# Essentials of Surface Water Treatment Online

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

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## Overview of Course:

Part 1
1. Background of Surface Water Treatment Rules
2. Filtration
3. Disinfection
4. Operations

Part 2
1. Reporting Requirements
2. Emerging Issues
3. Resources for Operators

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## 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*.

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## 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

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## 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.

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## Background - Source Water Considerations

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

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## 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)

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## 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.

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## 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

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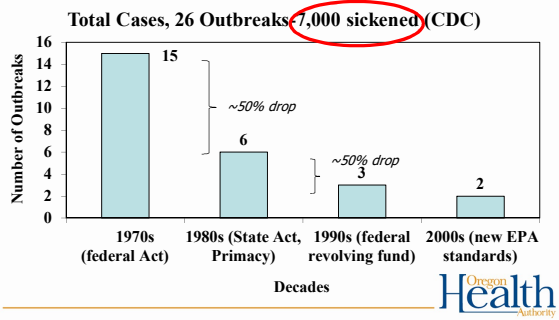
## Oregon Waterborne Disease Outbreaks

**(bacteria, viruses, parasites )**

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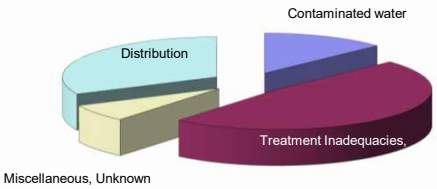
## Waterborne Disease Outbreak Causes




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

From August 2006 Access AWWA

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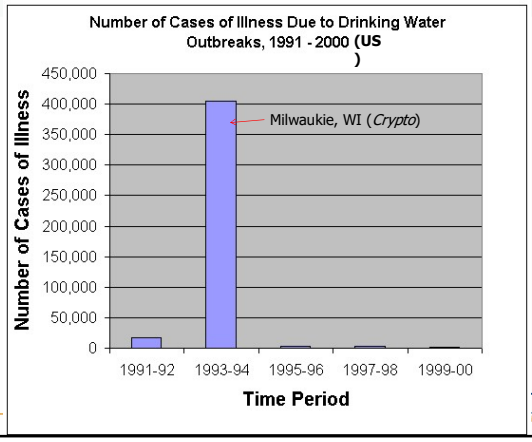


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## Types of Pathogens:

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

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

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

•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.

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## FILTRATION

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## 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.

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## Types of Filtration

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

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## 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.

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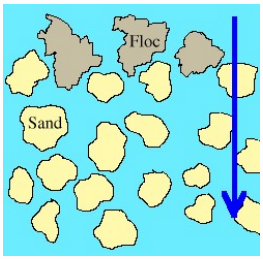
## Straining

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

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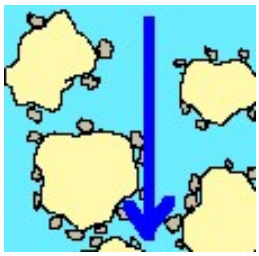
## Adsorption

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



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Rapid sand filter

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Backwash of filter

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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.

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## 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.

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## 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.

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Floc basin with baffling

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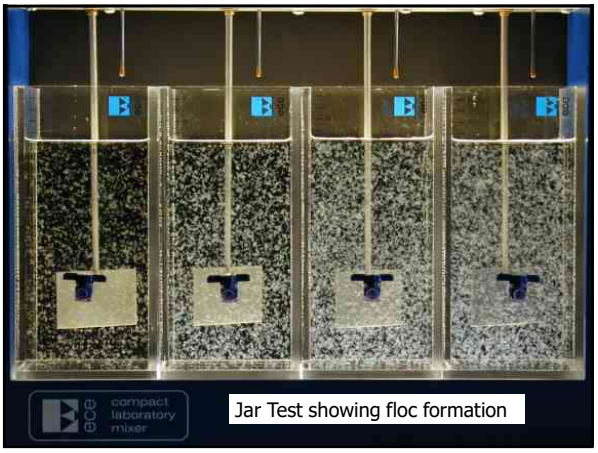


Jar Test showing floc formation

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## 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

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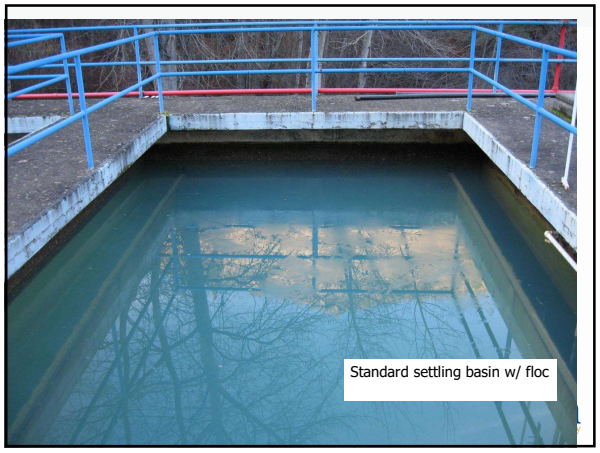

Standard settling basin w/ floc

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Tube settlers in a package plant

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## 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.

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Upflow clarifier. Note screens (upper portion) holding clarifier gravel or plastic beads in place.

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## 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.

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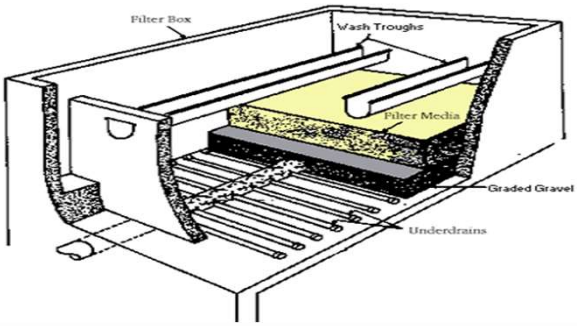


The filter is contained within a **filter box**, usually made of concrete. Inside the filter box are layers of **filter media** (sand, anthracite, etc.) and gravel. Below the gravel, a network of pipes makes up the **underdrain** which collects the filtered water and evenly distributes the backwash water. **Backwash troughs** help distribute the influent water and are also used in backwashing (which will be discussed in a later section.)

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## 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.

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## 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.

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## 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

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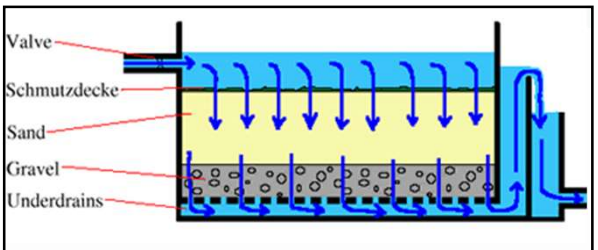


In the slow sand filter, water passes first through about 36 inches of sand, then through a layer of gravel, before entering the underdrain. The sand removes particles from the water through adsorption and straining. A layer of dirt, debris, and microorganisms builds up on the top of the sand. This layer 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.

