

Conventional and Direct Filtration

Focus on Public Health

Oregon Health Authority

OFFICE OF ENVIRONMENTAL PUBLIC HEALTH
Drinking Water Services

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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

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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?

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How do you set priorities?

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

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



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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

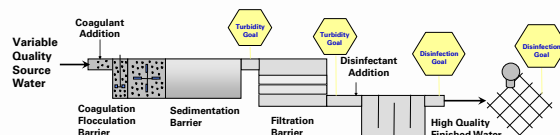


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How do you interpret the data you have?

- 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.)?

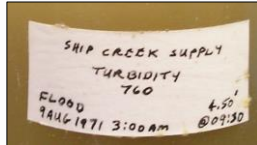


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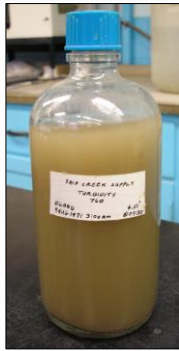
6

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



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Hopefully we can help you answer some of those questions today

But you have to be engaged!



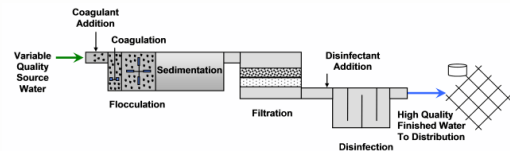
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Overview

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."



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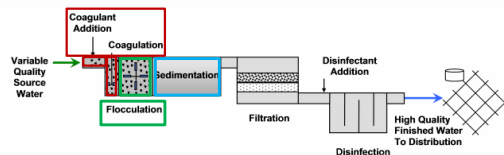
Overview

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 where floc particles settle out prior to filtration



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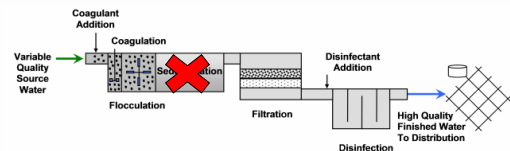
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Overview

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."



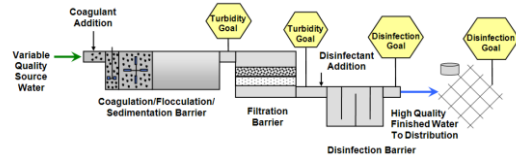
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Overview

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



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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.

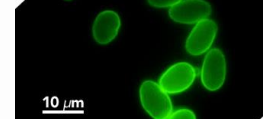


Photo Credits: H.D.A. Lindquist, U.S. EPA

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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.

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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.

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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?

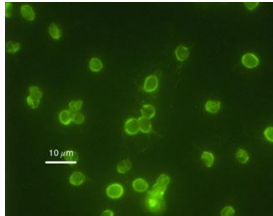
- Other symptoms may include:
 - Abdominal cramps, bloating, and flatulence;
 - Weight loss;
 - Vomiting;
 - Death is rare.
- A potentially serious consequence is nutritional insufficiency which may result in impaired growth and development of infants and children.
- In otherwise healthy people, symptoms 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 **Cryptosporidium 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

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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>

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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:

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

The disease is called cryptosporidiosis



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Overview - Cryptosporidium

What are the symptoms and the incubation time of Cryptosporidiosis?

- 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
 - Intestinal,
 - Tracheal (trachea ("windpipe") associated) or
 - 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).

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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.

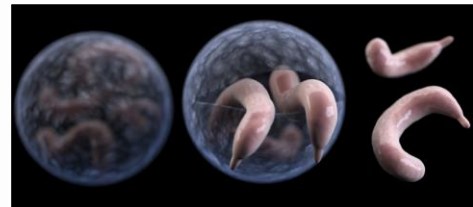
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How can you avoid outbreaks?

