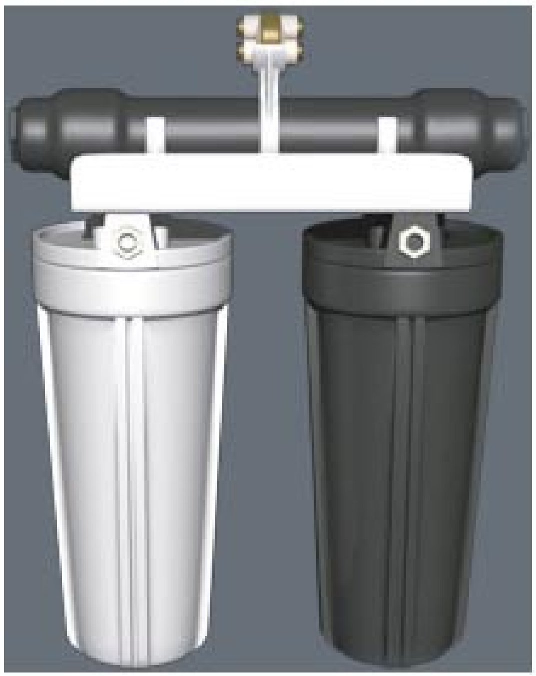
# Point-Of-Use Reverse Osmosis

## Complying With Arsenic Regulations in Small Drinking Water Systems



*** Current as of January of 2004**

# Table of Contents

## 1-INTRODUCTION

Using POU-RO for arsenic compliance



## 2-LAWS & REGULATIONS

Legislative history and outlook



## 3-DECIDING WHETHER TO USE IT

Evaluation and pilot testing

# Table of Contents

# Table of Contents

## 7-ESTIMATED COSTS

Considering all the factors

TABLE OF CONTENTS



SUMMARY

The purpose of this training is to familiarize engineers and other water treatment professionals with the use of centrally-managed, point-of-use reverse osmosis (POU-RO) to comply with the arsenic drinking water regulations.

Recent legislation permits the use of POU-RO units for drinking water treatment in small communities under certain conditions. These units are quite effective for removing arsenic from water, but there are several management and regulatory issues that must be resolved before they can be used extensively.

KEY CONCEPTS

Since POU-RO is a new compliance technology for small communities, it is important to understand its use and potential benefits.  Hopefully, by understanding the technology, it can be implemented more quickly. This training module will help you:

1. understand the role of the engineer in implementing point-of-use reverse osmosis treatment for a small water system,
2. recognize when point-of-use reverse osmosis treatment can be a cost-effective alternative to central treatment, and
3. design centrally-managed POU-RO treatment systems.

Other units will provide "Key Questions" to help you focus your study. Unit quizzes will test your knowledge of these concepts.

# 1.1 - How To Use This Program

More About This Program

This is a printable version of the POU-RO training module. You will see references throughout this document that apply only to the interactive version of the program. We encourage you to use this document as a reference to the interactive version, not as a substitute.

A variety of instructional methods are used in the online and CD-ROM versions of this training tool. Photos, illustrations and simulations will enhance your learning experience. Here's how to navigate these features:

Place your mouse cursor over the green orb labeled "More About This Program." Note the caption at the bottom of the screen. Click this orb now to learn about the navigational short-cuts available in this program. The orbs on the dial at left take you to other sections within your current unit and display the section title at the bottom of the screen. Clicking on colored text will call up additional resources:

- **Red text: Opens a document associated with the program**
- Blue text: Takes you to websites or e-mails
- **Yellow text: Brings up more information about that text**

As you work through this program, your progress is tracked and is available for viewing or printing at any time by clicking on the LOGBOOK tab (located above). When you leave the program, you will be asked to save your work. This will store your tracked progress on your computer and make it available when you return.

If at any time you have a question about how to do something, click on the context-sensitive help button (the question mark in the lower left corner). You may also click the HELP tab above to search through a list of help topics. For other questions and inquiries regarding the program, please contact us at:

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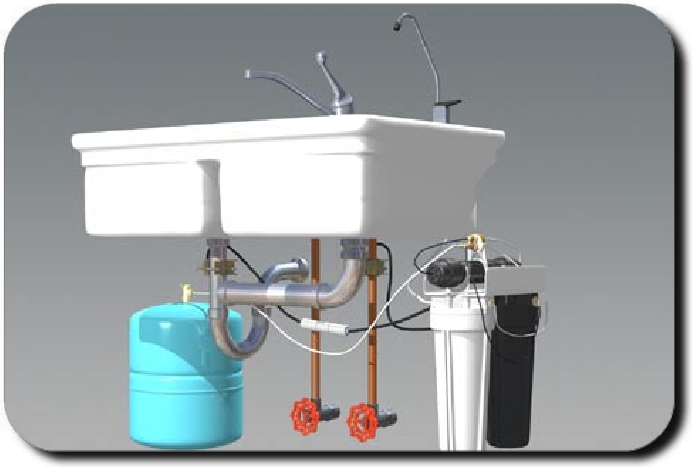
# 1.2 - Safe Drinking Water Act

Reverse Osmosis



Recent amendments to the Safe Drinking Water Act allow small communities to use centrally-managed, Point-Of-Use (POU) water treatment units to comply with the national primary drinking water regulations. Prior to the amendments, using POU units to treat drinking water for regulated contaminants was not allowed. The reason for the change was to enable small communities to use POU treatment in situations where they could produce safe drinking water at substantially lower costs than conventional central treatment. As a result of this change, the United States Environmental Protection Agency (EPA) has included several forms of POU treatment on its lists of small system compliance technologies.

Point-Of-Use Reverse Osmosis (POU-RO) is a specific compliance technology that has been approved for small systems (i.e., public water systems serving not more than 10,000 persons). These units are installed on the customer's premises to treat water at the point of delivery. The reverse osmosis process uses a semi-permeable membrane to remove dissolved constituents from water. POU-RO equipment is widely available, relatively inexpensive, and usually produces high quality product water.

POU-RO units are usually used to treat water at a single faucet and to provide water for cooking and drinking. Thus water from other faucets in the building will not be similarly treated. However, since consumption is the major route of exposure to arsenic, these units can provide effective protection for arsenic if consumers are properly educated about their use.

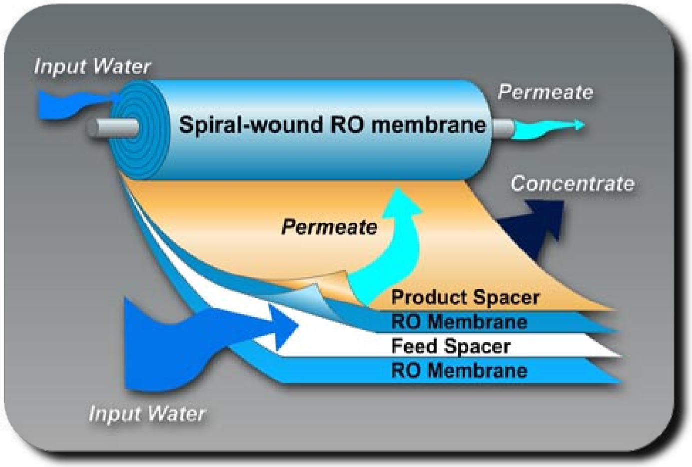
Currently, the EPA suggests that POU-RO should be considered for use in small communities when central treatment processes are not technically feasible or would be significantly more expensive to implement than POU-RO. The EPA estimates that 4 to 7 percent of communities with a population less than 500 persons requiring treatment to comply with the maximum contaminant level for arsenic (i.e., 0.010 mg/L) will use POU devices. However, the Arsenic Cost Working Group of the National Drinking Water Advisory Council has recommended broader usage of POU units for small communities if new studies indicate that they are cost-effective and practical.

# 1.3 - POU-RO Acceptance

Even though acceptance of POU-RO may be slow to come about, there are reasons to believe that eventually it will happen:

1. it works,
2. it produces high quality drinking water,
3. drinking water produced with POU-RO is relatively inexpensive, and
4. in certain situations, POU treatment may be more cost effective than central treatment.

**How POU-RO Removes Arsenic**




## 1. POU-RO works.

POU-RO devices have been demonstrated to effectively remove arsenic and other contaminants from drinking water. The best removal occurs when the arsenic is in the +5 oxidation state. POU-RO can be used to treat ground waters with a wide range of chemical compositions. POU-RO can also be used to treat surface waters, but RO membranes are susceptible to fouling from the fine silt present in some surface waters. On average the life span of an RO membrane is two to five years.

## 2. POU-RO produces high quality drinking water.

POU-RO devices remove many of the chemicals that cause taste and odor problems in water. Water produced by a POU-RO is similar to many of the bottled waters sold in stores.

## 3. Producing drinking water with POU-RO is relatively inexpensive.

It is not very expensive to buy and install a POU-RO unit in the home. A good quality unit can be purchased for $300 to $400. The most significant costs associated with a centrally-managed POU-RO system are for managing, maintaining, and monitoring the devices. If a sensible regulatory policy is developed for POU treatment, it should be possible to operate such a system at a reasonable cost.

## 4. In certain situations, POU may be less costly than central treatment.

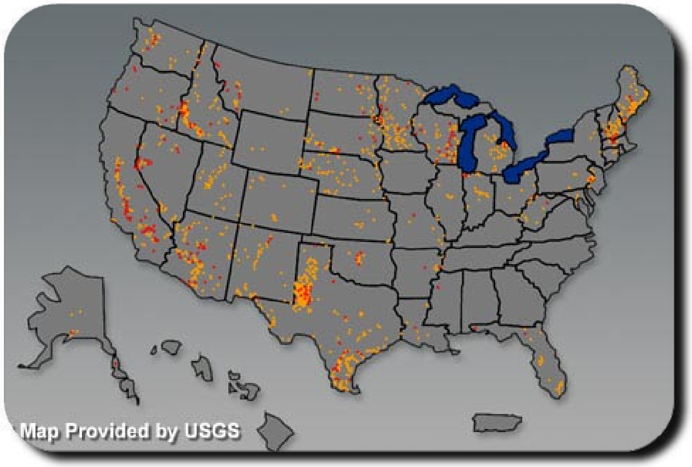
As drinking water regulations become stricter, it may be possible to reduce costs by focusing treatment on water that actually impacts human health. This is possible with POU units, because usually only water needed for cooking and drinking is treated. Under this scenario, the amount of water that would have to be treated to remove certain contaminants could be reduced by a factor of fifty or more. In small rural communities where large amounts of water are used for irrigation and other commercial activities, POU-based treatment could be significantly less expensive than central treatment. Another situation where POU treatment might be cost effective is when significant changes would have to be made to the distribution system to accommodate central treatment.

# 1.4 - Acceptance Has Been Slow

Even though POU-RO has been shown to be quite effective for removing arsenic from water, these devices are not being widely used for compliance with the drinking water regulations. There are several reasons why acceptance of POU units for compliance treatment has been slow.

1. POU treatment is unconventional.
2. There are unresolved management issues.
3. States have not developed regulatory procedures.
4. Engineers are not familiar with POU treatment.
5. Companies that can manage POU systems are not available in all areas.
6. Cost of POU treatment is not well understood.

**Acceptance Takes Time**




## 1. POU treatment is unconventional.

POU treatment is different from conventional central treatment because POU devices are installed at the customer's building and water is treated after it enters the building. This is fundamentally different from the way that conventional treatment systems operate, where all of the water is treated before it enters the distribution system. Some communities and/or regulatory agencies may believe that locating the treatment device in the home will limit their control over the treatment process and their ability to provide safe water.

## 2. There are unresolved management issues.

The law states that POU units must be centrally-managed by the public water system or by a company working for the public water system to ensure proper operation, maintenance, and compliance with the regulations. This makes sense, but there are some unresolved issues that impact how POU-based systems would be managed. For example, it will be necessary to gain access to homes in the community for installation and maintenance of the devices. If it is not possible to gain access to all of the residences in the community, is it acceptable to have less than 100% participation? Another issue deals with monitoring the quality of the treated water. How exactly is this to be done for POU units located in residences? Answers to these issues are being investigated at the present time (January 2004).

## 3. States have not developed regulatory procedures.

Even though federal regulations permit the use of POU units, state regulatory agencies have not as yet developed policies for dealing with small community water systems that may want to use them. At present, state regulatory agencies simply do not have the necessary experience to develop policies for regulating POU water treatment systems.

# 1.4 - Acceptance Has Been Slow Continued ...

**4. Engineers are not familiar with POU treatment.**

Most engineers who design drinking water treatment systems are not familiar with the use of POU units for applications where regulatory compliance must be achieved. For this reason, it may be difficult to get engineers to consider using POU units as an alternative to conventional central treatment.

**5. Companies that deal with POU systems are not in all areas.**

There are many companies that sell or lease POU water treatment devices. However, few of these have experience supplying, managing, and maintaining POU-based systems where regulatory compliance must be achieved. Developing companies that have this type of experience will be very important for implementing POU-based treatment systems.

**6. Cost of POU treatment is not well understood.**

Several management and regulatory issues that impact the cost of using POU units for compliance treatment have not yet been worked out. Until these issues have been resolved, it is difficult to accurately estimate costs for POU-based treatment systems.

Another reason is that since POU treatment will initially be difficult to implement, many regulators view it as a treatment method of last resort for a few very small communities. These are communities that may have difficulty using conventional central treatment to comply with the new arsenic regulations. Since these communities are typically the ones that have the least money and expertise to deal with their water treatment needs, they will probably put off implementing treatment until absolutely necessary. Considering the available exemptions, these communities may not have to comply with the arsenic regulations until January of 2015. However, keep in mind that exemptions are not easily given and will only be available to the few systems that have a true need.

# 1.5 - Scope of Engineering Work

Engineers have an important role to play in implementing POU treatment systems. An engineering firm should perform the following tasks and activities to develop a community implementation plan for a POU-RO based water treatment system:

1. Evaluate the needs of the community.
2. Develop a treatment system implementation plan for the community.
3. Work with the community to obtain the necessary permits for a POU-RO treatment system.

**Implementation Plan Checklist**


**1. Evaluate the needs of the community.**

Task 1 - Determine how many and what type of POU-RO units will be installed in residences and other buildings in the community.

Task 2 - Determine whether any raw water pretreatment and/or other preparatory work is needed for the POU-RO system.

Task 3 - Develop a plan for pilot testing POU-RO units in the community.

**2. Develop a treatment system implementation plan for the community.**

Task 1 - Determine how necessary equipment will be obtained. Evaluate options for either purchasing or leasing the equipment.

Task 2 - Develop plans for installing, maintaining, and monitoring the equipment. Evaluate options for having the public water system do the work or hiring a service company to do the work.

Task 3 - Develop an administrative/management plan for the treatment system.

# 1.5 - Scope of Engineering Work Continued ...

**3. Work with the community to obtain regulatory permits and funding for the POU-RO treatment system.**

Task 1 - Help to prepare a model ordinance for the community to implement the POU-RO treatment system.

Task 2 - Identify potential funding sources for implementation of the POU-RO treatment system and help the community apply for funds.

Task 3 - Work with state and local regulatory agencies to obtain the necessary permits for a POU-RO treatment system.

# 1.6 - Expand & Test Your Knowledge

Several excellent references are available that contain additional information about how to implement a POU-RO treatment system. If you have an internet connection, go to these sites for the most current information from EPA:

The Arsenic Treatment Technology Evaluation Handbook for Small Systems (may take awhile to download) from http://www.epa.gov/safewater/smallsys/arsenic_treatment_handbook_lo.pdf.

Guidance for Implementing a Point-of-Use Treatment Strategy for Compliance with the Safe Drinking Water Act is available at http://www.epa.gov/safewater/ars/implement.html.

A printable version of the program is available in PDF format (current as of January of 2004). **pou_ro_hard_copy.pdf**.

## Test Your Knowledge

TABLE OF CONTENTS



SUMMARY

Engineers should be aware of the legislative history and new regulations related to POU-RO treatment. Since POU-RO compliance standards were approved with 1996 amendments to the Safe Drinking Water Act, the controlling legislation is fairly recent. However, regulations in small community public water systems are still in the development stage. In order to plan a local POU-RO implementation, engineers will need to work closely with state regulatory agencies.