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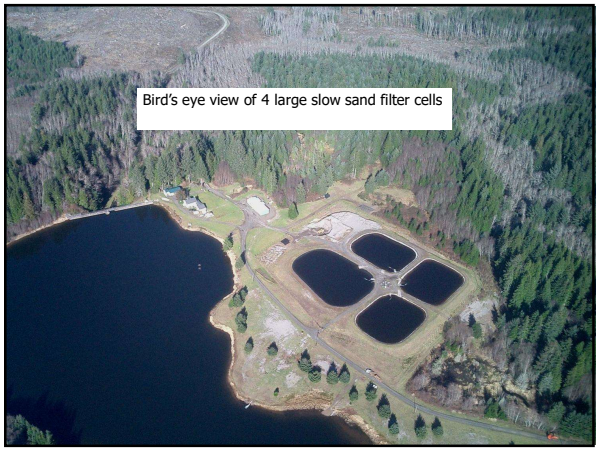


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Slow sand: left filter in service, right filter out of service

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Self-contained slow sand filters at a school

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## 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.

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## 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.

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**•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.)*

| Manufacturer | Model | | | $Log_{10}$ Removal Credit | | | Maximum Flow/Module (gpm) | Maximum Pressure Drop (psi @ 70°C) |
|---|---|---|---|---|---|---|---|---|
| | Pre-Filter | Main Filter | Housing | Crypto. | Giardia | Virus | | |
| Strainrite | HPM99-CC-2-SR | HPM99-CCX-2-SR | AQ2-2 | 2.0 | 2.0 | 0 | 20 | 25[b] |
| Filtration Systems | 500-P000-P2-DP | 700-P001-P2-IP | NS-122 | 2.0 | 2.0 | 0 | 15 | 15[c] |
| Rosedale | not applicable | PS 740 PPP 356 | 830-2P[a] | 2.0 | 2.0 | 0 | 10 | 15[c] |
| | not applicable | PS 740 PPP 356 | 18435-2F-1-150-SB700 | 2.0 | 2.0 | 0 | 80 | 31[c] |

[a] Adaptor basket required
[b] Absolute pressure drop across both filters.
[c] Pressure drop relative to new filters' startup pressure drop on the respective filters (pre- or final). For example, if the pre-filter exceeds 15 psid, replace pre-filter.
[d] Absolute pressure drop across the final filter. If using a pre-filter, see that manufacturer's specifications for that device.

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For more information, please call the OHA Drinking Water Program at ph. 971-673-0405 (8am-5pm PT, Mon-Fri)

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Cartridge housings in sequence

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Cartridge housings in parallel

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Another style of cartridge housings

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Filter cartridges that go in the housings

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Bag filter

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## 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).

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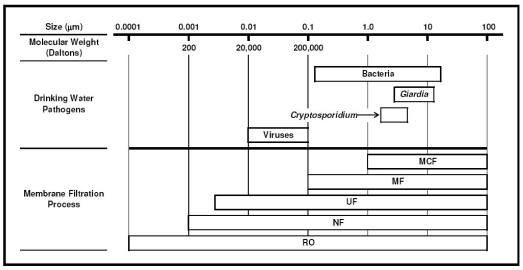
## Membrane Filtration

**Figure 2.1 Filtration Application Guide for Pathogen Removal**

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- The state maintains a list of approved membrane units on its website
- Approved under certain operating conditions (max flow, test pressures)

**Alternative Treatment Technologies Meeting Challenge Study Standards**
Oregon Administrative Rule 333-061-0050(4)(c)(I)
*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.)*

| Manufacturer | Model | $Log_{10}$ Removal Credit | | | Maximum Flux (gfd @ 20°C) | Maximum TMP (psi @ 20°C) | Maximum Flow/Module (gpm) | Minimum Static DIT[B] Pressure (psi) | Date Verified |
|---|---|---|---|---|---|---|---|---|---|
| | | Crypto | Giardia | Virus[A] | | | | | |
| DowTonka | SFX2860 | 3.5 | 3.5 | 0 | 60 | 30 | 23 | 30 | Feb-10 |
| GE Zenon | ZeeWeed 1000 V3 | 4.0 | 4.0 | 0 | 30 | 13 | 17 | 10 | Jul-09 |
| Pall | UNA-620A | 4.0 | 4.0 | 0 | 120 | 35 | 44 | 27 | 25-Feb-10 |
| | USV-6203 | 4.0 | 4.0 | 0 | 120 | 35 | 44 | 27 | 25-Feb-10 |
| | XUSV-6203 | 4.0 | 4.0 | 0 | 120 | 35 | 33 | 27 | 25-Feb-10 |
| Seccua | Phoenix | 4.0 | 4.0 | 0 | 47 | 72 | 42 | 22 | 5-Aug-10 |
| | Vinex Pro | 4.0 | 4.0 | 0 | 47 | 45 | 2.13 | 22 | 27-Oct-10 |
| Siemens | Memcor® S10V | 4.0 | 4.0 | 0 | 80 | 13 | 18.7 | 17.4 | 12-Nov-10 |
| Toray | Torayfil HFS-2020 | 4.0 | 4.0 | 0 | 120 | 29 | 47 | 18 | 21-Mar-12 |
| WesTech | Polymem UF 12052 | 4.0 | 4.0 | 0 | 27 | 21 | 48 | 16.3 | Aug-09 |

[A] 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.

[B] 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.

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Updated: 21 March 2012

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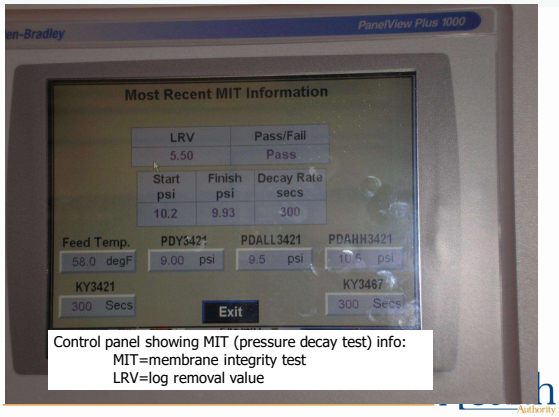


Control panel showing MIT (pressure decay test) info:
MIT=membrane integrity test
LRV=log removal value

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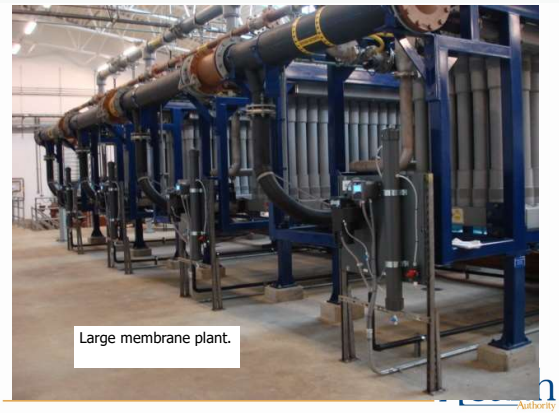


