Incorporating Microbiology Into Wastewater Process Control

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Wastewater from homes, industry, and sometimes storm water enter the WRP via interceptors.

Bar screens trap large debris.

Microorganisms mixed with wastewater (mixed liquor) in the presence of oxygen, consume biodegradable materials.

Primary tank floats oil & grease and removes settleable solids.

Water is slowed down to allow grit to settle out.

Primary solids are pumped to solids handling/processing.

Mixed liquor is pumped to secondary clarifiers where biological solids, containing microorganisms is separated from the liquid.

Secondary Clarifier

Most of the microorganisms are returned to aeration to feed on the continuous inflow of wastewater.

Aeration Basin

Final treated water is discharged to the waterbody.

Some secondary solids are wasted to solids handling/processing.

Final treated water is discharged to the waterbody.
Aeration Basin

Primary Effluent

RAS
Activated Sludge

- The Activated Sludge process is a biological process.
- In order to properly evaluate this process, we should incorporate biological tools.
- One of those biological tools is the microscope.
Microbiology of Activated Sludge

- Activated sludge is a mixture of microorganisms that come in contact with and digest bio-degradable materials (food) in wastewater.

- Different types of microorganism will always grow in the system. The organisms that are best suited to the environment will dominate.
Microbiology of Activated Sludge

- Activated Sludge Microorganisms
  - Bacteria (95%)
  - Protozoa (4%)
  - Metazoa (1%)
BACTERIA

- Bacteria are classified in many ways
  - **Aerobic** – require oxygen for growth and maintenance
  - **Anaerobic** – cannot tolerate oxygen
  - **Facultative** – prefer oxygen but can live without it

- The most important microorganisms in the activated sludge system are the aerobic bacteria.
Bacteria

- Single-celled microorganisms
- Consume the biodegradable material found in wastewater
- Proteins, carbohydrates, fats and many other compounds
Bacteria

- The primary role of bacteria
  - Removal of BOD
  - Produce more bacteria
  - Form biological floc large enough and compact enough to settle.
Bacteria

- Bacteria can only consume soluble organic material.
- Insoluble organics or particulates must be converted to soluble form before they can be consumed by the bacteria.
- “Like Pecans in the shell”
Bacteria: Adsorption & Absorption
Aeration Basin

Food

Primary Effluent

RAS
When there is plenty of food available, bacteria use the food mostly for growth and some for energy.

- A growing bacterium have flagella (hair-like structures on the outside of the cell).
- The flagella makes it motile, able to move in search of food.
Bacteria: Growth Characteristics

Influent

Return Sludge

High Food

Low Food

“Food”

Detention Time
Bacteria: *Growth Characteristics*

- When food becomes limited, bacteria take steps to conserve energy
  - The bacterium loses its flagella and can no longer swim.
  - They begin to form a thicker slime layer.
Bacteria: Growth Characteristics

- High Food
- Low Food

Influent

Return Sludge

“Food”

Floc Formation

Detention Time (Sludge Age)
Bacteria: *Growth Characteristics*

- **Sludge Age**
  - The key to good treatment is the separation of the biological solids from treated water.
PROTOZOA

- Most protozoa are aerobic microorganisms.
- Some smaller protozoa take in soluble nutrients through the cell membrane.
- Others have specialized structures or mouth-like openings and feed on other microorganisms such as bacteria and algae and other solid matter.
Protozoa

- Protozoa are classified based on how they move:
  - Amoeba
  - Flagellates
  - Ciliates
    - Free-swimming ciliates
    - Crawling (grazing) ciliates
    - Sessile (stalked or attached) ciliates
FOOD

BACTERIA
Protozoa: *Naked Amoeba*
Protozoa: *Amoeba*

- The presence of large numbers of amoeba in the mixed liquor sample indicate:
  - Shock loading of BOD
  - The presence of large amounts of particulate matter
  - Lack of oxygen
  - Low levels of toxicity or other unfavorable conditions
Protozoa: *Flagellates*
Protozoa: *Flagellates*
Protozoa: *Flagellates*

- The presence of large numbers of flagellates in the mixed liquor sample indicate:
  - Incomplete treatment
  - Shock loading of BOD
  - The presence of large amounts dead or decaying material
Protozoa: *Ciliates*

- 7,500 species of ciliates - generally classified base on cilia arrangement, but for the purpose of studying activated sludge, ciliates will be classified based on their ability to compete for food
  - Free-swimming ciliates
  - Crawling (grazing) ciliates
  - Sessile (stalked or attached) ciliates
Protozoa: *Free Swimming Ciliates*
Protozoa: *Free Swimming Ciliates*

- The presence of large numbers of free-swimming ciliates indicate:
  - An abundance of active bacteria
  - Early in the treatment process
  - Nutrients have not been depleted
BACTERIA

