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How to Lower the Levels of Arsenic in Well Water: What Choices Do Arizona Consumers Have?

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Arsenic levels are often above drinking water standards in Arizona groundwater, at levels that may affect health. Private well owners are responsible for testing and treating their own water. This publication gives an overview of arsenic in well water and discusses home water treatment options, including detailed descriptions of distillation, reverse osmosis (RO), and iron filters to lower arsenic and other common water constituents in drinking water.

Why should I be concerned about arsenic in my drinking water?

What is arsenic?

Arsenic is a naturally occurring element found in combination with other elements in the Earth's crust. Due to natural processes such as rock and mineral weathering and human activities such as mining, arsenic may be found in the soil, water, and air in some places at levels that are unsafe. Visit http://www.atsdr.cdc.gov/toxfaqs/tfacts2.pdf for more information on arsenic health effects.

How can I be exposed to arsenic?

Worldwide, the primary route of arsenic exposure is via drinking water (Naujokas et al. 2013). Exposure to arsenic may also occur through eating food or breathing airborne particles (dust) that contain arsenic. In addition, children may be exposed when they mouth their hands or objects like toys, which may be covered with soil and dust containing arsenic.

In several regions of the United States, including Arizona, arsenic can occur at high levels in soils and groundwater, due to complex natural geologic features and processes. High levels of arsenic in groundwater are problematic because groundwater is a primary source of drinking water in Arizona. For more information on Arizona aquifers see Extension Publications AZ1485 (Artiola & Uhlman 2009) and AZ1453 (Uhlman 2008)

How can arsenic in drinking water affect my health?

Consuming very large amounts of arsenic over the short term can cause poisoning. Consuming small amounts over many years can raise your risk for some cancers and have other health effects. Whether your health is affected depends on how much arsenic you are exposed to and for how long, as well as your sensitivity to arsenic.

What level of arsenic in my drinking water is considered safe?

The Safe Drinking Water Act requires the United States Environmental Protection Agency (US EPA) to set standards for drinking water quality, known as Maximum Contaminant Levels. The US EPA has set the arsenic standard at 10 ppb (parts per billion, or micrograms per liter) to protect consumers served by public water systems from the effects of long-term exposure to arsenic. Ten ppb is roughly equal to five teaspoons of ink in an Olympic-sized swimming pool.

However, even though public water utilities are required to lower arsenic levels in drinking water to less than 10 ppb, private wells are exempt from these rules. It is the responsibility of the well owner to test for arsenic and reduce it if needed. Read below for more information on how to do so.

Groundwater quality surveys conducted by the Arizona Department of Environmental Quality (ADEQ) have shown that about 1 in 5 water samples in Arizona had arsenic levels above the 10 ppb standard (Towne & Jones 2011; Figure 1). Thus, it is important for Arizona well owners to test their wells for arsenic.

How can I learn the level of arsenic in my drinking water?

Arsenic is colorless, odorless, and tasteless, so you cannot know it is there unless you test for it.

If you receive water from a municipal or privately owned water company, it is required to test your water for arsenic. You should receive an annual water quality report from your water supplier by July 1st of each year.

See also http://water.epa.gov/drink/local/

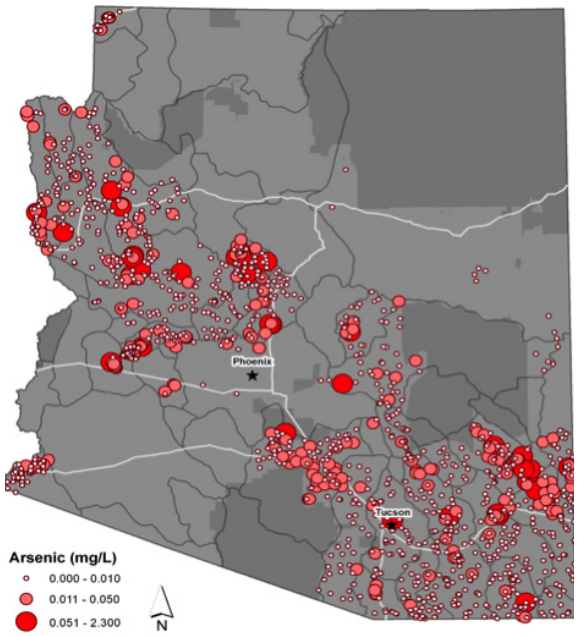

Figure 1. Arsenic levels in Arizona groundwater, 1995-2009 survey of 1,477 sites within 35 of the state's groundwater basins. Dot may include one or more wells. Arsenic concentrations reported in mg/L (1mg/L = 1,000 ppb); medium and large dots show samples over the 10 ppb arsenic standard (19% of samples). Source: Towne & Jones (2011).