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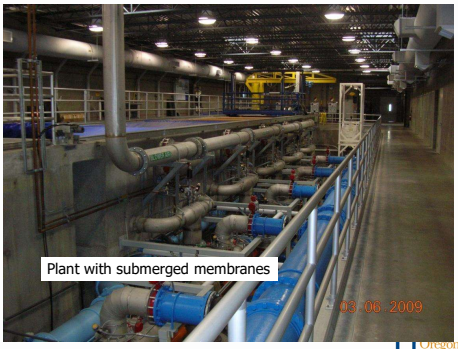


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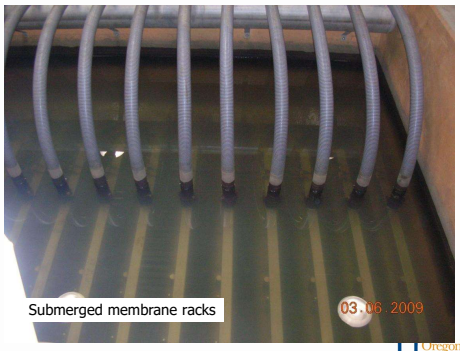


Submerged membrane racks

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Membrane backwash, submerged membranes

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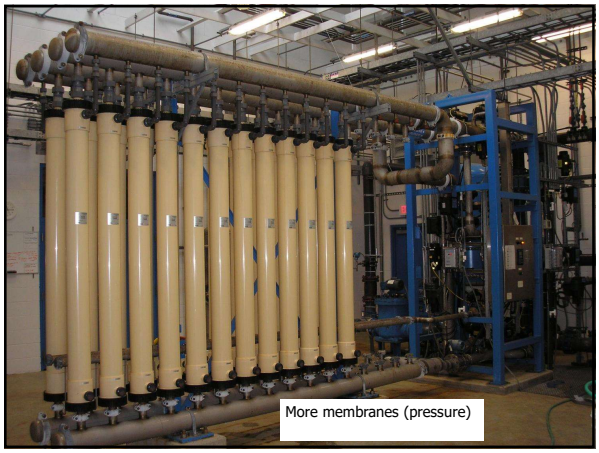

More membranes (pressure)

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Membrane clean-in-place chemicals

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## 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

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## 15 Minute Break

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## Disinfection

- For this section on disinfection you will need Exercise Handouts #1 - #3 found in the documents tab on the left.

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## Overview

- What is disinfection?
- Types of disinfectants
- Forms of chlorine
- NSF/ANSI Standard 60
- Disinfection requirements for surface water
- CTs
- Tracer Studies and Contact Time
- Impact of disinfectants on organics

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## What is disinfection?

- Process of killing microorganisms in water that might cause disease (pathogens)
- Should not be confused with sterilization which is the destruction of all microorganisms
- Two types:
  - Radiation (UV)
  - Chemical (chlorine, chloramines, chlorine dioxide, ozone)

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## Ultraviolet light

- Works by subjecting water to ultraviolet (UV) light rays as water passes through a tube
- Drawbacks:
  - Interfering agents such as turbidity can screen pathogens from the UV light
  - Effective against *Giardia* and *Cryptosporidium* but not viruses at normal doses
  - No residual is present in the water to continue disinfecting throughout the distribution system
  - For this reason, chlorination for residual maintenance is required when UV is used

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- **The state maintains a list of approved UV units on its website**
- **NSF 55 units not allowed for SW treatment** (only allowed for GW TC+ with small distribution)

**Alternative Treatment Technologies**
**Meeting Validation Test Standards**
Oregon Administrative Rule 333-061-0050(5)(k)(l)
*Oregon Health Authority, Drinking Water Program*

**ULTRAVIOLET REACTORS**

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

| Manufacturer | Model | $Log_{10}$ Removal Credit | | | Max. Flow (gpm) |
|---|---|---|---|---|---|
| | | Crypto. | Giardia | Virus | |
| Trojan | UVSwiftSC™ B03 | 3.5 | 3.5 | 0 | 132 |
| | UVSwiftSC™ 2L12 | —^ | — | | 94 |
| Viqua | Pro50/SV50/Sterilight50 | 3.5 | 3.5 | 0 | 70 |
| | Pro50/SV50/Sterilight50 | 3.0 | 3.0 | 0 | 80 |
| Wedeco | B100X | 3.0 | 3.0 | 0 | 387 |
| | B400XL | 3.0 | 3.0 | 0 | 1,760 |

^ Unit's validation test is undergoing verification.

| Manufacturer | Model | LT2 $Log_{10}$ Removal Credit | | | Max. Flow (gpm) |
|---|---|---|---|---|---|
| | | Crypto. | Giardia | Virus | |
| OAR 333-061-0050(5)(k)(l): "Non-Community water systems using only groundwater sources, and having minimal distribution systems as determined by the Department, may use ultraviolet light as the only disinfectant when total coliforms have been detected in the source water and no E. coli has been detected. UV units must meet the specifications of a Class A 55. The minimum ultraviolet light fallsafe dosage set point shall be equivalent to 40 mW-s/cm2 (40 mJ/cm2) with a wavelength between 200 and 300 nanometers." ***The following models are Class A NSF 55 certified and satisfy the Rule above:*** | | | | | |
| Kinetico | KUV 1200x | No Log Removal Credit Granted to NSF Class A 55 Models | | | 12 |
| Trojan | UVMax™ Pro 7 | | | | 8.2 |
| | UVMax™ Pro 10 | | | | 10 |
| | UVMax™ Pro 15 | | | | 17.8 |
| | UVMax™ Pro 20 | | | | 20 |
| | UVMax™ Pro 30 | | | | 30 |
| UV Pure Technologies | Hallet 15XS | | | | 14.6 |
| | Hallet 30 | | | | 30 |
| Viqua | SPV-200 | | | | 2.6 |
| | SPV-410 | | | | 5.9 |
| | SPV-600 | | | | 8.6 |
| | SPV-740 | | | | 11.2 |
| | SPV-950 | | | | 14.9 |

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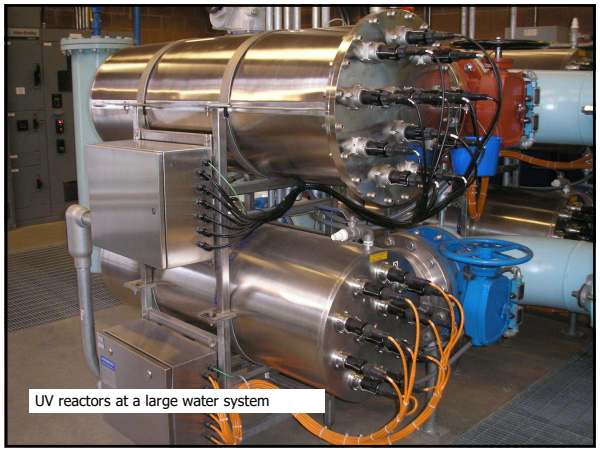

