Water Treatment for Domestic Water Supplies

Water treatment is essential for all dugout water supplies used for household/drinking purposes.

*“ **The Rural Water Quality Information Tool”** provides an abundance of information on water quality, water sampling, testing, and treatment. The tool allows you to input your own water test results, and it then provides a detailed interpretation of the test results.*

The tool can be found on the Alberta Agriculture and Forestry website located at:

http://www.agric.gov.ab.ca

Click on the search Button and then in the search box type in

*“ **Rural Water Quality Information Tool”**.*

If you are not going to adequately treat water, then haul good quality water for household purposes.

*Point-of-entry (**POE**) systems treat all the water as it enters the house.*

*Point-of-use (**POU**) devices treat small amounts of water at the tap.*

Water Treatment Systems

Water treatment of surface water for human drinking purposes is a complex and often difficult task. In this module, we discuss a basic description of methods and procedures of surface water treatment, but we are not able to provide exhaustive methods and details in the space available in this publication. Technicians that work in the water treatment industry require extensive education in order to understand the requisite knowledge. Hopefully this module will help you begin to understand some basic methods of surface-water treatment principles.

Water treatment involves a series of separate treatment processes in a standard sequence to produce a safe and aesthetically acceptable product. This sequence of treatment processes improves the quality of the water with each step, providing a multi-barrier, water treatment system. For surface water supplies, treatment must include steps to remove particulate and organic matter, followed by disinfection. Water treatment equipment can be expensive and always requires good maintenance practices to operate effectively over the long-term.

Surface runoff is usually high in particulate matter and plant nutrients. Algae and weed growth can be significant, particularly during the summer months, and dugouts generally have high levels of organic matter. While disinfection is an essential part of the water treatment process, high organic carbon levels can react with the disinfectant, producing potentially harmful by-products. The reduction of organic matter prior to disinfection is therefore an important step in the treatment process to produce biologically and chemically safe water.

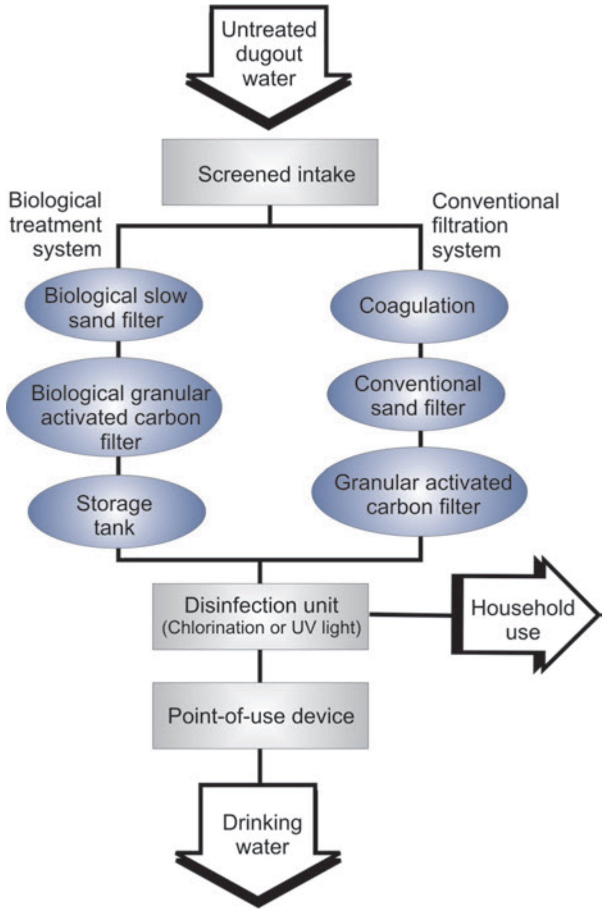
Traditionally for domestic use, dugout water treatment has consisted of either no treatment at all, or a combination of chlorination, rapid sand filtration, and/or granular activated carbon filtration. These types of treatments, by themselves, have not been successful at producing a high water quality product over the long term. Water produced from this type of treatment system should only be considered utility water and should not be consumed. While these processes can be effective to some extent, more effective pre-treatment is essential.

Figure 7-1 Surface Water Treatment Steps shows a schematic of two effective systems for treatment of dugout water as it enters the house. These systems are called ‘point-of-entry’ (**POE**) treatment systems. The first system includes chemical coagulation, filtration, and disinfection. The second system includes slow sand and biological activated carbon filtration followed by disinfection. In both cases, a final barrier such as a reverse osmosis (**RO**) membrane or distiller for drinking water, cooking water, and water for brushing teeth is added. This final barrier is called a “point-of-use” (**POU**) water treatment device. This type of treatment following point-of-entry treatment is referred to as “polishing”. Polishing devices are designed for use on high quality treated water and are not capable of treating raw dugout water.

An effective in-house treatment system should be represented by one of the configurations in Figure 7-1. Other technologies, such as micro filtration, may be used to replace some of the processes identified in Figure 7-1 if they are properly designed and operated.

The treatment processes described can effectively treat most dugout water. Effective systems are designed to treat specific water problems. Therefore, dugout water should be tested before designing the system. Water problems that are not typical of dugouts may require system modifications.

