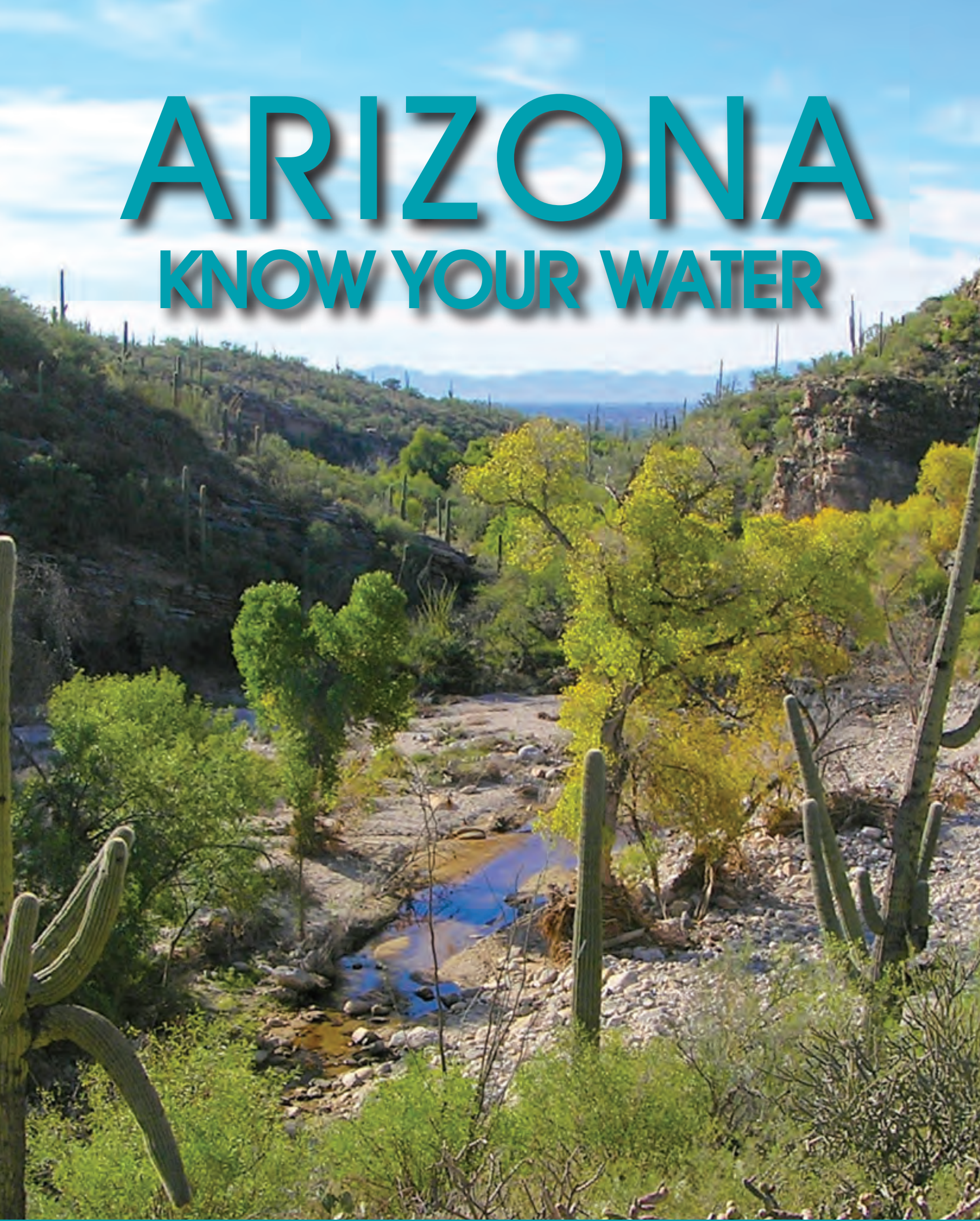
ARIZONA
KNOW YOUR WATER



A CONSUMER'S GUIDE TO WATER SOURCES, QUALITY, REGULATIONS, AND HOME WATER TREATMENT OPTIONS

THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
COOPERATIVE EXTENSION

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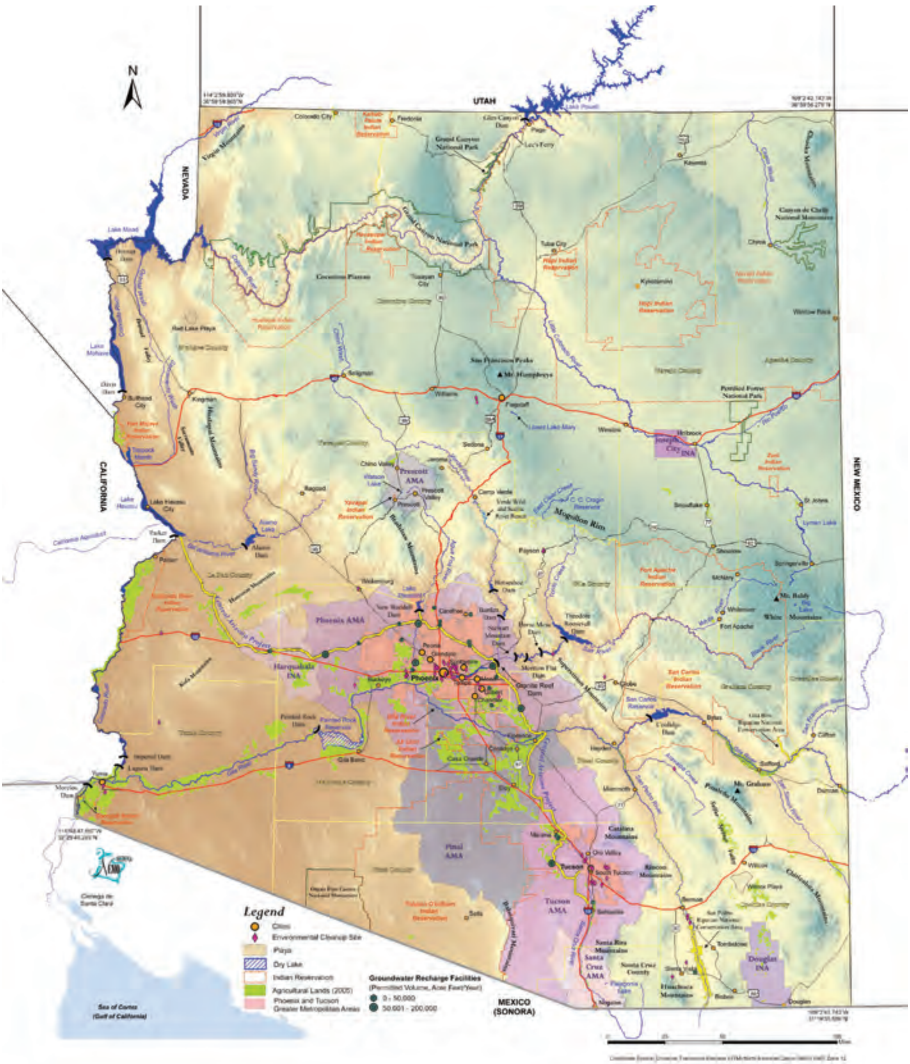

Map of Arizona. Source: Arizona Water Map Poster, 2009, Water Resources Research Center, CALS, University of Arizona.

ARIZONA:

KNOW YOUR WATER

A Consumer's Guide to Water Sources, Quality, Regulations,and Home Water Treatment Options

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Cover photo: Janick F. Artiola

This booklet is intended for Arizona residents who wish to become familiar with water-related issues in Arizona. Topics include:

- A short review of the history and sources of water in Arizona.
- An overview of the nature of water, the water cycle, water quality concepts, and a glossary of universal terms, including an overview of common minerals and contaminants found in Arizona water sources.
- A description of drinking water regulations, including National Primary and Secondary Drinking Water Standards.
- A detailed discussion of accepted home water treatment technologies and home water treatment selection guidelines, based on water quality and user preferences.
- Downloadable versions of this booklet can be found on the following University of Arizona websites:
    - The College of Agriculture and life Sciences (CALS) publications: ag.arizona.edu/pubs/
      Hard copies may also be purchased through the CALS website.
    - The Water Resources Research Center (publications tab): wrrc.arizona.edu/
    - The Superfund Research Program (SRP): superfund.pharmacy.arizona.edu/content/informational-materials
      A survey form to evaluate this publication is also available at the SRP site.

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Introduction

Our day-to-day existence depends on having access to **fresh water.** We are accustomed to **potable water** on demand. However, Arizonans, like other U.S. residents, also use large quantities of fresh water to produce food and goods.

> **Water Use Facts:** Arizonans use about 130 gallons (~500 liters) of potable water per person per day. Each adult drinks about _ gallon (~2 liters) of potable water per day and uses about 1 gallon (~4 liters) for cooking. Thus, most of the water delivered to homes is used for waste disposal (toilets), washing (showers, sinks, and laundry) and irrigation (landscape). In addition, each day in the U.S. about 1,400 gallons (~5,300 liters) of fresh water are needed to grow one person's food supply, produce electric power, and support industrial production.

The environment, the water cycle, and human activities determine water quality. Modern water treatment and delivery systems allow communities to control the levels of **contaminants** in water. In Arizona, wells and canals also provide and deliver fresh water to areas naturally water deficient (**arid**).

Public water systems are highly regulated providers of drinking water. Despite evolving federal water quality standards and public right-to-know laws, sales of bottled water continue to grow. Consumers often cite such issues as health, water quality, and convenience as justifications for using bottled water, even though bottled water is often higher in price than gasoline. Packaged drinking water is perceived to be of higher quality than tap water; however, it may not always be safer than tap water.

Today, homeowners have access to a variety of home **water treatment** systems to help control **mineral** levels and unwanted contaminants in their tap water. Nearly half of the homes in the U.S. have some type of water treatment device. Mistrust of public water utilities, uncertainty over water quality standards, concerns regarding general health issues, and limited understanding about home water treatment systems have all played a role in this increasing demand for home systems. However, choosing a home water system is difficult and complex, and the process is often confounded by incomplete or misleading information about water quality, treatment options, and costs.

Private well owners also need to provide safe drinking water for their families and have to make decisions as to how to treat their own water sources in order to meet this need. However, information about their water sources is often limited or difficult to obtain.

With all these concerns and choices, consumers should be aware of the water sources in Arizona and be familiar with the quality of their water. Consumers should be aware of what **minerals, contaminants**, **chemicals, organisms, pollutants**, and **pathogens** are or may be present in their water sources, and what amounts are or are not acceptable. Consumer decisions on home water treatment options should be based on sound water quality information, accepted drinking water standards, and realistic expectations about the cost and performance of home systems.

We Are Not Alone: Land animals, plants, and other living organisms also need fresh water to thrive. We also know that **surface water** and **groundwater** sources are often connected and interdependent. Therefore, groundwater overdraft often diminishes surface water resources with negative impacts to the surrounding environment.

Modern wastewater treatment facilities control the amounts of contaminants that we discharge into the environment. But residual pollutants that can adversely affect our environment cannot be completely removed from **reclaimed water**. Therefore, fresh water cannot be regenerated without huge economic costs.

What we do at home, at work, and outdoors to support our existence, as well as the demands we place on Arizona's limited and diminishing water resources, all have a direct influence on our environment. Therefore, we must achieve a sustainable water use that includes the needs of Arizona's unique ecosystem, if we want to preserve it for future generations.

PHOTO: Janick Artiola

Sabino Canyon with flowing water and healthy stand of cottonwood trees, Tucson, AZ.

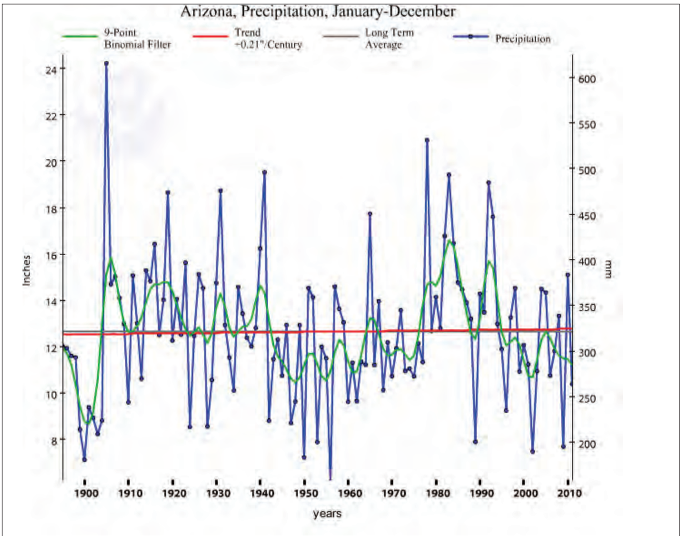
PHOTO: Janick Artiola

Rillito River with dead cottonwood trees due to excessive groundwater overdraft, Tucson AZ.

1.1 History of Water Use in Arizona

> **Water Facts.** Tucson averages about 11 inches of rainfall per year, Phoenix 7.5 inches, Yuma 3 inches, and Flagstaff 22 inches per year.

Arizona is an arid state where rainfall is highly variable from year to year and region to region, ranging from 2 inches per year in the western deserts to about 25 inches per year of rain and snow in the mountainous regions. Precipitation in the region has been measured since 1896. Historic precipitation patterns show a continuum of wet and dry periods over the last century with extended drought in the late 1890's to early 1900's; the late 1940's to the 1950's; and the late 1990's to the present.



Arizona Annual Precipitation, 1896-2011. Source: NOAA, 2012.

Early History

The search for an adequate water supply has always been a struggle in the desert southwest. The history of water use in Arizona is best defined as the management of water supplies through both wet and dry periods. There is evidence of human control over water resources that dates back to three thousand years ago. The remains of the world's most extensive gravity-based canal system – constructed by the Hohokam people – can still be seen today along the Gila River, and in the Salt River and Santa Cruz Valleys **(see next page).** These complex systems provided water for established Hohokam communities and their agricultural production until the Hohokam's mysterious disappearance (around A.D. 1450).

A few Indian settlements, dependent on irrigation, continued in Southern Arizona. The Spaniards who arrived in the late 1600s already were familiar with irrigation technology, which they had adopted from the Moorish presence in Spain prior to 1500. Wells were dug, more dams and ditches were constructed, and more land went into agricultural production. At the time, Tucson was the northern edge of the Spanish settlements. Conflict with the Indian population and the Mexican War for Independence slowed down further growth and expansion in the area.

Hohokam canals. Source: Southwest Parks and Monuments Association

Nineteenth and Twentieth Centuries

In 1825, American explorers, trappers, and settlers began to come into the territory. Settlers in the Salt River Valley reused the Hohokam canals until major diversion projects began in the early 1900s. A prolonged drought in the late 1800s increased pressure on the U.S. government to develop major water storage projects to provide stable water supplies for economic growth, particularly in agriculture and mining. Major reservoir systems were developed throughout the state on the Salt, Verde, Gila, and Agua Fria rivers, in addition to the reservoirs on the Colorado River. By the middle of the twentieth century, almost all natural surface water in Arizona had been developed.

Roosevelt Dam, completed in 1911. Source: Central Arizona Project

Further south in the Tucson area, rivers dried up as windmills, steam-powered pumps, and deeper wells accelerated groundwater pumping to such an extent that, by the early 1900s, local rivers no longer flowed.

Colorado River Compact:
During the early 1900s, the seven states of the Colorado River Basin negotiated for shares of Colorado River water. The Compact of 1922 divided the Colorado River between the lower basin states of Arizona, California, and Nevada, and the upper basin states of New Mexico, Wyoming, Colorado, and Utah – apportioning 7.5 million acre feet to each basin.

Water Facts: The Colorado River Compact water allocations were decided at a time of above average rainfall. Arizona was the last state to approve the Compact in 1944.

Today, in the lower basin, Arizona has rights to 2.8 million acre feet of Colorado River water per year, California is entitled to 4.4 million acre feet per year, and Nevada has an annual allocation of 325,851 acre feet. One **acre-foot** is the approximate amount used by a family of four in one year.

Water demand increased through the 1940s and required stable supplies of water particularly in Tucson, which by now was entirely dependent on groundwater supplies.

> **Water Facts:** After 22 years of lobbying, the Central Arizona Project **(CAP)** was approved by the federal government in 1968. It is one of the most significant milestones in Arizona water history.

Central Arizona Project (CAP): Construction of the Colorado River Project canal to bring water to southern Arizona started in 1968 and was completed just south of Tucson in 1993. Delivery of Colorado River water was a major initiative to provide water to central Arizona. Originally designated for agriculture, by the time of its completion, the water was needed to augment urban supplies for a growing population more than it was needed for agriculture and industry.

CAP zig-zag canal. Source CAP

The CAP, estimated to have cost over $4 billion, lifts water 2,900 feet through fourteen pumping plants for delivery up to 334 miles from the Colorado River.

Arizona Groundwater Management Act: Throughout the last century, groundwater continued to be withdrawn faster than it was being replenished, which created a condition called **overdraft** in the growing urban areas. Overdraft causes shortages of supplies, increases costs for drilling wells and pumping water, land **subsidence**, and reduces water quality. Overdraft also has caused the disappearance of 90% of all riparian habitats in Arizona. In 1980, the Arizona Groundwater Management Act was passed and the Arizona Department of Water Resources **(ADWR)** was formed. The act and state agency were designed to manage water resources more effectively to ensure supplies for the future.

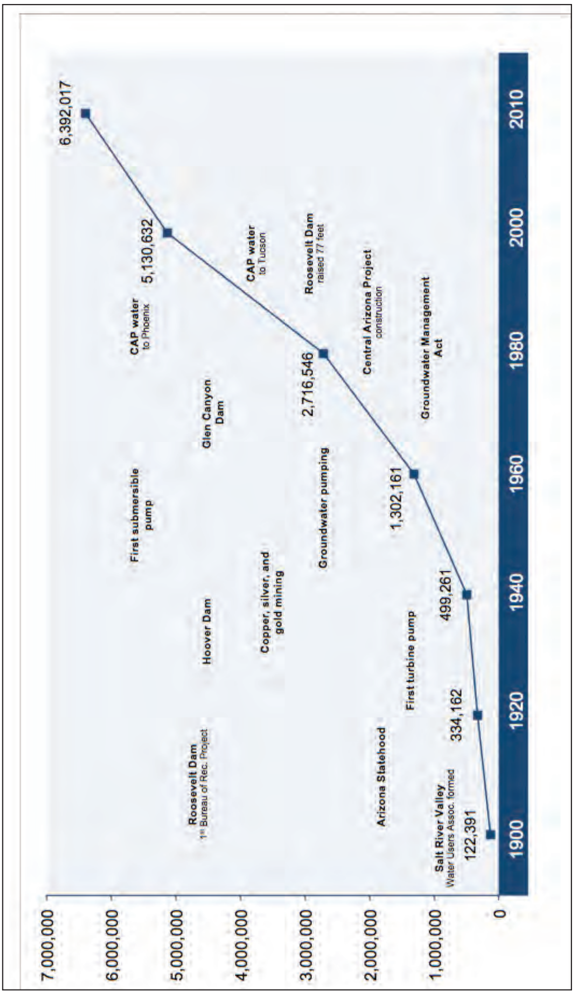
Water Facts: In Arizona, the ADWR has established five Active Management Areas **(AMAs)** to manage and balance the availability of groundwater resources until the year 2025. These areas include Phoenix and Tucson (see ADWR website link).

