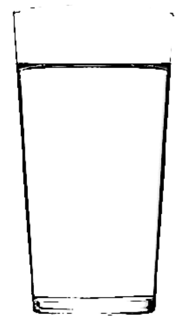
Disinfection

The purpose of disinfection is to remove disease causing (pathogenic) microorganisms.

Part 9 reviewed the basics of pretreating lake water to get it ready for the disinfection process. The water may look clear and taste fine, but parasites and bacteria are too small to see without a microscope that can magnify by 100 to 500 times, and to see viruses you would need to use an electron microscope that is 100 times more powerful than that.



Then, how can we tell if water is contaminated or not? "Indicator organisms" are used as the main screening tool for water potability. Coliforms, and particularly E. coli, are used because they show up when there is fecal contamination and they are reasonably easy to measure using "culturing" techniques. Culturing of parasites and viruses is very difficult, as they grow inside cells, but bacteria will grow in liquid or on moist surfaces.

One type of test plate: purple dots are colonies of E. coli; blue dots are colonies of other coliforms.

Test plate showing "too numerous to count" or "overgrowth" of coliforms.

A sample of water is spread over the surface of a specialized nutrient gel contained in a petri plate. The sample is then held at a temperature that promotes growth of the bacteria of interest. Each bacterial cell in the original sample will reproduce and create a visible "colony" dot on the surface of the gel. Special ingredients in the gel colour the colonies according to bacteria type. The colonies can then be counted to determine the number of bacteria that were in the original sample. Pete's Lake results can be viewed here:

https://www.healthspace.ca/Clients/VIHA/VIHA_Website.nsf/Water-Samples-Frameset

The notation "OG" stands for "overgrowth" which means that there were so many colonies that they all grew together and could not be counted. Any counts over 10 are bad news.

When you see the notation "L1" in water test results it means that no bacteria (less than 1) were found in the sample that was tested. This is good news!

The Drinking Water Protection Act – Drinking Water Protection Regulation (Schedule B) requires that at least 4 water samples must be taken per month from Pete's Lake water system, must be tested by an accredited laboratory and the samples must meet the following standards:

- All samples: No detectable fecal coliform bacteria per 100 ml
- All samples: No detectable Escherichia coli per 100 ml
- All samples: No more than 10 total coliform bacteria per 100 ml
- At least 90% of samples: No detectable total coliform bacteria per 100 ml

According to the PLWUS operating permit, Pete's Lake water must be treated in accordance with VIHA policy 3.3, Drinking Water Treatment for Surface Water Sources to achieve the following:

- Viruses: 4 log removal/inactivation *[max 1 surviving /10,000]*
- 3 log removal/inactivation of Giardia cysts and Cryptosporidium oocysts *[max 1 surviving /1000]*
- 2 treatment processes *[partial protection by second treatment in case of fault in one process]*
- 1 NTU turbidity (maximum) in finished water.

A Quick Recap from Part 6

- Giardia and Cryptosporidium
  - Easy to filter out with microfiltration
  - Not very sensitive to chlorine
  - Sensitive to UV
- Bacteria
  - Can be filtered out with ultrafiltration
  - Sensitive to chlorine
  - Sensitive to UV
- Viruses
  - Difficult to filter out because they are extremely small. Require nanofiltration or reverse osmosis.
  - Sensitive to chlorine
  - Moderately sensitive to UV

Primary and Secondary Treatment

Primary treatment refers to treatments that make sure the water is safe when it enters the distribution system. Secondary treatment ensures that the water continues to be safe all the way to the last consumer. *Secondary treatment usually means using adequate chlorine or chloramine so that it can still be detected at the last point on the distribution line.* This secondary treatment may be an after-effect of a primary chlorine treatment, or it may be added after a non-chlorine primary treatment.

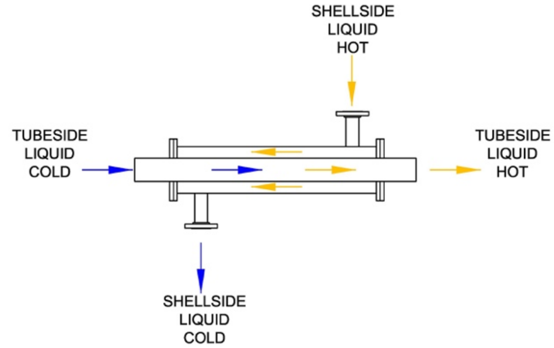
Multibarrier Approach to Water Disinfection

Best Risk Management Practice (BMP) for water treatment uses a *multibarrier approach* for primary treatment. If you look at the recap list above, you can see that the microorganisms of interest are not equally sensitive to the three listed processes. The multibarrier approach – using more than one treatment type –uses two or more treatments, one of which may be very effective and one which may be only moderately effective for each type of microorganism. It has the added benefit that if one of the treatments has a system failure of some sort, there is still a backup treatment that will be at least somewhat effective.