KEY QUESTIONS

1. What is the legal basis for the new arsenic regulations?
2. What current regulations control arsenic in drinking water?
3. What special regulations exist for small water systems?
4. What exemptions and variances are available to small systems faced with upgrading to meet arsenic regulations?
5. What special conditions must be met when POU units are used to treat water for regulatory compliance?

# 2.1 - Relevant Laws

Engineers should be aware of the background legislation and new regulations related to POU-RO treatment. Since the use of POU-RO units for compliance with drinking water standards was approved in the 1996 amendments to the Safe Drinking Water Act, the controlling legislation is fairly recent. Further, regulations for implementing POU-RO treatment by small community public water systems are in the process of being developed. In order to effectively develop plans for implementing POU-RO treatment, engineers will have to work with state regulatory agencies to apply the new regulations.

The 1996 Safe Drinking Water Act Amendments (SDWA) authorized EPA to institute a final drinking water rule for arsenic. An important objective of this rule was to set a new maximum contaminant level (MCL) for arsenic to adequately protect the public health. When the 1996 amendments were being written, there was concern that small drinking water systems would have difficulty complying with the new regulations. In particular, lawmakers anticipated that lowering the arsenic MCL would cause a significant financial burden on many small systems. Therefore, 1996 amendments also included a number of provisions specifically intended to help minimize the impact of new regulations on small systems.

The major features of the 1996 SDWA Amendments that affect small drinking water systems are contained in the following Sections of Title 42 of the U.S. Code:

TITLE 42 > CHAPTER 6A > SUBCHAPTER XII > Part B - Public Water Systems

Sec. 300g-1. National drinking water regulations
Sec. 300g-4. Variances
Sec. 300g-5. Exemptions
Sec. 300g-8. Operator certification
Sec. 300g-9. Capacity development

# 2.2 - U.S. Code

FAQs With Sam

### For Small Drinking Water Systems

The U.S. Code lists the requirements of the Safe Drinking Water Act relating to new technologies used in small drinking water systems. In Section 300g-1 of Title 42, U.S. Code states that when EPA develops drinking water regulations that establish an MCL, they shall list the technologies, treatment techniques, and other means which are feasible for meeting the MCL.

For small drinking water systems, the code includes the following requirements:

- The list of technologies shall include any technologies, treatment techniques, and other means that are affordable, as determined by the EPA in consultation with the states, and that achieves compliance with the MCL.

- Distinctions will be made as to which technologies are affordable for various sized small systems (i.e., 10,000 to 3,300; 3,300 to 500; and 500 to 25, population served).

- Technologies that can be used shall include packaged or modular systems and point-of-entry or point-of-use treatment units.

# 2.2 - U.S. Code Continued ...

**For Point-Of-Use Treatment Systems**

For POU treatment units, the code includes the following requirements:

- The units "shall be owned, controlled and maintained by the public water system or by a person under contract with the public water system to ensure proper operation, maintenance and compliance with the maximum contaminant level or treatment technique."
- The units "must be equipped with mechanical warnings to ensure that customers are automatically notified of operational problems."
- "If the American National Standards Institute has issued product standards applicable to a specific type of point-of-entry or point-of-use treatment unit, the individual units shall not be accepted for compliance with a maximum contaminant level or treatment technique requirement unless they are independently certified in accordance with such standards."

For point-of-use and point-of-entry products, these products will be certified to one of the following ANSI Standards:

- NSF/ANSI Standard 53 – Drinking Water Treatment Units - Health effects
- NSF/ANSI Standard 58 – Reverse osmosis drinking water treatment systems

For a list of certified systems:

http://www.nsf.org/Certified/DWTU/
http://www.ul.com/
http://www.wqa.org/

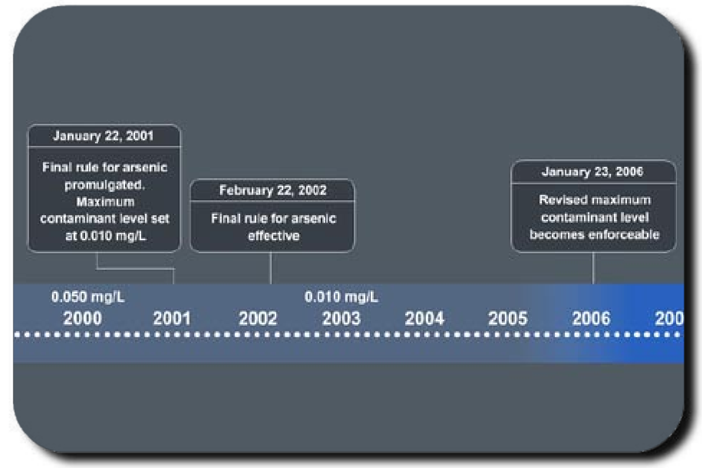
The full text of the relevant U.S. Code can be found at http://www.law.cornell.edu/uscode. You can search the U.S. Code at this site by Title and Section.

# 2.3 - Final Arsenic Rule

The EPA published a final arsenic rule in the Federal Register on January 22, 2001 (Volume 22, 2001). In this rule, EPA set an enforceable MCL for arsenic of 0.010 mg/L. This MCL will apply to community water systems and non-transient, non-community water systems. The final arsenic rule was effective on January 22, 2001 and the compliance date for the MCL is January 23, 2006.

The arsenic rule lists Best Available Technologies (BAT) for removing arsenic from drinking water. Other tables are provided in the rule listing Small System Compliance Technologies (SSCT). These tables list POU-RO as an affordable compliance technology for all sizes of small systems (i.e., communities with populations ranging from 25 to 10,000).

### Timeline For Final Arsenic Rule




The EPA has published a detailed guidance document entitled "Implementation Guidance for the Arsenic Rule." The document is available on the Arsenic Rule Implementation website at : http://www.epa.gov/safewater/ars/implement.html.

A useful quick reference guide to the arsenic rule is available at http://www.epa.gov/ogwdw/ars/quickguide.pdf.

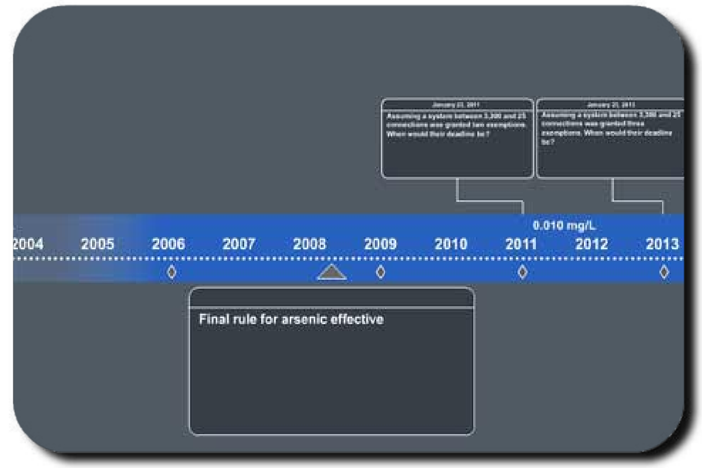
# 2.4 - Compliance Variances and Technologies

In the final arsenic rule, EPA determined that affordable technologies (SSCT) exist for all small system size categories. For this reason, EPA did not identify variance technologies for any size category or source water quality combination. Therefore, small system variances are not allowed for the final arsenic MCL.

Small systems may have installed or agreed to install a BAT treatment system, but due to source water quality cannot comply with the MCL. These small systems may still be eligible for a general variance. However, if a small community intends to use POU technology to meet the arsenic MCL, it may not be eligible for variance because POU technology is only listed as a small system compliance technology and not a BAT.

# 2.5 - MCL Compliance Date Exemptions

**Check Your Knowledge of Compliance Dates**




Section 300g-5 of Title 42 of the U.S. Code states that "a state which has primary enforcement responsibility may exempt any public water system within the state's jurisdiction from any requirement respecting an MCL or any treatment technique requirement, or from both, of an applicable national primary drinking water regulation."

As pertains to the arsenic rule, a public water system can receive an exemption of up to three years beyond the January 23, 2006 compliance date under the proper circumstances.

In the case of a system that serves a population of 3,300 or less which needs financial assistance for the necessary improvements, the initial three-year exemption can be renewed for one or more additional two-year terms. The two-year extensions cannot exceed a total of six years. Thus for a system serving 3,300 or less, the maximum extension beyond January 23, 2006 for compliance with the arsenic MCL is nine years.

Based on the allowable exemptions and assuming that all possible exemptions were granted, the following compliance deadlines apply for the arsenic MCL:

- For a small system serving a population between 10,000 and 3,300, the deadline would be January 23, 2009. (Any size system is eligible for an initial 3-yr exemption.)

- For a small system serving a population between 3,300 and 25, the deadline (with all possible exemptions taken) would be January 23, 2015.

Section 300g-5 of the U.S. Code indicates that an exemption may be granted under the following conditions:

- Due to compelling factors (e.g., economic factors), the public water system is unable to comply with such MCL or to implement measures to develop an alternative source of water supply.

- The public water system was in operation on the effective date of such MCL or for a system that was not in operation by that date only if no reasonable alternative source of drinking water is available to such new system.

# 2.5 - MCL Compliance Date Exemptions Continued ...

- The granting of exemption will not result in an unreasonable risk to health and management, or restructuring changes cannot reasonably be made that will result in compliance with this subchapter, or, if compliance cannot be achieved, improve the quality of the drinking water.

In addition, no exemption shall be granted unless the public water system establishes the following:

- The system cannot meet the standard without capital improvements which cannot be completed prior to the compliance date.
- If the system needs financial assistance for necessary improvements, it has entered into an agreement to obtain such financial assistance.
- The system has entered into an enforceable agreement to become a part of a regional public water system, and it is taking all practicable steps to meet the standard.

Exemptions ARE NOT widely used by states to extend the compliance period. Check with appropriate state regulatory agencies, well in advance, about the possibility of obtaining exemptions from the implementation deadline. An excellent reference on exemptions and other small systems arsenic implementation can be found at http://www.epa.gov/safewater/ars/congr_ars_mar_02.pdf.

## 2.6 - State Regulations


Establishing procedures by which states can regulate POU-based community water systems is a key requirement for their use. The federal government is in the process of working out the details of how POU systems can be used for compliance with drinking water regulations. At present, it appears that few if any states have developed a regulatory process specifically intended to deal with POU systems.

The State of Illinois has done some work to implement point-of-entry treatment for removal of radium from drinking water. Their regulatory approach was discussed at a conference conducted by NSF International (formerly, National Sanitation Foundation).

An outline of the presentation is available at http://www.nsf.org/cphe/pou/program.html.

# 2.7 - Expand & Test Your Knowledge

More information on arsenic rule implementation is available at http://www.epa.gov/safewater/arsenic.html.

## Test Your Knowledge

## TABLE OF CONTENTS



## SUMMARY

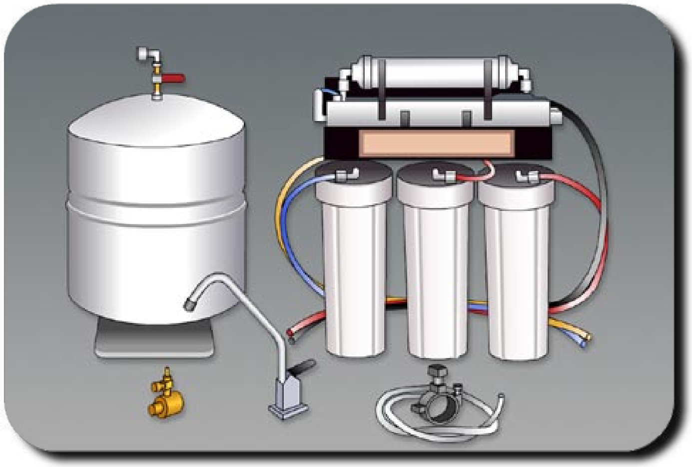
When performing a water treatment feasibility study, engineers must research the pros and cons of using POU treatment relative to local water characteristics. Alternative competing processes should be considered. Pilot testing allows a community to ensure that POU-RO treatment is the best solution, before purchase funds are committed.

## KEY QUESTIONS

1. When is POU-RO cheaper than conventional central treatment?
2. What are the requirements for using POU-RO to treat arsenic?
3. What preparation is needed for POU-RO system design?
4. How is a POU-RO pilot test conducted in a community?
5. What are the typical POU-RO operational characteristics?
6. What water quality characteristics can limit POU-RO use?
7. What pilot studies have been conducted for POU-RO treatment?

# 3.1 - Applications

To Use or Not To Use POU-RO



When engineers perform a water treatment feasibility study for a community, they must understand the advantages and disadvantages of POU-RO treatment in order to compare POU-RO with alternative competing processes.

The primary reason for using POU-RO treatment in a small community is to reduce the cost of supplying safe drinking water. Generally, POU-RO will be a cost-effective alternative to conventional centralized treatment only under certain conditions. The following scenarios provide examples of when it may be cost effective to use POU-RO treatment units for compliance with drinking water regulations:

- **Very small community water systems serving less than 200 residences** - Systems of this size may not have the financial resources and/or technical expertise to implement and maintain a conventional central treatment system.

- **Small community water systems where large amounts of water are used for purposes other than drinking water (i.e., agricultural or industrial)** - In situations like this, treating all water to meet the drinking water regulations might be impractical and even cause businesses to leave the community.

- **Small community water systems where central treatment would require a large expenditure for improving infrastructure** - For example, if a community had to install extensive piping to bring water to a central location for treatment, the cost might be prohibitive.

- **Small community water systems that are not ready to implement a long term solution** - If a community is not ready to make a decision on a long term solution to its compliance problem, a possible short term solution may be to lease POU-RO equipment and use it for five to ten years.

- **When a community has multiple water treatment needs** - Communities that have elevated concentrations of other water contaminants in addition to arsenic may find it possible to treat all of their water needs through the use of a single POU-RO.

The following conditions indicate situations when POU-RO treatment would not be permitted under the current regulations, or would not be technically feasible:

# 3.1 - Applications Continued ...

**Community water systems that serve more than 10,000 persons** - POU treatment is restricted to small community water systems.

- **Treating microbial contaminants** - Use of POU units for treatment of microbial contaminants is prohibited.

- **Treating contaminants where toxicity is acute or route of exposure is one other than ingestion** - POU units will not protect consumers if they can be exposed to a contaminant without drinking the water or if ingestion of even a small amount of water at an unprotected tap can cause illness.

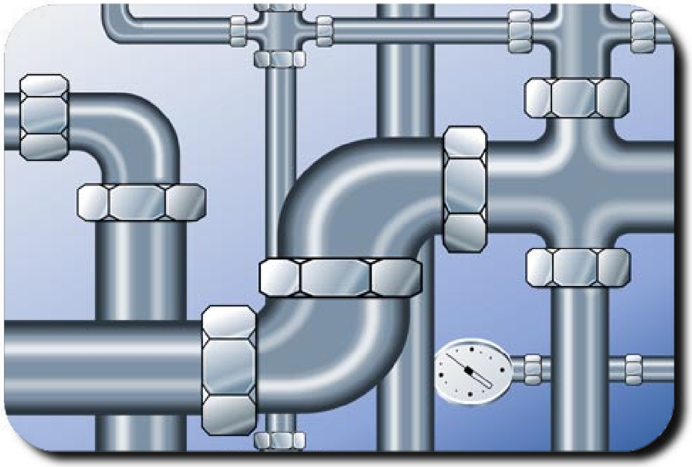
- **Treating ground water that contains high levels of certain minerals** - High levels of silica, barium, strontium, iron, manganese, or hardness can cause scaling, which degrades the performance of reverse osmosis membranes.

- **Treating water that promotes the growth of a biofilm** - Certain waters may promote growth of microbes in the reverse osmosis membrane. This can result in biofouling of the membrane which degrades performance.

