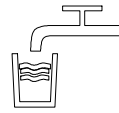


Demonstration Project Summary

May 2002

Drinking Water Assistance Program
for Small Systems (DWAP)



a program
of the
Montana University System
Water Center

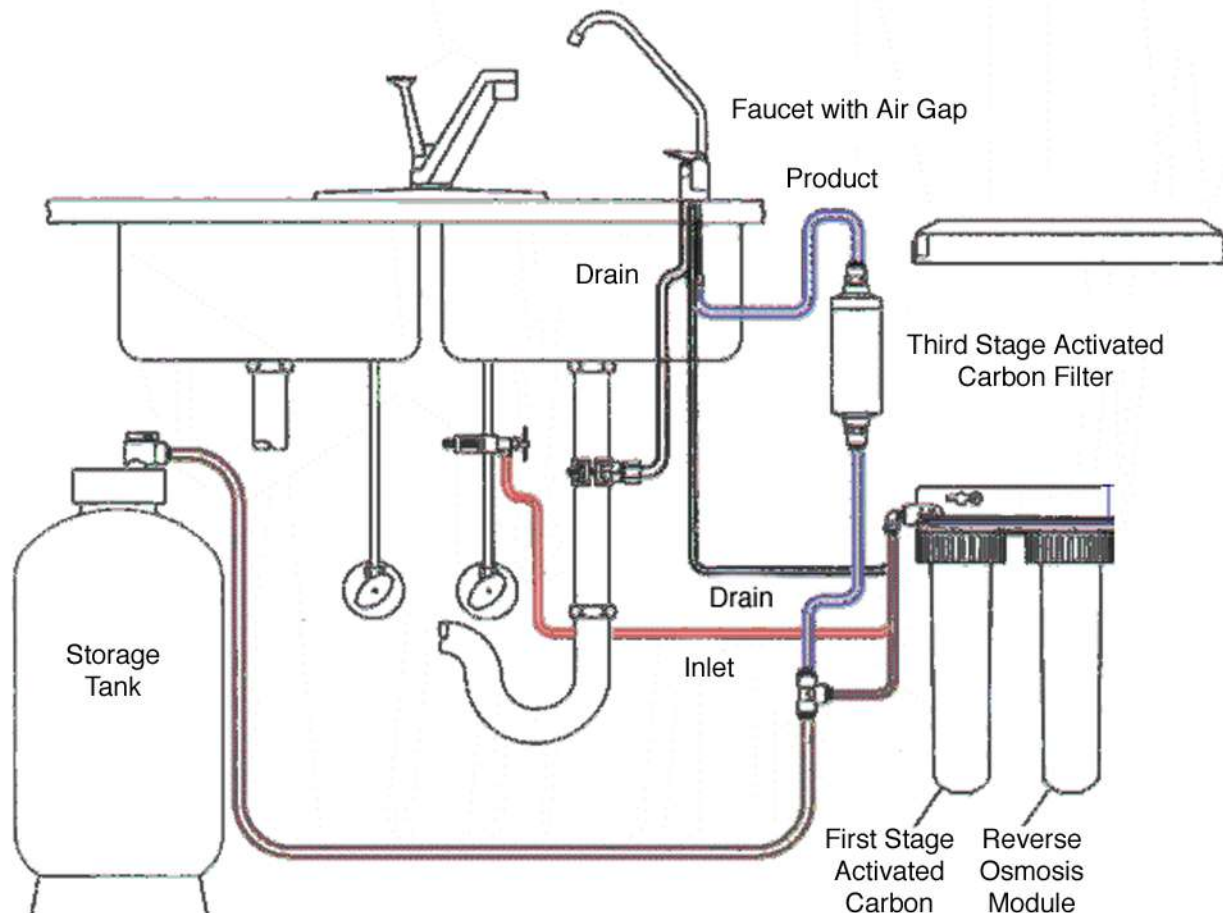
Point-of-Use Reverse Osmosis Treatment for Removal of Arsenic from Drinking Water

Abstract

The purpose of this project was to evaluate point-of-use reverse osmosis treatment (POU-RO) to remove arsenic from the groundwater supplies of small communities in North Dakota. Two POU-RO systems

were initially tested in the laboratory to determine how well they remove arsenic from water. Next, a pilot test was conducted in a small North Dakota community served by a public water system that will have difficulty meeting the 10 ppb MCL for arsenic. Twenty-one POU-RO

Figure 1. POU-RO Installation Configuration in a Household Kitchen



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systems were installed in homes and other buildings, then monitored for arsenic removal for six months. In addition to arsenic removal, questions about the management, maintenance, monitoring, and cost of the systems were also addressed by this research.

