Maine Center for Disease Control and Prevention
An Office of the Department of Health and Human Services

Department of Health and Human Services
Maine Center for Disease Control and Prevention
286 Water Street
11 State House Station
Augusta, Maine 04333-0011
Tel.: (207) 287-8016; Fax: (207) 287-9058
TTY Users: Dial 711 (Maine Relay)

Tel. (207) 287-2070 Drinking Water Program Fax (207) 287-4172

Surface Water Treatment Rule
Alternative Filtration Technologies (AFT)

AFT systems are usually employed by small water treatment systems. Some of these technologies are appropriate for home or camp use if properly designed, maintained and operated. The following information is pertinent to those public water supplies in Maine which use surface water as a source of drinking water.

CONTENTS:

What's an Alternative Filtration Technology?

The cost of the first three options has forced small systems to turn to Alternative Filtration Technologies. The Environmental Protection Agency says that a public water system may use a filtration system "if it demonstrates to the State, using pilot plant studies or other means, that the alternative filtration technology, in combination with disinfection treatment that meets the requirements of section 141.72(b), consistently achieves 99.9 percent removal and/or inactivation of Giardia lamblia cysts and 99.99 percent removal and/or inactivation of viruses."

In other words...

It means that the State must approve an Alternative Filtration Technology before it can be used to comply with the Surface Water Treatment Rule. Once the filtration technology has met the State's performance criteria, it is regulated as a slow sand filter.

How does an Alternative Filtration Technology get approval?

The Drinking Water Program has developed a review protocol that sets strict standards for approving Alternative Filtration Technologies. The protocol requires manufacturers and engineers to prove to the State that their Alternative Filtration Technology meets the standards set in the Safe Drinking Water Act. The protocol addresses raw water quality, engineering, construction, and routine maintenance. Each approved technology will have a predetermined log removal rating, service schedule, and recommended application based on real life pilot testing. An approved Alternative Filtration Technology has been tested and proven that it is capable of meeting the requirements of the Surface Water Treatment Rule.

Terms referred to in discussion of Alternative Filtration Technologies

Some of the more important terms identified in the definition of an alternative filtration technology are listed below.

Percent removal log reduction another way of saying "percent removal". Filters that remove 99% of the particles applied to them demonstrate 2 log removal. Filters that remove 99.9% of the particles applied to them demonstrate 3 log removal.

Giardia lamblia Tiny waterborne protozoans that cause giardiasis. Cysts are highly resistant to disinfection. Giardiasis, also known as beaver fever or Montezuma's revenge, is passed through fecal contamination from infected humans, beavers, dogs, etc. "Giardiasis can cause both and (sic) acute diarrhea as well as chronic abdominal symptoms such as diarrhea, cramps, fatigue, nausea, poor appetite, and weight loss." (Medical College of Wisconsin)

The Surface Water Treatment Rule Concerning Alternative Filtration Technologies

The Surface Water Treatment Rule addresses two components of Alternative Filtration Technologies. The first is filtration, the second is disinfection.

Rules Governing Filtration:

The Surface Water Treatment Rule defines filtered water turbidities, maximum allowable turbidities, methods for measuring turbidity and frequency of turbidity measurement.
Alternative filtration technologies must meet the following criteria as defined by the Surface Water Treatment Rule (40 CFR 141.73, section (b)).

1. "...the turbidity level of representative samples of a system's filtered water must be less than or equal to 1 NTU in at least 95 percent of the measurements taken each month, measured as specified in §141.74 (a)(4) and (c)(1), except that if the State determines there is no significant interference with disinfection at a higher turbidity level, the State may substitute this higher turbidity limit for that system."
2. "The turbidity level of representative samples of a system's filtered water must at no time exceed 5 NTU, measured as specified in §141.74 (a)(4) and (c)(1)."
    - The reference to §141.74 (a)(4) requires water systems to measure turbidity using Method 214A "as set forth in Standard Methods for the Examination of Water and Wastewater, 1985..." Make sure your turbidimeter meets these requirements.
    - The reference to §141.74 (c)(1) designates the number of turbidity measurements required each day. "Turbidity measurements as required by §141.73 must be performed on representative samples of the system's filtered water every four hours (or more frequently) that the system serves water to the public.