- **Treating surface water that contains very fine suspended solids** - Even small amounts of very fine silt in water can plug a reverse osmosis membrane and degrade performance.

A description of centralized and point-of-use small systems arsenic treatment options is contained in the "Arsenic Treatment Technology Design Manual for Small Systems". This PDF can be found at http://www.epa.gov/safewater/smallsys/arsenic_treatment_handbook_lo.pdf.

# 3.2 - Drinking Water System Design Requirements



When POU-RO units are used to control arsenic and comply with the drinking water regulations, the following conditions must be met:

1. The arsenic concentration in treated water must not exceed a maximum contaminant level of 0.010 mg/L.

2. Enough water must be supplied to satisfy household demand for drinking and cooking usage.

3. POU-RO units shall be owned, controlled and maintained by the public water system or by a person under contract with the public water system.

4. POU-RO units must be equipped with a mechanical warning unit to ensure that customers are automatically notified of operational problems.

5. POU-RO units must be certified under ANSI/NSF 58 product standards.

# 3.3 - Preliminary System Design Activities

The following activities will be needed to design a POU-RO treatment system for a community:

- Since all waters are different, a pilot test is required to determine whether POU-RO treatment can effectively reduce the arsenic concentration below 0.010 mg/L in a cost effective manner.
- The water consumption habits of the community will have to be evaluated. This must include the needs of households, public and private buildings, and commercial business.
- A determination will have to be made as to how the public water system will be financed, owned, and managed.
- A determination will have to be made as to what legislation will be needed within the community to support the public water system.
- An analysis will have to be done to estimate equipment costs, maintenance costs, and management costs for the system.

## Preliminary System Design Tasks

# 3.4 - Pilot Testing Procedures

### Implementing a Pilot Test

Since all waters are different, pilot tests must be done on a public water system with specific POU-RO equipment to verify that the units will perform properly. Engineers will be involved in planning the pilot tests and evaluating test results.

A pilot test designed for a community water system should determine whether:

1. A specific POU-RO unit is capable of reducing the concentrations of all targeted contaminants below their maximum contaminant levels (MCL's).

2. The contaminant concentrations in the treated water are maintained consistently below their MCL's when the unit is operating properly.

3. The unit is compatible with the water being treated such that the unit will operate for at least one year without requiring extensive maintenance.

A convenient way to do a pilot test in a community is to install POU-RO units in some public buildings. The advantages are that the units will be available to the public so they can taste the water and that there will be guaranteed access to collect samples and monitor the systems. The units should be located at different points in the community to account for possible changes in water quality throughout the distribution system. In order to properly evaluate membrane performance and potential fouling, the units should be installed in a kitchen or employee lunchroom where they will be used on a daily basis.

Engineers should check with the appropriate state regulatory agency before conducting a pilot test to determine if the agency has any special requirements.

Ideally, a pilot test should run for at least one full year to account for seasonal variations in water quality and to detect possible operational problems such as premature scaling/fouling of the RO membrane. Water samples should be collected from each POU-RO unit at least once every other month. The presence of the conductivity alarm, otherwise known as a TDS monitor, is a cost efficient means to determine if the membrane is functioning properly. It is also helpful to have a totalizing flow meter that can be read whenever a sample is collected. Samples should be collected and tested for targeted contaminants using approved methods. Whenever a sample is taken, the water should also be tested for pH and conductivity at the point of collection.

# 3.4 - Pilot Testing Procedures Continued ...

If it is not practical to run a pilot test for a full year, it may be possible to shorten the test to a three to six month study. In certain cases, it may not be necessary to run a pilot test when there are current POU-RO test case study results available that adequately represent the water treatment conditions for a specific community.

A POU-RO unit being used to comply with drinking water standards must be equipped with a warning device to immediately alert the consumer of an operational problem. The main reason for having a warning device is to prevent contaminant concentrations from exceeding their MCL's. A conductivity sensor is probably the most cost-effective warning device to use for POU-RO units. In order to properly calibrate the alarm connected to the conductivity sensor, pilot test data will be needed to correlate the acceptable range of contaminant concentrations in the treated water with a corresponding range of conductivity measurements. Conductivity and arsenic data collected from the POU-RO units can be used to develop this correlation.

A pilot test can also be used to compare the performance of several different POU-RO units or different RO membrane modules. When this is done, at least two units (or membranes) of each type should be operated for the test.

**Checklist**

Before conducting a pilot test, use the following checklist to help design the test:

- Define the purpose of the study and the expected end product.
- Collect and evaluate the available data on the quality and quantity of the source water.
- Compile a list of POU-RO units and membrane modules to be considered for testing.
- Establish the treatment goals and the operational constraints for the test.
- Determine the length of the test.
- Determine who will perform the test and where the units will be located.
- Determine the locations and frequency of sampling and analysis.

# 3.5 - Operational Characteristics & Limitations

Some operational characteristics for POU-RO units (typical three-stage with a thin film composite membrane) are listed as follows:

Typical 3 Stage Parameters

Maximum total dissolved solids - approx. 2000 mg/L
Total dissolved solids removal - approx. 75 to 95 %
As+5 removal - approx. 95 %
Operation & storage water temperature - 40 to 100 degreesF
Operation water pressure - 40 to 115 psi
Treated water recovery - 25 % of feed water
Feed water pH limits - 4 to 10
Treated water Production - 10 to 20 gal/day
Storage tank capacity - 2 to 5 gal
Prefilter - Carbon block (sediment)
Postfilter - Carbon block (taste/odor)
Automatic filter shutoff - required
Filter performance monitor - required with warning light
Air gap - required

Reverse osmosis membranes can be damaged if minerals precipitate on the membrane surface. This is called scaling. Scaling can be a problem when the water contains constituents such as silica, barium, strontium, or calcium; which may precipitate under the proper conditions. Biofouling of membranes can occur when the water supports growth of microorganisms within the membrane module. Particulate fouling can occur when the water contains fine silt that is not removed by a prefilter and accumulates in the membrane module.

Scaling and fouling are not as common in single stage POU-RO units as in multiple stage commercial reverse osmosis systems because the minerals are not concentrated by the additional stages. Since it is hard to predict exactly how water composition will affect the reverse osmosis membrane, pilot testing is needed to determine whether scaling or fouling will be a problem.

There are several good computer programs available that predict the effect of water composition on operation of a reverse osmosis system. For example, the ROSA program is used to evaluate the performance of Filmtec membranes. The available programs are specifically designed for commercial reverse osmosis systems, but they can also be used to estimate the potential for scaling in POU-RO units. More information on the ROSA program can be found at http://www.dow.com/liquidseps/design/rosa.htm. Using a computer program to evaluate membrane performance is not a substitute for pilot testing.

# 3.6 - Treatment Case Studies

POU-RO units have been used to treat drinking water for removal of regulated contaminants in a number of communities. Featured below are two such case studies:

**- VILLAGE OF SAN YSIDRO, NEW MEXICO**

**- CITY OF OAKES, NORTH DAKOTA**

San Ysidro Overview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**Village of San Ysidro, New Mexico**

A field test using POU-RO units was conducted in the Village of San Ysidro, New Mexico during the 1980's. POU treatment was selected for San Ysidro because it was a small community with limited financial resources for water treatment. At the time of the test, San Ysidro obtained its water from an infiltration gallery under a river. The raw water contained 0.075 mg/L of arsenic, 0.06 mg/L of iron, 0.05 mg/L of manganese, and 914 mg/L of dissolved solids.

Seventy-three POU-RO units were installed in homes, restaurants, gas stations and municipal buildings. The EPA funded the field test.

During the test, arsenic concentrations in the raw water ranged from 0.068 to 0.02 mg/L. The arsenic levels in the treated water were consistently below the detection limit (0.005 mg/L). The following conclusions were reported from analysis of the field test data:

1. "POU treatment is an effective, economical and viable alternative to central treatment in San Ysidro for removal of arsenic as well as other contaminants."

2. "POU treatment of drinking water can be a reliable and effective means of contaminant removal from drinking water in a small community."

3. "Adopting a POU treatment system in a small community requires more care than does central treatment relative to record keeping to monitor the individual units."

# 3.6 - Treatment Case Studies Continued ...

4. "POU units require special regulations regarding customer responsibilities, water utility responsibilities, and the requirement of installation of the units in each home obtaining water from the utility."

5. "POU systems require special considerations from regulatory agencies to determine appropriate methods for record keeping, monitoring, and testing frequency which may be contrary to existing regulations."

6. The reverse osmosis units with polyamide membranes installed in San Ysidro resulted in the following removal percentages, which brought all contaminant levels below the MCL's.

| | |
|---|---|
| Arsenic (total) | - 86% |
| Chloride | - 84% |
| Fluoride | - 87% |
| Iron | - 97% |
| TDS | - 88% |
| Manganese | - 87% |

7. "The cost to the customer of POU treatment per month ($7.00) in San Ysidro is less than half of the estimated cost of central treatment ($30 - $40 per month). The cost per gallon of treated water, however, is over three times that of central treatment, since central treatment treats the entire water supply and the POU unit treats a small fraction of the supply."

8. "Total usage of water through the R.O. units, including consumption, averaged from 8.5 to 17.0 gallons per day. The units were designed to produce 5 to 8 gallons of treated water per day."

9. "This project was ineffective in evaluating the removal of bacteria from the water source."

Note: The source of information on the San Ysidro study is the report entitled "Point-Of-Use Treatment of Drinking Water In San Ysidro, NM," by Karen Raborn Rogers, Leedshill-Herkenhoff, Inc., Albuquerque, NM, submitted to the Risk Reduction Engineering Laboratory, Cincinnati, Ohio, Project officer – Kim R. Fox, EPA/600/S2-89/050.

A summary of the San Ysidro project is contained in the proceedings of the Conference on Point-of-Use Treatment of Drinking Water. This publication also contains many other interesting papers on point-of-use treatment. It can be viewed at http://www.epa.gov/nepis/srch.htm by using the simple search and entering the name of the conference.

# 3.6 - Treatment Case Studies Continued ...

**City of Oakes, North Dakota**

A field test was conducted in the City of Oakes, North Dakota in 2001 - 2002. Oakes is a predominantly residential community located in southeast North Dakota. The city has a population of about 1760. Oakes drinking water is supplied by three wells situated in different parts of the city. Typical arsenic concentrations in raw water pumped from these wells range from 0.010 to 0.021 mg/L. The water delivered to residences in Oakes is not disinfected or treated in any way.

The Mayor of Oakes was contacted in April of 2001 and asked about having a POU-RO pilot test done. The Mayor and the City Council responded positively and an article was run in the local newspaper to solicit volunteers for test sites. Based on a preliminary screening of the volunteers, eighteen private residences, two public building, and one commercial office were selected for installation of POU-RO units.

Twenty-one POU-RO units were installed in Oakes. All were three-stage systems (i.e., they consisted of an activated carbon prefiltration stage followed by an RO membrane stage and then an activated carbon polishing stage). The price of the basic three-stage RO unit was $365.

The POU-RO systems used for the Oakes test were installed under the sink. In most cases, installation was a fairly simple process. Average installation time was about 45 minutes.

After the POU-RO systems were initially installed, samples of treated (i.e., RO permeate) and untreated (i.e., cold tap water) water were routinely collected from each test site. Monitoring was done for one year. Most of the samples were analyzed for conductivity, pH, and total arsenic. One set of samples was tested for total bacterial count.

The untreated tap water samples from Oakes typically had total arsenic concentrations between 0.010 and 0.020 mg/L. A total of 97 untreated water samples and 87 permeate samples were collected and analyzed over the one year test period. The arsenic concentration in the untreated drinking water ranged from 0.006 to 0.040 mg/L and the average arsenic concentration was 0.0135 mg/L. The arsenic concentration in the permeate samples ranged from 0 to 0.004 mg/L and the average arsenic concentration was 0.0025 mg/L.

Even though most of the permeate samples collected during the monitoring period from the POU-RO units installed in Oakes contained no measurable amounts of arsenic, a few of the systems did exhibit signs of reduced membrane performance over the course of the monitoring period. Reduced membrane performance was indicated by a gradual increase in the conductivity of permeate over time. However even when permeate conductivity exceeded one half of the untreated water conductivity, the system still produced substantial arsenic removal at 0.004 mg/L, compared to influent of 0.010-0.020.

# 3.6 - Treatment Case Studies Continued ...

Results from tests run on water produced by the POU-RO units indicated that total bacterial counts from the treated water were about the same as counts obtained from untreated cold tap water. Thus it appears that the POU-RO systems were not promoting bacterial growth in the treated water.

In September of 2001, a survey was conducted of the POU-RO users in Oakes. Seventeen of the twenty-one users completed and returned the surveys. The answers to the survey questions indicated that all of the respondents were using the RO treated water for drinking and cooking, that they were satisfied with how the systems were operating, and that they would recommend a similar system to their neighbors.

Additional information about the Oakes study can be found at http://water.montana.edu/pdfs/moretti.pdf.

**Other pilot studies**

The American Water Works Association Research Foundation is conducting a project entitled "Comparison of Conventional and Unconventional Approaches for Provision of Water." One of the issues being addressed with this project is the use of POU treatment to provide better quality water to consumers. For this project, the Los Angeles Department of Works and Power arranged for a vendor to install seven POU-RO units in homes that it served. The purpose of the units was to improve the taste and odor of the water. The customers were generally happy with the aesthetic qualities of the water produced by the POU-RO units. However, two months into the study, 30% of the samples tested positive for total coliforms. Microbial growth was reduced after customers were educated about keeping the POU spigot clean. This and other case studies were discussed at a recent conference sponsored by NSF International. Summaries of the conference presentations can be found at http://www.nsf.org/cphe/pou/program.html.

Greg McKelvey of CWM Environmental Inc. has presented useful information on a POU-RO treatment study. An outline of his presentation can be found at the same NSF link, listed above.

Other case studies dealing with the use of POU-RO units to treat drinking water for regulated contaminants are summarized in Appendix A of the EPA report entitled "Guidance for Implementing a Point-of-Use or Point-of-Entry Treatment Strategy for Compliance with the Safe Drinking Water Act." This report can be found at http://www.epa.gov/safewater/ars/implement.html.

# 3.7 - Expand & Test Your Knowledge

Detailed information about approved methods for analysis of arsenic in drinking water is contained in report entitled "Analytical Methods Support Document for Arsenic in Drinking Water" (Report # - EPA 815-R-00-010). The full text of this report is available at http://www.epa.gov/safewater/ars/methods.pdf.

## Test Your Knowledge

## TABLE OF CONTENTS



## SUMMARY

Engineers help to plan the installation of POU-RO systems, and evaluate basic attributes of the units. Engineers should understand how unit components interact, how many gallons of treated water are produced, what percent of dissolved solids is removed, and whether the unit meets arsenic treatment standards for drinking water. Proper installation is essential for the successful performance of POU-RO units.

## KEY QUESTIONS

1. What are the main components of a POU-RO unit?
2. What types of RO membranes are available to treat arsenic?
3. What are the important considerations for developing an installation plan for a POU-RO treatment system?
4. What standards exist for POU-RO units that are to be used to treat arsenic in drinking water?

# 4.1 - Description of a Basic POU-RO System

A basic POU-RO unit typically consists of a 5-micron activated carbon block prefilter, a spiral-wound reverse osmosis membrane module, and an activated carbon postfilter. Some systems have a particulate filter ahead of the first carbon prefilter. There are other designs with additional stages that can address specific water quality challenges.

POU-RO units come in a variety of shapes and styles. Pictures of two different POU-RO units are shown in Figure 4.1.1 and Figure 4.1.2. In Figure 4.1.1, the white plastic filter housings contain the activated carbon filters, the black housing contains the RO membrane module, and the blue tank is for treated water storage. The small device on top of the membrane housing with four tubes attached is a flow shutoff valve. Figure 4.1.3 is a diagram showing how a POU-RO unit is installed under a sink, and Figure 4.1.4 is a schematic diagram showing how water flows through the unit.