Figure 2. Overview of recommended steps for well owners. See text for additional details.

If you drink bottled water, bottled water companies are not required to report results of any water quality testing. If you choose bottled water, contact the supplier for information about contaminants, including arsenic.

If you have your own well, you are responsible for testing and maintaining its water quality. Although Arizona private wells are not legally required to meet drinking water standards, it is recommended that well owners monitor their well water quality regularly and consider using one or more water treatment options to treat their well water as needed to meet or exceed the arsenic and other water quality parameters (Figure 2). Read below for more information focused on treatment systems for private well owners.

For additional information, see http://www.azdhs.gov/phs/oeh/toxicology/wellwater.htm.

How often should I test my drinking well water?

Because drinking arsenic in water has negative health effects, the Arizona Department of Health Services recommends that all well owners use a state-certified laboratory to test your well water on this schedule:

- Test every year for bacteria and nitrates
- Test at least every three years for arsenic, lead, and radon

See more information on how to find a state-certified lab and using at-home testing kits in the sections below

What do my arsenic testing results mean?

Once you know the arsenic level in your well water, respond as follows:

If arsenic in your well water is **less than 10 ppb**, it is OK for drinking, cooking, and all other household purposes. Continue to test your untreated well water for arsenic at least every three years, using a state-certified laboratory. Follow the testing schedule for other contaminants.

If arsenic in your well water is **between 10 – 200 ppb**, it is not an emergency, but make plans to get water for drinking and cooking from a different source, or install a home treatment system. Well water with arsenic levels **below 100 ppb** is considered safe to irrigate water plants, including garden vegetables, and may be used as drinking water for livestock and poultry (Ayers and Westcot 1985). If you have household pets, consult your veterinarian. Continue to test your untreated well water for arsenic at least every three years, using a state-certified laboratory.

If arsenic in your well water is **over 200 ppb**, DO NOT use this water for drinking, cooking, irrigation, or watering animals. Use another drinking and cooking source immediately and consider installing and maintaining a home treatment system. If the arsenic is **less than 500 ppb**, you can continue to use this water for bathing and washing. Other sources of water include bottled water or connecting to a public water supply. If you

choose bottled water, contact the supplier for information about contaminants, including arsenic, and be sure to clean and disinfect your water containers regularly. Continue to test your untreated well water for arsenic at least every three years, using a state-certified laboratory.

For additional help understanding arsenic test results, call the Arizona Department of Health Services at (602) 364-3128.

What treatment options are available to me?

See Table 1 for a summary of your water treatment and testing options. If you install any water treatment system, whether it reduces arsenic or not, continue to test your treated well water for arsenic every year using a state-certified laboratory.

Monitoring your treatment system's performance

If you are treating for arsenic, once you have established that treatment is effective (the arsenic level in your water is less than the 10 ppb standard), continue to monitor the performance of your treatment system by testing your treated well water for arsenic every year using a state-certified laboratory.

State-certified testing laboratories

It is important to get an accurate measurement of how much arsenic is in your well water. Modern laboratory methods are extremely accurate and consistent and can detect arsenic at levels much lower, very close to, or much higher than the 10 ppb standard.

To find a state-certified testing laboratory, contact the Arizona Dept. of Health Services at (602) 364-0720. The cost for a single arsenic test in a laboratory may be as much as $50. However, commercial laboratories may offer group discount prices with other water contaminant tests with significant cost reductions. (See below for more information on other contaminants to test for.)

At-home arsenic testing kits

If you prefer to test at home, you may buy an at-home arsenic water testing kit. These kits vary in complexity and usually require mixing 2-4 chemicals with water to produce a chemical reaction[1]. Results are seen as a color change on a paper strip. Although faster and often more cost-effective than laboratory testing, at-home arsenic testing kits estimate arsenic levels between a wide range of numbers and are therefore not as accurate. Look for a testing kit that has been verified by the US EPA Environmental Technology Verification (ETV) program (Figure 3). However, even studies of ETV-verified kits suggest that they do not always detect arsenic accurately at or near the level of the 10 ppb arsenic standard (Abbgy et al. 2002, Spear et al. 2006, and George et al. 2012). Consumers may use these arsenic-testing kits to routinely verify arsenic levels after confirming the kit is accurate: the testing kit results should be within 20% of state-certified laboratory results obtained with the same water sample or sample taken from the same water source.

