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*.

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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

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

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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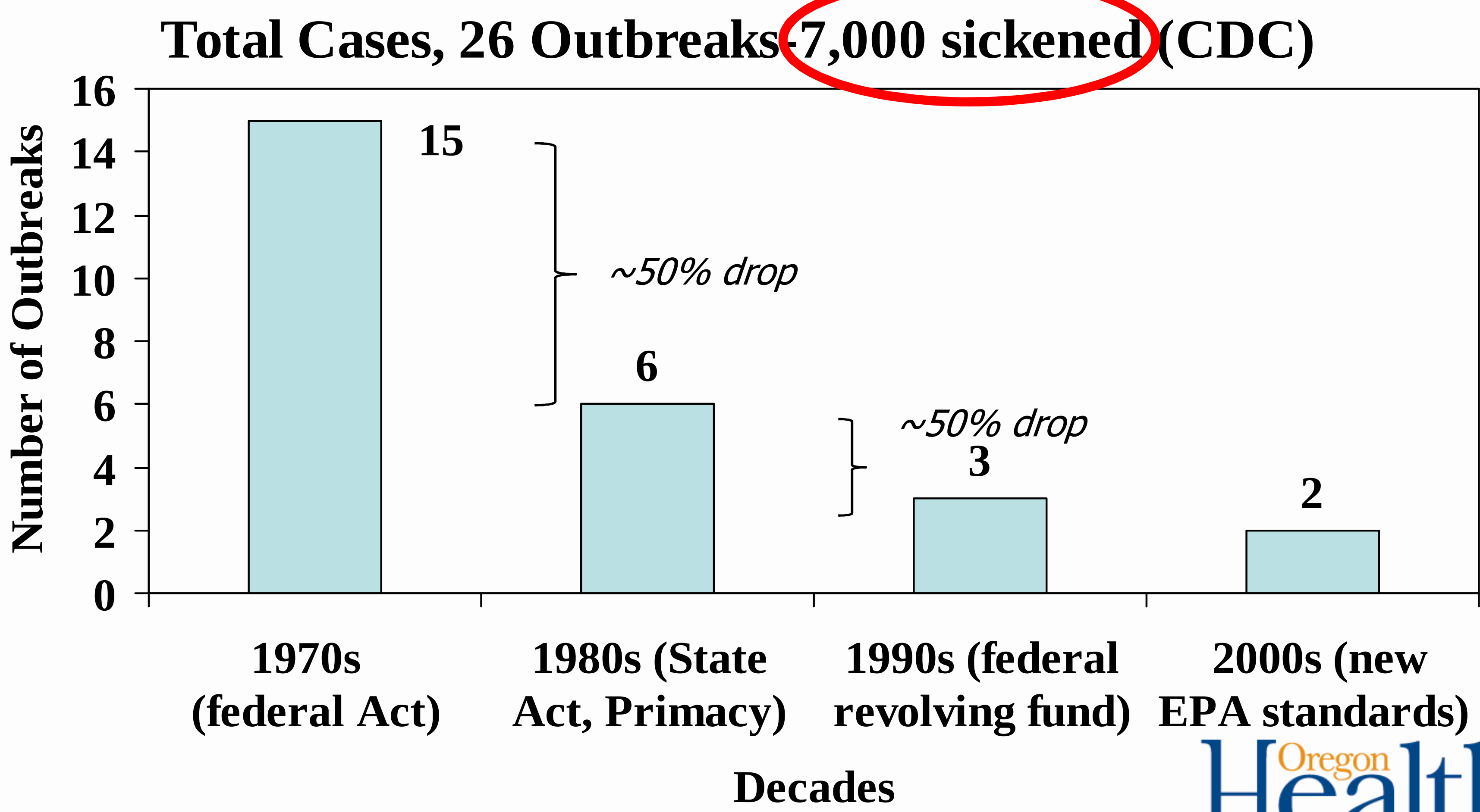
Raw Water Quality Factors

- 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

Oregon Waterborne Disease Outbreaks

(bacteria, viruses, parasites)



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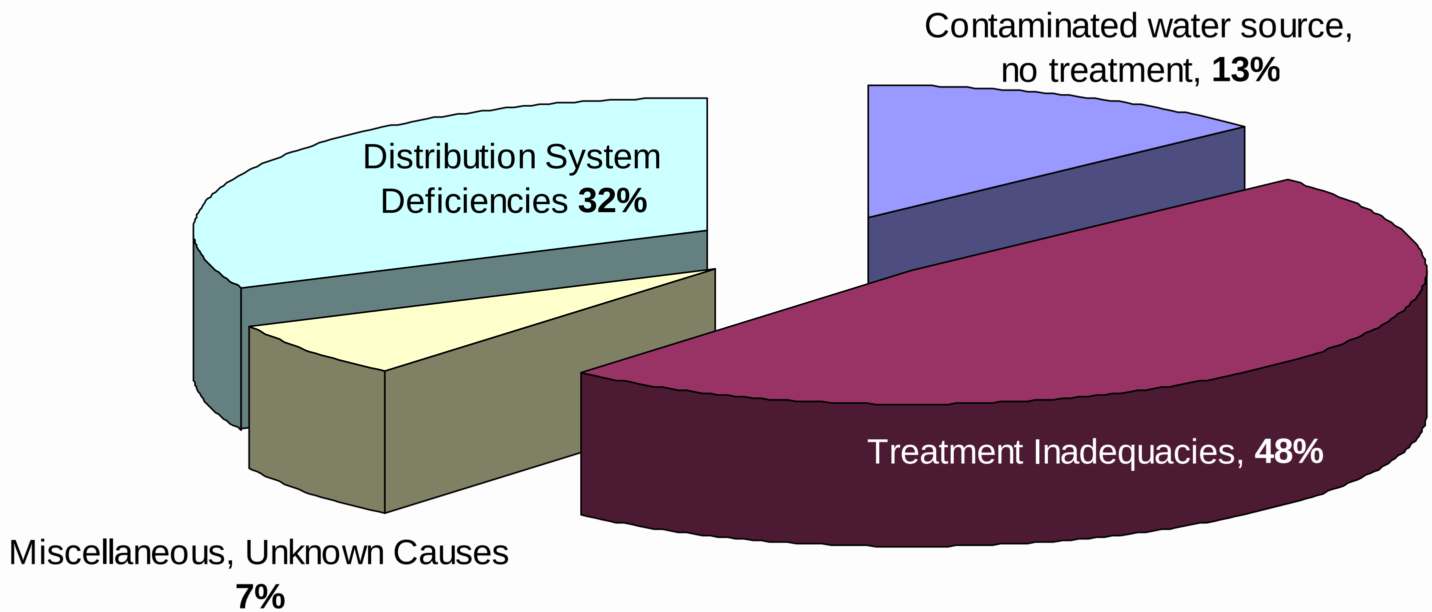
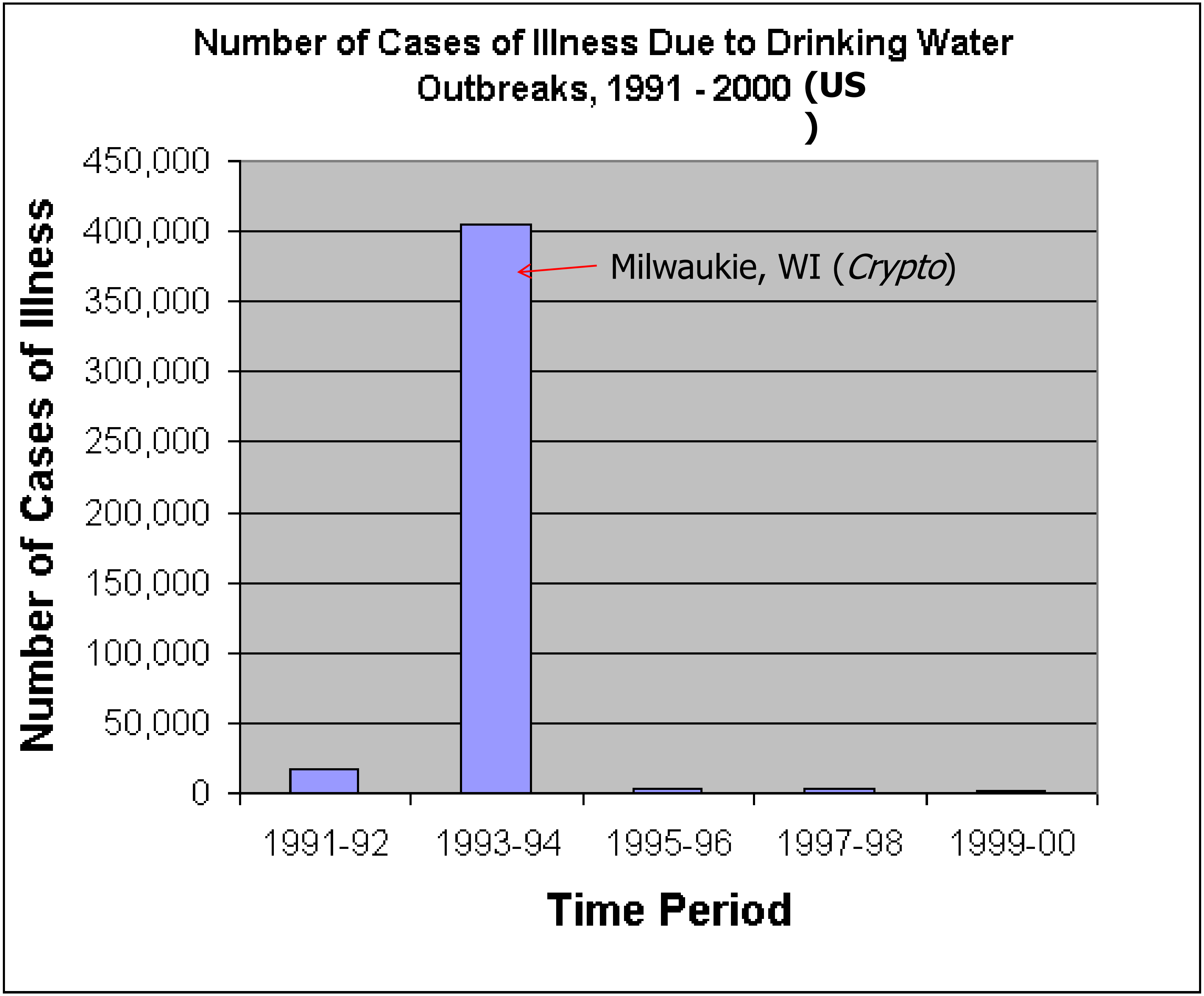
Waterborne Disease Outbreak Causes