Arizona Environmental Quality Act: In the 1980s, contamination was found in multiple groundwater sources. The public became concerned about possible contamination and its effect on quality of life. A number of wells were shut down in the metro-Phoenix and Tucson areas. By 1986, the Arizona Department of Environmental Quality **(ADEQ)** was formed under the Arizona Environmental Quality Act to establish a comprehensive groundwater protection program and administer all of Arizona's environmental protection programs.

Water Facts: The ADEQ provides state administration of federal programs and assures state compliance with federal EPA programs. State programs for which federal legislative or regulatory mandates exist must meet minimum **EPA** standards. ADEQ regulates public water systems that have at least 15 service connections or serve 25 people.

Safe Drinking Water Act

In 1974, the U.S. Congress passed The Safe Drinking Water Act that sets maximum contaminant level **(MCL)** standards for drinking water. Amendments to this act have since been passed that have imposed more stringent standards on drinking water quality. An example is the new arsenic rule, which has a significant impact in Arizona as groundwater frequently contains arsenic due to the local geologic formations through which the water flows. All water providers have to meet these new standards and the associated cost of the technology needed to reduce the levels of arsenic in their water sources.



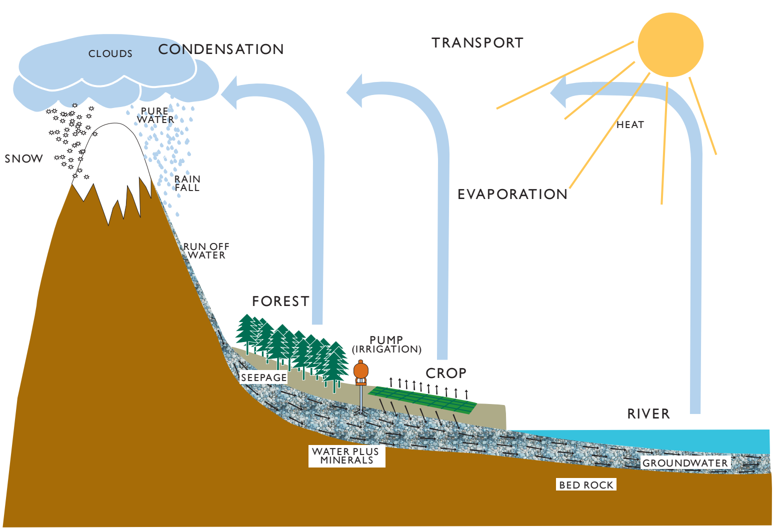
Water time line and population growth, 1800-2010. Source: Arizona Water Map Poster, 2002, Water Resources Research Center, CALS, University of Arizona, U.S. Census Bureau.

Portions of this text have been adapted from Kupel 2003, and from the ADWR and CLIMAS websites (see Appendix 2).

1.2 Sources of Water

Groundwater is considered a **non-renewable** source of fresh water since pumping exceeds recharge in most **aquifers** used as sources of fresh water. Surface sources of fresh water, such as lakes and rivers, are considered **renewable**. It is generally agreed that the total amount of water that circulates annually from the earth's surface to the atmosphere and back down to the earth has remained fairly constant in recent times. Therefore, on average, rivers and lakes produce the same amount of fresh water now as they did 100 years ago. However, the population of the world has increased more than six-fold in the last 100 years, adding demands on fresh water resources.

Water Facts: Water covers about 70% of the world's surface, and all life forms, including humans, depend on it for their basic survival. However, about 97% of the world's water is in the oceans and is considered highly **saline**. Ice located near the earth's poles, accounts for about 2% of the earth's water. About 0.6% of the world's water is fresh water stored below ground (groundwater), often thousands or millions of years ago. The atmosphere and the soil environment account for about 0.06% of the world's water. About 0.01% of the world's water is found in lakes, rivers, and streams.

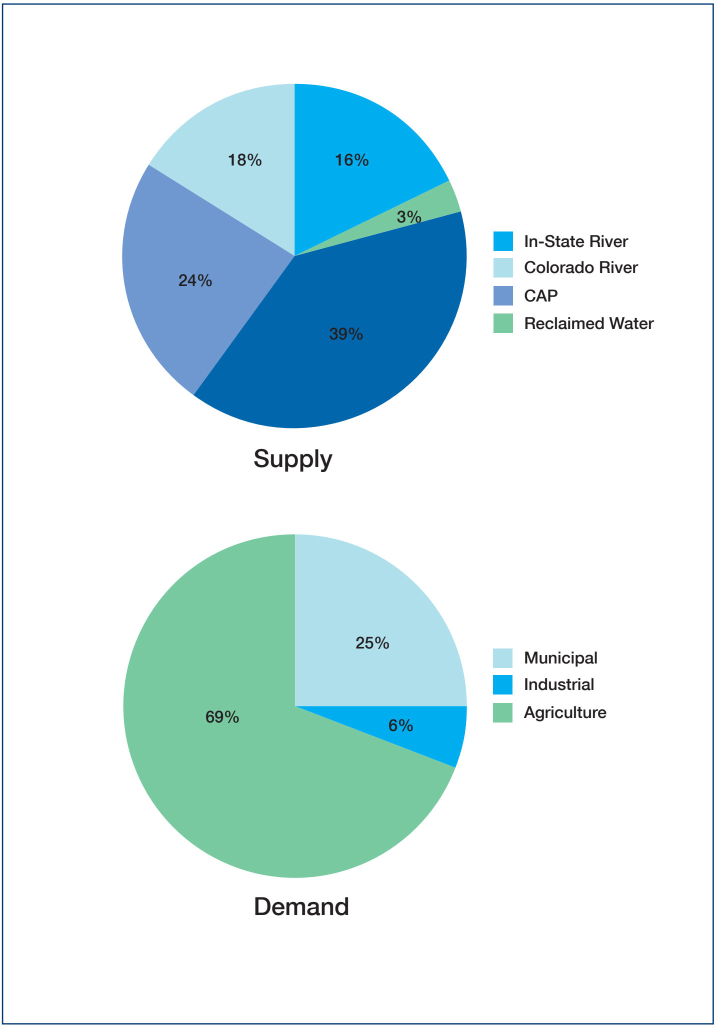


The water cycle

History and Sources 1

Arizona Water Sources

Much of the growth in arid areas like the southwest United States is sustained by the use of non-renewable groundwater and renewable river-fed reservoirs. Presently, about 39% of Arizona's water needs come from in-state groundwater sources. Arizona also has an under-utilized annual allocation of 2.8 million acres of Colorado River water (see Section 1.1). CAP water accounts for about 24% of the state's water supply. In-state surface water sources (Arizona rivers and lakes, excluding the Colorado River) provide about 16% of the state's annual water supply and reclaimed water is 3%. Agriculture remains the primary user of water resources in Arizona.



Arizona Water supplies and uses. Source Arizona Water Map Poster, 2010. Water Resources Research Center. CALS, University of Arizona.

Local Water Sources

Phoenix and its surrounding cities – Chandler, Mesa, Tempe, Glendale, Scottsdale, and Peoria – have diverse sources of renewable fresh water. These include several major surface water streams: the Salt, Gila, Verde, and Agua Fria rivers and, more recently, the CAP canal. Dams located on these rivers, which flow from the mountains north and east of Phoenix, form reservoirs that provide a steady supply of renewable water. However, it is unlikely that any of these surface water resources will increase in the near future. Phoenix and its surrounding communities also supplement their water needs by pumping from several large aquifers. But significant portions of the groundwater along the Salt and Gila rivers are high in salinity (> 3000 **mg/L Total Dissolved Solids (TDS)**). The city of Phoenix, which delivers potable water to 1.3 million persons, reported the use of only 8% groundwater in 2002.

Tucson has no surface water (streams) supplies. These sources were quickly depleted during the first part of the twentieth century, mostly by local groundwater pumping. Since then, growth has been sustained by the use of groundwater. It is estimated that about 15% of the water that is pumped out of the local aquifers is replaced annually by natural **recharge**. Thus, in less than fifty years, groundwater levels have dropped in the Tucson basin (center) by more than 200 feet (~60 meters). No one knows the exact amount of water available in the Tucson basin aquifers. However, we know that once water is removed, most of it is not replenished. Also, water pumping costs and mineral content (TDS) increase with aquifer depth. The recent arrival of CAP water (see Section 1.1) has slowed down the groundwater pumping in the Tucson basin. Since 2003 groundwater use has declined from 72% to 50% in 2008. Although CAP water is a renewable resource of water, its amount is not expected to increase in the near future.

Yuma obtains drinking water for its 93,000 residents from the Colorado River. Groundwater, while available, is only used in emergencies. Most of the water drawn from the Colorado River in Yuma is used in agriculture.

Flagstaff has diverse but limited sources of water. The primary sources are Lake Mary (located to the southwest) and the inner basin wells and springs (located to the north). However, both sources are fed by snowmelt, which can vary greatly year-to-year. Groundwater is also available but it is deep (1000–2000 feet) and, consequently, expensive to obtain.

Water Reuse

> **Water Facts:** Reclaimed water is becoming a valuable renewable water resource, accounting for 3–8% of total water use in Arizona in 2010.

About 40% of water delivered to homes is treated in wastewater treatment plants and can be used for irrigation or to recharge aquifers. But, reclaimed water is usually ~1.5 times higher in TDS than the original water source. For example, if the water source has 300 mg/L TDS, the reclaimed water will have about 450 mg/L TDS. Also, wastewater treatments kill or remove most pathogens (see Section 4.7), but do not remove all residual (trace) **organic chemicals** (see also pollutants). Recent national surveys on the quality of reclaimed water have documented the presence of chemicals not previously detected such as pharmaceuticals, human hormones and numerous other "emerging" contaminants. Only research will tell whether these contaminants are or will become a significant threat to us and the environment. The removal of excess salts and residual organic chemicals would increase the cost of wastewater treatment significantly (see Sections 4.4 and 4.5). Reclaimed water is considered safe for irrigation and recharge. However, faced with diminishing, increasingly impaired water resources and the presence of new, emerging contaminants in reclaimed waters, we must continue to monitor their impact in the environment to preserve the quality of our natural resources. We must continue, though to monitor its impact in the environment to preserve the quality of natural water resources.

Outlook

The earth has unlimited amounts of water, but only a very small fraction of the world's water is fresh and renewable. Non-renewable groundwater resources are being depleted in Arizona and many other parts of the world. Many countries in the world (including the U.S.) are experiencing both internal conflicts and conflicts with neighboring countries brought about by the combined pressures of population growth and limited fresh water resources.

In the near future, the wise management and use of local water resources will be critical to growth and to the preservation of our life and the environment.

Portions of this text have been adapted from Leeden et al., 1990; WRRC, 2010; and City of Phoenix Water Services Website, 2003.

Water, water everywhere but only a drop is fresh. (See p.15 Water Facts)

1.3 Domestic Wells

> **Water Facts:** There are over 100,000 domestic, privately owned and maintained water wells in Arizona that provide groundwater for drinking, household use, and irrigation to an estimated 350,000 Arizonans (5% of the states population).

The quality and safety of these drinking water sources are not tested or regulated by any state or federal agency. Therefore, private well owners should test their well water quality regularly to ensure that it meets safe drinking water standards. Also, well owners may need to select and maintain reliable home treatment systems (see Section 4.10). If the well is located in a large groundwater source, general well water quality information may be available from neighbors or local water utilities. However, the quality of groundwater is influenced by localized geologic conditions and above-ground, human-related influences such as septic systems. This and other topics of importance to well owners are covered in more detail in a booklet titled Arizona Well Owner's Guide to Water Resources (Artiola and Uhlman 2009) Extension bulletin #AZ1485 and others including #AZ1486b-i.

Testing Your Well Water

Domestic wells should be tested annually for the presence of **coliform bacteria**, as an indicator of pathogens. More frequent testing is suggested if visual changes in the water quality are noticed or if unexplained health changes occur. The table below provides a schedule and list of analyses for testing. When water tests positive for pathogens, owners may choose to use **shock-chlorination** to disinfect the well casing and household plumbing. This may not eliminate the contamination if it is found in the aquifer water itself. In that case, the owner should seek an alternate source of water or install a home water **disinfection** system (see Section 4.7).

Suggested Water Testing* Schedule

Initial Tests**
Hardness, sodium, chloride, fluoride, sulfates, iron, manganese, arsenic, mercury, lead, and radionucleides plus all tests listed below.

Annual Tests (at a minimum)
Total coliform bacteria and E.coli, TDS, pH, nitrate.

Monthly Visual Inspection
Look for and note changes in:
- Turbidity (cloudiness, particulates)
- Color, taste, and odor***
- Health changes (reoccurring gastrointestinal problems in children and/or guests)****

* See Table 4 (Appendix 3) for a comprehensive list of poor water quality symptoms, tests, and possible causes.
** Annual testing may not be needed, as these chemicals usually are naturally occurring and their concentrations do not change over time.
*** Consider one or more of the initial tests listed above (see also Section 4.10).
****Annual tests should be performed right away.

When the well produces well water of poor quality, it is important to determine the possible causes or sources of the contamination. Table 4 (Section 6.3) provides a list of water symptoms, recommended tests, and possible causes. If the causes cannot be removed, find an alternate source for home water. Otherwise, carefully consider the installation of a new or modified water treatment system (see Section 4.10) to control color, particulates, TDS, and/or inorganic contaminants such as nitrates and arsenic.

Homeowners should not attempt to treat or use as drinking water sources contaminated with industrial chemicals such as solvents, pesticides, and gasoline products at concentrations above National Primary Drinking Water Standards (**NPDWS**; see Section 6.3). See also Section 4.10 for treatment options.

Well owners should visit the following ADWR website for information on well construction standards for Arizona residents. www.water.az.gov/adwr/Content/Publications/files/well_owners_guide.pdf

PHOTO:James Russell

Old farm house with windmill well.

Portions of this text have been provided by and adapted from the ADWR and USGS websites, and USEPA 1997.

1.4 Bottled Water

> **Water Facts:** Annual sales of bottled* water in the U.S. now exceed 9 billion gallons.

There are numerous types and sources of bottled water. Common bottled waters include **mineral water** (with more than 250 mg/L TDS), **purified water** (which has been treated to reduce TDS levels), and **sparkling water** (which is naturally **carbonated**), among others. For a more complete list, see the National Sanitation Foundation **(NSF)** website.

Bottled water is regulated as a packaged food product by the Food and Drug Administration **(FDA)** and state governments. Self-imposed standards on bottled water are also required by members the International Bottled Water Association **(IBWA)**. The U.S. Environmental Protection Agency **(USEPA)** is not directly involved in the regulation of bottled water. However, if the bottled water suppliers use water from public water systems, these must meet USEPA standards. If private water sources are used, such as springs and wells, bottled water may be filtered, but the levels of minerals and contaminants may vary. Also, water disinfection is usually necessary, and packaging is done according to FDA food guidelines.

Water Quality

> **Water Facts:** Limited regulations and inadequate labeling **(see next page)** often make it difficult to determine the source, exact mineral content, and treatment of bottled water.

Large surveys conducted both in the U.S. and worldwide have shown that, in general, bottled water is no safer than tap water. Concerns about the safety of bottled water has prompted the World Health Organization **(WHO)** to work on the development of an international code of bottled water quality that would require the disclosure of the source, mineral content, and treatment of all bottled water.

One advantage of drinking bottled water is its portability and the fact that, unlike tap water, it requires no residual disinfection during storage or delivery to the consumer (see Section 4.6). Therefore, there is no unpleasant chlorine taste or smell.

Bottled water should be consumed quickly, not stored for months, as plastic bottles may degrade over time and contaminate the water with plastic residues.

* Source: Beverage Marketing Corporation.

History and Sources 1

PHOTO: Janick Artiola

Bottled water label conforming to USDA requirements and non-U.S. bottled water label (insert).

Portions of this text have been adapted from the NSF, FDA, IBWA, NRDC, and WHO websites (see Appendix 2).

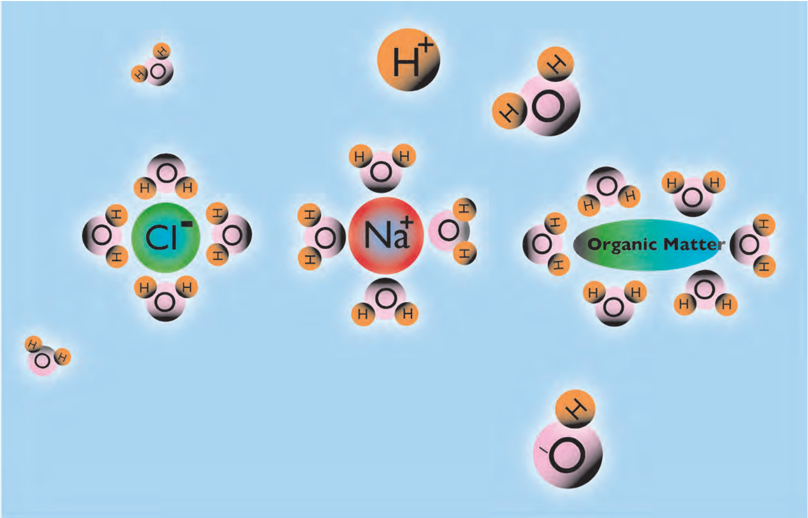
2.1 Minerals in Water

Water occurs naturally in three states: liquid, gas (vapor), and solid (ice), and moves between these states. Solid water, particularly the polar ice caps, helps protect the aquatic environment from abrupt changes in temperature. Water vapor is essentially **pure** water in a gaseous form. Water, in its liquid form, picks up chemicals (both minerals and particulates, some considered contaminants) as a result of **seepage** into its surrounding soil environment. Returning to its gaseous state as it evaporates, water leaves behind the solid residues it acquired in its liquid state.

How Water and Matter Interact

Figure below shows how water dissolves common **table salt** by separating its sodium (+) and chloride (-) ions (see **dissolution**). Within water's liquid state, these **ions** are kept separate by molecules whose task is to balance the positive (+) or the negative (-) properties of each element.

> **Water Facts:** Water is often referred to as the universal solvent because of its dual nature – it can both surround and separate other chemical substances inside its structure



Two-dimensional representation of water molecules interacting.

Other minerals can dissolve in water in a similar manner but in varying amounts. When liquid water comes into contact with the earth's surface and runs off, it can also carry with it visible solid parts (particulates such as silt, clay, and plant parts) that can remain **suspended** in water. Gases from the atmosphere and gaseous pollutants can also dissolve and be suspended (as bubbles) in water. For example, carbon dioxide dissolves in water and can lower its **pH** by forming carbonic acid (see carbonated water, Section 1.4).

Common Minerals Found in Water

> **Water Facts:** minerals composed of sodium and chloride ions have a very high water affinity **(solubility)** and are quickly washed out of the soil. Thus, most dissolved minerals in **seawater** are sodium and chloride (table salt).