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



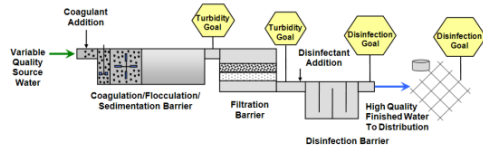
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Optimize Particle Removal

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



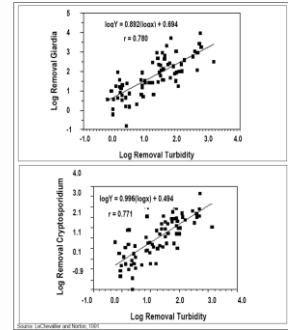
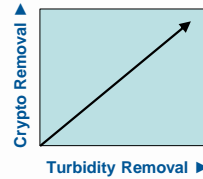
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Overview – Optimization Goals

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)



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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)

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)

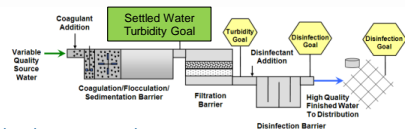
Log Reduction	Percentage
5-log	99.999%
4-log	99.99%
3-log	99.9%
2-log	99%
1-log	90%

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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



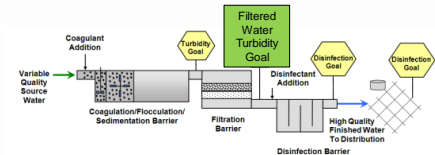
For conventional systems goals are based on maximum daily raw & settled water turbidity taken from grab samples or on-line instrumentation.

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Overview – Optimization Goals

Filter effluent turbidity optimization goals:

- IFE & CFE Turbidity ≤ 0.10 NTU 95% time
- 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.

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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

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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?

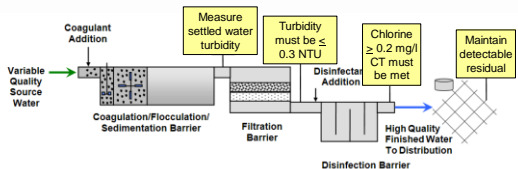
- Regulatory standards are there to help protect against major pathogen breakthrough (e.g. up to 90% removal of *Cryptosporidium* at 0.3 NTU), but they do not reflect optimized pathogen removal (e.g. $\geq 95\%$ removal at 0.1 NTU).
- Filter performance that exceeds regulatory standards for turbidity 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



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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
<i>Giardia</i>	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)*
<i>Cryptosporidium</i>	99% (2-log) removal	Conventional and direct	2-log (99%)	None in most cases depending upon levels of <i>cryptosporidium</i> 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*.

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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.

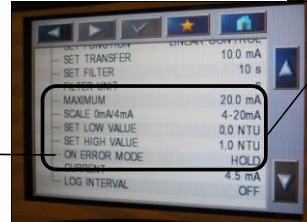
Make sure your instruments can record data up to 5.49 NTU (e.g. 0-10 NTU)

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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



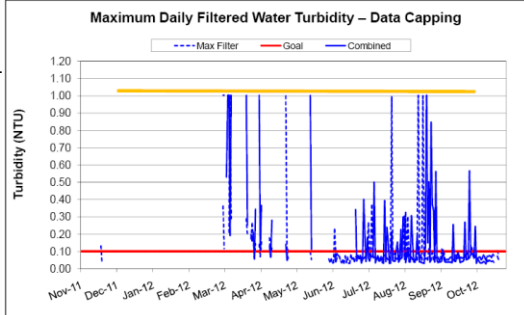
Low and high values of the on-line turbidimeters are set to 0 – 1.0 NTU
This means that the signal output is "read" by SCADA as
4 mA = 0 NTU
20 mA = 1 NTU

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



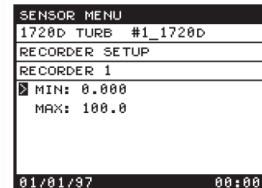
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Caution!

- 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



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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

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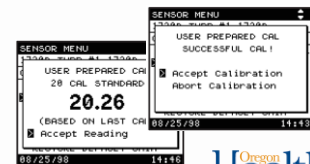
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Overview – Turbidity Requirements

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

Conventional & Direct Filtration Treatment Systems must:

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



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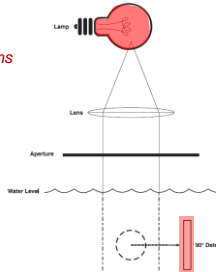
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Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Strength of bulb

Clean photo detector lens



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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@hachst.com

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Overview – Turbidity Requirements

Figure 4 Sample Flow Path Through the Turbidimeter Body

Accurate turbidity measurement depends on:

Strength of bulb

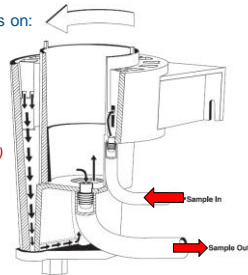
Clean photo detector lens

Sufficient flows

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

Good calibration

Good sample point



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Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Strength of bulb

