Microorganisms and the ecology of wastewater treatment

by Ibrahim El Saliby
Content

• Introduction to **Microorganisms** identification

• Microorganisms for wastewater treatment

• Microorganisms **ecology** in wastewater treatment
Classification of kingdoms

Old classifications

Protozoa
Chromista

Cavalier-smith classification 2004

Plantae
Animalia
Fungi
Protozoa
Chromista
Bacteria
Taxonomic ranks and Latin name


Bacteria

http://bioweb.uwlax.edu/bio203/s2008/moder_just/classification.htm
Bacteria (E. coli)

- Unicellular, prokaryotic microorganisms
- Size: few μm in length
- Shape: sphere (cocci), rod (bacillus) and spiral (spirillum)
- Sexual and mainly asexual reproduction or “binary fission”
- Motility in water by flagella (Bacterial gliding and changes in buoyancy for vertical movement)
Fungi (yeast)

- Eukaryotic, multicellular
- Size: varies among yeast, rusts, mildews, smuts and mushrooms
- Shape: variable
- Motility: Nonmotile
- Reproduction: sexual, capable of asexual

http://terpconnect.umd.edu/~asmith/emsarapay/yeast.jpg
## Protozoa, Algae and Worms

<table>
<thead>
<tr>
<th>Protozoa (Cryptosporidium)</th>
<th>Algae (Macrochloris sp.)</th>
<th>Worms (Nematodes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Eukaryotic, uni or multicellular</td>
<td>• Eukaryotic, uni or multicellular</td>
<td>• Eukaryotic multicellular</td>
</tr>
<tr>
<td>• Size: 10 μm to 1 mm</td>
<td>• Size: 10 μm to few metres</td>
<td>• Size: few μm to few metres</td>
</tr>
<tr>
<td>• Shape: variable</td>
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<td>• Shape: variable</td>
</tr>
<tr>
<td>• Motility: flagella, cilia, pseudopods</td>
<td>• Motility: nonmotile or by flagella</td>
<td>• Motility: tiny hair or bristles on the body</td>
</tr>
<tr>
<td>• Reproduction: sexual and asexual</td>
<td>• Reproduction: sexual and asexual</td>
<td>• Reproduction: sexual (hermaphrodite)</td>
</tr>
</tbody>
</table>
Microorganisms for wastewater treatment
Microorganisms in wastewater

- Bacteria
- Protozoa
- Wastewater
- Algae and Worms
- Fungi
# Energy and carbon sources

(Von Sperling 2007)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Energy source</th>
<th>Carbon source</th>
<th>Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photoautotrophs</td>
<td>Light</td>
<td>CO₂</td>
<td>Higher plants, algae, photosynthetic bacteria</td>
</tr>
<tr>
<td>Photoheterotrophs</td>
<td>Light</td>
<td>Organic matter</td>
<td>Photosynthetic bacteria</td>
</tr>
<tr>
<td>Chemoautotrophs</td>
<td>Inorganic matter</td>
<td>CO₂</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Chemoheterotrophs</td>
<td>Organic matter</td>
<td>Organic matter</td>
<td>Bacteria, fungi, protozoa and animals</td>
</tr>
</tbody>
</table>
Metabolism (Cellular level)

Catabolism (dissimilation)
- Reactions of energy production in which substrate decomposition occurs
  - Through a complex chemical transformation (energy cycles), endoenzymes for intracellular reactions and exoenzymes to decompose big molecules (suspended to dissolved), which can then be absorbed by the cell

Anabolism (assimilation)
- Formation of cellular material by using the energy from catabolism
### Energy and catabolism

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Electron acceptor before and after reaction</th>
<th>Process</th>
<th>Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic</td>
<td>Oxygen ($O_2$)$\rightarrow$ H$_2$O</td>
<td>Aerobic metabolism</td>
<td>Strict aerobic</td>
</tr>
<tr>
<td>Anoxic</td>
<td>Nitrate ($NO_3^-$)$\rightarrow$N$_2$</td>
<td>Nitrate reduction (denitrification)</td>
<td>Facultative</td>
</tr>
<tr>
<td>Anaerobic</td>
<td>Sulphate ($SO_4^{2-}$)$\rightarrow$H$_2$S</td>
<td>Sulphate reduction and Methanogenesis</td>
<td>Strict anaerobic</td>
</tr>
<tr>
<td></td>
<td>Carbon dioxide ($CO_2$)$\rightarrow$CH$_4$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Algae and bacteria

