Conventional and Direct Filtration

Focus on Public Health

OFFICE OF ENVIRONMENTAL PUBLIC HEALTH
Drinking Water Services

Class Outline

9 AM	Introduction/Overview
10:15 AM – 15 minute break	
10:30 AM	Coagulation/Flocculation
12 noon – Lunch (on your own)	
1 PM	Clarification/Sedimentation
2 PM	Filtration
2:15 PM – 15 minute break	
2:30 PM	Filtration (continued)
3:30 PM	General Operations
4:30 PM - End	

As we go through this training…

How you would answer the following questions?

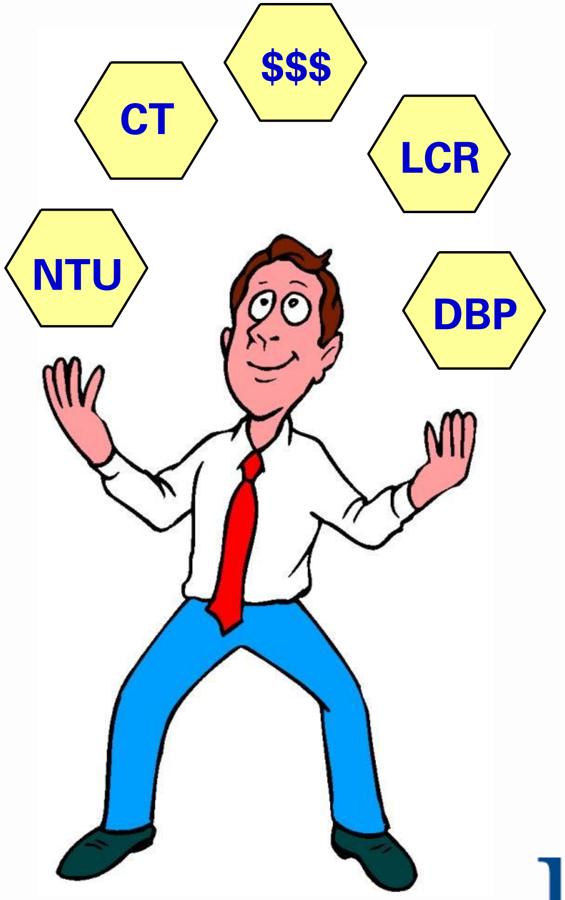
How do you define optimized performance?

What does a well managed plant look like?

How do you set priorities?

What is a basis for setting priorities in optimizing your treatment plant?

- Finished water quality?
- Production?
- Budgets?
- Time?

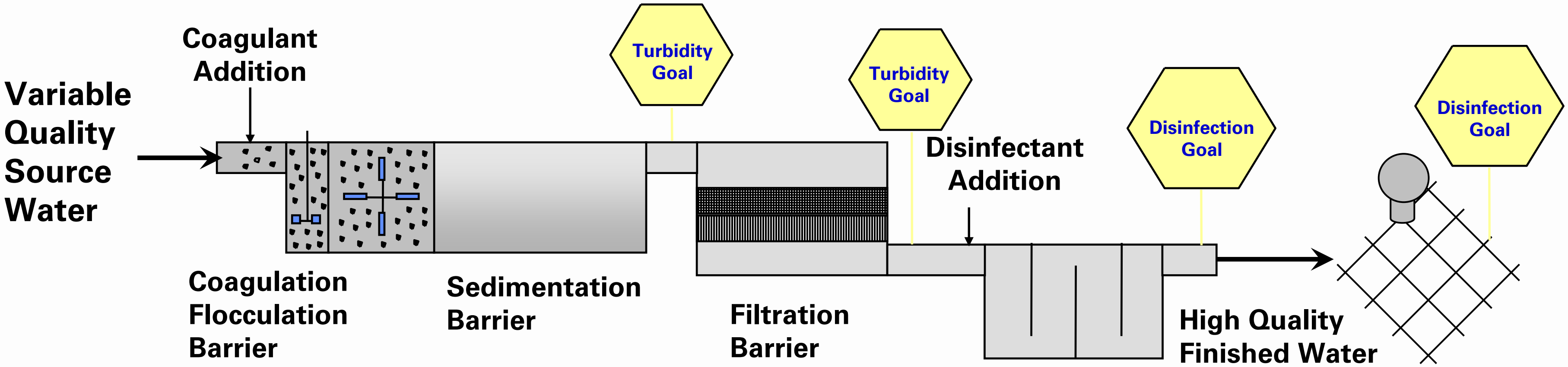


What Problem-Solving Tools Do You Have?

- Training
- Operational Guidelines
- Water quality goals
- Management support to conduct optimization studies often needed to meet those goals

How do you interpret the data you have?

- Is it valid data?
- Is it enough (or too much) data?
- What are you trying to determine?
- Is there anything to compare it to (optimization goals, level of service, etc.)?



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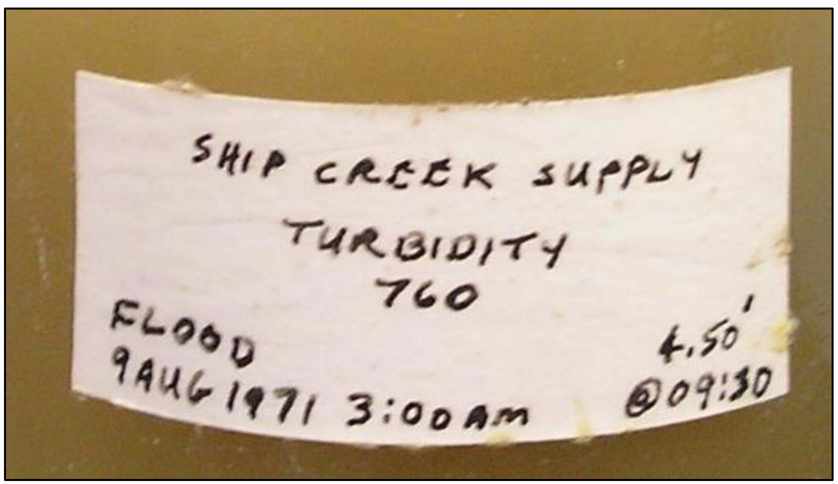
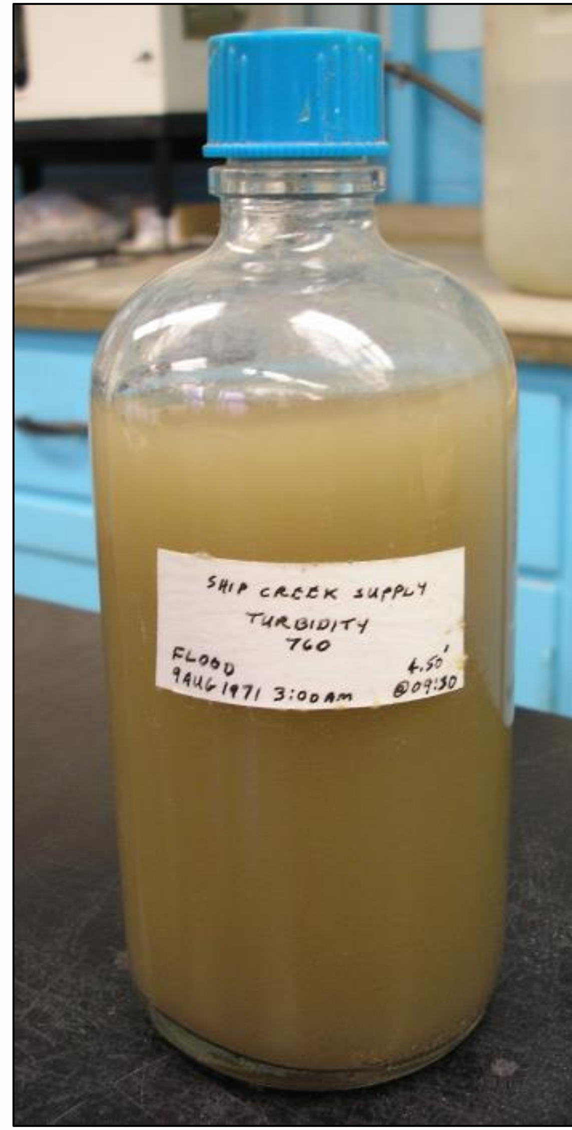
Are you prepared for unusual events?

- What happens if your streaming current meter stops working?
- Can you operate in fully manual mode?
- Can you treat water during a flood?



Sample of 760 NTU water taken from the Ship Creek supply Aug 9, 1971 – Fort Richardson, AK



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Hopefully we can help you answer some of those questions today

Hopefully we can help you answer some of those questions today

But you have to be engaged!

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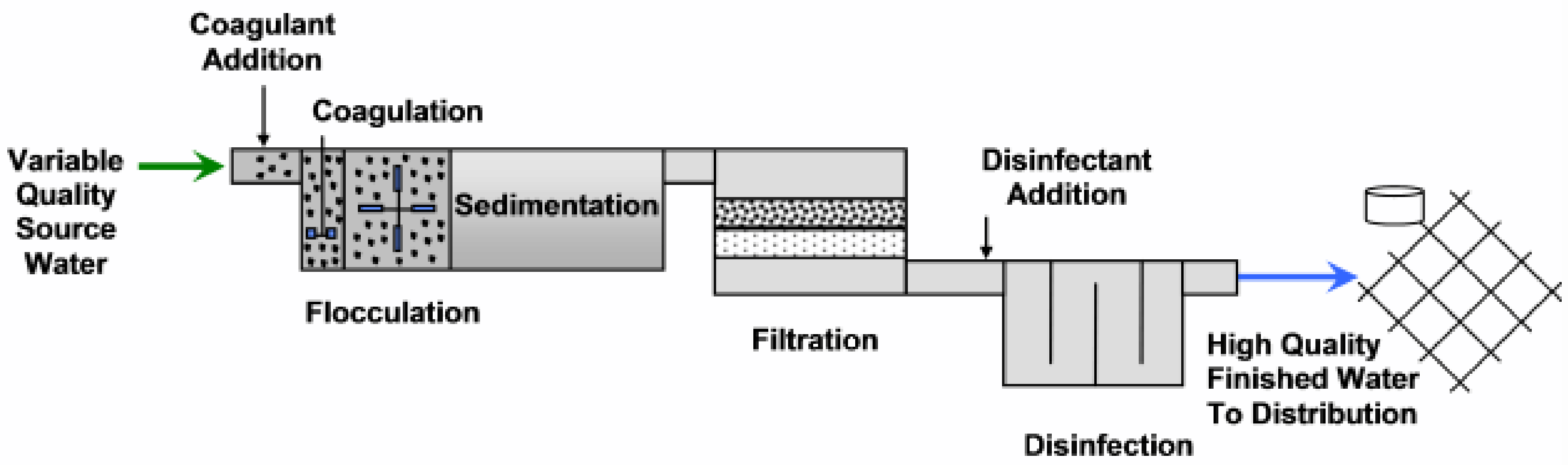
Overview

Conventional Filtration Treatment

> *"means a series of processes including coagulation (requiring the use of a primary coagulant and rapid mix), flocculation, sedimentation, and filtration resulting in substantial particle removal."*



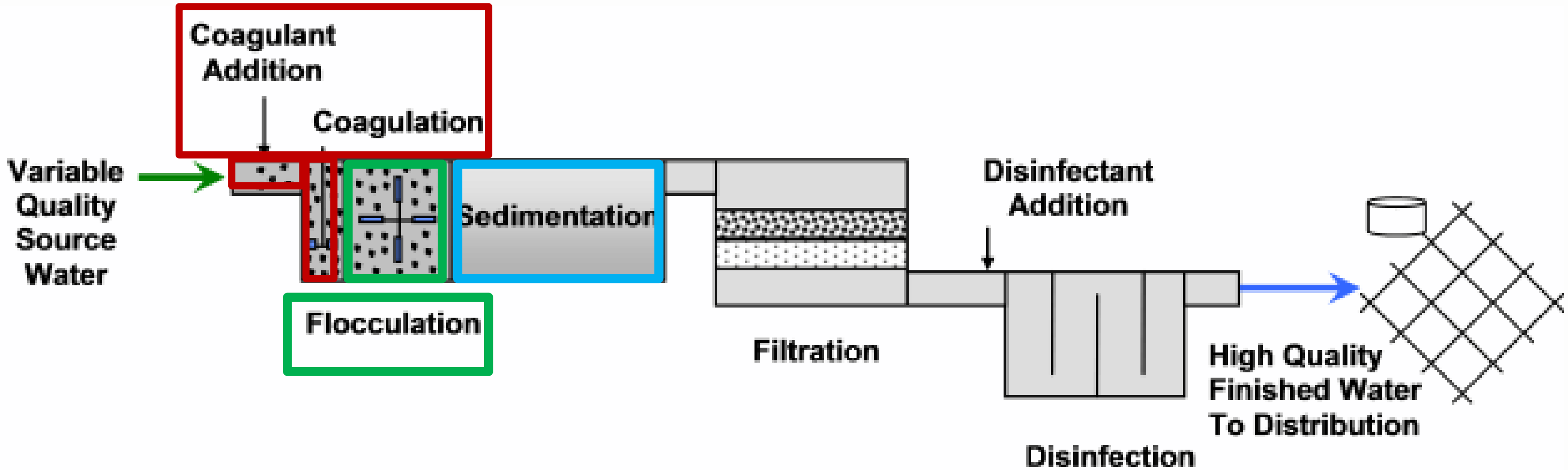
Overview

In conventional filtration treatment..

A coagulation chemical is added and rapidly mixed to neutralize particle charges

Flocculation is a stage of gentle mixing so that a larger settleable floc forms

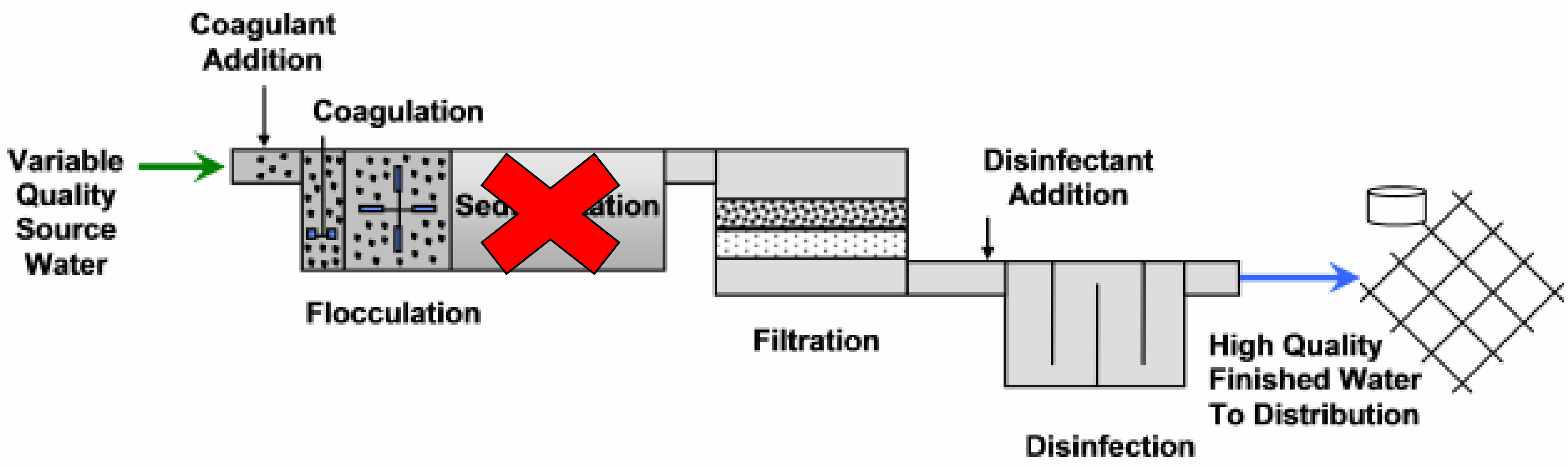
Sedimentation is the stage were floc particles settle out prior to filtration



Overview

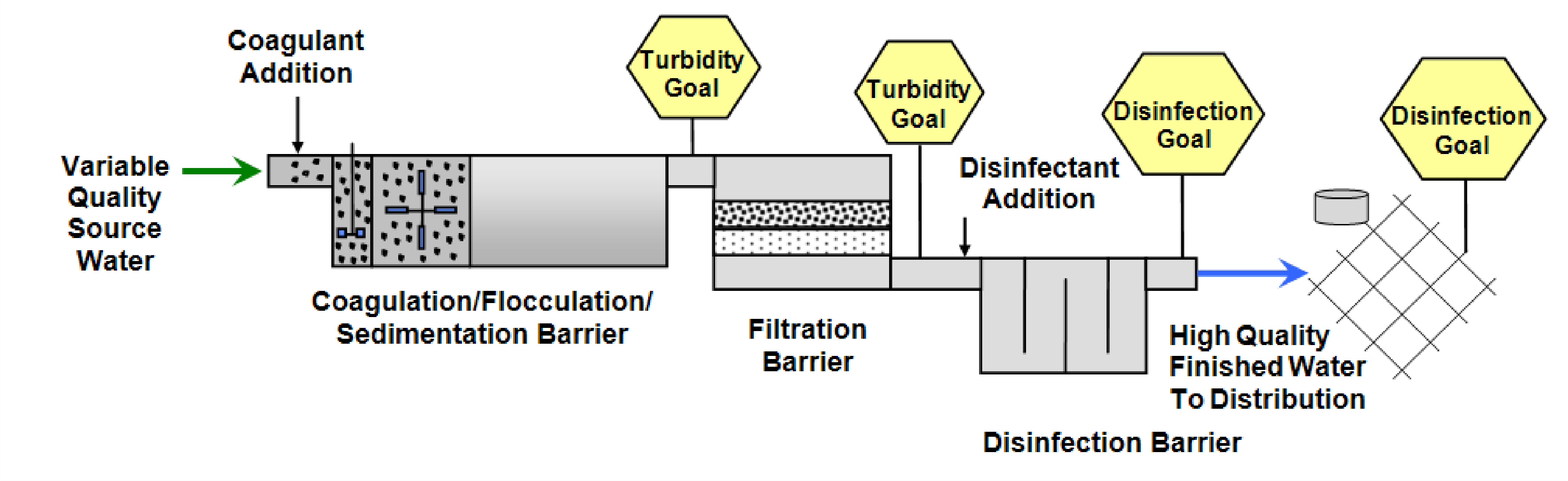
Direct Filtration Treatment

> *"means a series of processes including coagulation (requiring the use of a primary coagulant and rapid mix) and filtration but excluding sedimentation resulting in substantial particulate removal."*



Overview

Regardless of the filtration type, the multiple barrier approach to public health protection applies – i.e., optimize barriers to Giardia and Crypto.



Overview - Giardia

Giardia lamblia is a protozoan which occurs in cyst form in the environment.

This is an image of Giardia lamblia showing the red outline of the cyst wall, which makes the cyst somewhat resistant to disinfection.

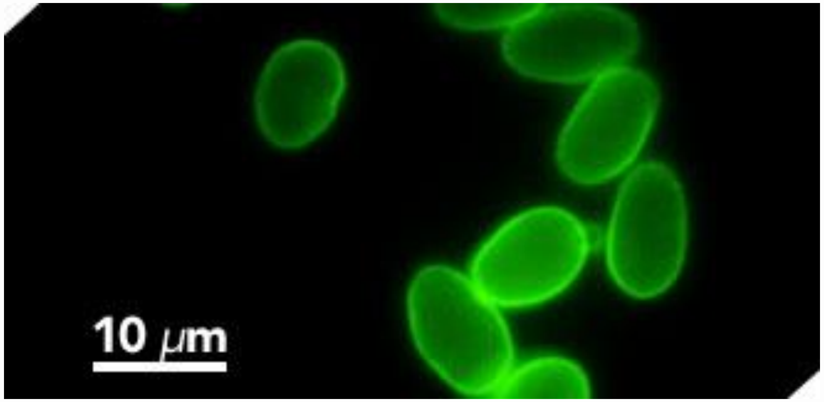


Photo Credits: H.D.A. Lindquist, U.S. EPA

Overview - Giardia

- Giardia are protozoan parasites which occur in a trophozoite and an oval-shaped cyst form.

- The trophozoite causes diarrheal disease of the small intestines called Giardiasis.

Image from CDC's site: http://www.cdc.gov/parasites/crypto/index.html

- Cysts excreted in the feces of an infected host move passively through the environment. If cysts are subsequently ingested, infection may be transmitted to another vertebrate host.

- Cysts can survive for 2 to 3 months in water temperatures of less than 10°C, and almost a month at 21°C. Cysts are killed in 10 minutes at 54°C and almost immediately at boiling.

Overview - Giardia

How infective is Giardia and what is the incubation time of Giardiasis?

- Giardia cysts are highly infective.
  - As few as ten human-source Giardia cysts produced infection in a clinical study of male volunteers. (EPA, *Giardia: Drinking Water Fact Sheet*, September 2000)
  - Each year 4,600 persons with giardiasis are estimated to be hospitalized in the United States. Hospitalized cases are primarily children under five years of age, and dehydration is the most frequent co-diagnosis (EPA, 2000).