Figure 3. Example of at-home Arsenic Testing Kit (no endorsement implied). Source: http://www.sensafe.com/arsenic-kits/

Considerations for choosing a home treatment system

Once you have your water testing results and decide you need to treat your water, you can select which treatment option is right for your needs and conditions. Choosing a home water treatment system can be a complicated process. A water quality professional can help you analyze your water treatment needs and identify an appropriate solution. This publication will review basic considerations. Additional details can be found in Extension Publication AZ1578 (Artiola et al. 2012). When choosing a treatment system, consider the following:

1. *What purposes do you use your well water for?* Possible well water uses include: drinking and cooking, landscape and vegetable garden watering, showers and toilets, and ranching. Think about which of these activities you will perform, and how much water they will require. See "What do my arsenic testing results mean?" for guidance on using water with arsenic in it for different purposes. Ultimately, it is up to the well owner to balance the health risks with cost and convenience when deciding whether and how much water should be treated.
2. *How much arsenic is in your well water?* Most systems remove a percentage of the arsenic, but not all of it. For example, even if a treatment removes 90% of the arsenic, if your starting level is 200 ppb, removing 90% still leaves arsenic in the drinking water at 20 ppb, above the standard.
3. *How much water do you need?* It may not be necessary to treat all the water from the well. Choose a unit that meets your needs assuming that each person in the household will need 2-3 gallons per day for cooking and drinking. Depending on how much water you need, you can choose a point-of-use (at a single tap) or point-of-entry (whole

[1] CAUTION: These tests produce small amounts of very toxic chemicals that should be handled in a well-ventilated space without spilling and disposed of according to hazardous waste regulations.

house) system. Point-of-use treatment can often treat enough water needed for drinking and cooking, while keeping installation and maintenance costs lower.

4. *What else is in your water?* The pH and the presence of other constituents and dissolved solids in your water may influence your treatment choice. See below for more details.

You can purchase water treatment systems from a variety of sources, including plumbers, hardware stores, water treatment companies, and through the Internet. Good planning and analysis is important so that you can buy the best system for your needs and conditions. Home water treatment systems often have one or more NSF[2] and/or ANSI[3] certifications attesting to the technology and quality of its components. However, as with all other consumer products, it is buyer beware. To ensure that you are buying a certified system, before buying make sure your product is listed on one of these websites:

- NSF International: www.nsf.org/certified/DWTU
- The Water Quality Association: http://www.wqa.org/Find-Products#/

What are my home treatment options?

Be aware that many common home water treatment techniques do not remove arsenic from water. These include: particle filters, activated carbon filters (e.g. Brita, Pur), chlorine (bleach) disinfection, and heating or boiling the water. Water softening systems remove calcium and other minerals from hard water but do not remove arsenic from water.

There are four major ways to lower the levels of arsenic in water: 1) distillation, the collection and cooling of steam from heated water to remove arsenic; 2) filtration, the use of a semi-porous membrane that does not allow arsenic to pass through it; 3) adsorption, the use of a solid or porous material to trap arsenic; and 4) chemical reaction, which leads to arsenic coming out of the water as a solid.

There are a number of technologies that use these four major methods to remove arsenic from water. Some technologies, such as chemical reaction, are more appropriate for the large volumes processed by municipal water treatment, while others have been adapted for home water treatment (US EPA 2003). The three technologies most commonly used to treat well water at home are: distillation, membrane filtration such as reverse osmosis, and adsorption with iron or activated alumina[4] . Distillation and reverse osmosis make use of well-known technologies and are more widely available, while iron adsorption is less well known and has less consumer options to date. Each method is discussed in detail below. Each technology has advantages and disadvantages depending on the starting level of arsenic in the water, what other constituents or conditions are present, how much water needs to be treated, and costs. After installation of any system, test your treated water to make sure treatment is effective. Maintain your system according to manufacturer's instructions.

Distillation

How does distillation work?

Distillation uses a physical process to separate contaminants from water (Figure 4). Contaminated water is boiled and the steam is collected in a separate container. The purified steam is then cooled, which causes it to condense back into water. Most constituents, including salts and metals such as arsenic, do not evaporate and are left behind. The boiling process also kills bacteria and other microorganisms. See also Extension Publication AZ1578 (Artiola et al. 2012) for a description of this and other water treatment methods.

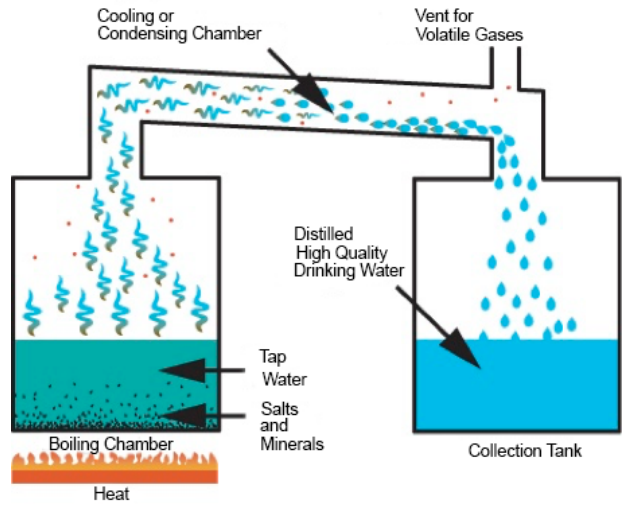

Figure 4. Diagram of the water distillation process.

