H. Phosphorus

- P is essential to the growth of algae and aquatic plants
- Microorganisms in biotreatment need P for reproduction and synthesis of new cell tissue
- P concentrations as low as 0.005 mg/l may cause nuisance algal blooms in surface waters
- May household detergents contain 12 to 13 percent P
- P content of digested sludges is about 1%
- P usually exists as orthophosphate (PO_4^-) or polyphosphate (PO_3, P_3O_{10}, P_2O_7)

I. Sulfate

- Major anion in natural waters
- May cause crown corrosion of sanity sewers
- $SO_4^=$ is reduced to H_2S under anaerobic conditions
- $SO_4^=$ serves as an electron acceptor for biochemical oxidation or organic matter by sulfate-reducing bacteria

J. Trace Inorganics

- Heavy metals in trace quantities are important to biological activity
- Heavy metals in higher concentrations are toxic to humans, fish, and aquatic life
- Principal source of metals is industrial wastes from manufacturing operations such as metal finishing

Thank you!

For Questions or Comments please reach out to the following:

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