The Technology

The point-of-use reverse osmosis systems examined in this study had four stages: a carbon-block pre-filter, a spiral-wound RO membrane unit, a pressurized storage tank, and a carbon-block post-filter. In practice these units are installed beneath a kitchen sink, where they are plumbed into the cold water line (*Figure 1*). They have a separate tap and a backflow prevention device. Depending on the source water quality and pressure, centralized pre-oxidation treatment may be needed, and some

household installations may require a permeate re-pressurization pump.

Laboratory Tests

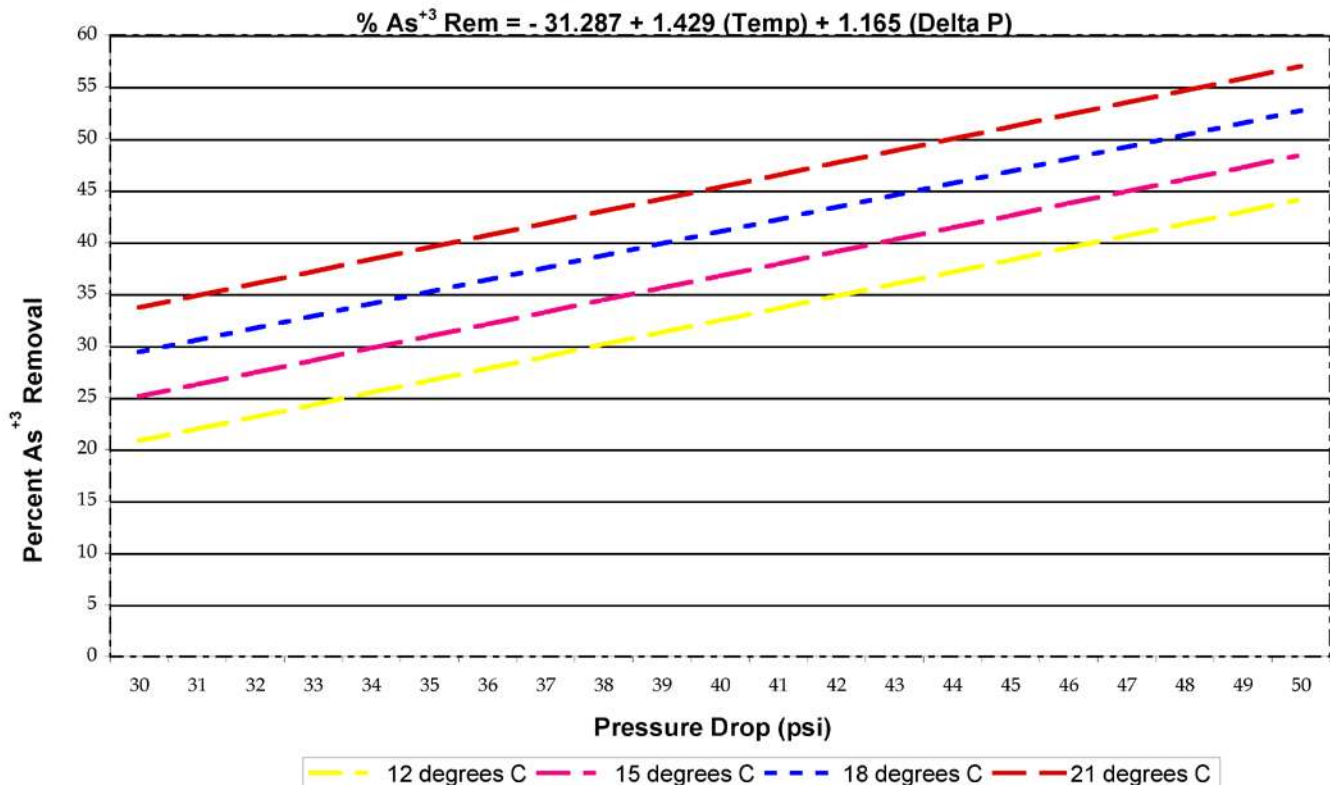
A series of laboratory tests was conducted to evaluate two different RO membranes.