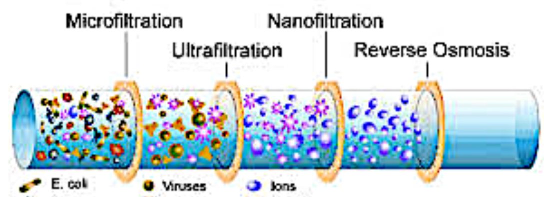
A good prefiltration system can count as one of the 2 required treatment processes and can contribute significantly to reduction of microorganisms, potentially providing all of the required removal of Giardia and Cryptosporidium (3 log reduction).

Centralized Disinfection Options

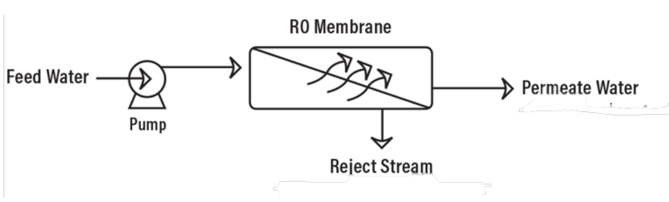
Heat processing:
It is possible to treat water through a heat exchange system similar to the way milk and juices are processed, or to "distill" water by heating it until it turns to hot vapor and then re-condensing it. That said, heat treatment is rarely used for centralized disinfection systems due to high energy requirements and lower cost alternatives.



Nanofiltration:
Extremely fine filtration can make water safe. Nanofilter pores can be 0.001 to 0.01 microns (1 to 10 nanometers), which is small enough to remove most viruses as well as to filter out many chemical contaminants. Extremely good pretreatment is needed to avoid fouling of the membrane. Because they are often through-flow filters, nanofilters can be relatively efficient with regard to water wastage. However, energy costs can be quite high to produce the operating pressures (in the range of 60 to 100 psi) that are required to get water to pass through the filter.

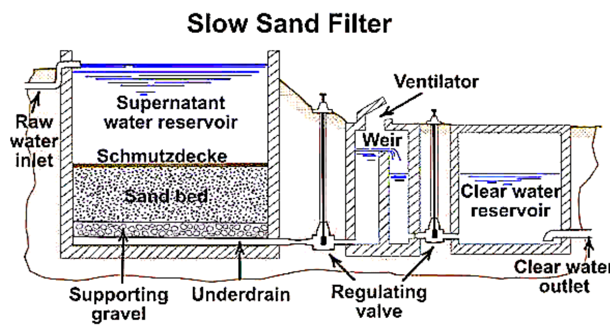


Reverse Osmosis:
Reverse osmosis (RO) goes a step further, with membrane pore size in the range of 0.0001 micron (0.1 nanometer). RO removes just about everything from its feed water, both harmful and beneficial. It will filter out both viruses and "heavy metals" such as arsenic and lead, but it also filters out calcium, magnesium and iron. RO is a very water-waste intensive process, producing 5 or more liters of waste water for every liter of clean water produced. This can be okay if your non-potable needs exceed your potable needs by 5 times or more (for example, you could use the rejected water for irrigation), if the rejected water stream can be added back to its original source, but concentration of contaminants in the source water can be an issue. Some systems apply further processing steps to recover part of the rejected water stream, reducing water wastage.



Slow Sand Filtration
Slow sand filters have a similar design to open rapid sand filters but they function quite differently. Slow sand filtration rate is only 1/50 to 1/20 that of a rapid sand filter and serves the purpose of disinfection treatment rather than a pretreatment. Whereas a rapid sand filter produces about a 2-log reduction (99% reduction) in bacteria and especially protozoan parasites like Giardia and Cryptosporidium, a good slow sand filter provides 4 to 6-log reductions (99.99 to 99.9999 %) of bacteria, and even a 2-log (99%) reduction of intestinal viruses.

On top of the coarse sand, there is a layer of very fine sand that allows the water to only drain very, very slowly. As a result, bacteria grow in the top layer of the sand to produce the active part of the filter: the schmutzdecke (means "dirt ceiling" in German). The schmutzdecke is a jelly-like biofilm layer of bacteria, fungi, protozoa, rotifers (microscopic animals) and insect larvae. As a schmutzdecke ages, algae and larger organisms including snails and segmented worms appear. As the water passes through the filter, pathogenic organisms are held back in the schmutzdecke on top of the fine sand. There they encounter well-established populations of organisms which destroy the harmful ones by out-competing them for food, poisoning them with their toxins, and even eating them. Although a "primitive" and very natural treatment system, slow sand filtration is very effective in providing disinfected water that is potable and ready to drink. For example, it has been used to treat London's water since the 19th century.

