DISINFECTION

CE326 PRINCIPLES OF ENVIRONMENTAL ENGINEERING
Iowa State University
Department of Civil, Construction, and Environmental Engineering
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March 22, 2009
Announcements

- Wednesday lab in Town classroom
  - Finish water treatment plant lab
  - Exam review
- 2nd exam scheduled for Friday, March 27th
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 domain 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.

http://www.americanchemistry.com/100years/timeline.html
Theory

- Chick’s Law:

\[
\frac{dN}{dt} = -kN
\]

rate, \( k \), is a function of concentration and time (i.e., CT) and type of organism

(\( pH \), temp, type of disinfectant, microorganism)

- Typical disinfectants:
  - Chlorine: \( \text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{Cl}^- \)
  - Chloramines

### Chloramines

- \( \text{NH}_3 + \text{HOCl} \rightarrow \text{NH}_2\text{Cl} + \text{H}_2\text{O} \)
- \( \text{NH}_2\text{Cl} + \text{HOCl} \rightarrow \text{NHCl}_2 + \text{H}_2\text{O} \)
- \( \text{NHCl}_2 + \text{HOCl} \rightarrow \text{NCl}_3 + \text{H}_2\text{O} \)

\( \text{HOCl} + \text{OCl}^- + \text{H}^+ \)

\( \text{Hypochlorous acid} \)
Chlorinators

Pellet dropper

Tablet feeder
Chlorinators

Gas – 2,000 pound

Courtesy Smith Group Consulting, LLC
Electrolytic Cell

\[ \text{NaCl} + \text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{NaOCl} + \text{H}_2 \]

\[ \text{Cl}^- \rightarrow \text{H}_2\text{OCl} + \text{Cl}^- \]  \[2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-\]
If the products are mixed, the result is household bleach.

\[ 2 \text{NaOH(aq)} + \text{Cl}_2(g) = \text{NaCl(aq)} + \text{NaOCl(aq)} + \text{H}_2\text{O} \]
Chlorine Contact Tank

Effluent enters here

www.wsddst.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 lamp 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
Six Desirable Qualities of a Disinfectant

1. **Destroys pathogen** (disease causing organism)
2. **Effective for wide range of water quality**
3. **Non-toxic to humans & animals**
4. **Inexpensive, safe, & easy to handle**
5. **Method to determine concentration**
6. **Persistant long lasting residual**
Factors Affecting Disinfection

1. Type of Disinfectant
   - how strong?
     - Ozone > Chlorine > Chlorine Dioxide > Chloramines
     - UV

2. Type of microorganism
   - how resistant to disinfection
     - Protozoan cysts > Spore (Giardia & Crypto) > Enteric non-sporing bacteria > Sporangia > Viruses > Sporangia (vegetative) > Bacteria

3. Concentration - Time
   - $CT = \text{concentration of disinfectant residual} \times \text{time of disinfection (until first user)}$
Example: A finished water supply has a pH= 7.0 and we want 3 log inactivation of Giardia cysts at 10°C. We have a residual chlorine concentration of 2.0 mg/L. How long do we need to disinfect (store) the water before the first user?

\[
CT = 124 \text{ (mg/L) min} \\
T = \frac{CT}{C} = \frac{124}{2} = 62 \text{ min}
\]
Example: What volume storage tank would be required to achieve 3 log inactivation of giardia cysts for a water treatment facility operating at 5 mgd (million gallons per day)? Assume a free chlorine residual concentration of 0.8 mg/L, pH = 8.5, and temperature = 10°C. Use the CT Table for your calculation.

\[
\text{Vol} = 830,000 \text{ gallons} \\
\text{5 mgd} \times 0.169 = \frac{158 + 226}{2} = 192 \text{ mg/L} \text{ min} \\
\text{CT} = \frac{2}{192} = 240 \text{ min} \frac{L}{60 \text{ min}} \frac{L}{24 \text{ h}}
\]
ADSORPTION

- takes advantage of physical/chemical bond of pollutant with adsorbent (typically g________ activated carbon or p________ activated carbon)
- one ounce of GAC has a surface area of 5-10 acres
- good process for removal of
  - THMs
  - DBPs
  - SOCs
  - VOCs
 ADSORPTION

- PAC dose is typically _____ mg/L can be as high as ______mg/L
- GAC can be used instead of a__________ in dual media filters,
  - called filter adsorbers
  - must replace GAC every _____ years
- separate stage adsorption unit (contactor unit)
  - GAC must be replaced or regenerated every ___ to ___ months
Particle Size vs. Treatment Alternatives

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<th>Approx. Molecular Wt.</th>
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- Aqueous Salts
- Atomic Radius
- Sugar
- Metal Ion
- Synthetic Dye
- Pesticide
- Herbicide
- Colloidal Silica
- Blue Indigo Dye
- Red Blood Cells
- Asbestos
- Gelatin
- Coal Dust
- Cryptosporidium
- Giardia Cyst
- Mist
- Beach Sand
- Granular Activated Carbon
- Ion Ex. Resin Bead
- Pin Point
- Yeast Cells
- Paint Pigment
- Bacteria
- A.C. Fine Test Dust
- Milled Flour
- Tobacco Smoke
- Latex/Emulsion
- Blood Cells
- Pollen
- Human Hair

Process For Separation
- Reverse Osmosis (Hyperfiltration)
- Ultrafiltration
- Particle Filtration
- Nanofiltration
- Microfiltration
Membrane Treatment

Large Suspended Particles

Macromolecules

Smaller Particles

Divalent salts

Monovalent salts

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 high pressure
- Water
- Pore
- Membrane
- Molecular
- Ion
- Concentrated solution out
- Semipermeable membrane
- Pure water out