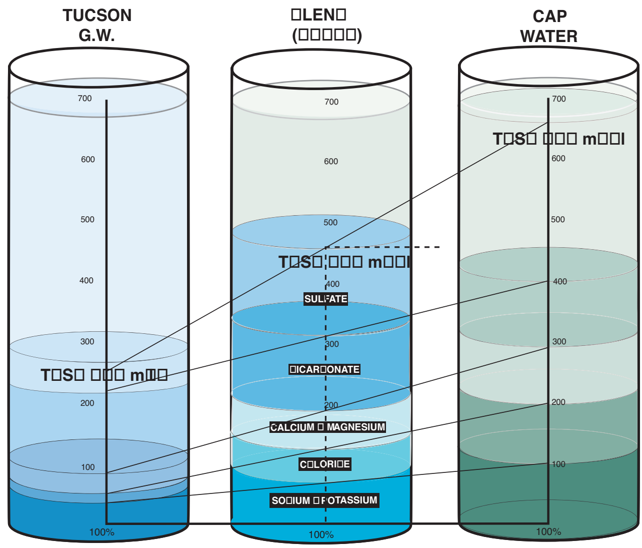
Besides table salt, fresh water also contains other common minerals that include gypsum, calcite, and dolomite (the main sources of calcium, magnesium, sulfate) and carbonate ions. These ions, together with potassium and table salt, usually account for about 95% (by weight) of the total dissolved solids (TDS) found in natural water. The amount and proportions of minerals in water affect its taste and can often be used to identify the origin of a water source. The figure on the next page shows the mineral compositions of Tucson groundwater and CAP water. A quick look at the figure shows that CAP water has more dissolved minerals and different proportions of minerals than Tucson groundwater.

Trace Elements in Water

Numerous other chemicals found in minerals are also found in water in trace amounts. These include beneficial elements like copper, zinc, and iron (see Section 3.1) and undesirable elements like arsenic, mercury, and radon gas (see Section 3.2). Waters that come into contact with minerals rich in these chemicals may contain elevated and potentially toxic amounts.

Contaminants in Water

Human activities can also contaminate natural waters with excessive levels of minerals or pollutants. These include agricultural and industrial release of pollutants; improper disposal of municipal and animal wastes into air, soil, surface, and ground waters; and transportation and recreation on air, land, and water. The types and quantities of contaminants that can be tolerated in public drinking waters are set by the USEPA (see Tables 1 and 2, Appendix 3). These standards are discussed in Section 3.



MINERAL CONTENT (Cumulative Graph) OF WATER SOURCES

Mineral composition of Tucson groundwater, CAP water, and 50:50 blend.

Total Dissolved Solids (TDS) in Arizona Waters

The mineral compositions of the water sources in Arizona vary depending on their origins. In general, the chemical composition of groundwater sources is more seasonally constant but can vary significantly by location. The quality of surface water sources tends to vary both seasonally and by location.

Phoenix and other surrounding cities such as Mesa and Gilbert use multiple surface water sources (including groundwater when necessary) that provide tap water with TDS values that exceed 500 mg/L (on average) and can change more than +250 mg/L through the year. The combined hardness of these water sources is considered hard to very hard (see Table 2, Appendix 3).

Tucson groundwater's TDS is, on average, about 290 mg/L, but TDS values can vary by about +100 mg/L depending on the location of various wells in the Tucson basin. CAP water has a higher TDS than Tucson groundwater. Therefore, mineral concentrations in tap water are increasing as more recharged CAP water mixes with groundwater. An estimate of the TDS and mineral composition of a 50:50 blend of Tucson groundwater and CAP water is about 470 mg/L (see figure previous page). The combined hardness of this blend is classified as moderately hard to hard (see Table 2, Appendix 3).

Flagstaff, on average, has about 200 mg/L TDS in its diverse (multiple surface and groundwater) sources, although values can change by more than +100 mg/L depending on the source. As in other Arizona cities, the hardness of Flagstaff city water ranges from moderately hard to very hard (see Table 2, Appendix 3).

Yuma residents obtain their potable water directly from the Colorado River and it is not desalinized prior to delivery. At that location, the Colorado River has an average TDS of about 800 mg/L that changes about +50 mg/L through the year. This source of water is classified as very hard (see Table 2, Appendix 3).

2.2 Contaminants in Water

Contaminants are divided into three categories: those of natural origin, those of natural origin but enhanced by human activities, and those human-made and introduced into the environment. Common minerals are also the most common contaminants found in waters (see Section 2.1). Water sources also have unwanted but naturally occuring toxic elements like arsenic. When arsenic is found in a drinking water source at concentrations above National Primary Drinking Water Standards (NPDWS), the water is "contaminated" with arsenic (see Section 3.2).

Contamination of Water Sources

Water Facts: The most common sources of water pollution are rainfall (air pollution), seepage, run-off from urban and agricultural areas, and discharges of contaminated water and wastewater into the open environment.

Water sources may also become contaminated with high concentrations of common elements like sodium through natural and human activities. This water may not be a threat to the environment, but it is unfit to drink or to use to irrigate crops. In this case, the water is considered contaminated with sodium and other salts, and is called saline. Some saline water sources may be acceptable for livestock or used to irrigate salt-tolerant plants common in Arizona.

Human-made contaminants are also commonly referred to as **pollutants**. These include synthetic organic chemicals such as agricultural pesticides, industrial solvents, fuel additives, plastics, and many other chemicals. Unfortunately, many of these chemicals are ubiquitous (present everywhere) in our environment due to their extensive use in modern society (see figure next page). Also, microbial pathogens derived from human and animal waste become pollutants when improperly disposed of and can adversely impact the quality of water resources.

Setting Limits on Contaminants

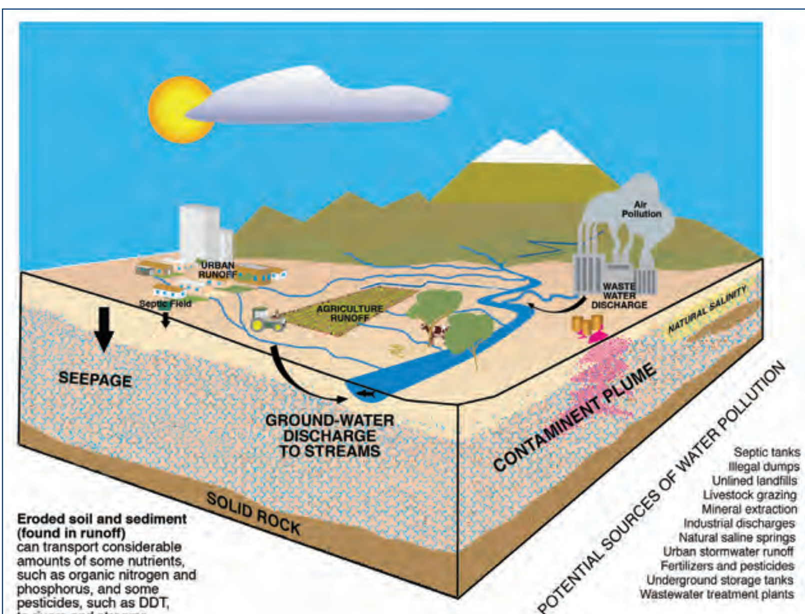
Few surface and groundwater sources in the world remain unaffected by contamination. Is all the water in the world "polluted"? The answer is "no" if limits are applied. The NPDWS and the National Secondary Drinking Water Standards **(NSDWS)** are designed to regulate contaminants in water sources because it is unreasonable to expect to have an unlimited amount of contaminant-free water (see Sections 3.1 and 3.2). Thus, drinking water can contain acceptable (by social consensus) amounts of contaminants.

Common Contaminants in Arizona Water Sources

Common water contaminants in water and probable sources include TDS (naturally high sodium, chloride, sulfate, and calcium), hardness (natural high calcium) nitrates, total coliform bacteria (animal waste, septic systems, and agriculture), arsenic, radon, lead (naturally occurring), pesticides, gasoline products, and solvents (agriculture and leaky tanks). With the exception of TDS, all of these contaminants are regulated in public drinking water supplies by the NPDWS (see Section 3.2).

New Contaminants

The USEPA is always evaluating so-called **emerging contaminants** that need to be regulated in our public water systems. These include the **perchlorate** ion found in rocket fuel and explosives (detected in both the groundwater and surface water of several states, including Colorado River water), new groups of water **disinfection by-products,** and new types of **endocrine disruptors**. Although the USEPA has not yet set or passed any national standards on these newly recognized contaminants, individual states may choose to have additional or stricter drinking water quality guidelines, as is the recent case of perchlorate in the state of California. Emerging water pathogens include a bacterium called *Mycobacterium avium.*



Sources of water pollution in the environment. Adapted from: Arizona Water Map Poster, 2002, Water Resources Research Center, CALS, University of Arizona.

3.1 Major Water Quality Parameters and National Secondary Drinking Water Standards (NSDWS)

The overall quality of water is measured by several parameters. The recommended values of major water quality parameters are given in the USEPA list of NSDWS (see Table 1, Appendix 3). These secondary standards, listed as maximum concentration levels **(MCLs),** are non-enforceable. Thus, public water systems are not required to reduce these chemicals below the EPA-recommended levels. However, water utilities control the levels of these chemicals in the water when needed in order to prevent tap water odor and taste-related customer complaints.

Water Facts: National Secondary Drinking Water Standards are important to public perception that water quality is safe. They provide guidance to water utilities on aesthetic (taste and odor), cosmetic (skin and tooth discoloration), and technical (water delivery) effects.

The NSDWS also imply that it is acceptable to have some quantities of contaminants, including minerals in fresh water sources and potable water supplies. Most of the minerals found in fresh water, are necessary life-sustaining nutrients, many are found in common vitamin supplements. These include calcium, magnesium, potassium, zinc, copper, iron, and others (see Section 2.1). In should be noted, however, that drinking tap water normally does not provide the recommended levels of most of these nutrients. For example, drinking 64 ounces (~2L) of water a day containing 50 mg/L calcium would only provide 1/10th of the adult daily requirement of calcium for adults 19-50 year-old recommended by the National Academy of Sciences.

Total Dissolved Solids (TDS)

This measurement combines most dissolved minerals found in water sources into one value. According to the NSDWS drinking water should not have more than 500 mg/L of TDS. Still, potable water that has a higher TDS is not necessarily unhealthy. However, high TDS water may cause deposits and/or staining, and may have a salty taste.

Water Facts: NSDWS may be exceeded in drinking water supplies. For example, the TDS levels in several Arizona cities is higher than the recommended 500 mg/L (see Section2.1).

pH

This value measures the active **acidity** or **alkalinity** of water. The pH of water is important in controlling pipe **corrosion** and some taste problems. The recommended pH range is 6.5–8.5.

Water Taste

> **Water Facts:** Both the TDS and the proportions of the major chemical (mineral) constituents determine the taste of water, including its hardness and alkalinity.

Note that TDS and pH do not determine the proportions of major minerals found in drinking water sources (see Section 2.1). However, the mineral composition of water may affect its taste. For example, water with a TDS of 500 mg/L composed of table salt would taste slightly salty, have a slippery feel, and be called **soft water.** Whereas, water with the same TDS value but composed of similar proportions of table salt, gypsum, and calcite would have a more acceptable (less salty) taste and feel less slippery due to its greater water hardness (see Section 2.1). Salty taste can be reduced by limiting the amounts of chloride and sulfate ions in potable water to less than 250 mg/L each.

Organic Matter

Other important water properties, listed as NSDWS, have to be controlled in tap water (these are listed in Table 1, Appendix 3). Water color, odor, and foaming are affected by the presence of natural organic matter substances often found in surface (but less frequently in groundwater) supplies. Most organic matter is routinely removed from water by water utilities with EPA-approved physical and chemical water treatments before home delivery.

Metals and Fluoride

The NSDWS also include recommended levels for aluminum, copper, iron, manganese, fluoride, and zinc. Most of these elements are found in trace quantities (less than 1 mg/L) in fresh waters. However, if not controlled, these elements can impart a metallic taste to water, cause staining, and even be toxic when present in tap water at concentrations above the recommended secondary MCLs (see Table 1, Appendix 3).

The Code of Federal Regulations. The EPA NSDWS are published in Title 40 (Protection of the Environment), Part 143. The EPA NPDWS (presented in Section 3.2) and their implementation are published in Title 40 (protection of the Environment), Part 141 and Part 142 and are now available in electronic format at http://ecfr.gpoaccess.gov.

3.2 National Primary Drinking Water Standards (NPDWS)

Water Facts: Drinking water regulations and standards are used by public water systems to control the levels of contaminants in potable water delivered to homes.

The EPA sets drinking water standards in collaboration with numerous other groups, organizations, and persons including scientists, state and local agencies, public water systems, and the public. States and Native American Communities facilitate implementation of these standards by means of public water systems. Drinking water standards are always evolving as new scientific information becomes available and new priorities are set about the potential health effects of specific contaminants found in water.

How Standards are Developed

Water Facts: Drinking water quality regulations are becoming more numerous and complex in response to public demands, new testing and treatment technologies, and newly discovered health effects of pollutants.

The USEPA considers many issues and factors to set a standard. These include current scientific data, availability of technologies for the **detection** and removal of contaminants, the occurrence or extent of contamination of a chemical in the environment, the level of human exposure, potential health effects **(risk assessment)**, and the economic cost of water treatment.

Public water systems must comply with NPDWS by providing water that does not exceed the MCL of any listed contaminant to their customers. Also, when water sources are treated by public water utilities, they must use EPA-mandated or EPA-accepted water treatment methods. However, small water systems (of up to 3,300 users) may obtain **variances** (extra time or exemptions) in order to comply with new standards.

Types of Contaminants

Water Facts: There now are over 90 individual and classes of contaminants regulated in public water supplies by the NPDWS.

Contaminants regulated under the NPDWS include **inorganic contaminants** (such as arsenic and lead), **organic contaminants** (such as insecticides, herbicides, and industrial solvents like tri-chloro ethylene or TCE), water disinfectants (such as **chlorine** and **chloramines**), disinfection by-products (such as chloroform), radiunucleides (such as uranium), and microorganisms (such as *Giardia* and intestinal viruses). The complete list of these contaminants, including their MCLs, is provided in Table 3, Appendix 3. An up-to-date list of NPDWS can always be found on the EPA website (see Appendix 2).

How NSDWS are Implemented

Water Facts: Recent right-to-know amendments to the SDWA require water providers to disclose the results of their water testing to the public. For example, Tucson Water has its 2004 annual water quality report on its website. This report provides a summary list of the regulated contaminants detected in Tucson water supplies, as well as concentration ranges and MCLs.

Water providers must monitor (test) all of their water sources – both groundwater wells and surface waters (lakes, rivers, and canals) – at regular intervals prescribed by the USEPA and by state regulatory agencies. This is done at the source, after any water treatment, and before water is introduced into the delivery system. Additionally, water providers must also check for the possible presence of pathogens (using coliform bacteria tests) and residual disinfection chemicals at points throughout their water distribution system. The mandated number of tests and intervals between tests depend on the water quality parameter, number and types of water sources, size of the distribution system, and number of water users.

The Safe Drinking Water Act **(SDWA)** has enforceable provisions for National Drinking Water Standards (see Section 1.1). States are the primary enforcers of drinking water standards. Usually, water quality standards are enforceable three years after being adopted by the EPA. From that time on, water providers affected by the new standard must test their water at regular intervals, maintain complete records of test results, and be subject to audits by state agencies and the EPA. Providers that do not keep records or that violate drinking water standards are subject to fines of up to $25,000 per day. According to the EPA, violations occur more often in smaller than in larger water systems.

Portions of this text have been adapted from USEPA websites EPA1, EPA2, and EPA3 (see Appendix 2).

4.1 Water Treatment

Water Treatment 4

4.1 Home Water Testing

To decide whether a home water treatment device is needed, you must first know the quality of your water source and the quality of your tap water. Try to obtain as much water quality information as possible from your local water provider or contact neighbors with wells near your own well.

If Your House is Connected to a Public Water System

Water Facts: Public water utilities are required by law to deliver water that meets NPDWS to your house (meter) inlet. Public water utilities should also deliver water with acceptable taste and aesthetics.

If your tap water is colored and/or cloudy, smells, or has an unusual taste, verify that your house pipes are not affecting your water quality. Note the appearance, taste, and smell of the water from an outlet located outside the house (as close to the main meter as possible). If the water is similar in quality both outside and inside your house, talk with neighbors, as they may be experiencing similar problems. If this is the case, contact your water provider immediately. Most water quality issues of this nature are temporary and will be resolved by your water provider. If your provider is unable to improve the water quality, you should contact the Arizona Department of Environmental Quality (ADEQ) for further assistance (see Appendix 2).

If you still are not satisfied with your water quality, you should request an annual water quality analysis report or obtain it from the appropriate water provider website (again, see links provided in Appendix 2). Verify that your water provider delivers water that meets all EPA standards and guidelines. Using this report, you may choose some water quality parameters that you would like to improve.

If You Own Your Own Water Source (Well)

First, obtain all available water quality information from the previous owner, neighbors, and local water utilities, then consider further testing (see the Suggested Water Testing Schedule found in Section 1.3). If your water source is cloudy, smelly, or has an unacceptable taste, it likely does not conform to NSDWS. Consider testing for some or all parameters found in Table 1 of Appendix 3 and review the last two tables of Section 4.10, which list water problems, their possible sources, water treatment options, and what tests to conduct. Finally, contact the ADEQ for information on possible or known sources of groundwater contamination in your area.

Water Testing

Before purchasing or installing a water treatment system, test your water at the tap. Be aware that water testing is not an easy or inexpensive step. Laboratory fees for water quality analysis vary greatly from one parameter to another. For example, testing for hardness, TDS, and pH may cost about $50. Testing for lead or nitrate may cost about $35. However, testing for all possible individual pollutants can cost more than $4,000 per sample. For a complete list for what to test, see Appendix 3.

If you suspect that your house plumbing may be contaminating your water, test your water at the tap for those contaminants that may be present. Carefully choose the list of contaminants to be tested with the assistance of a qualified water quality expert. See also Table 4, Appendix 3, for a list of water problems and suggested tests, and review the drinking water standards listed in Tables 1-3 of Appendix 3.

A good water testing laboratory should provide you with clean containers and clear instructions on how to collect a sample of your tap water sample. In order to prevent biased test results, it is essential that you follow the water sample collection, preservation, and shipment instructions carefully. To locate an Arizona state certified laboratory, call the Arizona Department of Health Services (ADHS) Bureau of State Laboratory Services for a list of certified water testing laboratories in Arizona (602-364-0728).

Water testing laboratories must comply with state and federal guidelines by using USEPA approved methods of analysis. Guidelines for water testing are regularly published and updated by the EPA and are also listed in the Code of Federal Regulations, Title 40, part 136. These are now available electronically at the Electronic Code of Federal Regulations website: http://ecfr.gpoaccess.gov.