UV reactors at a large water system

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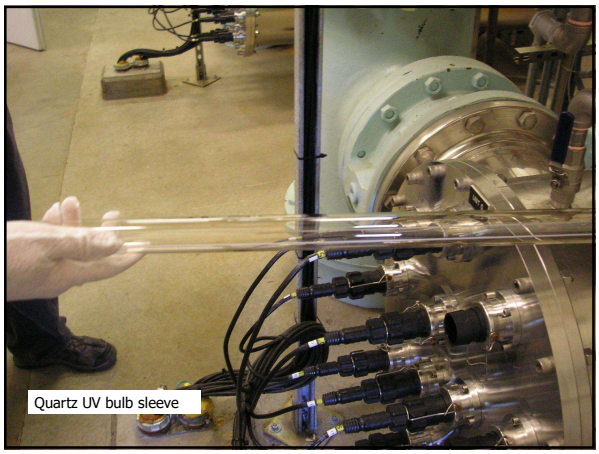


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## Chemical Disinfection

- Chlorine
- Chloramines
- Chlorine dioxide
- Ozone

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## Chlorine

- The most widely used form of disinfection
- Also used as an oxidizing agent for iron, manganese and hydrogen sulfide and for controlling taste and odors
- Effectiveness as a disinfecting agent depends on factors such as pH, temperature, free chlorine residual, contact time and other interfering agents

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## Forms of Chlorine

- Sodium Hypochorite
- Onsite generated sodium hypochorite
- Calcium Hypochlorite
- Chlorine Gas

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## Sodium hypochlorite

- The liquid form of chlorine
- Clear and has a slight yellow color
- Ordinary household bleach (~5% chlorine by solution) is the most common form
- Industrial strength: 12% and 15% solutions

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## Sodium hypochlorite (continued)

- Can lose up to 4% of its available chlorine content per month; should not be stored for more than 60 to 90 days
- Very corrosive; should be stored and mixed away from equipment that can be damaged by corrosion

84

## Diaphragm Pump/Tank for Chlorine

85

## On-site generated sodium hypochlorite

- 0.8% sodium hypochlorite is produced on demand by combining salt, water & electricity
- Electrolysis of brine solution produces sodium hydroxide and chlorine gas, which then mix to form sodium hypochlorite
- Hydrogen gas byproduct; vented to atmosphere
- Alleviates safety concerns associated w/ hauling and storing bulk chlorine
- Higher initial cost, high power cost
- Mixed oxidants (proprietary)

86

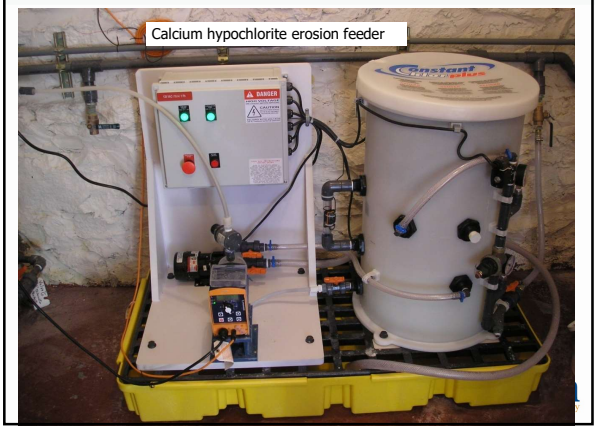
Electrodes for onsite chlorine generation

87

## Calcium hypochlorite

- The solid form of chlorine
- Usually tablet or powder form
- Contains ~65% chlorine by weight
- White or yellowish-white granular material and is fairly soluble in water
- Important to keep in a dry, cool place
- More stable than liquid
- Used by small systems w/ low flows or no power

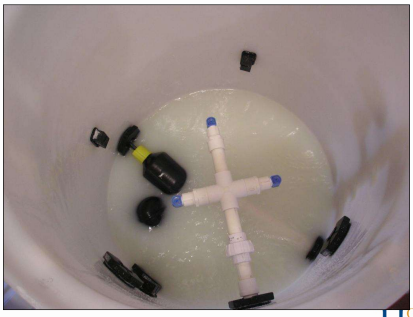
88



Calcium hypochlorite erosion feeder

89

## Calcium hypochlorite hopper interior

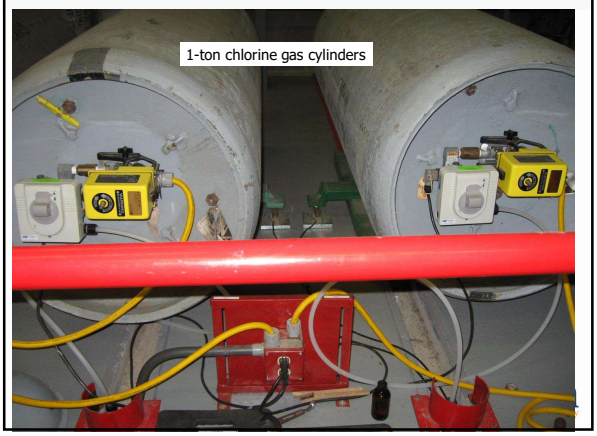


90

## Chlorine gas ($Cl_2$)

- 99.5% pure chlorine
- yellow-green color 2.5x heavier than air
- Liquified at room temperature at ~107 psi – hence the pressurized cylinders actually contain liquified chlorine gas.
- Liquified $Cl_2$ is released from tanks as chlorine gas, which is then injected into the water stream.
- usually used only by large water systems
- Smaller systems may find initial cost of operation prohibitive

91

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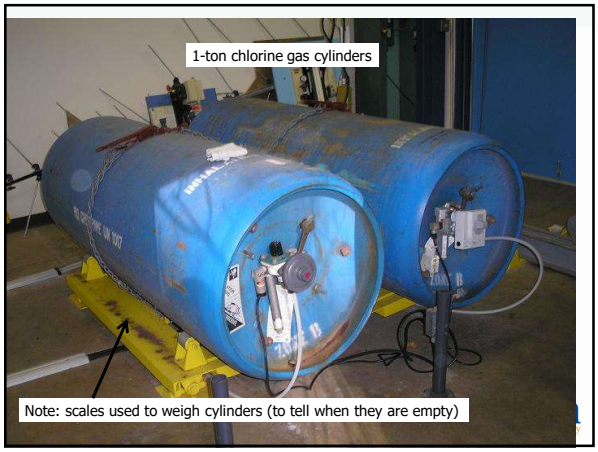



93

94

## Chloramines

- Chlorine + ammonia = chloramination
- Two advantages to regular chlorination:
  - produce a longer lasting chlorine residual (helpful to systems with extensive distribution systems)
  - may produce fewer by-products depending on the application
- Disadvantage:
  - Need a lot of contact time to achieve CTs compared to free chlorine (300 times more) which is why not used for primary disinfection
  - Requires specific ratio of chlorine to ammonia or else potential water quality problems