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

From August 2006 Access AWWA


Number of Cases of Illness Due to Drinking Water Outbreaks, 1991 - 2000 (US)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Number of Cases of Illness
Milwaukie, WI (*Crypto*)
1991-92
1993-94
1995-96
1997-98
1999-00
Time Period

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

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 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 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.

FILTRATION

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)

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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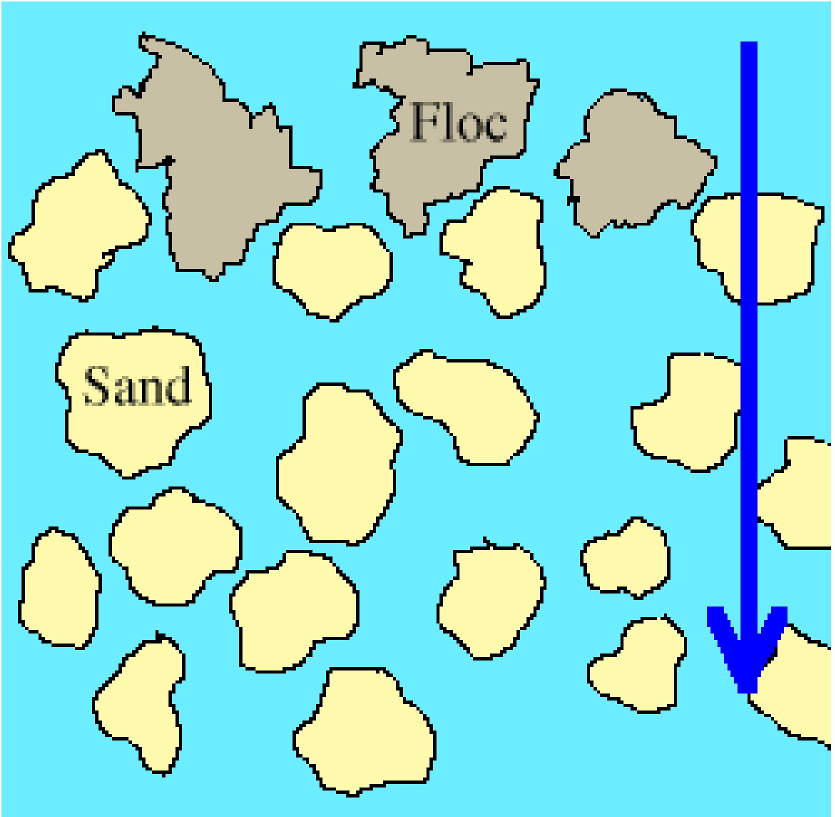
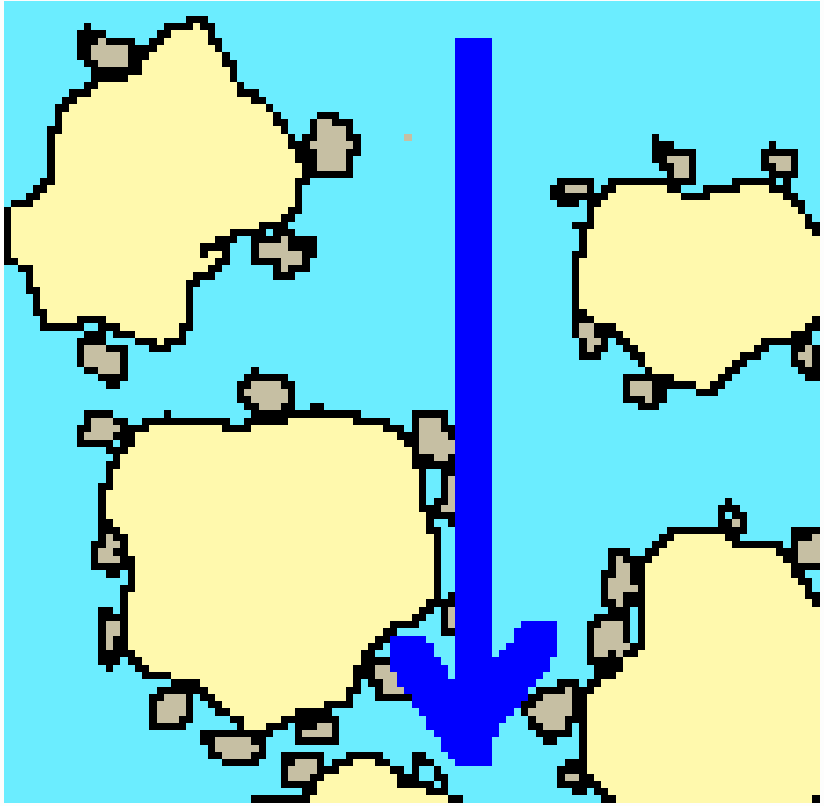
Straining