Laboratory Test Results

Have the tests results explained to you by a qualified analyst or water quality expert. For example, the term such as "BDL" (below detection limit) means that a pollutant could not be detected below a certain value or detection limit of the instrument. BDL values should be listed in the laboratory report, and they should always be lower than the NPDWS and the NSDWS MCLs listed in Tables 3 and 1, Appendix 6.3.

Determine which parameters have values above drinking water standards and which parameters you would like to lower in order to improve water quality.

PHOTO: Janick Artiola

Water testing is serious business: Laboratory analyst at work.

The following sections present details on the applications, principles, and cost of six common methods of home water treatment. They also include a list of common water quality problems, specifically those common in Arizona, discuss water scams, and present a list of key questions to ask before investing in a water treatment option. Use this information to make informed decisions about your home water treatment options.

4.2 Particle and Microfiltration

Particle filtration is a process that removes small amounts of suspended particles, ranging in size from sand to clay, from water. It can be used alone or ahead of other water treatment devices. Home filters are not intended to filter large amounts of particles. Instead, **sedimentation**, or sand filters, are used to filter and remove particles from large volumes of water. Microfiltration may also be used to remove some bacteria and large pathogens, like cysts (*Giardia and Cryptosporidium*). Note that microfiltration should not be relied on to disinfect water with high concentrations of bacteria and viruses, instead chemical disinfection should be used. Other forms of filtration include ultrafiltration and reverse osmosis (see Sections 4.3 and 4.4). See Filtration Application Guide, on the next page.

Operation and Construction

Filters function in two general modes:

Surface or screen filters remove the particles at or very near the filter surface. **Ceramic filters** are porous ceramic cylinders that filter at the surface. They are expensive but long lasting, may be cleaned, and filter a specific range of particle sizes. **Resin-bonded filters** look like ceramic filters but are produced by bonding particles with resin rather than heat.

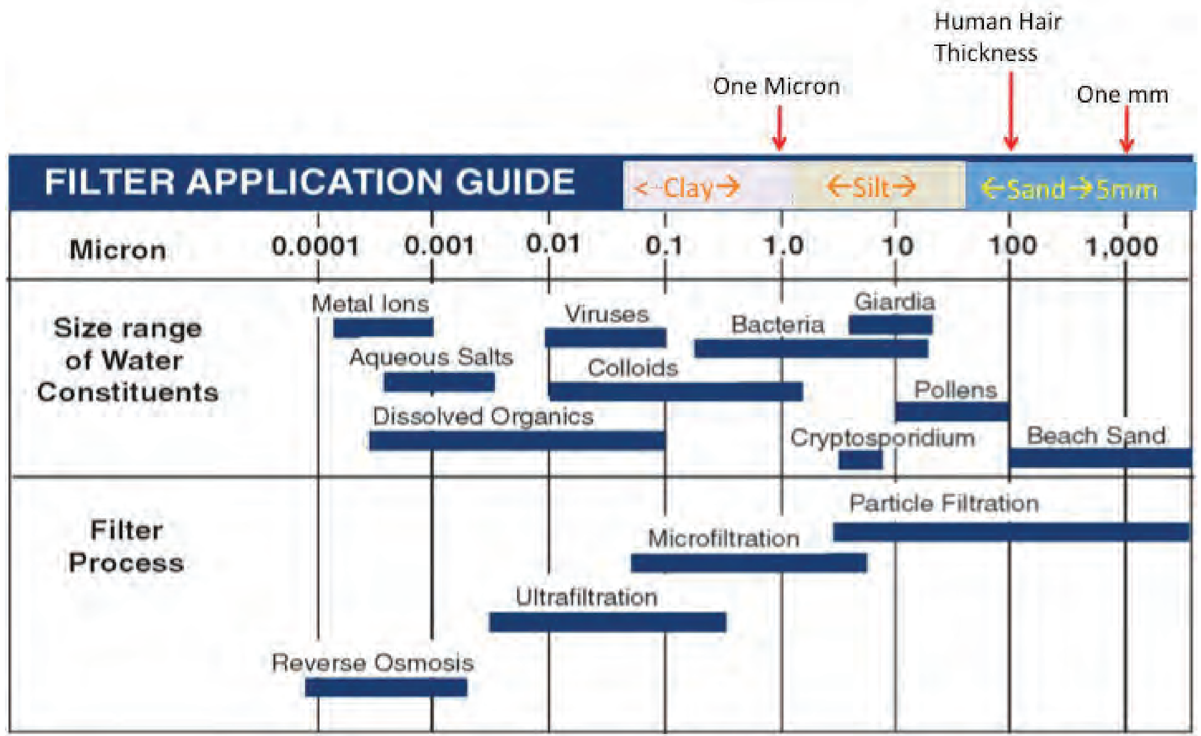
Depth filters have a thick filter medium. Particles are retained throughout the thick filter mat, and these filters may be used for a wide range of particle sizes. There are several types of depth filters. **String-wound filters** are easily recognized by the criss-cross pattern of the string (which may be made of cotton or synthetic materials such as polypropylene and nylon). **Spun-fiber filters** which look like a fuzzy fiber tube, are usually constructed from synthetic fibers (such as polypropylene and nylon) or natural fibers (such as cellulose). **Pleated-fiber filters** are constructed either of individual fibers that are pressed and bonded together or of a continuous sheet or membrane with very small openings.

Filter Rating

Particle filters have two types of ratings:

Average or nominal particle size implies that a range of particles pass through different sized openings within the filter.

Absolute particle size implies that no particle larger than the stated size may pass through the filter.

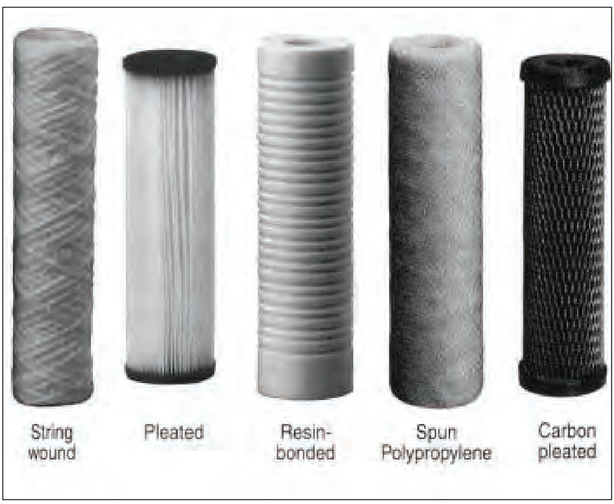


Filtration guide. Source: modified form Filtration Application Guide, Water Quality Improvement Center.

Filter Selection

Filters are rated by the smallest size particle they will remove, stated in microns. A micron is approximately 0.00004 inches (some common particles sizes are shown in the Filter Application Guide, previous page).

If no **colloidal** materials or pathogens are present, the filter with the largest rating size that will work is recommended as it will require less maintenance. If the filter must be very fine, such as for removing pathogens, two filters are often recommended. A depth filter with larger openings might be selected as the first filter and an absolute rated surface filter could be used as the second filter to ensure removal of the organisms.



Types of Particle Filters. Courtesy: U.S. Filter, Plymouth Products Division and water Conditioning and Purification.

Filter Cost

Particle filters and microfilters range in price from a few dollars for a small self-contained specialty type to $150 or more for a large ceramic filter system. Replacement cartridges range from a few dollars to $100 or more for ceramic cartridges. Total costs are highly variable depending on requirements and particulate load guidelines that determine the cartridge's service interval.

Filter Facts:

- Synthetic filters (made out of plastic fibers or resins) are a possible source of chemical contamination in themselves.
- Misuse of these devices, including overuse and fast or inadequate flushing, may prevent or reduce filtration of contaminants or may release large amounts of contaminants back into the water (initial flush effect).
- Filters should be used regularly. Long idle periods may lead to excessive bacterial growth, early clogging, and the possible release of high concentrations of potentially harmful bacteria when flow is restarted.
- Replace filters at manufacturer's prescribed intervals.

Portions of this text are adapted from Powell and Black 1987.

4.3 Activated Carbon

Water Facts: An activated carbon filter is used most frequently to reduce the unwanted taste and smell caused by water chlorination and can protect against spikes of organic contaminants.

Activated carbon filtration may be selected to reduce unwanted tastes, odors, and organic chemicals (such as disinfection by-products, pesticides, solvents, and emerging contaminants) from drinking water. Activated carbon will also reduce **radon** gas and residual chlorine. Activated carbon filters will not remove or reduce major inorganic ions (e.g., sodium, calcium, chloride, nitrate, and fluoride) or metals. However, some carbon filters can reduce lead, copper and mercury. Activated carbon filters will not soften the water or disinfect it. If the water source is cloudy, this type of filter may be used after a particle filter to remove particles that may plug or reduce its efficiency.

Principles of Activated Carbon Filtration

Activated carbon filtration makes use of a specially manufactured charcoal material. That substance is composed of porous carbon particles to which most organic contaminants are attracted and held (sorbed) on/in the porous surface. See figure next page (insert). However, organic pollutants have large differences in affinity for activated carbon surfaces. Also, the characteristics of the carbon material (particle and pore size, surface area, surface chemistry, density, and particle hardness), the size of the filter, and the flow rate of the water through the filter have a considerable influence on the pollutant removal efficiency of these filters. Usually, smaller carbon particles and slower water flows improve contaminant removal.

Types of Units

Faucet-attached devices, or point-of-use **(POU)** devices (see figure next page), may be directly attached to the faucet, or the filter may be placed on the countertop and connected to the faucet with a hose. These units may be equipped with a by-pass feature to draw unfiltered water. Units that attach to the faucet are very small in size and offer short contact time, relatively short life, and limited contaminant removal. Despite these limitations, these devices improve water taste and reduce smells when used as directed.

Pour-through filters also generally are small and portable. Some work merely with gravity filtration and tend to be slow; others contain a power-operated pump. These devices also improve water taste and reduce smells when used as directed.

Speciality filters are intended to treat water for appliances such as ice makers and water coolers. These also are small units, normally a combination particle and activated carbon filter, installed in the water supply pipe. When service is required, the entire unit is replaced.

Line by-pass and stationary filters are very similar. These are usually the largest units and they are connected directly into the house plumbing, requiring the services of a plumber for installation and maintenance.

Filter Selection

When purchasing an activated carbon filtration device, first consider the quality of the drinking water. An activated carbon unit that will remove of simple taste and odor problems is quite different from one designed to reduce low or hazardous levels of contaminants below national standards. The best unit for a given situation depends on the amount and type of carbon material contained in the unit, what contaminants it is certified to reduce, initial and replacement cost of filters, frequency of filter change, and operating convenience. Two other important factors to consider are the potential drop in water pressure in the home system after installation of a unit and the daily quantity of treated water supplied by the device.

Maintenance

Activated carbon filter units need to have the carbon changed periodically. For small speciality units, the entire unit is normally replaced. Cartridge filters are the easiest to change. The ease of opening the filter housing and the amount of space required to change the filter should be considered.

Cost

The devices commonly available for the home range in price from $30 for POU and pour-through filters to over $800 for point-of-entry (**POE**) units (installation not included). Replacement cartridges range in price from $10 to $50 or more. The filter cartridge replacement interval will determine annual maintenance cost.

PHOTO: Janick Artiola

Activated carbon filter (point-of-use) and activated carbon material (insert).

Activated Carbon Filter Facts:

- The carbon cartridge should have rigid sides to maximize contact between the water and the carbon.
- Only cold, disinfected water should be used.
- A newly installed device should be flushed with water, following the manufacturer's instructions. For pour-through models, water should flow slowly through the unit to assure adequate contact with the carbon.
- Filters should be changed on schedule to avoid contamination breakthrough.
- Filter material or cartridge should be replaced if left unused for an extended period of time (two weeks or longer).
- Hazardous (above NPDWS) levels of organic chemicals should be treated with properly sized, professionally tested, and properly maintained activated carbon filter devices.

Portions of this text have been adapted from Lemly, Wagenet, and Kneen 1995 and Plowman 1989a.

4.4 Reverse Osmosis

Reverse osmosis (RO) is a common home treatment method for contaminated drinking water. RO, probably best known for its use in water desalinization projects, can also reduce chemicals associated with unwanted color and taste. It also may reduce pollutants like arsenic, lead, and many types of organic chemicals.

Water Facts: RO can treat moderately saline to saline water, reducing the amounts of common minerals, including hardness, by 80–95%.

RO treatment is not effective for the removal of dissolved gases such as radon, or for some pesticides and **volatile** organic chemicals such as solvents. For example, RO will not effectively remove disinfection by-products like chloroform. Consumers should check with the manufacturer to determine which contaminants are targeted and what percent of the contaminant is removed.

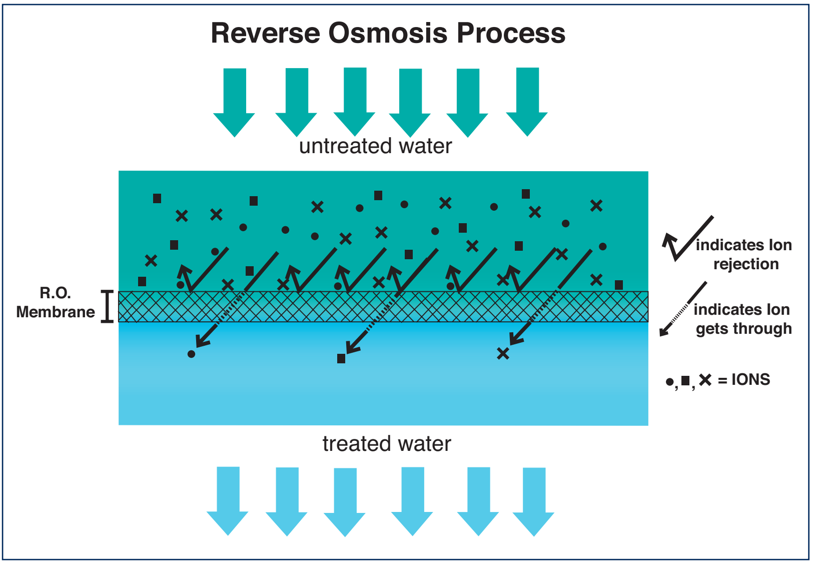
Water Facts: The removal effectiveness (percent of removal) depends on membrane type, water pressure, and the amount and properties of each contaminant.

RO is not recommended for sediment (particle) and pathogen removal. Pre-treatments such as particle filtration (to remove sediments), carbon filtration (to remove volatile organic chemicals), chlorination (to disinfect and prevent microbial growth), pH adjustment, or even water softening (to prevent excessive fouling produced by water with excessive hardness) may be necessary for optimum RO functioning.

Principles of Reverse Osmosis

The simplest home RO system consists of a semi-porous membrane (see figure on next page), a storage container for the treated water, and a flow regulator, and a valve to back-flush the membrane when it becomes clogged (or fouled). Tap water is passed through a membrane that filters out most of the contaminants. Eventually, the pores of the membrane become clogged with minerals and the flow-through of water slows down. To remove these residues, the membrane is back-flushed using tap water, which creates reject water high in salts. This brackish water is automatically discharged into the home drain system. When the membrane flow is restored, tap water can be treated again. The pressure for RO is usually supplied by the line pressure of the water system in the home. RO units installed in private water sources should have sediment and activated carbon pre- and/or post-filters.

Home RO units are often small cylindrical devices approximately 5 inches in diameter and 25 inches long, excluding any pre- or post-filtration devices. It is not practical to treat all water entering a residence with RO since typical household units do not produce enough water to meet all household needs. Also, RO water can be very **aggressive** and should not be circulated through or stored in metal pipes or containers. Often, the unit is placed beneath the kitchen sink to treat water used for cooking and drinking.



Reverse osmosis (RO) process.

Types of Reverse Osmosis Membranes

These membranes are made from organic chemicals like cellulose acetate, cellulose triacetate, aromatic polyamide resins, a mixture of these materials, and a variety of other materials. Membrane selection depends primarily on the quality of the water source. Some membranes are intended for use only with chlorinated water, others must have water with no chlorine, and still others may be used with either. Note that residual chlorine will quickly damage membranes not rated for chlorinated water.

All membranes used in home-size RO units are enclosed in a cartridge and are usually either hollow-fiber or spiral-wound. Spiral-wound membranes, more common in home systems, are designed to treat water with high levels of suspended solids. Hollow-fiber membranes are easily clogged by hard water, but they require less space and are somewhat easier to maintain than the spiral-wound configuration.

Reverse Osmosis System Selection

Key questions to ask and issues to consider before purchasing an RO system include:

- ✓ **How well does the RO unit remove contaminants found in your water supply?** Note that removals are given in percent removed of the total present in the source water and that this varies for each contaminant. For example: if tap water has 100 mg/L sodium, a membrane with an 85% reject value should produce water with no more than 15 mg/L of sodium. Again, remember that this removal percentage for sodium may not be the same for other contaminants.
- ✓ **How much treated water can be produced per day?** Since some RO units operate continuously, an oversized system will result in excessive waste of treated water.
- ✓ **How much back-flushing water is needed per gallon of treated water?** This often is an overlooked cost that may be difficult to determine in home systems that drain the back-flush water directly into the sewer. Home RO systems may spend as much as 10 gallons of water to back-flush the membrane for every gallon of clean water they produce. In contrast, industrial RO units may need only 3 gallons of back-flush water for every 7 gallons of treated water. For home RO systems, the range of water treatment efficiency may vary from ~10-50%, depending on the TDS and hardness of your water source, membrane type, removal efficiency, and system pressure.

Operation and Maintenance

RO units increase home water use since tap water must be used to regularly flush the membranes. Some devices might require continuous operation to maintain peak membrane performance. This may lead to frequent and excessive losses of treated water. Clogged or torn RO membranes require replacement; however, well-maintained membranes should last two to three years. In addition, an RO system that uses pre-and post-treatment devices has added purchase and maintenance costs.

Membrane inspection is not practical, so regular analysis of the treated water – using a TDS meter or more specific and expensive contaminant testing methods – is necessary. Also, some beneficial minerals – such as calcium and magnesium – are reduced significantly in RO water. As drinking water is not the primary source of these nutrients in our diet, this can be of minimal importance.

Cost

RO devices available for the home range in price from \$200–\$500, not including installation. Maintenance costs can range from \$50–\$120 a year.

RO Facts: Since extra tap water is needed to regenerate membranes, large home RO systems may result in significant increases in water use and fees. For example, a 10 gallon-a-day RO system with a 20% efficiency rating will require 1500 gallons of extra water use each month. Additionally, if water softening is needed prior to RO treatment, those costs also should be considered. However, these extra monetary and environmental costs are often overlooked.

4.5 Distillation

> **Water Facts:** Converting water to steam and back to liquid, effectively purifies and sterilizers water. It's the oldest and most natural form of water treatment.

