Water Quality Matters

APPROACHES TO WATER TREATMENT

December 1997

INTRODUCTION

The *Surface Water Quality Initiative (SWQI)* was funded by the Canada-Saskatchewan Agriculture Green Plan Agreement (CSAGPA). Its purpose was to seek affordable and dependable solutions to surface water quality problems encountered on Prairie farms. One approach to providing good quality, safe water for household use, including drinking and cooking, is to use in-house water treatment systems.

The research focused on treating surface water supplies, including small on-farm reservoirs called dugouts, which often have the greatest water quality problems. However, some work was also done on treating ground water supplies, which often require specific water treatment technologies to deal with problems unique to ground water supplies.

Individual water treatment processes can not be applied in a universal fashion. Each process has limitations and generally is used in combination with several processes to deliver water of an appropriate quality from the available water supply.

The purpose of this publication is to provide background information for other publications in the **Water Quality Matters** series by:

- broadly describing some of the available in-house water treatment systems;
- outlining the need to use a multiple barrier approach in treatment to ensure safe water;
- specifying the need for water quality testing; and
- describing general operation and maintenance requirements.

Specific in-house treatment systems that were studied under the SWQI are described in other **Water Quality Matters** publications.

IN-HOUSE TREATMENT SYSTEMS

Water treatment consists of physical, chemical and biological treatment processes. All three of these processes may be required to produce high quality and safe water from certain sources. Primary systems, used to treat sufficient volumes for all the uses in a household, are described first. Add-on components to primary systems, which provide higher quality, safer water for drinking and cooking, are then described. In-house treatment systems for both surface and ground water sources are described briefly. The need for disinfection as a final treatment step is outlined.

Primary Systems

Physical Treatment

The most common process in water treatment is the physical process of filtering water. For example, sand filters will remove large particulate matter from the water. Granular activated carbon (GAC) filters will filter particulate matter from the water and will also adsorb (soak up) dissolved organic matter and other contaminants. The adsorption capacity of a GAC filter is limited. The GAC filter is "spent" or "exhausted" when the capacity of the carbon media to adsorb contaminants is used up. Carbon is also an excellent media to support the growth of bacteria and bugs, which could adversely affect the operation of the filter and the water quality. Therefore, it is advisable to replace this media with new carbon after its adsorption capacity is exhausted. These filtration techniques are commonly used for surface water sources and must be followed by disinfection to deliver safe drinking water.

Chemical Treatment

A common chemical water treatment process known as coagulation is used to remove particles that are in suspension or that are dissolved in the water. Currently, coagulation is not used in rural farm applications due to the complexity of determining and adjusting chemical dosages. Work under the SWQI explored ways to simplify coagulation processes for farm water supplies (see the **Water Quality Matters** publication "Dugout Coagulation").

Biological Treatment

Biological water treatment processes are commonly used in small and large municipal water treatment plants in Europe and are now becoming more attractive for North American municipal water treatment plants. Biological processes rely on existing biological life in the water. Biological treatment involves optimizing conditions in the water to enable the growth of desirable biological activity within the filter unit. The biological treatment process is designed to biodegrade unwanted parameters such as dissolved organic matter, iron or arsenic. In addition, some biological processes are expected to "regenerate" the adsorption capability of exhausted carbon. Biological processes hold promise for the treatment of Prairie surface water rich in organic matter and for the treatment of certain parameters in ground water. The SWQI studied biological processes for in-house treatment of both surface and ground water supplies (see the **Water Quality Matters** publications "Biological Treatment of Surface Water" and "Biological Treatment of Ground Water").

Add-on Components

Treatment devices including membrane filtration, ceramic filters and distillation are often components added, after primary treatment processes. Such devices are usually more elaborate and their performance is usually limited by the quality of the supply water. These add-on components are used to provide smaller quantities of higher quality water, suitable for drinking and cooking.