95

96

## Ozone

- Colorless gas ($O_3$)
- Strongest of the common disinfecting agents
- Also used for control of taste and odor
- Extremely Unstable; Must be generated on-site
- Manufactured by passing air or oxygen through two electrodes with high, alternating potential difference

97

Large water system ozone

98

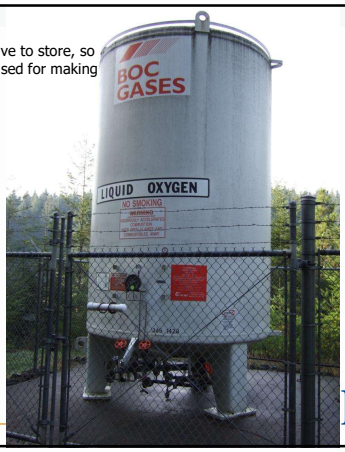
Large water system ozone

99

Ozone contactors

100

Ozone is to reactive to store, so liquid oxygen is used for making ozone




101

## Ozone advantages

- Short reaction time enables microbes (including viruses) to be killed within a few seconds
- Removes color, taste, and odor causing compounds
- Oxidizes iron and manganese
- Destroys some algal toxins
- Does not produce halogenated DBPs

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## Ozone disadvantages

- Overfeed or leak can be dangerous
- Cost is high compared with chlorination
- Installation can be complicated
- Ozone-destroying device is needed at the exhaust of the ozone-reactor to prevent smog-producing gas from entering the atmosphere and fire hazards

103

## Ozone disadvantages (continued)

- May produce undesirable brominated byproducts in source waters containing bromide
- No residual effect is present in the distribution system, thus postchlorination is required
- Much less soluble in water than chlorine; thus special mixing devices are necessary

104

## Chlorine dioxide

**Advantages**

- More effective than chlorine and chloramines for inactivation of viruses, *Cryptosporidium,* and *Giardia*
- Oxidizes iron, manganese, and sulfides
- May enhance the clarification process
- Controls T&O resulting from algae and decaying vegetation, as well as phenolic compounds
- Under proper generation conditions halogen-substituted DBPs are not formed
- Easy to generate
- Provides residual

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## Chlorine dioxide (continued)

**Disadvantages**

- Forms the DBP chlorite
- Costs associated with training, sampling, and laboratory testing for chlorite and chlorate are high
- Equipment is typically rented, and the cost of the sodium chlorite is high
- Explosive, so it must be generated on-site
- Decomposes in sunlight
- Can lead to production noxious odors in some systems.

106

## NSF/ANSI Standard 60

- Addresses the health effects implications of treatment chemicals and related impurities.
- The two principal questions addressed are:
  - Is the chemical safe at the maximum dose, and
  - Are impurities below the maximum acceptable levels?

107

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## Disinfection Requirements for Surface Water

- Surface Water Treatment Rule (SWTR) requires 3-log reduction of *Giardia* using a combination of **disinfection** and **filtration**
- 2.0 to 2.5-log removal is achieved through **filtration**
- 0.5 to 1.0-log inactivation is achieved through **disinfection**
- Determines which column of EPA tables used to calculate CTs (0.5 or 1.0-log)

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## What are CT's?

- It's a way to determine if disinfection is adequate
- **CT** = Chlorine **C**oncentration x Contact **T**ime
- Do not confuse "CT" and "Contact Time"

110

## How do we calculate CT's?

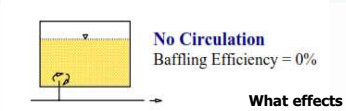
- We use the EPA tables to determine the CTs needed to inactivate *Giardia* ($CT_{required}$)
  - We need to know pH, temperature, and free chlorine residual at the first user in order to use the EPA tables.
- Then we compare that with the CTs achieved in our water system ($CT_{actual}$)
- $CT_{actual}$ must be equal to or greater than $CT_{required}$

111

## Tracer Studies and Contact Time:

- Used to determine contact time (T) which is used in calculating CT's
- Determines the time that chlorine is in contact with the water from the point of injection to the point where it is measured (sometimes referred to as the "CT segment")
  - May be at or before the 1st user
  - May be more than one CT segment
- Estimates of contact time are not allowed for calculating CT's for surface water!
  - ***The degree of short-circuiting is only <u>approximately</u> known until a tracer study is conducted.***

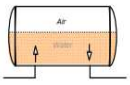
112



**No Circulation**
Baffling Efficiency = 0%

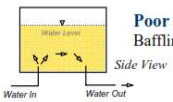
**What effects short-circuiting?**
**1) Flow rate**
**2) Flow path**

**No Circulation**
Baffling Efficiency = 0%
Bladder-Type Pressure Tank

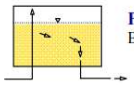



**Poor Circulation**
Baffling Efficiency = 10%
Hydropneumatic Tank

113

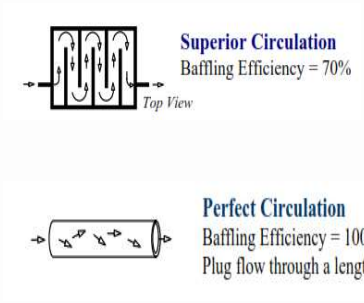



**Poor Circulation**
Baffling Efficiency = 5-10%



**Poor Circulation**
Baffling Efficiency = 10%

114

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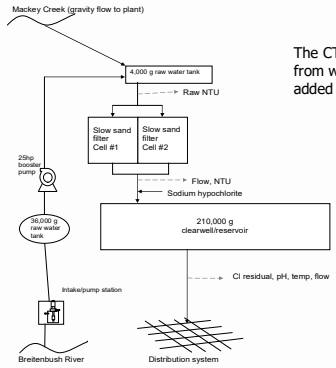
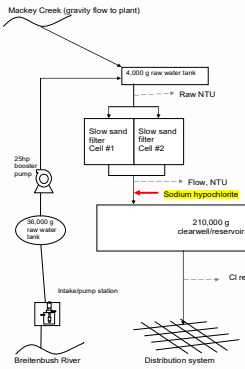


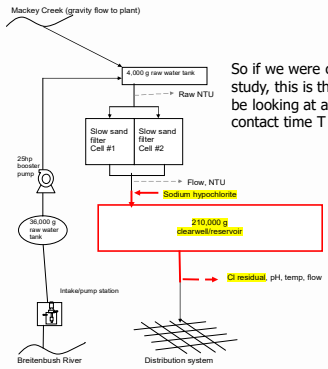

The CT segment is from where chlorine is added here:

116




Thru the clearwell, to where chlorine residual is measured here:

117




So if we were conducting a tracer study, this is the segment we would be looking at and determining the contact time T for.