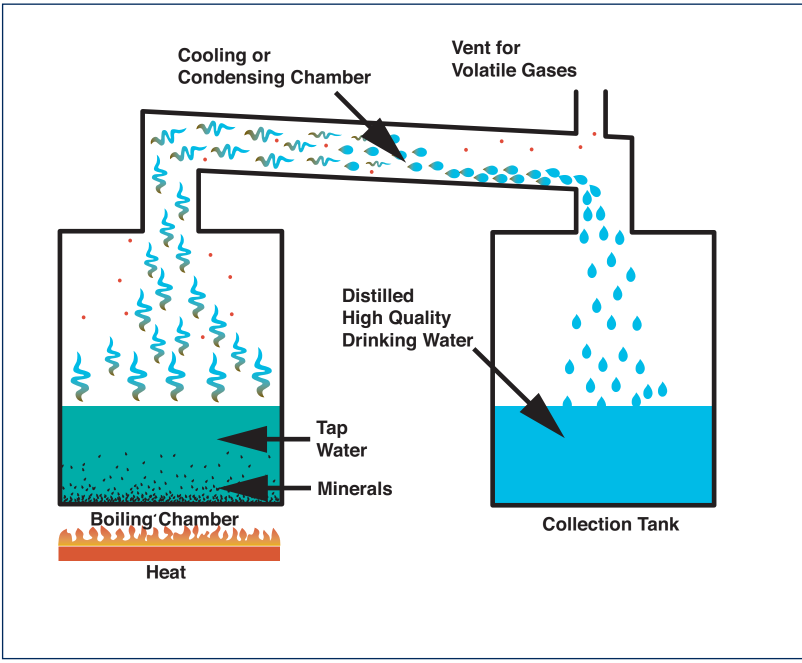
Distillation effectively removes inorganic contaminants (suspended matter including minerals, metals, and particulates) from water. Since distilled water has no minerals, some people claim distilled water tastes flat or slightly sweet. Distillation also kills or removes **microorganisms**, including most pathogens. Distillation can also remove organic contaminants, but its efficiency depends on the **chemical characteristics** of the contaminant. Volatile organic chemicals (VOCs) like **benzene** and **TCE** vaporize along with the water and re-contaminate the distilled water if not removed prior to distillation. Some distillation units may initially purge some steam and volatile chemicals. These units should be properly vented to prevent indoor air contamination. Some home distillation units have activated carbon filters to remove VOCs during distillation.

Principles of Distillation

The principle for operation of a distiller is simple. Water is heated to boiling in an enclosed container. As the water evaporates, inorganic chemicals, large non-volatile organic chemicals, and microorganisms are left behind or killed off in the boiling chamber. The steam then enters condensing coils or a chamber where the steam cools by air or water and condenses back to a liquid. The distilled water then goes into a storage container, usually 1.5–3 gallons in capacity. See figure next page.

Distillation Units

Also called stills, distillation units generally consist of a boiling chamber (where the water enters, is heated, and vaporized), condensing coils or chamber (where the water is cooled and converted back to liquid), and a storage tank for treated water. Distillation units are usually installed as point-of-use (POU) systems that are placed near the kitchen faucet and used to purify water for drinking and cooking only. Home stills can be located on the counter or floor, or attached to the wall, depending on size. Models can be manual, partially automated, or fully automated.



Distillation process

Operation and Maintenance

As with all home water treatment systems, distillation units require some level of regular maintenance to keep the unit operating properly. Contaminants left in the boiling chamber need to be regularly flushed out. Even with regular removal of the brackish (saline) residues, calcium and magnesium scale will quickly collect at the bottom of the boiling chamber. Over time, this scale reduces heat transfer and should regularly be removed either by hand scrubbing or by soaking with acetic acid. Vinegar a common cleaner used in home distillers.

Costs

Small still units (capacity: 1.5 gallons, 6 liters) cost $250 or more. Large units (capacity: 15 gallons, 57 liters) vary from $450 to $1,450 in purchase price.

Distillation Facts:

- Distillation is the most effective, but also the most expensive form of water purification because it uses so much energy.
- The power rating of the still and the local electricity rates determine the cost of operating these units.
- To calculate the cost to produce one gallon of water, multiply the price of a kilowatt-hour times the rated kilowatt-hour use of your model times the number of hours it takes to produce one gallon of water. For example, if local electricity costs 0.10 cents per kilowatt hour and your unit is rated at 800 watts (or 0.8 kilowatt-hour) and it takes 4 hours to produce one gallon of water, your operating cost is 0.32 cents per gallon, excluding purchase and maintenance costs.
- Distillation efficiency decreases as the TDS of the water increases.
- Distillers can effectively reduce most or all contaminants, including minerals, metals, organic chemicals, and microorganisms from water.
- Although minerals that can cause corrosion and scaling are reduced during distillation, distilled (and RO) water is very corrosive and should not be stored or transferred in metal pipes.
- Distillers vary from small, round units that distill less than one quart of water per hour to rectangular carts that distill about one-half gallon of water per hour.

Portions of this text have been adapted from Plowman 1989b.

4.6 Ion Exchange - Water Softening

> **Water Facts:** Home water softeners are popular in Arizona because they reduce water hardness associated with calcium and magnesium minerals.

Ion exchange units that replace calcium and magnesium ions from water are known as water softeners. They may also remove varying amounts of other inorganic pollutants such as metals, but they will not remove organic chemicals, pathogens, particles, or radon gas. Water softener units work most efficiently with particulate-free water.

Principles of Ion Exchange to Soften Water

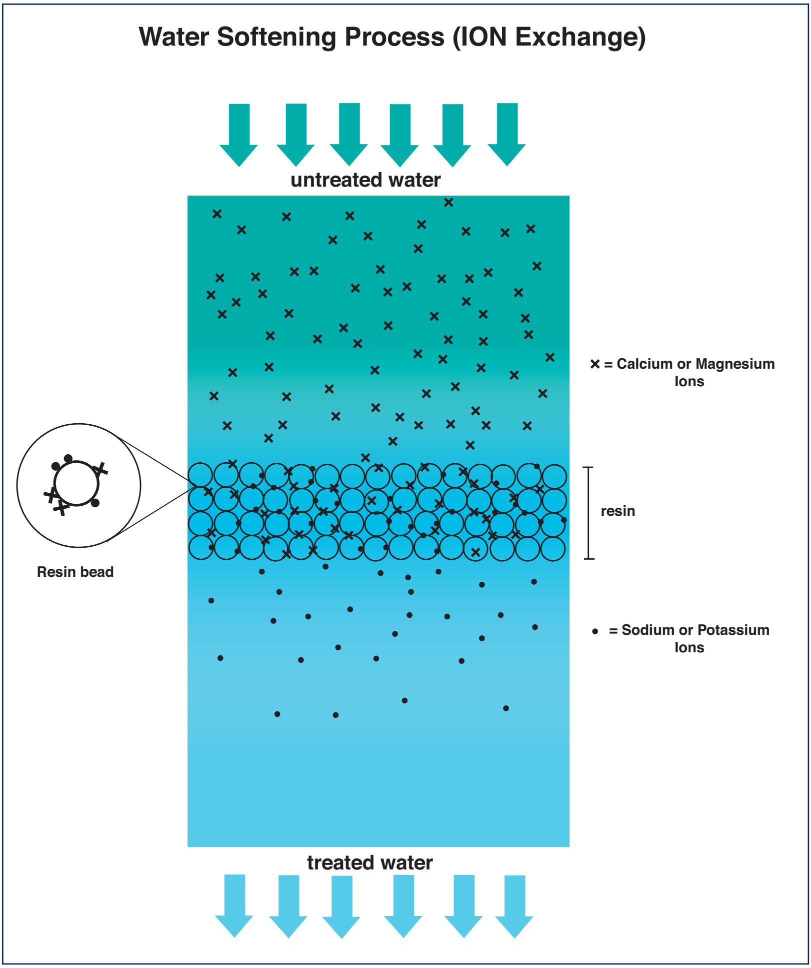
Calcium and magnesium ions are atoms that have a positive electrical charge, as do sodium and potassium ions. Ions of the same charge can be exchanged. In the ion exchange process, a granular substance (usually a resin) that is coated with sodium or potassium ions comes into contact with water containing calcium and magnesium ions. Two positively charged sodium or potassium ions are exchanged (released into the water) for every calcium or magnesium ion that is held by the resin. This "exchange or trade" happens because sodium or potassium are loosely held by the resin. In this way, calcium and magnesium ions responsible for hardness are removed from the water, held by the resin, and replaced by sodium or potassium ions in the water. This process makes water "soft." Eventually, a point is reached when very few sodium or potassium ions remain on the resin, thus no more calcium or magnesium ions can be removed from the incoming water. The resin at this point is said to be "exhausted" or "spent," and must be "recharged" or "regenerated."

Ion Exchange Unit Components

A water softener can be as simple as a tank to hold the exchange resin, together with appropriate piping for raw (inlet) and treated (outlet) water. Modern water softeners include a separate tank for the brine solutions used to regenerate the resin, additional valves to back-wash the resin, and switches for automatic operation.

Plumbing Requirements

New homes are plumbed to accomodate water softeners. Plumbing old homes for soft water can be very expensive. Not all the water coming into a home needs treatment. If the water is classified as very hard (10.5 or more grains per gallon or 180 or more mg/L of



Ion exchange process

calcium carbonate), a house point-of-entry (POE) treatment may be needed. Otherwise, only the hot water supply should be treated to reduce formation of calcium deposits (scale) in the water heater and pipes.

Personal preference may also influence the decision to treat hot and cold supplies going to the laundry room, showers, and sinks. Toilets and outdoor faucets should not receive softened water. Softened and untreated water may also be "blended" to produce water with a lower hardness and to decrease the amount of water that must be treated.

Unit Selection

The selection of a water softening unit depends on the hardness of the raw water and the amount of water to be softened. There are manual, automatic, semiautomatic, and fully automatic units that differ in the degree of resin regeneration automation. First, the number of fixtures in the home that will require softened water must be determined. Then, the flow rates from all the fixtures flow rates need to be added up. Note that conventional faucets use 3-5 gallons per minute (gpm) and conventional showers use 5-10 **gpm.** (Newer, water-saving fixtures may use only half these amounts).

Operation and Maintenance

Maintenance of water softeners is largely confined to restocking the salt supply for the brine solution. Semiautomatic models require either a manual start of the regeneration cycle or regular service for a fee.

The resin should never wear out but if resins are not regenerated on a regular basis, at the proper intervals, they may become contaminated with slime or impurities and require replacement. Resins can also become clogged with tiny particles of iron if the raw water contains that mineral. Back-washing, that is, reversing the normal flow of water through the treatment unit, may be required to remove the iron. Alternately, special additives may be added to the brine to help minimize this condition.

Costs

The initial cost of water softeners depends on the total hardness of the water, the degree of desired automation, the volume of water to be treated, and other design factors. Retail prices range from approximately $300 for a one-tank system capable of removing 12,000 grains before recharging, to more than $1000 for a two-tank system capable of removing 48,000 grains before recharging. Operating costs depend on the frequency of resin regeneration. Only salt made specifically for ion exchange units should be used. This salt costs about $3.50 for a 40-pound bag. Electrical costs should be considered as part of operating expense for ion exchange units. Seek units that are energy efficient as expressed by their Energy Efficiency Rating (**EER**).

Water Softener Facts:

- An often overlooked environmental cost of water softening systems is that they degrade the quality of **reclaimed** and **gray water** by increasing water **salinity (TDS)**. Remember, most of the additional sodium or potassium that is used in water softeners and the brackish water produced during resin regeneration is discharged into the sewage, septic*, gray water systems and, eventually, into the environment.
- House and yard plants should not be irrigated with **soft water.** This is due to its disproportionate ratio of sodium or potassium to calcium and magnesium ions. In general, water with a high sodium/calcium ratio has an adverse effect on soils, and plants are more stressed because **soft water** has a higher **salinity** and may lack calcium and magnesium (necessary plant nutrients).
- **Soft water** may not be as healthy to drink as hard water for persons that are on a low-sodium diet.
- The taste of **soft water** may not be as pleasant as hard water.

*The infiltration efficiency of some septic system soils may be degraded with the use of sodium-based water softeners.

4 Water Treatment

4.7 Disinfection

Drinking water should be free of **pathogens** that cause illnesses such as typhoid fever, dysentery, cholera, and gastroenteritis. Whether or not a person contracts these diseases from water depends on the type of **pathogen,** the number of organisms in the water, the strength of the organism (its virulence), the volume of water ingested, and the susceptibility of the individual.

The purification of drinking water that contains **pathogens** requires a specific treatment called disinfection. Disinfection does not produce sterile water but it does lower the concentrations of pathogens to acceptable levels. Also, disinfected water is quickly contaminated with many types of benign heterotrophic bacteria that are ubiquitous (present everywhere) in the environment. These benign bacteria are regulated and listed in the NPDWS as Heterotrophic Plate Count **HPC** (see Table 3, Appendix 3).

Disinfection Requirements

Water Facts: State and federal governments require public water systems to deliver water to homes with no harmful levels of pathogens.

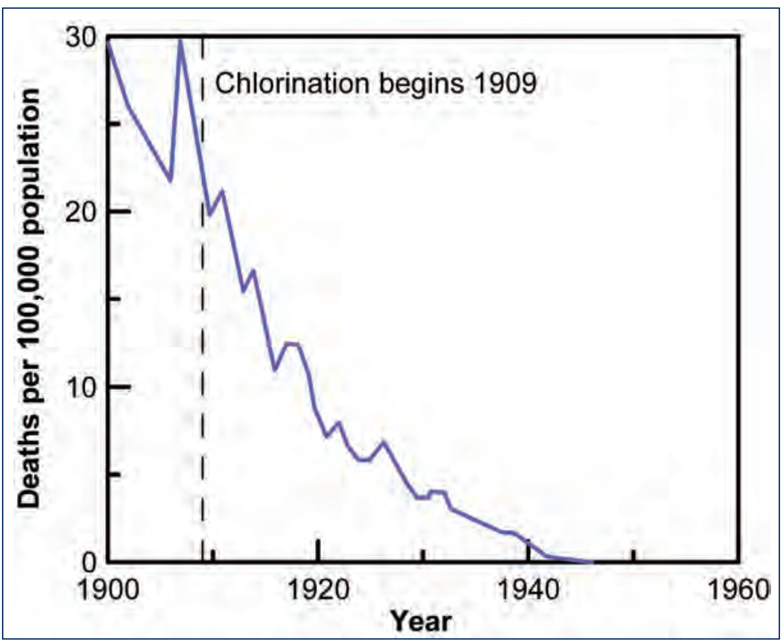
Water Facts: Private water sources, including wells, are vulnerable to contamination from septic systems, improper well construction, and poor quality water sources.

Disinfection reduces **pathogens** in water to levels designated safe by public health standards. This prevents the transmission of diseases. Ideally, an effective disinfection system should kill or inactivate (render harmless) all **pathogens** in the water. It should be automatic, simple to maintain, safe, and inexpensive. The ideal system should treat all the water and provide residual (long-term) disinfection. Chemicals should be safe and easy to store and not make the water unpalatable. Thus, water supply operators must disinfect and, if necessary, filter the water to remove *Giardia lamblia, Legionella,* coliform bacteria, viruses, turbidity to meet **USEPA** NPDWS.

Chlorine Treatment

> **Water Facts:** Although several disinfection methods can control pathogens in water, **chlorination** is the most common method of disinfection of public water systems. (see figure below). Chlorination is very effective against many pathogenic bacteria; however, at normal dosage rates, it does not kill all viruses, cysts, or worms.

Chlorine readily reacts with many contaminants found in water and, in particular, with natural organic matter **(NOM),** microorganisms, and plant matter. These include natural organic chemicals associated with taste and odor. There are many types of chemical reactions between chlorine and water contaminants that raise the amount of chlorine needed to disinfect water (chlorine demand). Additional chlorine may be added to provide continuous disinfection (residual). An ideal water disinfection system provides residual chlorine at a concentration of 0.3-0.5 mg/L. DPD (diethyl phenylene diamine) is a common water color test used to measure **chlorine breakpoint** and residual levels. Good test kits must measure **free chlorine**, not total chlorine, in drinking water.



Typhoid fever deaths since the beginning of water chlorination in the US. Source: US Centers for Disease Control and Prevention, Summary of Notifiable Diseases, 1997.

Water Chlorination Facts:

- Add sufficient chlorine to the water to meet the chlorine demand and provide residual disinfection so that water remains safe during storage and/or delivery.
- Disinfection using chlorine chemicals can produce unwanted volatile organic chemicals called disinfection by-products. The formation of these pollutants during chlorine disinfection is tied to the presence of NOM, type of chlorine treatment, and other water quality variables.
- The levels of disinfection by-products in public water supplies are regulated under the NPDWS (see Table 3, Appendix 3).
- The **contact time** necessary to disinfect water varies with chlorine concentration, the type of **pathogens** present, pH, alkalinity, and temperature of the water. Complete mixing of chlorine solution and water is necessary and a holding tank is often needed to achieve appropriate **contact time**.

Chlorination Guidelines

- Maintain a free chlorine residual of 0.3 0.5 mg/L after a 10-minute **contact time**. Measure the residual chlorine level frequently.
- Once the chlorine dosage is increased to meet greater demand, do not decrease it.
- Locate and eliminate the source of contamination to avoid continuous chlorination. If a water source is available that does not require disinfection, use it.
- Keep records of pertinent information concerning the chlorination system.

Caution: Do not store chlorine-free water in containers or trapped in water lines for long periods of time as bacteria will grow in it.

Chemicals for Home Chlorination Facts:

- Household bleach is a common form of liquid chlorine; available chlorine ranges from 5.25% (domestic laundry bleach) to 18% (commercial laundry bleach).
- Liquid chlorine solutions are unstable and only maintain their strength for about one week. Protect such solutions from sun, air, and heat.
- Chlorine powder chemicals must be dissolved in water. These solutions have an available chlorine content of about 4% and require filtration.
- Chlorine powder forms are stable when stored properly, but are a fire hazard if stored near flammable materials.

Types of Chlorine Used in Disinfection

Public water systems use chlorine in gaseous forms, which are considered too dangerous and expensive for home use. Private systems use liquid chlorine (sodium hypochlorite) or dry forms of chlorine (calcium hypochlorite). To avoid hardness deposits on equipment, manufacturers recommend using soft, distilled, or demineralized water when making up chlorine solutions.

Equipment for Continuous Chlorination

Continuous chlorination of a private water supply can be done by various methods: chlorine pump, suction device, aspirator, solid feed unit, and batch disinfection. The injection device should operate only when water is being pumped, and the water pump should shut off if the chlorinator fails or if the chlorine supply is depleted. Consult with a professional on equipment selection and tank requirements. For example, in a private well system, the minimum-size holding tank is determined by multiplying the capacity of the pump by a factor of 10. Thus, a 5 gallon-per-minute (gpm) pump requires a 50-gallon holding tank. Other methods to control contact time include the use of pressure tanks and coils.

Ultraviolet Radiation (UV)

Ultraviolet (UV) radiation as a disinfection method uses a UV lamp (source) enclosed in a transparent protective hollow sleeve through which water flows. RNA/DNA-damaging UV light is absorbed by bacteria and viruses, making them inactive and unable to reproduce. There are two classes of UV radiation systems based on their effectiveness to reduce **pathogens.** Class A UV systems are more effective at reducing pathogens than Class B units. Class B UV systems may be used at home to reduce the levels of heterotrophic bacteria present in clean tap water, although this many not necessarily make tap water safer. However, UV systems may provide an extra level of protection against pathogenic bacteria and protozoa. In summary, home UV Class B treatment systems are well suited to treat clean tap water with only residual levels of bacteria. Industrial grade UV Class A treatment units may also be used to kill or inactivate viruses, yeast, mold spores, and algae.

