Water Quality Matters

Biological Treatment of Ground Water

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WHAT IS BIOLOGICAL TREATMENT OF WATER?

Water used for drinking and household use, even water from a ground water supply, should be treated before it is used to ensure it is safe and aesthetically pleasing. One innovative method of water treatment is biological water treatment. Biological treatment has been used in Europe since the early 1900s and is now receiving more interest in North America.

Biological water treatment involves the use of naturally occurring micro-organisms in ground water to improve water quality. Under optimum conditions, including enough oxygen, the organisms break down material in the water such as dissolved organic carbon (DOC) and iron and thus improve water quality. Sand or carbon filters are used to provide a place on which these micro-organisms grow.

One type of in-house biological system for treating ground water was studied in two households in Saskatchewan as part of research conducted under the Canada-Saskatchewan Agriculture Green Plan Agreement.

WHY USE BIOLOGICAL TREATMENT OF WATER?

Biological water treatment processes are well suited to treat some problems common to Prairie ground water supplies, including iron, arsenic, and dissolved organic carbon (DOC), as well as colour and turbidity (see the **Water Quality Matters** publication "Prairie Water Quality Problems").

Research showed that the biological treatment system, including a slow sand filter and biological activated carbon (BAC) filter, effectively reduced DOC, colour and turbidity, as well as iron and arsenic. The biological system was not as effective in reducing manganese concentrations as first anticipated.

HOW WILL BIOLOGICAL TREATMENT IMPROVE WATER QUALITY?

Biological treatment of ground water improves water quality by reducing iron and arsenic, which are aesthetic and health problems, respectively. The biological process also reduces colour and turbidity as well as concentrations of DOC, which can cause health problems in chlorinated water (see the **Water Quality Matters** issue "Prairie Water Quality Problems"). Reduced DOC levels can also improve the taste and odour of the water, and can reduce the amount of chlorine needed for disinfection.

WHAT WERE THE SYSTEM COMPONENTS?

The biological treatment system has three parts:

- a slow sand filter where water flows through by gravity; it is designed so that biological processes establish themselves in the filter to reduce levels of iron and arsenic;
- a biological activated carbon (BAC) filter to reduce manganese and DOC; and
- a 1000 L storage tank to meet peak household demands.

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The system was designed to operate continuously, providing high quality non-potable water to the entire household. After the storage tank, the water was softened to reduce hardness for washing and bathing. An ultraviolet (UV) disinfection lamp was installed after the softener on one ground water system to deal with microbiological problems. For drinking and cooking water at each site, a reverse osmosis (RO) membrane, complete with booster pump, was installed as an additional protective barrier at the kitchen sink. The RO unit reduces sulphate, sodium, total dissolved solids and hardness, which are parameters which the BAC filter will not treat. The RO unit will also remove micro-organisms including bacteria, viruses and parasites, providing it is properly operated and maintained.

HOW WELL DID THE BIOLOGICAL TREATMENT SYSTEMS PERFORM ON GROUND WATER SUPPLIES?

The results of the sampling conducted on one of the two ground water treatment systems (the water containing higher arsenic concentrations) are shown in Table 1. Although the sand filter was often sufficient to reduce the concentration of target parameters below the stated goal, the BAC filter significantly improved the quality of the water.

The slow sand filter effectively reduced iron and arsenic concentrations. The BAC filter effectively reduced the DOC to less than 1 mg/L. Together, the sand and BAC filters reduced colour and turbidity.

The biological treatment system improved the water quality by removing:

- 85% to 90% of DOC;
- 87% to 90% of the colour;
- 93% of arsenic (in the water supply where arsenic exceeded the regulated level of 0.025mg/L);
- more than 99% of the turbidity;
- 34% to 94% of the manganese; and
- more than 99% of the iron.

A biological sand filter reduced high levels of iron and arsenic, naturally-occuring from the deep well water supply

Table 1: Ground Water Quality at Site with High Arsenic Concentrations After Each Stage of the Biological Treatment System

Parameter	SWQI Goals	Before Sand Filter	After Sand Filter	After BAC Filter	After RO Membrane
Iron (mg/L)	<0.3	4.34	0.01	<0.01	0.07
Manganese (mg/L)	<0.05	0.322	0.247	0.212	0.002
Arsenic (mg/L)	<0.025	0.029	0.002	0.002	<0.001
DOC (mg/L)	<5.0	4.3	4.002	0.628	0.072
Colour (TCU)	<15	33	8	4	3
Turbidity (NTU)	<1.0	39.4	0.3	0.2	0.2

NOTE: shaded areas indicate results met goal

The biological treatment system was inconsistent in reducing manganese. The equipment manufacturer continues to work on the ability of the system to reduce manganese concentrations.