Since the removal of As^{+3} is much more variable than As^{+5} in reverse osmosis, the main focus of these tests was to evaluate As^{+3} removal. The feed water used for the tests was City of Grand Forks tap water spiked with enough As^{+3} to achieve a concentration of approximately 20 ppb.

The pressure, temperature, and pH of the feed water were varied to determine their effects on arsenic removal.

As expected, a larger pressure drop across the membrane and higher water temperature produced greater percent

Figure 2. Desal-18 Percent As^{+3} Removal vs. Temperature and Pressure Drop Across the Membrane



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water recovery and water production for both membranes (*Figure 2*). A larger pressure drop also produced greater As^{+3} removal for both membranes. However, with respect to water temperature and percent As^{+3} removal, the two membranes appeared to behave differently. The Filmtec[®] membrane achieved greater As^{+3} removal at lower water temperatures, while the Desal[®] membrane produced greater As^{+3} removal at higher water temperatures.

In general, the Filmtec[®] membrane appeared to perform slightly better than the Desal[®] membrane with respect to As^{+3} removal, water production, and water recovery.

Field Pilot Test

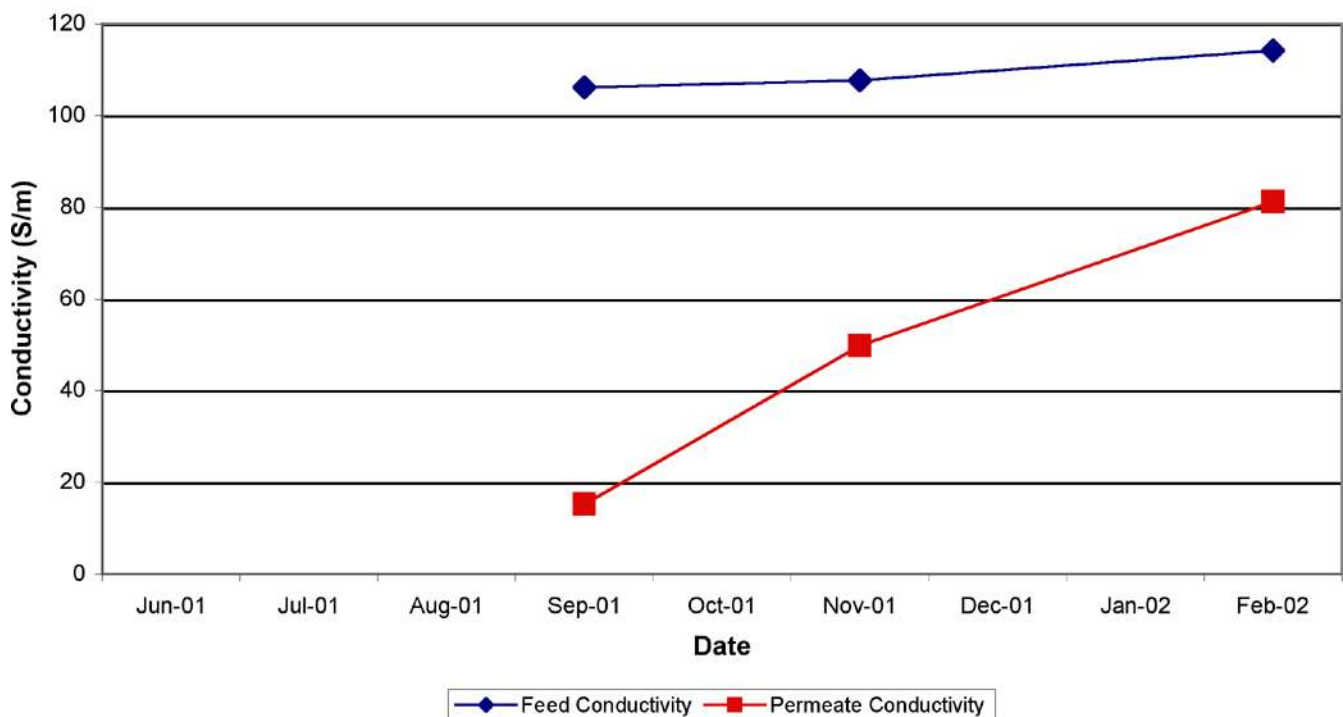
The second task of the study was to conduct an arsenic treatment pilot test. This was done between September 2001 and February 2002 in Oakes, North Dakota. The City of Oakes is a predominantly

residential community located in southeast North Dakota, that has a population of about 1760. Oakes drinking water is supplied by three wells. Typical arsenic concentrations in raw water pumped from these wells range from 10 to 21 ppb. The water delivered to residences in Oakes is not disinfected or treated in any way.