118

## Tracer studies (continued):

- Different methods:
  1. If water is pumped from the clearwell at different rates depending on time of year, do tracer study at each of those flow rates
  2. Do at typical winter/summer peak hour demand flows
  3. Otherwise use "worst-case scenario" parameters:
     - Highest flow rate out of clearwell (conduct during peak hour or conditions that simulate e.g. open a hydrant)
     - Keep flow rate constant
     - Keep clearwell water level close to normal minimum operating level

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## Tracer studies (continued):

- Must redo if peak hour demand flow increases more than 10% of the maximum flow used during the tracer study
- Community water systems with populations <10,000 and non-profit non-community systems can use the circuit rider to perform a tracer study
- Must submit a proposal to DWS for approval prior to conducting the tracer study (even if using the circuit rider).

120

## Exercise #1

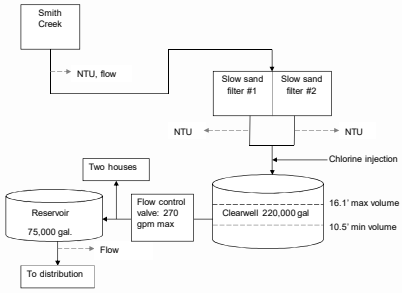
- **Tracer studies**

121

**Exercise #1: Tracer studies**

**Directions:** Look at the diagram and answer the questions.

**Figure 1: Water Treatment Plant**




**Questions:**

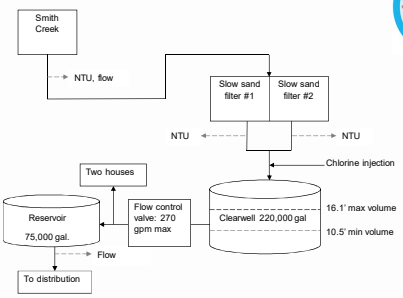
- If this was your treatment plant, highlight the part of the plant where you might conduct a tracer study.
- In a "worst-case scenario" tracer study, what would the flow rate be? _____
- In a "worst-case scenario" tracer study, what would the clearwell level be? _____

122

**Exercise #1: Tracer studies**

**Directions:** Look at the diagram and answer the questions.

**Figure 1: Water Treatment Plant**



**Questions:**

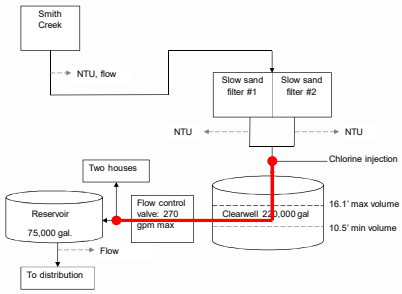
- If this was your treatment plant, highlight the part of the plant where you might conduct a tracer study.
- In a "worst-case scenario" tracer study, what would the flow rate be? _____
- In a "worst-case scenario" tracer study, what would the clearwell level be? _____

123

**Exercise #1: Tracer studies**

**Directions:** Look at the diagram and answer the questions.

**Figure 1: Water Treatment Plant**




**Questions:**

- If this was your treatment plant, highlight the part of the plant where you might conduct a tracer study.
- In a "worst-case scenario" tracer study, what would the flow rate be? **270 gpm**
- In a "worst-case scenario" tracer study, what would the clearwell level be? **10.5 feet**

124

## How info from tracer study is used to calculate CTs

- Use the time T from the tracer study on the monthly reporting form in the "Contact time (min)" column
  - Use the smallest T (highest flow) if the tracer study was done at multiple flow rates
- This may not be your exact time, but it represents your worst case (as long as the peak flow is less and clearwell volume is more than they were at the time of the tracer study)

125

## How info from tracer study is used to calculate CTs (cont.)

- Or, once you know the time T from the tracer study, you can back-calculate to determine the baffling factor of the clearwell
  - Baffling factor (%) = $\frac{\text{Time (min) x Flow During Tracer Study (gpm)}}{\text{Clearwell Volume During Tracer Study (gal)}}$
- T can be adjusted based on flow (at <110%) with the following equation:
  - T = $\frac{\text{Current clearwell Volume (gal) x Baffling Factor (\%)}}{\text{Peak Hourly Demand Flow (gpm)}}$
- If tracer study includes pipeline segments or multiple tanks, contact the state for guidance on using baffling factors

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## Impact of chlorine and ozone on organics

- Disinfectants can react with organics to form disinfection byproducts
  - Chlorine: TTHMs & HAA5s
  - Ozone: Bromate
- Pre-chlorination
- TOC

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## OPERATIONS

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## Overview

- Proper instrument sampling locations
- Proper treatment plant sampling locations
  - Turbidity
  - Chlorine residual
  - TOC
- Instrument calibration
  - Turbidimeters
  - Chlorine analyzers
  - Chemical feed pumps
- Operations & Maintenance Manuals

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## Proper instrument sampling location

- Data provided by instruments provides the basis for assessing water quality – important to get it right!
- Common problems
  - Sampling location
  - Measurement techniques
  - Calibration frequency and approach
- Possible solutions
  - May require investigations (special studies)
  - Modifications to sample lines
  - Establish guidelines on sample line cleaning
  - Establish calibration procedure

130

## Proper treatment plant sampling locations: Turbidity

- Raw turbidity
  - Applies to all SW systems
  - Location: pre-treatment
  - Frequency: no regulatory requirement but need to know for proper treatment plant operation
- Individual filter effluent (IFE) turbidity
  - CF, DF & membranes only
  - Location: after each individual filter
  - Frequency: continuous (every 15 minutes)
  - Know what the triggers are!

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## IFE Triggers (Conventional/Direct)

- Report the following events immediately and conduct a filter profile within 7 days (if no obvious reason exists) if the IFE turbidity is:
  - > 1.0 NTU in 2 consecutive 15-min readings
  - > 0.5 NTU in 2 consecutive 15-min readings within 4 hours of being backwashed or taken off-line
- Report the following events and conduct a filter self assessment within 14 days if the IFE turbidity is:
  - > 1.0 NTU in 2 consecutive 15-min readings at any time in each of 2 consecutive months.
- A CPE must be done within 30 days if the IFE turbidity is:
  - > 2.0 NTU in 2 consecutive 15-min readings at any time in each of 2 consecutive months.