### Components of a POU-RO System

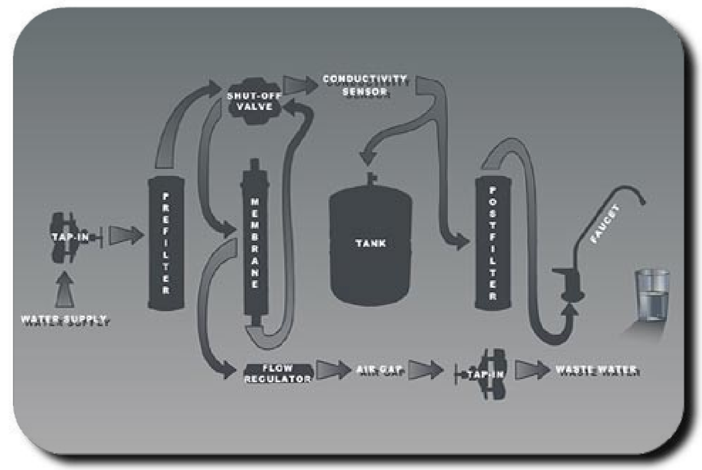



Figure 4.1.1

Figure 4.1.2

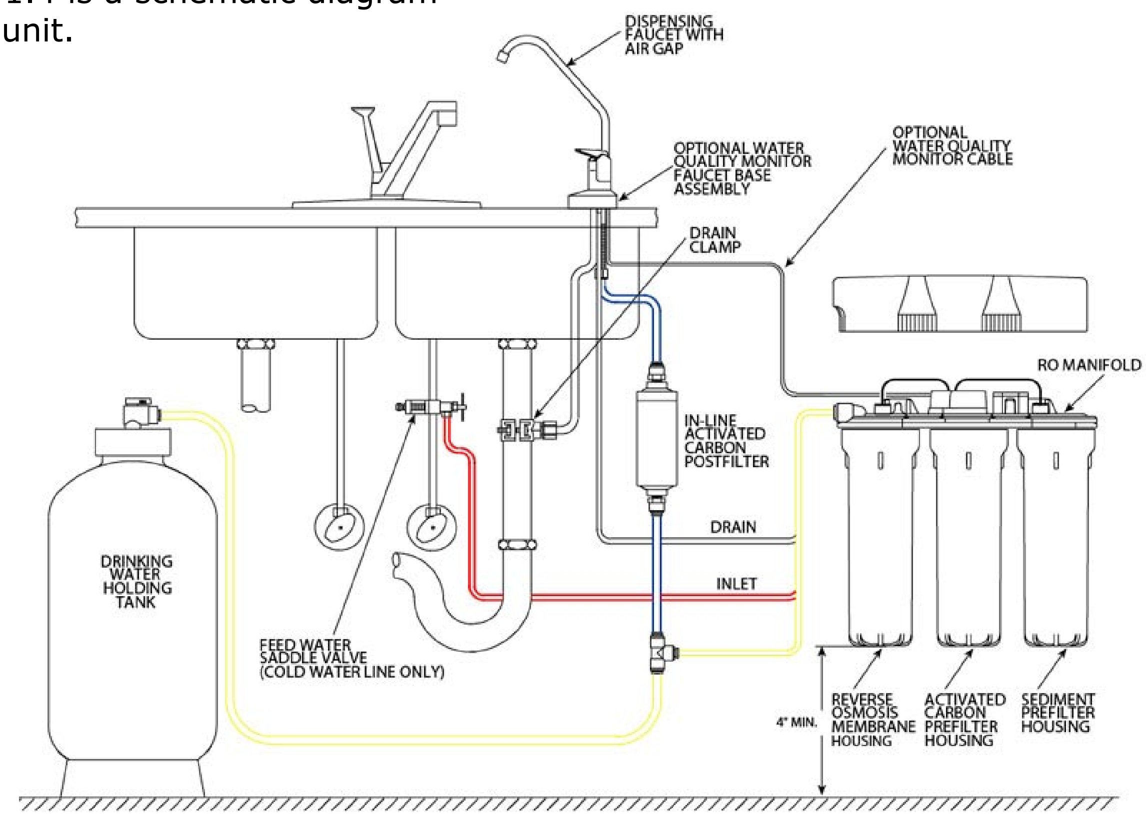



Figure 4.1.3

# 4.1 - Description of a Basic POU-RO System Continued ...

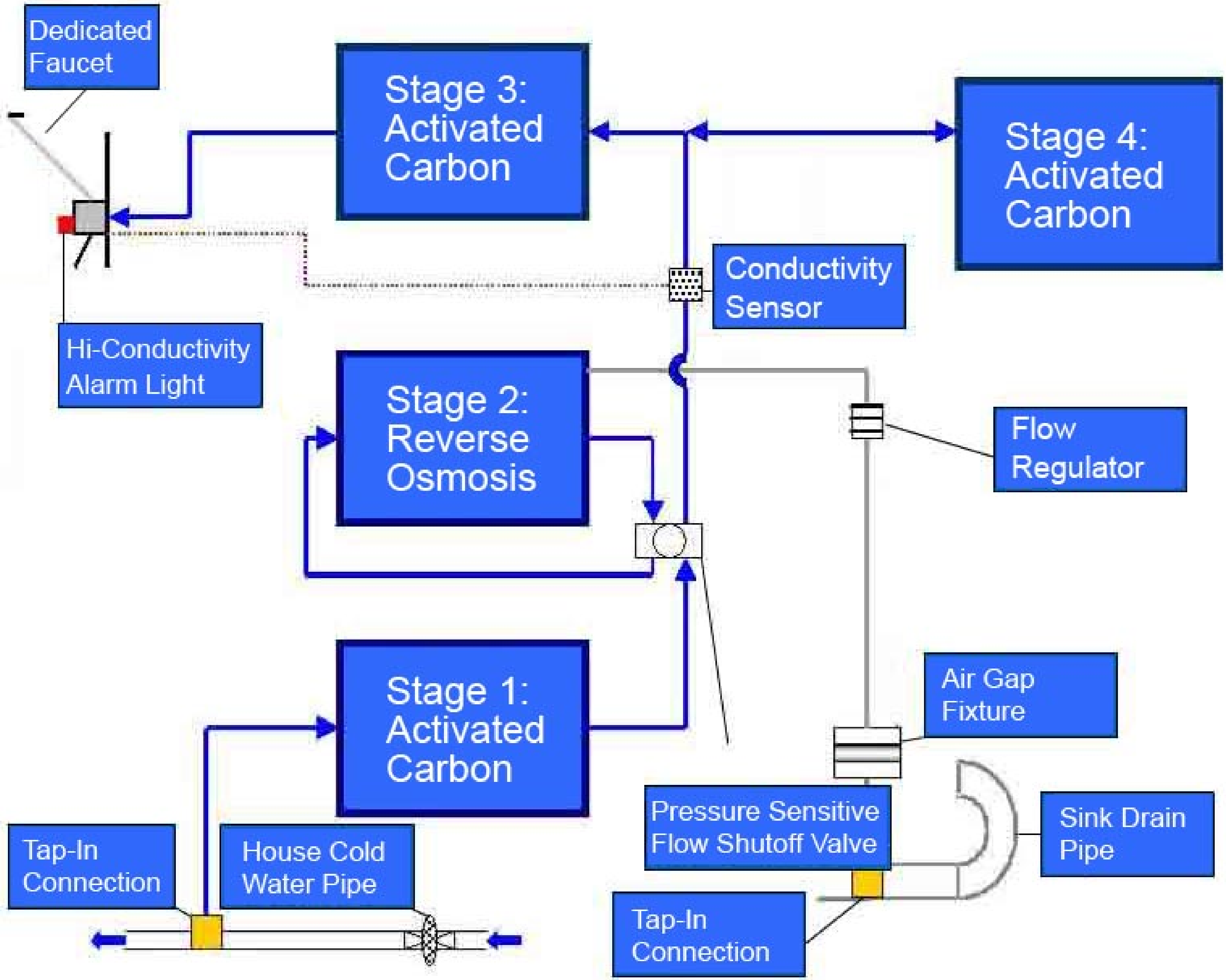



Figure 4.1.4

# 4.1 - Description of a Basic POU-RO System Continued ...

The various system components are described as follows:

Tap-in Valve for House Cold Water Line
(see Figure 4.1.5)

This valve is used to tap into copper pipe to obtain feed water for the system. The valve usually has a clamp that attaches to the pipe and a sharpened stem that punctures the pipe. When the cold water line is plastic pipe, a different type of connection should be used. Appropriate tap-in fittings for plastic pipe can be obtained from a plumbing supply store.

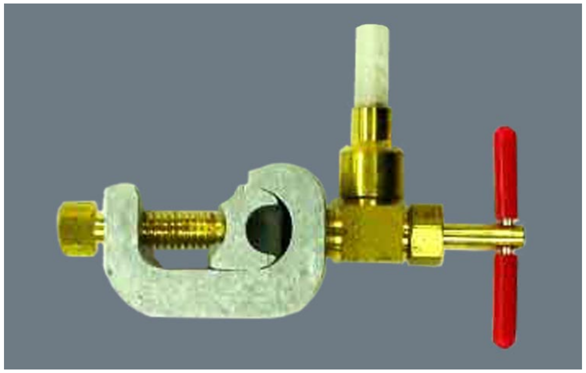


Figure 4.1.5

Stage 1 Activated Carbon Filter
(see Figure 4.1.6)

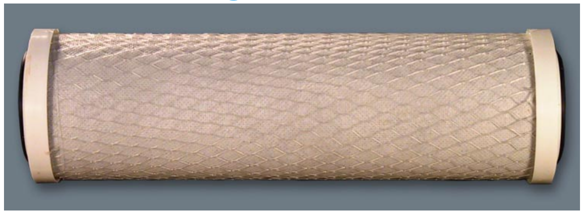


Figure 4.1.6

The first stage of a typical three-stage POU-RO unit is an activated carbon filter. The primary purpose of this filter is to remove sediment and chlorine from the water before it can damage the RO module. The filter is usually a radial flow, carbon block type with a nominal 5-micron pore size. The filter is housed in a suitable plastic pressure vessel. The carbon filter should have sufficient capacity to last at least one year before it needs to be replaced.

Pressure Sensing Flow Shutoff Valve
(see Figure 4.1.7)

The flow shutoff valve stops flow to the RO module when the storage tank is full. Without a shutoff valve, water would continuously run through the system, resulting in a significant waste of water. The shutoff valve works by sensing the pressure in the storage tank as it fills, and stopping water flow to the RO module when the tank backpressure reaches about 25 psi.

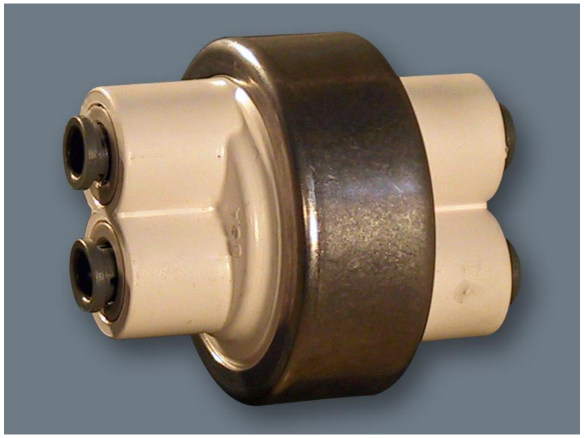


Figure 4.1.7

# 4.1 - Description of a Basic POU-RO System Continued ...

Reverse Osmosis Membrane Module
(see Figure 4.1.8)

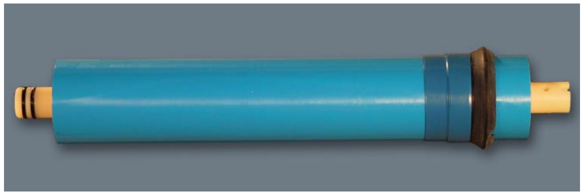


Figure 4.1.8

The membrane module is the key component of the POU-RO unit. These units are usually equipped with a spiral wound, thin film composite (TFC) membrane module, though other membrane types are available. A flow restrictor controls the rate at which water flows through the membrane module. Most POU-RO membrane modules are rated to produce 10 gallons per day of treated water under standard operating conditions. However there are NSF-certified membrane modules available for POU-RO units that have a rated production capacity as high as 35.5 gallons per day. The actual water production rate will depend on a number of factors such as temperature, pressure, and water composition. Membranes designed for POU-RO units typically operate at low pressures in the range of 40 to 80 psi and normally remove about 95% of common dissolved solids such as sodium, magnesium, sulfate, and chloride.

TFC membranes are well suited to POU-RO systems because of the following:

- Resist hydrolytic breakdown for greater membrane stability
- Have a strong membrane structure for greater durability
- Have high membrane flux for better productivity and lower operating pressures
- Operate over a wide pH range
- Operate over a wide temperature range

A disadvantage of TFC membranes is their limited tolerance to chlorine, which necessitates feed water pretreatment with activated carbon.

More information about residential reverse osmosis membrane modules can be found at:
http://www.dow.com/liquidseps/pc/res_ele.htm and http://www.osmonics.com/products/Page1062.htm

# 4.1 - Description of a Basic POU-RO System Continued ...

Conductivity Sensor
(see Figure 4.1.9)

Figure 4.1.9

An effective way of verifying that a POU-RO unit is removing arsenic from water is to monitor the dissolved solids concentration of the treated water. When the unit removes most of the dissolved solids from water, normally it also removes most of the pentavalent (+5) arsenic. Since the dissolved solids concentration is proportional to the conductivity of the water, continuous conductivity measurement is a convenient way to monitor the quality of the treated water. Inserting a conductivity sensor into the treated water line of the POU-RO unit will allow continuous measurement of conductivity. The sensor can be connected to some type of warning device to alert the consumer when the unit is not operating properly. Often a warning light is mounted on the faucet.

Continuous conductivity measurement can be done either by inserting a single probe into the treated water delivery line, or by inserting probes into both the system feed water line and the treated water delivery line. With the first approach (as shown in Figure 4.1.4), the probe is usually programmed to signal an alarm when the permeate conductivity exceeds about 15% of the average feed water conductivity. With the second approach, the probes are usually programmed to signal an alarm when the difference in the conductivities measured by the two probes drops below about 85%. The single probe approach should work as long as the dissolved solids in the feed water remains fairly constant over time.

Treated Water Storage Tank
(see Figure 4.1.10)

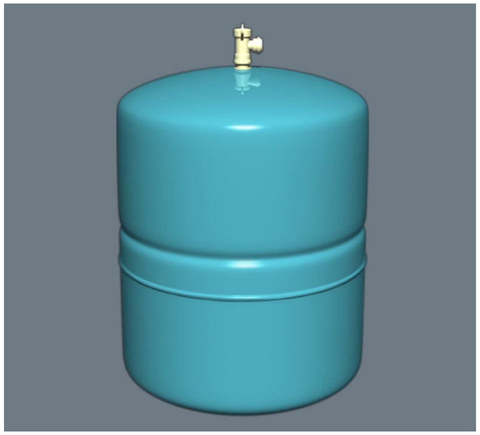


Figure 4.1.10

Since POU-RO units produce water at a rather slow rate, a storage tank is needed to collect enough treated water to meet the needs of the consumer. A two- or three-gallon capacity metal tank is typically used. The storage tank is equipped with an internal bladder to keep the contents under pressure. The correct pressure in the tank is necessary to operate the flow shut-off valve and to pump water to the faucet. Most storage tanks are made of metal and use an air-filled bladder to maintain pressure, but some tanks are made of plastic and use water to pressurize the tank. The pressure in a metal tank will increase as the tank fills, but the pressure in a plastic tank remains constant as it fills.

# 4.1 - Description of a Basic POU-RO System Continued ...

Stage 3 Activated Carbon Filter
(see Figure 4.1.11)

The third stage of the POU-RO unit is another activated carbon filter. Treated water passes through this filter before it goes to the faucet. The purpose of the postfilter is to remove any tastes and odors that may develop in the storage tank. The postfilter is usually a radial flow, carbon block type with a 5-micron pore size that is designed for taste and odor removal. The filter is housed in a suitable plastic pressure vessel. The carbon filter should be large enough to last at least one year before it needs to be replaced.

