DISINFECTION

CE326 PRINCIPLES OF ENVIRONMENTAL ENGINEERING
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Department of Civil, Construction, and Environmental Engineering
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HISTORY

- John Snow and the Broad Street pump in 1854
- he was able to show that 59 of the 77 cholera victims used the pump on Broad Street
- There was a workhouse in the vicinity where cholera was endemic but nobody at this workhouse got cholera.
- This particular workhouse had its own well.
- The cause of contamination turned out to be the drain of an infected person that was within three feet of the well.
Broad Street Pump
Chlorination

- Disinfection of water supplies by chlorination began in Chicago and New Jersey in 1908,
- within 2 years chlorination of water supplies was practiced in N.Y., Montreal, Milwaukee, Cleveland, Nashville, Baltimore, and Cincinnati.
- By 1918, over 1000 cities treating more than 3 bgd were chlorinating their water supplies.
- By 1923 the typhoid death rate had dropped more than 90%
- By the beginning of WWII, typhoid, cholera, dysentery were practically eliminated in U.S.
Theory

- Chick’s Law:
  \[
  \frac{dN}{dt} = -kN
  \]
  rate, \( k \), is a function of concentration and time (i.e., CT) and type of organism

- Typical disinfectants:
  - **Chlorine:** \( \text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{Cl}^- \)
  - **Chloramines**
    \[
    \begin{align*}
    \text{NH}_3 + \text{HOCl} & \rightarrow \text{NH}_2\text{Cl} + \text{H}_2\text{O} \\
    \text{NH}_2\text{Cl} + \text{HOCl} & \rightarrow \text{NHCl}_2 + \text{H}_2\text{O} \\
    \text{NHCl}_2 + \text{HOCl} & \rightarrow \text{NCl}_3 + \text{H}_2\text{O}
    \end{align*}
    \]
Pellet dropper

Chlorinators

Tablet feeder
Chlorinators

Gas – 2,000 pound

Courtesy Smith Group Consulting, LLC
Chlorine Contact Tank

Effluent enters here

www.wsd.dst.il.us/tour/imgbig/contact_tk_1.jpg
Ozonation

- strong oxidant, but no residual
- no THM formation but other (non-chlorinated) DBPs possible
- often used as a primary disinfectant
Chlorine Dioxide

- strong oxidant, but not as powerful as ozone
- dose limited to 1.0 mg/L due to health concerns of chlorite and chlorate
- residual is not long lasting
Ultraviolet (UV) Light

- uses thin layer of water and mercury vapor arc light emitting UV in the range of 0.2 to 0.29 micron
- depth of light penetration limited to 50 - 80 mm
- powerful, but no residual
ADSORPTION

- takes advantage of physical/chemical bond of pollutant with adsorbent (typically granular activated carbon or powdered activated carbon)
- one ounce of GAC has a surface area of 5-10 acres
- good process for removal of
  - THMs
  - DBPs
  - SOC s
  - VOCs
- PAC dose is typically 5-10 mg/L can be as high as 50 mg/L
- GAC can be used instead of anthracite in dual media filters,
  - called filter adsorbers
  - must replace GAC every 1-3 years
- separate stage adsorption unit (contactor unit)
  - GAC must be replaced or regenerated every 3 to 4 months
### Particle Size vs. Treatment Alternatives

<table>
<thead>
<tr>
<th>Micrometers (Log Scale)</th>
<th>ST Microscope</th>
<th>Scanning Electron Microscope</th>
<th>Optical Microscope</th>
<th>Visible to Naked Eye</th>
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</thead>
<tbody>
<tr>
<td>Ionic Range</td>
<td>0.001</td>
<td>0.01</td>
<td>0.1</td>
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<tr>
<td>Molecular Range</td>
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<td>100</td>
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<td>1000</td>
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<tr>
<td>Macro Molecular Range</td>
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<tr>
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</table>

<table>
<thead>
<tr>
<th>Angstrom Units (Log Scale)</th>
<th>10</th>
<th>100</th>
<th>1000</th>
<th>10000</th>
<th>100000</th>
<th>1000000</th>
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</table>

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<thead>
<tr>
<th>Approx. Molecular Wt. (Saccharide Type-No Scale)</th>
<th>100</th>
<th>200</th>
<th>1000</th>
<th>10000</th>
<th>100000</th>
<th>500000</th>
</tr>
</thead>
</table>

#### Relative Size of Common Materials

- Aqueous Salts
- Atomic Radius
- Carbon Black
- Endotoxin/Pyrogen
- Paint Pigment
- Bacteria
- A.C. Fine Test Dust
- Sugar
- Virus
- Milled Flour
- Tobacco Smoke
- Latex/Emulsion
- Colloidal Silica
- Blue Indigo Dye
- Red Blood Cells
- Human Hair
- Metal Ion
- Synthetic Dye
- Asbestos
- Blue Blood Cells
- Human Hair
- Pesticide
- Herbicide
- Gelatin
- Coal Dust
- Cryptosporidium
- Giardia Cyst
- Mist

#### Process For Separation

- REVERSE OSMOSIS (Hyperfiltration)
- ULTRAFILTRATION
- PARTICLE FILTRATION
- NANOFILTRATION
- MICROFILTRATION
Membrane Treatment

Micro filtration (MF) - bacteria, algae, clay, large MW humic acids
Ultra filtration (UF) - humic acids, viruses, protein
Nanofiltration (NF) – viruses, divalent salts
Reverse Osmosis (RO) – monovalent salts
Reverse Osmosis

Raw water in → High pressure pump → Raw water under pressure

Molecule
Ion

Concentrated solution out

Semipermeable membrane

Pure water out

Raw water under high pressure

Water

Pore
Membrane