Pros and cons of distillation?

A properly used distillation unit can produce water free of salts, metals, and other constituents, including removal of arsenic to a level much below the drinking water standard of 10 ppb. However, volatile organic compounds, such as solvents (e.g., gasoline, degreasers, dry cleaning liquids) that boil at temperatures less than the boiling point of water will vaporize along with the water. If you suspect your water has these contaminants, you must take additional steps to purify the water. Note that some distillation units have activated carbon filters to reduce volatile organic compounds.

How much water can be treated?

Home distillation systems can be used to produce small quantities (about 1-4 gallons/day) of water that is essentially free of salts and metals (including arsenic).

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[2] The NSF International is an "independent, third-party testing and certification" organization that tests and certifies water treatment systems and other consumer products.

[3] The American National Standards Institute (ANSI) is a private, non-profit organization that develops standards and certifies water treatment units and many other consumer and industry products.

[4] Activated alumina filters are usually not effective to remove arsenic from water with pH above 7, common in Arizona groundwater, and are not considered here.

How to buy/install/maintain and how much does it cost?

Distillation systems are used as point-of-use, self-contained devices. Start-up costs start at around $200 for tabletop models. Before purchasing a distillation unit, consumers should note its energy use and gallons of distilled water produced per hour or day. For example, a distillation unit that consumes 800 watts-hour and runs for 8 hours will cost about $1 of electricity each day and may produce 2-3 gallons of distilled water. Distillation units generate heat and some gases and should be installed and operated in a well-ventilated area. Follow manufacturer recommendations to clean and maintain the unit. Because distilled water is corrosive do not store it in metal containers or in any container for long periods of time.

Distillation summary

This option may be useful when the daily volume of drinking water needed in the home is limited to less than 5 gallons/day. Distillation produces demineralized, arsenic-free water, but up-front equipment costs and electricity use can be significant depending of the unit size and volume of water needed.

Reverse osmosis (RO)

How does RO work?

Reverse osmosis (RO) is a type of filtration that uses pressure to force water through a semi-permeable membrane, leaving metals (such as arsenic), salts, and other contaminants behind.

Pros and cons of using RO?

Reverse osmosis systems are readily available for purchase by the general public, and are the most common method used by Arizona well owners to lower contaminants (particularly arsenic) in their well water. RO can be very effective at reducing the levels of many contaminants, such as salts, metals (including arsenic), nitrates, fluoride, uranium, and organic compounds.

RO systems do not require the addition of chemicals, but do require periodic maintenance as membranes and other components wear out. In addition, RO home systems operate at low pressures (40-60psi), which makes them inefficient; that is, they waste several gallons of water per gallon of water produced, resulting in an increase of total water use for drinking and cooking of about 3-8 times above previous use. Salts can collect and plug the membrane and these must be flushed out regularly. This problem is aggravated by water hardness (high levels of calcium and magnesium) that is usually high in Arizona groundwater. Thus, RO water treatment is more efficient in combination with pre-treated soft water.

Note that RO units do not remove the same amounts of each constituents from water; removal rates range from about 50% to about 95%+ and depend primarily on the type of constituents. For example, most RO systems are more effective at removing calcium, magnesium, and sulfate than sodium, potassium, chloride, or nitrate, (Figure 5).

RO systems can be very effective at removing arsenic (up to 95%), but efficiencies can vary dramatically, depending on the brand of system, how well it is maintained, and the starting level of arsenic. A recent study (Lothrop et al. 2015) of the water quality in five households using RO systems in a central Arizona community illustrates this variation (Figure 6). Three out of the five homes had starting levels of arsenic above the 10 ppb standard. In one home (A), RO reduced arsenic levels by 85%, but this still left arsenic above the 10 ppb standard. Two homes (C and D), started with different levels of arsenic, and RO reduced the arsenic by different amounts, resulting in levels below the 10 ppb standard for each home. In two other homes (B and E), arsenic started below the 10 ppb standard and an RO system did not have a significant effect. These results are similar to a survey of 57 households in a Western US state (Walker et al., 2007). That study reported that RO systems removed an average of 80% of the arsenic in treated water, leaving arsenic above the 10 ppb standard in one-third of the homes. This survey also showed that the varying effectiveness of RO systems depended on other water conditions such as salinity and forms of arsenic. One form of arsenic called arsenite (arsenic III) is less likely to be filtered out than the more common arsenate (arsenic V) form. However, this