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

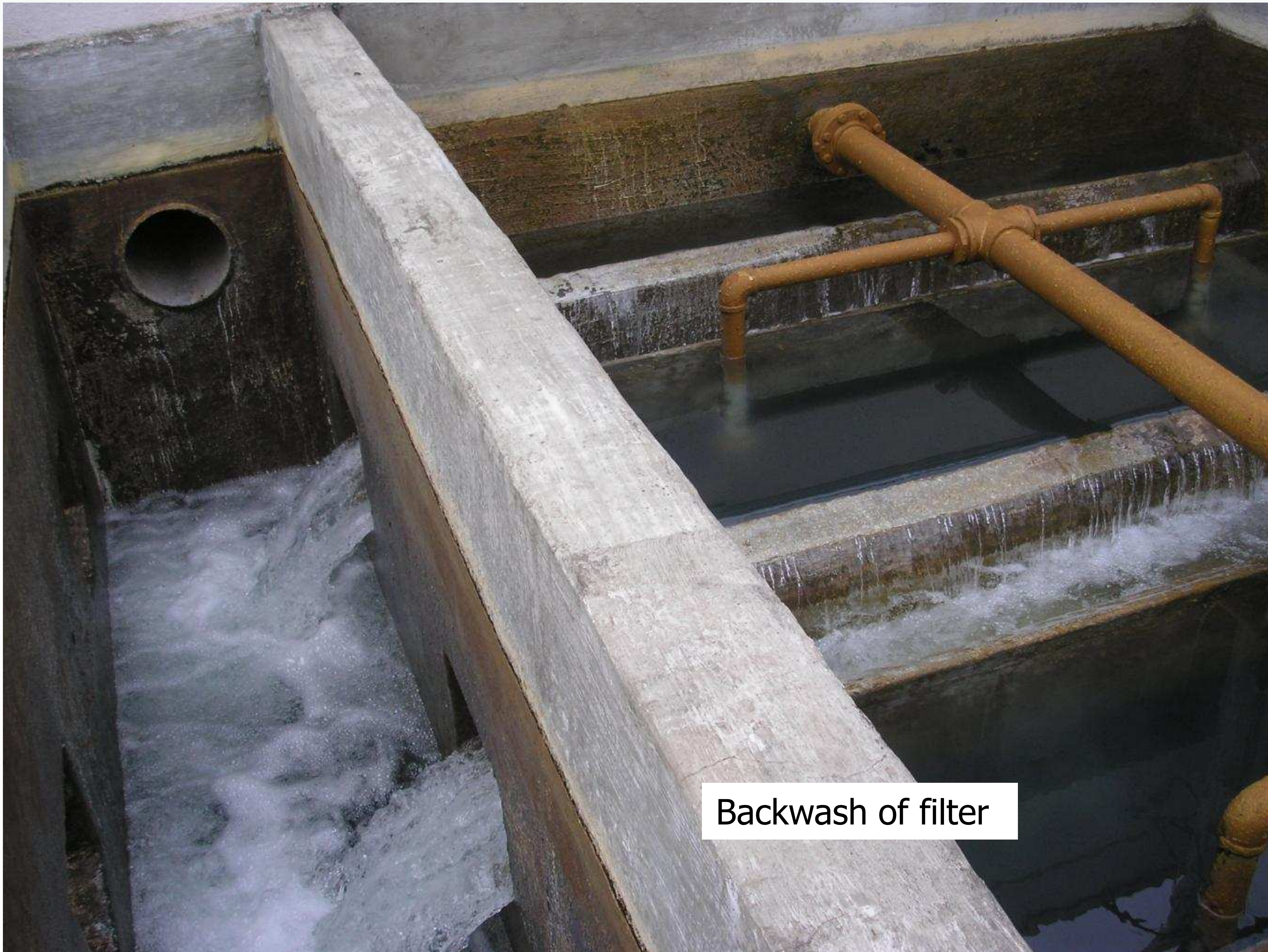


Adsorption

- 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.

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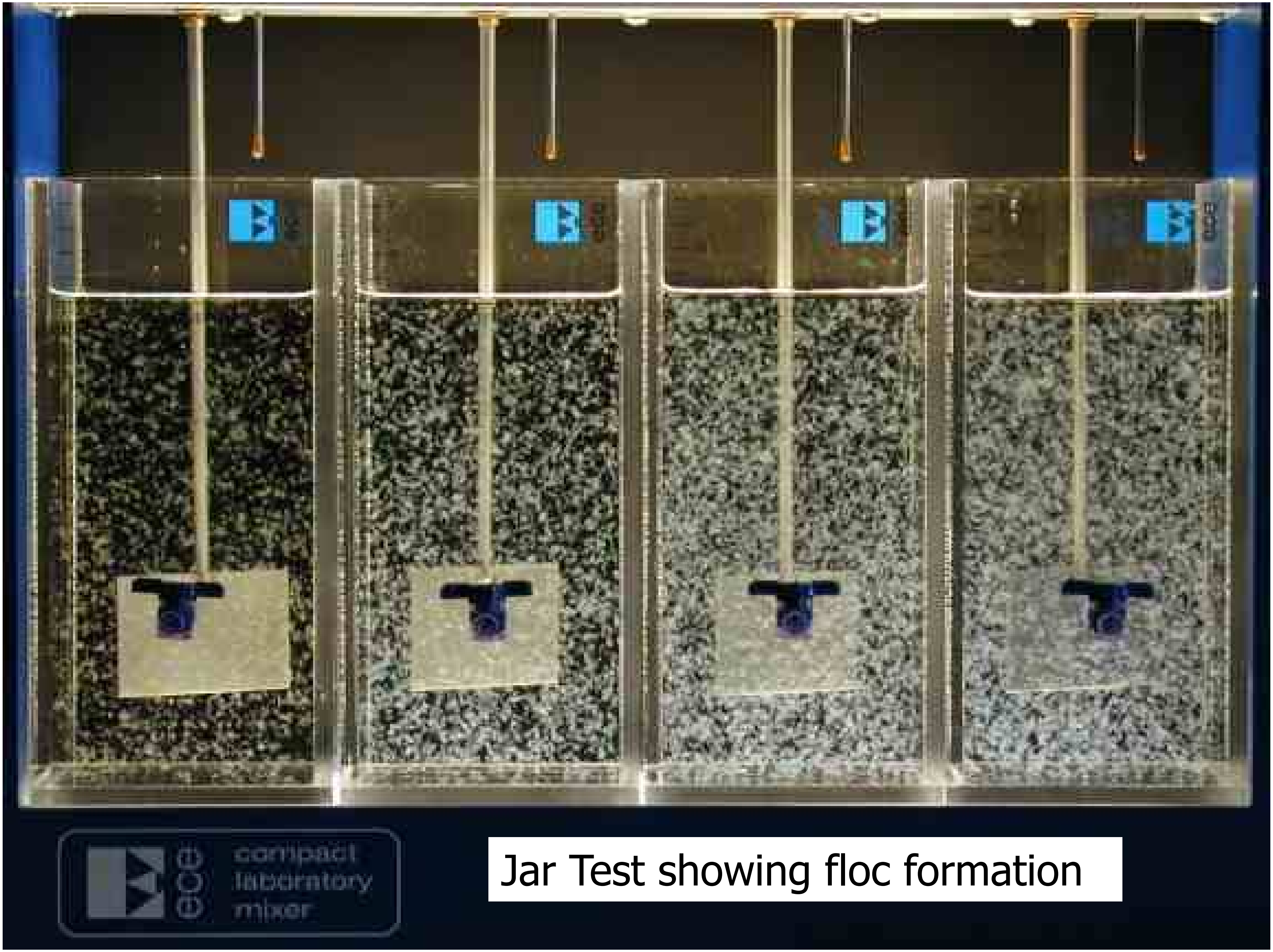
ALUMINUM SULFATE
13-T-04
3264