Figure 7-1 Surface Water Treatment Steps



Steps in Water Treatment

The recommended system, in Figure 7-1, consists of several consecutive steps. As previously discussed in Module 3 – Planning, the first step in a multi-barrier water treatment system is protection of the source water.

Screened Intake

A screened intake in the dugout is recommended as a pre-treatment to sieve out larger particles, including algae, as well as reduce high turbidity.

Coagulation

Coagulation is a chemical process that can reduce turbidity, dissolved organic compounds, and colour. The chemicals most often used for coagulation are aluminum sulphate, ferric chloride, ferric sulphate, and polyaluminum chloride.

The coagulant causes small particles to join to form larger particles. During mixing, more particles combine to form even larger particles called **floc**. The floc is visible to the naked eye and can be removed from the water through sedimentation or direct filtration.

Coagulation can be done in dugouts or coagulation cells, or by using in-house coagulation systems. The two most common methods of coagulation for rural use are:

- constructing a small lined dugout or coagulation cell to treat a six to twelve month supply of household water
- utilizing a commercial in-house coagulation system for continuous treatment of household water.

Coagulant chemicals must be dosed and mixed properly to achieve maximum benefits. On-farm coagulation has been experimentally successful, using simple treatment techniques for rural water supplies. Simple predictive tests have been developed for use on-site to determine the required dose rate.

For more information about coagulation, contact 310-FARM (310-3276) and ask for an agriculture water specialist.

Conventional Filtration

Conventional filtration is also known as rapid filtration, to distinguish it from slow sand or biological filtration. Figure 7-2 Coagulation and Conventional Filtration System shows continuous coagulation treatment followed by conventional filtration. Filtration is an important step in the treatment sequence to remove particles from water. Types of filter media that can be used include sand, dual media, multi-media, and granular activated carbon. Pressure sand filters and granular activated carbon filters are commonly used in domestic systems. Granular activated carbon filters can be used as a final step to remove taste and odour. In all cases, filters require backwashing to maintain performance. Backwashing is accomplished by reversing the flow of the water and lifting the media bed. Solids clogging the filter are dislodged and flushed out with the backwash water, which is discarded.

Biological Filtration

As an alternative to conventional filtration, biological filtration, as shown in Figure 7-3 Biological Filtration System, can be a simple but effective treatment for small water supplies. Slow sand filtration, followed by disinfection, represents one of the earliest systems developed for the treatment of surface water supplies. While these filters are commonly employed in many European treatment systems, they are not heavily used in North America.

Biological filtration is an effective treatment for small water supplies.

Biological filtration makes use of naturally occurring microorganisms to purify water. By providing the right environment, certain populations of microorganisms can be encouraged to grow in the filter. The process is simple. Water is percolated slowly through a filter bed and into a storage tank. A storage tank is required for the treated water because filtration is slow. A constant supply of air must be introduced to the filter and the flow of water must be continuous to ensure survival of the microbial colonies. As with the rapid sand filter, backwashing is required to maintain the operation of the filter. Some biological systems are ideally suited to treat surface water problems, such as dissolved organic carbon, turbidity, colour, taste, and odour. One system that has been successful in the treatment of surface water consists of a gravity-fed, slow sand filter, followed by a biological, granular, activated carbon filter and a storage tank.

This system offers an effective alternative to more conventional treatment systems and produces high quality, household water. With further treatment, water from these systems can be made safe for drinking. Although no chemicals or bacteria have to be added to these systems, regular backwashing with a mixture of air and water in a ‘reverse’ up-flow through each filter is a necessary maintenance procedure.