UV systems are simple and relatively maintenance free. However, their efficiency depends on several things: the design and energy of the UV chamber and source, the flow rate of the water, the amounts and types bacteria and other microorganisms present, and the clarity of the water.

No chemicals are needed with this method of disinfection. But UV treatment provides no residual disinfection and it is not effective with cloudy or turbid water.

UV Systems Maintenance and Costs

UV lamp must be replaced annually (having a lifetime of 9 months to 1 year). The cost is approximately $80. A UV sensor is recommended to determine the UV dose needed to kill bacteria. The cost of a home UV disinfection system starts at around $500.

Other Disinfection Methods

Although **chlorination** is the method of choice for most municipal and private water treatment systems, alternatives do exist (see box).

Emergency Disinfection

The use of household chemicals (such as bleach or iodine) to disinfect water without the appropriate equipment or technical supervision should only be considered under emergency situations. For a list of appropiate chemicals and their safe use, see the EPA website: www.epa.gov/OGWDW/faq/emerg.html (for other EPA links, see Appendix 2).

Other Disinfection Methods

Ozonation

- ozone is a more powerful disinfectant than chlorine
- its disadvantage is that it cannot be purchased but must be generated on-site
- the machinery to generate ozone is complicated and difficult to maintain
- the effects of **ozonation** chemical by-products are not fully understood
- like UV radiation, ozone treatment does not provide residual disinfection

Boiling

- two minutes of vigorous boiling ensures biological safety
- boiling kills all organisms in water (whereas chlorination reduces them to safe levels)
- boiling is practical only as an emergency measure
- once boiled, cooled water must be protected from re-contamination

Pasteurization

- **pasteurization** uses heat to disinfect but not boil water
- **flash pasteurization** uses high temperature for short time (160° F, 15 seconds)
- **low-temperature pasteurization** uses lower temperature for longer time (140° F, 10 minutes)

Portions of this text have been adapted from EPA7, and Wagenet and Lemley 1988.

4.8 Other Treatment Methods

Bacteriostatic filters are activated carbon filters that also contain silver particles to help control bacterial growth inside the filter. However, their effectiveness is controversial. Silver may help contain, but not necessarily reduce, bacterial growth in activated carbon filters. The National Sanitation Foundation (NSF) lists and certifies some filter devices (and manufacturers) with "bacteriostatic effects." However, their efficiency at controlling bacteria in tap water is not stated.

KDF (redox) filters are a new type of home water filtration device that may work as intended to reduce already low levels of bacteria, chlorine, some metals, and some types of organic pollutants from water. The effectiveness of this type of filter is also controversial. The NSF lists KDF filter media in its website. These filters should not be used for any other reason than to (possibly) improve water aesthetics (control taste, odors, or residual chlorine).

Ion Exchange Applied to the Removal of Other Ions

Organic resins can also be used to remove from water any type of ion besides calcium and magnesium (see Section 4.6). Ion exchange resins are commonly used as **POU** treatment devices to produce ultra pure (near completely demineralized) water in commercial and industrial laboratories. Usually, a water source with a very low **TDS** (less than 5 mg/L) is used. This usually requires pretreatment of the water source using an **RO** system. Typically, a series of mixed bed [anionic (-) and cationic (+)] resins followed by activated carbon filtration (packed in cartridges) are used to "polish" the water to strict standards. However this approach is not practical, cost-effective, or even necessary for home water treatment.

Ion Exchange Facts:

- Mixed-bed resins are quickly exhausted when tap water is used because ions like sodium, calcium, chloride, and sulfate (among others) quickly overwhelm and saturate the resin sites.
- Unlike water-softening resins, mixed-bed resins cannot be regenerated at home and must be purchased new when exhausted, or regenerated commercially. The cost of each cartridge starts at over $100 and varies upward depending on size.
- The efficiency of removal of trace levels of pollutants like cadmium, chromium, lead, and many other metal ions varies greatly and depends mostly on the **TDS** of the water source. The higher the **TDS**, the lower the efficiency of removal.
- To maintain strict water quality, commercial laboratories regularly test the level of contaminants of their water source with sophisticated instruments.

PHOTO: Janick Artiola

Laboratory grade water deionizer system that uses four mixed-bed resins and activated carbon and particle filters.

4.9 Water Scams

Consumers may become victims of several types of water scams related to water testing, water treatment, bottled water, and health issues (quackery). Consumers can decrease their chance of becoming victims by staying well informed.

Water Facts: To avoid water scams

- evaluate any claim carefully (remember, if it seems too good to be true, it probably is).
- consider only widely accepted and scientifically proven methods of water treatment.
- avoid pseudo-scientific (unproven) methods.
- be skeptical of testimonials from “satisfied” customers.
- avoid impulse buying or pressure buying tactics.
- report scams to local authorities and to the office of the Arizona State Attorney General.

Water Testing Scams

These can best be avoided by having your water tested by an independent laboratory (Arizona certified) that uses state-of-the-art USEPA-approved methods (for web links, see Appendix 2). Avoid “free” home water tests. Sellers may claim that they are using “EPA-registered” methods to test your water. This only means that they have registered their test with the USEPA; it does not mean that the USEPA has approved their test. It is very easy to make the color of water change with the addition of a drop of some chemical. Color changes do not necessarily mean that your water has a particular pollutant or excessive levels of pollutants.

Water Treatment Scams

These can be relatively benign, for example, being sold a treatment device you do not need. They also can be “fraudulent” when consumers are sold a device that does not work as claimed. There are several devices that claim to control or eliminate scale formation and/or remove minerals from water. These include magnets (magnetic or electromagnetic), electronic devices, depressurizing devices, catalytic, oscillation, vibration, and light devices (other than ultraviolet; for a discussion of ultraviolet radiation, see Section 4.7). There is no scientific evidence that any of these devices reduce or remove salts, prevent scale formation, or perform any other type of useful home water treatment. Again, consumers may encounter home water treatment systems that claim to be "EPA-registered." As with water testing, this does not mean that their system has been tested, approved, or endorsed for home use by the USEPA. The NSF certifies all water treatment technologies for the reduction of specific contaminants (including those previously discussed in this section), and it maintains a list of manufacturers that have tested and registered their home treatment devices with this organization (see Appendix 2).

Bottled Water Scams

These may be benign in nature, but they also can be costly over time (see discussion in Section 1.4). A notable scam claims that oxygenated or super-oxygenated water will provide all sorts of benefits: adding extra oxygen to your blood, changing the structure of water, "hydrating you faster" to "retarding" aging. Other bottled water scams may claim that "magnetized" or "ionized" water from remote glaciers or springs has numerous healing properties. None of these claims has any scientific evidence (visit the NSF website for descriptions of bottled water).

Portions of this text have been adapted from Hairston et al., 2003.

PHOTO: Janick Artiola

Glass of water with a twist of magnetism?

4.10 Selecting Water Treatment Devices

Water Facts: When considering home water treatment, inform yourself and consult with water treatment professionals at reputable dealership(s) to determine the best treatment approach for your particular problem(s).

There are several types of water problems than can occur in water supplies. A complete listing of water problems, including water appearance, water tests, and possible sources of contamination, can be found in Table 4 of Appendix 3.

There are two primary categories of home water treatment devices: point of entry **(POE)** and point of use **(POU)**. The effectiveness of these devices will vary depending on the quality of the water source and consumer need.

If more than one water quality problem exists, choosing a treatment device can be especially confusing and complicated. Well owners, for example, sometimes can eliminate two problems with one treatment. Occasionally, one treatment can create another problem. For example, it may be impractical to install a distiller to remove lead from your drinking water if your water is corrosive and continues to remove lead from the household piping system. Similarly, a reverse osmosis unit will not work efficiently if the water also contains particulates or if the water is very hard, as these can clog the membrane filter.

The following guidelines for water treatment are based on the fact that it is practical and efficient to treat some water quality problems before others. For instance, turbidity, acidity, hardness, and iron have to be controlled before activated carbon filters, reverse osmosis, or distillation units will operate efficiently. See also the table of Water Problems: Symptoms, Causes, and Possible Treatments at the end of this section for more details on water treatment options presented below.

Treatment Options for Users of Public Water Supplies

Common Arizona Water Quality Issues

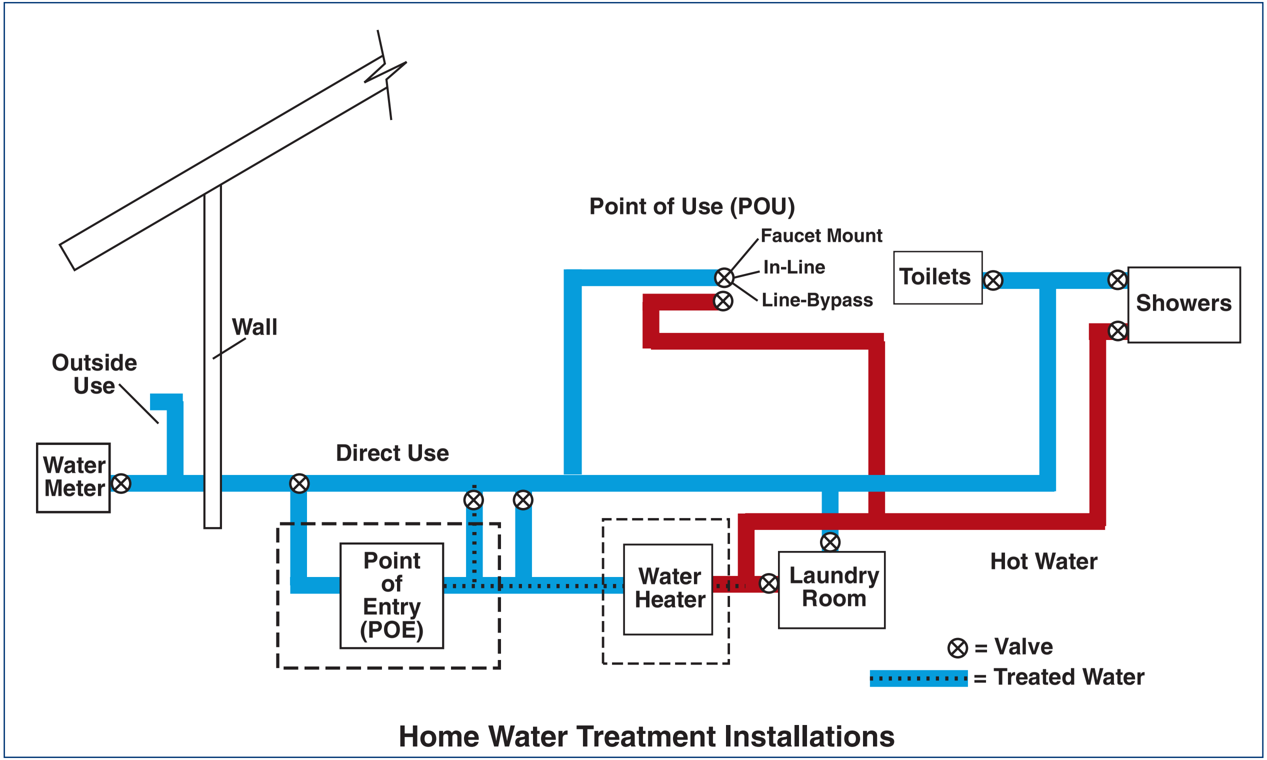
- **Hardness:** symptoms include excessive scale deposits and stains in showers, toilet bowls, and faucet ends; early appliance failures; and poor swamp cooler performance. Excessive hard water may be controlled using a water softener. The treatment device can be either **POE** or **POU**. Note: New homes are often plumbed to provide soft water to the kitchen and laundry room.

- **Salinity/high TDS:** symptoms include excessive staining in showers and aluminum cookware, and houseplants that are stunted or have burned leaf tips. Excessive **salinity** in water may be reduced or eliminated by using either a reverse osmosis or a distillation unit. The treatment device should be **POU**. Note: High **salinity** is often associated with high **alkalinity** and hardness.
- **Taste and smell:** symptoms include a chlorine-like taste and smell, and earthy or musty smells due to the presence of residual chlorine and **disinfection by-products**. Odorous chemicals produced by soil bacteria can be controlled with an activated carbon filter. The treatment device should be **POU.**
- **Arsenic, nitrate, lead and other inorganic pollutants:** the levels of these pollutants may be further reduced using reverse osmosis or distillation systems. Treatment devices should be **POU.**
- **Volatile organic chemicals, including disinfection by-products, certain pesticides, and gasoline products:** symptoms include a chlorine-like smell and taste. Use an activated carbon filter to reduce these smells. The treatment device should be **POU**. Note: While the smell of disinfection-related chemicals is common, the presence of other smells in your tap water should be reported immediately to your water provider.
- **Radon gas:** this gas is colorless and odorless, and its levels in tap water are regulated and controlled by water providers with **aeration.** Some activated carbon filters have been found to reduce further **radon** in tap water. The treatment device should be **POU**.

Treatment Options for Users of Private Water Supplies

Treatments Listed in Order of Priority

- **Turbidity:** symptoms include cloudiness (a yellow, brownish, or black cast) that clears after standing for 24 hours. **Turbidity** is due to the presence of sediments (including fine sand, silt, and clay particles) as well as insoluble iron and manganese particles. To treat, use **flocculation** and **sedimentation** or particle and micro filtration. Your choice will depend of the volume of water to



Home water treatment installlation options.

be treated and the amount of materials present. Note: Surface water sources are usually contaminated with cystic pathogens. This makes **sedimentation** or **particle filtration** a necessary first step.

- **Hydrogen sulfide and soluble iron and manganese:** symptoms include a rotten egg odor and staining of fixtures and clothes. Also, after standing for 24 hours, brownish/black sediments are observed at the bottom of a glass. This suggests an acidic, oxygen-starved water source. To remove these chemicals, water must be oxidized using **aeration**, **chlorination,** and/or an **oxidizing filter**, followed by particle sedimentation or filtration. Water sources rich in these chemicals tend have high acidity (low pH) upon treatment. They may also require acidity control (see below). Treatment devices should be **POE**.
- **Color-high natural organic matter (NOM):** symptoms include a transparent yellowish-brown tone that does not clear after standing for 24 hours. Normally associated with surface water sources, it indicates the presence of high levels of dissolved **NOM**. Small concentrations and water volumes can be controlled with activated carbon filtration. **Chlorination** may also destroy **NOM** and should be followed by activated carbon filtration to remove residual **disinfection by-products. Flocculation** is used by water utilities to removed **NOM** from water sources.
- **Acidity:** symptoms include green stains, pH levels below 6.0, and metallic taste (high copper and zinc content). It may be treated using **acid neutralizing filters** or by the addition (feeding) of alkaline chemicals such as lime. Treatment devices should be **POE.**
- **Alkalinity:** symptoms include high measured value, high pH (more than 8.4), and high sodium. **Alkalinity** may be reduced with the addition of acid chemicals. Reverse osmosis or distillation systems also may be used to reduce or eliminate water **alkalinity.** If alkalinity is associated with excessive scale formation, the treatment device should be **POE.**
  Note: Water softeners will not reduce alkalinity.
- **Corrosion:** symptoms include blackened or tarnished metal utensils and pipes due to high chloride and sulfate levels and/or to high water acidity and **hydrogen sulfide.** This problem must be controlled with **POE** devices (see above for treatments that lower salinity).

- **Pathogens:** symptoms include mild to severe gastrointestinal problems including diarrhea and vomiting. Once particles have been removed (see turbidity above), **chlorination**, UV radiation, or **ozonation** may be used to disinfect your water source. Storage and transfer of water will require residual **chlorination** not provided with UV radiation or **ozonation** treatments. Residual chlorination is necessary to store or transfer drinking water in potentially contaminated places like water pipes and large water storage tanks. Chemicals used to disinfect water may be added in excess to maintain residual chlorine levels. Chloramine chemicals may also be added after chlorination is completed in order to maintain acceptable chlorine residual levels. Disinfection should be done with **POE** devices.
- **Hardness:** see section above "Common Arizona Water Quality Issues."
- **Salinity:** see section above "Common Arizona Water Quality Issues."
- **Volatile organic chemicals, including disinfection by-products, certain pesticides, and gasoline products:** see section a above "Common Arizona Water Quality Issues."
- **Radon gas:** see above.
- **Arsenic, nitrate, lead and other inorganic pollutants:** see section above "Common Arizona Water Quality Issues."

Water Symptoms, Causes, and Possible Treatments

(* indicates a common Arizona water quality issue)

	Symptom	Cause	Treatment
Illness	Gastrointestinal problems such as diarrhea and vomiting	Pathogens	· Remove source of contamination · Reduce pathogens through chlorination[1], UV radiation, or ozonation (POE)
Visual (Water appearance)	Cloudiness of water with a yellow, brown, or black cast that clears after standing 24 hours	· Turbidity (cloudiness) · Silt, clay, or suspended particles in water	· New well screen · Particle filter (sand trap) (POE) · Microfiltration (POE) · Flocculation and sedimentation
	Transparent yellow-brown tint to water that doesn't clear after standing 24 hours	High levels of natural organic matter (NOM), usually in surface water	· Activated carbon filter[2] (POE) · Chlorination[1] followed by activated carbon filter[2] (POE) NOTE: Water utilities use flocculation to remove natural organic matter (NOM)
	Blue-green tint to water	Acidity (pH below 6.8; reacts with brass and copper plumbing)	· Acid-neutralizing filters (calcite or calcite/magnesium oxide) (POE) · Soda ash (lime) chemical feed followed by particle filter (POE)
	Excessive salt deposits	Hardness and alkalinity (high pH and sodium)	· Reverse osmosis (POE) · Distillation (POE) NOTE: Consider acid neutralization of excessive alkalinity
	Detergent odor or foaming water	Septic tank leaking into groundwater supply	· Eliminate source and shock chlorinate well · Activated carbon filter will absorb a limited amount
	Milky colored (water cloudy when drawn)	Precipitated sludge that is created when water is heated	Flush water heater periodically
		High volume of air in water from poorly functioning pump or highly performing aerator	· Water will clear quickly after standing · Service pump
		Excessive coagulant-feed being carried through filter	· Reduce coagulant quantity being fed · Service filter(s)
	Reddish slime or tint to water. Water turns reddish brown during cooking or heating	Presence of dissolved iron and iron bacteria	Low amounts: Reduce by · Particle filter (POE or POU) · Reverse osmosis (POE or POU) · Distillation (POE or POU) · In warmer climates, residential aerator and particle filter will substantially reduce iron (POU) High amounts: Remove by · Potassium permanganate-regenerated oxidizing filter (POE) · Particle filter (POE) Very high amounts (over 10 mg/L): Remove by · Chlorination1 (in a retention tank that allows for oxidation) followed by particle filter and/or dechlorination (POE) NOTE: Consider well, distribution, and storage shock chlorination to kill iron bacteria.