Rules Governing Disinfection of Filtered Water:

- The Surface Water Treatment Rule requires alternative filtration technologies to achieve "99.9 percent removal and/or inactivation of Giardia lamblia cysts..." 99.9 percent (3 log) of all cysts must be either filtered out or "inactivated" by the time water reaches the first customer. Inactivation as the term applies to microorganisms is spelled out by the Surface Water Treatment Rule's section on disinfection (40 CFR 141.72 (b)).

- "Disinfection treatment must be sufficient to ensure that the total treatment processes of that system achieved at least 99.9 percent (3-log) inactivation and/or removal of Giardia lamblia cysts and at least 99.99 percent (4-log) inactivation and/or removal or viruses, as determined by the State."

- "The residual disinfectant concentration in the water entering the distribution system, measured as specified in §141.74 (a)(5) and (c)(2), cannot be less than 0.2 mg/l for more than 4 hours."

- "The residual disinfectant concentration in the distribution system, measured as total chlorine, (or) combined chlorine...cannot be undetectable in more than 5 percent of the samples each month for any two consecutive months that the system serves water to the public."

- §141.74 (a)(5) specifies how residual disinfectant concentrations must be measured.

- §141.74 (c)(2) states that "systems serving 3,300 or fewer persons may take grab samples"...on an ongoing basis at the frequencies each day prescribed below however the day's samples cannot be taken at the same time. The sampling intervals are subject to State review and approval.

Required Frequency of Grab Samples	
System size by population	**Samples per day**
± 500	1
501 to 1000	2
1001 to 2,500	3
2501 to 3300	4

- If at any time the residual disinfectant concentration falls below 0.2 mg/l in a system using grab sampling in lieu of continuous monitoring, the system must take a grab sample every 4 hours until the residual disinfectant concentration is equal to or greater than 0.2 mg/l."
- It's a good idea to sample disinfectant residual entering the distribution system when you sample for turbidity. Disinfectant residual samples should be regularly taken from points in the distribution system.

In Summary, systems using Alternative Filtration Technologies must:

- ✓ consistently produce filtered water with a turbidity of 1 NTU or lower
- ✓ not exceed a maximum turbidity of 5 NTU
- ✓ measure turbidity once for every four hours of operation
- ✓ measure disinfectant residual at least once per day
- ✓ maintain a disinfectant residual of at least 0.2 mg/l entering the distribution system
- ✓ maintain a disinfectant residual throughout the distribution system
- ✓ submit monitoring results to State by 10th day of following month

Multiple Barrier Approach

Even the cleanest surface water supplies can contain cysts and other organisms that can infect human beings and make them sick. To help reduce the risk of infection from microorganisms, water systems that supply surface water to the public use the following three step process.

Step 1: Clean up the source

Make sure contamination sources within the watershed are accounted for and addressed. Swimming areas, cow pastures, agricultural runoff and roadways can contaminate surface water supplies. If possible, restrict a 200' radius around the intake from activities that could contaminate your supply. Post the location as a drinking water supply to improve public awareness. Less contamination in the source makes it easier to filter water and reduce risk.

Step 2: Filter the water

Filtration is a series of processes designed to remove particles from water. Most Alternative Filtration Technologies use bag filters or cartridge filters to remove particles. Typical arrangements include a roughing filter that removes large particles and a finishing filter which removes smaller particles. Even the best filters can't remove all of the tiniest contaminants, so the water must be disinfected.

Step 3: Disinfect the water

After the water has been filtered, some microorganisms remain. A disinfectant is added to the water and allowed to remain in contact with the water before it goes to the first tap. This phase is called Contact Time. Your engineer will calculate the amount of contact time you need to both protect your customers from pathogens and meet the rules.

Filtration Overview

Understanding what the filter is supposed to do is the fundamental factor in operating a filtration system. A filter is designed to remove particles. If you review the Surface Water Treatment Rule requirements, you'll see something about "filtered water must be less than or equal to 1 NTU".