- **Facultative or stabilization ponds**
  - Copy of natural process
  - Detention time 45 days
  - Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis.
## Bacteria and Protozoa

### Bacteria
- **Heterotrophic (OM decomp)**
  Achromobacter, Alcaligenes, Arthrobacter, Flavobacterium, Pseudomonas, and Zoogloea
- **Agglomerate (flocs, biofilms)**
- **Ammonia → nitrite → nitrate**
  Nitrobacter and Nitrosomonas (chemoautotrophic bacteria)
- **Nitrate to nitrogen gas**
  (chemoheterotrophic bacteria)
- **Exoenzymes**

### Protozoa
- **Aerobic and facultative heterotrophic**
- **Consume organic matter**
- **Flagellates, Amoebas and ciliates (free-swimming)**
- **Feed on free bacteria**
  (natural enemy in the food web)
- **Improving the quality of final effluent**
Fungi

- Compete with bacteria
- Few are capable of oxidizing ammonia to nitrite, and fewer still to nitrate.
- Low importance role mainly...
  - **Filamentous structure** of some fungi $\rightarrow$ detrimental effect on sludge settleability $\rightarrow$ reduced process efficiency
- **But...** important in treating low pH and N industrial wastewater
Worms

- Indicate aerobic conditions and the abundance of bacterial food

- Present in large numbers in secondary wastewater effluent, trickling bio-filters or rotating biological contactors (RBC's) where an older biofilm develops

- Stimulate microfloral activity and decomposition by enhancing oxygen penetration in the floc structures by their grazing activities

- Worms indicate a relatively healthy, older system, no toxicity, progressing along in a sludge age towards stable to endogenous age

http://www.environmentalleverage.com/Worms.htm
Microorganisms ecology in wastewater treatment
Temp., $O_2$, carbon and $pH$

- **Temperature**
  - Psycrophilic (-10 - 30°C)
  - Mesophilic (20 - 50°C)
  - Thermophilic (35 - 75°C)

- **Carbon load**
  - High: flagellated protozoan and bacteria.
  - Conventional: Bacteria and ciliated protozoan.
  - Low: worms, rotifers and bacteria

- **pH**
  - 4 - 9.5 bacteria
  - Neutrality is preferable for others

- **Oxygen**
  - High: aerobic bacteria, protozoa and rotifers
  - Low: facultative bacteria
  - Absent: anaerobic bacteria
Suspended or dispersed biomass growth

- Biomass grows in a dispersed form (*floc*) in the liquid (no supporting structure)
  - *Systems:*
    - Stabilization ponds and variants
    - Activated sludge and variants
    - Upflow anaerobic sludge blanket reactor

Anoxic/anaerobic zone
- Low nutrient
- Reduced viability

Aerobic zone

Typical floc
Microorganisms and floc structure

- Filamentous = floc-forming organisms (equilibrium)
  - Good settleability and thickening properties of the sludge
- Filamentous < floc-forming organisms
  - Insufficient rigidity, weak floc, poor settlability
  - Result: Pin-point floc
- Filamentous > floc-forming organisms
  - Extended filaments impeding the adherence of other flocs
  - Flocs occupy large volume, problem in settling, bad quality effluent
  - Condition called: Sludge bulking

Polysaccharide matrix
- Zoogloea ramigera and Pseudomonas sp.

Protozoan

Filamentous bacteria

Floc-forming bacteria
Attached growth

• Biomass grows attached to a support medium (stones, sand, soil or plastic etc...) forming a biofilm

– *Systems:*
  • Trickling filters
  • Rotating biological contractors
  • Submerged aerated biofilters
  • Anaerobic filters
  • Land disposal systems
Biofilm formation

• Influenced by:
  • Cell-to-cell interaction
  • Presence of polymer molecules
  • Composition of the medium

• Stages in the formation
  1. Thin: High bacterial growth and similar to dispersed biomass
  2. Intermediate: bacterial growth constant, maintenance metabolism in low organic medium
  3. High: decay of bacteria, dislodgment of biofilm
Important considerations

✗ Always check that the hydraulic detention time (HDT=volume/flow) is greater than the doubling time of the microorganisms (DTM)

✗ Use favourable conditions of pH, temperature, carbon loads and oxygen for the optimal growth of microorganisms

✗ Don’t use microorganisms that are natural enemies unless your goal is to do so
Thank you