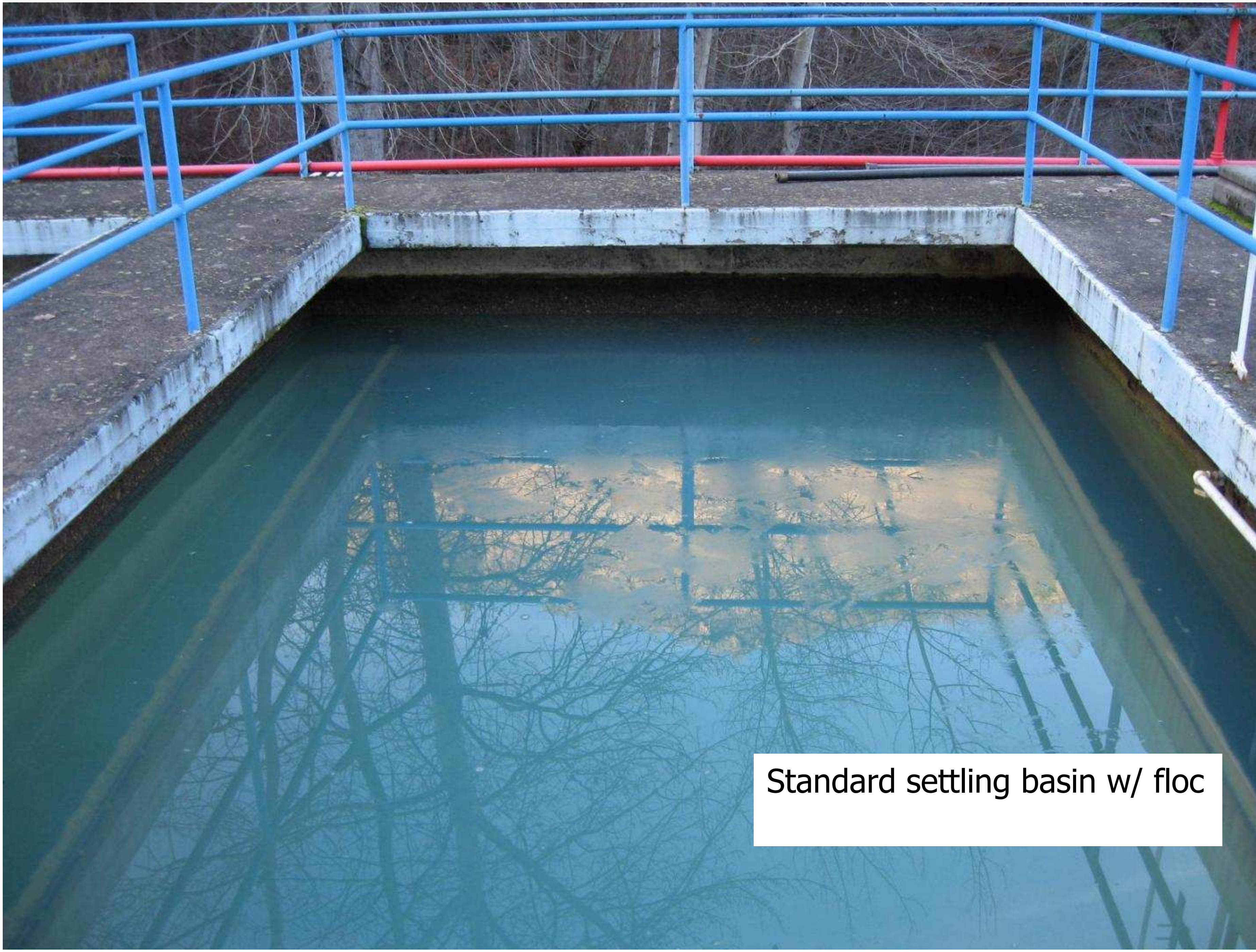

Floc basin with baffling



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



Standard settling basin w/ floc

Tube settlers in a package plant

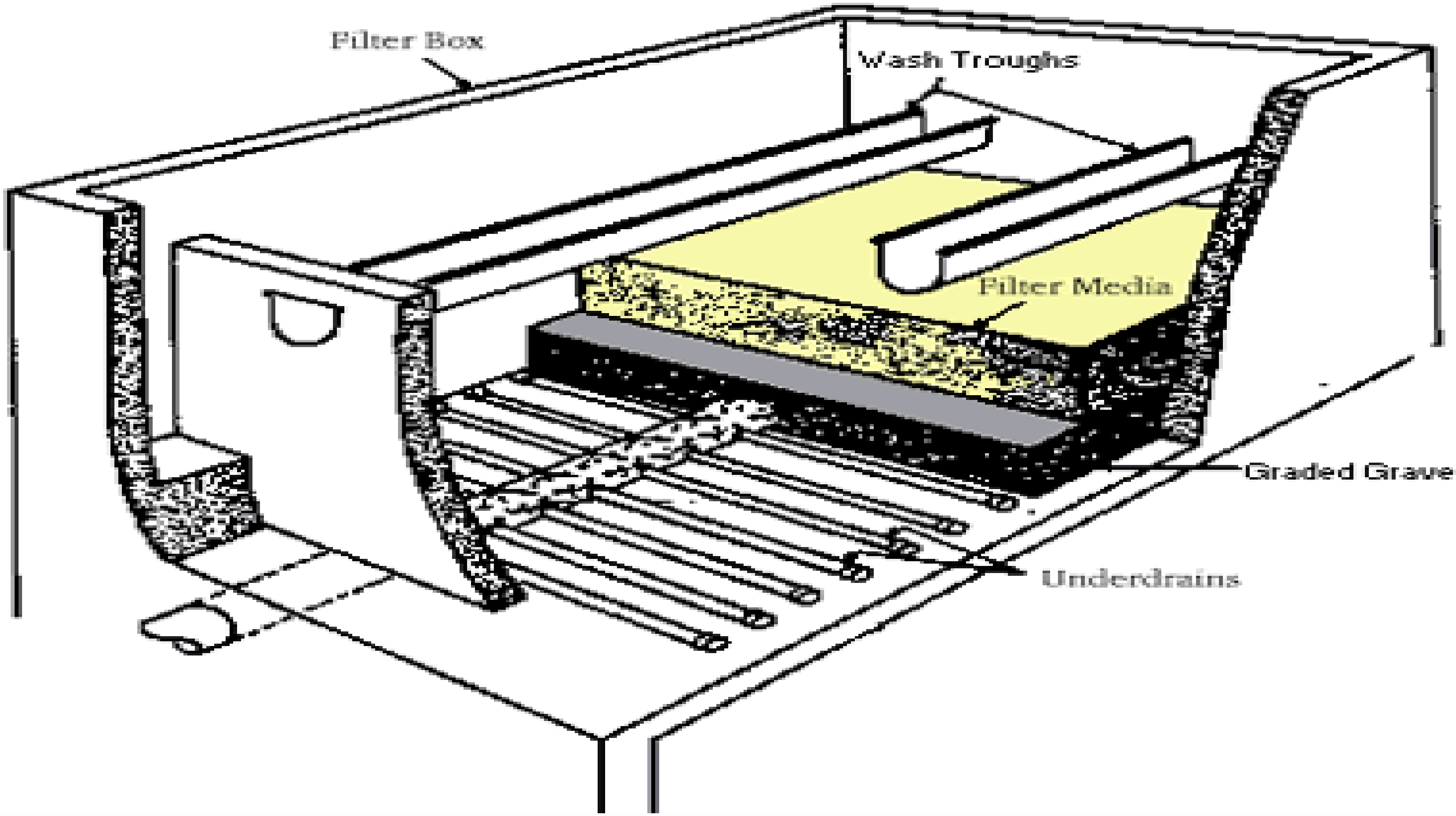
Adsorption (Upflow) Clarifiers

- 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.

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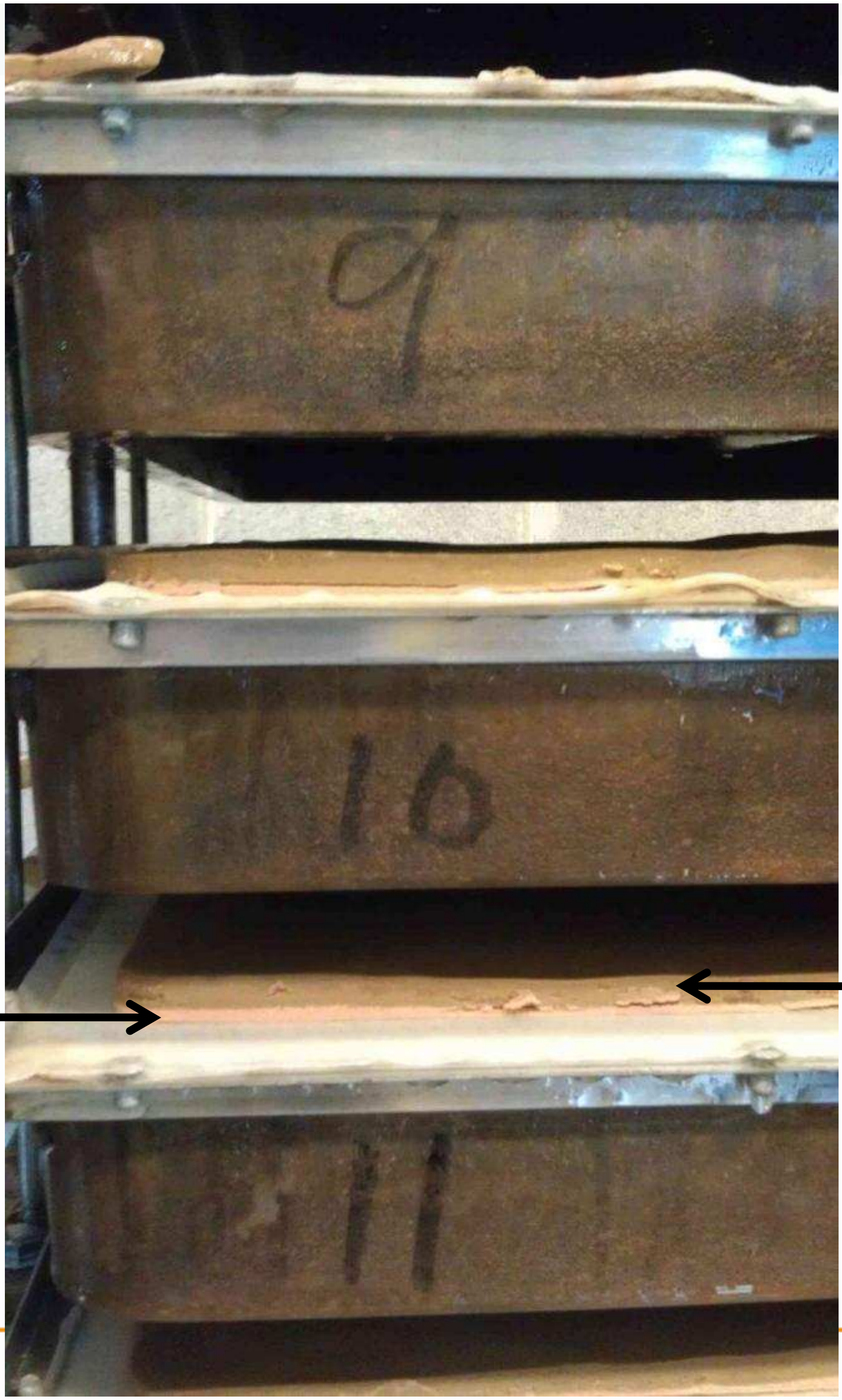
Pressure filters