- The incubation period (time interval between ingestion and the first appearance of symptoms) can range from 3 to 25 days.

Overview - Giardia

What are the symptoms of Giardiasis?

- Giardia infection may be acquired without producing any symptoms, and this is often the case for children.
- In symptomatic patients, acute diarrhea is the predominate feature.
- In some instances, diarrhea may be transient and mild, passing without notice, while in others diarrhea can be chronic.
- Stools may be pale, greasy, and malodorous.

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Overview - Giardia

What are the symptoms of Giardiasis?

- Other symptoms may include:
  - Abdominal cramps, bloating, and flatulence;
  - Weight loss;
  - Vomiting;
  - Death is rare.

- A potentially serious consequence is nutritional insufficiency which may result in impaired growth and development of infants and children.

- In otherwise healthy people, symptoms of giardiasis may last 2-6 weeks, however, occasionally they may last for months or years. Medications can help decrease this time.

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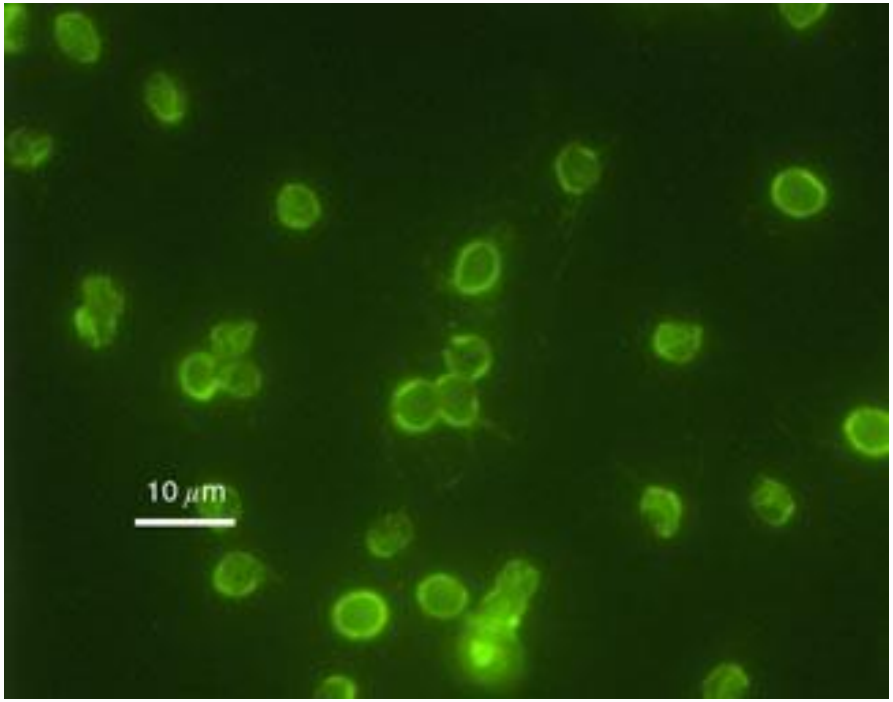
Overview - Cryptosporidium

Cryptosporidium is another protozoan which occurs in cyst form.



This is an image of Cryptosporidum parvum oocysts (C. parvum), stained to show the intense green outline of the oocyst wall, which makes the oocyst very resistant to disinfection – optimal coagulation/filtration is critical to their removal.

Photo Credit: H.D.A. Lindquist, U.S. EPA

Overview - Cryptosporidium

- The infective stage of Cryptosporidium is called an oocyst. The oocyst consists of a very tough "shell" surrounding four individual parasites.
- After the oocyst is swallowed, the shell breaks open and the parasites are released.

Image from CDC's site: http://www.cdc.gov/parasites/crypto/index.html

Overview - Cryptosporidium

The parasites enter the cells that line the lower small intestine and begin to develop. After the parasite cells reproduce, two kinds of oocysts are produced:

1. Thin-walled oocysts that start another cycle of infection
2. Thick-walled oocysts that enter the environment in the feces and can then infect other animals

The disease is called cryptosporidiosis

Overview - Cryptosporidium

What are the symptoms and the incubation time of Cryptospordiosis?

- Symptoms may appear anytime from two to ten days after infection, with the average being from four to six days.
- The nature of acute disease (having a rapid onset and following a short but severe course) associated with C. parvum is
  1. Intestinal,
  2. Tracheal (trachea ('windpipe') associated) or
  3. Pulmonary (lung-associated) cryptosporidiosis.
- The most common symptom of cryptosporidiosis is watery diarrhea. Other symptoms may include stomach cramps, nausea, vomiting, dehydration, low-grade fever (99-102°F), fatigue, weakness and weight loss.
- Pulmonary and tracheal cryptosporidiosis in humans is associated with coughing and low-grade fever.
- Some people will be asymptomatic (will not develop any symptoms).

Overview - Cryptosporidium

How long do symptoms last?

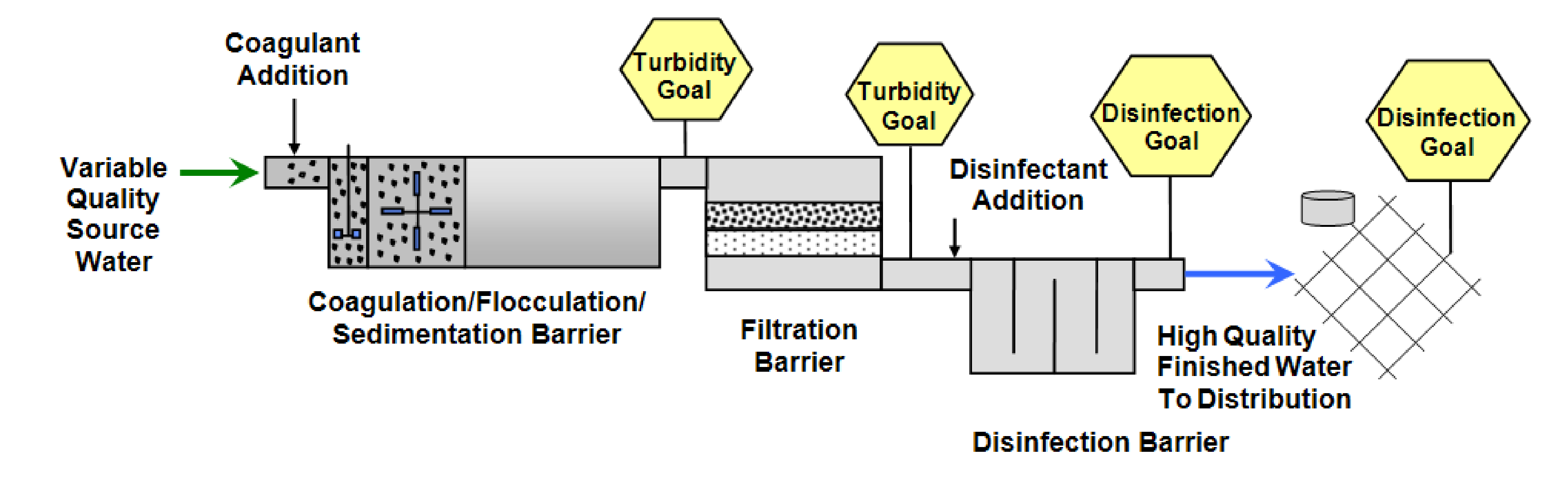
- The C. parvum infection is self-limiting, and people with healthy immune systems are usually ill with cryptosporidiosis for one to two weeks before the infection begins to resolve.
- Some infected individuals may not even get sick
- In immune-compromised patients (elderly, very young, people with certain illnesses or organ donor recipients taking anti-rejection medications) symptoms are more severe and may last for several weeks with hospitalization being required.
- It is also possible for the infection to become chronic, and in some cases fatal.
- Those who are infected may shed oocysts in their feces for months, even after they no longer appear to be ill.

How can you avoid outbreaks?

So how can you help protect your community from pathogens and avoid outbreaks?

Optimize Particle Removal

Optimize treatment for pathogen removal by optimizing particle removal (i.e. turbidity)

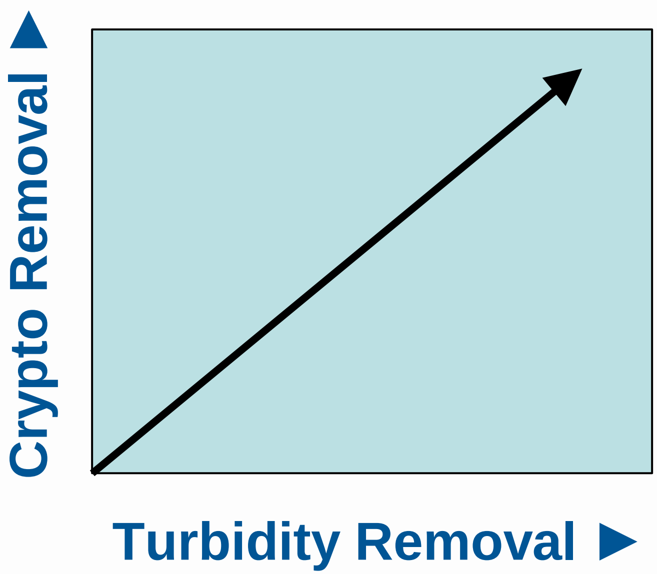


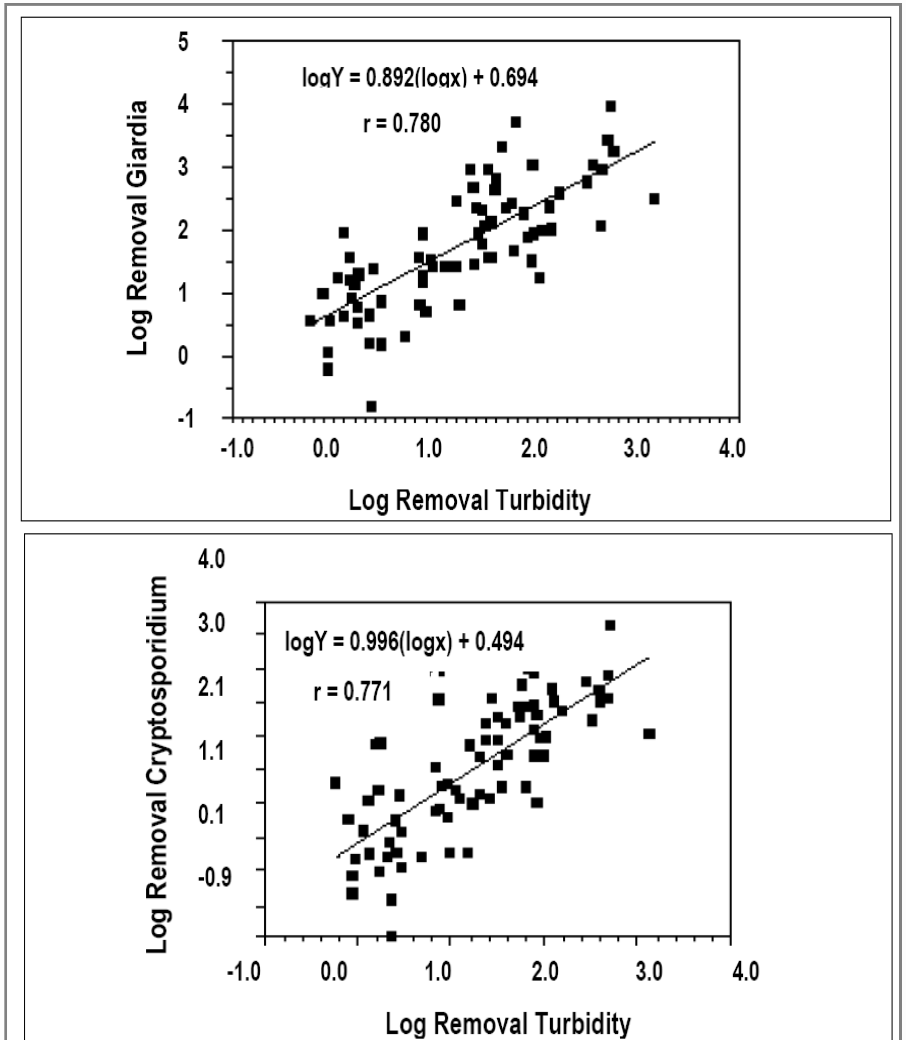
Overview – Optimization Goals

Why turbidity?

Turbidity removal is strongly correlated to removal of Giardia and Cryptosporidium.

- Emelko (2000) - Pilot scale work to assess *Cryptosporidium* removal through filtration *(University of Waterloo)*





Source: LeChevallier and Norton, 1991.

Overview – Optimization Goals

Why turbidity?

Turbidity removal is strongly correlated to removal of Giardia and Cryptosporidium.

- Emelko (2000) - Pilot scale work to assess *Cryptosporidium* removal through filtration *(University of Waterloo)*
  - Stable operation: 5 to 6 log (turbidity ~ 0.04 NTU)
  - **End-of-run: 2 to 3 log (turbidity increase to 0.10 NTU)**

Log Reduction	Percentage
5-log	99.999%
4-log	99.99%
3-log	99.9%
2-log	99%
1-log	90%

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Overview – Optimization Goals

Why turbidity?

Turbidity removal is strongly correlated to removal of Giardia and Cryptosporidium.

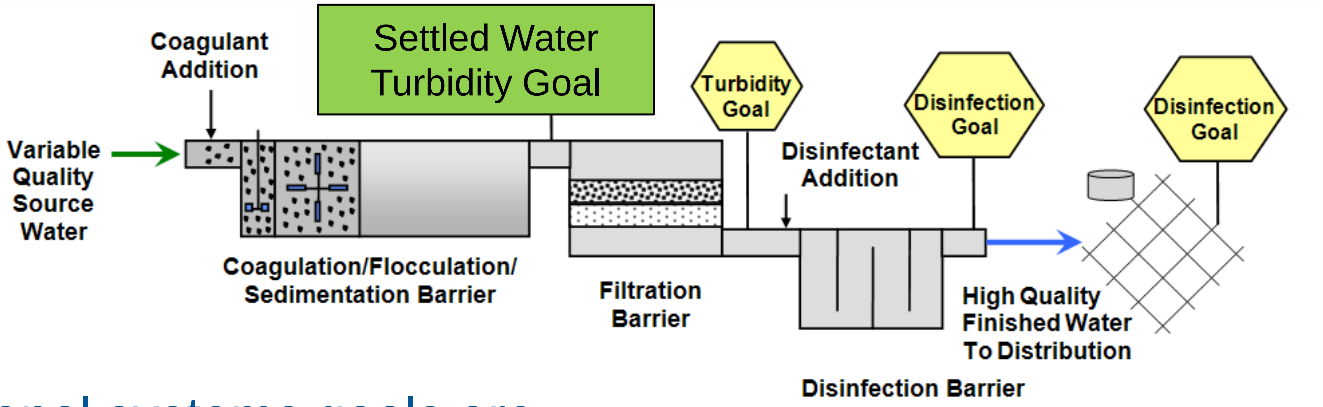
- Emelko (2000) - Pilot scale work to assess *Cryptosporidium* removal through filtration *(University of Waterloo)*
  - Stable operation: 5 to 6 log (turbidity ~ 0.04 NTU)
  - **End-of-run: 2 to 3 log (turbidity increase to 0.10 NTU)**
  - **Breakthrough:** 1.5 to 2 log (turbidity increase to 0.3 NTU)

Log Reduction	Percentage
5-log	99.999%
4-log	99.99%
3-log	99.9%
2-log	99%
1-log	90%

Overview – Optimization Goals

Settled water turbidity optimization goals:

- Settled turbidity ≤ 1 NTU, 95% of the time if average annual raw water turbidity is ≤ 10 NTU
- Settled turbidity < 2 NTU, 95% of the time if average annual raw water turbidity is > 10 NTU

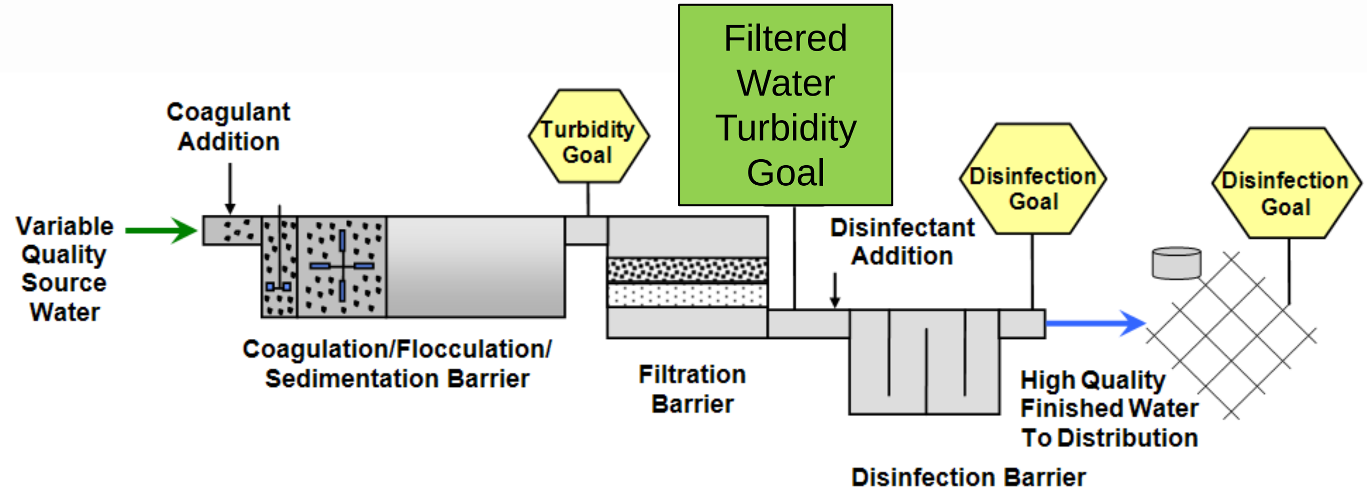


For conventional systems goals are based on maximum daily raw & settled water turbidity taken from grab samples or on-line instrumentation.

Overview – Optimization Goals

Filter effluent turbidity optimization goals:

1. IFE & CFE Turbidity ≤ 0.10 NTU 95% time
2. Maximum IFE & CFE Turbidity: ≤ 0.30 NTU



Goals are based on continuous 1-minute readings of individual filter effluent (IFE) and combined filter effluent (CFE) readings.

Overview – Optimization Goals

Post backwash turbidity optimization goals

3. Minimize spike during filter-to-waste period (< 0.30 NTU)
4. Return to ≤ 0.10 NTU within 15 minutes
5. Return to service at ≤ 0.10

Overview – Goals Summary

Settled water turbidity optimization goals

1. Settled water ≤ 1 NTU 95% of time (Average raw water ≤ 10 NTU)
2. Settled water ≤ 2 NTU 95% of time (Average raw water > 10 NTU)

Filter effluent turbidity optimization goals

1. Turbidity: ≤ 0.10 NTU 95% of time
2. Maximum turbidity: ≤ 0.30 NTU

Post backwash turbidity optimization goals

3. Minimize spike during filter-to-waste period (≤ 0.30 NTU)
4. Return to ≤ 0.10 NTU within 15 minutes
5. Return to service at ≤ 0.10 NTU

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Overview – Goals Summary

Why not just meet the regulatory turbidity standards?

- Regulatory standards are there to help protect against major pathogen breakthrough (e.g. up to 90% removal of Cryptosporidium at 0.3 NTU), but they do not reflect optimized pathogen removal (e.g. $\geq$ 95% removal at 0.1 NTU).
- Filter performance that exceeds regulatory standards for turbidity requires notification to the State, corrective action, and public notification (either a boil notice, notice within 30 days, or in the Consumer Confidence Report, depending upon the level of turbidity).
- Barely meeting the regulatory standards is generally not good practice.

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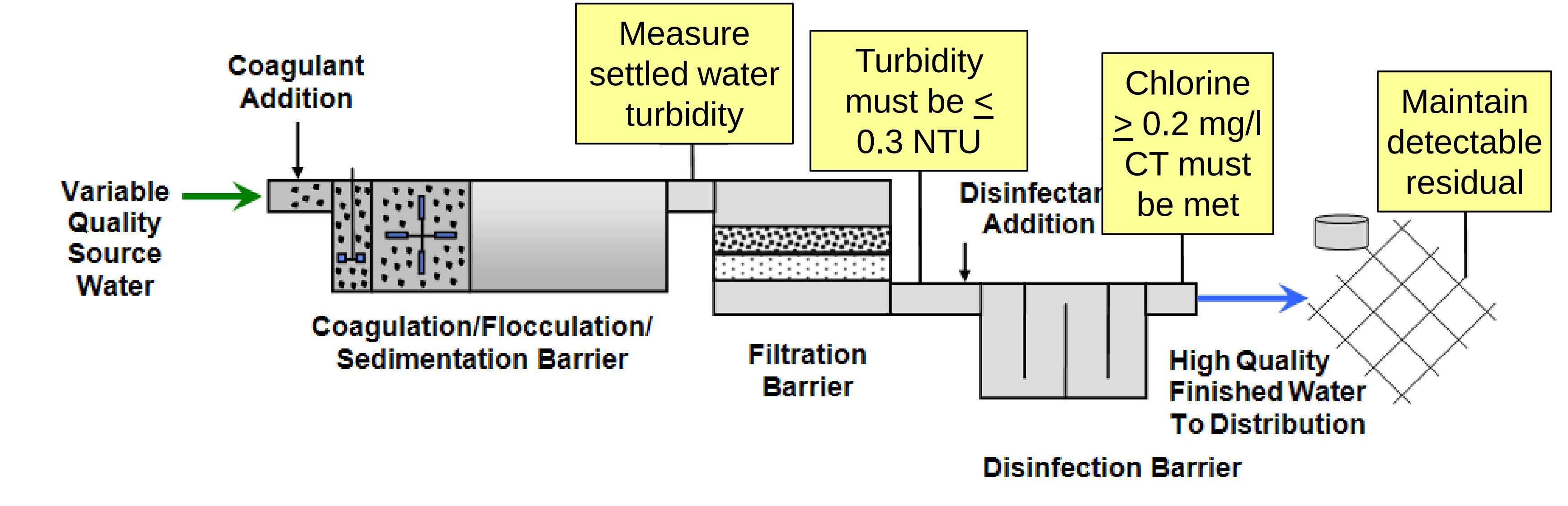
Overview – Regulatory Requirements

Regulatory requirements also employ the multiple barrier approach



Overview – Regulatory Requirements

Well operated systems that achieve substantial particle removal (turbidity reduction) should be able to meet the Giardia and Cryptosporidium removal credits shown below.