	Symptom	Cause	Treatment
Visual (Water appearance)	Reddish slime or tint to water. Water turns reddish brown during cooking or heating	Precipitated iron (water is discolored when drawn)	· If pH is higher than 6.7, a manganese greensand filter will remove up to 10 mg/L iron (POE) · If pH is higher than 6.8 and oxygen is 15% of the total iron content, use a manganese-treated, nonhydrous aluminum silicate filter (POE) · Downflow water with good backwash will remove up to 1 mg/L iron (POE) · To remove more than 1 mg/L, use a calcite filter followed by a downflow water softener (POE)
		Iron dissolved from old pipe with pH below 6.8	Calcite filter to remove precipitated iron (POE)
	Brownish cast that does not precipitate from (drop out of) the water	Organic (bacterial) iron	· Shock chlorinate well, follow with chlorination1 and filtration · Chemical feed of potassium followed by permanganate and then particle filter (POE)
	Reddish color in water sample after standing for 24 hours	Colloidal iron	Chlorination1 followed by activated carbon filter2 to remove chlorine
Visual other	Houseplants stunted or with burned leaf tips	Salinity	· Reverse osmosis (POU) · Distillation (POU)
Taste	Taste of chlorine, gasoline, or oil	Volatile organic chemicals (VOCs) including chlorine, disinfection by-products, pesticides, fuel (gasoline, diesel), or oil products	· Activated carbon filter2 (POE) · Aeration (POE)
	Metallic taste	Very low pH (below 5.5)	· Acid-neutralizing filters (calcite or calcite/magnesium oxide) (POE) · Soda ash (lime) chemical feed followed by particle filter (POE)
	Salty or bitter taste	· High total dissolved solids, sodium, sulfates, or nitrates · High salinity	· Reverse osmosis (POU) · Distillation (POU) · Deionize drinking water only with disposable mixed-bed (anion/cation) resins (POU) NOTE: No economical home treatment when sodium levels exceed 1800 mg/L
	Soda taste	High total dissolved solids AND high alkalinity	Reverse osmosis (POU) NOTE: No economical home treatment if level of alkalinity is more than 3.08 mg/L
Smell	Chlorine-like smell	Volatile organic chemicals (VOCs) including chlorine, disinfection by-products, pesticides	· Activated carbon filter2 (POU) · Aeration (POU)
	Gasoline-like smell	Gasoline, diesel, oil products	NOTE: There is no practical treatment system available. It is essential to locate and remove underground source. Activated carbon filters2 can provide some treatment.
	Phenol (chemical) odor	· Industrial waste seeping into groundwater · Leaching of applied pesticides into groundwater	Activated carbon filter2 will help for a short time (POE)

	Symptom	Cause	Treatment
Appliance/ Hardware Problems	Early appliance failure	Hardness	Water softener (POE or POU)
	· White or grayish stains on tile, faucet ends, in toilet bowls · White scaly deposits in pipes, water heater, or appliances · Soap curd and scum in sinks, bathtub	Hardness	· Water softener (POE or POU) · Reverse osmosis (POE or POU) · Distillation (POE or POU)
	Poor evaporative cooler performance	Build-up of scale on pads (high hardness and/or high salinity)	Use bleed-off mechanism to prevent build-up of salts and minerals (more information on Water Conservation website)
	Brown-orange or red-brown (rusty) stains on sinks, fixtures, laundry	Presence of dissolved iron and iron bacteria	Low amounts: Reduce by · Particle filter (POE or POU) · Reverse osmosis (POE or POU) · Distillation (POE or POU) · In warmer climates, residential aerator and particle filter will substantially reduce iron (POU) High amounts: Remove by · Potassium permanganate-regenerated oxidizing filter (POE) · Particle filter (POE) Very high amounts (over 10 mg/L): Remove by · Chlorination1 (in a retention tank that allows for oxidation) followed by particle filtration and/or dechlorination (POE) NOTE: Consider well, distribution, and storage shock chlorination to kill iron bacteria.

Possible Sources of Water Problems and Suggested Tests

Problem	Water Aesthetics	Tests Suggested	Possible Sources	Additional Tests based on Possible Sources
Stains, deposits (fixtures+clothes)	-Red or brown Slime -Black -Green/blue	-Hardness -Iron+ iron bacteria -Manganese -Copper	-Natural or due to mining, oil/gas drilling	Industrial sources: TDS, sulfates, pH, acidity, metals scan, corrosive index
Off-color	-Cloudy -Black -Brown or yellow	Turbidity -Hydrogen sulfide, manganese Iron, tannins, total organic carbon (TOC)	-Sediments, soil -Hydrogen sulfide and manganese -Natural organic matter, iron-rich aquifer	Septic systems, industrial sources: TDS, total coliform bacteria
Unusual taste and odor	-Rotten egg -Salty -Metallic -Septic -Musty, earthy	-Hydrogen sulfide -TDS and chloride, nitrates -Copper, lead, pH corrosive index. -Total coliform bacteria, nitrates -Total Coliform, bacteria, cyanobacteria	-Natural or due to intensive agricultural activities, including excessive fertilizer use, low irrigation efficiency, septic systems, feedlots, runoff.	Mining and Drilling: metals scan including barium, strontium, aluminum. manganese, copper, anions scan including sulfates
	-Gasoline or oil	-VOCs (hydrocarbons)	-Leaky underground fuel tanks.	Industrial sources
	-Soapy	-Surfactants	Natural or Septic systems	Biosolids (sludge) and animal wastes: TDS, nitrates, phosphates.
	-Alkali	-pH, alkalinity, TDS		Industrial sources
	-Unknown	-Pesticides and VOCs scans, TOC	-Mining and oil and gas drilling, landfills, road salt use. -Agriculture, fuel leakes.	Industrial sources
Corrosive water	-Pitting, deposits	-pH, corrosive index, copper, lead	-Natural or due to: mining and oil and gas drilling, landfills.	Industrials sources: TDS, sulfates, total acidity, metals scan.

4.11 Questions to Ask When Purchasing Water Treatment Equipment

In the past, the home water treatment industry focused on improving the aesthetic quality of drinking water. New products for home treatment claim to further reduce or eliminate contaminants in drinking water that may pose a health hazard. Product manufacturers now promise to make drinking water "safe," "pure," and "contaminant free." Consequently, consumers are left to sift through advertising claims and technical data as they try to select the appropriate treatment method(s) best suited to address their water needs.

Water Facts and Reminders:

- All water sources contain minerals and some contaminants. If a water source meets the standards set by the **USEPA, NPDWS**, and **NSDWS**, it is considered safe to drink.
- No water treatment device can completely eliminate all minerals and all contaminants from water all of the time.
- Proven treatments, if properly operated and maintained, can reduce contaminants below **NSDWS** and/or **NPDWS** levels.
- Before buying a home water treatment device, know the quality of your water source and decide
  - a) which contaminants you want reduced,
  - b) to what level, and
  - c) how much treated water you need every day.
- Home water treatment devices can break and, if misused, can contaminate your drinking water.
- Home treatment devices require regular use and periodic maintenance. They are not "install and forget" devices.

Before purchasing a home water treatment system, the consumer should ask the following questions (or use them as guidelines). The extent to which a manufacturer or distributor is willing to provide answers can help consumers make informed choices.

Questions

✓ **What exactly does your analysis of the water show? Are health hazards indicated? Which ones? Ask for specifics. Should more testing be done?**

Many water treatment companies include free in-home testing of the water. Most contaminants cannot be evaluated this way. For example, organic chemicals and trace metals, which have been associated with serious health problems, must be analyzed in a laboratory with sophisticated equipment. You should be wary of home analyses claiming to determine more than basic water quality constituents such as **TDS**, hardness, pH, iron, and hydrogen sulfide. It is best to rely on water testing done by an independent laboratory.

✓ **Have the product and the manufacturer been rated by the National Sanitation Foundation (NSF) or other third party organizations?**

✓ **Was the product tested (1) for the specific contaminant (or group) in question, (2) over the advertised life of the treatment device (with more than 1 gallon of water), and (3) under household conditions (including local tap water quality, actual flow rates, and pressures)?**

✓ **What is the performance value (removal efficiency and water purity), of this device? And who guarantees the performance and for how long ?**

The **NSF**, whose function is similar to the Underwriter's Laboratory for electrical and electronic products, sets performance standards for water treatment devices. Because companies can make unsubstantiated statements regarding product effectiveness, you must evaluate test results of the device to determine if claims are realistic. Keep in mind that the water treatment system you are evaluating may have components that are NSF approved, but that the entire system may not have been evaluated (for more information about NSF, contact them at 800-NSF-MARK or at www.nsf.org; for other valuable links, see Appendix 2).

✓ **Does the water quality problem, as determined by a certified laboratory analysis, require whole-house treatment (POE)? Or, will a single-tap (POU) device be adequate?**

Although less than 1% of tap water is used for drinking and cooking, some contaminants are as hazardous when inhaled or absorbed through the skin as when ingested. Treatment of all the water used in the household may be required. Reverse osmosis and distillation units are connected to a single tap; activated carbon devices can be installed on a single tap or where water enters the house. The device selected depends upon the type and level of the contaminant in question. Remember to use a state certified laboratory for your analysis. Contact the ADHS Bureau of State Laboratory Services at 602-255-3454 for a list of certified laboratories in Arizona (see also Appendix 2).

✓ **Will the unit produce enough treated water daily to accommodate household usage?**

Be sure that enough treated water will be produced for everyday use. The maximum flow rate should be sufficient for the peak home use rate.

✓ **If a filter or membrane is involved, how often does it need to be changed, back-flushed, or regenerated? How do you know when to do it?**

✓ **Besides maintaining filters and membranes, are any other types of maintenance needed? How often? Who does it? What does it cost?**

All proven home treatment devices such as activated carbon units, reverse osmosis units, and iron filters need routine maintenance. You should be fully informed of all maintenance requirements.

✓ **What is the total purchase price plus the expected maintenance costs (monthly/annual) of the device?**

✓ **Will the company selling the device also install and service it, and will there be a fee for labor?**

✓ **Can you perform maintenance tasks, or must a water treatment professional be involved?**

✓ **Will the unit substantially increase water and/or electrical usage in your home?**

Watch out for hidden costs such as separate installation fees, monthly maintenance fees, or equipment rental fees. Additionally, the disposal of waste materials (such as reject water, spent cartridges from activated carbon units, and used filters) can add to the cost of water treatment and should be figured into the purchase price. Some devices can be installed by you, the homeowner.

- ✓ **Is there an alarm or indicator light on the device to alert you to a malfunction?**

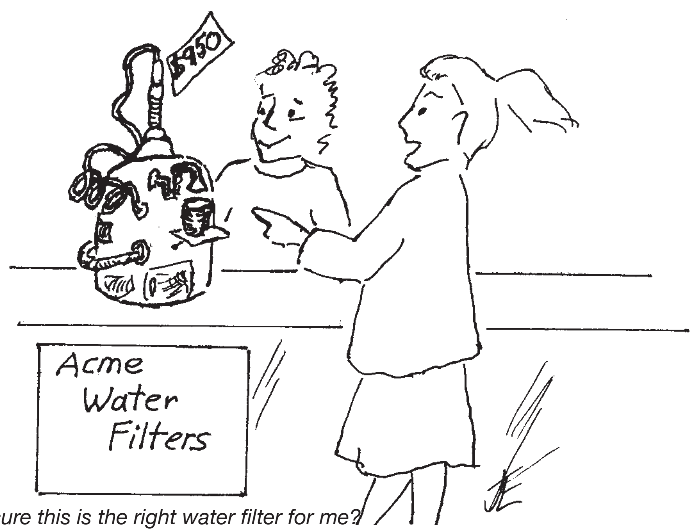
  Many units have backup systems or shutoff functions to prevent you from consuming untreated water.

- ✓ **Will the manufacturer include in the purchase price a retesting of the water after a month or two?**

  Testing the water a month after the device is installed will assure you that the unit is accomplishing the intended treatment. Remember, testing for specific contaminants can be very expensive.

- ✓ **What is the expected lifetime of the product? What is the length of the warranty period? What does the warranty cover?**

  The warranty may cover only certain parts of a device, so you should be aware of the warranty conditions.



Artist: Judi Ellwanger

Are you sure this is the right water filter for me?

Final Remarks

These guidelines are directed for those of you who are planning to consult a water treatment industry representative or who are planning to do your own research into water treatment devices. Be aware that treatment can be for aesthetic as well as for health factors. If drinking water poses a health risk, you should also consider the cost of purchasing bottled water as an alternative to treatment.

Monetary compensation for treatment of problem water resulting from environmental contamination may be possible. Contact the Arizona Department of Environment Quality (1-800-234-5677) for more information concerning this option.

Portions of this text have been adapted from Wagenet and Lemley, 1989b.

5. Glossary

A

Acid neutralizing filters are used to reduce water acidity. They contain some form of crushed calcite or other carbonate-based mineral. Like all filters, they must be replaced periodically.

Acidity is the total amount of acid and acid forming substances in water. See also pH.

Acre-foot equals 1 acre area filled with 1 foot of water. This volume of water is approximately 325,851 gallons or 1.24 million liters.

ADEQ (Arizona Department of Environmental Quality) administers all of Arizona's EPA programs and regulates public water systems that have at least 15 service connections or serve 25 people.

ADWR (Arizona Department of Water Resources) has established five Active Management Areas (AMAs) to manage and balance the availability of groundwater resources until 2025.

Aeration or air stripping is a water treatment process that uses forced air to remove volatile contaminants from water.

Aggressive water refers to low (TDS) mineral or mineral-free water. It easily dissolves minerals from pipes including scale deposits and metal pipes. Aggressive water is also corrosive. Only plastic piping and containers are recommended to transport mineral-free water.

Alkalinity is the total amount of bicarbonate and carbonate ions present in water, reported in mg/L of calcium carbonate ($CaCO_3$). Water alkalinity helps protect (buffers) against abrupt pH changes, limiting its range to between 7.5 and 8.5. Alkalinity and hardness also control pipe scale formation. There is no drinking water standard for alkalinity.

AMAs (Active Management Areas) are set by the ADWR to manage and balance groundwater resources in Arizona.

Anions are negatively charged ions. Examples: chloride and sulfate.

Aquifers are bodies of porous and permeable geologic material that can contain and transfer groundwater.

Arid climates (as in Arizona) average less than 12 inches of rainfall per year. The high heat and low humidity of these climates can evaporate more than 100 inches of water per year from exposed containers.

B

Benzene is a volatile organic chemical used as an industrial solvent and is a major component of gasoline.

BDL (below detection limits) is a term used in laboratory reports to indicate non-detected contaminants.

C

Calcite is a very common mineral composed of calcium and carbonate ions ($CaCO_3$).

CAP (Central Arizona Project) is a 350-mile canal from Parker Dam (near Lake Havasu) that brings Colorado River water to southwest Arizona cities (Phoenix and Tucson). CAP water is a blend of Colorado River water stored in Lake Havasu and water from Lake Pleasant (located north of Phoenix).

Carbonated water contains carbon dioxide gas (CO_2) under pressure. This water, like soda pop, usually has an acid pH between 2-3, and is regulated by the FDA.

Cations are positively charged ions. Examples are sodium and calcium.

Chemical characteristics of atoms or molecules include size, boiling point, (see volatile), and solubility in water.

Chemicals are any matter composed of known chemical elements such as hydrogen, carbon, nitrogen, etc... listed in the periodic table of elements.

Chloramine chemicals are chlorine- and ammonia-based chemicals used for long-term residual disinfection of potable water. Chloramines are very effective at controlling bacterial and algal growth in water; however, they also are very toxic to fish.

Chlorination is the addition of chlorine-based chemical to disinfect water.

Chlorine is a dangerous gas used to disinfect water and manufacture user-friendly chlorine-based chemicals like bleach.

Chlorine breakpoint is the point at which residual chlorine is available for continuous disinfection.

Coliform bacteria (see Table 2, Appendix 3). Routine water testing for coliform bacteria is used as an indicator of animal or human fecal contamination. Positive results may indicate the presence of pathogens such as bacteria, viruses, and parasites (present in surface waters only) in the water.

Colloidal materials are very fine particles like clay minerals that stay in suspension in water for very long periods and make water cloudy.

Contact time in chlorination is that period between the introduction of chlorine to the water and when the water is safe to drink (the necessary time for needed to effectively disinfect the water).

Contaminants are foreign substances (such as chemical, microbe, or plant and/or mineral particulate matter) found in water. Contaminants may or may not be harmful to human health.

Corrosion in metal pipelines occurs spontaneously by the presence of oxygen in water. Pipe corrosion is accelerated by corrosive water, high TDS, low (acidic) pH, low **alkalinity**, and high concentrations of chloride and sulfate ions. Iron metal pipes corrode the most, followed by zinc (galvanized iron) and copper metal pipes. Modern plastic pipes used in home construction do not corrode.

D

Density is mass (weight) divided by volume. The density of pure water at 4° C (39.2° F) is 1.000 grams per cubic centimeter (cm^3) or 8.35 pounds per gallon.

Detection is the testing or measurement of contaminants. It is common to detect contaminants at concentrations below the MCLs (see Tables 1-3, Appendix 3). This does not necessarily make the water unsafe to drink.

Detection limit of a chemical is a value below which measurement or detection is not possible. Laboratories report pollutants not detected as being below detection limits (BDL).

Disinfection of potable water to kill or inactivate pathogens is commonly done by public water systems with chlorine chemicals and ozone (O_3) gas. These include chlorine gas (most common), chloramines, and chlorine dioxide gas. Residual chlorine is added to prevent pathogen recontamination, (usually 0.1 to 0.4 mg/L chlorine or chloramines is needed in potable water that is delivered through the distribution system to homes). The use of these chemicals at home is not recommended or allowed. However, safe disinfection systems are available for home use (see Section 4.7).

Disinfection by-products are organic chemicals such as chloroform that can form during water disinfection using chlorine-based chemicals. Their concentrations are regulated under the NPDWS (see Table 3, Appendix 3).

Dissolution of minerals in water means that water separates and surrounds each mineral component (atoms or molecules) and holds them in solution.

Dolomite is a common mineral composed of calcium, magnesium, and carbonate ions ($CaMg[CO_3]_2$).

E

EER (Energy Efficiency Rating) is an important consideration when purchasing water softening systems.

Emerging contaminants are newly-recognized contaminants that require USEPA evaluation (see also contaminants, disinfection by-products, and endocrine disruptors).

Endocrine disruptors are a class of water pollutants that affect the human endocrine system. These include pesticides and emerging contaminants like pharmaceuticals and surfactants.

EPA – (U.S. Environmental Protection Agency) see USEPA.

F

FDA – (Federal Food and Drug Administration) is the federal agency responsible for writing and enforcing food and bottled water regulations for the United States.

Flash pasteurization (see pasteurization).

Flocculation is usually done before sedimentation. It involves the addition of flocculants and coagulants (chemicals) to form large particles (aggregates) from the fine solids suspended in water so they can settle quickly or be filtered faster.

Free chlorine portion of total chlorine available for disnfection.

Fresh water usually contains less than 500 mg/L TDS.