Membranes

Membranes are synthetic materials that act like a very tight sieve, producing a limited quantity of treated water while rejecting larger quantities of poorer quality water. The tightest membrane process is reverse osmosis (RO) with a Molecular Weight Cut Off (MWCO) of 50 to 200; it is capable of rejecting even the smallest inorganic ions such as aluminum as well as bacteria, viruses, parasites and protozoa. The next tightest membrane is nanofiltration (NF) varying from a MWCO of 200 to 1,000. An NF membrane is also capable of rejecting bacteria, viruses, parasites and protozoa; if the NF membrane is 300 MWCO or less, it is also capable of rejecting high percentages of organic matter. Looser membranes include ultrafiltration (UF), which rejects particles sized from MWCO 1,000 to 0.1 microns, and microfiltration (MF), which rejects particles sized from 0.1 to 2.0 microns. These ranges are approximate and may have a wide range of overlap depending on how the manufacturer classifies the membrane. Single unit membranes generally reject about 10 L of water for every 1 L that they produce. Greater volumes of water will be rejected with cooler temperatures, inadequate pre-treatment or membrane fouling. Membrane processes require adequate pressure to force the water through the membrane and may even need booster pumps to work effectively.

Ceramic Filters

Ceramic filters are capable of delivering very high quality water free of bacteria and parasites by passing water through a porous ceramic cartridge. Because a limited volume of water can be treated, these filters are limited to kitchen sink units that produce drinking and cooking water. These filters may not be able to remove certain viruses if they are present in the water. Ceramic filters tend to plug up quickly if the water contains particulate matter, or if it is turbid.

Distillers

Distillers purify the water by condensing steam produced when electrical energy is used to heat the water. Maintenance is important as the distiller must be cleaned regularly to remove scale build-up. Because distillers use power, electrical costs are a factor to consider with these devices.

Ground Water Treatment Systems

Ground water treatment processes are designed to deal with problems unique to ground water. For example, iron and manganese are often treated with air stripping, oxidation or manganese greensand filtration. Calcium and magnesium (hardness) are usually treated with ion exchange softening filtration devices. Arsenic, sodium and sulphate problems may be reduced with more refined processes such as distillation or reverse osmosis membrane filtration.

Disinfection

The final step in any water treatment process for surface or ground water should be disinfection, to ensure the water is microbiologically safe (free from bacteria, viruses and protozoan parasites). The goal is to ensure that the disinfection process has sufficient contact time and concentration (strength) to kill microbial contamination before the water is distributed. Even after treatment, water can become re-contaminated in pipelines (e.g. by an organic slime layer build-up on the walls of the pipes). Therefore, it is important that treated water contain sufficient excess disinfection chemical (a residual) to ensure that no microbial re-growth and re-contamination occur in the water as it is being distributed in the pipelines.

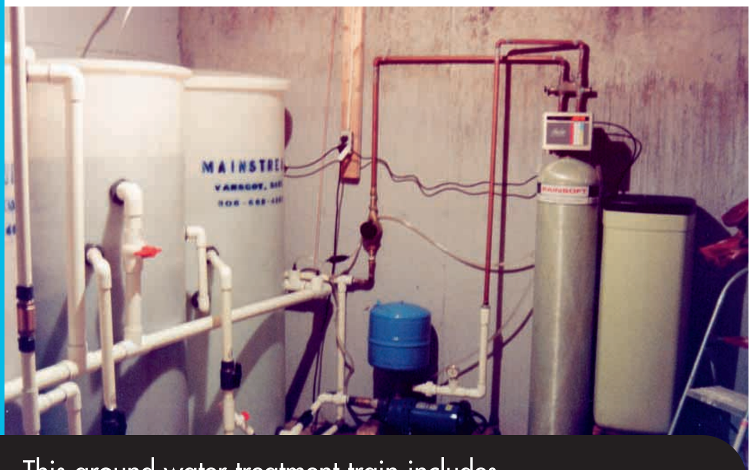
The most common, economical and trustworthy disinfection process is chlorination. The benefit of using chlorination is that chlorine residuals can be maintained and measured in the pipeline system and household taps to ensure the disinfection process is continuing during water distribution. Newer processes include ozonation and ultraviolet light disinfection but the effectiveness of these processes is harder to measure.

Regardless of the disinfection process used, water must be properly treated prior to disinfection to ensure disinfection occurs and the water remains free of microbial contamination.