Regulated Pathogen	Total Treatment Required	Filtration Type	Credit for Filtration	Treatment Needed Through Disinfection
Viruses	99.99% (4-log) removal/inactivation	Conventional and direct	**0**	4-log
Giardia	99.9% (3-log) removal/inactivation	Direct	**2-log (99%)**	1-log (0.5-log must be after filtration)
		Conventional	**2.5-log* (99.5%)**	0.5-log (all after filtration)*
Cryptosporidium	99% (2-log) removal	Conventional and direct	**2-log (99%)**	None in most cases depending upon levels of cryptosporidium in source water.

* Some conventional plants with inadequate/undersized sedimentation are treated more like direct filtration with a lower filtration credit and a higher disinfection requirement for *Giardia*.

Overview – Turbidity Requirements

OAR 333-061-0030(3)(b)(A) – Maximum turbidity limits

Maximum contaminant levels for turbidity in drinking water measured at a point representing filtered water prior to any storage:

1. *Turbidity must be ≤ 0.3 NTU in at least 95% of the measurements taken each month.*
2. *Turbidity must not exceed 1 NTU at any time.*

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Overview – Turbidity Requirements

OAR 333-061-0040(1)(d) – Turbidity > 5 NTU

All surface water systems that provide filtration must report within 24 hours after learning that the filtered water turbidity exceeds 5 NTU.

Make sure your instruments can record data up to 5.49 NTU (e.g. 0-10 NTU)

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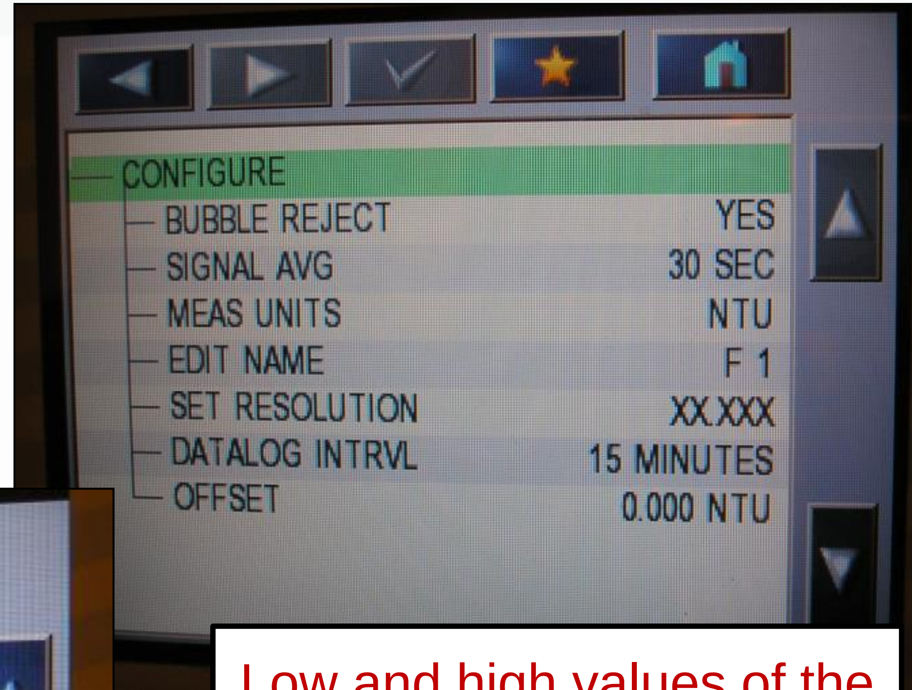
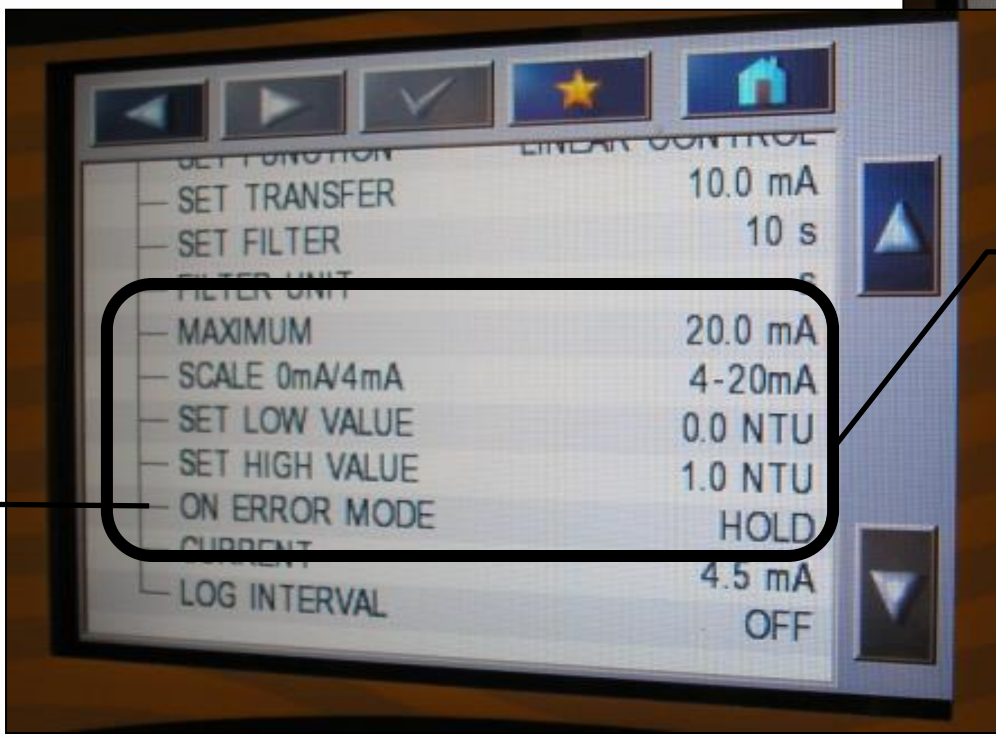
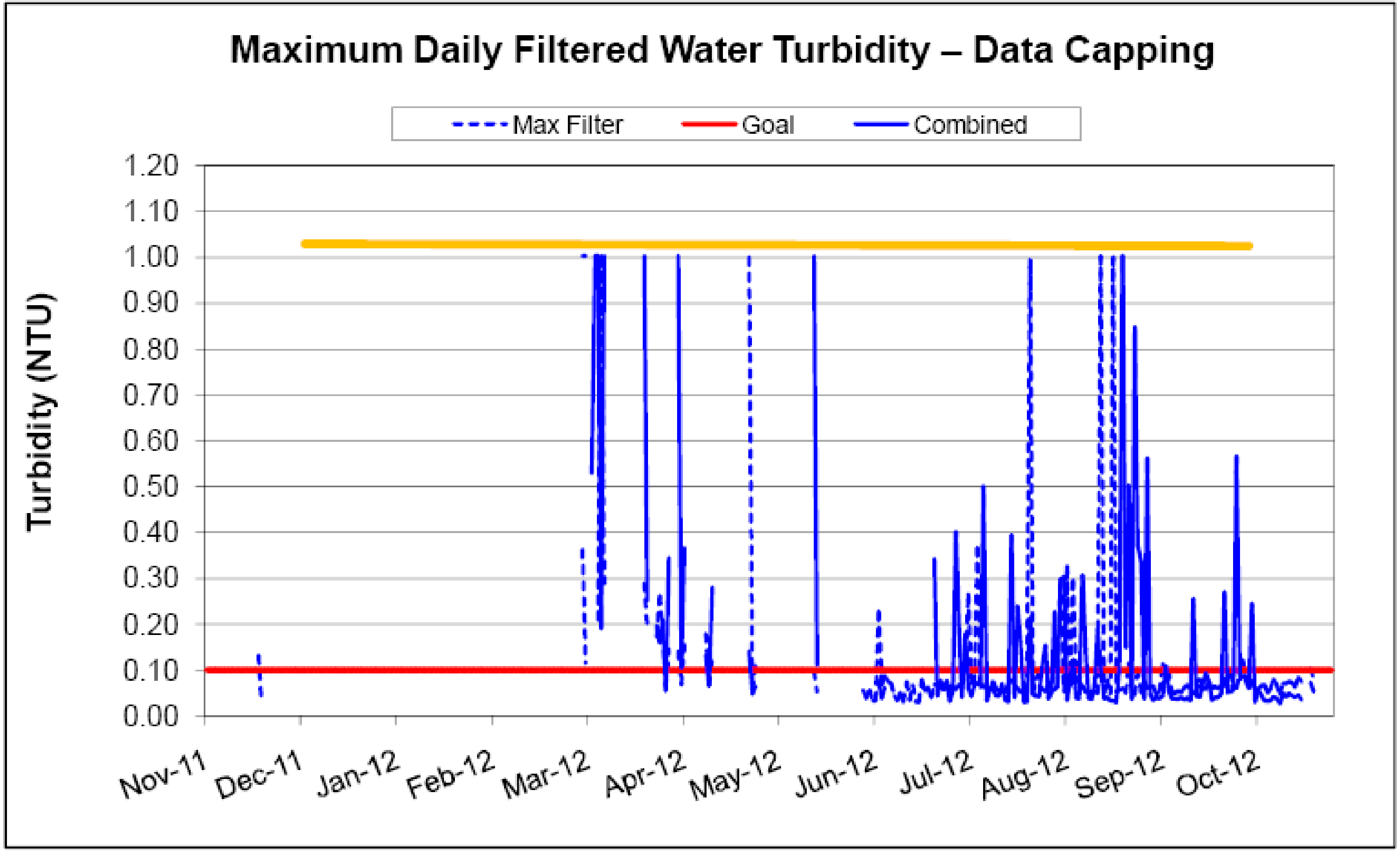
Error Mode is set to “Hold”
This means that the controller will send the last turbidimeter reading to SCADA should an error in the meter occur





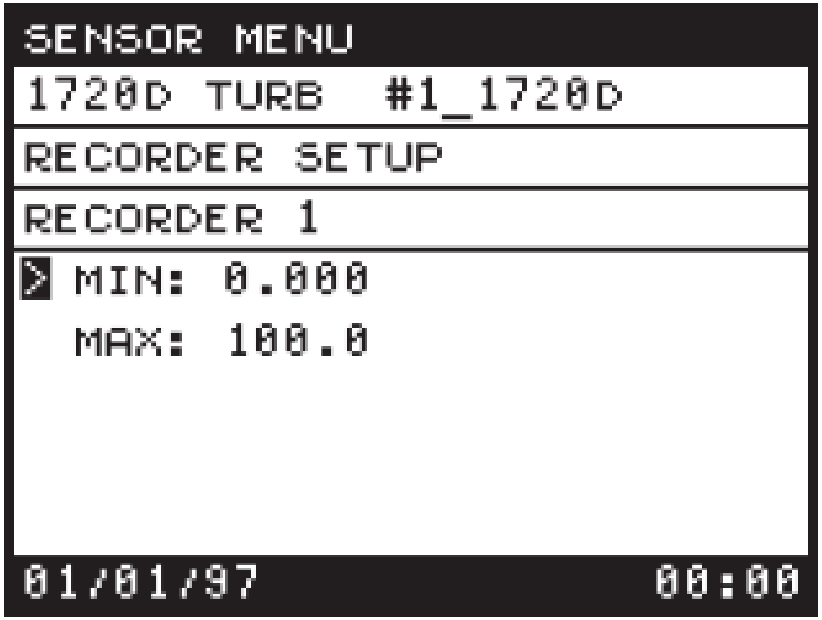
Low and high values of the on-line turbidimeters are set to 0 – 1.0 NTU
This means that the signal output is “read” by SCADA as
4 mA = 0 NTU
20 mA = 1 NTU

Scaling limited to 1 NTU may show up as "Data Capping"



Caution!

- The 4-20 mA scale must be set in both the turbidimeter controller and the PLC
- Example, the scale is changed in the controller to send a 20 mA signal when the turbidity is 10 NTU, but the change was not made in the PLC.
- A spike to 10 NTU occurs at which point the PLC receives a 20 mA signal. This spike will be stored in the SCADA system as a 1 NTU spike



Overview – Turbidity Requirements

OAR 333-061-0036(5)(b) – Settled Water Turbidity Monitoring

Conventional filtration systems must measure settled water turbidity every day.

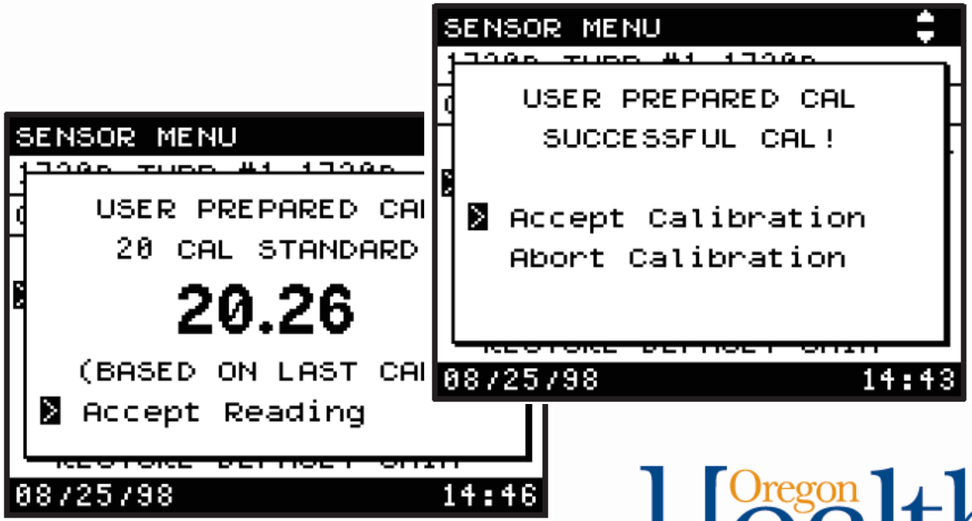
Individual Settled Water Turbidimeters
Seaside Roberts Pacer II contact adsorption clarifier plant 2015

Overview – Turbidity Requirements

OAR 333-061-0036(5)(b) – Combined Filter Effluent (CFE) Monitoring

Conventional & Direct Filtration Treatment Systems must:

1. *Measure combined filter effluent (CFE) water turbidity (prior to storage) every four hours (or more frequently).*
2. *Turbidimeters must be calibrated at least quarterly & per manufacturer.*



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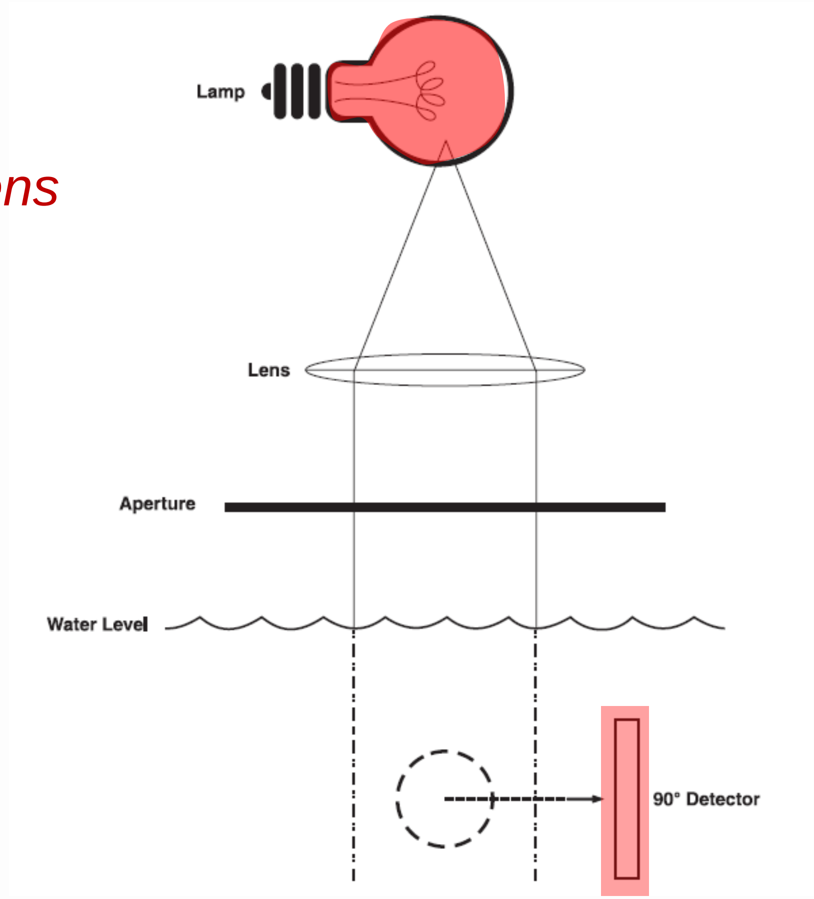
Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Strength of bulb

Clean photo detector lens



Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Strength of bulb

Clean photo detector lens

Photocells can leak fluid in 1720D and E, which may cause erratic readings

"The filling solution establishes a common refractive index so as the light passes through to the photocell it is as though there is no window. If only air were in the space of course the light would refract. One can typically see a bubble when the photocell is laid face up but not always. But if the area is void (the solution has leaked out) it is normally pretty obvious. The 1720D is now obsolete so I don't know whether or not we can still supply replacement photocells. If it seems to work okay, I wouldn't worry about it."