Figure 7-2 Coagulation and Conventional Filtration System

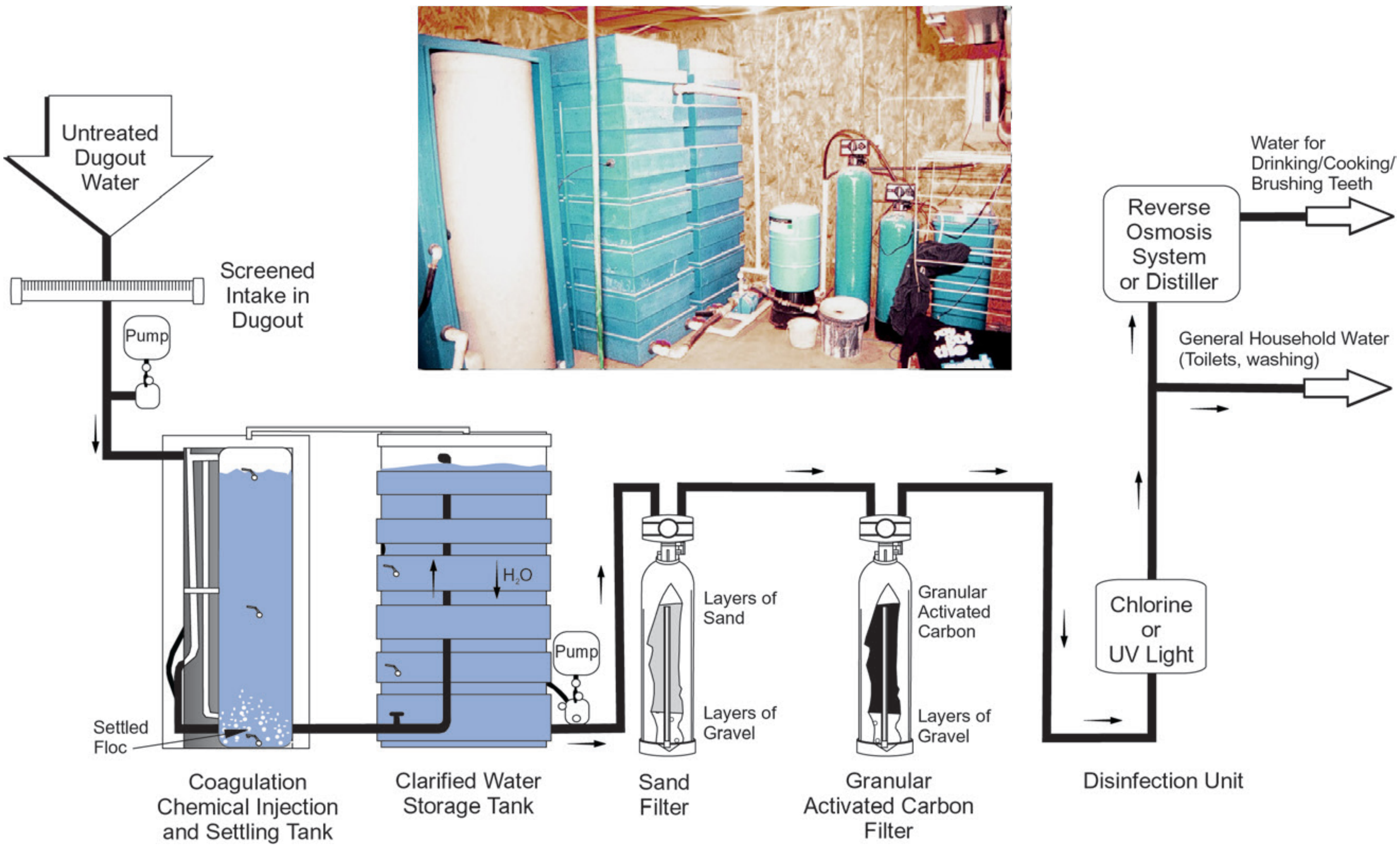
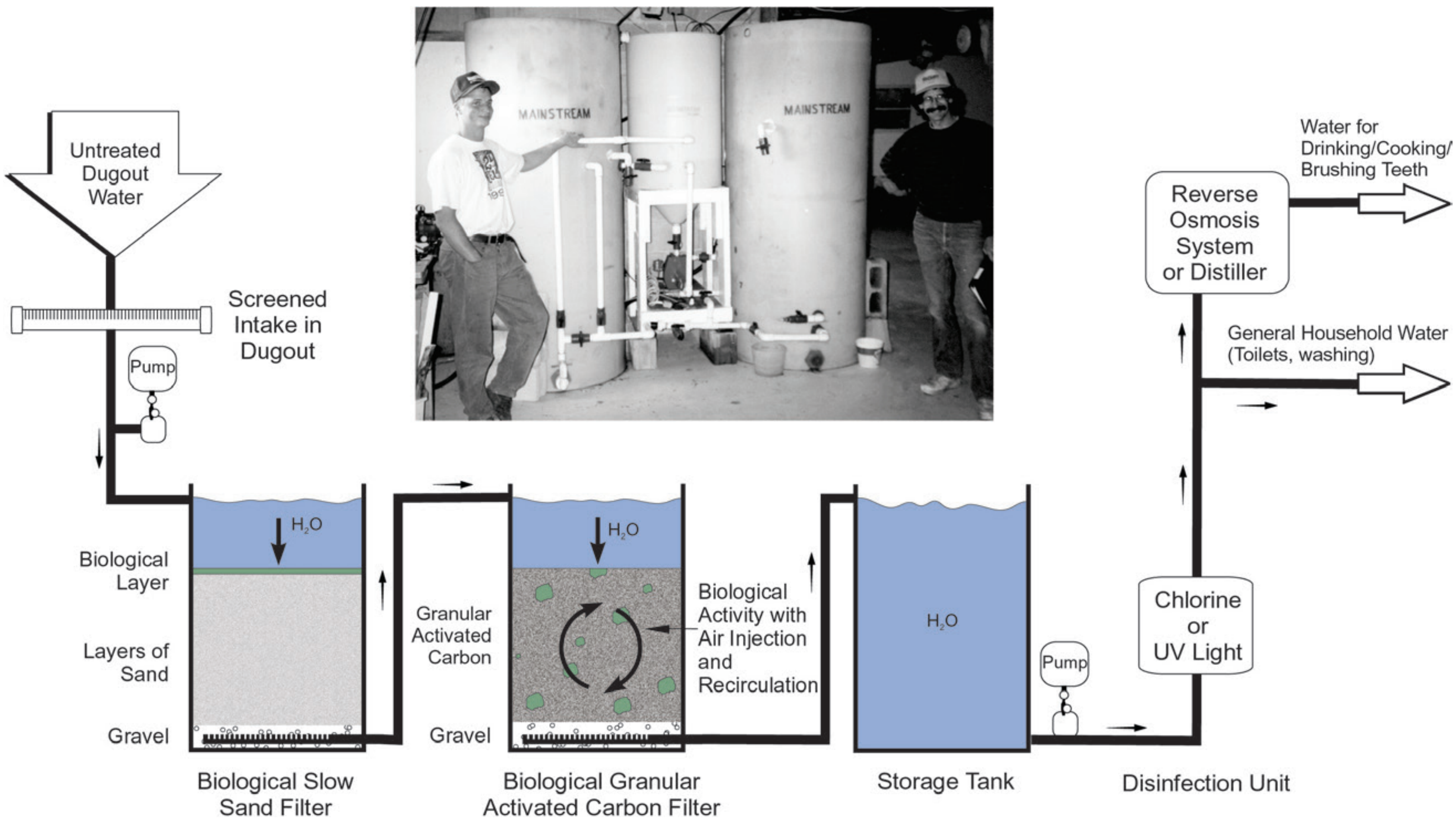