Measuring turbidity:

NTU stands for Nephelometric Turbidity Unit. The NTU is a measure of the amount of turbidity (suspended particles) in a water sample. Drinking water sources range from 5 NTU for relatively dirty water to below 0.1 NTU for filtered water. Alternative Filtration Technologies must be sampled at least once daily to prove that they are producing water with turbidities less than 1 NTU.

Turbidity is measured with an electronic instrument called a turbidimeter. A turbidimeter shines a light source through a water sample and measures the shadow that the particles in the sample make. Turbidimeters range in cost from $900 for a portable, grab sample turbidimeter to over $1,600 for a unit that continuously monitors turbidity. (prices from 1996 Hach catalog)
The advantage of a portable turbidimeter is lower cost and the fact that it can be used to sample both raw water turbidity and filtered water turbidity. Portable turbidimeters do not require a technical background for operation. The disadvantage is that they are small and expensive and could easily be dropped or stolen.

A process turbidimeter can be installed in only one location and is more expensive than its portable counterpart. Turbidity is measured continuously and no expertise is required to measure the sample. It is mounted permanently on a wall and not likely to be stolen. The advantage of a process turbidimeter is that it measures turbidity constantly. Data can be outputted to a computer for printing and analysis. Data charts may indicate turbidity spikes that correlate to pumps starting and stopping or filter replacement. Virtually all large surface water systems use process turbidimeters to analyze and monitor turbidity. How filters work:
Filters need to consistently remove turbidity, and this needs to be proven to the state. Most of the alternate technologies

employed in Maine systems use disposable filters. When water goes through the filters, particles get trapped in the fabric. As more particles get trapped in the filters, less water can flow through. Eventually the filters must be replaced.

Some systems use several filters, each with a different nominal size rating. These size ratings are often measured in microns. One micron is equal to one one thousandth of a millimeter. Remember that microorganisms like Giardia lamblia can be as small as 7 microns. So the smaller the nominal size rating, the more effective the filter is at removing tiny particles.
Some of the terms used to define these filters include roughing and polishing filters. Typically the roughing filters are used to remove larger particles, and often cost less than the smaller micron polishing filters. Roughing filters are designed to reduce the number of large particles that reach the polishing filters. By removing all but the smallest particles, roughing filters prolong the life of the polishing filters.

Because every source of water is different, different filter combinations are used in different systems. Changes in seasonal water quality complicate treatment. For example, changes in temperature cause changes in the density of water, making it turn over. Algal blooms can occur, causing increased loading on filters which reduces their operational life. Heavy rains can wash sediment into the water, adding particles that reduce filter runs. Boating or other activity can stir up bottom sediments which can increase turbidity and bacterial loading. Each system must be carefully evaluated to determine the best combination of roughing and polishing filters.

When to change a filter:

Filters are designed to remove particles from water. The filters will have been tested by the manufacturer to predict operating life under a given set of water quality parameters.
As water requires more force to go through the filters, it builds up a pressure differential that can be measured with pressure gauges. For instance, if you install a clean filter, you read the pressure before the filter and the pressure after the water goes through the filter. Let's say that the pressure before the filter is 50 psi and the pressure after the filter is 30 psi. 50 - 30 equals a pressure differential of 20 psi. Over time, particles accumulate in the filter and the pump needs to exert more force to get water through fewer openings. The pressure before the filter may rise to 60 psi, while the pressure after the filter may stay at 30 psi. 60 - 30 equals a pressure differential of 30 psi. If your filters are designed to be changed out at 30 psi, then they're "full" and need to be changed.

Why you should change filters:

Failure to replace the filters when they are due to be changed can cause problems. Pressures could increase so much that bag filters are overwhelmed and "blow out", rupturing like an overfilled balloon. This can cause particle breakthrough and allow all of the trapped particles to go into the next filter or into the water system. Without pressure or turbidity alarms, it would be too late to shut down the system and people would have consumed the most dangerous particles.

How to prevent failure:

It is highly unlikely that your filters will fail if they were designed properly, if pressure is monitored carefully and if turbidity levels are met. Filters require careful attention if they are to work properly. Some systems change out filters on a routine basis to avoid turbidity problems and reduce maintenance.