Terry Engelhardt
Application Sales Engineer - HACH
tengelhardt@hachhst.com

Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Strength of bulb

Clean photo detector lens

Sufficient flows

(e.g. 250-750 ml/min for HACH 1720D/E)

Good calibration

Good sample point

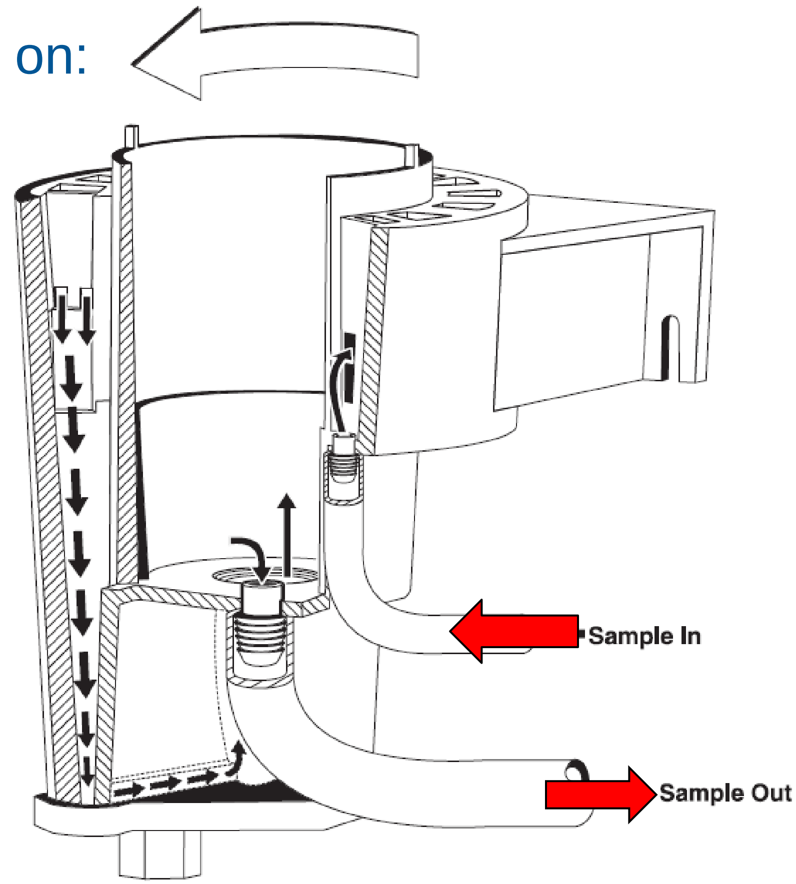


Figure 4 **Sample Flow Path Through the Turbidimeter Body**

Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Strength of bulb

Clean photo detector lens

Sufficient flows

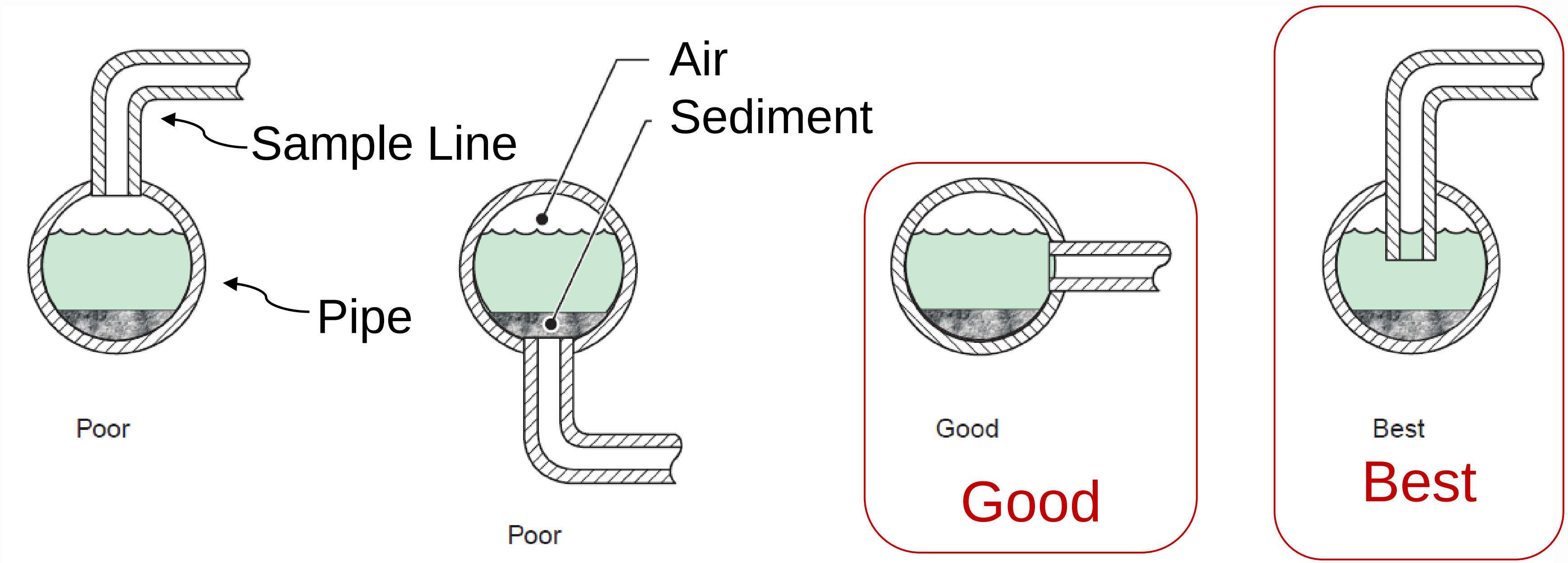
Good calibration

Good sample point

Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Good (or "Best") sample point



Poor Sample Taps

Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Strength of bulb

Clean photo detector lens

Sufficient flows

Good calibration

Good (or “Best”) sample point

Attentive Operator

Overview – Turbidity Requirements

Anything wrong with this picture?

Overview – Turbidity Requirements

Anything wrong with this picture?

How about now?

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Introduction/Overview

How about this one?

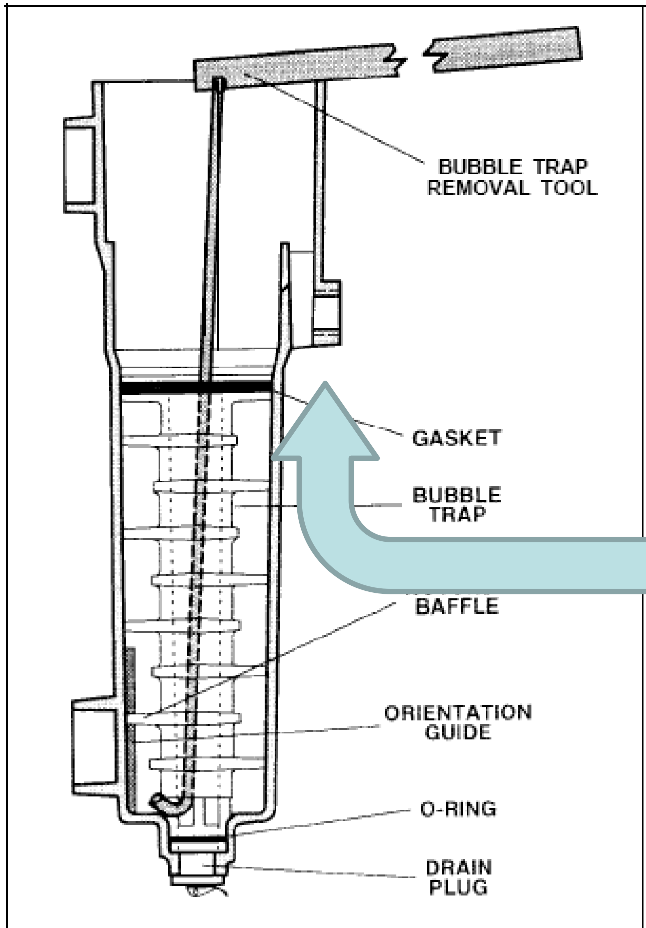
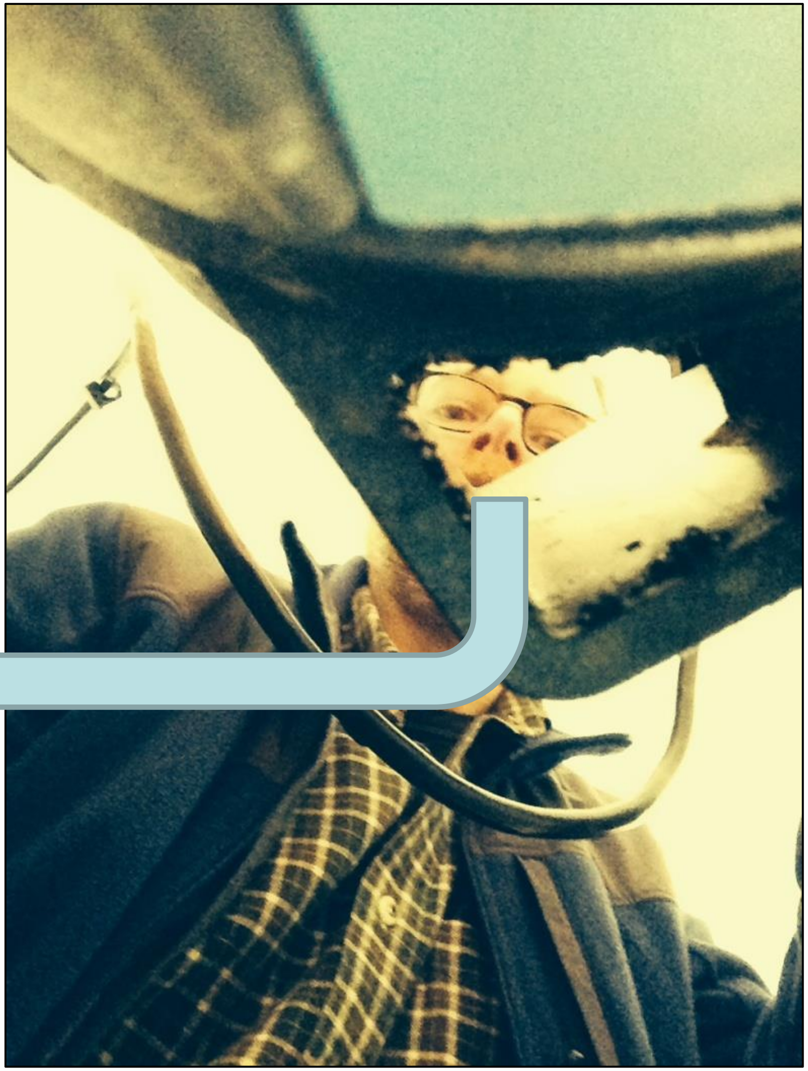


FIGURE 14 BUBBLE TRAP REMOVAL



Turbidity Data Integrity

- 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

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Overview – Turbidity Requirements

OAR 333-061-0036(5)(d) – Individual Filter Effluent (IFE) Monitoring

Conventional & Direct Filtration Treatment Systems must also:

1. *Conduct continuous turbidity monitoring for each individual filter. IFE results must be recorded every 15 minutes. Turbidimeters must be calibrated at least quarterly & per manufacturer.*
2. *If there is a failure in continuous monitoring equipment, grab samples must be taken every 4 hours until the equipment is repaired and back on-line. Systems serving 10,000 people or more have 5 days to repair equipment while systems serving less than 10,000 people have 14 days.*
3. *Systems having only 1 or 2 filters may conduct continuous monitoring of CFE turbidity in lieu of IFE monitoring, although the recording and calibration requirements of -0036(5)(d) still apply*

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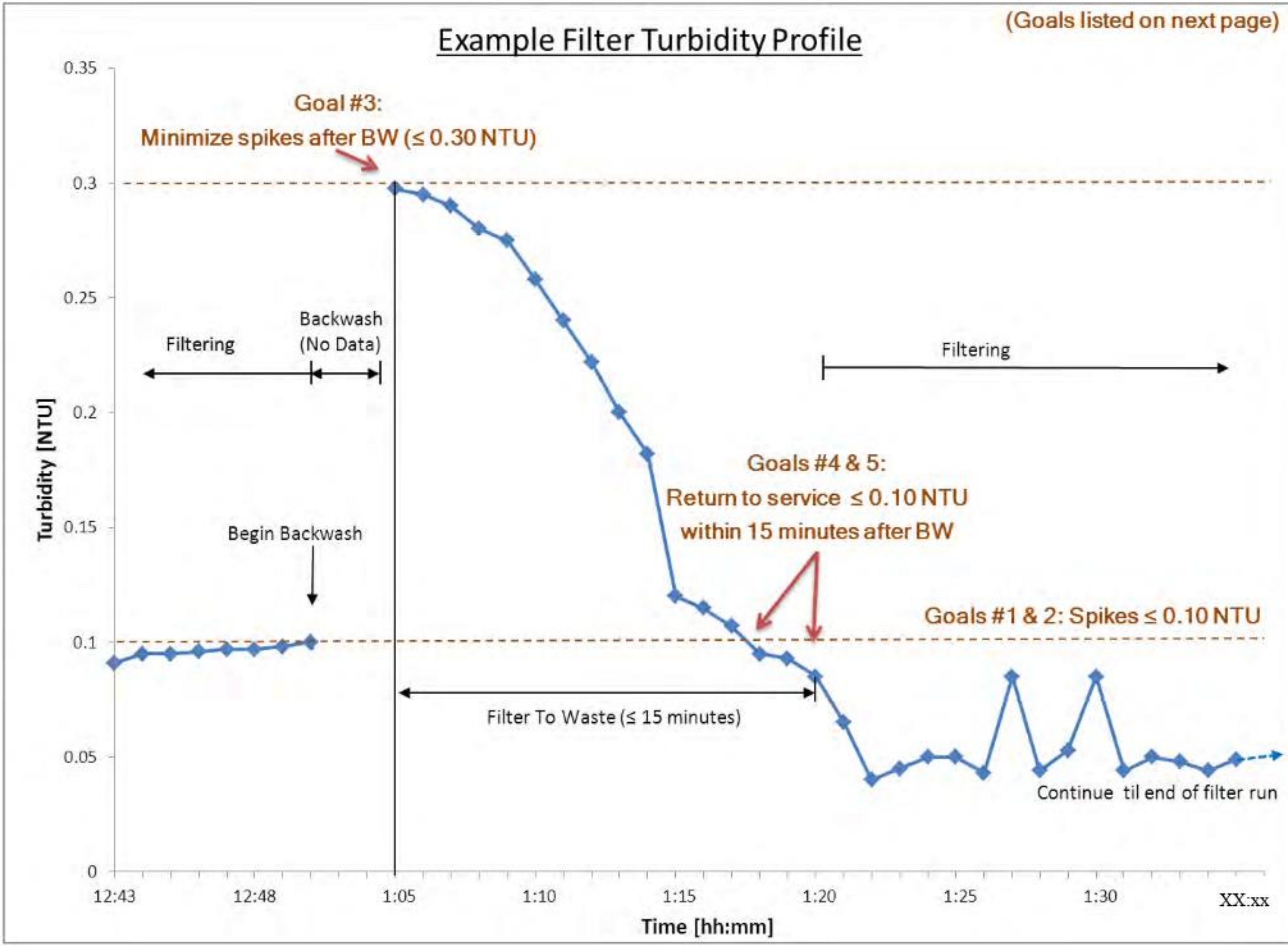
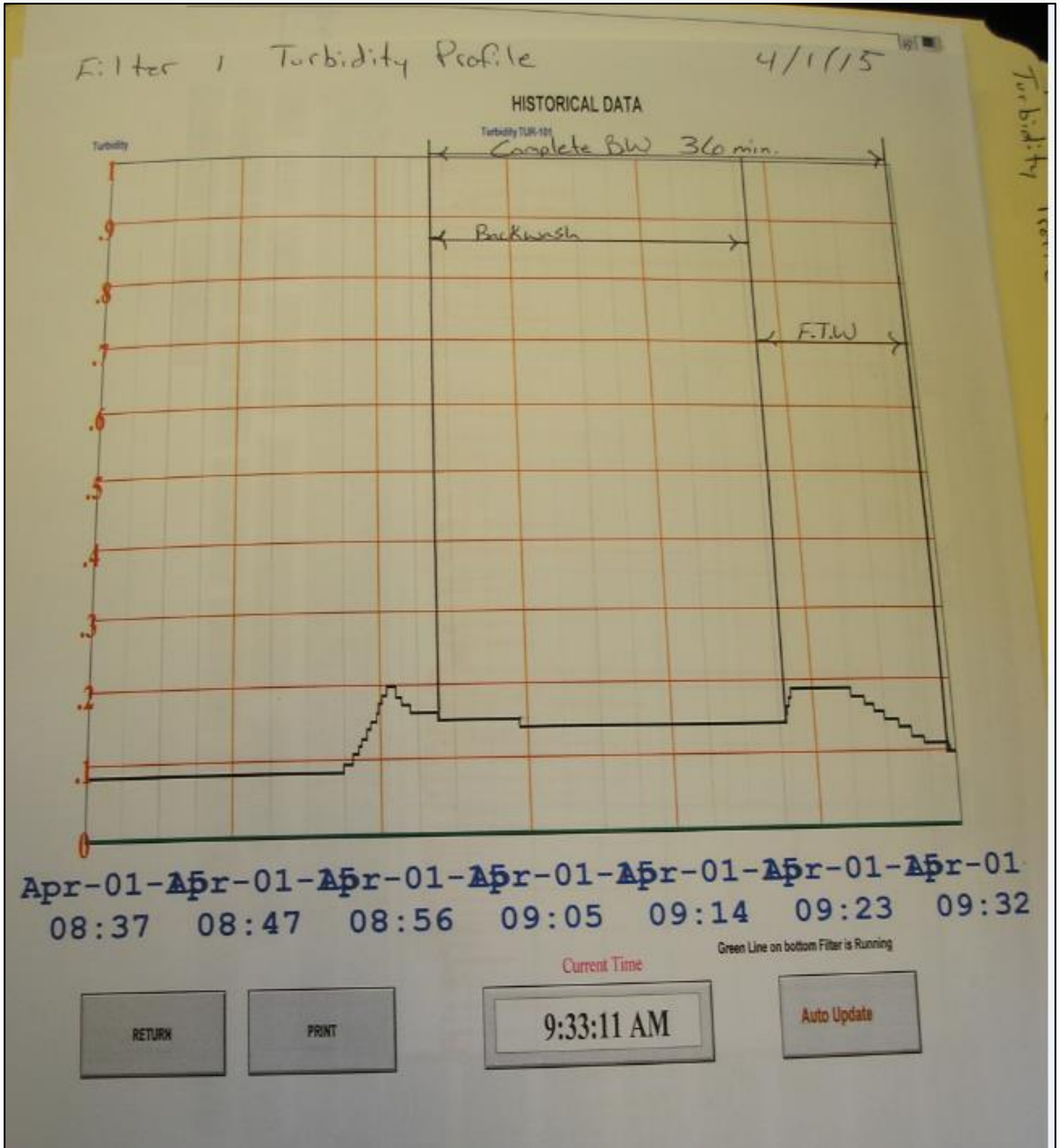
Overview – Turbidity Requirements

OAR 333-061-0036(5)(b) – Turbidity Profile

Conventional & direct filtration systems must develop turbidity profiles for individual filters every calendar quarter.

Profiles consist of a graph showing turbidity over a complete filter run, including filter start-up, duration of the run, backwash, and filter-to-waste.


(Goals listed on next page)
Example Filter Turbidity Profile
Goal #3:
Minimize spikes after BW (≤ 0.30 NTU)
Filtering
Backwash
(No Data)
Filtering
Goals #4 & 5:
Return to service ≤ 0.10 NTU
within 15 minutes after BW
Begin Backwash
Goals #1 & 2: Spikes ≤ 0.10 NTU
Filter To Waste (≤ 15 minutes)
Continue til end of filter run
Turbidity [NTU]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
12:43
12:48
1:05
1:10
1:15
1:20
1:25
1:30
XX:xx
Time [hh:mm]



This is a good example of a filter profile of the backwash and filter-to-waste process in that:

- The scale is readable,
- The start and end of backwash and filter-to-waste are clearly labeled;
- backwashed at 0.2 NTU.
- Post-backwash FTW until turbidity ≤ 0.1 NTU

Overview – Turbidity Requirements

OAR 333-061-0040(1)(e)(B)(ii) and -0040(1)(e)(C)(i) – Turbidity Triggers

- Certain circumstances or "triggers" require water systems to take corrective actions, based on population served.
- *If a system only has one or two filters and only measures CFE turbidity, these triggers also apply to the CFE readings.*
- *There are 4 turbidity triggers.*
- *Corrective actions may include developing or performing a:*
  1. *Filter Turbidity Profile*
  2. *Filter Self-Assessment*
  3. *Comprehensive Performance Evaluation*

Oregon Health Authority

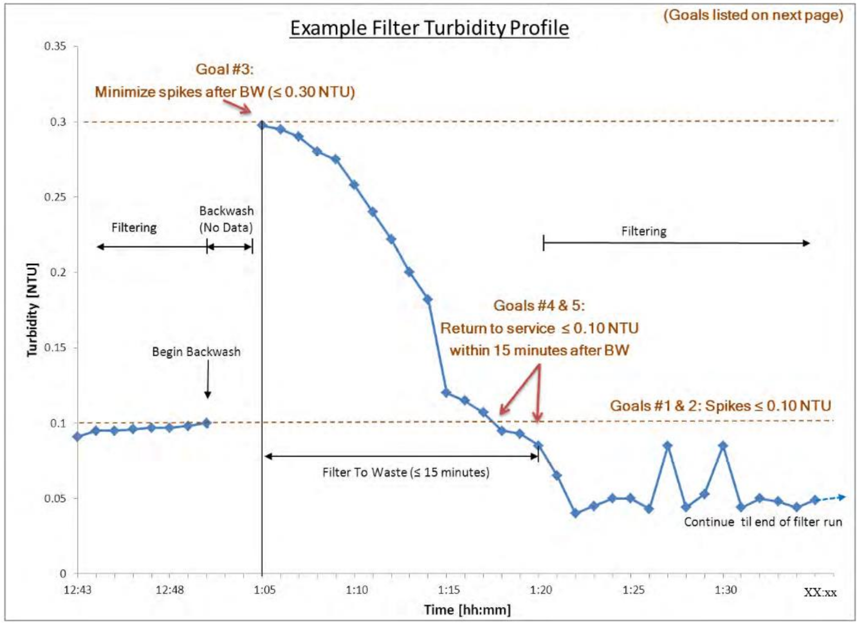
IFE Turbidity Triggers	Required Actions: Serving 10,000 or more people	Required Actions: Serving fewer than 10,000 people
1. IFE turbidity > 1.0 NTU in 2 consecutive measurements taken 15 minutes apart	Report: 1. Filter number, name, or identifier 2. Turbidity values over 1.0 NTU 3. Dates of occurrence 4. Cause of occurrences 5. A filter turbidity profile may be needed	
2. IFE turbidity > 1.0 NTU in 2 consecutive measurements taken 15 minutes apart for 3 consecutive months	1. Report filter number, turbidity level, and date of occurrence. 2. Conduct a filter self-assessment within 14 days of the third high turbidity level.	1. Conduct a filter self-assessment within 14 days of the third high turbidity level. 2. A Comprehensive Performance Evaluation (CPE) may be conducted in lieu of a filter self-assessment.
3. IFE turbidity > 2.0 NTU in 2 consecutive readings taken 15 minutes apart for 2 consecutive months.	1. Report filter number, turbidity level, and date of occurrence. 2. Arrange to have a CPE conducted within 30 days of the 2nd month of the high turbidity. 3. Submit the CPE report within 90 days of the 2nd month of high turbidity.	1. Report filter number, turbidity level, and date of occurrence. 2. Arrange to have a CPE conducted within 60 days of the 2nd month of the high turbidity. If you wish to have the State conduct the CPE, the request must be made by the 10th of the third month. 3. Submit the CPE report within 120 days of the 2nd month of high turbidity.
4. IFE turbidity > 0.5 NTU in 2 consecutive readings taken 15 minutes apart within the first 4 hours of continuous operation after the filter has been backwashed or during startup after the filter has been off-line.	1. Report filter number, turbidity level, and date of occurrence. 2. Produce a filter turbidity profile within 7 days of the incident. 3. Report the reason for the abnormal performance if known.	No required action for these systems.