Treatment Trains

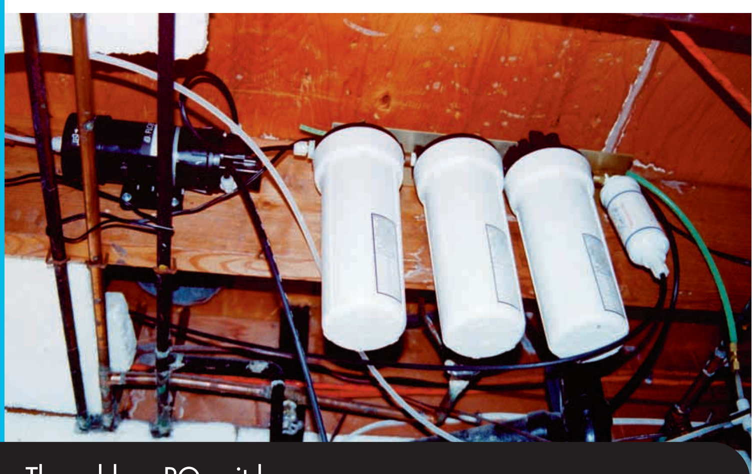
A water treatment train is a system of more than one specific water treatment process or device that is required to treat a water supply that may have several quality problems. The most common in-house treatment train or system currently used on Canadian Prairie farms for surface water supplies includes a pressure sand filter, a carbon filter, a softener and a chlorinator.

A general treatment train for a typical water supply could consist of the following steps. Chemical coagulation could be used to improve the settling of dissolved and particulate matter in the source water. The clarified “cleaner” water could then be filtered by sand filtration and if warranted, additional treatment processes could be added to the train. GAC filtration is often used when the source water has high levels of organic matter, as is the case of dugouts. If the water is hard (as is often the case with ground water), a softening process may be incorporated. Often the pH of the water must be adjusted to optimize treatment and to deliver water that is not acidic or alkaline. Disinfection is usually the last step in the treatment process.



This ground water treatment train includes a number of barriers:

- a biological sand filter,
- a biological carbon filter,
- a storage tank,
- a softener, all used to deliver general household water, and
- an add-on reverse osmosis (RO) unit for the kitchen sink.



The add-on RO unit has:

- a booster pump to increase pressure
- a depth cartridge pre-filter
- a carbon pre-filter
- the RO membrane, and
- a carbon post filter.

MULTIPLE BARRIER APPROACH TO TREATMENT

The "multiple barrier" approach is a fundamental principle in the production of high quality and safe water used by all well-designed and well-operated community drinking water treatment plants. A "barrier" is incorporated at each stage of supplying and delivering the water. The barriers are designed to protect and improve the water quality. Individual farms can also adopt a multiple barrier approach. A generalized multiple barrier approach is summarized in Table 1 below.

Table 1: Multiple Barriers

Stage	Barrier	Examples, details
1	Watershed Protection Plan	land use BMPs, e.g. keep livestock waste away from water source
2	Water Source BMPs	e.g. surface water intake placement, use of algicides, shock chlorination of wells
3	Settling (surface water)	allows larger particles to settle out of water
4	Treatment Train	chemical coagulation (surface water) filtration (sand, carbon, or other processes if required) softening (generally used for gound water supplies)
5	Disinfection	after treatment, and maintained in distribution system
6	Safe Operation and Maintenance	required for treatment and distribution systems
7	Monitoring of Final Water Quality	regular testing of the water at the point of consumption

No single water treatment component is able to effectively and efficiently address all the problems of a particular water supply. Each barrier in the treatment train is designed to protect water quality and / or address specific water quality problems. A water treatment system with several different barriers is able to address different water quality problems, increasing the level of protection at each stage of the treatment system. Treatment systems should be designed with barriers that address the specific water quality problems of that particular water source. The final barrier in any water treatment system should be disinfection for protection against microbial contamination. This is critical to ensure the water is safe at the time of treatment, and remains safe after distribution in pipes.

Drinking water from any surface water supply (such as a river, lake, or reservoir) must be treated, no matter what the source nor how good it appears. Even if the water is not used for drinking, filtration and disinfection will assist in delivering a safer and better quality water. For Prairie surface water, which often has high levels of organic matter, the best approach involves reducing dissolved organic carbon (DOC) before disinfection. A treatment system for a surface water supply could include sand filtration, followed by carbon filtration, followed by chlorination. This would deliver general household water. For safe drinking and cooking water in the kitchen, a final barrier could be either a chlorine-tolerant RO or NF membrane, a distiller or ceramic filter.