Disinfection Overview

Disinfection is the second component of an Alternative Filtration Technology.

How does disinfection work?

When chlorine or sodium hypochlorite (laundry bleach) is added to water, it creates a series of chemical reactions which work to destroy microbial particles by disrupting enzymatic systems required for life. A variety of factors have an effect on the use of chlorine as a biocide. One of the most important factors is pH.

pH is a term that refers to the acidity or basicity of a water sample. pH is measured on a log scale ranging from 0 to 14 with 7 as perfectly neutral. Water with a pH of 7 has 10-7 mole/l of hydrogen ions present. Low pH (lemon juice) is acidic, and high pH (baking soda) is basic.

pH is important in water disinfection because it changes the type of chlorine available to kill bacteria. As pH rises (water becomes more basic), the chlorine available is less effective. As pH decreases, chlorination becomes more effective.
Another important factor is temperature. In general, warmer water is easier to disinfect than colder water.

The final factor is time. Time and disinfection are required to kill waterborne organisms. Think of a Giardia lamblia cyst. It's very small, but it is highly resistant to disinfection. Ten minutes of contact time at 0.2 mg/l of free chlorine may kill the coliform bacteria that you submit to the State for testing each month, but giardia cysts may still be present in significant numbers.
In general, the number of microorganisms killed by disinfection is proportional to the product of the concentration of a disinfectant and the time at which microogranisms are in contact with that disinfectant.

If the disinfectant residual is low, more time is needed to kill the same number of microorganisms. If the disinfectant residual is high, less time is needed. By designing more time than is actually required, a greater number of microorganisms will be killed, and the water will be safer to drink. This also protects against times when the filters may not be performing optimally. Increasing time and reducing disinfectant concentration to achieve the same kill rate can reduce taste, odor, and by-product generation problems.

Remember that the Surface Water Treatment Rule states "removal and/or inactivation". Your filters don't need to remove all of the giardia lamblia cysts. But the cysts that pass through the filters must be destroyed through disinfection.
For example, assume an Alternative Filtration Technology has passed its testing protocols with the State. The engineer or manufacturer has presented evidence to show that the filters demonstrate 2 log removal. The rules state that the Alternative Filtration Technology must remove "and/or inactivate" 3 log of Giardia lamblia cysts. 3 log minus 2 log is one log. Therefore, 1 log of inactivation is required in the disinfection stage.

Calculating Contact Time and log inactivation:

How do you determine 1 log of inactivation? The Environmental Protection Agency created tables in Appendix E of the Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources (March, 1991) which specify how to determine the amount of inactivation which is obtained from a certain concentration of disinfectant at a given pH and temperature. A sample table of CT 99.9 Values for Inactivation of Giardia Cysts by Free Chlorine at 5 C (50 F) has been reproduced below.

CT Values for 1.5 Log Inactivation of Giardia Cysts by Free Chlorine at 5 C (41 F) or Lower

Chlorine Concentration (mg/l)	pH = 6	pH = 6.5	pH = 7	pH = 7.5	pH = 8.0	pH = 8.5	pH = 9.0
0.4	49	59	70	83	99	118	140
0.6	50	60	72	86	102	122	146
0.8	52	61	73	88	105	126	151
1	53	63	75	90	108	130	156
1.2	54	64	76	92	111	134	160
1.4	55	65	78	94	114	137	165
1.6	56	66	79	96	116	141	169
1.8	57	68	81	98	119	144	173
2	58	69	83	100	122	147	177
2.2	59	70	85	102	124	150	181
2.4	60	72	86	105	127	153	184
2.6	61	73	88	107	129	156	188
2.8	62	74	89	109	132	159	191
3	63	76	91	111	134	162	195

Assume the lowest temperature of the water you wish to treat is 5 Celsius. Assume that the pH is 7.0. The filters have been designed to remove 2 log of Giardia lamblia cysts under these conditions. The desired free chlorine residual ([Cl2] in mg/l) is 0.6 mg/l. 1.0 log of inactivation is required.