Clean photo detector lens

Sufficient flows

Good calibration

Good sample point



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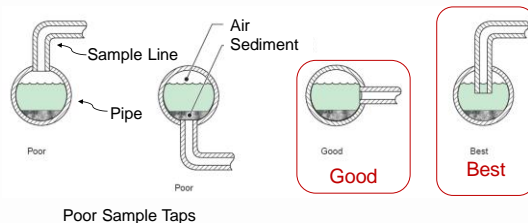
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Overview – Turbidity Requirements

Accurate turbidity measurement depends on:

Good (or "Best") sample point



Poor Sample Taps

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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



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Overview – Turbidity Requirements

Anything wrong with this picture?



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Overview – Turbidity Requirements

Anything wrong with this picture?

How about now?



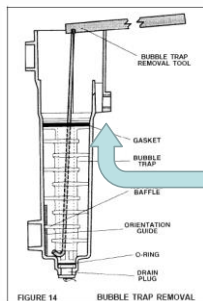
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Introduction/Overview

How about this one?



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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

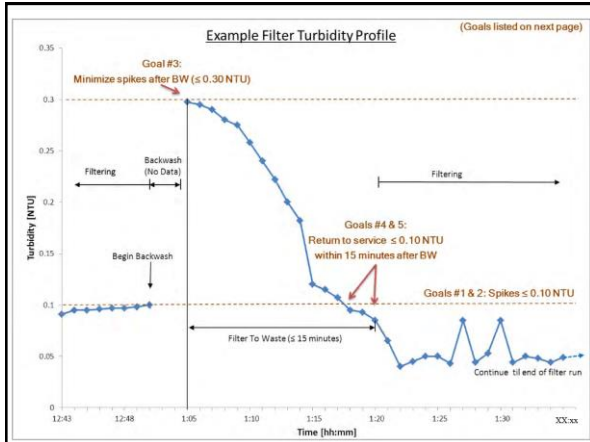
Conventional & direct filtration systems must develop turbidity profiles for individual filters every calendar quarter.

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.

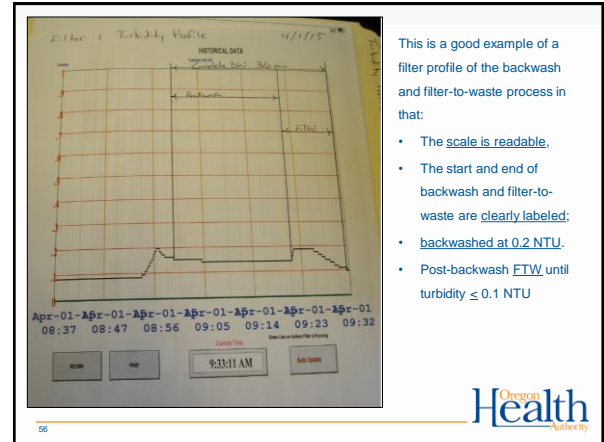
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Overview – Turbidity Requirements

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:
 - Filter Turbidity Profile
 - Filter Self-Assessment
 - Comprehensive Performance Evaluation

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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 2 nd month of the high turbidity. 3. Submit the CPE report within 90 days of the 2 nd 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 2 nd month of the high turbidity. If you wish to have the State conduct the CPE, the request must be made by the 10 th of the third month. 3. Submit the CPE report within 120 days of the 2 nd 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

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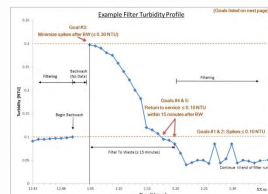
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Overview – Turbidity Requirements

Explanation of Turbidity Trigger Actions

- 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



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Overview – Turbidity Requirements

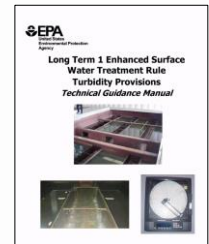
Explanation of Turbidity Trigger Actions

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

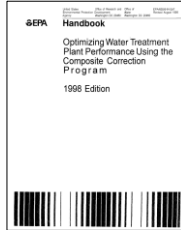
Explanation of Turbidity Trigger Actions

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



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

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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

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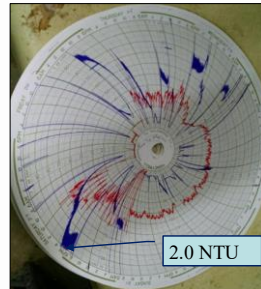
62

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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.