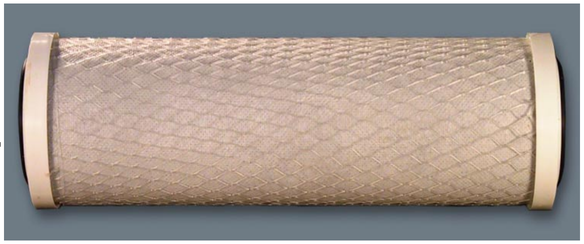


Figure 4.1.11

Dedicated Faucet with High-Conductivity Alarm Light
(see Figure 4.1.12)

The POU-RO unit should have a dedicated faucet. This is usually a touch-lever type faucet that can be mounted next to the sink. These faucets are available with a built-in warning light that can be connected to the conductivity sensor. Faucets are also available with a built-in air-gap feature or without the warning light feature.


Figure 4.1.12

Flow Regulator
(see Figure 4.1.13)

In order for the RO module to function properly, water flow through the module must approximately correspond with the design specifications. For example, if an RO module is rated to produce 18 gallons per day of treated water and the production rate is 20% of inflow under standard conditions, the flow through the reject line should be about 190 milliliters per minute. The flow regulator serves to maintain the proper flow. If the original RO module is replaced with a module designed for a different water production rate, the flow regulator should be changed as well to match the module specifications. If water flow through the module is too low, it may reduce the life of the module.

Figure 4.1.13

# 4.1 - Description of a Basic POU-RO System Continued ...

Air-Gap Backflow Prevention Device
(see Figure 4.1.14)

Most plumbing codes require an air-gap type, back-flow prevention device for drinking water systems that are connected to a sewage line. The back-flow prevention device must be installed on the discharge line between the sink drain and the backpressure regulator. There are air gap fixtures available that mount on top of the sink and others that are built into the POU-RO faucet. Some POU-RO units use a check valve to control possible back-flow.

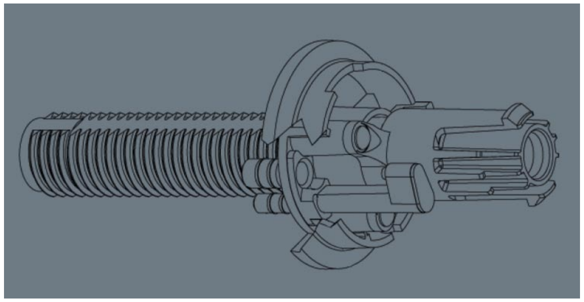


Figure 4.1.14

Tap-In Saddle for Under-Sink Drainpipe
(see Figure 4.1.15)

A tap-in saddle is necessary to connect the reject water discharge line to the sink drainpipe.

Figure 4.1.15

Plastic Tubing and Fittings to Connect Components
(see Figure 4.1.16)

Plastic tubing is needed along with appropriate fittings to connect all of the components of the POU-RO unit. Some type of bracket is also needed to hold the unit.

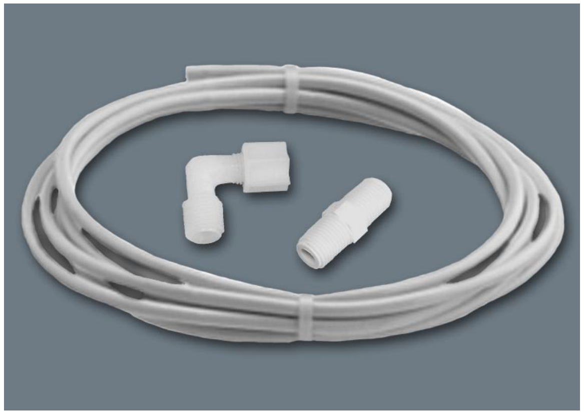


Figure 4.1.16

# 4.2 - Optional Components

| POU-RO Unit Option | Purpose of the Option |
|---|---|
| Sediment Pre-Filter | Used to remove large particulates such as sand or rust from the feed water prior to any other stages. |
| Ceramic Post-Filter | Used to remove bacteria from the water. |
| Increased Membrane Production Capacity | Membrane modules are available that will fit into a standard module housing and can produce up to 50 gallons of water per day under standard conditions. |
| UV Lamp | Used to kill bacteria and viruses in the water. |
| Booster Pump | An electric pump used to boost the feed water pressure to the RO. Sometimes necessary if the house pressure is low. |
| Permeate Pump | A non-electric pump used to boost the feed water pressure to the RO. This type of pump transfers energy from the rejected water stream to the RO feed stream and thus does not require additional energy. |

Table 4.2.1) Optional Components for POU-RO Units

## Optional Components

When the objective is to remove dissolved contaminants from water, a basic three-stage POU-RO unit should be suitable for many applications. However, there are a number of options that can be added to the basic system to meet special needs. These options are listed in Table 4.2.1.

Another option to consider is a zero-waste retrofit kit. This recently-available component returns unused water from the POU-RO system back to the facility's hot water supply. The benefits of zero waste are: faster storage tank fill time, conserves water while increasing membrane production, ideal for low-pressure connections and private wells, and eliminates the need for an air-gap faucet. It also eliminates the noise of an air-gap faucet if one is already installed.

# 4.3 - Equipment Certification

POU-RO units used to comply with the drinking water standards by law must be independently certified in accordance with the American National Standards Institute (ANSI) product standards. NSF International has developed a certification program for water treatment equipment under the direction of ANSI. ANSI/NSF standard 58 covers certification of reverse osmosis drinking water units. Other organizations such as the Underwriter's Laboratory (UL) and the Water Quality Association (WQA) are also able to certify water units.

The purpose of ANSI/NSF standard 58 is to establish minimum requirements for (1) materials, (2) design and construction, and (3) performance for reverse osmosis drinking water treatment units. Standard 58 also specifies the minimum product literature and the minimum service related obligations manufacturers shall provide to system owners.

For more information about NSF certification and NSF certified POU-RO units, go to http://www.nsf.org/DWTU/.

Table 4.3.1 shows some of the removal requirements specified by NSF for various contaminants.

Dow Chemical and Osmonics both manufacture RO membranes that are certified by NSF under standard 58 for all three criteria. In addition, transfer procedures have been developed for the Filmtec® (Dow) and Desal® (Osmonics) membranes so that their certifications can be transferred to POU-RO system manufacturers when certain conditions are met.

The Filmtec® transfer procedure indicates that if total dissolved solids removal and water production rate for a POU-RO system meet stated requirements, then their claims about removal of specific contaminants can be transferred to the manufacturer's system. This linkage between removal of specific contaminants and removal of total dissolved solids from water is a commonly used criterion for evaluating the operation of POU-RO units.

Several points should be made about ANSI/NSF certification. First, the contaminant removals specified by NSF in Table 4.3.1 are achieved under prescribed test conditions. However, similar removals may or may not be obtained with certified systems when treating different types of waters under various system operating conditions. Also, the arsenic removals specified in Table 4.3.1 are only for pentavalent arsenic ($As+^5$).

# 4.3 - Equipment Certification Continued ...

Qualify for Treatment System Certification

| Substance | Average Influent* | Maximum Effluent* |
|---|---|---|
| Arsenic (pentavalent) | 0.3 mg/l | 0.025 mg/l |
| Barium | 10 mg/l | 2 mg/l |
| Cadmium | 0.03 mg/l | 0.005 mg/l |
| Chromium (hexavalent) | 0.3 mg/l | 0.1 mg/l |
| Chromium (trivalent) | 0.3 mg/l | 0.1 mg/l |
| Copper | 3 mg/l | 1.3 mg/l |
| Fluoride | 8 mg/l | 2 mg/l |
| Lead | 0.15 mg/l | 0.01 mg/l |
| Radium 226/228 | 25 pCi/l | 5 pCi/l |
| Selenium | 0.1 mg/l | 0.05 mg/l |

* Influent: The influent represents the average amount of contaminant that is added to the water.
* Effluent: The effluent represents the maximum concentration of contaminant that is permitted in the product water (i.e., permeate).

# 4.4 - Installation Procedures

Proper installation is essential for successful performance of POU-RO units. Engineers will be involved in making plans for installing the units. When POU-RO units are serving an entire community and the treated water is expected to comply with drinking water standards, installation should be done by a properly trained professional. The community may choose to hire and train technicians, hire a plumber, or hire a service company to do the installations. Be sure to check state and local codes pertaining to installation of drinking water treatment devices before choosing a particular option.

**POU-RO Unit Installation**

Installing a POU-RO unit in a home is normally a routine operation. This should not take more than one hour to complete unless some unusual plumbing problems occur. Most POU-RO units are supplied with detailed installation instructions and some special connecting hardware intended to fit standard under-the-sink plumbing. However, it is not unusual to encounter situations that require special procedures and fittings. When special fittings are needed, they can usually be obtained from a local hardware supplier.

POU-RO units installed in the kitchen are usually placed either directly under the sink or else in the basement. The above photo shows a POU-RO unit installed under the sink. There may be an advantage to installing a unit in the basement if it is to serve multiple outlets, for example a sink and a refrigerator. However, if the system is installed in the basement, the pressure at the faucet will be reduced because the water will have to be pumped from the storage tank to the faucet.

Installing a system typically involves connecting the inlet line to the cold water supply pipe and the outlet line to the sink drainpipe. If there is a shutoff valve on the cold water line, tap into the line downstream from the valve so that the inflow can be shut off when necessary. A self-tapping inlet fitting for copper pipe is often provided with the system. If the cold water line is plastic tubing, appropriate fittings can be purchased for the connection. The outlet line is usually connected to the drainpipe using a drain saddle supplied with the system. Always install the drain saddle above the trap in the drain line.

Since the POU-RO unit is connected directly to a sink drainpipe, it is possible for a cross connection to occur. For example, if the inlet line is subjected to a negative pressure while the sink is backed up, polluted water could be sucked into the unit. To avoid cross connections, many plumbing codes require installation of an air-gap fixture with the POU-RO unit. The air-gap allows air to enter the system rather than polluted water in the event of negative pressure. Various types of air-gap fixtures are available including faucets with a built-in air-gap feature.

# 4.4 - Installation Procedures Continued ...

A water supply pressure of about 40 psi is needed to properly operate a POU-RO unit. If the pressure is less than 40 psi, the system may not be able to produce water fast enough to meet the needs of the consumer. When necessary, the supply pressure can be increased by installing an electric booster pump or a permeate pump. A booster pump for a POU-RO unit costs about $100. The disadvantages of using a booster pump are that an electric outlet must be located close to the POU-RO unit and the pump will eventually burn out and have to be replaced. A permeate pump uses the energy of the water flowing through the POU-RO unit to generate additional pressure. A permeate pump produces less pressure than a booster pump, but it does not require electricity.

Installing POU-RO units in public and commercial buildings may be more complicated than in single-family residences. Buildings with several drinking fountains and commercial applications that use relatively large amounts of water for cooking and drinking will require appropriately sized POU-RO units. Larger capacity units are significantly more expensive than residential POU-RO units.

**Access for Residential Installation**

Since a POU-RO unit will have to be installed in every residence in the community, it will probably be necessary to include an appropriately worded clause in a community ordinance to ensure that technicians can enter the home to install the equipment.

# 4.5 - Expand & Test Your Knowledge

An excellent discussion of how a POU-RO unit works and what to look for when buying a unit is available at http://www.osmonics.com/products/Page700.htm.

Another good discussion about what to look for when buying a POU-RO unit is available at http://www.awqinc.com/buying_ros.html.

Additional information about POU-RO installation is available at http://www.awqinc.com/pdf/Roinst.PDF. This document also has some useful instructions for installing a POU-RO unit in the basement.

There are many service companies that install POU-RO units. A list of companies that are members of the Water Quality Association can be found at http://www.wqa.org/. (When using this link, from the WQA homepage go to "Find a Professional," then under Retailer/Dealer Member search by company name for RO.)

## Test Your Knowledge

TABLE OF CONTENTS



SUMMARY

An effective maintenance program is essential for successful operation of a public water system using POU-RO units for arsenic compliance. Improperly maintained units can present a health hazard to consumers if they become contaminated with harmful bacteria. Engineers will be responsible for developing a system maintenance plan.

When POU-RO units are used to comply with the arsenic drinking water regulations, a monitoring program will be needed to ensure adequate treatment. This will include some form of continuous monitoring of the treated water in addition to periodic direct arsenic measurements. Engineers will be involved in planning the monitoring program.

KEY QUESTIONS

1. How much maintenance is needed for POU-RO units?
2. How is a POU-RO system maintenance plan developed?
3. What service companies are available to maintain large numbers of POU-RO units for a small public water system?
4. What monitoring guidelines should be followed for POU-RO devices being used to comply with arsenic regulations?
5. How extensive must the monitoring program be?
6. What records must be kept for monitoring activities?

# 5.1 - Maintenance

## Scheduled Maintenance

A properly operating POU-RO unit does not normally require a great deal of maintenance. However, scheduled maintenance procedures should include the following:

- Changing carbon filters at least once each year
- Checking the conductivity monitoring device once each year
- Disinfecting the entire system once each year
- Changing the RO membrane element when necessary

These tasks can normally be done in a single yearly service call to the home by a qualified technician. Depending on the conditions, the RO membrane element may function properly for two to five years before it needs to be changed.

The conductivity sensor and alarm can also be checked and samples taken for arsenic testing during a scheduled maintenance call.

## Unscheduled Maintenance

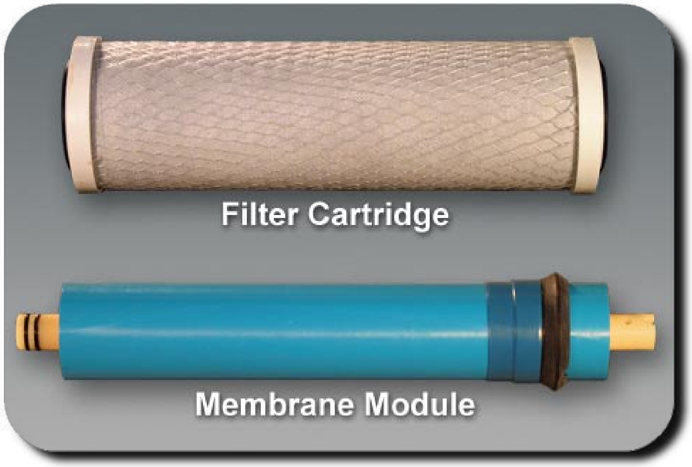
In addition to performing the scheduled maintenance described above, a technician will have to be available to respond to calls for unscheduled maintenance. Some common reasons why customers might call for assistance are: when the conductivity alarm is signaling improper operation, the system is not delivering water, or the water has an unusual taste or odor.

## Access for Monitoring

Since POU-RO units will be installed in every residence in the community, it will probably be necessary to include an appropriately-worded clause in a community ordinance to ensure that technicians can enter the home to check monitoring equipment and collect water samples for analysis.

# 5.2 - Replacement Filters and Membranes

The treatment capacity of the activated carbon prefilter will have to be at least 7300 gallons if the prefilter treats 20 gallons of water per day. There are several commercially available activated carbon cartridges that meet this requirement. The filter cartridge pictured to the side is a high capacity, radial flow carbon block filter. This filter cartridge is rated for >90% chlorine reduction of 20,000 gallons of water at a 1.0 gallon per minute flow rate. It is an effective chemical removal filter with high VOC reduction capacity, high chlorine and chloroform performance, and particulate reduction >99.9% at 2 microns. It is also good for enhancing the taste and reducing the odor of water. This type of filter should last for one year if there is not too much sediment in the water supply. Figure 5.2.1 shows a close up of a typical 2.5" X 9.75" carbon block filter cartridge. If scheduled maintenance is to be accomplished with a single annual service call, activated carbon cartridges used for POU-RO units must last for at least one year.




