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 (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 $\leq 0.3$ NTU, all readings $<1$ NTU for systems with population $\geq 10,000$.
- 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 - Source Water Considerations

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

Number of Outbreaks

<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>
</tr>
</tbody>
</table>

~50% drop
Waterborne Disease Outbreak Causes

Most of these outbreaks involve microbiological agents that would respond to proper disinfection

From August 2006 Access AWWA
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</td>
<td>15,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Talent - treated surface water</td>
<td></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 out-breaks. 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:
  - $\leq 0.3$ NTU (95% of the time) for conventional or direct filtration; always $< 1$ NTU.
  - $\leq 1$ 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 sand and anthracite coal, or garnet, sand, and anthracite coal. The media in a dual or multi-media filter are 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.
Jar Test showing floc formation
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
Tube settlers in a package plant
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.
Upflow clarifier. Note screens (upper portion) holding clarifier gravel or plastic beads in place.
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.
The filter is contained within a **filter box**, usually made of concrete. Inside the filter box are layers of **filter media** (sand, anthracite, etc.) and gravel. Below the gravel, a network of pipes makes up the **underdrain** which collects the filtered water and evenly distributes the backwash water. **Backwash troughs** help distribute the influent water and are also used in backwashing (which will be discussed in a later section.)
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.
Pressure filters
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.
DE cake (pink layer)

Sediment that’s been filtered out (brown layer)
Sediment removed

DE cake
Slow Sand Filtration

- Filtration rate < 0.1 gpm/ft²
- Need raw water < 5 NTU
- No coagulants used
- Pathogen removal occurs due to biochemical processes and adsorption.
- Cleaned by raking, and eventually removing, top 1/8” to ½” of sand.
- 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 "dirty skin." 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.
Bird’s eye view of 4 large slow sand filter cells
Large slow sand filter bed
Slow sand filters – 3 bays
Slow sand: left filter in service, right filter out of service
Self-contained slow sand filters at a school
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.

### Alternative Treatment Technologies Meeting Challenge Study Standards

**Oregon Administrative Rule 333-061-0050(4)(c)(J)**

**Oregon Health Authority, Drinking Water Program**

#### CARTRIDGE & BAG FILTERS

*(Other units not on this list may meet the standards. Contact DWP for details on verifications for units not listed.)*

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Log Removal Credit</th>
<th>Maximum Flow/Module (gpm)</th>
<th>Maximum Pressure Drop (psig @ 20°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strainte</td>
<td>HPM08-CC-2-SR HPM08-CCX-3-SR AQ2-2</td>
<td>Crypto 2.0, Giardia 2.0, Virus 0</td>
<td>20</td>
<td>25&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Filtration Systems</td>
<td>500-P000-P2-DP 700-P001-P2-DP NS-122</td>
<td>Crypto 2.0, Giardia 2.0, Virus 0</td>
<td>15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rosedale</td>
<td>not applicable PS 740 PPP 356 839-2F&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Crypto 2.0, Giardia 2.0, Virus 0</td>
<td>10&lt;sup&gt;d&lt;/sup&gt;</td>
<td>15&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rosedale</td>
<td>not applicable PS 740 PPP 356 18435-2F-1-150-98700</td>
<td>Crypto 2.0, Giardia 2.0, Virus 0</td>
<td>80</td>
<td>31&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Adapter basket required

<sup>b</sup> Absolute pressure drop across both filters.

<sup>c</sup> Pressure drop relative to new filters' startup pressure drop on the respective filters (pre- or final). For example, if the pre-filter exceeds 15 psig, replace pre-filter.