Figure 7-3 Biological Filtration System



Disinfection

Disinfection is an essential step in the treatment of dugout water for domestic use. The purpose of disinfection is to reduce populations of pathogenic microorganisms to prevent the transmission of water borne diseases. This is different from sterilization, which completely destroys organisms. Common disinfectants include chlorine, chloramines, and ultraviolet (**UV**) light disinfection. It is important that the water has been successfully filtered prior to the disinfection step.

Organic material and mineral particles can shield microorganisms from the disinfectant, resulting in water that may be unsafe even after treatment. In addition, if chlorine is used as the disinfectant, and organic matter has not been reduced to low levels, potentially harmful chlorination by-products may form.

Contact time, pH, water temperature, organic concentration, and chlorine dose influence the effectiveness of chlorine disinfection.

You must disinfect dugout water for domestic use.

Many rural residents prefer UV light disinfection, as it imparts no smell, taste, or odour to the water. UV light disinfection does not require chemical feed pumps and mixing tanks; however, it does not leave a disinfectant residual like chlorine for protection throughout the household distribution system. Wavelength, exposure time, water temperature, intensity of the light, and the presence of turbidity affect the effectiveness of UV light disinfection.

Polishing Treatment for Drinking Water

While it is recommended that the entire household water supply be disinfected to protect all water outlets in the home, a final barrier to supply safe drinking and cooking water is also recommended. This additional polishing step requires a distiller, or kitchen sink reverse osmosis (RO) unit. For additional detail on distillers and RO systems, see pages 92 – 95 in this module.

Maintenance of Treatment Systems

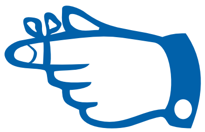
Operation and maintenance of in-house treatment systems is critical. If dugout owners are not prepared to invest the time and money required into treatment system maintenance, safe drinking water should be obtained elsewhere. Some treatment systems can be purchased with maintenance contracts to reduce the time and work associated with proper maintenance. A well-operated system will ensure that the water supply is safe and aesthetically pleasing. Regular monitoring of systems will give users confidence that the water they are using is safe. Maintenance should be tracked in a record book. If changes in quality are observed, corrective measures should be taken.

Be prepared to invest time and money into maintenance of treatment systems.

Conventional Pressure Sand or Multi-Media Filters

Pressure sand filters require regular backwashing as shown in Figure 7-4 Filter Backwashing. The backwash cycle can be set to start automatically. Backwashing frequency will depend on how much loading is placed on the filter by the feed water. In summer, when particulate loading is high, backwashing may be required as frequently as once a day. In winter, backwashing may only be required once every three to seven days. If water is pre-treated with continuous coagulation before the filter, the requirements for backwashing may be increased as unsettled floc from the coagulation process may clog the filter.

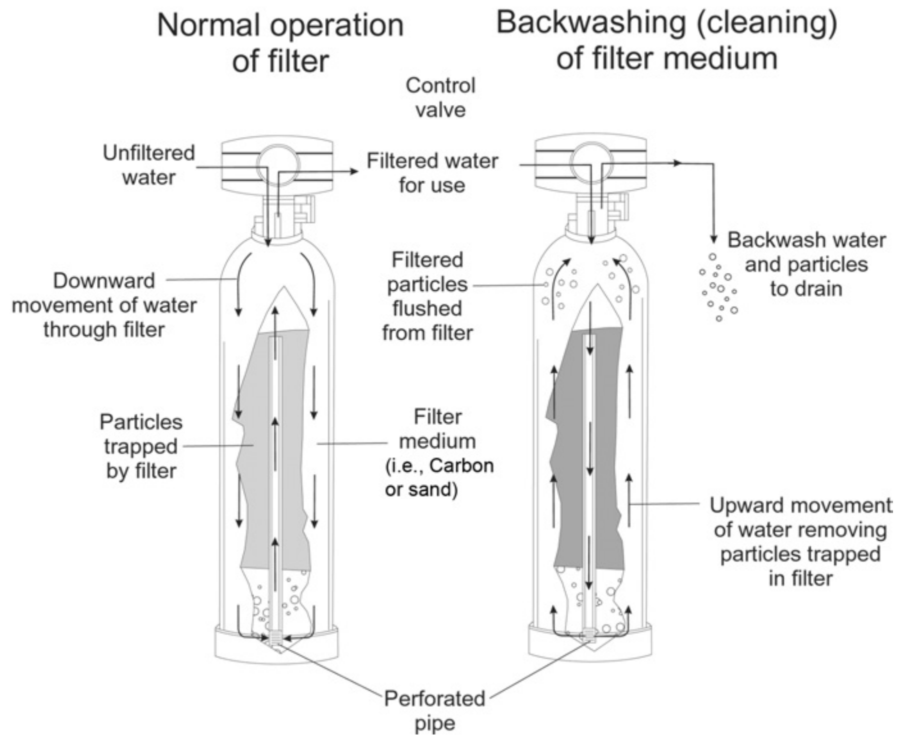
Organic matter will accumulate and plug pressure sand filters over time. For this reason, a manual backwash should be done at least twice annually, once in spring after snowmelt and once in fall, just before freeze-up. A manual backwash involves turning on the filter in backwash mode, unplugging the timer, and running a large quantity of water through the filter. Clean filtered water is preferred for backwashing. However, if raw water is used in this process, the wastewater should look as clear as the raw water. The backwash water should be inspected every 5 minutes for clarity. The manual backwash should be repeated until the backwash water is clean. If a filter is very dirty, backwashing may have to be repeated. If organic slime buildup is a problem, the filter can also be shock-chlorinated after the manual backwash. Filter media rarely require replacement unless the coarse filter gravel is displaced during overly aggressive backwashing.