Water Quality		TDS	Alkalinity	
Before RO (ml/L)		400	145	
After RO (mg/L)		35.8	2.5	
Removal (%)		91	98	
Water Quality	**Sodium**	**Potassium**	**Chloride**	**Nitrate**
Before RO (mg/L)	38.8	2.2	12.4	3.69
After RO (mg/L)	7.6	0.66	3.29	2.14
Removal (%)	80	70	73	42
Water Quality	**Calcium**	**Magnesium**	**Sulfate**	
Before RO (mg/L)	69.1	12.5	143	
After RO (mg/L)	2.3	0.5	4.38	
Removal (%)	97	96	97	

Figure 5. Reverse osmosis removal rates of total dissolved solids (TDS) and common constituents found in a southern Arizona water sample: Source: J. Artiola.

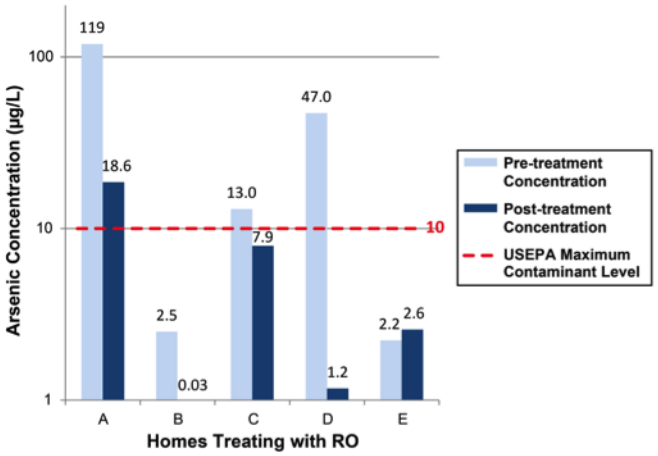

Figure 6. Arsenic concentrations in water samples before home treatment (Pre-treatment Concentration) and after RO treatment (Post-treatment Concentration) from central Arizona homes with paired samples (Lothrop et al 2015).

is normally not an issue of concern for Arizona well owners since most aquifers contain arsenate. Information about the brand of RO system and how the RO systems were maintained was not provided in either of these surveys.

Because RO effectiveness can vary, it is important for well owners to: test untreated water before RO installation; test treated water after RO installation; and re-test treated water annually to confirm the system is working.

How much water can be treated?

RO units vary in size, and may run as needed to keep the treated storage tank full. Select a unit that has a large enough storage tank to provide water during cooking times when larger volumes of water may be needed quickly. Note that using water with elevated levels of arsenic (up to 200 ppb) may be acceptable for landscape irrigation. Consult your veterinarian for advice on using this water for animals.

How to buy/install/maintain and how much does it cost?

RO is usually applied as a point-of-use system. There are a wide variety of choices for RO systems commercially, and many plumbers are familiar with them. Home RO systems start at about $200. As with other consumer products, more durable RO units tend to cost more money. Annual maintenance costs are about $50 and up depending on the membrane type and number of pre-and post RO treatment filters replaced. Note that RO units now include two or more pre- and post-treatment filters (micro filter and activated carbon) that must be replaced regularly[5] with the RO membrane (Figure 7).

Well owners should consider hiring a professional to install the RO system and test it for effective arsenic removal. Since professional installation costs may exceed $500, the buyer should request a performance guarantee of the unit. It is also recommended that the well owner have the water tested independently after installation to verify manufacturer claims and successful installation.

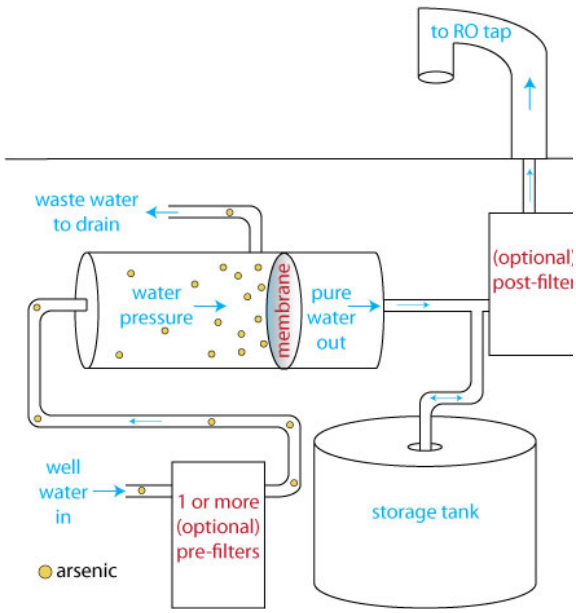

Figure 7. Diagram of a modern RO system with pre- and post-filters.