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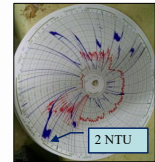
63

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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.

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CPE 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

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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

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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.

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Overview – Disinfection Requirements

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

- 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

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Overview – Disinfection Requirements

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

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 - 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
- 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

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Overview – 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
- 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.

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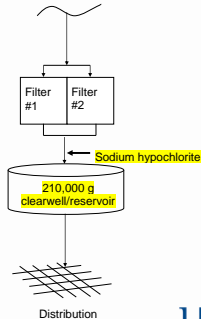
71

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Measuring Entry Point Residual

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

Mackey Creek (gravity flow to plant)



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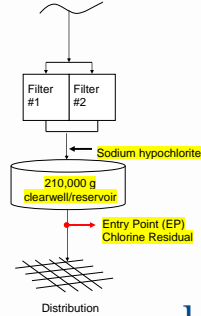
72

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.

Mackey Creek (gravity flow to plant)



Distribution

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

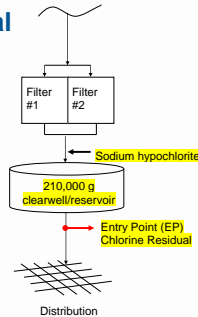
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Measuring Distribution Residual

Where would you measure in the distribution system?

Mackey Creek (gravity flow to plant)



Distribution

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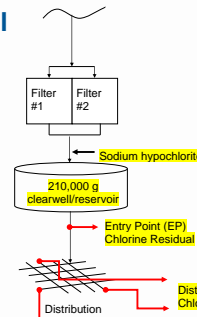
Measuring Distribution Residual

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)

Mackey Creek (gravity flow to plant)



Distribution

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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# 41

PWS Name: _____

City, County: _____

Phone: _____ Fax: _____

Name: _____

Address: _____

City, State, Zip: _____

Sample Collected Date/Time: MM / DD / YYYY Hour: AM PM

Collected By: _____

ORELAP#: _____

Lab Name: _____

Address: _____

Phone/Fax: _____

Bottle#: _____

☐ Results do not meet NELAC Standards-See page 2

Lab Sample ID#: _____

Chlorinated: ☐ No ☐ Yes

Free Chlorine: _____ mg/L

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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)

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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



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How do we calculate CT?

Do not confuse "CT" and "Contact Time"

$$\text{CT} = \text{Chlorine } \mathbf{C} \text{oncentration} \times \text{Contact } \mathbf{T} \text{ime}$$

- 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....



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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.



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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.



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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 Conventional or Direct Filtration							County:
Name:	ID #1:	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 [NTU]
1							
2							
3							
4							
5							
6							



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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.



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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 [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:
Call (877) 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)

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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.

Conventional or Direct Filtration

95% of the 4-hour turbidity readings \leq 0.3 NTU? **Yes** ~~No~~

All the 4-hour turbidity readings \leq 1 NTU? **Yes** ~~No~~

All turbidity readings < IFE² triggers? **Yes** ~~No~~

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 [NTU]
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							

Notify the State if NTU > 1 NTU.
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Public Health After Hours Duty Officer:
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Oregon Emergency Response System:
1-800-452-0311

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

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

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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.

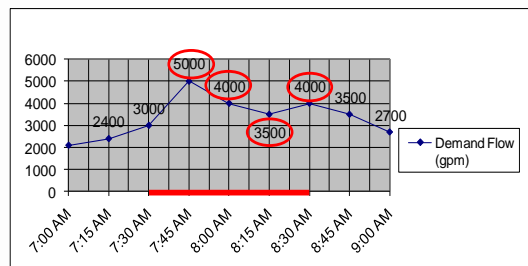
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Overview – NTU and Disinfection Reporting Requirements

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.