Biological Sand Filters

Biological gravity sand filters may be designed for two types of maintenance regimes. The first regime involves backwashing the filter once every two to four weeks. The second involves replacement of the top layer of sand with new sand. Each spring and fall, the sand filter may require several cycles of backwashing to remove any accumulated material.

Figure 7-4 Filter Backwashing



Conventional Pressure Carbon Filters

Granular activated carbon filters are often referred to as GAC filters or activated carbon filters or even carbon filters. Pressure carbon (GAC) filters also require regular backwashing. If a sand filter is operating efficiently, the pressure carbon filter will require backwashing once every 3 to 14 days. It is always important to follow manufacturer's recommendations and adjust the frequency of backwashing to the type of water being treated. Manually backwashing for a longer time than the automated backwash may be useful if particulate matter has overloaded the filter. This should be done any time overloading is suspected.

A significant problem associated with carbon filters is carbon exhaustion. This occurs when the carbon simply cannot adsorb any more taste and odour compounds or dissolved matter. Carbon exhaustion is identifiable by treated water that is coloured or has a bad odour. The adsorption capacity of activated carbon in a pressure carbon filter will not last forever. For dugout water supplies, carbon exhaustion times can be highly variable, depending on water quality and the volume of water treated. Carbon media should be replaced at least twice a year, once in fall and once in spring. Fall replacement, when organic matter has died off, provides better carbon filtration throughout the winter months. Spring carbon replacement, after spring runoff, provides for more effective filtration of water high in organic matter.

For dugout water supplies, replace the carbon media at least twice a year, once in the fall and once in the spring.

Granular activated carbon in the filters is often only effective for 2 to 3 months. Carbon can be an excellent surface for unwanted microorganisms to grow on. Backwashing may not remove them and pre-treatment with chlorine will not prevent them from growing. Carbon must be replaced regularly to guarantee high quality water.

Biological Granular Activated Carbon Filters

Biological, granular activated carbon filters should be backwashed every 6 months. After the backwash, the filter should be drained of treated water until the water runs clear. Some fine carbon particles will wash through the system and should be discarded. Periodic shock chlorination is not required on biological carbon filters. If carbon media degrade, they require replacement. Long-term experiments on biological carbon filters have shown that the filters have performed well for seven years without any need for carbon replacement. The keys to successful biological carbon filtration are:

- ensuring that the system is sized properly
- providing a continuous air supply
- backwashing frequently.

Raw water should not be chlorinated before passing through the filter, nor should it contain any compounds, such as copper, that may poison the organisms.

Chlorination Disinfection

To ensure the water is safely disinfected, chlorine must be applied after filtration. The chlorine feed pump is set to feed the chlorine solution into the filtered water. Chlorine solutions must be batched to a mixing tank and enough contact time must be maintained. Contact time must be 10 to 20 minutes and the dose must be large enough to ensure that the residual at the tap is at a suitable level.

The only way to know the concentration of chlorine at the tap is to test it. Test kits are cheap and easy to use. Testing must be done at least once a week and doses adjusted if necessary. A loss of chlorine residual at the tap may be due to the loss of prime at the chemical feed pump, or the failure of the treatment system. This type of monitoring is an excellent way to track the system's performance. Keep a logbook and record the results. Take any necessary corrective action if a problem is noticed. Properly managed and monitored, chlorination systems are the most effective way of ensuring that filtered water is safe for domestic use.

Ultraviolet Light Disinfection

Ultraviolet disinfection lamps occasionally become impaired by poor quality water. If the lamp becomes coated with organic material or mineral scale, disinfection will be incomplete. Lamp maintenance under these conditions is not practical, and it is therefore critical that UV is **not** used to treat hard water or under conditions where bio-fouling occurs.