The treatment capacity of the postfilter cartridge will have to be at least 3650 gallons if the postfilter is sized to treat up to 10 gallons of water per day. A typical filter that would be chosen for this application is a high capacity, radial flow carbon block filter. It is likely to be rated for >90% chlorine reduction of 3750 gallons of water at 1.0 gallon per minute flow rate. It should have excellent dirt-holding capacity and be a very effective taste/odor enhancer. This type of activated carbon postfilter should last for one year unless a large amount of bacterial growth occurs.

# 5.2 - Replacement Filters and Membranes Continued...

The expected life of the activated carbon filters can be evaluated during the pilot test.

The effective life of the RO membrane will depend on many factors. However, scaling caused by precipitation of minerals on the membrane can lead to premature failure. For example, water that is over saturated with carbonate hardness can rapidly deposit a mineral scale on the membrane. If this is the case, some type of water softening device may be needed in front of the POU-RO unit to ensure cost-effective operation. Other factors that can cause scaling or fouling of membranes include the presence of oxidized iron and manganese in the water, the presence of minerals that have low solubility in water, and the growth of bacteria on the membrane. Figure 5.2.2 shows a picture of a typical POU-RO membrane module.

Sometimes it is difficult to predict whether a serious scaling or fouling problem will develop with a POU-RO unit when treating a particular water, even when the chemical composition of the water is well known. Useful information about operational problems can sometimes be obtained from homeowners and water treatment companies in the area that use similar equipment. Information obtained from pilot tests should be useful for identifying potential operational problems.

All replacement filters and membranes used for POU-RO units should be certified by NSF International or an equivalent organization.

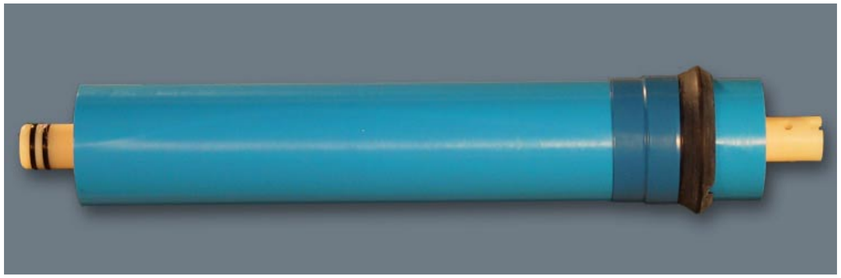


Figure 5.2.1 - 2.5" X 9.75" Carbon Block Filter Cartridge

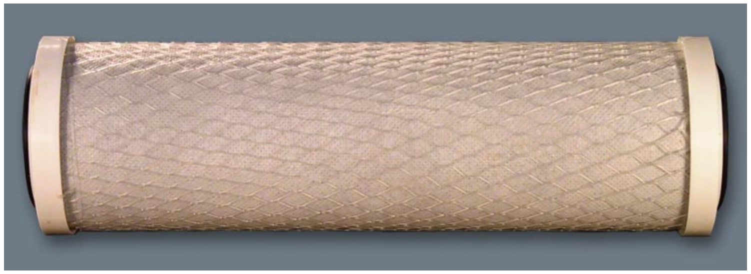


Figure 5.2.2 - Typical POU-RO Membrane Module

# 5.3 - Disinfection Procedures

The carbon filters in a POU-RO unit are a good medium for promoting growth of bacteria. For this reason, the entire system should be disinfected at least once a year. A convenient time to do this is when the carbon cartridges are being changed. Disinfection can be done as follows:

**Disinfecting the System**


1. Replace the activated carbon filters and inspect the membrane element.

2. Fill the filter and membrane housings with a 3% hydrogen peroxide solution.

3. Reconnect the filter and membrane housings.

4. Turn on the water to the system and allow the storage tank to fill.

5. Allow the hydrogen peroxide solution to remain in the system for several hours.

6. Open the faucet and drain the storage tank.

**Maintenance Service Contractors**

When POU-RO units are serving an entire community and the treated water is expected to comply with drinking water standards, maintenance such as disinfecting the system should be done by properly trained professionals. The community may choose to hire and train a technician, hire a plumber, or hire a service company to do the maintenance. Be sure to check state and local codes pertaining to maintenance of drinking water treatment devices before choosing a particular option.

There are many service companies that maintain POU-RO devices. Some contacts are listed at the end of this unit.

# 5.4 - Continuous Monitoring

RO Conductivity Measurement


When a POU-RO unit 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, effective monitoring of the POU-RO unit can be conveniently accomplished by measuring conductivity.

The law requires that when POU-RO units are used for compliance treatment, the units must be equipped with a mechanical warning device to ensure that customers are automatically notified of an operational problem. The simplest way to accomplish this is to continuously measure the dissolved solids concentration with a conductivity meter. The conductivity meter can be connected to an alarm to satisfy the notification requirement.

Continuous conductivity measurement can be done either by inserting a single conductivity probe into the treated water delivery line or by inserting conductivity probes into both the system feed water line and the treated water delivery line. Using the first approach, the probe could be programmed to signal an alarm when the effluent conductivity exceeds about 15% of the average feed water conductivity. Using the second approach, the probes could be programmed to signal an alarm when the difference in the conductivities measured by the two probes drops below about 85%. The single probe approach should work as long as the dissolved solids in the feed water remains fairly constant over time. If this is not the case, the two-probe approach may be necessary. Figure 5.4.1 shows a picture of a dual probe conductivity-monitoring device.

Setting the conductivity signal point for the treated water at 15% of the feed water conductivity should provide adequate protection to the consumer, but it may be overly conservative. The only way to determine a more accurate signal point is to develop a statistically valid correlation between measured conductivity and regulated contaminant concentration(s) in the treated water. It may be possible to develop such a correlation from the pilot test data.

# 5.4 - Continuous Monitoring Continued ...

Conductivity monitoring can be used as the monitoring mechanism for POU-RO units being used to comply with drinking water standards if the following conditions are met:

- Adequate pilot testing for the specific target contaminants has been done
- An NSF-certified membrane element is being used
- The units have been properly installed
- The units are being properly maintained and managed

**Figure 5.4.1 - Dual Probe Conductivity Monitoring Device**

# 5.5 - Direct Arsenic Monitoring

Although conductivity monitoring should indicate whether regulated contaminants are being controlled, it will probably be necessary to do some ongoing sampling and analysis of the treated water to confirm that the arsenic concentration is below the MCL.

Guidelines for sampling and measurement of arsenic removal by POU-RO units are currently (2004) in revision by the EPA. In EPA's current "Guidance for Implementing a Point-of-Use or Point-of-Entry Treatment Strategy for Compliance with the Safe Drinking Water Act," these recommendations are made:

POU-RO Implementation Game

- "Systems must continue to conduct all previously required sampling at wellhead or central point of distribution."

- "Systems should sample the finished water produced by each household at least one time during the year in which the POU or POE treatment devices are initially installed."

- "Assuming that the devices are found to successfully reduce contaminant concentrations below the MCL, systems should sample finished water from one-quarter of all households in each subsequent year."

# 5.6 - Expand & Test Your Knowledge

Information on availability and cost of replacement activated carbon cartridges and RO membrane modules can be found at http://www.pwgazette.com/filter.htm.

POU-RO troubleshooting & maintenance information can be found at http://www.wattspremier.com/edu.

More information about POU-RO units can be found at http://www.osmonics.com/products/Page700.htm.

A list of service contractor companies that are members of the Water Quality Association can be found at http://www.wqa.org/. (navigate to "Find a Professional," then under Retailer/Dealer Member search by company name for RO.)

## Test Your Knowledge

For more information about equipment for monitoring of total dissolved solids for POU-RO units, go to http://www.touchflo.com/touchfloframe3.html.

For more information about analytical methods for arsenic analysis, go to http://www.epa.gov/safewater/ars/methods.pdf.

## TABLE OF CONTENTS



## SUMMARY

The law requires that when POU-RO units are used for compliance with arsenic regulations, the units shall be owned, controlled, and maintained by the public water system or by a person under contract with the public water system to ensure proper operation and maintenance and compliance with the arsenic MCL. This means the community supporting the public water system is ultimately responsible for administering the installation, operation, and maintenance of the units. Engineers will assist the community in developing an administrative program.

## KEY QUESTIONS

1. Who manages a POU-based treatment system?
2. What should be addressed in a POU-RO management plan?
3. What companies can help manage a POU-based system?
4. What types of community ordinances may be needed to manage a POU-based treatment system?

# 6.1 - Administration and Management

The main administrative responsibilities for a POU-based water treatment system are:


- Establishing responsibility for control of the units
- Working with equipment suppliers and contractors to implement the treatment system
- Working with employees or persons under community contract to install, monitor, and maintain the units
- Ensuring access to residences for installation, monitoring, and maintenance of the units
- Communicating with residents for public outreach and education about the system
- Keeping records
- Securing funding for implementing the system
- Establishing service charges to support the system on an ongoing basis

# 6.2 - Controlling the Treatment System

Implementing a POU-RO based treatment system in a small community will require a serious commitment from local government. Regardless of whether the community intends to do the work with its own employees or hire contractors for the work, local government must accept ultimate responsibility for controlling the POU-RO units through a public water system. For this reason, developing effective plans for administering and managing the system is critical to success.

Since centrally-managed point-of-use treatment is a new approach for supplying drinking water, any community that chooses to use it will have to "pioneer" the process. Technical support provided by engineers will be extremely important for local governments trying to convince regulators that point-of-use treatment is feasible. Sound technical support will help communities sell this new idea to state and local regulatory agencies that may have little experience with POU-RO treatment.

One of the first tasks for a community seeking to implement POU-RO treatment is to develop local laws to support the public water system. At a minimum, an ordinance should be enacted to ensure access to all residential and commercial sites to allow technicians to install, maintain, monitor, and replace equipment as needed for proper operation of the system.

The EPA has developed some model ordinance language that can be used by communities seeking to implement the use of POU-RO units for treatment of arsenic. The model ordinance defines the responsibilities of residential and non-residential water users with regard to:

- Required installation of water treatment equipment
- Ownership of equipment
- Access for installation, scheduled maintenance, emergency maintenance, and monitoring
- Suspension of service
- Service charges
- Enforcement
- Liability
- Severability

# 6.2 - Controlling the Treatment System Continued ...

The Village of San Ysidro, New Mexico passed a local ordinance when it implemented a POU-RO treatment system in 1985. This ordinance covered the required installation of water treatment equipment, installation access, scheduled maintenance, charges, emergency maintenance and monitoring. In 1987, San Ysidro passed an amendment to the original ordinance that clarified responsibilities, distinguished between residential and commercial water users, and added enforcement powers. The amended ordinance contained the following changes:

- A much more detailed description of water user responsibilities with regard to installation, maintenance, and monitoring of the equipment

- An allowance for commercial users to choose any type of system as long as the water produced meets the treatment standards (this would not be allowed under the current drinking water laws)

- A limitation on the liability of the village for damages caused by the installed units

- Powers for enforcing the ordinance including the power to shut off water service to users who refused to abide by the ordinance

- A more detailed discussion of charges

- Specific compliance language and deadlines

**The full text draft of the amended San Ysidro ordinance is available on the CD-ROM program (POU_Sample_Ordinance.doc) in the "extras\documents" folder.**

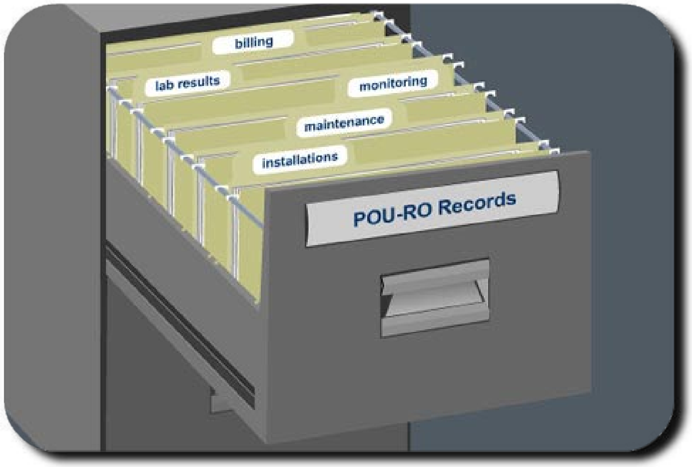
For more information about the San Ysidro study, see the report entitled "Point-Of-Use Treatment of Drinking Water In San Ysidro, NM," by Karen Raborn Rogers, Leedshill-Herkenhoff, Inc., Albuquerque, NM, submitted to the Risk Reduction Engineering Laboratory, Cincinnati, Ohio, Project Officer - Kim R. Fox, EPA/600/S2-89/050.

# 6.3 - Record Keeping

An important element of a management plan for a centrally-managed point-of-use treatment system is developing record keeping procedures. At a minimum, the following information should be recorded:

- Where and when the equipment was installed
- All scheduled and unscheduled maintenance
- Sample collection for monitoring
- Results of laboratory analyses
- Customer billing

**Records**



# 6.4 - Certification and Training Requirements

Managers and technicians working with a POU-RO treatment system should be properly trained. Some states require water system operators and other personnel to participate in structured training programs or obtain certifications. However, since centrally-managed point-of-use treatment is a relatively new idea, it is not clear exactly what training activities and/or certifications will be required for service personnel.

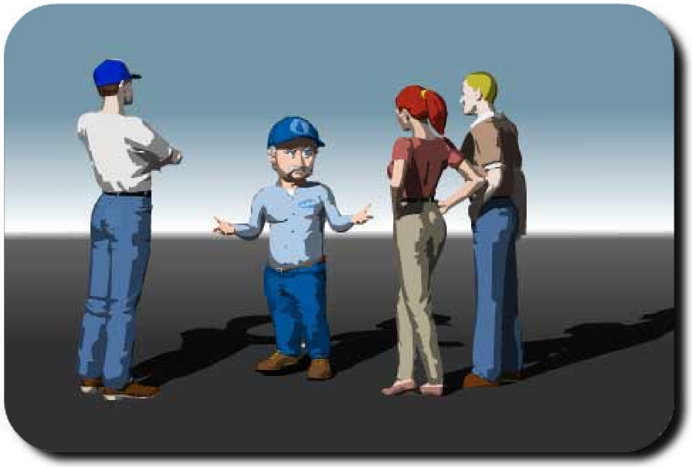
Training is available from various sources. Manufacturers often provide training for vendors and service technicians that work with their equipment. It may be possible to have public water system personnel attend these training sessions. Equipment vendors may also provide training on operation and maintenance of equipment they sell. Organizations like NSF International and the Water Quality Association offer training courses dealing with point-of-use treatment. Also, some states may eventually offer training courses dealing with the use of POU-RO equipment.

If the water system contracts with a service company to install and maintain the POU-RO units, the service company should provide training for its personnel. Even when the work is contracted out, the public water system is still responsible for ensuring that installation and maintenance are being done properly.

# 6.5 - Public Relations

Managing a POU-RO treatment system will require a high level of interaction with the public for installation, operation, and maintenance of the units. In order to facilitate this interaction, a well-organized public relations effort will be needed. Customers should be kept informed about the following:

- What equipment is being installed and how it works
- The quality of the water being provided
- How the water quality is assured
- What maintenance work has to be done and why it is necessary
- How to arrange for service when operational problems occur
- How service charges are determined

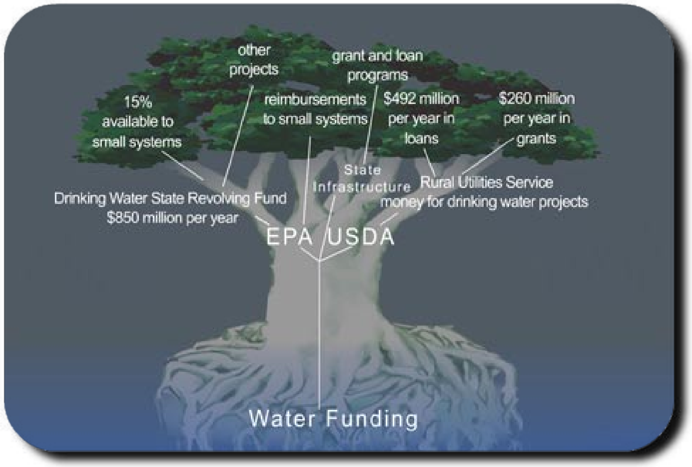


# 6.6 - Funding Sources for Small Systems

The EPA has developed a small community drinking water assistance plan to:

- Enhance access to financial assistance
- Expand technical assistance and training
- Improve system capacity and effectiveness
- Simplify program implementation through the use of exemptions for qualifying systems

### The Money Tree




There are currently two major federal financial assistance programs that are available to small drinking water systems working to comply with the arsenic rule. These are the EPA Drinking Water State Revolving Fund (DWSRF), and the United States Department of Agriculture Rural Utilities Service (RUS) grant and loan program.