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 filter stack

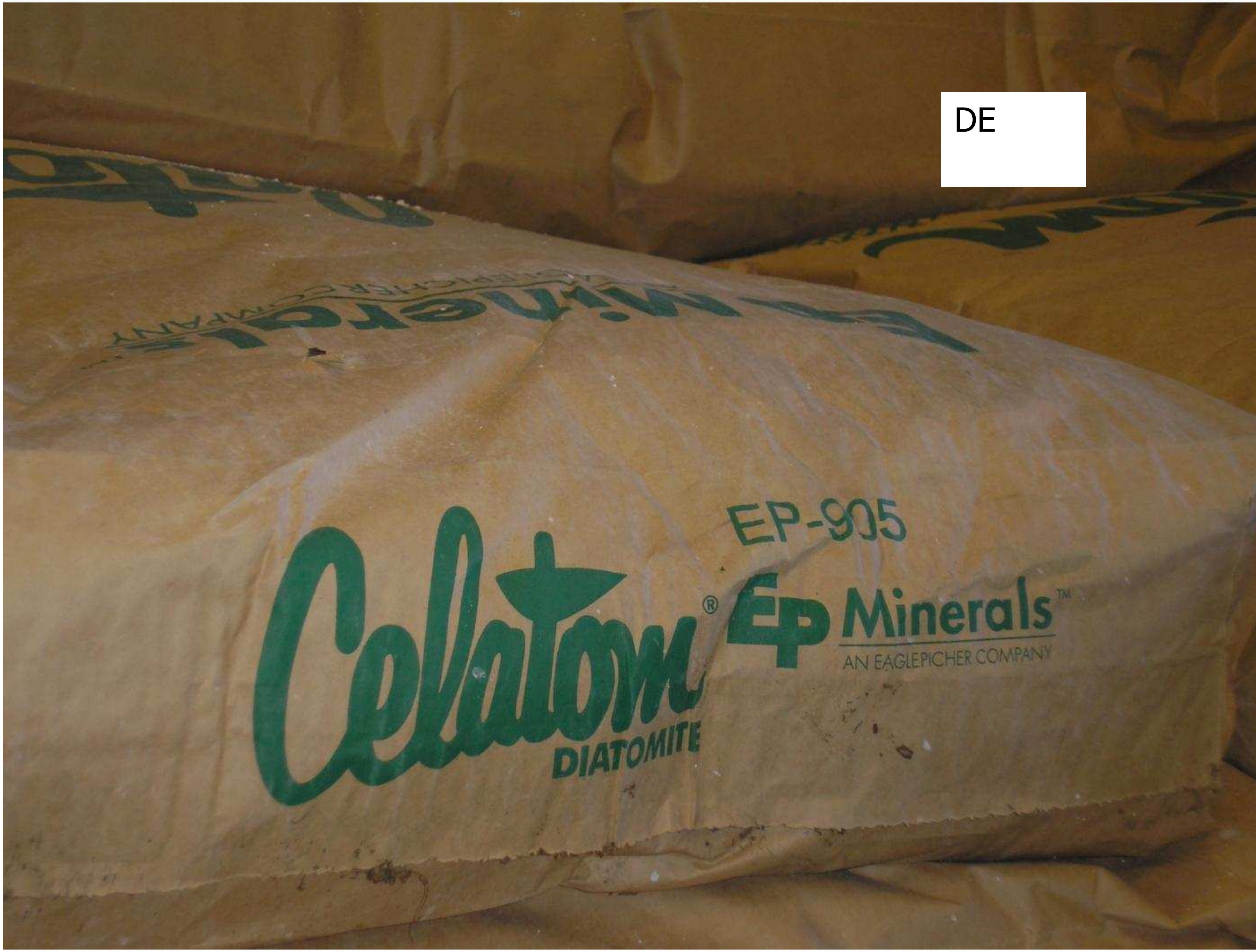


DE cake (pink layer)

Sediment that's been filtered out (brown layer)


Sediment removed
DE cake
Rubbermaid

DE


EP-905
Celatom®
DIATOMITE
EP Minerals™
AN EAGLEPICHER COMPANY

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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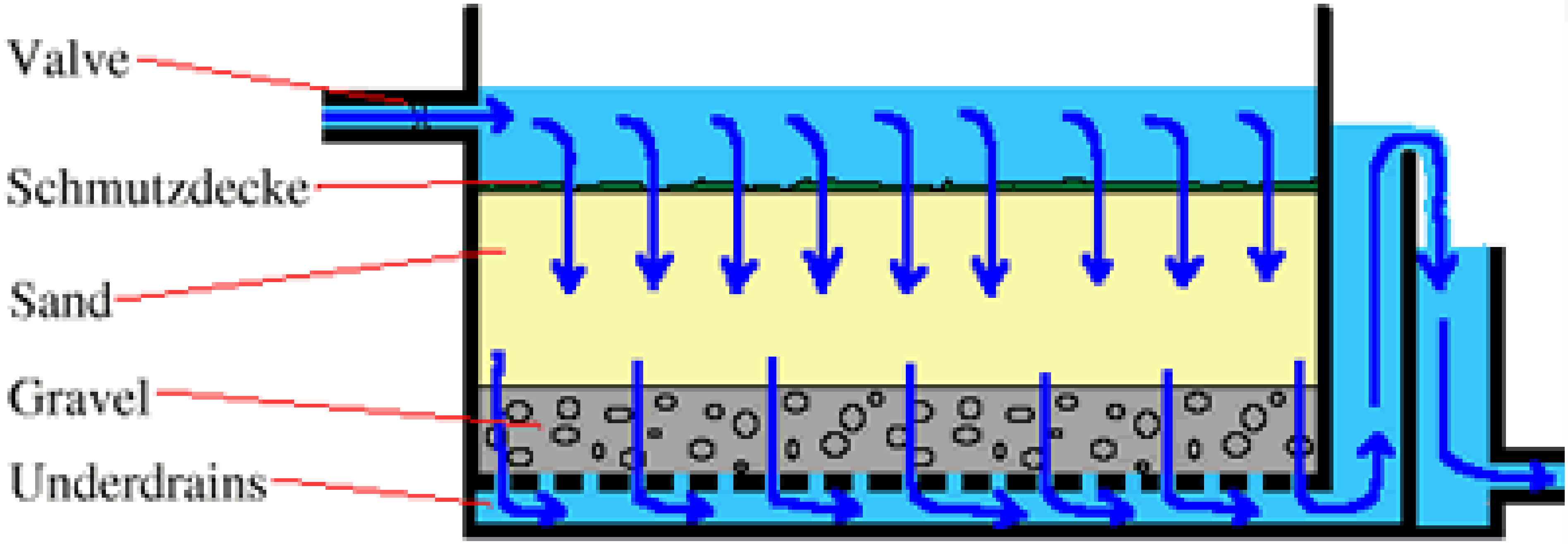

In the slow sand filter, water passes first through about 36 inches of sand, then through a layer of gravel, before entering the underdrain. The sand removes particles from the water through adsorption and straining. A layer of dirt, debris, and microorganisms builds up on the top of the sand. This layer 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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Bird’s eye view of 4 large slow sand filter cells

Large slow sand filter bed

slow sand filter - drained

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 verfications for units not listed.)