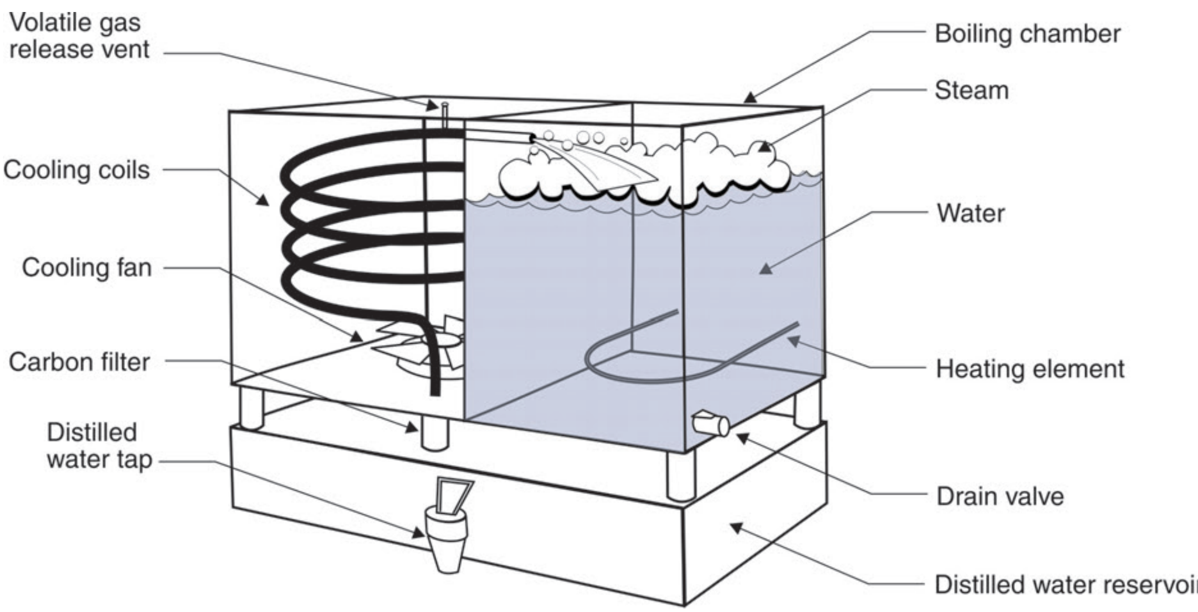
UV lamps must be routinely replaced.

UV bulbs must be routinely replaced in accordance with manufacturer's instructions or when so indicated by warning lights. There is no way of knowing if the lamp is disinfecting properly, other than to test the water at a laboratory for microbial contamination. There are concerns that UV performance can be critically impaired by electrical supply variations. A dedicated power supply to the lamp is recommended. Do not install lamps on circuits that have other high load demands. It is extremely important that the bulb be functioning properly and that units be equipped with indicator lights to serve as a reminder for bulb replacement.

Distillers

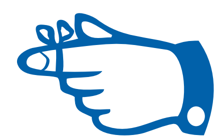
Distillers, as shown in Figure 7-5 Water Distiller, require regular cleaning using compounds recommended by the manufacturer. Cleaning frequency will depend on the type of water being treated. Distillers remove chlorine, so when testing for chlorine residual, draw the sample ahead of the distiller.

Figure 7-5 Water Distiller



Reverse Osmosis Units

There are many types of reverse osmosis (RO) membrane units available. All are designed for use on very high quality feed water. It is common to incorporate a 5-micron filter, followed by a granular activated carbon filter, before the membrane as shown in Figure 7-6 RO Treatment Process. A compressed carbon block filter cannot be used in place of granular activated carbon filter. Both the 5-micron and the granular carbon filters require replacement at least four times per year. If the canister housings of the filters are slimy, they can be shock chlorinated and scrubbed as a part of the maintenance regime.



RO membranes as shown in Figure 7-7 RO Membrane reject most of the dissolved solids in water. If a total dissolved solids (**TDS**) test shows more than 50 TDS, the membrane is not working satisfactorily. Some units have indicators to warn of this condition. The RO membrane requires replacement once every one to three years. Sealing rings and end caps are critical features of the membranes. If they are damaged or incorrectly installed, water will by-pass the membrane and remain untreated. Corrective action is required immediately. If an RO unit stops producing water, the filters or the membrane are likely plugged. Replacement is required.

