Essentials of Surface Water Treatment

Oregon Health Authority
Drinking Water Services
www.healthoregon.org/dwp

Overview of Today's Course:
1. Background of Surface Water Treatment Rules
2. Filtration
3. Disinfection
4. Operations
5. Reporting Requirements
6. Emerging Issues
7. Resources for Operators

Background of Surface Water Treatment Rules

• 1989: SWTR required most SW and GWUDI (Groundwater Under Direct Influence) systems to filter.
• States required to identify GWUDI sources.
• Required 3-log (99.9%) Giardia and 4-log (99.99%) virus removal.
• CF/DF: 95% of turbidity readings ≤ 0.5 NTU; all < 5 NTU
• Slow sand/DE/alt: 95% of turbidity readings ≤ 1 NTU; all < 5 NTU
• Required detectable disinfectant residual.
• Did not address Cryptosporidium.

Background - Source Water Considerations

• Watershed control
• Intake structure or configuration
• Pumping facilities
• Factors affecting water quality

Background (continued)

• 1998 Interim Enhanced Surface Water Treatment Rule (IESWTR)
• Addressed concerns about Crypto (required 2-log removal)
• CF/DF: Lowered turbidity standard to 95% of readings ≤ 0.3 NTU, all readings ≤ 1 NTU for systems with population ≥10,000.
• Required Individual Filter Effluent (IFE) turbidimeters

Background (continued)

• 2002 Long-Term 1 Enhanced Surface Water Treatment Rule (LT1)
  - Extended 0.3 NTU requirement to systems with <10,000 population.

• 2006: LT2 requires additional Crypto treatment for systems with ≥ 0.075 oocysts/L in their source water.
  – So far only one water system is required to install additional treatment in Oregon.
Background - Watershed Control

- Owned or managed by the water system?
  - Most systems have little control over their watersheds.
- Drinking water protection plan
- Emergency response plan
- Patrols, gates, etc.
- Inter-agency agreements (USFS, BLM, ODF, COE)

Background - Intakes and Pumps

- Screens: well screens, traveling screens, self-cleaning rotating drum screens.
- Clean with air or water blast
- Vertical turbine pumps in wet wells common in larger systems.
- Submersible pumps in slotted or perforated pipe laid on riverbed.
- Infiltration galleries: Slotted pipes or well screens underneath riverbed, provides rough filtration.

Raw Water Quality Factors

- Logging, storm events increase turbidity
- Recreation (gasoline engines, oil)
- Development (increased stormwater drainage with associated pollutants)
- Seasonal and/or daily fluctuations in temp or pH
- Algae becoming an increasing problem
- Sewage treatment plants upstream, occasional overflows

Oregon Waterborne Disease Outbreaks

(bacteria, viruses, parasites)

Total Cases, 26 Outbreaks - 7,000 sickened (CDC)

<table>
<thead>
<tr>
<th>Decades</th>
<th>Number of Outbreaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970s (federal Act)</td>
<td>15</td>
</tr>
<tr>
<td>1980s (State Act, Primacy)</td>
<td>6</td>
</tr>
<tr>
<td>1990s (federal revolving fund)</td>
<td>3</td>
</tr>
<tr>
<td>2000s (new EPA standards)</td>
<td>2</td>
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</tbody>
</table>

Waterborne Disease Outbreak Causes

Most of these outbreaks involve microbiological agents that would respond to proper disinfection.
Types of Pathogens:

- Protozoa or Parasites: Giardia Lamblia, Cryptosporidium Parvum
- Bacteria: Campylobacter, Shigella, Legionella
- Viruses: Hepatitis A, Norwalk Agents

### U.S. Outbreaks of Cryptosporidiosis in Surface Water Supplies

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Type of System</th>
<th>Estimated Number of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bernalillo County, New Mexico</td>
<td>1986</td>
<td>Untreated surface water supply</td>
<td>78</td>
</tr>
<tr>
<td>Carroll County, Georgia</td>
<td>1987</td>
<td>Treated surface water supply</td>
<td>13,000</td>
</tr>
<tr>
<td>Jackson County, Oregon</td>
<td>1992</td>
<td>Medford - chlorinated spring; Talent - treated surface water</td>
<td>15,000</td>
</tr>
<tr>
<td>Milwaukee County, Wisconsin</td>
<td>1993</td>
<td>Treated surface water supply</td>
<td>403,000</td>
</tr>
<tr>
<td>Cook County, Minnesota</td>
<td>1993</td>
<td>Treated surface water supply</td>
<td>27</td>
</tr>
<tr>
<td>Clark County, Nevada</td>
<td>1994</td>
<td>Treated surface water supply</td>
<td>78</td>
</tr>
</tbody>
</table>

- Five of the outbreaks were associated with filtered drinking waters.
- Three systems (Carroll, Jackson - Talent, and Milwaukee) were experiencing operational deficiencies and high finished water turbidities at the time of the outbreaks. All three plants utilized conventional treatment processes that included rapid mix, flocculation, sedimentation, and filtration.
- The Clark County outbreak was the only outbreak associated with a filtered drinking water for which no treatment deficiencies were noted.
- All five systems were in compliance with the federal regulations in effect at that time.

### Why Measure Turbidity?

- Removes pathogens and protects public health.
- Turbidity removal has been shown to be directly related to removal of *Giardia* and *Crypto*.
- Turbidity maximum contaminant levels (MCLs) are based on the technology used:
  - ≤ 0.3 NTU (95% of the time) for conventional or direct filtration; always < 1 NTU.
  - ≤ 1 NTU (95% of the time) for slow sand, cartridge, and membrane; always < 5 NTU.