The kitchen sink RO membrane provided excellent reductions of most parameters, including manganese and other inorganic parameters such as hardness and total dissolved solids.

The UV disinfection unit was originally installed before the softener and became ineffective due to a build-up of calcium scale. The UV lamp provided effective disinfection after it was replaced and reinstalled after the water softener.

The raw groundwater did not contain coliform bacteria, which are indicators of the presence of biological organisms. Coliforms were detected in the sand and BAC filters, which is not surprising as these are not sealed units. However, coliforms were generally not detected or were found at very low levels after the water had passed through the RO membrane.

WHAT DID IT COST AND HOW LONG DID IT LAST?

Each treatment system was capable of supplying all household water for one dwelling, and at one site, the system was actually able to supply two households with all domestic water needs, including drinking and cooking water (a total volume of 1,700 L/day or 380 gallons per day). The cost was about $7,000, which included the sand and BAC filter, storage tank and kitchen sink RO unit as well as miscellaneous components such as an air pump. Add-on equipment such as a softener and disinfection unit cost an additional $3,000. Both ground water supplies required softening for washing and bathing purposes to reduce the calcium and magnesium which create hardness.

The systems at both sites have operated for two years. One site required carbon replacement after about 18 months, as the filter became clogged with calcium. Improved operating procedures such as backwashing or acid regeneration may solve this problem.

An add-on softener will reduce hardness. The ultraviolet light (UV) was added after the softener to disinfect the ground water

WHAT OPERATION & MAINTENANCE IS REQUIRED FOR BIOLOGICAL SYSTEMS?

- The biological treatment system is easy to operate and has a long life expectancy. Good operation and maintenance is essential to ensure it works well.
- An appropriate air supply system is needed to supply oxygen to the microbes in the BAC filter.
- The slow sand filter must be backwashed manually using air and water to remove the accumulated material and prevent loss of productivity. Backwashing is required about once every two to eight weeks or after approximately 30,000 L to 40,000 L (6,000 to 9,000 gallons) of water.

- Backwashing of the BAC filter with air and water is required about every two to five months, or after treating approximately 40,000 L to 60,000 L (9,000 to 13,000 gallons) of water. More frequent backwashing may be needed if the filter begins to plug.
- Acid regeneration of calcified media may be necessary, but proper procedures must be followed.

ARE THERE ANY LIMITATIONS TO USING BIOLOGICAL WATER TREATMENT?

- Biological treatment converts ammonium to nitrate. If the source water is high in nitrates, then biological treatment may increase nitrates to a level that exceeds Canadian Drinking Water Quality Guidelines. It should be noted that an RO unit would reduce nitrates to a safe level.
- Biological treatment of water is not designed to reduce levels of total dissolved solids, hardness, calcium, magnesium, sodium or sulphate, all of which are also common problems in ground water.
- Iron may break through the sand filter if it is used beyond its capabilities.
- Calcium may build up in the carbon filter. On the one ground water source where this occurred, the carbon was replaced and the backwashing frequency was adjusted to once every two to three months. Acid regeneration of the carbon media may eventually be required as a maintenance procedure.
- As with other water treatment systems, the treated water must be disinfected (through methods such as chlorination, membrane filtration, or distillation for example) before the water is used for drinking and cooking.

THE BIGGER PICTURE

The biological treatment systems that were studied were effective multiple-barrier treatment systems for ground water supplies with iron, arsenic and dissolved organic carbon problems. In combination with a softener and kitchen sink reverse osmosis unit, the systems delivered high quality domestic water and safe drinking and cooking water for individual farms. Biological treatment processes may prove to be valuable for treating ground water supplies for individuals or communities. Both producers involved in the study were satisfied with the treatment provided by the biological system.

Further study of biological treatment systems is however needed:

- to determine how much treated water the system is capable of delivering (flow rates);
- to determine long-term performance of the systems; and
- to deal with iron breakthrough and calcium build-up. The system manufacturer is continuing to research ways to improve the system's manganese removal rates.

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

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