Figure 7-6 RO Treatment Process

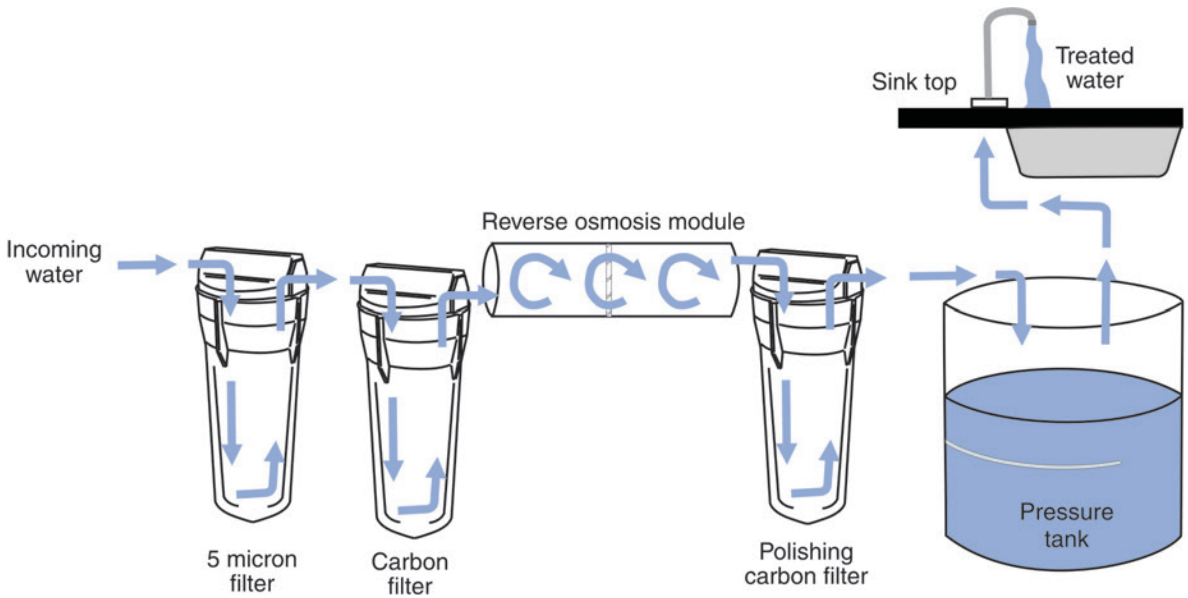
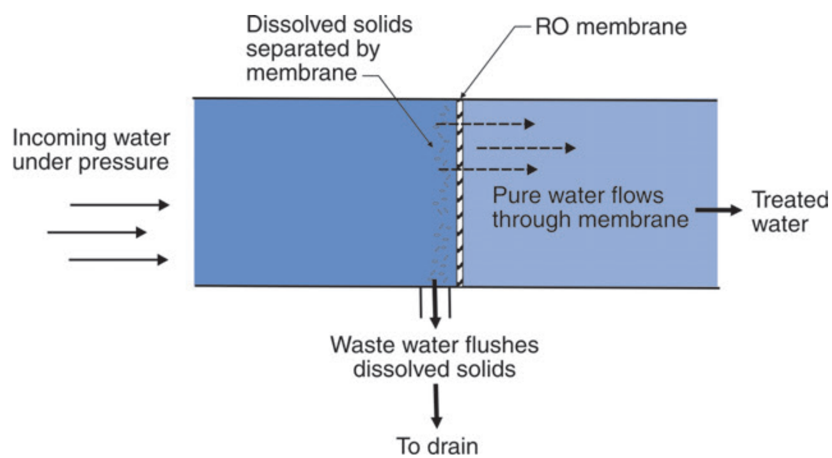


Figure 7-7 RO Membrane

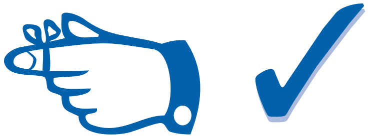


Do not shock chlorinate RO membranes since they only tolerate low levels of chlorine. RO membranes remove chlorine, so when testing for chlorine residual, draw the sample ahead of the RO membrane.

Always follow manufacturer's recommendations for correct operation and maintenance procedures. The procedures must be suited to the specific treatment device.

A granular activated carbon, polishing filter is often incorporated after the RO unit. This filter should be replaced at least four times per year. Granular activated carbon, polishing filters do not have to be discarded when replaced. They can be re-used once as the carbon filter in front of the RO unit.

Monitoring

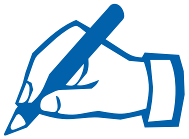


Regular monitoring is the only way to determine how well a treatment system is performing. Keep a record of chlorine residuals, backwashing frequency adjustments, source water appearance, clarity, smell, and taste. Monitoring costs very little and increases confidence that the system is working well.

To judge the performance of a treatment system, test tap water for microbial safety at least twice per year. Critical times for water testing are:

- following spring runoff
- following any major runoff event
- mid-summer
- during maximum ice thickness.

Collect water in sterile bottles following the instructions of the lab performing the tests. Samples must be properly labeled and packaged, and delivered to the lab within 24 hours. Keep all results in a binder.



The following two Operation and Maintenance Schedule examples, Figures 7-8 Conventional Water Treatment System Schedule and 7-9 Biological Water Treatment System Schedule, show both the conventional treatment system and biological treatment system. Carefully review the examples to see the type of information recorded. Blank schedules for your use are located in the pocket at the back of the manual.

Equipment Certification

In Canada, water treatment equipment for private systems is not required to meet any standards or regulations. Furthermore, there is no Canadian certification mechanism for the effectiveness of water quality treatment.