Manufacturer	Model			Log_{10} Removal Credit			Maximum Flow/Module (gpm)	Maximum Pressure Drop (psi @ 20°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[d]
	not applicable	PS 740 PPP 356	18435-2F-1-150-SB700	2.0	2.0	0	80	31[d]

[A] Adapter 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)

Updated: 14 September 2011

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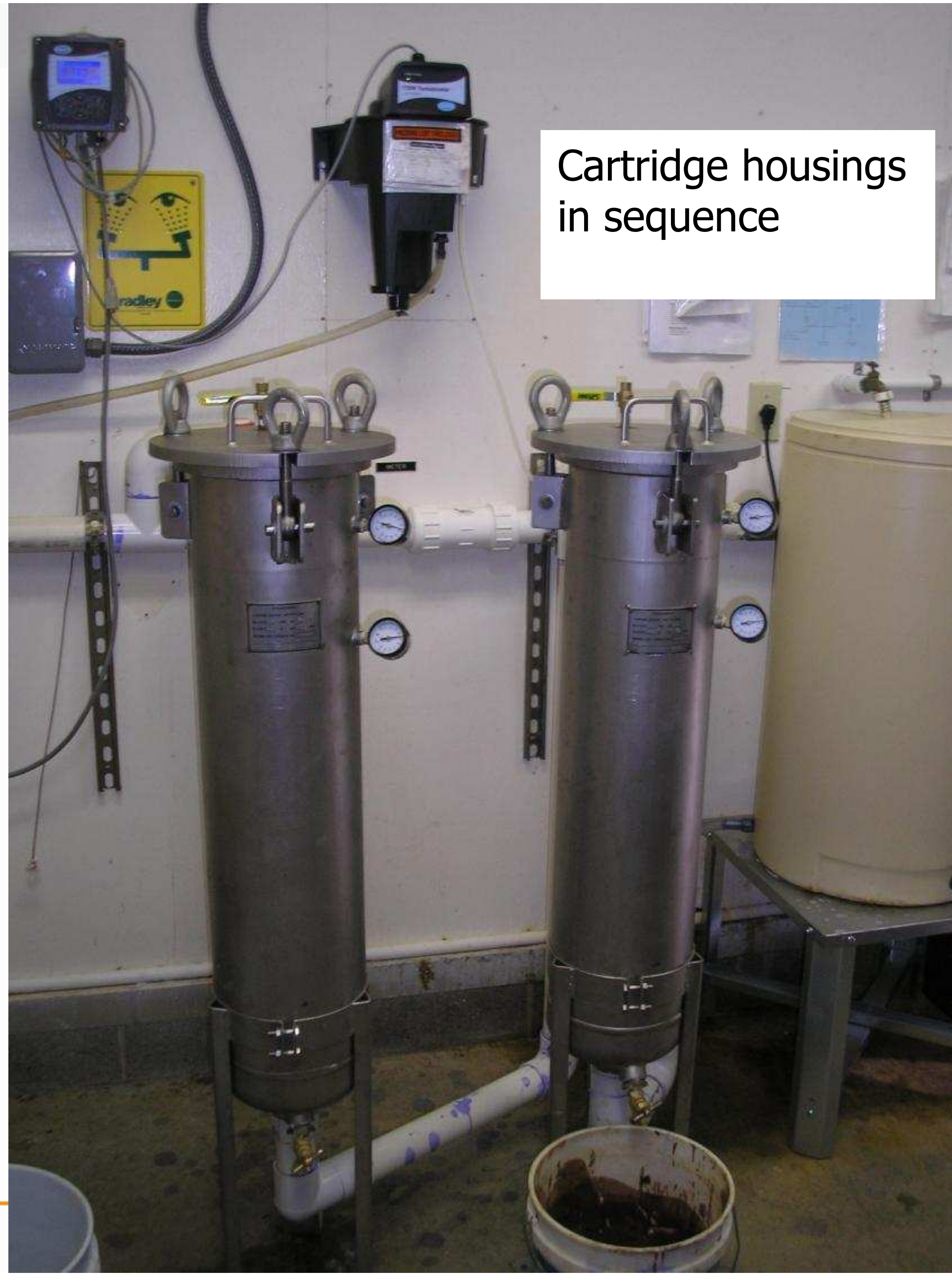
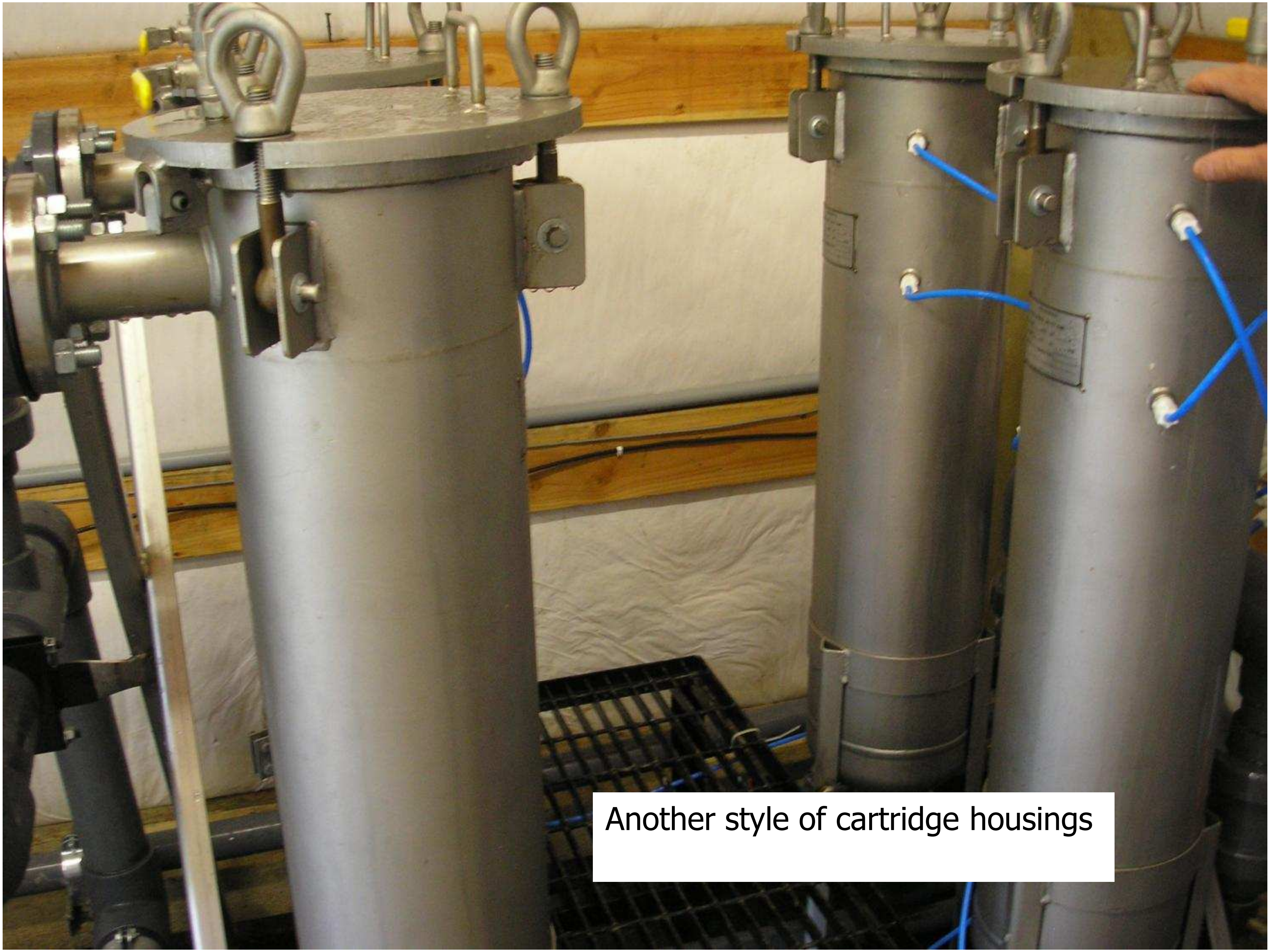
Cartridge housings in sequence