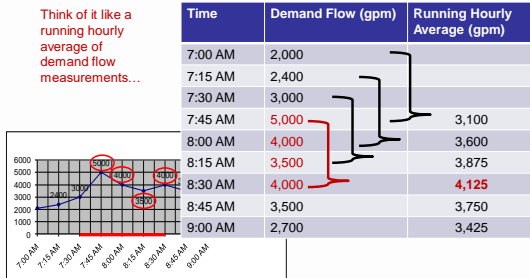
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Overview – NTU and Disinfection Reporting Requirements

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



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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 1 st User (C) ¹ (ppm or mg/L)	Contact Time (T) (minutes)	Actual CT	Temp (°C)	pH	Required CT	CT Met? ¹	Peak Hourly Demand Flow (GPM)
	C	T	C x T			Use tables	Yes / No	
1 / 9 AM	???	???						1,000
2 /								
3 /								
4 /								

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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

$$CT = \text{chlorine Concentration} \times \text{contact Time.}$$

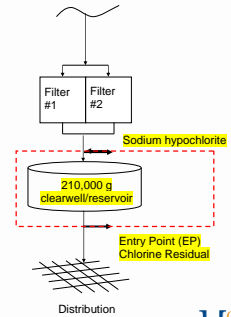
- Contact time is the time that chlorine is in contact with the water from the point of injection to the point where it is measured (sometimes referred to as the "CT segment")
 - May be at or before the 1st user
 - May be more than one CT segment
- Tracer studies are often conducted to simulate a worst-case 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.

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Overview – NTU and Disinfection Reporting Requirements

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

Mackey Creek (gravity flow to plant)

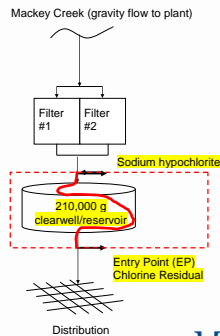


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Overview – NTU and Disinfection Reporting Requirements

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.



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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.



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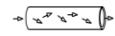
Overview – NTU and Disinfection Reporting Requirements

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.

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

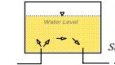
- Baffling efficiency improves with high flow path length to width ratios, found in pipelines and simulated in tanks with the use of baffles (hence the term baffling efficiency or factor).



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



Superior Circulation
Baffling Efficiency = 70%



Poor Circulation
Baffling Efficiency = 5-10%

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Tracer studies

Conducting a tracer study:

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

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Tracer studies (continued)

Conducting a tracer study:

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

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Example

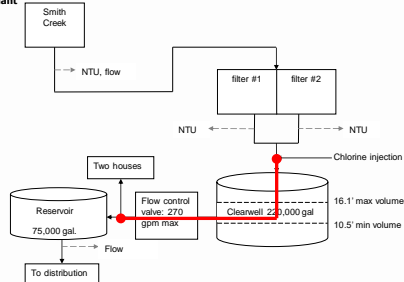
Conducting a tracer study



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Example: Tracer studies Figure 1: Water Treatment Plant



Questions:

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

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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 C _t Residual at 1" User (°C)	Contact Time (T) [minutes]	Actual C _t C X T	Temp [°C]	pH	Required C _t Use tables	CT Met? Yes / No	Peak Hourly Demand Flow [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
 - 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

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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}** = Chlorine residual x contact Time

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) ¹ (ppm or mg/L)	Contact Time (T) (minutes)	Actual CT C x T	Temp (°C)	pH	Required CT	CT Met? ²	Use	Peak Hourly Demand Flow (GPM)
1 / 9 AM	0.5	100	60						
2 /									
3 /									
4 /									

Notify the State within 24-hrs if chlorine residual < 0.2 mg/l
Public Health After Hours Duty Officer:
Call (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} ≥ CT_{required}**

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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)

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1 / 9 AM	0.6	100	60	12	6.8				1,000
2 /									
3 /									
4 /									

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

- Regression Equation (for Temp > 12.5°C)**
 $CT = (0.361^{\circ}L)(-2.261 + e^{(2.69-0.069^{\circ}T+0.111^{\circ}C+0.361^{\circ}pH)})$

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)

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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.
 $^{\circ}\text{C} = 5/9 \times (^{\circ}\text{F} - 32)$
- If water temp is between values, then round down
- Disinfection is less effective at colder temperatures.



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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