Typical total-arsenic removal of the field-installed RO units was better than 90%. Almost none of the POU-RO permeate samples collected from the 21 units contained measurable amounts of arsenic (i.e., total arsenic concentration > 1 ppb).

Some of the POU-RO systems equipped with Desal[®] membranes did exhibit signs of reduced membrane performance over the monitoring period. However, no loss of performance was indicated for any of the POU-RO systems equipped with Filmtec[®] membranes over the monitoring period. Reduced membrane performance was indicated by a gradual increase in the

Figure 3. POU-RO Conductivity Data (Membrane Degradation Indicated)



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permeate conductivity and arsenic concentration over time. The only functional difference between the systems with Filmtec® membranes and the systems with Desal® membranes was that the latter were equipped with permeate pumps. Whether the presence of the permeate pump somehow contributed to observed loss of membrane function is not known.

Management, Maintenance, Monitoring and Cost of POU-RO Systems

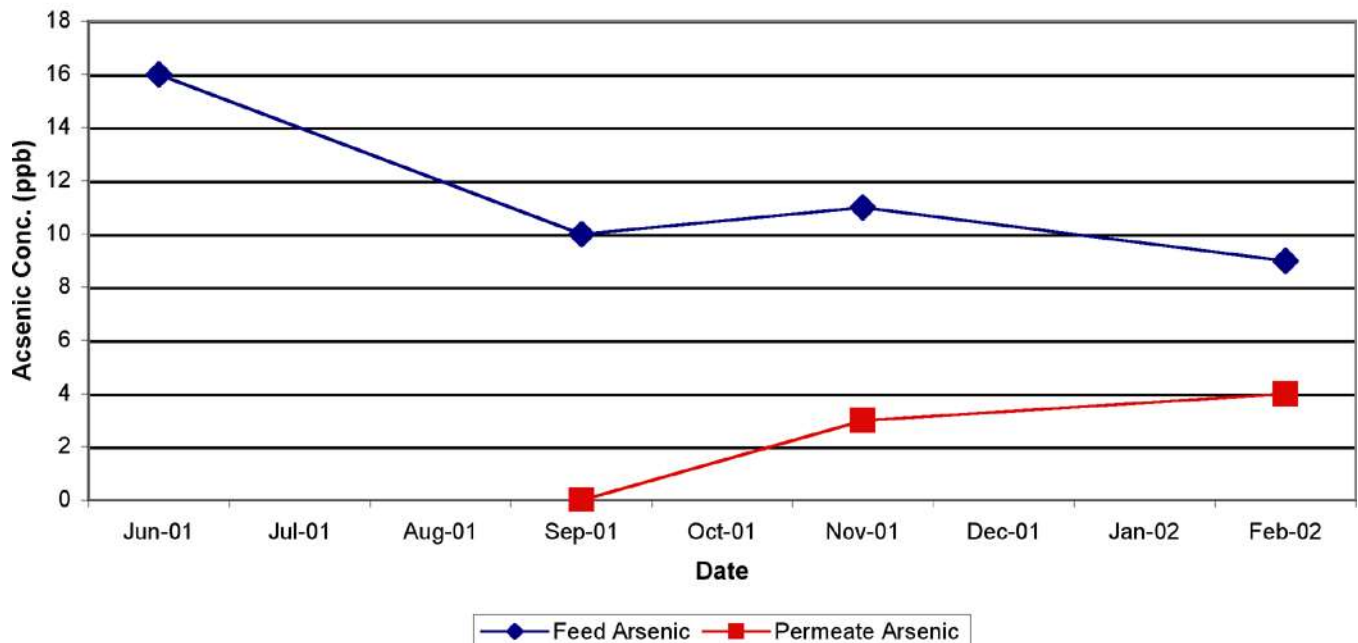
The governing body of the community in which POU-RO systems are to be used must establish a legal framework for controlling the systems. This will require passing and enforcing an ordinance that covers access for managing the systems, among other things.

The simplest approach to monitoring the performance of POU-RO systems is continuous dissolved solids measurement. When a POU-RO system is operating

properly, it will usually remove 90 to 95 percent of the dissolved solids from the water. The actual percentage removal of dissolved solids will vary depending on the type of dissolved solids in the water, the pH of the water, the type and age of membrane in the system, the temperature of the water, and the pressure of the water supplied to the system. Since the dissolved solids concentration is directly proportional to the conductivity of the water, monitoring can be conveniently accomplished by measuring conductivity.

