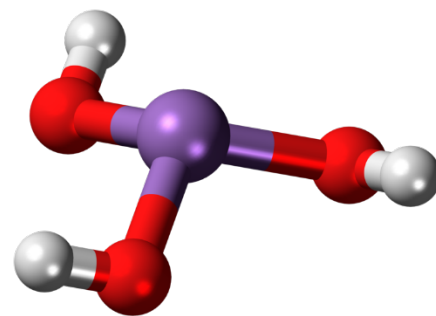


Groundwater Fact Sheet

Arsenic (As)



Constituent of Concern

Arsenic

Synonym

"Arsenic Black", "Colloidal arsenic", "Gray arsenic"
(additional aliases exist for the compound forms of arsenic)

Chemical Formula

As

CAS Number

7440-38-2

Storet Number

01002

Summary

Arsenic is a trace element with an established State Maximum Contaminant Level (MCL) in drinking water of 10 µg/L. It is a human carcinogen according to the Environmental Protection Agency (EPA). Volcanic activities, the erosion of rocks and minerals, and forest fires are the most common natural sources. Groundwater can also be contaminated with arsenic from a variety of anthropogenic sources such as pesticides, wood preservatives, glass manufacture, and other miscellaneous uses of arsenic. Main forms of arsenic in natural waters are arsenite (As^{3+}) and arsenate (As^{5+}), which are, respectively, more prevalent in groundwater (reductive conditions) and surface waters (oxidizing conditions).

Based on State Water Resources Control Board (SWRCB) data from 2007 to 2017, 931 active and standby public supply water wells (of 9,381 sampled, 5,314 detections) had at least one detection of arsenic above the MCL. Most detections above the MCL occurred in Kern (155), Los Angeles (68) and San Bernardino (44) counties. The maximum measured concentration was 650 µg/L, in a Sonoma County well.

REGULATORY WATER QUALITY LEVELS ¹		
ARSENIC (As)		
Type	Agency	Concentration
Federal MCL	EPA ²	10 µg/L
State MCL	SWRCB ³	10 µg/L
Detection Limit for Purposes of Reporting (DLR)	SWRCB ³	2 µg/L
Public Health Goal (PHG)	OEHHA ⁴	0.004 µg/L
Cancer Potency Factor (1/10 ⁶ cancer risk)	Cal/EPA ⁵	0.0023 µg/L
IRIS ⁶ Reference Dose (RfD), non-cancer health	EPA ²	2.1 µg/L

¹These levels are generally related to drinking water. Other water quality levels may exist. For further information, see "A Compilation of Water Quality Goals", 17th Edition (SWRCB 2016).

²EPA – United States Environmental Protection Agency

³SWRCB - State Water Resources Control Board.

⁴OEHHA – Office of Environmental Health Hazard Assessment

⁵Cal/EPA – California Environmental Protection Agency

⁶IRIS – Integrated Risk Information System. Concentration reported as a drinking water level.

ARSENIC DETECTIONS IN PUBLIC WATER WELL SOURCES⁷	
Number of active and standby public water wells with arsenic concentrations > 10 µg/L ⁸	931 of 9,381 wells tested with 5,314 detections
Top 3 counties with arsenic detection in public wells above the MCL	Kern (155), Los Angeles (68), San Bernardino (44).

⁷Based on 2007-2017 public standby and active well (groundwater sources) data collected by the SWRCB.

⁸Water from active and standby wells is typically treated to prevent exposure to chemical concentrations above MCL. Data from private domestic wells and wells with less than 15 service connections are not available.

ANALYTICAL INFORMATION				
Approved EPA methods	200.7	200.8	200.9	1632
Detection Limit (µg/L)	53 (estimated)	0.1	0.5	0.003
Notes	Determination of metals and trace elements in water by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES)	Determination of trace elements in waters and wastes by Inductively Coupled Plasma - Mass Spectrometry (ICP/MS)	Determination of trace elements by stabilized temperature Graphite Furnace Atomic Absorption (GFAA)	Chemical Speciation of Arsenic in Water by Hydride Generation Quartz Furnace Atomic Absorption Spectrometry (FAAS)
Known Limitations to Analytical Methods	Few laboratories are equipped to conduct ICP/MS analysis necessary for low detection limit quantification and speciation. Sample handling and preservation methods differ for different analytical methods. No single method is appropriate for all sample matrices, but preservation is very important due to speciation concerns. Sulfide interference may occur in field-testing methods (colorimetric). Sample filtration may be done but is not required.			
Public Drinking Water Testing Requirements	Arsenic is a regulated chemical for drinking water sources, with monitoring and compliance requirements (Title 22, Section 64431, et seq.).			

Arsenic Occurrence

Anthropogenic Sources

Arsenic is widely distributed throughout the earth's crust, most often as arsenic sulfide or as metal arsenates and arsenides. Usually, arsenic is obtained as a by-product of smelting of ores of copper, lead, cobalt, and gold. Mining of these ores and the management of waste materials associated with mining operations is a significant source of arsenic release in the environment.

Commercial and industrial uses include alloying agents in the manufacturing of transistors, lasers, semiconductors, and solar cells. Other sources can include processing of glass, ceramics, paints, pigments, dyes and soaps, textiles, paper, metal adhesives, wood preservatives, pyrotechnics, and ammunition. Agricultural sources include pesticides, insecticides, cattle and sheep dips, algaecides, and hide tanning. Medicinal sources include antisyphilitic drugs.