Chlorine Concentration	pH = 6					pH = 6.5					pH = 7.0				
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5
mg/L	Log treatments										Log treatments				
0.4	12	24	37	49	61	73	12	24	37	49	61	73	12	24	37
0.6	8	16	24	32	40	48	8	16	24	32	40	48	8	16	24
1.0	5	10	15	20	25	30	5	10	15	20	25	30	5	10	15
1.5	4	8	12	16	20	24	4	8	12	16	20	24	4	8	12
2.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
2.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
3.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
3.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
4.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
4.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
5.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
5.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
6.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
6.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
7.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
7.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
8.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
8.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
9.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
9.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
10.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
10.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
11.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
11.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
12.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
12.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
13.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
13.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
14.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
14.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
15.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
15.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
16.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
16.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
17.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
17.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
18.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
18.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
19.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
19.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
20.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
20.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
21.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
21.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
22.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
22.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
23.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
23.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
24.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
24.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
25.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
25.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
26.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
26.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
27.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
27.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
28.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
28.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
29.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
29.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
30.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
30.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
31.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
31.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
32.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
32.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
33.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
33.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
34.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
34.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
35.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
35.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
36.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
36.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
37.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
37.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
38.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
38.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
39.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
39.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
40.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
40.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
41.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
41.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
42.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
42.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
43.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
43.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
44.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
44.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
45.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
45.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
46.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
46.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
47.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
47.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
48.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
48.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
49.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
49.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
50.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
50.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
51.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
51.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
52.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
52.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
53.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
53.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
54.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
54.5	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
55.0	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9
55.5	3	6	9	12	15	18	3	6							

