Activated Sludge Basics

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Session Overview
» Wastewater Characteristics
» Bacterial Growth
» Microorganisms
» Aeration Basin Process Objectives
» Secondary Clarifier Process Objectives
» Process Controls
Wastewater Solids Definitions

TOTAL SOLIDS
- Settleable Solids
- Colloids
- Total Volatile Solids
- Total Fixed Solids
- Total Suspended Solids
- Total Dissolved Solids
- Volatile Suspended Solids
- Fixed Suspended Solids
- Volatile Dissolved Solids
- Fixed Dissolved Solids

Wastewater Organics

TOTAL ORGANIC CARBON
- Chemical Oxygen Demand (COD)
- Biodegradable Organics or Ultimate Biochemical Oxygen Demand (UBOD)
- Total Biochemical Oxygen Demand (TBOD or BOD₅)
- Soluble BOD₅ (SBOD₅)
- Readily Available BOD₅ (rBOD₅)
Wastewater Organics
Biological Oxygen Demand

NBOD + CBOD = Total Oxygen Demand

Adsorption and Absorption

- Adsorption is the adherence of food to the bacterial cell.

- Absorption is the transfer of food into the microorganisms cell.

- Many filamentous organisms and other bacteria (e.g., nitrifiers) can only absorb food.
Process Description

OXIDATION AND SYNTHESIS

$\text{COHNS + nutrients} \xrightarrow{\text{bacteria}} \text{CO}_2 + \text{NH}_4 + \text{C}_2\text{H}_4\text{NO}_2 + \text{other end products}$

ENDOGENOUS RESPIRATION

$\text{C}_2\text{H}_4\text{NO}_2 + \text{O}_2 \xrightarrow{\text{bacteria}} 5\text{CO}_2 + 2\text{H}_2\text{O} + \text{NH}_4 + \text{energy}$

Bacterial Growth

[Graph showing bacterial growth phases: LAG, LOG, DECLINING GROWTH, STATIONARY, INCREASING DEATH, LOG DEATH, DEATH]
Aerobic Respiration Oxidizes Organics to $\text{CO}_2$ and $\text{H}_2\text{O}$ for Energy

Cells Energy Harvesting
Cellular Respiration

- Mitochondria are engine of our cells
- Sugar is burned as fuel
- Exhaust is $\text{CO}_2$ and $\text{H}_2\text{O}$
Cells Energy Harvesting
Two Ways

» Step 1 - Glycolysis

» Step 2
  - Aerobic – Cell Respiration
    • Available free oxygen
  - Anaerobic - Fermentation
    • No available free oxygen

Cells Energy Harvesting
Glycolysis

» Glycolysis does not need oxygen
» First step for both aerobic and anaerobic reactions
» Happens in cytoplasm

2 pyruvic acid molecules

4 $\text{H}^+$ + energy stored in 2 ATP molecules
Cells Energy Harvesting
Aerobic Respiration

» Pyruvic acid molecules are broken down completely to CO₂ and H₂O
» 34 ATPs

Pyruvic Acid + 2 H⁺ + 3 O₂ → 3 Carbon Dioxide + 3 H₂O + 34 ATP

Cells Energy Harvesting
Fermentation
(Anaerobic Respiration)

» Pyruvic acid molecules are turned into some waste product
» Two common types
  – Lactic acid fermentation
  – Alcohol fermentation

Pyruvic Acid + 2 H⁺ → Lactic Acid
Lactic Acid → Ethanol + Carbon Dioxide
» 2 ATP
Cells Energy Harvesting Comparison

**Aerobic Respiration**
» Requires free O₂
» 34 ATP Produced
» Byproducts
  – CO₂
  – H₂O

**Fermentation**
» No free O₂
» 2 ATP Produced
» Byproducts
  – Lactic Acid
  – Ethanol
  – CO₂

Forms of Aerobic Respiration

» Aerobic
  – Free oxygen available

» Anoxic
  – Denitrification
  – NO₃ to N₂ provides source of O₂ for aerobic respiration providing energy to cell

» Anaerobic
  – ATP reduces to ADP to provide energy for cell
ATP & ADP Energy Storage

ADP-ATP Energy Conversion

\[ \text{ADP} + \text{P} \rightarrow \text{ATP} \rightarrow \text{ADP} + \text{P} \]

Uses Energy
Yields Energy

Rate of Removal

Process converts BOD to Bacterial mass

Therefore,

\[ \text{BOD uptake rate} = \text{Bacterial Growth Rate} \]
Microorganisms

» Bacteria
» Fungi, yeast
» Protozoa
» Metazoa

Bacteria and Filaments Bound Together in Floc Particles

Microorganisms

Amoebas
Microorganisms

Free-Swimming Ciliate

Microorganisms

Halosphaera minor

Flagellates
Microorganisms

Stalked Ciliate

Rotifer

Microorganisms

Cilia
Mouth
Digestive gland
Intestine
Corona
Mastax
Pseudocoel
Stomach
Anus
Foot with toes
Microorganisms

Filamentous Organisms

Predominance of Organisms vs. Food

Increase Wasting
Activated Sludge Process

Aeration Basin Process Objectives

» Oxidize aerator influent carbonaceous biochemical oxygen demand (cBOD)
» Convert cBOD to suspended solids
» Adsorb suspended solids onto floc
Secondary Clarifier Process Objectives

» Flocculate mixed liquor suspended solids (MLSS)
» Separate MLSS from treated effluent
» Collect settled sludge for return to aeration basin
» Remove solids from system (wasting)

Controls of Activated Sludge
Activated Sludge Controls

» Dissolved oxygen (DO)
» Return activated sludge (RAS)
» Waste activated sludge (WAS)

Dissolved Oxygen

» Ensures *aerobic* conditions throughout the aeration basin
» Ensures aerobic conditions throughout floc

D.O. must penetrate to center of floc
Return Activated Sludge (RAS)

» Distribution tool
  – Balances MLSS between aeration basin and secondary clarifier
» Determines Waste Activated Sludge (WAS) concentration
» Not for inventory control

Waste Activated Sludge (WAS)

» Inventory control tool
  – Determines mass of solids maintained in system
  – Determines F/M ratio
  – Determines point on growth curve
  – Determines Sludge Age
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