Cartridge housings in parallel



Another style of cartridge housings

Filter cartridges that go in the housings

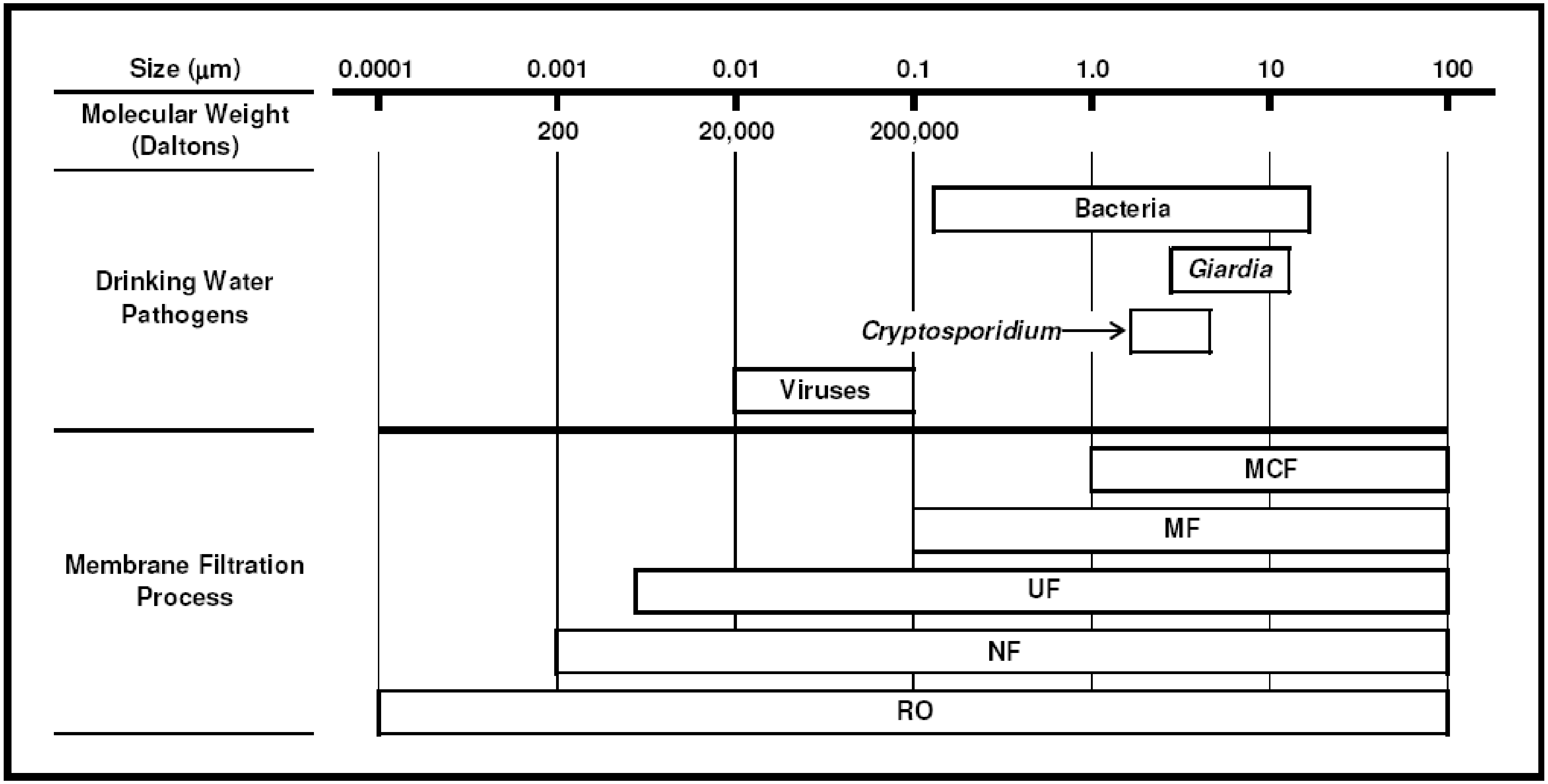

Bag filter

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



- **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 verfications 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]					
Dow/Tonka	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-5203	4.0	4.0	0	120	35	33	27	25-Feb-10
Seccua	Phoenix	4.0	4.0	0	47	72	42	22	6-Aug-10
	Virex Pro	4.0	4.0	0	47	45	2.13	22	27-Oct-10
Siemens	Memcor® S10V	4.0	4.0	0	80	13	16.7	17.4	12-Nov-10
Toray	Torayfil HFS-2020	4.0	4.0	0	120	29	47	18	21-Mar-12
WesTech	Polymem UF 120S2	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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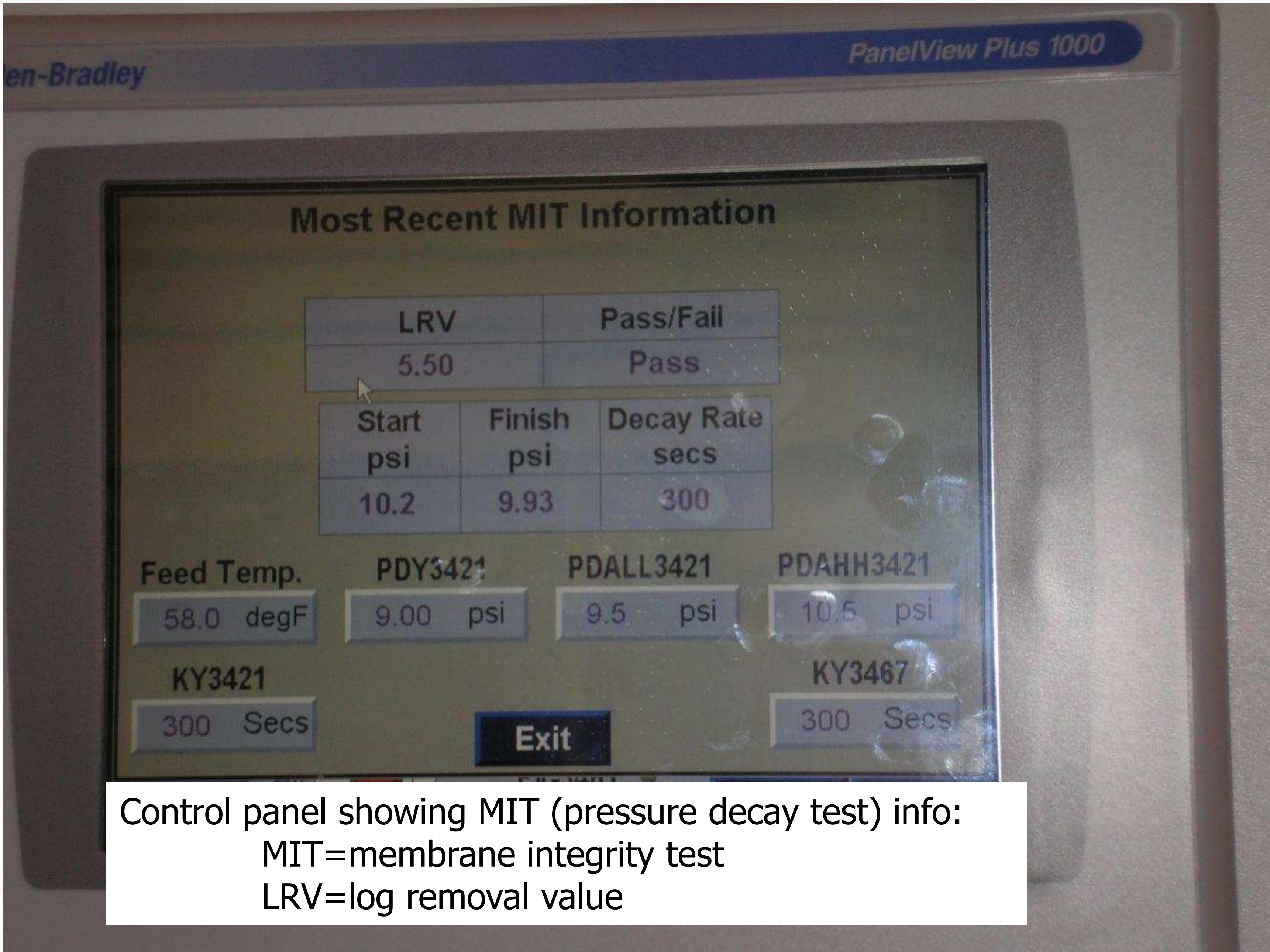
Updated: 21 March 2012