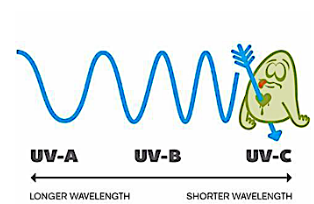


Rapid sand filters, using only the coarser sand portion, are kept clean and fast flowing by back-flushing to a waste stream when the flow rate diminishes, basically to prevent the development of a schmutzdecke and keep the water fast-flowing even with just atmospheric pressure.

The slow sand filter is very very slow, but when it gets even slower – essentially blocked – it requires a major cleaning intervention. The water system (or at least the portion being treated by that particular filter) is shut down and drained. Most of the schmutzdecke is removed by scraping it off and it is disposed of. Then more fine sand is added to replace what was removed, and the water coming through the filter cannot be used for potable purposes for up to two weeks or however long it takes for a new biolayer to establish. It is often important to partially pre-filter the water before it is put through the sand filter. If the feed water is high in particulates, the biofilter will clog more quickly, requiring more frequent system shutdowns. Because of the required shut-down period each time a slow sand filter is cleaned, systems often run multiple filters in parallel and shut them down for cleaning in a regular cycle.

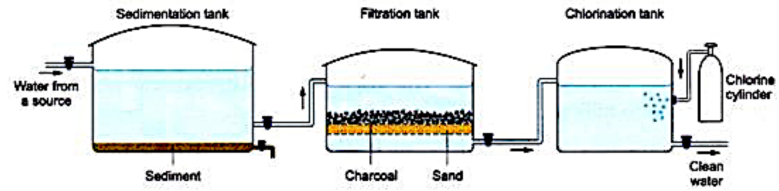
Ultraviolet Light:

Water treatment using UV light has been available for some time and is widely used as one step of water disinfection programs. The big change recently is the availability of LED lights that produce UV radiation for very low energy cost. Like how sunlight exposure can cause damage to our skin, UV light causes changes to DNA and RNA, which prevents microorganisms from multiplying. The organisms don't necessarily die, but they are made harmless because they can no longer cause infection. Water treatment with UV creates no waste water and neither adds anything to nor removes anything from the water.



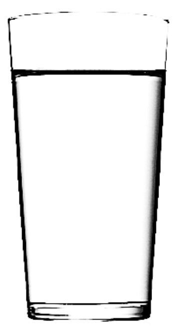
Chlorine:

Chlorine damages bacteria and viruses by directly causing chemical damage to proteins. This can include damage to the membranes that surround the "body" of the bacteria often causing the cell to break open and literally "spill its guts". Sometimes the damage is not as great, but the bacteria will be inactivated and unable to reproduce or cause infection. In order for chlorine treatment to be both safe for



human consumption and effective at killing disease-causing organisms, the water must be quite "clean" before treatment and the dose and holding time must be closely controlled. If the water contains too many organics, many potentially cancer-causing THMs (trihalomethanes) and other chlorinated hydrocarbons may be formed. If the dose is too low or the holding time too short, the harmful organisms may survive. If the dose is too high, the resulting water may be unsafe to drink because the chlorine could cause damage to cells in the intestines. At very low doses that usually exist in drinking water, the chlorine is inactivated in the stomach and intestines before it can cause any cell damage.

Chlorine is often used as a primary water treatment, but it is also used as a secondary treatment. As a primary treatment, chlorine is added to the water and the water is held for 10 to 15 minutes before it enters distribution lines. If used as a secondary treatment, the chlorine is injected, at a lower concentration, after the water has been disinfected by some other method (for example after nanofiltration, RO, UV or slow sand filtration) but before the beginning of the distribution pipe.



The glass of water that is drawn off after disinfection may not look any different than the one drawn off after pretreatment. It may now smell and taste of residual chlorine from secondary treatment, but if that is objectionable, the flavor and odor can be removed with a carbon filter.

Now you have a thorough grasp of the dangers of consuming raw water, have reviewed the operating performance of the PLWUS system, introduced yourself to the government's rules and regulations and brushed up on the key points of pretreatment and treatment of water for distribution. You are ready to give well-informed input into the system upgrades that we need.

Do we want non-domestic water only, Point of Entry or Point of Use treatment, a modern water processing plant, or something in between? Do we want to look after water supply as a group, want to have everyone look after their own, or should we lobby the qathet Regional District to take it over?

The last chapter in this series outlines some options that may be available for us.

Coming soon!
The Final Chapter:
Where do we go from here?