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

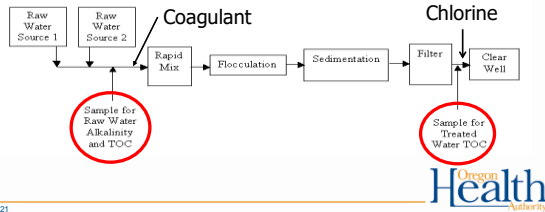
Chlorine Concentration (mg/L)	Log Inactivation	Log Inactivation	Log Inactivation
0.5	1.0	1.0	1.0
1.0	1.5	1.5	1.5
1.5	2.0	2.0	2.0
2.0	2.5	2.5	2.5
2.5	3.0	3.0	3.0
3.0	3.5	3.5	3.5
3.5	4.0	4.0	4.0
4.0	4.5	4.5	4.5
4.5	5.0	5.0	5.0
5.0	5.5	5.5	5.5
5.5	6.0	6.0	6.0
6.0	6.5	6.5	6.5
6.5	7.0	7.0	7.0
7.0	7.5	7.5	7.5
7.5	8.0	8.0	8.0
8.0	8.5	8.5	8.5
8.5	9.0	9.0	9.0
9.0	9.5	9.5	9.5
9.5	10.0	10.0	10.0
10.0	10.5	10.5	10.5
10.5	11.0	11.0	11.0
11.0	11.5	11.5	11.5
11.5	12.0	12.0	12.0
12.0	12.5	12.5	12.5
12.5	13.0	13.0	13.0
13.0	13.5	13.5	13.5
13.5	14.0	14.0	14.0
14.0	14.5	14.5	14.5
14.5	15.0	15.0	15.0
15.0	15.5	15.5	15.5
15.5	16.0	16.0	16.0
16.0	16.5	16.5	16.5
16.5	17.0	17.0	17.0
17.0	17.5	17.5	17.5
17.5	18.0	18.0	18.0
18.0	18.5	18.5	18.5
18.5	19.0	19.0	19.0
19.0	19.5	19.5	19.5
19.5	20.0	20.0	20.0
20.0	20.5	20.5	20.5
20.5	21.0	21.0	21.0
21.0	21.5	21.5	21.5
21.5	22.0	22.0	22.0
22.0	22.5	22.5	22.5
22.5	23.0	23.0	23.0
23.0	23.5	23.5	23.5
23.5	24.0	24.0	24.0
24.0	24.5	24.5	24.5
24.5	25.0	25.0	25.0
25.0	25.5	25.5	25.5
25.5	26.0	26.0	26.0
26.0	26.5	26.5	26.5
26.5	27.0	27.0	27.0
27.0	27.5	27.5	27.5
27.5	28.0	28.0	28.0
28.0	28.5	28.5	28.5
28.5	29.0	29.0	29.0
29.0	29.5	29.5	29.5
29.5	30.0	30.0	30.0
30.0	30.5	30.5	30.5
30.5	31.0	31.0	31.0
31.0	31.5	31.5	31.5
31.5	32.0	32.0	32.0
32.0	32.5	32.5	32.5
32.5	33.0	33.0	33.0
33.0	33.5	33.5	33.5
33.5	34.0	34.0	34.0
34.0	34.5	34.5	34.5
34.5	35.0	35.0	35.0
35.0	35.5	35.5	35.5
35.5	36.0	36.0	36.0
36.0	36.5	36.5	36.5
36.5	37.0	37.0	37.0
37.0	37.5	37.5	37.5
37.5	38.0	38.0	38.0
38.0	38.5	38.5	38.5
38.5	39.0	39.0	39.0
39.0	39.5	39.5	39.5
39.5	40.0	40.0	40.0
40.0	40.5	40.5	40.5
40.5	41.0	41.0	41.0
41.0	41.5	41.5	41.5
41.5	42.0	42.0	42.0
42.0	42.5	42.5	42.5
42.5	43.0	43.0	43.0
43.0	43.5	43.5	43.5
43.5	44.0	44.0	44.0
44.0	44.5	44.5	44.5
44.5	45.0	45.0	45.0
45.0	45.5	45.5	45.5
45.5	46.0	46.0	46.0
46.0	46.5	46.5	46.5
46.5	47.0	47.0	47.0
47.0	47.5	47.5	47.5
47.5	48.0	48.0	48.0
48.0	48.5	48.5	48.5
48.5	49.0	49.0	49.0
49.0	49.5	49.5	49.5
49.5	50.0	50.0	50.0
50.0	50.5	50.5	50.5
50.5	51.0	51.0	51.0
51.0	51.5	51.5	51.5
51.5	52.0	52.0	52.0
52.0	52.5	52.5	52.5
52.5	53.0	53.0	53.0
53.0	53.5	53.5	53.5
53.5	54.0	54.0	54.0
54.0	54.5	54.5	54.5
54.5	55.0	55.0	55.0
55.0	55.5	55.5	55.5
55.5	56.0	56.0	56.0
56.0	56.5	56.5	56.5
56.5	57.0	57.0	57.0
57.0	57.5	57.5	57.5
57.5	58.0	58.0	58.0
58.0	58.5	58.5	58.5
58.5	59.0	59.0	59.0
59.0	59.5	59.5	59.5
59.5	60.0	60.0	60.0
60.0	60.5	60.5	60.5
60.5	61.0	61.0	61.0
61.0	61.5	61.5	61.5
61.5	62.0	62.0	62.0
62.0	62.5	62.5	62.5
62.5	63.0	63.0	63.0
63.0	63.5	63.5	63.5
63.5	64.0	64.0	64.0
64.0	64.5	64.5	64.5
64.5	65.0	65.0	65.0
65.0	65.5	65.5	65.5
65.5	66.0	66.0	66.0
66.0	66.5	66.5	66.5
66.5	67.0	67.0	67.0
67.0	67.5	67.5	67.5
67.5	68.0	68.0	68.0
68.0	68.5	68.5	68.5
68.5	69.0	69.0	69.0
69.0	69.5	69.5	69.5
69.5	70.0	70.0	70.0
70.0	70.5	70.5	70.5
70.5	71.0	71.0	71.0
71.0	71.5	71.5	71.5
71.5	72.0	72.0	72.0
72.0	72.5	72.5	72.5
72.5	73.0	73.0	73.0
73.0	73.5	73.5	73.5
73.5	74.0	74.0	74.0
74.0	74.5	74.5	74.5
74.5	75.0	75.0	75.0
75.0	75.5	75.5	75.5
75.5	76.0	76.0	76.0
76.0	76.5	76.5	76.5
76.5	77.0	77.0	77.0
77.0	77.5	77.5	77.5
77.5	78.0	78.0	78.0
78.0	78.5	78.5	78.5
78.5	79.0	79.0	79.0
79.0	79.5	79.5	79.5
79.5	80.0	80.0	80.0
80.0	80.5	80.5	80.5
80.5	81.0	81.0	81.0
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138.5	139.0	139.0	139.0
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139.5	140.0	140.0	140.0
140.0	140.5	140.5	140.5
140.5	141.0	141.0	141.0
141.0	141.		

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.



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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.

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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 \leq 2.0 L/mg-m
6. Finished water RAA SUVA \leq 2.0 L/mg-m

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

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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

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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

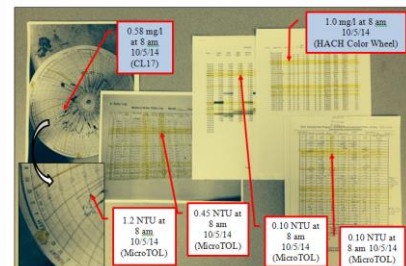
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Overview – Homework!

Trace data from the sample tap to regulatory reporting forms.

What did you find?



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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)



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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).



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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*



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