Adapted from *Pipeline* article – OHA, Summer 2008

Overview – Turbidity Requirements

Explanation of Turbidity Trigger Actions

1. Filter Turbidity Profile – previously described, this includes a graph showing turbidity over a complete filter run, including filter start-up, duration of the run, backwash, and filter-to-waste.



See "Preparing a Filter Turbidity Profile" under "Forms & Tools" on-line at www.healthoregon.org/swt

Overview – Turbidity Requirements

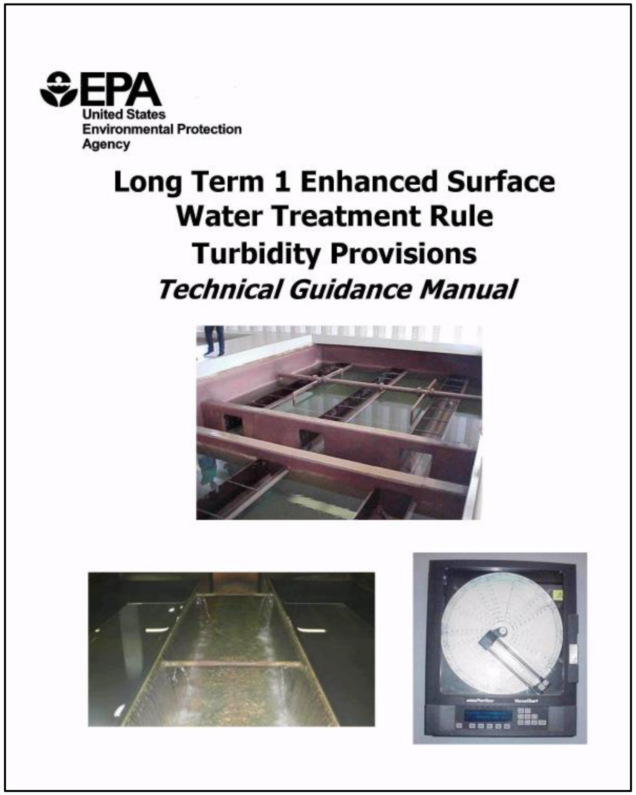
Explanation of Turbidity Trigger Actions

2. Filter Self-Assessment

Consists of a written report assessing filter performance, including

- A filter turbidity profile;
- Identification and prioritization of factors limiting filter performance; and
- Assessment of the applicability of corrections.

See link under “Filtration” at www.healthoregon.org/swt



http://www.epa.gov/safewater/mdbp/pdf/turbidity/chap_05.pdf

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Overview – Turbidity Requirements

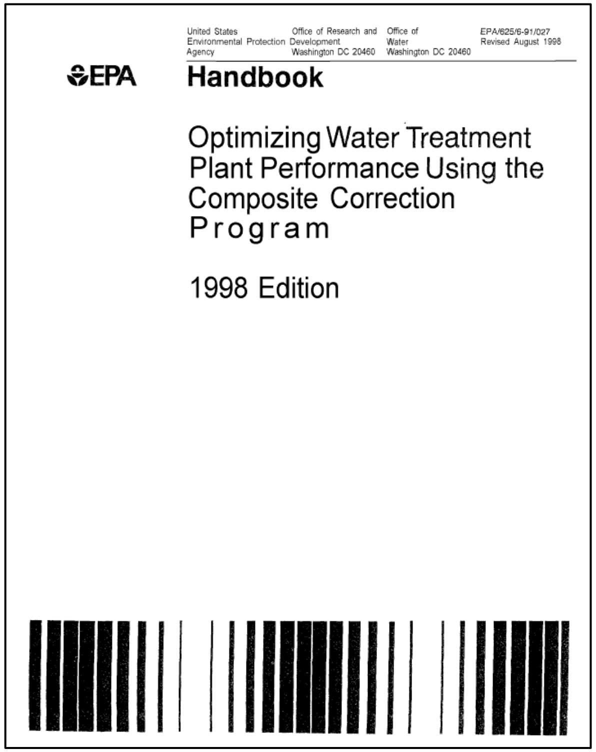
Explanation of Turbidity Trigger Actions

3. Comprehensive Performance Evaluation

Consists of a written report is a thorough evaluation of an existing treatment plant, including a review of the design as well as operational, and managerial practices that may limit the plant's performance.

The results of the evaluation establish the plant capacity and identify a set of prioritized factors that limit performance.

See link for EPA's 1998 Handbook for Optimizing Water Treatment Plant Performance Using the Composite Correction Program under "Filtration" at www.healthoregon.org/swt


United States Environmental Protection Agency | Office of Research and Development Washington DC 20460 | Office of Water Washington DC 20460 | EPA/625/6-91/027 Revised August 1998

EPA

Handbook

Optimizing Water Treatment Plant Performance Using the Composite Correction Program

1998 Edition

http://public.health.oregon.gov/HealthyEnvironments/DrinkingWater/Operations/Treatment/Documents/1998CCPManual.pdf

Oregon Health Authority

Overview – Turbidity Requirements

Filter Coring

Corvallis CPE 2007

Evaluating Media Depth

Warm Springs CPE 2008

Measuring Filter Bed Expansion

Ilwaco CPE 2012

Sludge Solids Analysis

Albany CPE 2012

Measuring Backwash Trough Turbidity

Midland CPE 2015

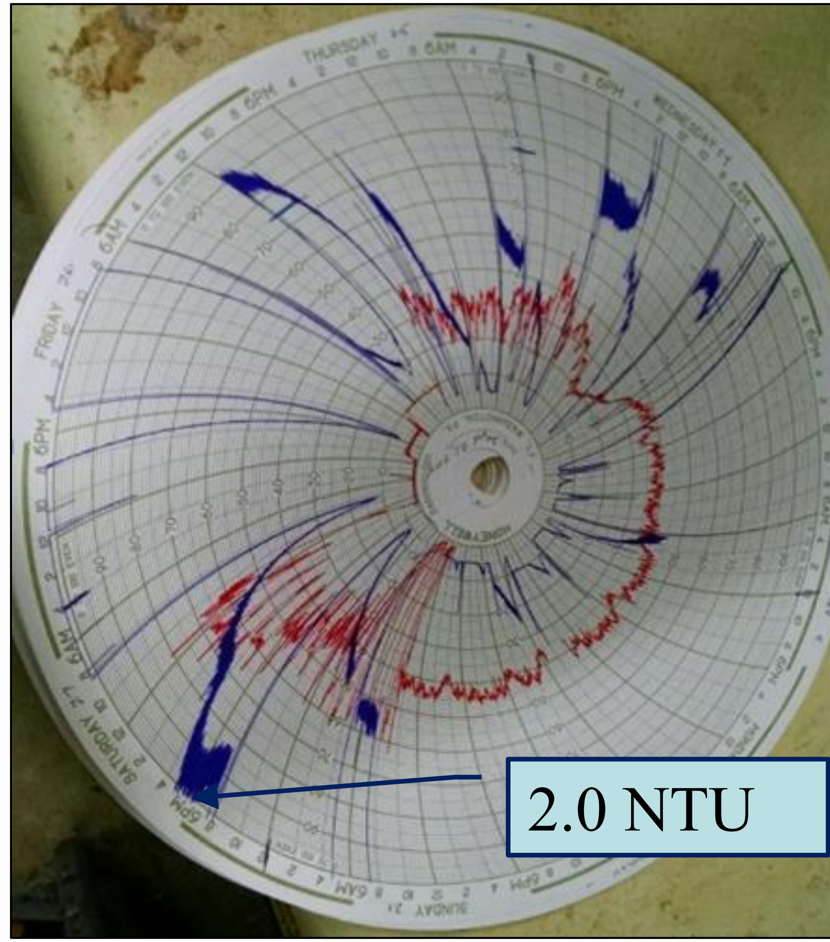
These are some of the activities performed at CPEs in Oregon

Oregon Health Authority

Overview – Turbidity Requirements

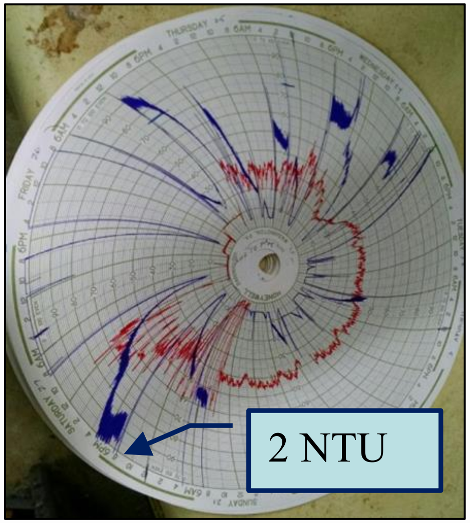
This is an example of a circle chart for a system in Oregon in which IFE triggers were exceeded enough to require a CPE (Turbidity on a scale of 0-2 NTU is shown in Blue; red is chlorine residual).

- Filtered water turbidity exceeded 1.0 NTU in 2 consecutive 15-minute readings for 3 consecutive months (actually exceeded for 4 months).
- Filtered water turbidity exceeded 2.0 NTU in 2 consecutive 15-minute readings for 2 consecutive months.



Overview – Turbidity Requirements

The turbidity exceedances occurred due in part to power interruptions resulting in improper SCM-controlled coagulant feed pump, heavy rains, and un-staffed operation which resulted in significant delays in responding to high turbidity alarms.



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Overview – Turbidity Requirements

The resulting CPE identified many issues in addition to inadequate coagulation control including:

- Inoperable surface wash arm.
- Improperly installed and calibrated plant effluent flow meter.
- Non-compliant pH meter.
- Poor filter bed expansion during backwash (<15%).
- Excessive backwash times.
- Inadequate disinfection at the plant (required "do not drink" signs to be posted at the plant)
- Insufficient budgeting practices and availability of operations staff without automated safeguards.

Positive findings included supportive management and willingness of operator to seek help and make improvements as needed.

CFE Turbidity Monitoring (summary)

- Combined filter effluent (CFE) turbidity
  - Applies to all SW systems
  - Location: post all filtration prior to chemical addition and any storage
  - Frequency: At least every 4 hours for conventional/direct filtration
  - Limits:
    - 95% of 4-hr readings $\leq$ 0.3 NTU (9 or less out of 180 readings in a month)
    - All readings less than 1 NTU

Oregon Health Authority

IFE Turbidity Monitoring (Summary)

Individual filter effluent (IFE) turbidity

- Applies to all conventional & direct systems (membrane systems also)
- Location: after each individual filter
- Frequency: continuous (every 15 minutes)
- Know what the IFE triggers are!

IFE Sample Tap
City of Seaside, 2011

IFE Triggers (Summary)

- 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.

Overview – Disinfection Requirements

OAR 333-061-0032(5) – Disinfection Requirements

a. Disinfection must be sufficient to ensure that the total treatment process, including filtration credit, achieves:

- 3-log (99.9%) inactivation and/or removal of Giardia lamblia cysts (2.0 to 2.5-log is achieved through filtration)
- 4-log (99.99%) inactivation and/or removal of viruses

Overview – Disinfection Requirements

OAR 333-061-0032(5) – Disinfection Requirements

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   - 4-log (99.99%) inactivation and/or removal of viruses

b. The residual disinfectant concentration of water entering the distribution system (entry point or "EP") cannot be less than 0.2 mg/l for more than 4 hours.
   - » Continuous (on-line) monitoring if > 3,300 population
   - » 4x/day if serving 2,501 – 3,300 people
   - » 3x/day if serving 1,001 – 2,500 people
   - » 2x/day if serving 501 – 1,000
   - » 1x/day if serving < 500 people

Overview – Disinfection Requirements

OAR 333-061-0032(5) – Disinfection Requirements

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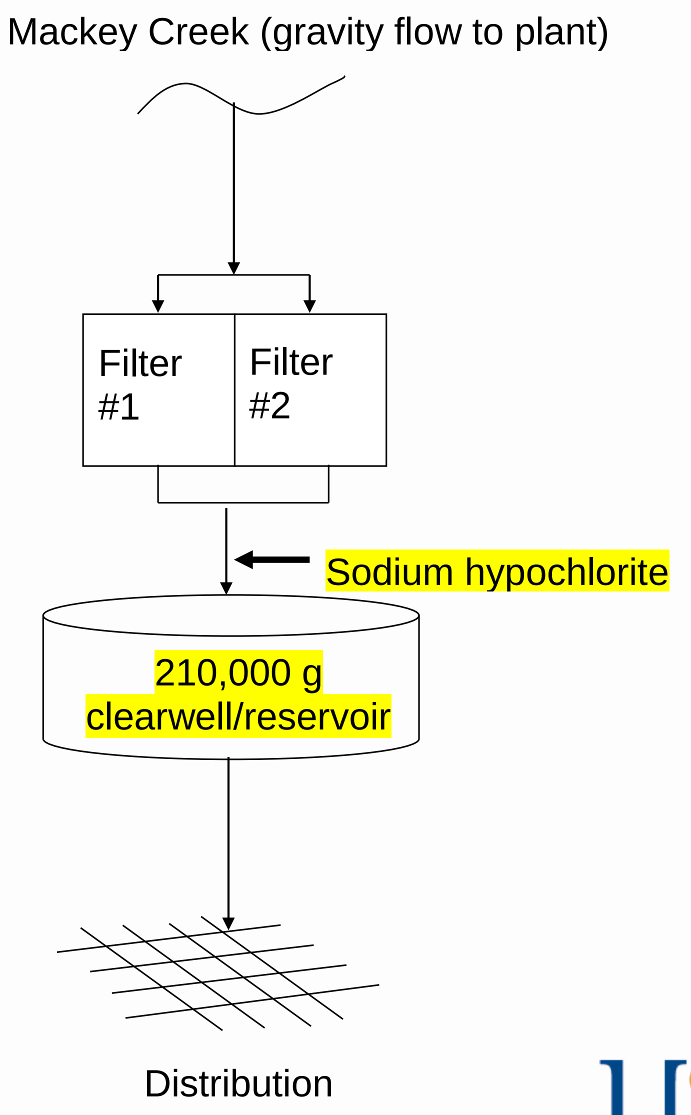
» 4x/day if serving 2,501 – 3,300 people
» 3x/day if serving 1,001 – 2,500 people
» 2x/day if serving 501 – 1,000
» 1x/day if serving < 500 people

c. The residual concentration in the distribution system, cannot be undetectable in more than 5% of samples each month, for any two consecutive months that the system serves water to the public.

Oregon Health Authority

Measuring Entry Point Residual

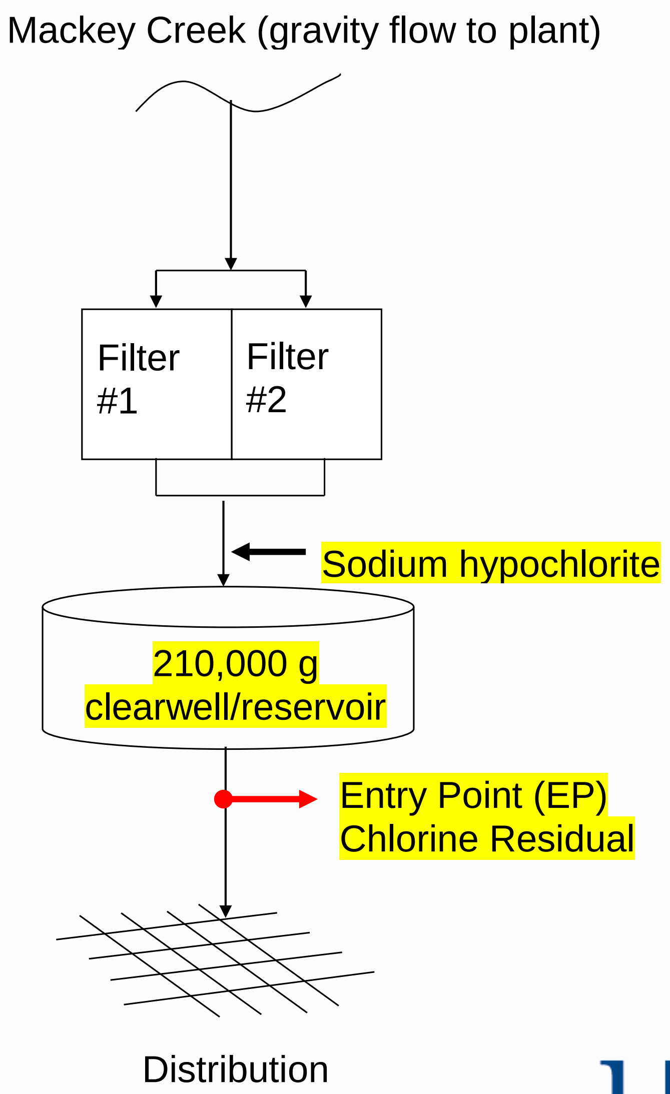
Where would you measure the chlorine residual entering the distribution system?



Measuring Entry Point Residual

At the entry point - after the clearwell and prior to the distribution system.

"Clearwell" in this case refers to a storage tank or reservoir used to hold chlorinated water for a sufficient amount of time for effective disinfection.



Reporting Entry Point Residual

What EP residual would you report?

Report the lowest daily residual on the "Surface Water Quality Data Form"

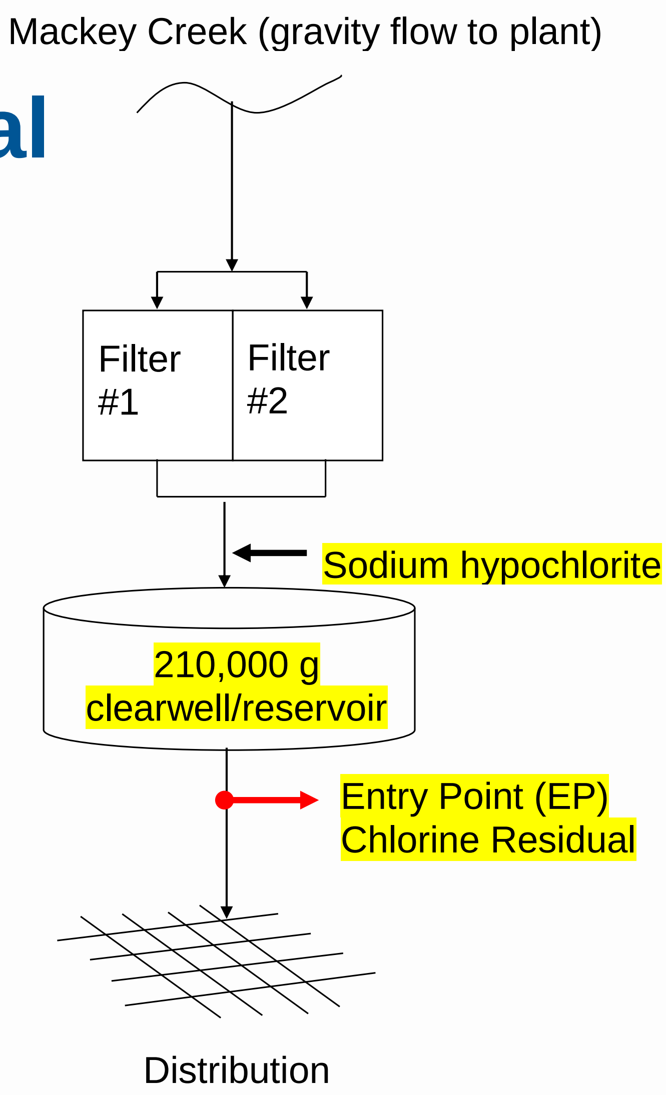
OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1st User (**C**) [3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met? [3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 /								
2 /								

Measuring Distribution Residual

Where would you measure in the distribution system?