### Types of Filtration

- Conventional rapid sand
- Direct (no sedimentation process)
- Diatomaceous earth (DE, only a few in Oregon)
- Slow Sand
- Alternative (membrane, cartridge)

### Conventional Rapid Sand Filtration

- Requires coagulation for charge neutralization (static mixer) and some degree of flocculation (large paddle wheel flocculator).
- Sedimentation allows settling of coagulated particles, relieves burden on filter.
- Filtration process involves adsorption and physical straining of coagulated particles.
Straining

- Passing the water through a filter in which the pores are smaller than the particles to be removed

Adsorption

- The gathering of gas, liquid, or dissolved solids onto the surface of another material

Rapid sand filter

Backwash of filter

Cross-section through a dual media filter.

Typically, the layers (starting at the bottom of the filter and advancing upward) are:

1. Sand
2. Anthracite
3. Garnet
4. Sand
5. Anthracite

The media in a dual or multi-media filter is arranged so that the water moves through media with progressively larger pores.

Coagulants

- Aluminum sulfate (alum): very common, only effective in narrow pH range.
- Ferric chloride: More expensive, but works in wider pH range.
- Poly aluminum chloride (PAC): not affected by pH, doesn’t change pH, works well with low alkalinity, leaves less sludge because dosage is low.
- Aluminum Chlorohydrate (ACH): similar to PAC.
Factors Affecting Coagulation

- Dosage: determined by jar test for optimum qualities of floc: (size, settling rate).
- Mixing: Mechanical or static. Need to rapidly mix chemicals.
- Alkalinity: 50 mg/l or less can shift pH downward.
- Temperature: Colder water slows coagulation.
- Color: Pre-oxidation may be required.
- Turbidity: Changing conditions require more frequent jar tests.

Sedimentation

- Standard basin:
  - Usually rectangular, goal is to slow down the water so solids settle to bottom by gravity.
  - Settled (clarified) water moves to filters slowly.
- Tube settlers:
  - Add capacity
  - Solids only need to settle a few inches
  - Water flows up through tubes, solids collect on the side and slide out of the bottom
  - Some standard sed basins can be retrofitted with tube settlers
- Plate Settlers (Lamella Plates)
  - Perform same function as tube settlers
  - Not as common in Oregon as tube settlers
Adsorption (Upflow) Clarifiers

- Coagulated water flows up through clarifier.
- Clarifier media either gravel or plastic beads. Clarifier is periodically “rinsed” of solids.
- Clarified water flows onto filter.
- Configured as a package plant, small footprint, easy to increase the capacity.

Rapid Sand Filtration

- Involves adsorption and physical straining of flocculated particles.
- Filtration rate 2-4 gpm/ft²
- Requires controllable backwash with water and perhaps air scour.
- Mixed media filters: layers of support gravel, sand, anthracite.

Direct Filtration

- No sedimentation process.
- OK for small systems with consistent raw water quality.
- May be gravity or pressure filtration.
- Usually cannot observe backwash process if pressure filtration.
Diatomaceous Earth (DE)

- Common in swimming pools, also approved for drinking water.
- Fine, porous, angular media processed from fossil skeletons of microscopic diatoms.
- Requires a continuous “body feed” injection of DE, which collects on a filter screen (“septum”).
- Only a few DE systems in Oregon.
Slow Sand Filtration

- Filtration rate < 0.1 gpm/ft²
- Need raw water < 10 NTU
- No coagulants used
- Pathogen removal occurs due to biological processes and adsorption.
- Cleaned by scraping, and eventually removing, top 1/8” to ¼” of sand or wet harrowing (raking).
- Credited with 2.0-log Giardia/Crypto removal

In the slow sand filter, water passes first through about 36 inches of sand, then through a layer of gravel, before entering the underdrain. The sand removes particles from the water through adsorption and straining. A layer of dirt, debris, and microorganisms builds up on the top of the sand. This layer is known as schmutzdecke, which is German for “dirt blanket”. The schmutzdecke breaks down organic particles in the water biologically, and is also very effective in straining out even very small inorganic particles from water.
Alternative Filtration Technologies

• Cartridge / Bag Filters

• Membranes

• Need approved models that have met challenge studies (third party verification of performance) or on-site pilot data.

Cartridge Filters

• Good for small systems with low flow rates (5-20 gpm).
• Some cartridges require a specific pre-filter.
• No backwash, cartridges are replaced when pressure differential reaches specified limit.
• Must pass a challenge study in order to be approved.

- The state maintains a list of approved cartridge units on its website
- Operational boundaries (max flow, max pressure drop) associated w/ approval & log removal credit
Membrane Filtration

- Very small pore sizes, 1 micron or less
- Therefore need pre-filter (maybe with coagulant)
- Requires direct integrity test daily (usually air-hold, pre-programmed into controls).
- Membrane periodically cleaned with acid and/or chlorine.
- Failed membrane fibers can be “pinned” (plugged).
The state maintains a list of approved membrane units on its website.

Approved under certain operating conditions (max flow, test pressures).

Membrane "skid"

Control panel showing MIT (pressure decay test) info:
MIT=membrane integrity test
LRV=log removal value

Membranes (pressure)

Plant with submerged membranes.
Different methods of filter cleaning:
- CF/DF
  - Backwashing
  - Replacing/adding media eventually
- Slow sand
  - Scraping/ripening
  - Replacing/adding sand eventually
- Membrane
  - Backwash
  - Chemical cleaning
- Cartridge/bag
  - Discard/replace used filters

Questions about filtration?