Figure 7-8 Conventional Water Treatment System Schedule

Operation and Maintenance Schedule

Conventional Water Treatment System Operation and Maintenance Log

N.B. Chlorine always tested at kitchen sink tap

Date	Coagulation	Sand Filter	Carbon Filter	Chlorinator	Distiller
Feb 28	*Little floc visible*	*Backwash once/7 days*	*Backwash once/7 days*	*Tot. Cl = 0.5 mg/L*	*Cleaned Unit*
March	*Not tested; on holidays*				
April 2	*Adjusted dose for spring water*	*Manual backwash for 30 minutes and shock chlorinated filter; backwash once/4 days*	*Replace carbon media; backwash once/6 days*	*Tot. Cl = 0.0 mg/L increased to 0.5 mg/L*	*Cleaned unit; replaced elements*
April 9	*Settled floc OK*	*Backwash once/4 days*	*Backwash once/6 days*	*Tot. Cl = 0.2 mg/L; new batch and re-set to 0.5 mg/L*	*Working OK*
April 16	*Floc seems to be thickening*	*Backwash changed to once/3 days*	*Changed backwash to once/5 days*	*Tot. Cl = 0.1 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
April 23	*More floc evident*	*Backwash changed to once/2 days*	*Changed backwash to once/4 days*	*Tot. Cl = 0.3 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
April 30	*Floc is similar to last week*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 0.6 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 7	*Floc turning brownish*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 1.0 mg/L Re-set to 0.5 mg/L*	*Working OK*
May 14	*Floc brownish, same density*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 0.1 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 21	*Thick floc (algae and sediment from rain)*	*Re-set backwash to once/day*	*Backwash once/4 days*	*Tot. Cl= 0.3 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 28	*Floc is still thick*	*Backwash once/day*	*Changed backwash to once/3 days*	*Tot. Cl = 0.2 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
June 7	*Floc is thinner*	*Re-set backwash to once/2 days*	*Re-set backwash to once/4 days*	*Tot. Cl = 0.7 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*

Figure 7-9 Biological Water Treatment System Schedule

Operation and Maintenance Schedule

Date	Slow Sand Filter	Biological Carbon Filter	Storage Tank	Ultraviolet Light	Reverse Osmosis
Feb. 28	*Air pump working*	*Air pump working*	*Air pump working*	*UV lamp is on*	*TDS is 350 mg/L (RO needs replacement)*
March	*On holidays; neighbours opened taps to flow 500 L of water weekly; air pump OK*			*Removed lamps; stained!*	
April 2	*Two manual backwashes with air and water and shock chlorinated filter*	*Three manual backwashes with air and water, filtered water was dirty, drained until clean*	*Shock chlorinated tank*	*Replace UV bulb and quartz sleeve*	*Replaced membrane and all filters (5 micron, both carbon filters); TDS is 50 mg/L*
April 9	*Air stone replaced; old air stone was plugged*	*Air stone was replaced*	*Air pump and air stone is OK*	*Farm power surge. UV on/off test performed to check UV, OK*	*TDS measured 45 mg/L*
April 16	*Air pump working*	*Air pump working*	*Air pump working*	*UV lamp OK*	*TDS measured 45 mg/L*
April 23	*Air pump OK*	*Air pump OK*	*Air pump OK*	*UV quartz sleeve cleaned*	*TDS measured 53 mg/L*
April 30	*Manual air and water backwash*	*Air pump OK*	*Air pump OK*	*Replaced UV ballast (damaged by power surge)*	*TDS measured 55 mg/L*
May 7	*Air pump OK*	*Air pump OK*	*Air pump OK*	*UV lamp OK*	*TDS measured 150 mg/L ?? calibrated meter, TDS 65 mg/L*
May 14	*Dirty water but filter working OK*	*Filter OK, air supply OK*	*Water still OK and air system working*	*UV lamp OK*	*TDS measured 57 mg/L*
May 21	*Filter starting to plug, so performed mini-backwash*	*Flow rate slowing down*	*Air system OK*	*UV on/off self-test performed*	*TDS measured 70 mg/L*
May 28	*Manual air and water backwash*	*Filter flow OK after sand backwashed*	*Air system OK*	*UV lamp indicator OK*	*TDS measured 60 mg/L*
June 7	*Air pump working*	*Air pump working, stone OK, circulation seems fine*	*Air system OK*	*UV quartz sleeve dirty; cleaned sleeve*	*Replaced plugged 5 micron filter TDS measured 55 mg/L*

Although private treatment systems are not regulated in the United States and Canada, the National Sanitation Foundation International (NSF International) does certify small treatment devices if the manufacturer is willing to apply and pay for the third party evaluation. Try to find equipment that meets certification by NSF International to ensure that equipment performance has been validated against accepted standards. Be aware, however, that the test was probably not performed using water that is as challenging to treat as dugout water.

Devices may also be registered with the United States Environmental Protection Agency (USEPA). This registration means the equipment has been tested to ensure the device will not give off contaminants that may harm the consumer. The USEPA does not test equipment performance.

Most importantly, work with a dependable water treatment company.

Try to use water treatment equipment that has been certified by NSF International.

In 1999, Health Canada conducted the "Survey of Drinking Water Treatment Services Available on the Canadian Retail Market". The survey covered seventeen cities across Canada including seven cities on the Prairies. The treatment devices studied included softeners, distillers, reverse osmosis systems, filtration systems, microbial purifiers, and UV systems. About half the devices surveyed were filtration systems, and about one-quarter were reverse osmosis systems. The devices were divided into three groups:

- treatment devices for disinfecting water contaminated by microorganisms
- treatment devices for improving taste, odour, and appearance
- treatment devices for removing chemical contaminants.

Health Canada Survey of Treatment Devices	
Models surveyed	318
Certified	34.0%
Uncertified	62.0%
Not NSF, but bearing name/logo	4.0%

The survey indicated that only one-third of the devices sold by retail were tested and certified by professional testing agencies such as NSF, Canadian Standards Association (CSA), or Underwriters Laboratories (UL). This leaves many questions unanswered as to the effectiveness and reliability of such devices in the treatment of dugout water.