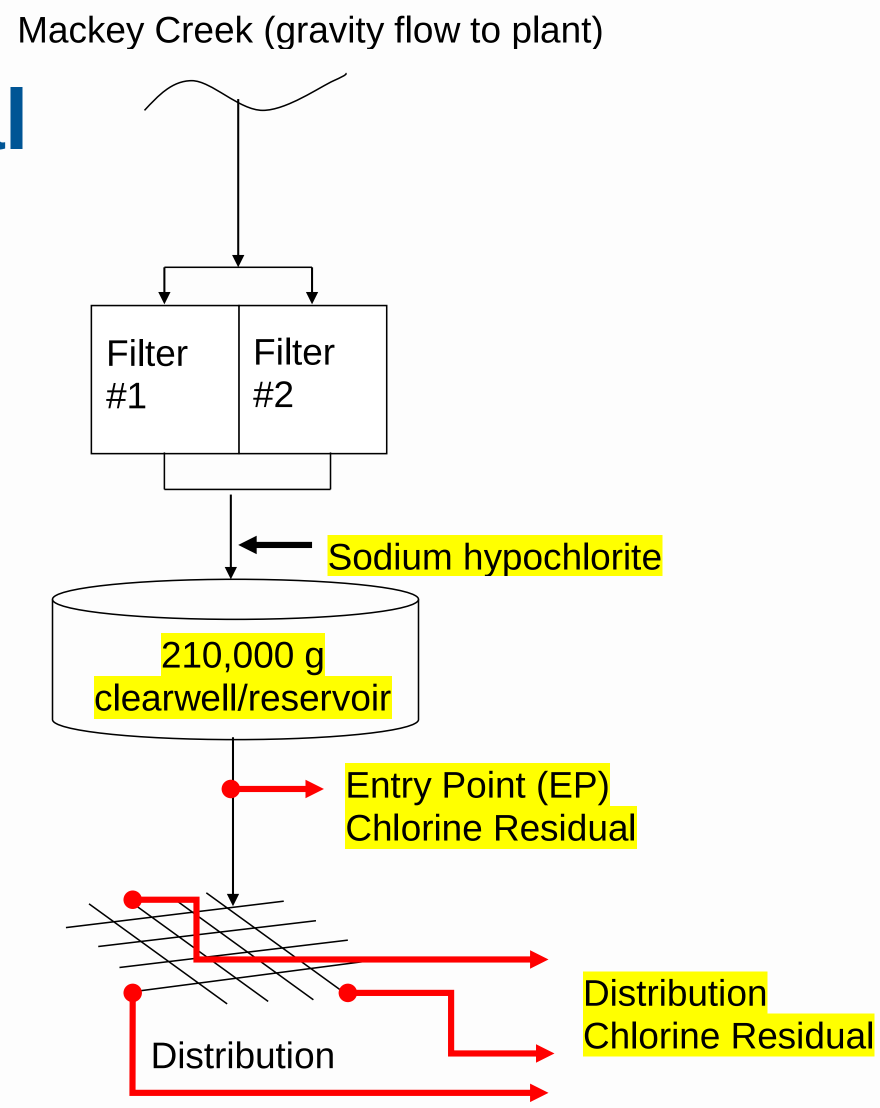


Measuring Distribution Residual

Where would you sample in the distribution system?

A. At one or more representative points at a frequency that is sufficient to detect variations in chlorine demand and changes in water flow but in no case less often than twice per week" OAR 333-061-0036(9)(a)(A)

B. At the same points in the distribution system and at the same times as total coliforms are sampled" -0036(9)(a)(B)



Reporting Distribution Residual

What distribution residual would you report?

- Keep semiweekly residuals on-site for two years
- Use the coliform sample lab form to report residual at the time of coliform sampling.

PWS# 4 1 ______________________________

PWS Name: ______________________________

City, County: ______________________________

Phone: __________________ Fax: __________________

Return address for report:

Name: ______________________________

Address: ______________________________

City, State, Zip: ______________________________

ORELAP#:

Lab Name:

Address:

Phone/Fax:

Bottle#: ______________________________

□ Results do not meet NELAC Standards-See page 2

Lab Sample ID#: ______________________________

Sample Collected Date/Time: ____ / ____ / _____ (MM DD YYYY) ___ : ___ (Hour : Min) □ AM □ PM

Collected By: ______________________________

Chlorinated: □No □Yes

Free Chlorine: ________ mg/L

Overview – Disinfection Requirements

Do not exceed these limits…

OAR 333-061-0031(1) – Maximum Residual Disinfectant Levels (MRDLs)

Disinfectant Residual	MRDL in mg/l
Chlorine	4.0 (as Cl_2)
Chloramines	4.0 (as Cl_2)
Chlorine Dioxide	0.8 (as ClO_2)

Oregon Health Authority

Overview – Disinfection Requirements

OAR 333-061-0036(5)(b) – Monitoring CT

Conventional & Direct Filtration Treatment Systems must calculate **CT** each day the plant is in operation.

CT is a way to measure if disinfection is adequate

How do we calculate CT?

Do not confuse “CT” and “Contact Time”

CT = Chlorine **C**oncentration x Contact **T**ime

- The chlorine concentration is from daily measurements taken at or before the entry point to the distribution system or “1st user”.
- More on CT later….

Overview – NTU and Disinfection Reporting Requirements

OAR 333-061-0040(1)(d) – Reporting requirements

All surface water systems that provide filtration must report within 24 hours after learning:

1. *That the filtered water turbidity exceeds 5 NTU.*
2. *Of a waterborne disease outbreak potentially attributable to the water system*
3. *That the disinfectant residual of the water entering the distribution system fell below 0.2 mg/l and whether or not the residual was restored to at least 0.2 mg/l within 4 hours.*

Overview – NTU and Disinfection Reporting Requirements

OAR 333-061-0040(1)(d) – Reporting requirements, continued

Conventional & Direct Filtration Treatment Systems must also report within 10 days after the end of each month:

1. *The total number of filtered water turbidity taken each month (min of every 4 hours);*
2. *The number and percentage of results exceeding 0.3 NTU; and*
3. *The date and value of any turbidity that exceeded 1 NTU.*

Oregon Health Authority

Overview – NTU and Disinfection Reporting Requirements

Use the State's Turbidity Monitoring Report form to help fulfill reporting requirements - maintain records for at least three years.

Form is available on-line under "Forms & Tools" link at www.healthoregon.org/swt

OHA - Drinking Water Services – Turbidity Monitoring Report **County:**
Conventional or Direct Filtration

Name: **ID #41:** **WTP-:** **Month/Year:**

DAY	12 AM [NTU]	4 AM [NTU]	8 AM [NTU]	NOON [NTU]	4 PM [NTU]	8 PM [NTU]	Highest Reading of the Day[1] [NTU]
1							
2							
3							
4							
5							
6							

Overview – NTU and Disinfection Reporting Requirements

Form is available on-line under “Forms & Tools” link at www.healthoregon.org/swt

There are 5 forms:

- Conventional/Direct
- Slow Sand / DE / Unfiltered
- Cartridge
- Membrane
- UV (if used for Giardia credit)

Must use the correct form because each has questions that must be answered that are specific to filtration type.

Overview – NTU and Disinfection Reporting Requirements

CFE Turbidity

OHA - Drinking Water Services – Turbidity Monitoring Report
Conventional or Direct Filtration

County:

Name: **ID #41:** **WTP-:** **Month/Year:**

DAY	12 AM [NTU]	4 AM [NTU]	8 AM [NTU]	NOON [NTU]	4 PM [NTU]	8 PM [NTU]	Highest Reading of the Day[1] [NTU]
1			0.34				0.50
2			0.24				0.66
3			0.44				
4							
5							
6							

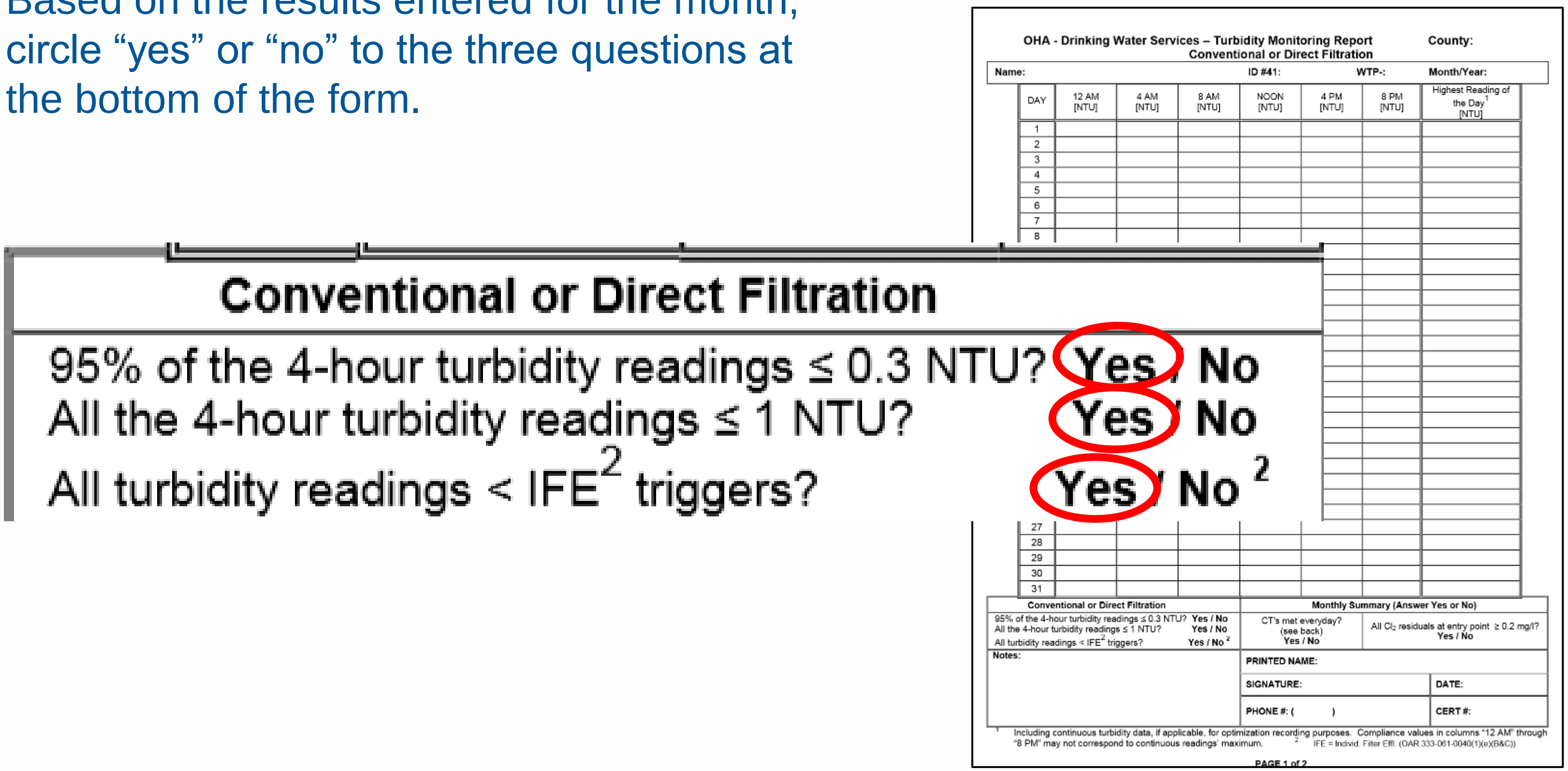
Notify the State if NTU > 1 NTU.
Notify the State within 24-hrs if turbidity > 5 NTU (includes after hours)
Public Health After Hours Duty Officer:
Cell (971) 246-1789
Oregon Emergency Response System:
1-800-452-0311

- Chose time closest to when daily turbidity is measured and enter results
- Enter highest turbidity of all measurements for the day (e.g., online instrument or highest of multiple daily grab samples)

Overview – NTU and Disinfection Reporting Requirements

CFE & IFE Turbidity

Based on the results entered for the month, circle "yes" or "no" to the three questions at the bottom of the form.



OHA - Drinking Water Services – Turbidity Monitoring Report **County:**
Conventional or Direct Filtration

Name: **ID #41:** **WTP-:** **Month/Year:**

DAY	12 AM [NTU]	4 AM [NTU]	8 AM [NTU]	NOON [NTU]	4 PM [NTU]	8 PM [NTU]	Highest Reading of the Day[1] [NTU]
1							
2							
3							
4							
5							
6							
7							
8							
27							
28							
29							
30							
31							

Conventional or Direct Filtration	Monthly Summary (Answer Yes or No)	
95% of the 4-hour turbidity readings ≤ 0.3 NTU? **Yes / No** All the 4-hour turbidity readings ≤ 1 NTU? **Yes / No** All turbidity readings < IFE[2] triggers? **Yes / No** [2]	CT's met everyday? (see back) **Yes / No**	All Cl_2 residuals at entry point ≥ 0.2 mg/l? **Yes / No**
Notes:	**PRINTED NAME:**	
	SIGNATURE:	**DATE:**
	PHONE #: ( )	**CERT #:**

[1] Including continuous turbidity data, if applicable, for optimization recording purposes. Compliance values in columns "12 AM" through "8 PM" may not correspond to continuous readings' maximum. [2] IFE = Individ. Filter Effl. (OAR 333-061-0040(1)(e)(B&C))

PAGE 1 of 2

Conventional or Direct Filtration

95% of the 4-hour turbidity readings ≤ 0.3 NTU? Yes / No
All the 4-hour turbidity readings ≤ 1 NTU? Yes / No
All turbidity readings < IFE[2] triggers? Yes / No [2]

Overview – NTU and Disinfection Reporting Requirements

Peak hourly demand flow (gpm)

Enter peak hourly demand (PHD) flow and the time that the PHD flow occurred.

This flow should not exceed 10% above the peak flows replicated at the time of the tracer study.

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1^{st} User (**C**)[3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met?[3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 /								
2 /								
3 /								
4 /								
5 /								
6 /								
7 /								
8 /								
9 /								
10 /								
11 /								
12 /								
13 /								
14 /								
15 /								
16 /								
17 /								

Revised October 2013
s/turb-conv-direct.pdf

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1^{st} User (**C**)[3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met?[3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 / 9 AM								1,000
2 /								
3 /								
4 /								

Oregon Health Authority

Overview – NTU and Disinfection Reporting Requirements

What is peak hourly demand flow?

- The greatest volume of water passing through the system during any one hour in a consecutive 24-hr period
- Not the same as Peak Instantaneous Flow
- Report demand flow (flow leaving the clearwell, not plant flow (in most cases)

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1st User (**C**) [3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met? [3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 / 9 AM								1,000
2 /								
3 /								
4 /								

Overview – NTU and Disinfection Reporting Requirements

How do you determine peak hourly demand flow?

For systems with a totalizing flow meter only:

– Spot check throughout the day to determine the time of peak demand (e.g. 9 am or 9 pm for residential or mid-day for industrial uses)
– Then record how much water is used during that hour in gallons and divide by 60 minutes to get the peak hour demand in gpm.

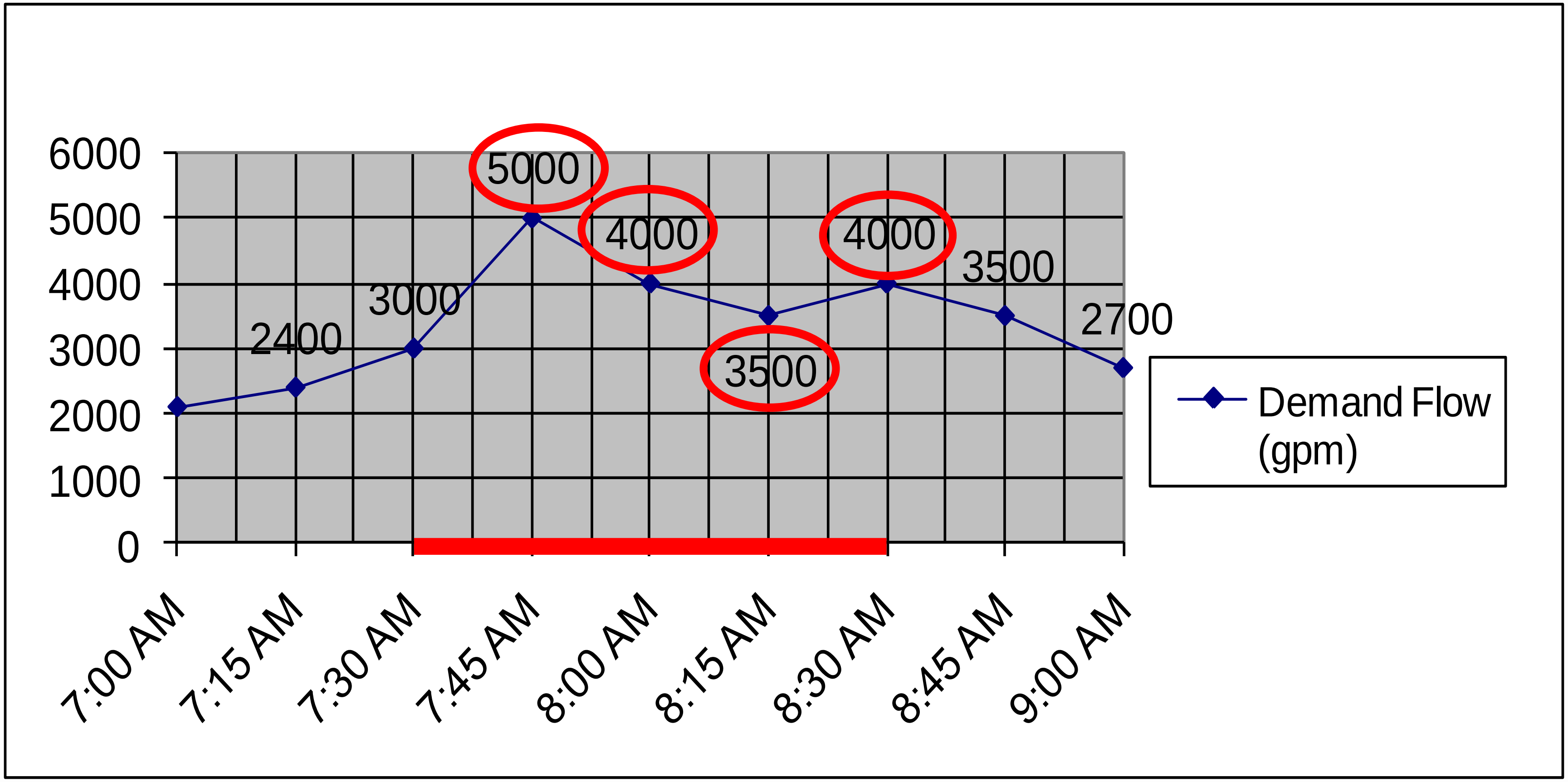
For systems that can measure and record flow rate:

– On a daily basis, use the best available operational data to identify the hour within the 24-hr period that had the highest demand flow.
– For the hour of highest demand flow:
    - Calculate the average flow rate within the one hour period (i.e., add the flow rates and divide by the number of data points).
    - Use as many data points as possible, preferably no less than four data points taken at 15 minute intervals.

Oregon Health Authority

Overview – NTU and Disinfection Reporting Requirements

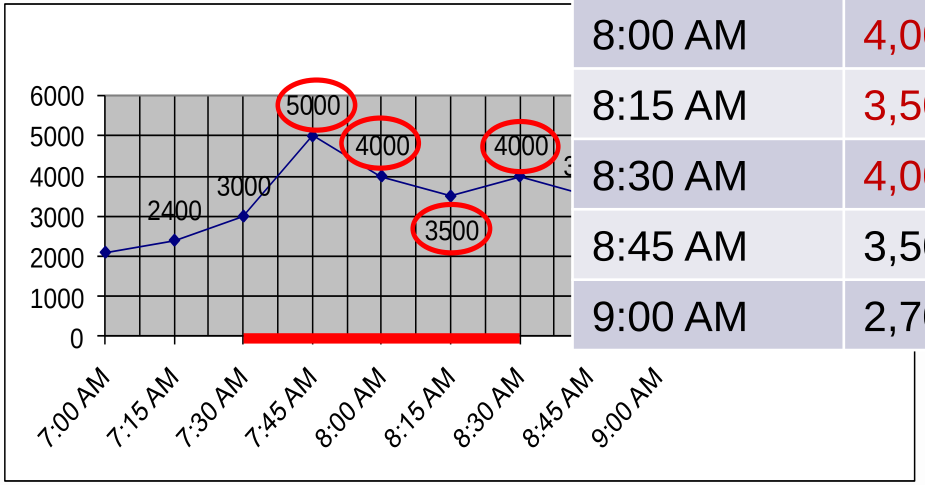
The red line represents the span of 1 hour with the highest demand (7:30 am – 8:30 am). The average of the 4 data points is 4,125 gpm.



Overview – NTU and Disinfection Reporting Requirements

Think of it like a running hourly average of demand flow measurements…

Time	Demand Flow (gpm)	Running Hourly Average (gpm)
7:00 AM	2,000	
7:15 AM	2,400	
7:30 AM	3,000	
7:45 AM	5,000	3,100
8:00 AM	4,000	3,600
8:15 AM	3,500	3,875
8:30 AM	4,000	**4,125**
8:45 AM	3,500	3,750
9:00 AM	2,700	3,425



Overview – NTU and Disinfection Reporting Requirements

Minimum chlorine residual and contact time

– The minimum chlorine residual is measured at the end of the disinfection segment at the entry point prior to or at the first user

– Contact time is the time that the disinfectant is in contact with the water within the disinfection segment.

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1st User (**C**) [3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met? [3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 / 9 AM	???	???						1,000
2 /								
3 /								
4 /								

Overview – NTU and Disinfection Reporting Requirements

How is contact time determined?