The DWSRF provides capitalization grants and loans to states for drinking water projects. The DWSRF receives about $850 million per year of federal funding. By law, states are directed to make at least 15% of these funds available to small systems serving fewer than 10,000 people. To date, states have provided 41% of these funds to small systems.

The RUS program provides an average of $492 million per year in loans and $260 million per year in grants for drinking water projects. All assistance is targeted toward small systems serving less than 10,000 people.

In addition, Sect. 300g-8 of the U.S. Code states that the EPA will reimburse systems serving 3,300 or fewer persons for training and certification costs when needed for compliance with state operator certification programs.

Many states' departments of commerce also have infrastructure grant and loan programs.  The drinking water primacy agency can help a small water utility identify these opportunities.

# 6.7 - Expand & Test Your Knowledge

### Test Your Knowledge

The full text of the EPA model ordinance, as well as an excellent discussion of funding sources for centrally managed point-of-use treatment systems, can be found at http://www.epa.gov/safewater/ars/implement.html.

The full text draft of the amended San Ysidro ordinance is available on the CD-ROM (POU_Sample_Ordinance.doc) in the "extras\documents" folder.

For more information about the San Ysidro study, see the report entitled "Point-Of-Use Treatment of Drinking Water In San Ysidro, NM," by Karen Raborn Rogers, Leedshill-Herkenhoff, Inc., Albuquerque, NM, submitted to the Risk Reduction Engineering Laboratory, Cincinnati, Ohio, Project Officer - Kim R. Fox, EPA/600/S2-89/050.

Links to NSF and WQA training information:

For more information concerning tools for public education about point-of-use check these links:
http://www.epa.gov/safewater/ars/implement.html
http://www.wattspremier.com/community/

Information on troubleshooting POU-RO units that may be useful for customers can be found at http://www.wattspremier.com/edu/.

## TABLE OF CONTENTS



## SUMMARY

Cost estimates depend largely on location and water quality, but guidelines are available.

## KEY QUESTIONS

1. What are estimated costs for pilot tests, purchase, installation, maintenance, monitoring and management of POU-RO treatment?
2. How does the cost of POU-based treatment compare with the cost of conventional central treatment?

# 7.1 - Why It's Hard to Estimate Costs

It is difficult to accurately estimate costs for using POU-RO units for compliance treatment of drinking water. The following reasons can be given for this:

• very little compliance treatment has been done with POU-RO equipment, so there is not much historical information to use as a guide

• installation and maintenance costs are highly dependent on labor rates; labor rates can vary widely depending on technical expertise, location, and regional plumbing codes

• several important regulatory issues related to managing, maintaining, and monitoring point-of-use reverse osmosis treatment have not yet been clarified

**Costs**

# 7.2 - Estimated Costs Relating to POU Treatment

Since so many factors can affect the cost of POU-RO treatment, the approach taken herein is to estimate a range of costs based on various economic and regulatory scenarios.

Sam VS You


The main costs involved in set-up and operating POU-RO units for compliance with drinking water standards are:

1. Engineering
2. Equipment
3. Pilot testing
4. Installing equipment
5. Maintaining equipment
6. Monitoring equipment
7. Administration and management
8. Financing equipment and startup

Engineering, equipment, pilot testing, and installation costs can be considered initial costs for the treatment system; maintenance, monitoring, administration/management, and finance costs will be annual costs.

In the following sections, each category is broken down into discrete cost elements and analyzed.

### Engineering Cost

Since centrally-managed POU treatment is new, it is difficult to estimate how much engineering time and effort will be needed to implement the system. This unit includes hypothetical cost estimates for various treatment scenarios. Engineering costs for these scenarios are estimated to be 20% of the initial costs for the system (i.e., equipment purchase, pilot test, and installation costs). This approach is used only for estimating purposes; actual charges for engineering work will probably be based on a cost plus fixed fee basis.

### Equipment Cost

The major factors influencing equipment costs for POU-RO treatment include the specific type of unit purchased, the total number of units purchased, the method of ownership (i.e., purchase or lease), the expected life of the units, and the extent of pilot testing.

# 7.2 - Estimated Costs Relating to POU Treatment Continued ...

POU-RO units certified under ANSI/NSF standard 58 are listed on the web at http://www.nsf.org/Certified. These units range widely in price, but typically they cost between $300 and $600. It is also reasonable to assume that as the market for POU-RO units expands, more manufacturers will have their products certified.

In a recent study funded by the American Water Works Association Research Foundation (AwwaRF) and others, several quotes were obtained for a three-stage POU-RO treatment unit suitable for compliance treatment of drinking water. The cost for a POU-RO unit estimated from these quotes was $400. This cost seems reasonable. However it is also reasonable to assume that a substantial price discount can be obtained if a community purchases a large number these units.

A basic three-stage POU-RO unit intended for compliance treatment of arsenic in drinking water should be equipped with two NSF-certified activated carbon filters, an NSF-certified RO membrane module, an automatic flow shutoff valve, a conductivity monitor with an alarm, and an air-gap backflow preventor.

The service life estimated for the POU-RO unit in the AwwaRF study was seven years. This may be a conservative estimate. Since there are very few moving parts in a POU-RO unit, it seems reasonable to assume that it would last for ten years or more if it is well maintained. As long as the unit is designed such that parts can be easily replaced, it could serve for well over ten years.

Estimating capital costs for POU-RO equipment is fairly simple when the equipment is being purchased outright. However when the units are being leased, estimating costs may be more difficult. Leasing costs will depend on factors such as the length of the lease, the equipment specifications, and the availability of companies offering the necessary equipment. The lease agreement may also cover installation and some maintenance.

**Pilot Study Cost**

The estimated cost of a pilot test using two identical POU-RO systems is about $5000. This covers planning, purchase and installation of two systems, sample collection and analyses, and a report. Samples of both the treated and untreated water would be collected and analyzed for pH, conductivity, and any regulated contaminants that the systems were intended to treat. The estimated cost range for pilot tests using five to ten systems is $10,000 to $15,000.

# 7.2 - Estimated Costs Relating to POU Treatment Continued ...

## Installation Cost

The major factors influencing installation costs for POU-RO units are labor cost, installation time, and travel time. A trained technician should require on average about one hour to install a POU-RO unit in a residence. In general with allowance for travel and other factors, it should be possible for one worker to install about six units in an eight-hour workday(1 hour 20 minutes per unit on average with break and travel time included). If it is assumed that the labor cost for a POU-RO technician including benefits is about $25/hr, the labor cost for installing a unit will be about $35. Adding $15 for miscellaneous expenses, the total installation cost for a system would be about $50.

| Installation Cost Breakdown | Labor rate $15/ hour | Labor rate $25/ hour | Labor rate $50/ hour |
|---|---|---|---|
| Labor cost | $21 | $35 | $70 |
| Miscellaneous cost | $15 | $15 | $15 |
| Total installation cost | $36 | $50 | $85 |

Table 7-1. Installation Cost as a Function of Labor Rate

However, installation cost could be higher depending on site-specific conditions. For example, if local plumbing codes require that the units be installed by a licensed plumber, or that significant modifications be made to the plumbing in the residence, installation cost could be $100 or more. Table 7-1 shows how labor cost can impact installation cost.

## Maintenance Costs

Maintenance will be the largest single cost component for a POU-based treatment system. The major factors influencing maintenance costs for POU-RO treatment are labor cost, maintenance time, maintenance schedule, cost of replacement parts, and travel.

A scheduled maintenance call should be made for every POU-RO unit at least once a year to change the activated carbon filters, disinfect the system, and change the RO element if necessary. It is more difficult to estimate costs for unscheduled maintenance than for scheduled maintenance. However, if it is assumed that scheduled and unscheduled maintenance calls will cost about the same, and that one quarter of the systems will require unscheduled maintenance each year, the cost of unscheduled maintenance should be about one quarter of the cost of scheduled maintenance.

The major miscellaneous maintenance costs are for replacement parts and transportation. Assuming that the two carbon filters are replaced every year and that the average life of the RO membrane element is five years, the annual replacement cost for filters, membrane element, and miscellaneous parts would be about $35 per unit. This cost includes a 25% volume discount for all replacement filters. Assuming that the service life of a truck is five years, a reasonable estimate for annual transportation cost would be about $5 per unit.

# 7.2 - Estimated Costs Relating to POU Treatment Continued ...

The largest unknown factor in the maintenance costs discussed above is probably labor rate. In general, an hourly rate of $25 would be a reasonable assumption for a skilled technician. However, in a small community it may be possible to hire a suitable worker for $15 per hour. Or at the other extreme, it might cost $50 an hour, if local codes require that a licensed plumber do the work. Because of the uncertainty about labor cost, three alternative annual maintenance costs were calculated for POU-RO treatment. These rates are summarized in Table 7-2.

When a community does not want to employ its own maintenance personnel, it may be able to obtain the necessary services by contracting with a reputable water treatment company. Contracting for maintenance of POU-RO units is a viable alternative for any size system, but it is probably the best approach for very small communities. For example, if a community has fewer than about 500 residences, employing a full-time employee to maintain the systems will probably not be cost-effective. However if a reputable water treatment service company is located in the area, they may agree to maintain the systems for a fixed price. The cost of a service contract should be similar to the costs outlined above for community-maintained systems.

| Maintenance Cost Item | Labor rate $15/ hour | Labor rate $25/ hour | Labor rate $50/ hour |
|---|---|---|---|
| Scheduled labor | $18/yr | $30/yr. | $60/yr. |
| Unscheduled labor | $4.5/yr. | $7.50/yr. | $15/yr. |
| Filter replacement | $35/yr. | $35/yr. | $35/yr. |
| Miscellaneous | $5/yr. | $5/yr. | $5/yr. |
| Total annual maintenance cost | $62.5/yr. | $75/yr. | $115/yr. |

Table 7-2. Annual Maintenance Cost as a Function of Labor Rate

### Monitoring Cost

The major factors that influence monitoring costs for POU-RO treatment are monitoring strategy, analysis cost, labor cost, sampling time, and travel time.

At present, determining an appropriate monitoring strategy is difficult, because the EPA and the states have not yet developed clear regulatory guidelines. Until the guidelines are established, it must be understood that estimates of monitoring costs for POU-RO treatment will vary widely.

Monitoring POU-RO units will involve maintaining the conductivity probe and periodically analyzing treated water samples for arsenic concentration. The question is: how often will each unit have to be sampled? Probably the most conservative scenario is sampling every unit once per year. Alternatively, testing might be required for as few as 25% of the units each year. Actually, the lower testing frequency may be adequate as long as the conductivity of the treated water is continuously monitored and a good correlation has been established between arsenic concentration and conductivity.

# 7.2 - Estimated Costs Relating to POU Treatment Continued ...

It costs about $15 to have a water sample analyzed for arsenic by a commercial laboratory. Since the samples could be collected during a scheduled maintenance call, the labor and travel would be covered under maintenance cost. Costs for maintaining the conductivity probe/alarm unit should also be covered by the scheduled maintenance activities. If all of the units were tested each year, the annual monitoring cost would be about $15 per unit. If 25% of the units were tested each year, the annual monitoring cost would be $3.75 per unit.

**Administrative/Management Cost**

The primary activities that determine administrative costs for POU-RO treatment are record keeping, installation scheduling, maintenance and monitoring activities, public outreach and education. Since the scope of administrative and management activities depends to some extent on regulatory guidelines that are being developed, it is difficult to accurately estimate these costs.

A system administrator/manager will be needed to coordinate activities and oversee operations for the entire system. This will probably be a part time job for a community employee. For estimating purposes, assume that an administrator will work 0.2 hours per unit per year at a rate of $25 per hour. An administrative assistant will do the record keeping, scheduling, and public outreach for the system. Again this will probably be a part time job for a community employee. For estimating purposes, assume that an administrative assistant will work 1.0 hour per unit per year at a rate of $15 per hour. The cost of materials and postage for public outreach can be estimated as $3 per unit per year. Thus the annual administrative cost for the system would be $23 per unit.

**Financing Equipment and Startup Costs**

Financing the upfront costs of a POU program may be slightly different than financing centralized treatment. As with more conventional treatment, the utility will wish to secure grants covering as much of the startup cost as possible. Beyond that, it will need to seek a low-interest loan, and revise its water rates to assume loan payments. Public agencies that specialize in infrastructure loans will be the first choice: state commerce department programs, USDA Rural Utility Services, and SDWA revolving loan funds administered by the state primacy agencies are likely sources. In the near term, there may be a private-sector source as well. At least one small utility was loaned the needed funds by the manufacturer of the POU units it installed, which wished to underwrite a full-scale community installation. However, the loan rate was higher than those offered by public agencies for conventional treatment. As long as POU treatment is considered innovative, both public and private lenders will probably set relatively high loan rates, as insurance against uncertainty. This is one factor that is likely to raise the cost of POU treatment relative to conventional treatment.

# 7.3 - Four Alternative Cost Scenarios

Since it is difficult to accurately estimate costs for a POU-RO water system, four different scenarios are considered below to define a range of possible treatment costs. The scenarios were developed with the following assumptions:

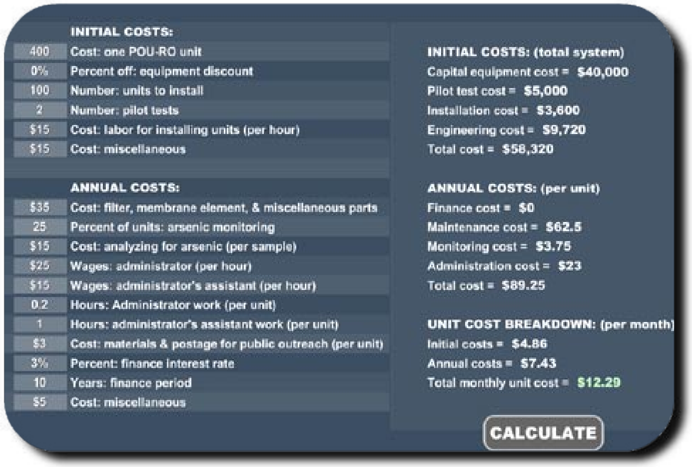
**Case 1 -** Very small community (100 residences), low labor cost, low interest rate, and low monitoring requirements

**Case 2 -** Small community (500 residences), low labor cost, low interest rate, and low monitoring requirements

**Case 3 -** Very small community (100 residences), high labor cost, high interest rate, and high monitoring requirements

**Case 4 -** Small community (500 residences), high labor cost, high interest rate, and high monitoring requirements

### Calculator




Cost breakdowns for the four scenarios are below.