<sup>d</sup> Absolute pressure drop across the final filter. If using a pre-filter, see that manufacturer's specifications for that device.
Cartridge housings in sequence
Cartridge housings in parallel
Another style of cartridge housings
Filter cartridges that go in the housings
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).
Membrane Filtration

Figure 2.1 Filtration Application Guide for Pathogen Removal

- State-of-the-art technology
- Very small pore sizes, 1 micron or less
- Therefore need pre-filter (maybe with coagulant)
- Requires direct integrity test daily (usually air)
- Membrane periodically cleaned with acid and/or chlorine
- Small holes in membrane can be repaired

[Diagram showing the filtration process and pathogen sizes]
The state maintains a list of approved membrane units on its website.

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

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**Alternative Treatment Technologies Meeting Challenge Study Standards**

*Oregon Administrative Rule 333-061-0050(4)(c)(l)*

**Oregon Health Authority, Drinking Water Program**

**MEMBRANE FILTERS**

(Other units not on this list may meet the standards. Contact DWP for details on verifications for units not listed.)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Log Crypto. Removal Credit</th>
<th>Maximum Flux (gpm @ 20°C)</th>
<th>Maximum TMP (psi @ 20°C)</th>
<th>Maximum Flow/Module (gpm)</th>
<th>Minimum Static DIT (psi)</th>
<th>Date Verified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow/Tonka</td>
<td>SFX2880</td>
<td>3.5</td>
<td>80</td>
<td>30</td>
<td>23</td>
<td>30</td>
<td>Feb-10</td>
</tr>
<tr>
<td>GE Zenon</td>
<td>ZeeWeed 1000 V3</td>
<td>4.0</td>
<td>13</td>
<td>17</td>
<td>10</td>
<td>Jun-09</td>
<td></td>
</tr>
<tr>
<td>Pall</td>
<td>UNA-820A</td>
<td>4.0</td>
<td>120</td>
<td>25</td>
<td>44</td>
<td>27</td>
<td>25-Feb-10</td>
</tr>
<tr>
<td></td>
<td>USV-6203</td>
<td>4.0</td>
<td>120</td>
<td>35</td>
<td>44</td>
<td>27</td>
<td>25-Feb-10</td>
</tr>
<tr>
<td></td>
<td>XUSV-5203</td>
<td>4.0</td>
<td>120</td>
<td>35</td>
<td>33</td>
<td>27</td>
<td>25-Feb-10</td>
</tr>
<tr>
<td>Seconix</td>
<td>Phoenix</td>
<td>4.0</td>
<td>47</td>
<td>72</td>
<td>42</td>
<td>22</td>
<td>6-Aug-10</td>
</tr>
<tr>
<td></td>
<td>Virex Pro</td>
<td>4.0</td>
<td>47</td>
<td>45</td>
<td>2.13</td>
<td>22</td>
<td>27-Oct-10</td>
</tr>
<tr>
<td>Siemens</td>
<td>Memcor® S10V</td>
<td>4.0</td>
<td>80</td>
<td>13</td>
<td>16.7</td>
<td>17.4</td>
<td>12-Nov-10</td>
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<tr>
<td>Toray</td>
<td>Torayfil HFS-2020</td>
<td>4.0</td>
<td>120</td>
<td>20</td>
<td>47</td>
<td>18</td>
<td>21-Mar-12</td>
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<tr>
<td>WesTech</td>
<td>Polymem UF 12092</td>
<td>4.0</td>
<td>27</td>
<td>21</td>
<td>48</td>
<td>16.3</td>
<td>Aug-09</td>
</tr>
</tbody>
</table>

*Note:
- Virus removal credits are not available in Oregon due to lack of a direct integrity test for virus-sized particles. All approvals and removal credits are subject to change should information indicate the model is not capable of meeting regulatory requirements.
- DIT – Direct Integrity Test. Acceptable pressure decay rates during a DIT are, in part, a function of system volume and must be confirmed with DWP during plan review for each installation.*
Control panel showing MIT (pressure decay test) info:
MIT=membrane integrity test
LRV=log removal value
Large membrane plant.
Membranes (pressure)
Submerged membrane racks
Membrane backwash, submerged membranes
More membranes (pressure)
Membrane clean-in-place chemicals
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?