132

## Proper treatment plant sampling locations: Turbidity (cont.)

- Combined filter effluent (CFE) turbidity
  - Applies to all SW systems
  - Location: post all filtration prior to chemical addition and any storage
  - Frequency:
    - CF/DF > 3,300 pop. – continuous
    - CF/DF ≤ 3,300 pop. – every 4 hrs
    - Alternative - daily

133

## Proper treatment plant sampling locations: Chlorine residual

- Location: entry point (EP) to the system
  - EP = post clearwell, at or before 1st user
- Frequency
  - Continuous > 3,300 population
  - 1-4x/day for ≤ 3,300 population
- Must maintain minimum 0.2 ppm at all times

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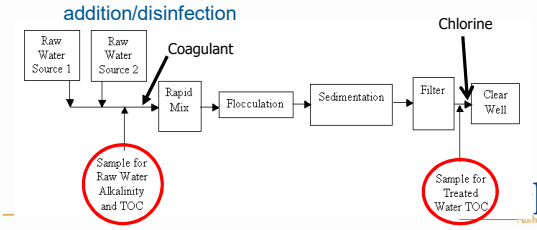
## Proper treatment plant sampling locations: Total organic carbon (TOC)

- Applicability
  - CF (2.5-log plants): required raw TOC & alkalinity and filtered TOC
  - All others: raw TOC required to qualify for DBP monitoring reduction (>500 population)
- Frequency
  - Monthly; may be reduced to Quarterly if filtered TOC is <2.0 ppm for 2 years, or <1.0 ppm for 1 year
  - Quarterly if DBP reduction is granted

135

## Proper treatment plant sampling locations: Total organic carbon (TOC) (cont.)

- Location
  - Raw TOC & alkalinity: pre-treatment
  - Filtered TOC: CFE prior to chemical addition/disinfection

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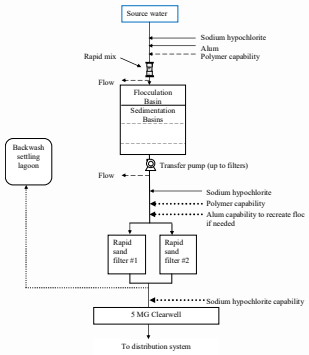
## Exercise #2

- Proper sampling locations for turbidity, chlorine residual, and TOC
  - Work in groups to determine proper sampling locations on WTP diagrams

137

**Exercise #2: Proper sampling locations in a treatment plant for turbidity, chlorine residual, and TOC**



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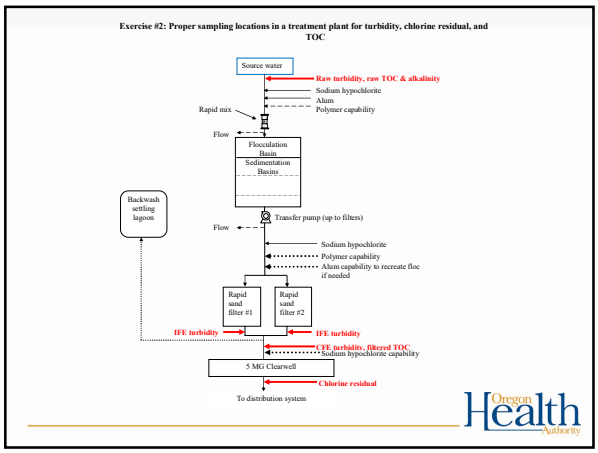


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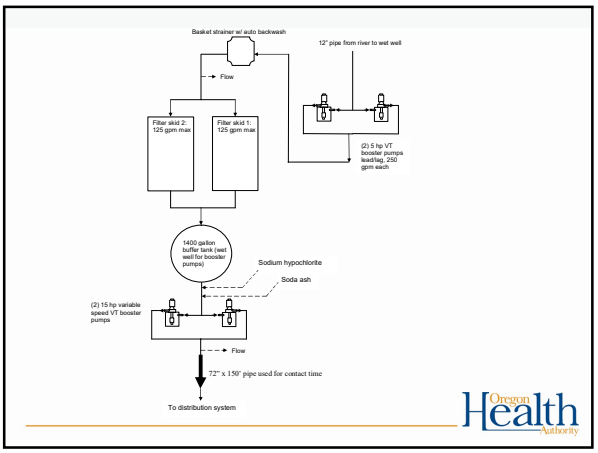


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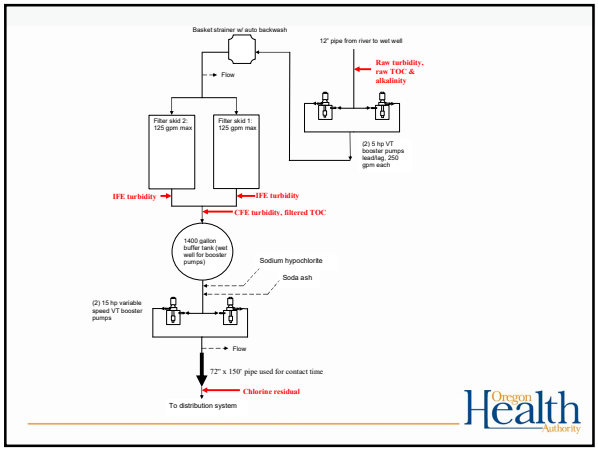


141

## Instrument calibration

- Turbidimeters (online, portable or benchtop)
  - Must be calibrated per manufacturer or at least quarterly with a primary standard
    - Formazin solution
    - Stablcal (stabilized formazin)
  - Secondary standards used for day-to-day check
  - Check is used to determine if calibration with a primary standard is necessary
    - Gelex
    - Manufacturer provided (e.g. Hach ICE-PIC)

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Portable turbidimeter

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## Instrument calibration

- Chlorine analyzers
  - Handheld
    - Follow manufacturer's instructions
  - Inline
    - Check calibration against a handheld that has been calibrated
    - At least weekly
    - Follow manufacturer's instructions if out of calibration

144

Portable colorimeter

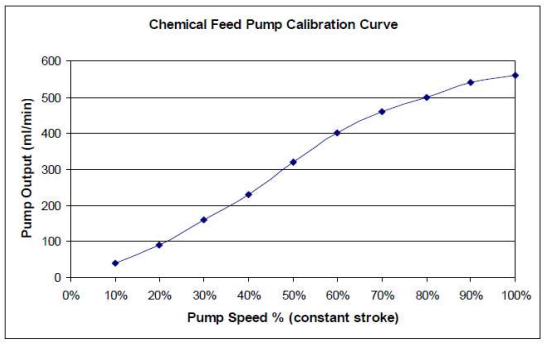
145

## Instrument calibration

- Chemical feed pumps
  - Calibration measures both the speed and the stroke (amount of chemical pumped) so accurate dosages can be calculated
  - Create a "pump curve";
    - Set the stroke at half way point
    - On a graph, plot speeds of 10% to 100% on X axis
    - Plot chemical output amount on Y axis (ml/min)
    - Record drawdown in graduated cylinders for 1 minute

146

**Calibration Graphs: Pump Output Vs. Pump Speed**




147

## Instrument calibration (cont.)

- Chemical feed pumps (cont.)
  - Pump curve is an important tool to identify when a pump may be in need of maintenance or replacement
  - A smooth pump curve is good (should fit close to a straight line)
  - Must compare information at varying speeds to be a full pump calibration process
  - Suggested frequency: no less than annual

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Chemical feed pumps

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## Exercise #3

- Create a pump curve using made-up data points
- **Directions:** Use the data provided in Exercise #3 to create a pump curve. Pump curves should be smooth and fairly linear. A bouncing or jagged pump curve indicates the pump needs maintenance. Maintenance needed may include cleaning, diaphragm replacement and/or seal replacement.