If concerns exist about the ability of an on-farm treatment system to produce safe drinking water, one option may be to use the treatment system to provide general household water for bathing and washing, while hauling safe drinking water from a dependable treated water supply. However, handling and storage procedures must not compromise the safety of the water. Hauled drinking water should be handled in clean containers and refrigerated. If these precautions are not taken, microbiological organisms can establish themselves, and the water can become contaminated.

WATER QUALITY TESTING

All treated water should be tested for several reasons:

- to confirm the systems are delivering safe water of high aesthetic quality;
- to determine the effectiveness of treatment; and
- to select appropriate water treatment processes to deal with the specific water quality problems.

Drinking water used on a farm should be tested seasonally, four times per year to ensure that it is safe and does not contain microorganisms. The treated water should be sampled in appropriate containers supplied by a commercial or public health laboratory and should be tested for the presence of coliforms. Good quality drinking water should contain no detectable coliforms, which are an indicator that the water may be contaminated.

It is a good idea to test surface water sources each February and August for DOC, phosphorus, colour, turbidity and oxygen to monitor changes in water quality. If the concentrations of these parameters do not meet the desired goals, it may be necessary to improve watershed management practices, to improve BMPs of the water source, or to alter or up-grade in-house treatment processes, for example by replacing exhausted carbon media.

Water supplied from a ground water well should also be tested each February and August for the specific parameters that are believed to be a problem. Shallow wells may be tested for parameters such as coliforms, DOC and nitrates. Deep wells should also be tested for coliforms, DOC and other parameters of concern such as arsenic, iron, manganese, sodium, hardness and sulphate. For further information on these topics, please see the **Water Quality Matters** publication “Prairie Water Quality Problems.”

OPERATION AND MAINTENANCE

Every water treatment process has limitations and requires specific operation, maintenance and replacement of critical components, in accordance with manufacturer’s recommendations. If these are not followed the performance of the treatment system will be compromised. Operation and maintenance procedures are discussed with specific processes addressed in other publications in this series, but generally include the following actions:

- sand and carbon filters must be regularly backwashed;

- carbon media must be replaced when the media is exhausted; for Prairie dugout water, carbon media can become rapidly exhausted and may require replacement several times each year if optimum water quality is required;
- chlorinators require adjusting; chlorine dose should be monitored weekly to ensure adequate chlorine residual at the drinking tap; assuming adequate filtration and chlorine contact time, the residual of total chlorine should be 0.5 mg/L or the residual free chlorine should be 0. 2 mg/L;
- membrane depth cartridge pre-filters (usually 5 µm) must be replaced at least two to four times per year for kitchen sink RO membranes;
- membrane carbon pre-filter canisters for kitchen sink units must be replaced several times per year;
- membranes may need to be replaced every two to five years; and
- distillers must be cleaned, usually monthly.

CONCLUSION

The challenge for water treatment is to deliver high quality water in an affordable manner, coping with all potential problems with a given water supply and with each treatment system. To ensure good quality water for all household purposes, it is necessary to use a multiple barrier approach that addresses the specific problems of a given water supply. For any treatment system to work well, it must be properly operated and maintained, and the quality of the water should be tested regularly to ensure the system is functioning properly.

The general principles and outline of water treatment in this publication provide background material for subsequent publications in the **Water Quality Matters** series that address specific in-house treatment technologies studied under the Saskatchewan Surface Water Quality Initiative, funded by the CSAGPA.

For further information on rural Prairie water quality and treatment technology:

- contact your local Prairie Farm Rehabilitation Administration office (PFRA is a branch of Agriculture and Agri-Food Canada);
- read the other publications in PFRA's **Water Quality Matters** series;
- get a copy of "Rural Prairie Water Quality: Searching for Solutions for On-farm Users" available from PFRA; or
- read Prairie Water News, available from PFRA, or on the Internet at www.quantumlynx.com/water

AUTHORED BY: D. Corkal, PFRA

FUNDING: This publication was funded in part by the Canada-Saskatchewan Agriculture Green Plan Agreement and the Canada-Saskatchewan Agri-Food Innovation Fund.

Agriculture and Agri-Food Canada Agriculture et Agro-alimentaire Canada

Canada