- Tracer studies are used to determine contact time (T) which is used in calculating CT achieved, where

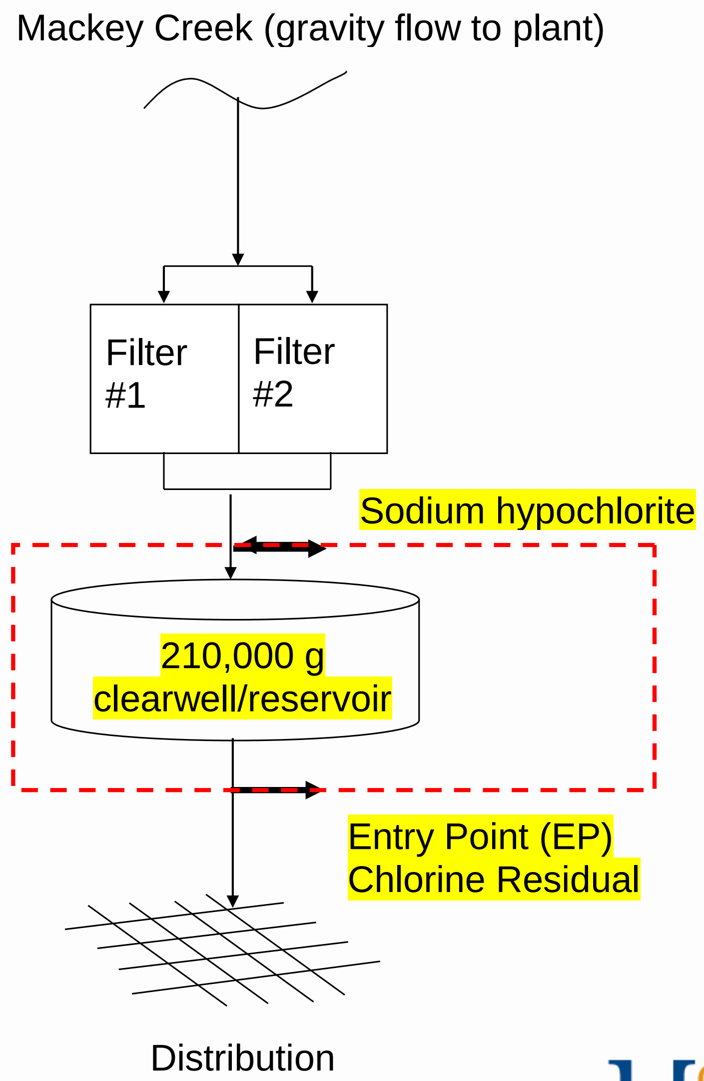
CT = chlorine Concentration x contact Time.

- Contact time is 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

- Tracer studies are often conducted to simulate a worst-case scenario where peak hour demand flows are high and reservoir levels are low. This gives a conservative (i.e. lower) contact time than would normally be expected.

Overview – NTU and Disinfection Reporting Requirements

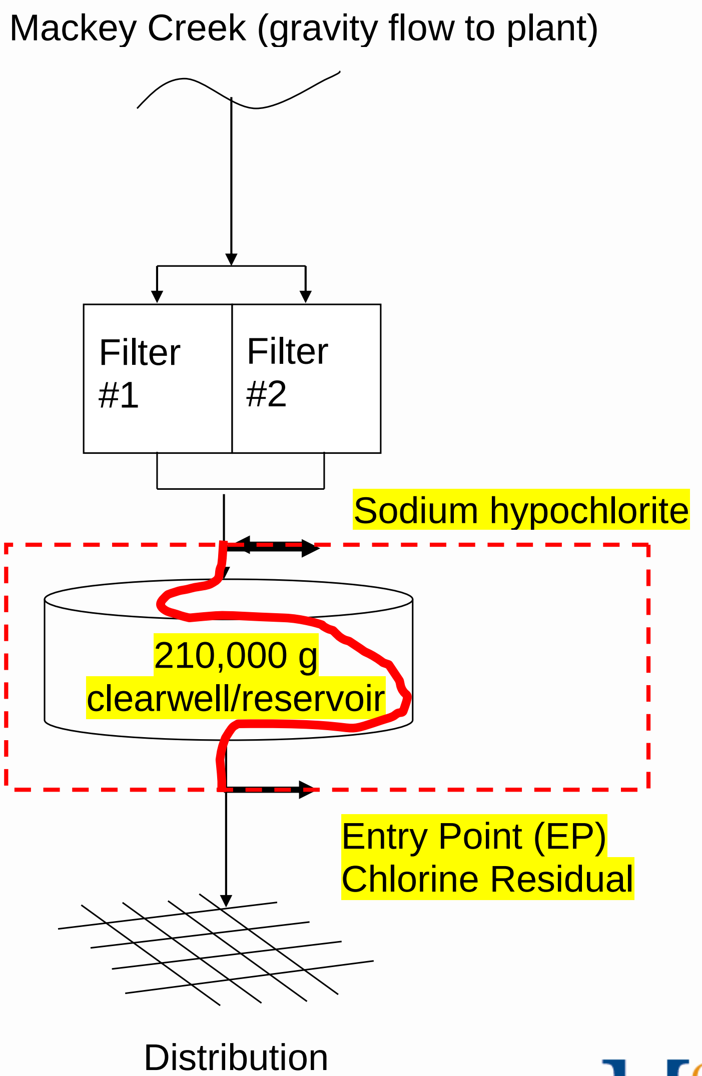
Remember, the disinfection segment is between the point of chlorine injection and the entry point.



Overview – NTU and Disinfection Reporting Requirements

Remember, the disinfection segment is between the point of chlorine injection and the entry point.

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



Overview – NTU and Disinfection Reporting Requirements

What impacts contact time?

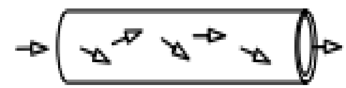
- The less short-circuiting there is in a reservoir or tank, the more contact time is available for disinfection.
- Estimates of contact time for tanks or reservoirs are not allowed for calculating CT's for surface water!
- Contact time achieved only through pipelines may be calculated without conducting a tracer study.

Oregon Health Authority

Overview – NTU and Disinfection Reporting Requirements

What impacts contact time?

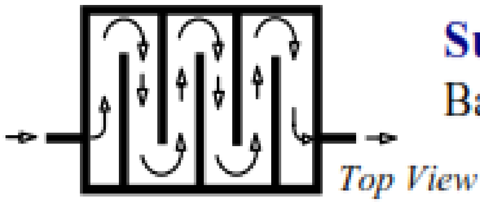
- Pipe flow is assumed to have a baffling efficiency of 100%, meaning the entire volume of water in the pipe may be used to calculate contact time.



Perfect Circulation
Baffling Efficiency = 100%
Plug flow through a length of pipe

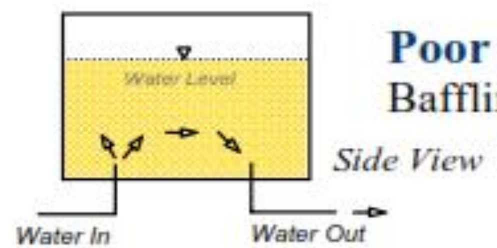
$$Contact\ time\ (minutes) = \frac{Volume\ of\ water\ in\ pipe\ in\ gallons}{Flow\ through\ pipe\ in\ gpm}$$

- Baffling efficiency improves with high flow path length to width ratios, found in pipelines and simulated in tanks with the use of baffles (hence the term baffling efficiency or factor).



Superior Circulation
Baffling Efficiency = 70%

- Low baffling efficiency means the volume of water available for contact time (effective volume) is reduced due to short-circuiting through the tank.



Poor Circulation
Baffling Efficiency = 5-10%

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Tracer studies

Conducting a tracer study:

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. Conduct study 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

Tracer studies (continued)

Conducting a tracer study:

4. Community water systems with populations <10,000 and non-profit non-community systems can use the circuit rider to perform a tracer study

5. Must submit a proposal to the state for approval prior to conducting the tracer study (even if using the circuit rider).

6. Must redo tracer study if peak hour demand flow increases more than 10% of the maximum flow used during the tracer study

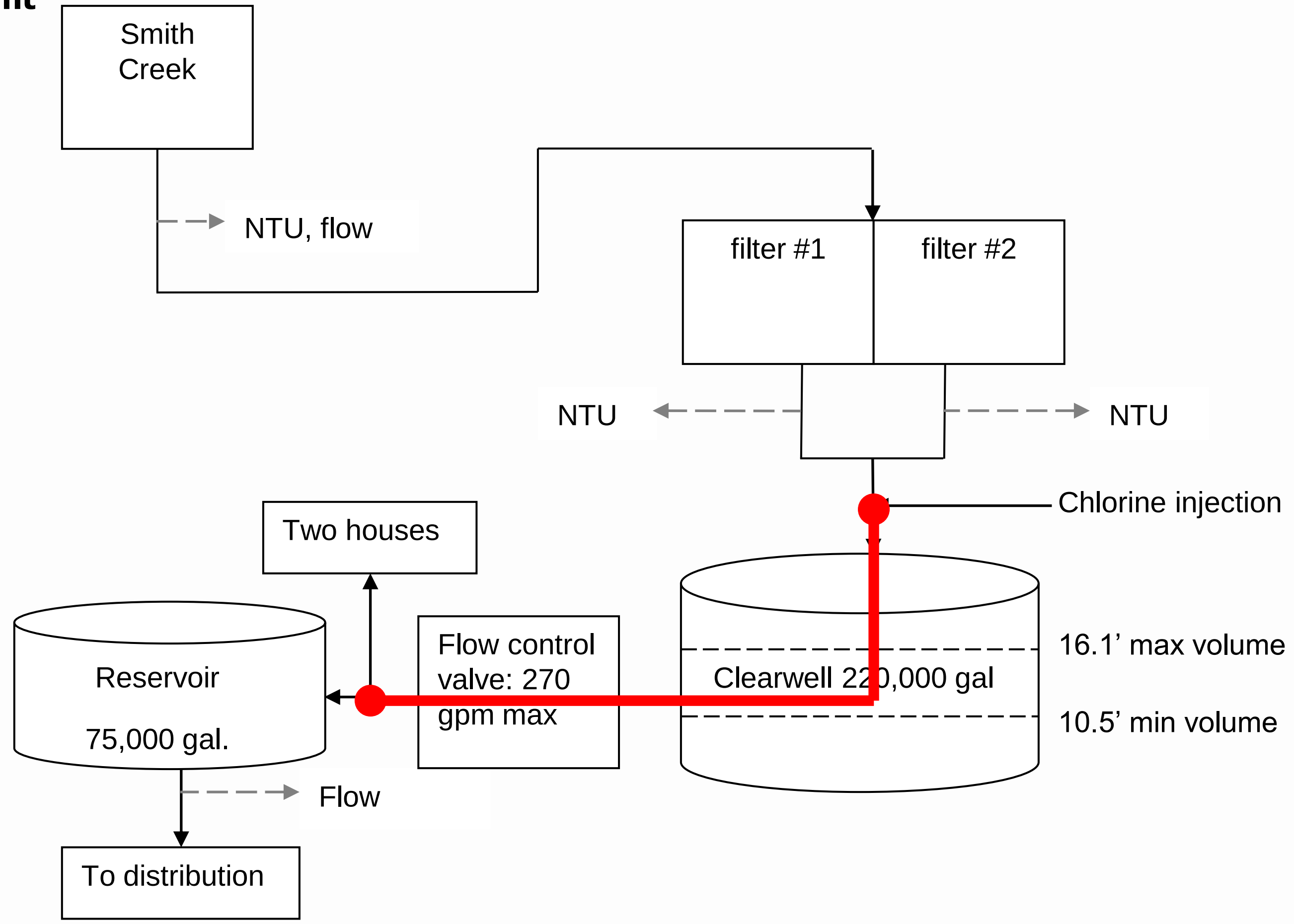
Example

Conducting a tracer study

Example: Tracer studies

Directions: Look at the diagram and answer the questions.

Figure 1: Water Treatment Plant



Questions:

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

Where do I report contact time?

- 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

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1st User (**C**) [3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met? [3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 /								
2 /								

- 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)

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Can I use a baffling factor?

- Once you know the time T from the tracer study, you can back-calculate to determine the baffling factor of the clearwell

  - $$\text{Baffling factor (\%)} = \frac{\text{Time (min)} \times \text{Flow During Tracer Study (gpm)}}{\text{Clearwell Volume During Tracer Study (gal)}}$$

- T can be adjusted based on flow (at <110%) with the following equation:

  - $$T = \frac{\text{Current clearwell Volume (gal)} \times \text{Baffling Factor (\%)}}{\text{Peak Hourly Demand Flow (gpm)}}$$

- If tracer study includes pipeline segments or multiple tanks, contact the state for guidance on using baffling factors

Overview – NTU and Disinfection Reporting Requirements

Now we can enter the min chlorine residual, contact time, and CT_{actual}

- The minimum chlorine residual is measured at the end of the disinfection segment at the entry point prior to or at the first user
- Contact time is the time that the disinfectant is in contact with the water within the disinfection segment.
- **CT_{actual}** = **C**hlorine residual x contact **T**ime

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1st User (**C**)[3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met?[3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**			Use		
1 / 9 AM	0.6	100	60					
2 /								
3 /								
4 /								

Notify the State within 24-hrs if chlorine residual < 0.2 mg/l
Public Health After Hours Duty Officer:
Cell (971) 246-1789
Oregon Emergency Response System:
1-800-452-0311

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How do I know if CT_{actual} is adequate?

- We use the EPA tables to determine the CTs needed to inactivate *Giardia* ($CT_{required}$)

  In order to use the EPA tables, we need to know the log Giardia inactivation required to meet a total removal/inactivation of 3.0-log (generally either 0.5-log or 1-log). 0.5-log Giardia inactivation will also achieve 4.0-log virus inactivation.

  We also need to know the following parameters, measured each day at or before the first user or entry point:
  - pH,
  - temperature, and
  - free chlorine residual

- Then we compare $CT_{required}$ with Ct_{actual}

- Must keep $CT_{actual} \geq CT_{required}$

Overview – NTU and Disinfection Reporting Requirements

Now enter the pH, temperature, and circle the appropriate log removal required

Log removal required is for Giardia and is always going to be at least 0.5-log.

Although the requirement can vary from plant to plant, generally for conventional plants, 0.5-log is needed and for direct plants, 1.0-log is needed (check with your regulator if uncertain)

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1st User (**C**) [3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met? [3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 / 9 AM	0.6	100	60	12	6.8			1,000
2 /								
3 /								
4 /								

Calculating $CT_{required}$

- You should know how to use the EPA tables to determine the CTs needed to inactivate *Giardia* ($CT_{required}$) – more on that later!
- You can also use "regression" equations determined by EPA
- Regression equations are built into the Microsoft Excel reporting forms on-line under the "Forms and Tools" section of our surface water treatment page on-line at www.healthoregon.org/swt

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Calculating $CT_{required}$ Using Regression Equations

Regression equations can be programmed into plant SCADA or spreadsheets

- **Regression Equation (for Temp < 12.5°C)**

  $$CT = (0.353*L)(12.006 + e^{(2.46-0.073*T+0.125*C+0.389*pH)})$$

- **Regression Equation (for Temp > 12.5°C)**

  $$CT = (0.361*L)(-2.261 + e^{(2.69-0.065*T+0.111*C+0.361*pH)})$$

- **Variables:**

  CT = Product of Free Chlorine Residual and Time required

  L = number of log inactivation for Giardia (L = 1 for slow sand)

  T = temperature, in Celsius

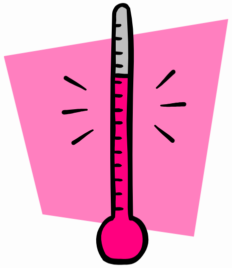
  C = chlorine residual in mg/L

  pH = pH of water

  e = 2.7183, base for natural log

(Smith, Clark, Pierce and Regli, 1995, from EPA's 1999 Guidance Manual for Disinfection Profiling and Benchmarking)

Calculating $CT_{required}$ Using EPA CT Tables - Temperature



You should all be able to use the CT tables to calculate $CT_{required}$

- There are six EPA CT tables based on temperature

- Find the correct table based on your water temperature in degrees Celsius.
  °C = 5/9 x (°F – 32)

- If water temp is between values, then round down

- *Disinfection is less effective at colder temperatures.*

Calculating $Ct_{required}$ Using EPA CT Tables - Temperature

If the water temperature = 12°C

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 10° C   10°C – 14.9°C

Use 10°C table for T = 10 – 14.9°C
(round down for temp)

Chlorine Concentration mg/L <=	PH < 6 Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0	6.1 – 6.5 PH = 6.5 Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0	6.6 – 7.0 PH = 7.0 Log Inactivations 0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.4	12	24	37	49	61	73	15	29	44	59	73	88	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.6	13	25	38	50	63	75	15	30	45	60	75	90	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.8	13	26	39	52	65	78	15	31	46	61	77	92	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	13	26	40	53	66	79	16	31	47	63	78	94	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.2	13	27	40	53	67	80	16	32	48	63	79	95	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.4	14	27	41	55	68	82	16	33	49	65	82	98	19	39	58	77	97	116
1.6	14	28	42	55	69	83	17	33	50	66	83	99	20	40	60	79	99	119
1.8	14	29	43	57	72	86	17	34	51	67	84	101	20	41	61	81	102	122
2	15	29	44	58	73	87	17	35	52	69	87	104	21	41	62	83	103	124
2.2	15	30	45	59	74	89	18	35	53	70	88	105	21	42	64	85	106	127
2.4	15	30	45	60	75	90	18	36	54	71	89	107	22	43	65	86	108	129
2.6	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131
2.8	16	31	47	62	78	93	19	37	56	74	93	111	22	45	67	89	112	134
3	16	32	48	63	79	95	19	38	57	75	94	113	23	46	69	91	114	137

Chlorine Concentration mg/L <=	7.1 – 7.5 PH < 7.5 Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0	PH = 8.0 Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0	PH = 8.5 Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0
0.4	21	42	63	83	104	125	25	50	75	99	124	149	30	59	89	118	148	177
0.6	21	43	64	85	107	128	26	51	M	102	128	153	31	61	92	122	153	183

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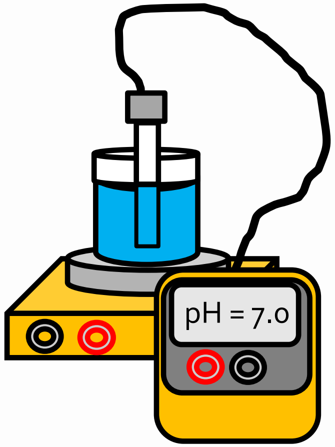
Calculating $CT_{required}$ Using EPA CT Tables - pH

There are 7 sections for pH on each table

- Find the section that corresponds to your water's pH level
- If your pH is between the choices, then round up to the higher pH
- *Disinfection is less effective at higher pH*
- *Rounding up is more conservative (leads to a higher $CT_{required}$)*



Calculating $CT_{required}$ Using EPA CT Tables, Continued

Assume the pH = 6.8°C

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 10° C   10°C – 14.9°C

Chlorine Concentration mg/L < =	PH < 6						6.1 – 6.5 PH = 6.5						6.6 – 7.0 PH = 7.0					
	Log Inactivations						Log Inactivations						Log Inactivations					
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.4	12	24	37	49	61	73	15	29	44	59	73	88	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.6	13	25	38	50	63	75	15	30	45	60	75	90	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.8	13	26	39	52	65	78	15	31	46	61	77	92	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	13	26	40	53	66	79	16	31	47	63	78	94	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.2	13	27	40	53	67	80	16	32	48	63	79	95	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.4	14	27	41	55	68	82	16	33	49	65	82	98	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.6	14	28	42	55	69	83	17	33	50	66	83	99	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.8	14	29	43	57	72	86	17	34	51	67	84	101	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	15	29	44	58	73	87	17	35	52	69	87	104	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.2	15	30	45	59	74	89	18	35	53	70	88	105	21	42	64	85	106	127
2.4	15	30	45	60	75	90	18	36	54	71	89	107	22	43	65	86	108	129
2.6	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131
2.8	16	31	47	62	78	93	19	37	56	74	93	111	22	45	67	89	112	134
3	16	32	48	63	79	95	19	38	57	75	94	113	23	46	69	91	114	137

Use pH = 7.0 column

For pH = 6.6 – 7.0

(round up for pH)

Chlorine Concentration mg/L < =	7.1 – 7.5 PH < 7.5						PH = 8.0						PH = 8.5					
	Log Inactivations						Log Inactivations						Log Inactivations					
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	21	42	63	83	104	125	25	50	75	99	124	149	30	59	89	118	148	177
0.6	21	43	64	85	107	128	26	51	M	102	128	153	31	61	92	122	153	183

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Calculating $CT_{required}$ Using EPA CT Tables – Log

Assume the required log inactivation of Giardia for a conventional treatment plant is 0.5-log

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 10° C   10°C – 14.9°C

Chlorine Concentration mg/L <=	PH < 6						PH = 6.5 (6.1 – 6.5)						PH = 7.0 (6.6 – 7.0)					
	Log Inactivations						Log Inactivations						Log Inactivations					
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	12	24	37	49	61	73	15	29	44	59	73	88	17	35	52	69	87	104
0.6	13	25	38	50	63	75	15	30	45	60	75	90	18	36	54	71	89	107
0.8	13	26	39	52	65	78	15	31	46	61	77	92	18	37	55	73	92	110
1	13	26	40	53	66	79	16	31	47	63	78	94	19	37	56	75	93	112
1.2	13	27	40	53	67	80	16	32	48	63	79	95	19	38	57	76	95	114
1.4	14	27	41	55	68	82	16	33	49	65	82	98	19	39	58	77	97	116
1.6	14	28	42	55	69	83	17	33	50	66	83	99	20	40	60	79	99	119
1.8	14	29	43	57	72	86	17	34	51	67	84	101	20	41	[illegible]	[illegible]	[illegible]	[illegible]
2	15	29	44	58	73	87	17	35	52	69	87	104	21	41	[illegible]	[illegible]	[illegible]	[illegible]
2.2	15	30	45	59	74	89	18	35	53	70	88	105	21	42	[illegible]	[illegible]	[illegible]	[illegible]
2.4	15	30	45	60	75	90	18	36	54	71	89	107	22	43	[illegible]	[illegible]	[illegible]	[illegible]
2.6	15	31	46	61	77	92	18	37	55	73	92	110	22	44	[illegible]	[illegible]	[illegible]	[illegible]
2.8	16	31	47	62	78	93	19	37	56	74	93	111	22	45	[illegible]	[illegible]	[illegible]	[illegible]
3	16	32	48	63	79	95	19	38	57	75	94	113	23	46	69	91	114	137

Use the 0.5-log column

Chlorine Concentration mg/L <=	PH < 7.5 (7.1 – 7.5)						PH = 8.0						PH = 8.5					
	Log Inactivations						Log Inactivations						Log Inactivations					
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2 .5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	21	42	63	83	104	125	25	50	75	99	124	149	30	59	89	118	148	177
0.6	21	43	64	85	107	128	26	51	M	102	128	153	31	61	92	122	153	183

Image from CDC's site: http://www.cdc.gov/parasites/crypto/index.html

Calculating $CT_{required}$ Using EPA CT Tables – Chlorine

Match up your chlorine residual with the log inactivation column as shown below. Where they intersect is the $CT_{required}$.