Effects of arsenic starting level and RO effectiveness on final arsenic level - examples:

- If the water starts with 50 ppb arsenic and the unit has a 70% removal rate, treated water would still have 15 ppb of arsenic, above the standard of 10 ppb.
- If the water starts with 100 ppb arsenic and the unit has a 95% removal rate, treated water should have 5 ppb of arsenic, below the standard of 10 ppb.
- If the water starts with 250 ppb arsenic and the unit has a 95% removal rate, treated water should have 12.5 ppb of arsenic, above the standard of 10 ppb.
- Keep in mind that system maintenance also affects final arsenic level.

Homeowners familiar with plumbing may choose to purchase and install RO units by themselves. They should research units available on their local market first, as these are more likely to work for the local water conditions. Buyers should carefully review the claims of removal rates for arsenic and use it to calculate the final arsenic level in their RO-treated water. See text box for examples. After installation of an RO unit, it is strongly suggested that the RO effectiveness be tested initially and regularly to measure the level of arsenic in the treated water. The user should remain vigilant, check the unit for leaks, and clean and replace filter holders and filters at manufacturer-prescribed intervals.

RO summary

Reverse osmosis is a widely available water treatment technology suitable for home use, especially when total dissolved solids are below 1,000 mg/L and arsenic levels are below 100 ppb. Reverse osmosis systems are best installed and maintained by professionals or skilled do-it-yourselfers.These systems may increase household water consumption significantly. Reverse Osmosis wastewater may safely be used to irrigate landscape plants and trees. See Extension publication AZ1610 (Artiola et al. 2014).

Iron Filter Adsorption

How do iron filters work?

The chemistry of metal-based filters to lower arsenic levels is used in industrial water treatment and similar materials are also used in home treatment systems (AWWARF 2005). A typical iron filter is a cylinder tightly packed with grains or beads (Figure 8). It is designed so that water flows through, allowing arsenic to adsorb (stick) to the filler material. Most iron filters use some form of ferric (iron) hydroxides or oxides in granular forms (grains) or coated onto plastic beads or sand; the unique fillers are often patented (Hussan et al. 2008). An iron filter is placed in-line with the water line at the point of use and usually consists of a replaceable unit or a fixed filter holder with replaceable iron filter cartridges. Iron filters designed to adsorb arsenic may also lower selenium and fluoride levels in water.

[5] Usually done at manufacturer-recommended intervals.

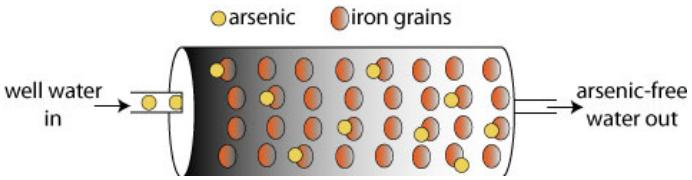

Figure 8. Schematic cross-section of an iron filter showing how arsenic molecules adsorb to iron grains.

Pros and cons of using iron filters?

Iron filters may offer a simpler alternative to the more complex RO systems to lower arsenic levels in well water. They are more energy-efficient, using no electricity or extra water. In addition, unlike distillation or reverse osmosis, iron filters can lower arsenic levels while still allowing important water nutrients such calcium and magnesium to go through.

However, this method of arsenic removal is still not fully developed for home use. As a developing technology, it is up to the consumer to decide among the available filters and determine, often at his/her expense, how efficient and durable these iron filters are to treat well water.

Despite the mechanical simplicity of these filters, there are a number of water quality parameters and constituents that can affect the performance and durability of these filters. For example, pH levels above 7 may reduce arsenic removal rates, and soluble silica, phosphate, sulfate, or iron may interfere (compete) with arsenic attachment to iron filler materials. Other constituents like manganese, bicarbonate, chloride, fluoride, selenium, sulfide ions and organic matter may also react with filters. In additional to testing for arsenic, well owners should have their water quality tested, and have the results on hand before they invest in this technology. This additional water quality information is needed to ensure the efficiency and longevity of the iron filter. Read below for more details.

What should you know about your water quality before buying an iron filter to treat arsenic?

1. ***Highest Priority:***
   a. Arsenic (As) should be less than 100 ppb.
   b. pH should be 6.5 - 8.5.
   c. Total dissolved solids (TDS) should be less than 500 mg/L.

If arsenic exceeds 100 ppb and/or TDS exceed 500 mg/L, consider using an RO system instead, either alone or in combination with an iron filter.