The pilot test performed in Oakes indicated that conductivity measurements are an effective indicator of arsenic removal for that specific application. The data collected from the systems where the membranes had begun to fail indicate that (1) failure of the membranes is a very gradual process and (2) that the conductivity of the permeate can increase to about 50% of the conductivity of the feed water before any significant amounts of arsenic begin

**Figure 4. POU-RO Arsenic Data
(Membrane Degradation Indicated)**



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to pass through into the permeate (Figures 3 and 4). Thus, if permeate conductivity is monitored continuously and the alarm is set to sound when the permeate conductivity exceeds 15% of the feed water conductivity, there should be adequate warning to prevent arsenic breakthrough and protect the consumers. Of course this assumes that a maintenance worker is available to promptly respond to the alarm and replace the RO membrane if necessary.

A properly operating POU-RO system should not require a great deal of maintenance. However the following routine maintenance procedures will probably be needed:

- *changing carbon filters once each year,*
- *checking the conductivity monitoring device once each year,*
- *disinfecting the entire system once each year, and*
- *changing the RO membrane module when necessary.*

Proper installation and maintenance will be required for successful operation of a community water system using POU-RO systems. In order to provide proper

for managing the systems, among other things.

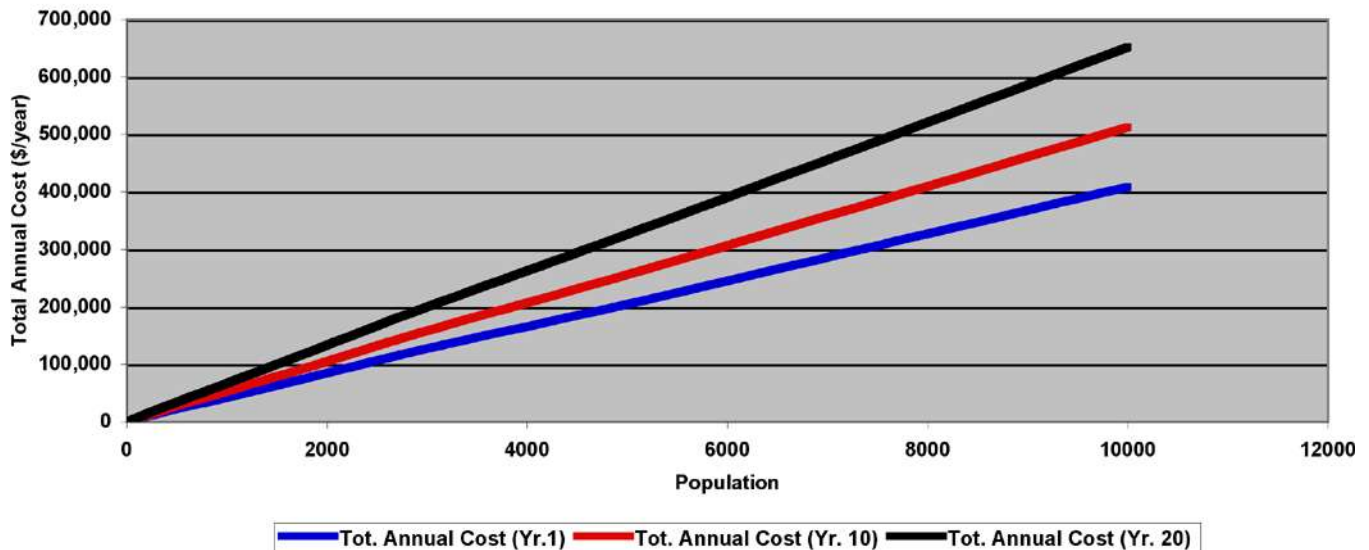
The simplest approach to monitoring the performance of POU-RO systems is continuous dissolved solids measurement.

When a POU-RO system is operating properly, it will usually remove 90 to 95 percent of the dissolved solids from the water. The

- *purchasing the POU-RO systems*
- *installing the POU-RO systems,*
- *maintaining the POU-RO systems, and*
- *keeping records.*

In this study the investigators developed basic cost curves that can be used for very rough cost comparisons between centralized treatment and POU-RO, for small systems that must treat to remove arsenic (Figure 5).

Figure 5. Total Annual Cost for POU-RO Systems VS. Population Served



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