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 10° C 10°C – 14.9°C

Chlorine Concentration mg/L < =	PH < 6 Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0
0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.6	13	25	38	50	63	75
0.8	13	26	39	52	65	78
1	13	26	40	53	66	79
1.2	13	27	40	53	67	80
1.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Chlorine Concentration mg/L < =	PH = 6.5 (6.1 – 6.5) Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0
0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.6	15	30	45	60	75	90
0.8	15	31	46	61	77	92
1	16	31	47	63	78	94
1.2	16	32	48	63	79	95
1.4	16	33	49	65	82	98
1.6	17	33	50	66	83	99
1.8	17	34	51	67	84	101
2	17	35	52	69	87	104
2.2	18	35	53	70	88	105
2.4	18	36	54	71	89	107
2.6	18	37	55	73	92	110
2.8	19	37	56	74	93	111
3	19	38	57	75	94	113

Chlorine Concentration mg/L < =	PH = 7.0 (6.6 – 7.0) Log Inactivations 0.5	1.0	1.5	2.0
0.4	[illegible]	[illegible]	52	69
0.6	18	[illegible]	54	71
0.8	18	37	55	73
1	19	37	56	75
1.2	19	38	57	76
1.4	19	39	58	77
1.6	20	40	60	79
1.8	20	41	61	81
2	21	41	62	83
2.2	21	42	64	85
2.4	22	43	65	86
2.6	22	44	66	87
2.8	22	45	67	89
3	23	46	69	91

3.0	0.5	1.0	1.5
[illegible]	[illegible]	[illegible]	52
90	18	[illegible]	54
92	18	37	55
94	19	37	56
95	19	38	57

If residual falls between values in the table, round up to yield a higher $CT_{required}$

Chlorine Concentration mg/L < =	PH = 8.0 Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0	PH = 8.5 Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0
0.4	25	50	75	99	124	149	30	59	89	118	148	177
0.6	26	51	M	102	128	153	31	61	92	122	153	183

Chlorine Concentration mg/L < =	Log Inactivations 0.5	1.0	1.5	2.0	2.5	3.0
0.4	21	42	63	83	104	125
0.6	21	43	64	85	107	128

Calculating $CT_{required}$ Using EPA CT Tables – Chlorine

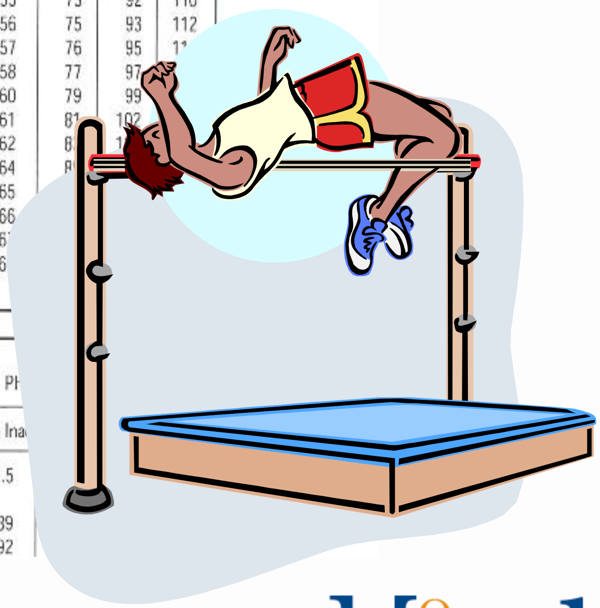
Match up your chlorine residual with the log inactivation column as shown below. Where they intersect is the $CT_{required}$.

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 10° C   10°C – 14.9°C

Chlorine Concentration mg/L < =	PH < 6						PH = 6.5 (6.1 – 6.5)						PH = 7.0 (6.6 – 7.0)					
	Log Inactivations						Log Inactivations						Log Inactivations					
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52	69	87	104
0.6	13	25	38	50	63	75	15	30	45	60	75	90	18	[illegible]	54	71	89	107
0.8	13	26	39	52	65	78	15	31	46	61	77	92	18	37	55	73	92	110
1	13	26	40	53	66	79	16	31	47	63	78	94	19	37	56	75	93	112
1.2	13	27	40	53	67	80	16	32	48	63	79	95	19	38	57	76	95	[illegible]
1.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98	19	39	58	77	97	[illegible]
1.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99	20	40	60	79	99	[illegible]
1.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	101	20	41	61	81	102	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	104	21	41	62	[illegible]	[illegible]	[illegible]
2.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	105	21	42	64	[illegible]	[illegible]	[illegible]
2.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	107	22	43	65	[illegible]	[illegible]	[illegible]
2.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	110	22	44	66	[illegible]	[illegible]	[illegible]
2.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	111	22	45	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	113	23	46	[illegible]	[illegible]	[illegible]	[illegible]

Chlorine Concentr[illegible] mg/L < =	[illegible]						[illegible]						PH [illegible]		
	[illegible]						[illegible]						Log Ina[illegible]		
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5
0.4	21	42	63	83	104	125	25	50	75	99	124	149	30	59	89
0.6	21	43	64	85	107	128	26	51	M	102	128	153	31	61	92

If you get confused on which way to round, think about how you want to set the bar ($CT_{required}$) as high as possible to be the most conservative and most protective of public health.



Oregon Health Authority

Overview – NTU and Disinfection Reporting Requirements

Now enter Required CT and indicate if CT was met

(i.e. put "Yes" if $CT_{actual} \geq Ct_{required}$)

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: **ID #41:** **WTP-:** **Month/Year:** **Log Requirement (Circle One): 0.5 1.0**

Date / Time	Minimum Cl_2 Residual at 1st User (**C**) [3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met? [3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 / 9 AM	0.6	100	60	12	6.8	18	Yes	1,000
2 /								
3 /								

Notify the State within 24-hrs if CT was not met.
Public Health After Hours Duty Officer:
Cell (971) 246-1789
Pager (503) 938-6790
Oregon Emergency Response System:
1-800-452-0311

Overview – NTU and Disinfection Reporting Requirements

Everyone needs to fill out the CT section of the Monthly Summary

Monthly Summary (Answer Yes or No)	
CT's met everyday? (see back) Yes / No	All Cl_2 residual at entry point ≥ 0.2 mg/l? Yes / No
PRINTED NAME:	
SIGNATURE:	DATE:
PHONE #: ( )	CERT #:

Overview – NTU and Disinfection Reporting Requirements

Be sure your reports are complete before sending them in by the 10th of each month

OHA - Drinking Water Services – Turbidity Monitoring Report Conventional or Direct Filtration **County:** Clatsop

Name: XWZ Water System **ID #41:** 99999 **WTP-:** A **Month/Year:** 09/2015

DAY	12 AM [NTU]	4 AM [NTU]	8 AM [NTU]	NOON [NTU]	4 PM [NTU]	8 PM [NTU]	Highest Reading of the Day[1] [NTU]
1	0.08	0.09	0.07	0.08	0.09	0.06	0.12 NTU
2							
3							

Conventional or Direct Filtration	Monthly Summary (Answer Yes or No)	
95% of the 4-hour turbidity readings ≤ 0.3 NTU? Yes / No All the 4-hour turbidity readings ≤ 1 NTU? Yes / No All turbidity readings < IFE[2] triggers? Yes / No [2]	CT's met everyday? (see back) Yes No	All Cl_2 residuals at entry point ≥ 0.2 mg/l? Yes No
Notes:	**PRINTED NAME:** Evan Hofeld	
	SIGNATURE: [signature]	**DATE:** 09/26/15
	PHONE #: (971) 322-8027	**CERT #:** 12345

OHA - Drinking Water Program – Surface Water Quality Data Form - *Giardia* Inactivation

Name: XWZ Water System **ID #41:** 99999 **WTP-:** A **Month/Year:** 09/15 **Log Requirement (Circle One):** 0.5 1.0

Date / Time	Minimum Cl_2 Residual at 1st User (**C**)[3]	Contact Time (**T**)	Actual CT	Temp	pH	Required CT	CT Met? [3]	Peak Hourly Demand Flow
	[ppm or mg/L]	[minutes]	**C X T**	[°C]		Use tables	Yes / No	[GPM]
1 /9 AM	0.6	100	60	12	6.8	18	Yes	1,000

Overview – NTU and Disinfection Reporting Requirements Common Mistakes

- Not calculating CT's daily
  - Don't wait until the end of the month to do the calculations because if you discover you didn't meet CT's, it's too late!

- If adjusting contact time according to flow rate, use the demand flow, not the plant flow.

- Failure to answer questions at bottom of form correctly (or at all)

- Always answering "Yes" to the questions at the bottom of the form without actually looking at the numbers

Overview – NTU and Disinfection Reporting Requirements Common Mistakes, Continued

- Rounding errors when using EPA tables to determine $CT_{required}$
  - Must round down for temperature
  - Must round up for pH
  - Must round up for free chlorine residual

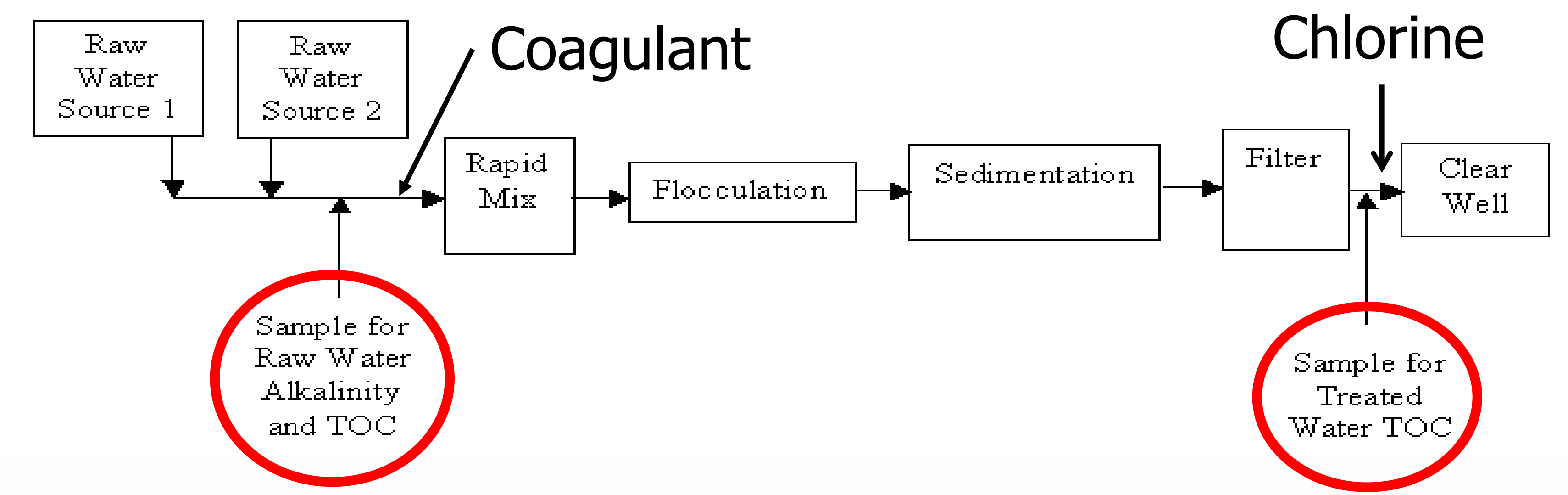
- Bad CT formulas in excel spreadsheets:
  - Make sure you understand your formula
  - Wilkes Equation not allowed, must use Regression Equation

Overview - TOC

OAR 333-061-0036(5) – Total Organic Carbon (TOC)

Conventional Filtration Treatment Systems must:

1. *Monitor source water TOC and alkalinity prior to treatment (this can be from a combined header after blending of more than one source water)*
2. *Monitor combined filter effluent (CFE) water TOC.*



Overview - TOC

OAR 333-061-0036(5) – Total Organic Carbon (TOC)

Conventional Filtration Treatment Systems must:

1. *Monitor source water TOC and alkalinity prior to treatment (this can be from a combined header after blending of more than one source water)*
2. *Monitor combined filter effluent (CFE) water TOC.*
3. *Source TOC and alkalinity and CFE TOC must be taken at the same time as a "paired" sample set used to determine TOC removal efficiency.*
4. *Sampling must be done each month*
5. *Reductions to quarterly sampling can occur if average CFE TOC < 2.0 mg/l for 2 consecutive years or < 1 mg/l for one year*
6. *If annual average treated water TOC $\geq$ 2.0 mg/l, the reduction is lost and monthly monitoring must resume at the end of the quarter.*

Overview - TOC

OAR 333-061-0032(10)(d) – TOC removal requirements

Community (e.g., year-round residents) and Non-transient Non-community (e.g. schools, businesses, etc.) using conventional filtration must operate with enhanced coagulation or enhanced softening to achieve certain total organic carbon (TOC) percent removal levels specified in -0032(10)(e) unless at least one of the following alternative compliance criteria are met:

1. *Source water TOC < 2.0 mg/l (calculated quarterly as a running annual average (RAA)).*
2. *Treated water RAA TOC < 2.0 mg/l*
3. *Source water RAA TOC < 2.0 mg/l & RAA alkalinity > 60 mg/l & TTHM & HAA5 < ½ the MCL (TTHM MCL = 0.080 mg/l, HAA5 MCL = 0.060 mg/l)*
4. *TTHM & HAA5 < ½ the MCL and chlorine is the only disinfectant used*
5. *Source water RAA SUVA ≤ 2.0 L/mg-m*
6. *Finished water RAA SUVA ≤ 2.0 L/mg-m*

Note: Softening systems have additional criteria – SEE OAR 333-061-0032(10(d)(B)

Oregon Health Authority

Overview – Recycle Streams

OAR 333-061-0032(11) – Recycled water requirements

Both conventional and direct plants that recycle spent filter backwash water, thickener, supernatant, or liquids from dewatering processes must notify the State and will generally be expected to return these flows to the head of the treatment plant prior to coagulant injection

Overview – Significant Deficiencies

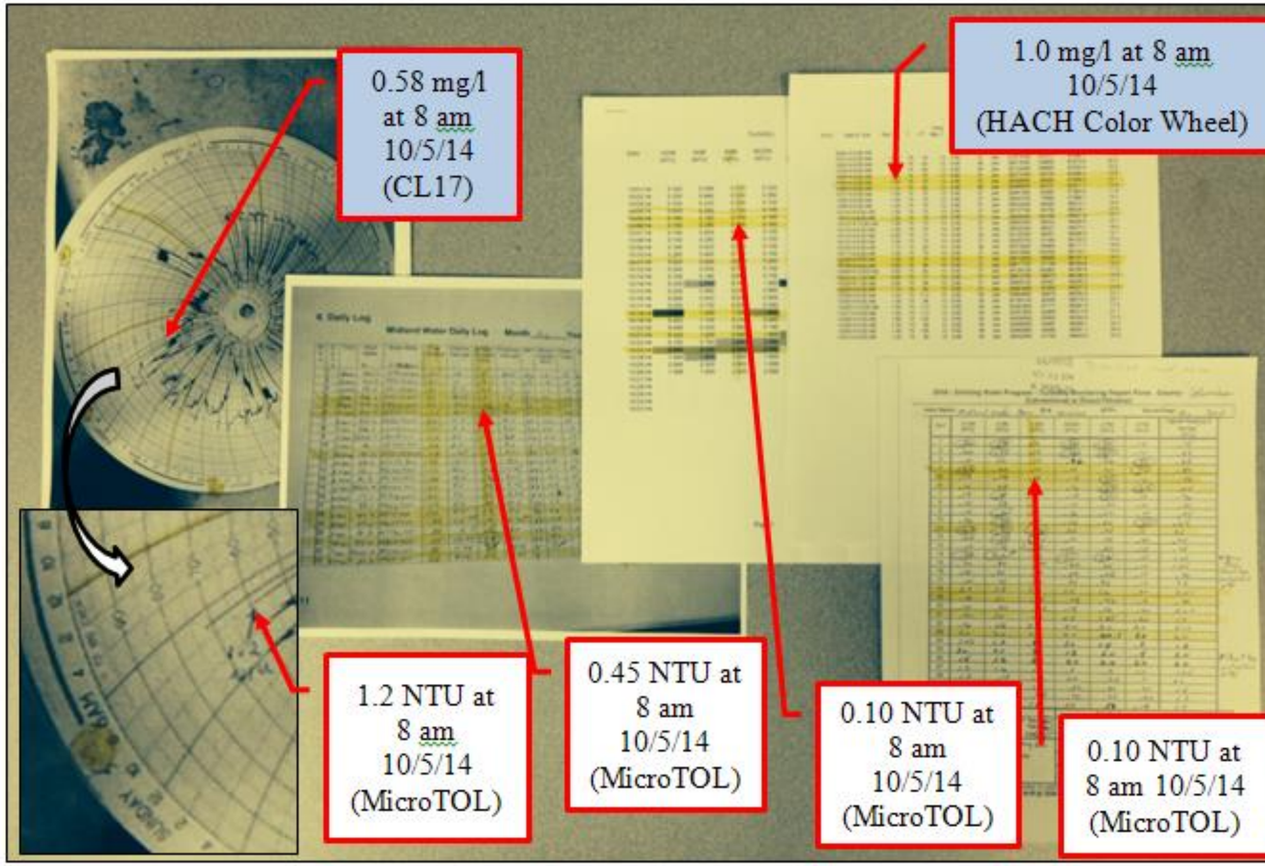
In addition to other rule violations, significant deficiencies identified during a water system survey would include the following commonly found issues:

1. Monitoring not completed as required;
2. Incorrect location for compliance turbidity monitoring;
3. Turbidimeters not calibrated quarterly;
4. Regardless of size, no auto-dial, call-out alarm or auto-plant shutoff for high turbidity when no operator is on-site;
5. Settled water turbidity not measured daily for conventional plants;
6. For systems serving more than 3,300 people, no auto-dial, call-out alarm or auto-plant shutoff for low chlorine residual;
7. No means to adequately determine flow rate on clearwell;
8. No means to determine disinfection contact time under peak flow and minimum storage conditions;
9. Failure to calculate CT correctly; and
10. Inadequate written Operations and Maintenance procedures

Overview – Homework!

Trace data from the sample tap to regulatory reporting forms.

What did you find?



Overview – Homework!

- Write an SOP for CT determination
  - Check how T is calculated at your plant
  - Do all treatment plant operators understand it?
  - Review spreadsheet equation for CTs (if applicable)
  - Arrange for a tracer study if necessary
  - Calculate CT and fill out monthly report daily

- Know what to do and who to call when things go wrong (contact State regulator & refer to Emergency Response Plan)

Overview – Homework!

- Make data reliability a plant goal
- Establish protocols for collection and recording of data. Only collect data used for process control or compliance reporting
- Establish a data verification process that can be routinely used to confirm data integrity
- Turn data into information (e.g., draw the graph).

Oregon Health Authority

Class Outline

9 AM	Introduction/Overview
10:15 AM – 15 minute break	
10:30 AM	Coagulation/Flocculation
12 noon – Lunch (on your own)	
1 PM	Clarification/Sedimentation
2 PM	Filtration
2:15 PM – 15 minute break	
2:30 PM	Filtration (continued)
3:30 PM	General Operations
4:30 PM - End	