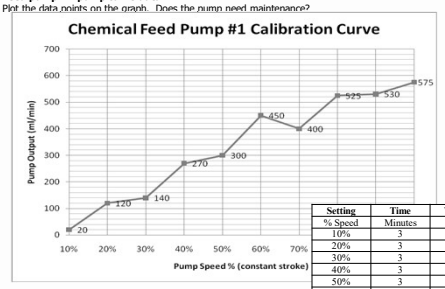
150

**Exercise #3: Creating a chemical feed pump curve**

**Directions:** Use the data provided in the examples below to create a pump curve. Pump curves should be smooth and fairly linear. A bouncing or jagged pump curve indicates the pump needs maintenance. Maintenance needed may include cleaning, diaphragm replacement and/or seal replacement.

**Feed pump #1 pump curve data:**

Plot the data points on the graph. Does the pump need maintenance?



| Setting | Time | Volume | Flow Rate |
|---|---|---|---|
| % Speed | Minutes | ml | ml/min |
| 10% | 3 | 60 | 20 |
| 20% | 3 | 360 | 120 |
| 30% | 3 | 420 | 140 |
| 40% | 3 | 810 | 270 |
| 50% | 3 | 900 | 300 |
| 60% | 1 | 450 | 450 |
| 70% | 1 | 400 | 400 |
| 80% | 1 | 525 | 525 |
| 90% | 1 | 530 | 530 |
| 100% | 1 | 575 | 575 |

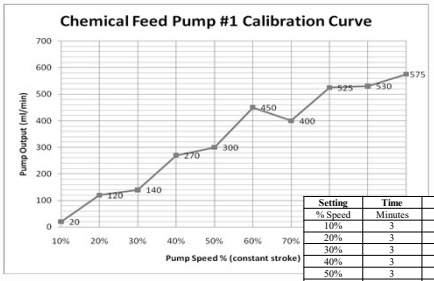
151

**Exercise #3: Creating a chemical feed pump curve**

**Directions:** Use the data provided in the examples below to create a pump curve. Pump curves should be smooth and fairly linear. A bouncing or jagged pump curve indicates the pump needs maintenance. Maintenance needed may include cleaning, diaphragm replacement and/or seal replacement.

**Feed pump #1 pump curve data:**

Plot the data points on the graph. Does the pump need maintenance? **Yes (jagged line)**




| Setting | Time | Volume | Flow Rate |
|---|---|---|---|
| % Speed | Minutes | ml | ml/min |
| 10% | 3 | 60 | 20 |
| 20% | 3 | 360 | 120 |
| 30% | 3 | 420 | 140 |
| 40% | 3 | 810 | 270 |
| 50% | 3 | 900 | 300 |
| 60% | 1 | 450 | 450 |
| 70% | 1 | 400 | 400 |
| 80% | 1 | 525 | 525 |
| 90% | 1 | 530 | 530 |
| 100% | 1 | 575 | 575 |

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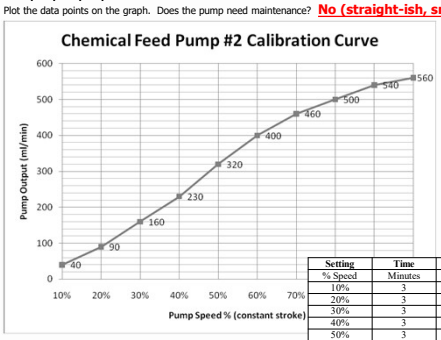
**Feed pump #2 pump curve data:**

Plot the data points on the graph. Does the pump need maintenance? **No (straight-ish, smooth line)**




| Setting | Time | Volume | Flow Rate |
|---|---|---|---|
| % Speed | Minutes | ml | ml/min |
| 10% | 3 | 120 | 40 |
| 20% | 3 | 270 | 90 |
| 30% | 3 | 480 | 160 |
| 40% | 3 | 690 | 230 |
| 50% | 3 | 960 | 320 |
| 60% | 1 | 400 | 400 |
| 70% | 1 | 460 | 460 |
| 80% | 1 | 500 | 500 |
| 90% | 1 | 540 | 540 |
| 100% | 1 | 560 | 560 |

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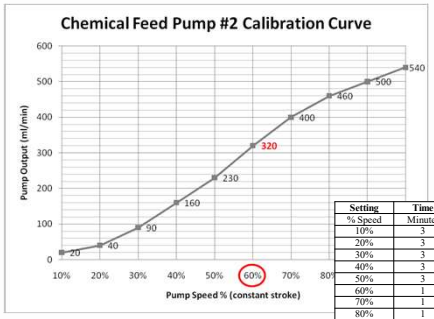
**Bonus question:** Referring to feed pump #2 data above, if you normally have your speed set at 50% in order to maintain 1 ppm of chemical, what speed do you need to change it to if you do a new pump curve and get the following results:

**Feed pump #2 *NEW* pump curve data**

Answer: **60%**




| Setting | Time | Volume | Flow Rate |
|---|---|---|---|
| % Speed | Minutes | ml | ml/min |
| 10% | 3 | 60 | 20 |
| 20% | 3 | 120 | 40 |
| 30% | 3 | 270 | 90 |
| 40% | 3 | 480 | 160 |
| 50% | 3 | 690 | 230 |
| 60% | 1 | 320 | 320 |
| 70% | 1 | 400 | 400 |
| 80% | 1 | 460 | 460 |
| 90% | 1 | 500 | 500 |
| 100% | 1 | 540 | 540 |

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## Lessons learned from data assessments done in the past

- Common findings:
  - Most systems have some problems with the way they monitor, record, assemble, and/or report data
  - Operators do not know which data to report and which to exclude
  - Operators do not know how to correctly use their tracer studies/calculate CTs
  - Most system managers and operators are surprised by what they find out from a data assessment

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## Data assessments (cont.)

- Even automated systems require a knowledgeable person to correctly assemble data
- Data assessments often used to justify invalidation of turbidity data which would have triggered a CPE
- Effective optimization can only be achieved when using valid performance data

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## How can operators become better data managers?

- Make data reliability a plant goal
- Only collect data used for process control or compliance reporting
- Establish protocols for collection and recording of data
- Establish a data verification process that can be routinely used to confirm data integrity
- Turn data into information!

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## Operations & Maintenance Manual

Keep written procedures on:

- Instrument calibration methods and frequency
- Data handling/reporting
- Chemical dosage determinations
- Filter operation and cleaning
- CT determinations
- Responding to abnormal conditions (emergency response plan)

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## End of Part 1

- 0.3 CEU certificates for Part 1 will be e-mailed to you soon.
- Make sure you sign up for Part 2 to receive an additional 0.3 CEU certificate.
- Register under "Free Training Resources" at www.healthoregon.org/swt
- E-mail questions to: DWS.SurfaceWater@dhsoha.state.or.us

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