FOOD
Protozoa: *Crawling Ciliates*
Protozoa: *Crawling Ciliates*

- The presence of large numbers of crawling ciliates indicate:
  - Most of the organic material has been removed
  - Bacteria are clumping together to form floc
  - Adequate detention time
Protozoa: *Stalked Ciliates*

*Vorticella*
Protozoa: *Stalked Ciliates*
Protozoa: *Stalked Ciliates*

*Carchesium*
Protozoa: *Stalked Ciliates*
Protozoa: *Stalked Ciliates*
Protozoa: *Stalked Ciliates*

- The presence of large numbers of stalked ciliates indicate:
  - Most of the organic material has been removed
  - As sludge ages, the dominance of stalked ciliates changes from single stalks to colonial species
  - “The greater the number of heads, the older the sludge”
BACTERIA

FOOD

Rubin Jr.
Protozoa: *Attached Ciliates*

*Stentors*
Protozoa: *Attached Ciliates*

*Suctoria*
Protozoa: *Attached Ciliates*

*Suctoria*
Metazoa include all multicellular organisms including microorganisms. Metazoa have very little to do with the removal of organic material from the wastewater. Metazoa dominate in longer age systems including lagoon treatment systems.
Metazoa

- Multi-cellular microorganisms that feed on bacteria, algae and protozoa.
  - Rotifers
  - Nematodes
  - Tartigrades (water bear)
Metazoa: *Rotifers*
Metazoa: *Rotifers*
Metazoa: *Nematodes*
Metazoa: Waterbear
Metazoa: *Waterbear*
Why Microbiology?

- Any shift in the treatment system environment will affect the behavior of the microorganisms either positively or negatively.
- Observing their behavior will help monitor the process and help predict treatment system upsets, before they become a problem.
Microscopic Observations

- Relative Protozoa Count
- Nutrient Deficiency
- Toxicity or Adverse/Unfavorable Conditions
Microscopic Observations:

Protozoa Count

- Relative Abundance
  - The relative number of protozoa in each of the protozoa groups
    - Amoeba
    - Flagellates
    - Free-swimming ciliates
    - Crawling ciliates
    - Stalked ciliates
    - Rotifers, Nematodes, etc.
Microscopic Observations: Protozoa Count

- Relative Abundance

- In a well operating system the three dominant groups should be:
  - free-swimming ciliates
  - crawling ciliates
  - stalked ciliates
Microscopic Observations:  
*Nutrient Deficiency*

- Often in industrial and municipal system nutrient deficiency may occur.
- Nitrogen and Phosphorus are the nutrients that are usually deficient.
- Nutrient ratio 100:10:1 (BOD:N:P)
Microscopic Observations: *Nutrient Deficiency*

Gram negative

- Lipopolysaccharide
  - “Slime Layer”
- Phospholipid
- Lipoprotein
- Cell Wall
- Cell Membrane

Gram negative

- Lipopolysaccharide
  - “Slime Layer”
- Lipid
- Cell Wall
- Cell Membrane
Microscopic Observations: 
*Nutrient Deficiency*
Nutrient Deficiency: Slime Bulking
Microscopic Observations: Nutrient Deficiency
Microscopic Observations: 

*Nutrient Deficiency*
Microscopic Observations: Nutrient Deficiency
Process Control: *Slime Bulking*

*India Ink Test*
Protozoa: *Stalked Ciliates*
Microscopic Observations: Nutrient Deficiency
Microscopic Observations: Nutrient Deficiency
Microscopic Observations: 

*Unfavorable Conditions*

- Under unfavorable conditions, bacteria, protozoa and metazoa develop protective characteristics.
Microscopic Observations: Unfavorable Conditions

- Bacteria
  - Encasements
  - Filaments
  - Dispersed
Filamentous Bacteria Identification

- When unfavorable conditions occur, filamentous bacteria will begin to dominate in the treatment system.
  - Insufficient dissolved oxygen
  - Excess oils & grease
  - Long sludge age
  - Low food: microorganism ratio (not enough food)
  - Insufficient nutrients
Filamentous Bacteria Identification

- Different types of filamentous bacteria dominate under different conditions.
- Identify the filament, then you can identify the condition.
- Then corrective actions can be taken.
Dispersed Bacteria
Unfavorable Conditions: *Protozoa*

- Under adverse or unfavorable conditions, protozoa develop a variety of protective mechanisms including the formation of “shells” and “tubes”
Protozoa: *Testate Amoeba*

*Difflugia*
Protozoa: *Testate Amoeba*

*Arcella*
Protozoa: *Testate Amoeba*
Protozoa: *Flagellates*
Protozoa: Stalked Ciliates
Protozoa: *Tube Dwellers*
Protozoa: *Tube Dwellers*
Metazoa: *Shelled Rotifers*
Metazoa: *Shelled Rotifer*