Find 0.6 mg/l in the column on the left. Find 1.0 in the "Log inactivations" row at the top. From the table above, the contact time required to remove 99.9 % of all Giardia lamblia cysts (CT99.9) is 48 min mg/l.
How much time is required for 1 log removal? Divide 0.6 mg/l into 48 min mg/l to get 80 minutes. If 80 minutes is too long, increase the chlorine residual to 1.2 mg/l. Contact time drops to just over 33 minutes.

Contact time varies with changes in pH and temperature. As pH decreases, CT decreases. As temperature decreases, CT increases. Low pH water is easier to disinfect than high pH water, and warm water is easier to disinfect than cold water. Your engineer or filter vendor will have completed all of the required CT calculations for you, using conservative numbers. That is, your engineer will have determined an average temperature and assumed for the purposes of CT calculations that it is somewhat colder. Your engineer will probably design more contact time than you actually need to make certain that your Alternative Filtration Technology meets the Surface Water Treatment Rule under a variety of seasonal conditions.
In general, it is better to increase contact time than increase disinfectant concentration. High concentrations of disinfectant can form byproducts called trihalomethanes (THM). THM is a suspected carcinogen. High concentrations of disinfectant are more volatile than low concentrations and require increased safety measures. Many treatment plants are switching away from chlorine gas because of the hazards and insurance required to keep it on site.

Maintaining a disinfectant residual:
Disinfection requires constant attention. Failure to disinfect filtered water can allow living organisms to proliferate in drinking water and cause disease. The Safe Drinking Water Act requires a minimum of 0.2 mg/l of disinfectant entering the distribution system. The rules also require surface water systems to maintain a disinfection residual throughout the distribution system. Dead end lines in some systems get contaminated with bacteria because chlorine has been used up by bacteria and other organic compounds.

To reduce this problem, some systems have small lines called bleeders that allow water to run continuously to improve circulation. Bleeders are used to ensure that water does not stagnate and forces chlorinated water throughout the system. The best way to ensure that water is disinfected is to inspect disinfection equipment daily and measure chlorine residuals at representative taps in the system.

How do you determine existing contact time?

The most common methods of achieving contact time are the circuitous pipe method and baffled storage tank method.
The circuitous pipe method uses large, long runs of water pipes to store water for contact time requirements. Engineers will design either long, straight sections of pipe or achieve the same length by winding pipes back and forth in a serpentine pattern. Many systems can take advantage of the pipe already in the ground. If you know the inside diameter and length of the pipe through which the water flows, and you know the number of gallons per minute that your pump is rated for, you can determine how many minutes it takes to fill up or flush the pipe.

Storage Values of Pipe per Foot

Pipe Diameter	Storage
2 inches	0.163 gallons per foot
4 inches	0.651 gallons per foot
6 inches	1.465 gallons per foot
8 inches	2.605 gallons per foot
10 inches	4.070 gallons per foot
12 inches	5.861 gallons per foot
14 inches	7.978 gallons per foot
16 inches	10.420 gallons per foot

Assume you had a pipe with an internal diameter of 6" and a length of 200'. Assume your pump was rated at 20 gallons per minute. How long does it take for water flowing at 20 gpm to get from the beginning of the pipe to the end of the pipe?
6" pipe holds 1.465 gallons per foot of length. Multiply the number of gallons each foot of pipe holds by the total length of the pipe. 1.465 x 200' equals 293 gallons. Divide 293 gallons by 20 gallons per minute to determine the time it takes for water to move through 200' of pipe at 20 gallons per minute. 293 gallons / 20 gpm equals 14.65 minutes.

Some storage tanks are specially built to provide contact time. These tanks can be premanufactured and rated at a certain time per flow rate, or they can be manufactured by adding baffles to an existing tank. In these cases, contact time is difficult to determine unless the exact tank dimensions are known. The length, height and width of the tank and the dimensions of the baffles should be measured and determined in the calculation of contact time. Ideally, engineers will perform a tracer study to determine the precise amount of contact time provided by the structure.

The following lists indicate features of an Alternative Filtration Technology that Drinking Water Program engineers look for during plan review and field inspections. Some of the recommendations below may not be applicable to all systems.