Membrane "skid"



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

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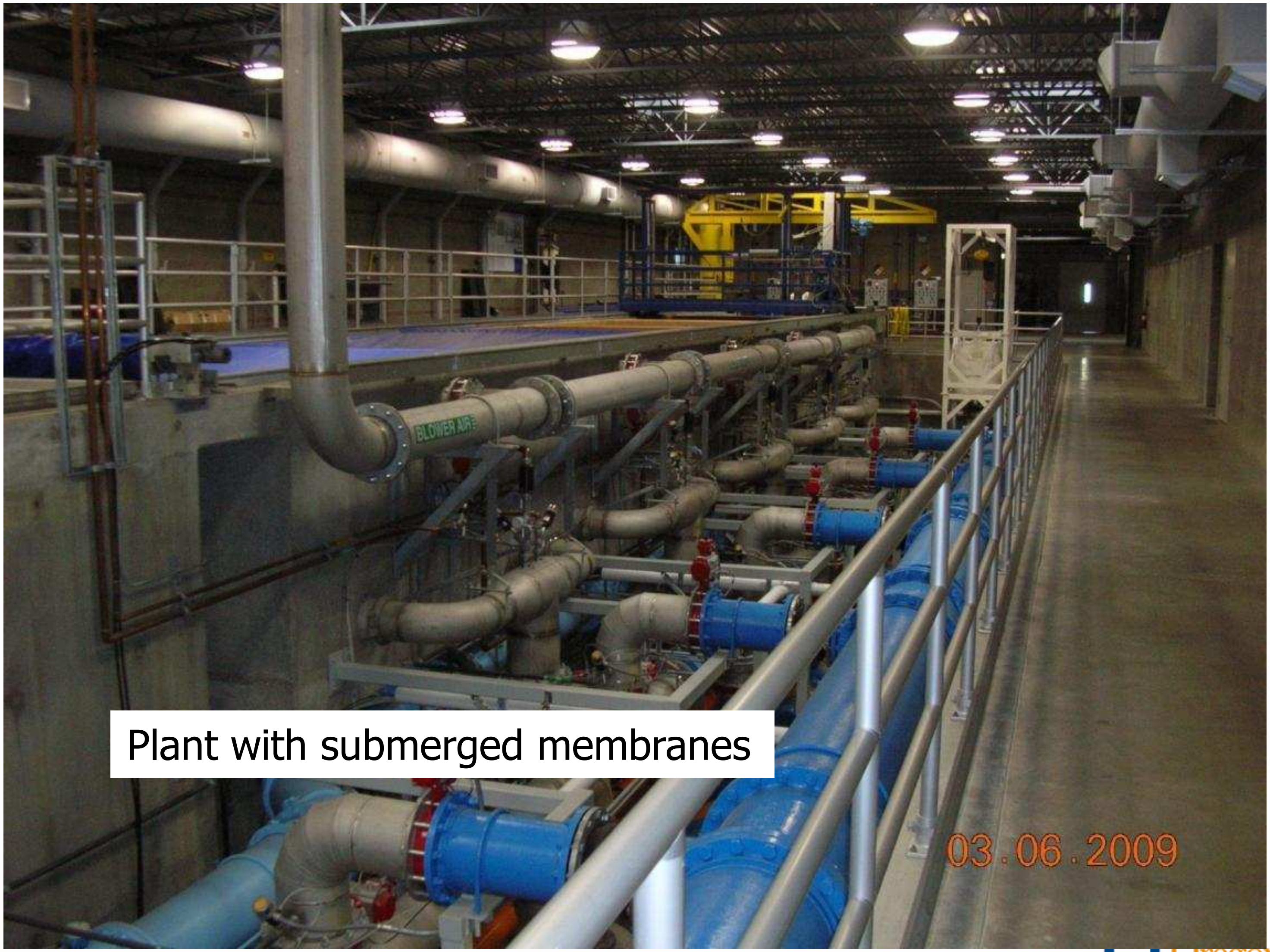
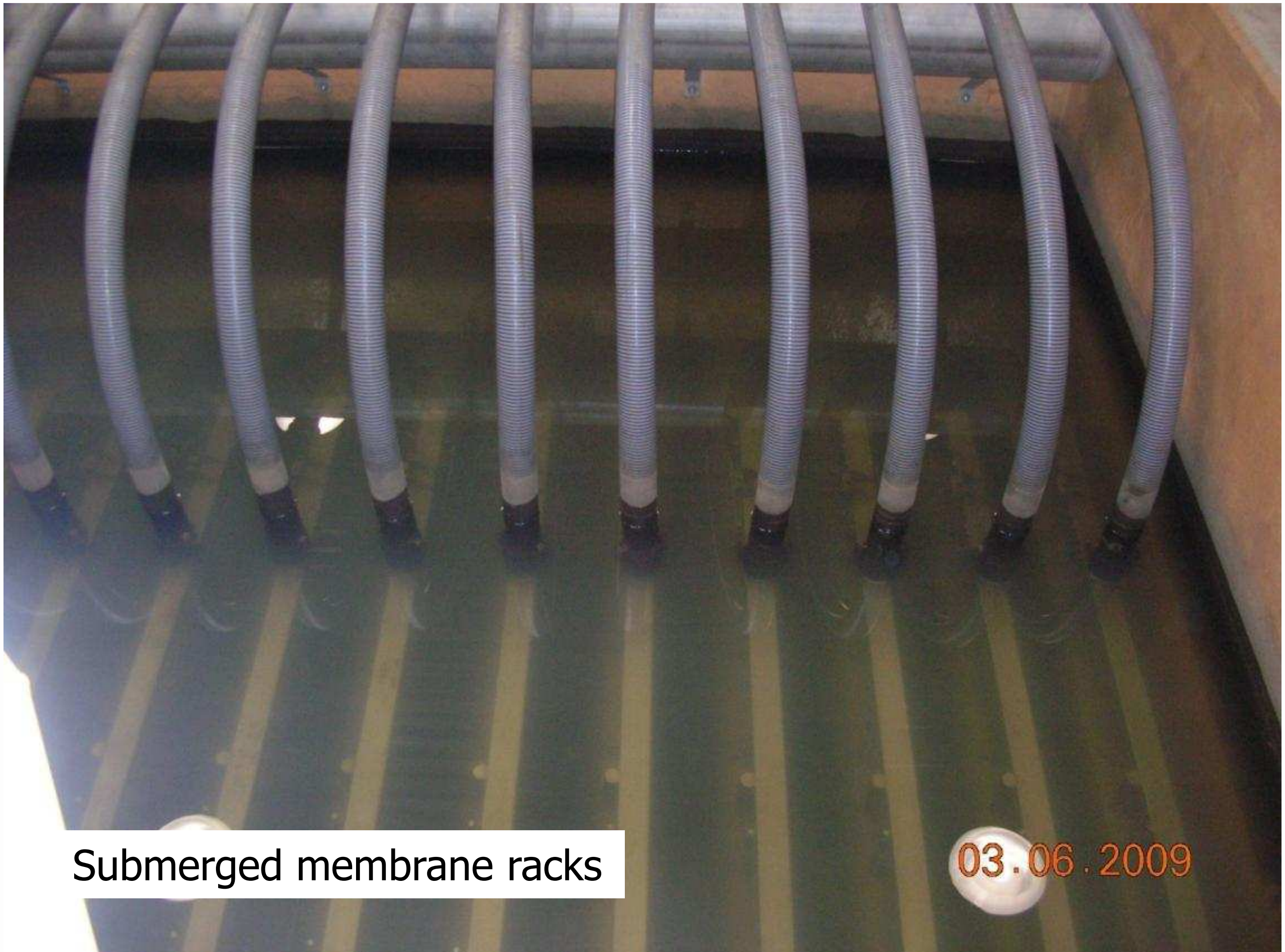
Large membrane plant.

Membranes (pressure)



Plant with submerged membranes



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

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Questions about filtration?