2. ***Additional considerations*** (*listed from the most likely to least likely to affect filter performance*):

   a. Silica (SiO_2) should be less than 30 mg/L. If reported as Silicon (Si), it should be less than >14 mg/L.
   b. Sulfate ($SO_4^{=}$) should be less than 100 mg/L or less than 33 mg/L if reported as SO_4-S
   c. Phosphate (PO_4^{-3}) should be less than 0.5 mg/L or less than 0.2mg/L if reported as PO_4-P
   d. Fluoride (F^-) should be less than 1 mg/L. However, a survey of nearly 2000 wells showed that fluoride levels above 1 mg/L are common in Arizona groundwater (Towne & Jones 2011).
   e. Bicarbonate (HCO_3^-) is the major constituent of water alkalinity at pH values between 7-8.2, common in AZ groundwater. Most Arizona aquifers have very hard water (high in calcium and magnesium) ranging from ~50mg/L to several hundred mg/L (Towne & Jones 2011) and this is usually associated with similar levels of alkalinity. Bicarbonates can reduce arsenic sorption to iron filters. However, the concurrent presence of calcium ions, common in AZ groundwater sources may lower the competition of bicarbonate ions (alkalinity) for arsenic adsorbing sites on iron filter media.
   f. Manganese (Mn) should be less than 0.05 mg/L.
   g. Iron (Fe) should be less than 0.3 mg/L.
   h. Sulfides (H_2S, HS^-) should be less than 0.1mg/L.

If any of these constituents is above the level shown above, consider using distillation or RO instead.

How to buy/install/maintain and how much does it cost?

The installation and operation of these in-line filters are usually simple. Costs range from $100 to several hundred dollars depending on the filter size. Initial and regular testing is recommended to determine the filter's arsenic removal efficiency and capacity.

How much water can be treated?

An iron filter can be used to produce a few hundred gallons of arsenic-free water before replacement is needed. However, this will depend on the filter size, arsenic level, and other water quality parameters as discussed above. Once used, these filters cannot be reused. Take care not to throw used filters in the trash; instead, take them to your local hazardous waste recycling center for proper disposal.

Iron filter summary

This option may be appropriate for people who have arsenic less than 100 ppb, pH between 6.5 and 8.5, and total dissolved solids less than 500 mg/L and who are comfortable tinkering with their system and using a new technology.

Other water treatment options

Consumers can also get a professionally installed and maintained arsenic filter system that employs one or more US EPA-approved technologies, such as tanks filled with ion exchange resins or iron oxide coated resins, which usually require installation of an RO system as well. These resin-filled tanks are replaced or regenerated periodically by vendors that offer this service. Keep in mind that efficient arsenic removal using ion exchange is limited to low total dissolved solids/low sulfate water that often requires RO pretreatment (US EPA 2003).

Conclusions

Arizona and other parts of the United States have elevated levels of arsenic in groundwater due to the geochemical conditions found in many of its aquifers. It is important for well owners to test their well water for arsenic. The main options for Arizona

well owners to treat their well water to lower arsenic levels are distillation, reverse osmosis, and iron filters. Consumers should use water treatment systems that use technologies that are US EPA accepted and NFS/ANSI certified, and they should demand system performance guarantees from manufacturers or installers. When installed and maintained properly these consumer-oriented point-of-use technologies can produce sufficient quantities of water to meet the daily cooking and drinking needs of a household. The selection and efficient operation of a water treatment system needs to be based on detailed information about the groundwater quality. After installation of any system, test your water to make sure treatment is effective, and maintain your system according to manufacturer's instructions.

Additional Note: Consumers should be aware that the three treatment technologies discussed above will not only lower contaminants in water such as arsenic but also other beneficial constituents such as calcium, magnesium and fluoride from drinking water. Consult with your doctor or dietician if you plan the long-term use of low mineral or demineralized water (produced by RO and distillation) in your diet.

References

Abbgy, A., T. Kelly, C. Lawrie, and K. Riggs. 2002. U.S. EPA Environmental Technology Verification Report. ETV Advanced Monitoring Systems Center. Quick™ Arsenic Test Kit. July 2002. Battelle, Columbus, OH. 43201.

Artiola, J.F., K. Farrell-Poe, and J. Moxley. 2012. Arizona Know Your Water: A consumer's guide to water sources, quality, regulations, and home water treatment options. University of Arizona Cooperative Extension Publication AZ1578.

Artiola, J.F., G. Hix, C. Gerba, and JJ. Riley. 2014. An Arizona Guide to Water Quality and its Uses. University of Arizona Cooperative Extension Publication AZ1610.

Artiola, J.F. and K Uhlman. 2009. Arizona Well Owner's Guide to Water Supply. University of Arizona Cooperative Extension Publication AZ1485.

Ayers, R.S. and D.W. Westcot. 1985. Water Quality in Agriculture. FAO Irrigation and Drainage Paper 29 Rev.1. Food and Agriculture Organization of the United Nations. Rome.