Recommendations

Recommended filtration components:

Screened intake
A pump for pressurizing the water from the intake to the filters
Roughing filters for removing large particles
Finishing filters for removing smaller particles
Extra filters that are clearly labeled
Gauges to determine head loss across filtration components
A turbidimeter to measure the amount of particles in water
A raw water tap
A filtered water tap
Shut off valves for changing out filters and performing routine maintenance
A metering device to determine how much water is going through the filters
A daily log to record time of operation, turbidity and disinfection results
An operations manual provided by the engineer who designed the system

Recommended disinfection components:

At least one chemical feed pump for injecting disinfectant into the filtered water
A chemical storage drum w/ secondary containment
Chemical safety handling equipment (eye protection, rubber apron and gloves)
A disinfectant residual measuring kit
A way to pace disinfectant to flow
A contact tank for storing disinfected water
A blow-off line to drain or flush the contact tank
A finished water tap after the contact tank
A screened vent/overflow on the contact tank
A finished water pump/pressure tank

Types of Approved Alternative Filtration Technologies Approved in Maine, with Manufacturer Information

Model	Manufacturer	Contact	Address	City	State	Zip	Phone
Cartridge Series	Custom Fabrication	Bob Campbell	25 Scollay Circle	Salem	NH	03079-2548	(603) 893-8536
Non-Coagulant Filter	Kinetico	Customer Service	PO Box 193	Newbury	OH	44065	(440) 564-9111
Cartridge Filter	Rosedale Filters	Dan Morosky	PO Box 1085	Ann Arbor	MI	48106	(734) 665-8201
GLR Model - Bag Filter	Rosedale Filters	Dan Morosky	PO Box 1085	Ann Arbor	MI	48106	(734) 665-8201
523 Model - Bag Filter	RP Products, Inc. *	Don Wallace	PO Box 388	Three Rivers	MI	49093	(616) 273-1512
525 Model - Bag Filter	RP Products, Inc. *	Don Wallace	PO Box 388	Three Rivers	MI	49093	(616) 273-1512
Bag Filter	U.F. Strainrite	Dan Mosley	48 Commercial Street	Lewiston	ME	04241-1667	(207) 777-3100
Prefilter HPM99-CC-2-SR Final Filter HPM00-CC-35-2-SR or HPM-99-CCx-2-SR	Aqua-Rite Used in series granted 2.5 log Crypto/Giardia removal. Final filter used alone or with different pre-filter is granted 2.0 log Crypto/Giardia removal. Used with 50 gpm at Vinalhaven and Frye Islands	Bob Campbell	25 Scollay Circle	Salem	NH	03079-2548	(603) 893-8536
Poly-Pleat Model PP-BB-20-1	Harmsco Approved for 2.5 log *Giardia lamblia* and 2.0 log *Cryptosporidium* when used in series. Remaining 0.5 log Giardia must be met through disinfection. Used on several small Transient SW PWS	Bob Campbell	25 Scollay Circle	Salem	NH	03079-2548	(603) 893-8536
HC/170-LT2	Harmsco Approved for 2.0 log *Cryptosporidium* and 2.5 log *Giardia*	Bob Campbell	25 Scollay Circle	Salem	NH	03079-2548	(603) 893-8536

	lamblia. Remaining 0.5 log Giardia must be met through disinfection. Used at Camp Skylemar						

FOR DWP USE ONLY

ORIGINATOR: DWP Compliance Staff

CURRENT-OWNER: Rules Manager

REVIEW SCHEDULE: (How often does this document need to be reviewed for potential revision?)
Annually

ASSOCIATED DOCUMENTS:

Protocol for Review of Small System Alternate Drinking Water Filtration Technologies (DWP0016)

SUPERCEDED DOCUMENTS:

All previous uncontrolled versions of this document.

RETENTION:

1. This document is retained per the DWP Record Retention Schedules.

REVISION LOG:

Section	Page	Rev.	Date	Description Of Change	Approved by:
			6/28/18	First Controlled version of this document	DWP Compliance Manager
		A	4/5/19	Added 2 filter types	Teresa Trott
Table	8-9	B	5/17/22	Added 1 filter type	Ami Stillings