**CASE 1 --------------------------------------------------------**

Total System Costs for a Very Small Community (100 residences), Low Labor Cost, Low Interest Rate, and Low Monitoring Requirements

**Assumptions:**

| | |
|---|---|
| POU-RO unit cost | - $400 |
| Equipment discount | - 0 |
| Number of units installed | - 100 |
| Labor cost | - $15/hr. |
| Arsenic monitoring | - 25% of units tested per year |
| Pilot test | - two units for one year |
| Engineering | - 20% of equipment, pilot test, and installation cost |
| Finance interest rate | - 3% |
| Initial costs finance period | - 10 years |

# 7.3 - Four Alternative Cost Scenarios Continued ...

**Case 1 total cost breakdown:**

Initial costs (total system)

| | |
|---|---|
| Capital equipment cost | - $400 x 100 units |
| Pilot test cost | - $5000 |
| Installation cost | - $36 x 100 units |
| Engineering | - $9,720 |
| Total | - $58,320 |

Annual costs (per unit)

| | |
|---|---|
| Finance cost (3%, 10 yr.) | - $10.03/unit yr. |
| Maintenance cost | - $62.5/unit yr. |
| Monitoring cost | - $3.75/unit yr. |
| Administration cost | - $23/unit yr. |

**Case 1 monthly unit cost breakdown:**

| | |
|---|---|
| Initial costs | - $4.86/unit mo. |
| Annual costs | - $8.27/unit mo. |
| Total monthly unit cost | **- $13.13/mo.** |

**CASE 2 ------------------------------------------------------**

Total System Costs for a Small Community (500 residences), Low Labor Cost, Low Interest Rate, and Low Monitoring Requirements

**Assumptions:**

# 7.3 - Four Alternative Cost Scenarios Continued ...

| | |
|---|---|
| POU-RO unit cost | - $400 |
| Equipment discount | - 25% |
| Number of units installed | - 500 |
| Labor cost | - $15/hr. |
| Arsenic monitoring | - 25% of units tested per year |
| Pilot test | - ten units for one year |
| Engineering | - 20% of equipment, pilot test, and installation cost |
| Finance interest rate | - 3% |
| Initial costs finance period | - 10 years |

**Case 2 total cost breakdown:**

Initial costs (total system)

| | |
|---|---|
| Capital equipment cost | - $400 x .75 x 500 units |
| Pilot test cost | - $15000 |
| Installation cost | - $36 x 500 units |
| Engineering cost | - $36,600 |
| Total | - $219,600 |

Annual costs (per unit)

| | |
|---|---|
| Finance cost (3%, 10 yr.) | - $7.55/unit yr. |
| Maintenance cost | - $62.5/unit yr. |
| Monitoring cost | - $3.75/unit yr. |
| Administration cost | - $23/unit yr. |

**Case 2 monthly unit cost breakdown:**

| | |
|---|---|
| Initial costs | - $3.66/unit mo. |
| Annual costs | - $8.07/unit mo. |
| Total monthly unit cost | **- $11.73/mo.** |

# 7.3 - Four Alternative Cost Scenarios Continued ...

**CASE 3 -----------------------------------------------------**

Total System Costs for a Very Small Community (100 residences), High Labor Cost, High Interest Rate, and High Monitoring Requirements

**Assumptions:**

| | |
|---|---|
| POU-RO unit cost | - $400 |
| Equipment discount | - 0 |
| Number of units installed | - 100 |
| Labor cost | - $50/hr. |
| Arsenic monitoring | - 100% of units tested per year |
| Pilot test | - two units for one year |
| Engineering | - 20% of equipment, pilot test, and installation cost |
| Finance interest rate | - 6% |
| Initial costs finance period | - 10 years |

**Case 3 total cost breakdown:**

Initial costs (total system)

| | |
|---|---|
| Capital equipment cost | - $400 x 100 units |
| Pilot test cost | - $5000 |
| Installation cost | - $85 x 100 units |
| Engineering cost | - $10,700 |
| Total | - $64,200 |

Annual costs (per unit)

| | |
|---|---|
| Finance cost (6%, 10 yr.) | - $23.05/unit yr. |
| Maintenance cost | - $115/unit yr. |
| Monitoring cost | - $15/unit yr. |
| Administration cost | - $23/unit yr. |

# 7.3 - Four Alternative Cost Scenarios Continued ...

**Case 3 unit cost breakdown:**

| | |
|---|---|
| Initial costs | - $5.35/unit mo. |
| Annual costs | - $14.67/unit mo. |
| Total monthly unit cost | **- $20.02/mo.** |

**CASE 4 ------------------------------------------------------**

Total System Costs for a Small Community (500 residences), High Labor Cost, High Interest Rate, and High Monitoring Requirements

**Assumptions:**

| | |
|---|---|
| POU-RO unit cost | - $400 |
| Equipment discount | - 25% |
| Number of units installed | - 500 |
| Labor cost | - $50/hr. |
| Arsenic monitoring | - 100% of units tested per year |
| Pilot test | - ten units for one year |
| Engineering | - 20% of equipment, pilot test, and installation cost |
| Finance interest rate | - 6% |
| Initial costs finance period | - 10 years |

# 7.3 - Four Alternative Cost Scenarios Continued ...

**Case 4 total cost breakdown:**

| | |
|---|---|
| Capital equipment cost | - $400 x .75 x 500 units |
| Pilot test cost | - $15000 |
| Installation cost | - $85 x 500 units |
| Engineering | - $41,500 |
| Total | - $249,000 |
| | |
| Finance cost (6%, 10 yr.) | - $17.88/unit yr. |
| Maintenance cost | - $115/unit yr. |
| Monitoring cost | - $15/unit yr. |
| Administration cost | - $23/unit yr. |

**Case 4 unit cost breakdown:**

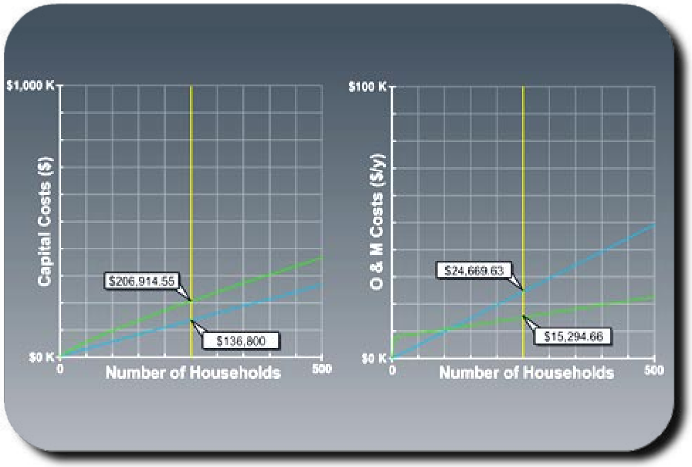
| | |
|---|---|
| Initial costs | - $4.15/unit mo. |
| Annual costs | - $14.24/unit mo. |
| | |
| Total monthly unit cost | **- $18.39/mo.** |

# 7.4 - POU-RO vs. Central Treatment Cost Comparison

Estimated costs for central treatment of drinking water were compared with the estimated costs for POU-RO treatment outlined in section 7.3, to determine when POU-RO might be a cost-effective alternative.

Costs for centralized treatment were obtained from information contained in the EPA report entitled "Arsenic Treatment Technology Design Manual for Small Systems." This report contains charts that indicate capital costs, operation and maintenance costs for various types of treatment as a function of system capacity. See the report for details on cost assumptions related to the following estimates. The full text of "Arsenic Treatment Technology Design Manual for Small Systems" is available at http://www.epa.gov/safewater/smallsys/arsenic_treatment_handbook_lo.pdf.

**Comparing POU-RO & Greensand Filtration**




The cost comparison is only for illustrative purposes. Systems that will consider selecting greensand filtration will have high iron in the source water above the secondary standard. To consider POU, iron would still need to be removed or possibly sequestered, whereas the greensand option would address both iron and arsenic.

For comparison purposes, costs for greensand filtration were determined since this is a commonly used and economical central treatment option for control of arsenic in drinking water. Cost estimates were developed for two cases, a very small community having 100 residences and a small community having 500 residences. The following assumptions were used for the greensand treatment cost estimates:

- A new greensand filtration system was installed
- Potassium permanganate feed rate is 10 mg/L
- Filter service rate is 4 gpm/square foot
- Backwash flow rate is 10-12 gpm/square foot
- Backwash waste is discharged into the municipal sewer system
- An average of three persons are living in each residence

# 7.4 - POU-RO vs. Central Treatment Cost Comparison Continued ...

- Average daily water consumption is 150 gal/cap day
- Design flow rate for treatment process is 375 gal/cap day
- Design life for capital equipment is 20 years
- Arsenic concentration in treated water must be less than 0.010 mg/L

For a very small community serving 100 residences, the following cost estimates were determined for a centrally-located greensand filtration system:

- Total system capital cost = $98,000 (based on a design flow rate of 0.112 mgd)
- Operation and maintenance = $11,000/yr. (based on an average flow rate of 0.045 mgd)

These costs were converted to a monthly residence charge of $14.33/mo.

For a small community serving 500 residences, the following cost estimates were determined for a centrally-located greensand filtration system:

- Total system capital cost - $367,000 (based on a design flowrate of 0.56 mgd)
- Operation and maintenance cost - $23,000/yr. (based on an average flowrate of 0.225 mgd)

These costs were converted to a monthly residence charge of $6.79/mo.

# 7.4 - POU-RO vs. Central Treatment Cost Comparison Continued ...

Based on the cost estimates for POU-RO and centralized greensand filtration, the following comparisons can be made for a community with 100 residences:

- POU-RO treatment cost (per residence) - $13.13 to $20.02/month
- Centralized greensand filtration cost (per residence) - $14.33/month

Based on the cost estimates for centrally managed POU-RO and centralized greensand filtration, the following comparisons can be made for a community with 500 residences:

- POU-RO treatment cost (per residence) - $11.73 to $18.39/month
- Centralized greensand filtration cost (per residence) - $6.79/month

The results of the comparison indicate that the cost of POU-RO treatment is roughly equivalent to centralized greensand treatment for a community of 100 residences, particularly under the lower POU-RO cost scenario. However for a community with 500 residences, centralized greensand treatment appears to be significantly less expensive than POU-RO. The main reason for the cost difference is that maintenance costs for POU-RO units are about the same regardless of the number of units used, while operation and maintenance cost per residence for greensand filtration decreases sharply as the number of residences increases.

It should be noted that other factors can affect the cost comparisons reported above. For example if water usage in a community is higher than that assumed for the estimates, it would tend to increase the cost of central treatment. Similarly, if significant distribution system changes were required to accommodate central treatment, it would also increase the cost of central treatment.

# 7.5 - Expand & Test Your Knowledge

POU-RO units certified under ANSI/NSF standard 58 are listed on the web at http://www.nsf.org/Certified.

The full text of "Arsenic Treatment Technology Design Manual for Small Systems" is available at http://www.epa.gov/safewater/smallsys/arsenic_treatment_handbook_lo.pdf.

Two presentations dealing with cost estimation for point-of-use treatment were given at a recent conference sponsored by NSF International. The title of the conference was "Public Water System Compliance Using Point-of-Use and Point-of-Entry Treatment Technology," Feb. 13-14, 2003, Orlando, Florida.

## Test Your Knowledge

The EPA's approach for estimating costs was summarized in a presentation entitled Point-of-Use/Point-of-Entry Devices Cost Considerations. An outline of the presentation can be found at http://www.nsf.org/cphe/pou/Kempic_Khera.pdf.

A paper entitled Point-of-Use/Point-of-Entry Treatment for Arsenic Removal Operational Issues and Costs was included in the conference proceedings. This paper was based on a study funded by the American Water Works Research Association. The full text of the paper can be found at http://www.nsf.org/cphe/pou/Narasimhan.pdf.

A printable version of the program is available on this disc in PDF format (current as of January of 2004). **pou_ro_hard_copy.pdf**.

# Activities, Links, and Documents Provided

## ACTIVITIES:

UNIT 1
- 1.1 - More About This Program
- 1.2 - Reverse Osmosis
- 1.3 - How POU-RO Removes Arsenic
- 1.4 - Acceptance Takes Time
- 1.5 - Implementation Plan Checklist
- 1.6 - Test Your Knowledge

UNIT 2
- 2.2 - FAQs With Sam
- 2.3 - Timeline For Final Arsenic Rule
- 2.5 - Check Your Knowledge of Compliance dates
- 2.7 - Test Your Knowledge

UNIT 3
- 3.1 - To Use or Not To Use POU-RO
- 3.3 - Preliminary System Design Tasks
- 3.4 - Implementing a Pilot Test
- 3.5 - Typical 3 Stage Parameters
- 3.6 - San Ysidro Overview
- 3.7 - Test Your Knowledge

UNIT 4
- 4.1 - Components of a POU-RO System
- 4.2 - Optional Components
- 4.4 - POU-RO Unit Installation
- 4.5 - Test Your Knowledge

UNIT 5
- 5.3 - Disinfecting the System
- 5.4 - RO Conductivity Measurement
- 5.5 - POU-RO Implementation Game
- 5.6 - Test Your Knowledg

UNIT 6
- 6.3 - Records
- 6.6 - The Money Tree
- 6.7 - Test Your Knowledge

UNIT 7
- 7.1 - Costs
- 7.2 - Sam VS You
- 7.3 - Calculator
- 7.4 - Comparing POU-RO & Greensand Filtration
- 7.5 - Test Your Knowledge

# Activities, Links, and Documents Provided on The CD Continued...

**LINKS:**

UNIT 1

1.1 - http://www.adobe.com/products/acrobat/readstep2.html
1.6 - http://www.epa.gov/safewater/smallsys/arsenicdesignmanualpeerreviewdraft.pdf
1.6 - http://www.epa.gov/safewater/ars/implement.html

UNIT 2

2.2 - http://www.nsf.org/Certified/DWTU/
2.2 - http://www.ul.com/
2.2 - http://www.wqa.org/
2.2 - http://www.law.cornell.edu/uscode
2.3 - http://www.epa.gov/safewater/ars/implement.html
2.3 - http://www.epa.gov/ogwdw/ars/quickguide.pdf
2.5 - http://www.epa.gov/safewater/ars/congr_ars_mar_02.pdf
2.6 - http://www.nsf.org/cphe/pou/program.html
2.7 - http://www.epa.gov/safewater/arsenic.html

UNIT 3

3.1 - http://www.epa.gov/safewater/smallsys/arsenic_treatment_handbook_lo.pdf
3.5 - http://www.dow.com/liquidseps/design/rosa.htm
3.6 - http://www.epa.gov/nepis/srch.htm
3.6 - http://water.montana.edu/pdfs/moretti.pdf
3.6 - http://www.nsf.org/cphe/pou/program.html
3.6 - http://www.nsf.org/cphe/pou/program.html
3.6 - http://www.epa.gov/safewater/ars/implement.html
3.7 - http://www.epa.gov/safewater/ars/methods.pdf

UNIT 4

4.1 - http://www.dow.com/liquidseps/pc/res_ele.htm
4.1 - http://www.osmonics.com/products/Page1062.htm
4.3 - http://www.nsf.org/DWTU/
4.3 - http://www.epa.gov/safewater/ars/implement.html
4.5 - http://www.osmonics.com/products/Page700.htm
4.5 - http://www.awqinc.com/buying_ros.html
4.5 - http://www.awqinc.com/pdf/Roinst.PDF
4.5 - http://www.wqa.org/

# Activities, Links, and Documents Provided on The CD Continued...

UNIT 5

5.6 - http://www.pwgazette.com/filter.htm
5.6 - http://www.wattspremier.com/edu
5.6 - http://www.osmonics.com/products/Page700.htm
5.6 - http://www.wqa.org/
5.6 - http://www.touchflo.com/touchfloframe3.html
5.6 - http://www.epa.gov/safewater/ars/methods.pdf

UNIT 6

6.7 - http://www.epa.gov/safewater/ars/implement.html
6.7 - http://www.epa.gov/safewater/ars/implement.html
6.7 - http://www.wattspremier.com/community/
6.7 - http://www.wattspremier.com/edu/

UNIT 7

7.4 - http://www.epa.gov/safewater/smallsys/arsenic_treatment_handbook_lo.pdf
7.5 - http://www.nsf.org/Certified
7.5 - http://www.epa.gov/safewater/smallsys/arsenic_treatment_handbook_lo.pdf
7.5 - http://www.nsf.org/cphe/pou/Kempic_Khera.pdf
7.5 - http://www.nsf.org/cphe/pou/Narasimhan.pdf

**DOCUMENTS (found on the CD):**

UNIT 6

6.2 - POU_Sample_Ordinance.doc **extras\documents**
6.7 - POU_Sample_Ordinance.doc **extras\documents**
arsenic_treatment_handbook_lo.pdf **extras\pdf**