G

gpm (gallons of water per minute) is a unit of measure for flow; note that one gallon = 3.8 liters.

Grain is a mass unit commonly used in water treatment. One grain is about 0.065 grams.

Gray water is home water collected only from showers, sinks, and laundry, and used for home landscape irrigation (see Little 2002).

Groundwater (or ground water) is stored below the earth's surface inside the pores (void space) of geologic materials called aquifers. Groundwater may be fresh or saline.

Gypsum is a common mineral composed of calcium and sulfate ions and water ($CaSO_4.2H_2O$).

H

Hardness is the total amount of calcium and magnesium ions found in water. Hard water affects detergents (by limiting suds formation). Scale formation in pipes is accelerated with hard water. Some scale formation is desirable to protect pipes from corrosion. Excessive scaling clogs pipes and can shorten the life of home appliances. There is no drinking water standard for hardness, and it is usually reported in mg/L of calcite (Table 3, Appendix 3 provides a ranking of water by the USGS).

Hydrogen sulfide is a toxic, rotten egg-smelling gas that occurs naturally in aquifers and sediments.

I

IBWA (International Bottled Water Association)

Inorganic contaminants are chemicals taht do not contain carbon in their composition with the exception of carbonate, bicarbonate and carbon dioxide.

Ions are chemicals (atoms or molecules) with positive (+) [called cations] or negative (-) [called anions] charges. Common ions found in fresh water include: sodium (Na^{+}), calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^{+}), chloride (Cl^{-}), sulfate ($SO_4^{=}$), nitrates (NO_3^{-}), carbonates ($CO_3^{=}$), bicarbonates (HCO_3^{-}) .

L

Low-temperature pasteurization (see pasteurization).

M

MCL is the maximum contaminant level or maximum concentration of a contaminant allowed in drinking water.

mg/L (milligrams per liter) is a unit of measure for concentration; also equals ppm (parts of a chemical per million parts of water). Note that the units of most chemicals in the NDWS listed in the Appendix tables are in mg/L.

Microorganisms are organic carbon based organisms that are not visible with the naked eye, these include bacteria and viruses.

Mineral water is water with more than 250 mg/L TDS.

Minerals are natural crystalline materials found in rocks (such as granite, marble, and sandstone) and soils (as sand silt and clays).

Minerals are composed of chemical elements like oxygen, silicon, aluminum, iron, and many other elements including those listed in under ions.

N

NOM is natural organic matter (mostly from plant and animal tissue decay) present most often in surface water sources and contaminated groundwater. Colored water usually has high concentrations of NOM.

Non-renewable fresh water sources are used at a rate that exceeds recharge. Groundwater is a non-renewable source of fresh water.

NPDWS (National Primary Drinking Water Standards). are used to establish the potability of public drinking water supplies by the U.S. Environmental Protection Agency. See Section 3.2

NSDWS (National Secondary Drinking Water Standards). See Section 3.1

NSF (The National Sanitation Foundation) is a nonprofit organization that acts an independent testing facility for drinking water treatment devices. See Appendix 2

O

Organic chemicals or contaminants refer to carbon-based compounds, including pesticides and oil-derived products (fuels, plastics, and solvents). This should not be confused with the popular use of "organic" food, meaning "food grown without pesticides."

Overdraft means groundwater pumping in excess of recharge.

Oxidizing filters can reduce both ferric (yellow cloudy) and ferrous (green clear) iron, manganese, and hydrogen sulfide gas from well waters. Note that oxidizing filters require periodic back-washing to flush particulates and restore flow and regeneration with potassium permanganate to restore oxidizing properties.

Ozonation is the use of ozone gas to disinfect water.

P

Particle filtration removes particulates from water, including soil minerals (such as sand, silt, and clay), asbestos, sediments, plant matter, and parasitic pathogens.

Pasteurization is the use of heat to disinfect liquids such as milk or water. Flash pasteurization uses a high temperature for a short time

(160° F, 15 seconds). Low-temperature pasteurization uses a lower temperature for a longer time (140° F, 10 minutes).

Pathogens (technical term) or germs (popular term) are microorganisms that produce diseases. Common pathogens regulated in drinking water include bacteria (such as *Salmonella*) and protozoan parasites (such as *Giardia* and *Cryptosporidium*). Other pathogens (such as enteric [intestinal] viruses) are controlled in drinking water and associated with turbidity (see Table 2, Appendix 3). Note that water sources are commonly tested for the possible presence of pathogens by measuring total coliform bacteria.

Perchlorate is found in rocket fuel and explosives, and it has been found in both the groundwater and surface water of several states (see also "emerging" contaminants).

pH values range from 1–14 units. Water with a pH of 7 is neutral, below 7 is acidic, and above is basic (usually alkaline). Most water sources in AZ have a basic pH (7–8.5) due to their natural alkalinity.

POE (point of entry) is a device that treats all or most of the water entering the home.

Pollutants are unwanted contaminants and pathogens of anthropogenic origin that can be found in water, soil and air. Pollutants are chemicals and organisms that have been associated with adverse environmental and health effects.

Potable water is water considered safe to drink.

POU (point of use) is a device that treats water at a particular tap source.

ppm (parts per million) is a unit of measure for concentration. More specifically it is one gram (g) of a chemical in a million grams of water; similar to 1 gr/metric ton of water or 1 mg/L of water.

Precipitation of a mineral is the opposite of dissolution. That is, the mineral crystallizes and forms a solid again.

Public water systems include municipal water companies, homeowner associations, schools, and other provides of water for use by at least 15 persons or 15 connections.

Pure implies that water contains no measurable or detectable (see detection) contaminants (minerals or pollutants) of any kind.

Purified water is a vague and misused term subject to misinterpretation. Webster's definition: "made pure." However, it usually implies that level of contaminants (salts, metals, etc.)

have been reduced, but not completely eliminated. The NSF website defines it as "A type of water which has been produced by distillation, deionization, reverse osmosis, or other suitable processes. Purified water may also be referred to as 'demineralized water.' It meets the definition of 'purified water' in the United States Pharmacopoeia."

R

Radon is a radioactive gas that may be present in groundwater sources that come into contact with uranium-rich minerals (see Table 2, Appendix 3).

Recharge of aquifers often occurs from seepage of water from the earth's surface soil and from surface water sources such as lakes, rivers, streams, and reservoirs.

Reclaimed water comes from sewage that is processed using physical, biological, and chemical treatments at a sewage treatment plant, which allows for a beneficial reuse. See Bulletin # AZ1568.

Renewable water resources are constantly being replenished by natural water cycles.

Reservoirs of fresh water are formed behind river dams. They provide a steady supply of water by controlling river flows and storing water during dry periods.

Residual disinfection (see disinfection).

Resin substances are synthetic chemicals in the form of small beads (sand size) that are capable or holding and exchanging large amounts of ions on their surfaces. Natural materials with ion exchange properties include clay and zeolite minerals.

Reverse osmosis (RO) is a method of reducing the levels of salts or other impurities from water by forcing water through a semipermeable membrane. See also Section 4.4.

Risk assessment is a scientific process that estimates the chances of getting a disease (for example, diarrhea or cancer) from drinking water with a contaminant at a given concentration. The estimated risks from drinking water usually assume that the average adult drinks about 2 liters (about .5 gallons) of water a day over a 70-year lifespan.

S

Salinity is a measure of the quantity of dissolved salts (minerals) in water. See also TDS.

Saline water exceeds 1,000 mg/L TDS or salts. This means that it contains 0.1% total salts or about 2/3 teaspoons (tsp.) per gallon. Moderate and highly saline waters (seawater) contain from 3,000 to 35,000 mg/L of salts (0.3 to 3.5% total salts). Moderately saline water is often referred to as brackish or briny.

Scale (hard residues) coats the inside of water pipes and appliances and is the result of the precipitation of minerals composed of calcium and magnesium carbonates. Hot water helps form scale.

SDWA – (Safe Drinking Water Act) is the federal legislation passed in 1974 that regulates the treatment of water for human consumption and contact and requires testing for an elimination or reduction of contaminants that might be present in the water. See also Section 1.

Seawater, on average, contains 35 grams per liter (1.13 ounces Troy of salts per gallon) of TDS. About 85% (30 grams) of the total salts in seawater are sodium chloride (table salt).

Sedimentation or clarification is a particle filtration process that requires special chemicals (called flocculants and coagulants) and water holding tanks. This filtration process is complex and expensive, and it is used to treat large volumes of surface water high in sediments and soil particles like silt and clay.

Seepage means percolation through the voids of soil and sediment materials.

Shock-chlorination is the circulation of a strong chlorine-based (bleach) solution through the well casing and house plumbing (see Hassinger et al. 1994; see also disinfection).

Soft water contains mostly sodium or potassium ions. Hard water can be "softened" by replacing calcium and magnesium for sodium or potassium ions using a water softener system. Water naturally low in TDS is also called soft water.

Solubility describes the amount of a chemical or mineral that can be dissolved in water (see also dissolution).

Sparkling water is naturally carbonated water.

Sublimation is the evaporation of water directly from ice.

Subsidence is the sinking or downward settling of the land surface that can be associated with groundwater pumping. It causes damage to roads, buildings, utility infrastructure, and other underground infrastructure.

Surface water sources include both fresh (rivers, lakes, and streams) and saline (some lakes, seas, and oceans) sources.

Suspended minerals (such as silt and clay particles) and plant residues make water cloudy. These particles are not dissolved and can be filtered out of water using a particle filter or sedimentation.

T

Table salt is a mineral composed of sodium and chloride ions.

TCE (trichloroethylene) is the abbreviation is a volatile industrial solvent notorious for industrial groundwater contamination.

TDS (total dissolved solids) is a quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter (mg/L) or parts per million (ppm). For example, a TDS of 500 mg/L (or 500 ppm) is equal to 0.5 gr/L or about 1/3 tsp per gallon of water.

Turbidity is a measure of the amount of suspended solids (particles) in the water.

U

USEPA (U.S. Environmental Protection Agency) is the federal agency responsible for writing and enforcing the environmental regulations for the United States. See also Appendix 2.

USGS (U.S. Geological Survey) is the federal agency, which collects, monitors, analyzes, and provides scientific understanding about natural resources conditions, issues, and problems of the U.S. and the world at large. See also Appendix 2.

V

Variances allow the use of an alternative water treatment technology to meet a water standard. EPA approved.

VOCs are volatile organic chemicals such as chloroform, TEC and benzene.

Volatile is a characteristic of organic chemicals that have boiling points lower than water. These include gasoline products, industrial solvents, and water disinfection by-products. Volatile organic chemicals are commonly abbreviated as VOCs.

W

WHO (World Health Organization) is the directing and coordinating authority for health within the United Nations system. See also Appendix 2.

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Appendix 2 Website Links

Various Agencies

ADEQ: Arizona Department of Environmental Quality. www.azdeq.gov/environ/water/index.html

ADHS: Arizona Department of Health Services. www.azdhs.gov

ADHS Lab Services: Arizona Department of Health Services, Bureau of State Laboratory Services. www.azdhs.gov/lab/index.htm

ADWR: Arizona Department of Water Resources. www.azwater.gov/dwr/gov

ADWR Well Owner's Guide: www.azwater.gov/dwr/Content/Publications/files/well_owners-guide.pdf

CAP: Central Arizona Project. www.cap-az.com/

e-CFR: Electronic Code of Federal Regulations. ecfr.gpoaccess.gov

European Communities: 1998 Council Directive 98/83/EC on the Quality of Water Intended for Human Consumption. www.emwis.org/IFP/Eur-lex/l_33019981205en00320054.pdf

FDA: U.S. Food and Drug Administration. www.fda.gov/

SRP: Salt River Project. www.srpnet.com/about/history/default.aspx

USGS: US Geologic Survey, Arizona water science center. www.az.water.usgs.gov/

Universities

Clemson University, Water Quality Problems, Causes and Treatments. www.cdc.gov/nasd/docs/d001201-d001300/d001240/d001240.html

CLIMAS: Climate Assessment for the Southwest. www.climas.arizona.edu/

North Carolina Cooperative Extension, Home Drinking Water Systems. extoxnet.orst.edu/faqs/safedrink/treat.htm

Purdue Extension, Homes and Water Quality. www.ces.purdue.edu/waterquality/publications02.htm

Texas A&M Cooperative Extension, Home Water Treatment Systems fcs.tamu.edu/housing/water/home/l-2280.htm

University of Arizona: Cooperative Extension Water Quality Education Program. http://extension.arizona.edu/water-portal/safe-drinking-water-education-program

University of Arizona: Water Resources Research Center (WRRC) wrrc.arizona.edu

University of Arizona Water and Environmental Technology Center wet.arizona.edu

University of Arizona Water Sustainability Program. wsp.arizona.edu

Water Quality Reports

City of Chandler Water Services: www.chandleraz.gov/default.aspx?pageID=44

City of Flagstaff: www.flagstaff.az.gov/index.asp?SID=322

City of Glendale: www.ci.glendale.az.us/Utilities/CCR.cfm

City of Mesa: www.ci.mesa.az.us/utilities/water/water_quality_report/mesa_water_sources03.asp

City of Phoenix Water Services: www.ci.phoenix.az.us/PCD/wmonov.html

City of Scottsdale: www.scottsdaleaz.gov/water/Quality/default.asp

City of Tempe: www.tempe.gov/water/ccr.htm

City of Tucson: www.ci.tucson.az.us/water/water_quality/annual_wq_reports/annual_wq_reports.htm

Metro Water District: www.metrowater.com/quality.htm

City of Yuma: www.ci.yuma.az.us/2002_water_chart.pdf

USEPA Water

EPA: USEPA Groundwater and Drinking Water Website. www.epa.gov/safewater

EPA1: Setting Drinking Water Standards. www.epa.gov/safewater/standard/setting.html

EPA2: Complete Table of PDWS. www.epa.gov/safewater/mcl.html#mcls

EPA3: Safe Drinking Water Enforcement. www.epa.gov/compliance/civil/programs/sdwa/

EPA4: Private Wells. www.epa.gov/safewater/privatewells

EPA5: State Certification Offices for Drinking Water Laboratories (see Arizona addresses). www.epa.gov/safewater/privatewells/labs.html

EPA6: Surf Your Watershed. cfpub.epa.gov/surf/state.cfm?statepostal=AZ

EPA7: List of Household Chemicals and Their Safe Use to Disinfect Water. www.epa.gov/OGWDW/faq/emerg.html

USEPA: U.S. Environmental Protection Agency Main Website. www.epa.gov

USEPA: Frequently Asked Questions. www.epa.gov/safewater/faq/faq.html

Private and Non-profit Organizations

AWWA: American Water Works Association. www.awwa.org/

Home Water Purifiers and Filters: Very good website of a company that sells water purification systems. The website has detailed information on contaminants, water quality, and treatment options, and the information appears to be fairly objective: www.home-water-purifiers-and-filters.com/

Is your Tap Water Safe? 2012. http://www.goodhousekeeping.com/health/womens-health/water-safety

IWQA: International Bottled Water Association. A trade association representing the bottled water industry: www.bottledwater.org/

NDWAC: National Drinking Water Advisory Council. Advisory group with members of the general public, state and local agencies, and private groups concerned with safe drinking water that advises the EPA Administrator on everything that the Agency does relating to drinking water, see website: www.epa.gov/safewater/ndwac/council.html

NESC: National Environmental Services Center, National Drinking Water Clearinghouse: History of Treating Drinking Water. www.nesc.wvu.edu/ndwc/ndwc_dwhistory.htm

NRDC: National Resources Defense Council: Bottled Water www.nrdc.org/water/drinking/qbw.asp

NRDC: Natural Resources Defense Council: U.S. Cities Water Quality Reports. www.nrdc.org/water/drinking/uscities/contents.asp

NSF: The National Sanitation Foundation, a "not-for-profit, non-governmental organization" that tests and certifies consumer products (including water treatment devices) and lists common water treatment methods (standards). www.nsf.org

Water Casa: Residential Greywater Reuse Fact Sheet. www.watercasa.org/research/residential/fact.htm

WHO: World Health Organization: Drinking Water Quality. www.who.int/water_sanitation_health/dwq/en/

WQA: Water Quality Association. A "not-for-profit international trade association representing the household, commercial, industrial, and small community water treatment industry." www.wqa.org

WRA: Western Resources Advocates. Arizona Water Meter Report, 2008. www.westernresourceadvocates.org/azmeter/

Useful Links for Well Owners

Arizona Department of Water Resources Well Owners Guide
www.azwater.gov/dwr/Content/Publications/files/well_owners_guide.pdf

Arizona Department of Water Resources, Arizona Water Atlas.
www.azwater.gov/azdwr/statewideplanning/wateratlas/default.htm

University of Arizona Well Owner's Guide to Water Supply, 2009.
wrrc.arizona.edu/publications/well-owners-guide

EPA Private Drinking Water Wells
www.epa.gov/safewater/privatewells/publications.html

Santa Clara, California 18-page Well Owners Guide
www.valleywater.org/media/pdf/Guide%20for%20Well%20Owners.pdf

Wilkes Bar University Well Owners web site
www.water-research.net/privatewellowner/privatewellowner.htm

Appendix 3 Water Quality Standards Tables

Table 1. NSDWS table from EPA

Contaminant	Secondary MCL	Noticeable Effects above the Secondary MCL	Secondary MCL
Aluminum	0.05 to 0.2 mg/L*	colored water	
Chloride	250 mg/L	salty taste	
Color	15 color units	visible tint	
Copper	1.0 mg/L	metallic taste; blue-green staining	1.3 mg/L
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining	
Fluoride	2.0 mg/L	tooth discoloration	4.0 mg/L
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odor	
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining	
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste	
Odor	3 TON (threshold odor number)	"rotten-egg", musty or chemical smell	
pH	6.5 - 8.5	low pH: bitter metallic taste; corrosion high pH: slippery feel; soda taste; deposits	
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye	
Sulfate	250 mg/L	salty taste	
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste	
Zinc	0.5 mg/L	metallic taste	

* mg/L is milligrams of substance per liter of water.

Modified from: http://water.epa.gov/drink/contaminants/secondarystandards.cfm

Table 2. Hardness Table from USGS

USGS Water Hardness Classification: calcium and magnesium contents in water reported as calcium carbonate.

Ranking	milligram per liter (mg/L)	grains per gallon
Soft	0-60	0-3.5
Moderately Hard	61-120	3.6-7.0
Hard	121-180	7.1-10.5
Very Hard	>180	>10.5

Table 3. NPDWS table from EPA

EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Acrylamide	TT[8]	Nervous system or blood problems;	Added to water during sewage/wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG=4[1]

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

1

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
D	Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[7]; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	Cryptosporidium	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

2

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT[8]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	Giardia lamblia	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadien e	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[7]; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	Legionella	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

3

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and *E. coli*)	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

4

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

NOTES

1 Definitions

- Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- Maximum Contaminant Level (MCL)—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium* (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- *Giardia lamblia*: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing <10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

4 No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E. coli* fecal coliforms, system has an acute MCL violation.

5 Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

8 Each water system must certify, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

5

For an up-to-date list go to: http://water.epa.gov/drink/contaminants/upload/mcl-2.pdf

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