AWWARF. 2005. Adsorbent treatment technologies for arsenic removal. American Waterworks Association Research Foundation and U.S. Environmental Protection Agency. http://www.waterrf.org/publicreportlibrary/91084.pdf

George, C.M., Y. Zheng, J.H. Graziano, S.B. Rasul, Z. Hossain, J.L. Mey, and A. van Green. 2012. Evaluation of an arsenic test kit for rapid well screening in Bangladesh. Environmental Science and Technology. dx.doi.org/10.1021/es300253p | Environ. Sci. Technol. 2012, 46

Hussan, A, S. Ahamed, and A.K.M Munir. 2008. Arsenic filters for groundwater in Bangladesh: Toward a sustainable solution. In: Technologies for Clean Water, Fall 2008. National Academy of Engineering of the National Academies.

Lothrop, N., S.T. Wilkinson, M. Verhougstraete, A. Sugeng, M.M. Loh, W. Klimecki, P.I. Beamer. 2015. Water. 7, doi:10.3390/w70x000x. In preparation.

Naujokas, M.F., B. Anderson, H. Ahsan, H.V. Aposhian, J.H Graziano, C. Thompson, W.A. Suk. 2013. The broad scope of health effects from chronic arsenic exposure: update on a worldwide public health problem. Environmental Health Perspectives. 121(3):295-302.

Spear, J.M. Y. Zhou, C.A. Cole, and Y.F. Xie. 2006. Evaluation of arsenic field test kits for drinking water analysis. Journal AWWA 98:12. 97-105. 2006

Towne, D, and J. Jones. 2011. Groundwater Quality in Arizona: A 15-Year Overview of the ADEQ Ambient Monitoring Program (1995-2009). http://www.azdeq.gov/environ/water/assessment/download/1104ofr.pdf

Uhlman, K. 2008 Arsenic in Arizona Groundwater: Source and Transport Characteristics. University of Arizona Cooperative Extension Publication AZ1453. Tucson, AZ 85721.

US EPA, 2003. Arsenic treatment technology evaluation handbook. U.S. Environmental Protection Agency. Office of Water (4606). EPA 816-R-03-014. July 2003.

Walker, M., R.L. Sieler, and M. Meinert. 2007. Effectiveness of household reverse-osmosis systems in a Western U.S. region with high arsenic in groundwater. Science for the total environment. 389:245-252.

Additional Resources and References

Water Quality Association. www.wqa.org

National Groundwater Association.www.wellowner.org

NSF International. www.nsf.org

Table 1. Arsenic in Well Water– Summary of Treatment Options			Suggested Point-of Use (POU) Water Treatment Options		
Contaminants	**Treatment Considerations**	**Suggested Testing**	**Distillation**	**RO**	**Iron Filter**
If your arsenic is less than 10 ppb, no treatment is required unless other water quality parameters exceed drinking water standards.		If you live in an area of AZ known to have groundwater with elevated arsenic levels, you should test your water every 3 years.	NTR	NTR	NTR
If your arsenic is 10-100 ppb, use another source of water and/or install treatment system. Note: water may be safe for animals. Consult your veterinarian.	Three POU water treatment Options may be available: Reverse Osmosis (RO), Iron (Fe) filter, and steam Distillation. Iron filter arsenic removal efficiency depends on the levels of other water constituents such as silica, fluoride… See text.	Test the arsenic removal efficiency of your POU*** treatment system before you buy it and at least once a year thereafter.	Yes	Yes*	Yes**
If your arsenic is >200 ppb, stop drinking immediately and install treatment system. Note: water is not safe for animals.	Iron filtration may not lower arsenic below DWS in well water that contai ns arsenic levels above 200 ppb and/or elevated levels of other constituents such as silica, fluoride, sulfate...), see text for more details on the use of these filters.	Test the arsenic removal efficiency of your POU*** treatment system before you buy it and at least once a year thereafter.	Yes	Yes**	NR
If your water also has elevated levels of salts (total dissolved solids-TDS>500mg/L), nitrate (>10mg NO_3-N), fluoride (>4 mg/L)….	Consider an RO treatment system.	Test the arsenic removal efficiency of your POU*** treatment system before you buy it and at least once a year thereafter. See also UA Extension Publication AZ1485.	Yes	Yes*	NR
If your well/tap water fails the Fecal Coliforms test (E.coli)	See UA Extension Publications AZ1586, AZ1605	Test your well water once a year. See also UA Extension Publication AZ1485.	Yes	No	NR

* Pretreatment with a water softener may be needed if water is very hard.

**Iron Filters and RO systems may not lower arsenic levels below the 10 ppb drinking water standard.

*** POU filtration systems typically use cartridges that must be replaced regularly to ensure peak efficiency.

NR=Not Recommended

NTR= No Treatment Required

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