Natural Sources

The primary source of arsenic in the environment is from the weathering of arsenic-containing rocks. Naturally occurring arsenic is found in a variety of solid phases, including a component of volcanic glass in volcanic rocks, adsorbed to and co-precipitated with metal oxides (especially iron oxides), adsorbed to clay-mineral surfaces, and associated with sulfide minerals and organic carbon. The concentrations of arsenic in soil (0.1 to 40 ppm) and sedimentary rocks (13 ppm) are generally higher than the average (2 ppm) in the earth's crust due to movement and accumulation of the arsenic through weathering. Additionally, volcanic activity and forest fires can release arsenic into the atmosphere where it later falls to earth; however, precipitation in unpolluted areas usually contains less than 1 ppb of arsenic.

History of Occurrence

Arsenic is found in groundwater predominantly due to natural sources. It may also be present in localized environments in high concentrations as a result of specific releases, such as from mine tailings and chemical spills.

Contaminant Transport Characteristics

In water, the most common valence states of arsenic are As^{5+} , or arsenate, which is more prevalent in well-oxygenated (aerobic) surface waters, and As^{3+} , or arsenite, which is more likely to occur in anaerobic groundwater or deep lake sediments (reducing environments). The solubility, mobility, and toxicity of arsenic in the environment are dependent upon its oxidation state and increase with increasing alkalinity and salinity. Arsenic mobility in groundwater is dependent on the physical and chemical properties of the aquifer, although two types of processes generally control its movement: adsorption/desorption reactions and precipitation/dissolution reactions. During adsorption reactions, dissolved arsenic adheres to the surface of solid aquifer materials. Desorption removes the arsenic from aquifer materials and releases it into the surrounding groundwater. The mobility of arsenate is low in acidic soils with high content of oxides and clays. Arsenite is more mobile, toxic, and difficult to remove from groundwater than arsenate.

Remediation and Treatment Technologies

In-situ Treatment

Arsenic remediation is typically expensive because large volumes of groundwater must be treated. The main types of treatment processes used are:

Precipitative processes

using ferric and aluminum salts, including coagulation/filtration, direct filtration, coagulation-assisted microfiltration, enhanced coagulation, lime softening, and enhanced lime softening.

Adsorption processes

specifically activated alumina.

Ion exchange processes

specifically, anion exchange.

Membrane filtration

including reverse osmosis and electrodialysis reversal.

Permeable reactive barriers (PRB)

Two promising arsenic removal processes are granular ferric hydroxide (GFH) and zero-valent iron (ZVI) fillings. These methods involve chemical adsorption of arsenic species to iron oxides. GFH and ZVI filters are easy to operate and have been found suitable for individual wellhead or other small-scale treatment systems.

Health Effect Information

Arsenic is a known human carcinogen, and ingestion of arsenic has been reported to increase the risk of cancer in the liver, bladder, kidney, lungs, and skin. Arsenic is known to the State of California to cause cancer for purposes of the Safe Drinking Water and Toxic Enforcement Act of 1986 ("Proposition 65") and was added to the list of carcinogens in 1987. In November 2008, the California MCL for arsenic was revised from 50 µg/L to 10 µg/L. The National Academy of Sciences estimated that the lifetime risk of developing bladder or lung cancer from arsenic in tap water (assuming 2 liters consumption per day) is greater than 3 in 1,000 for an arsenic level of 10 µg/L. The EPA MCL of 10 µg/L has been in effect in California since January 2006.

When groundwater is the transport and exposure medium, we are primarily concerned with ingestion of contaminated water as the route for greatest human exposure to arsenic. In humans, arsenic is quickly absorbed after ingestion, while dermal (skin) exposure to arsenic only results in a small amount of arsenic entering the body. Upon absorption from the gastrointestinal tract, the liver changes some of the arsenic to a less harmful organic form. Both inorganic and organic forms are excreted from the body in urine. Most of the arsenic will be excreted within several days, although some will remain in the body for several months or longer.

Inorganic arsenic has been recognized as a human poison since ancient times, with large oral doses (above 60,000 µg/L in food or water) producing death. Ingestion of moderate to elevated levels of inorganic arsenic (greater than 300 µg/L) may cause irritation of the stomach and intestines, with symptoms such as pain, nausea, vomiting, and diarrhea. Other effects from the ingestion of arsenic include decreased production of red and white blood cells, abnormal heart rhythm, blood-vessel damage, and impaired nerve function causing a "pins and needles" sensation in the hands and feet. Although there is no strong evidence that arsenic can affect pregnant women or their fetuses, studies in animals show that doses of arsenic that are large enough to cause illness in pregnant females may cause low birth weight, fetal malformations, or even fetal death. Long-term oral exposure to inorganic arsenic may cause patterns of skin changes, including a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. A small number of the corns may ultimately transform into skin cancer.

Key Resources

1. Ahuja S., 2008. Arsenic Contamination of Groundwater: Mechanism, Analysis, and Remediation. Germany: Wiley, 2008.
2. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Arsenic. (August 2007). <http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=22&tid=3>.
3. California State Water Resources Control Board. Division of Drinking Water. California Regulations Related to Drinking Water. (June 2016).
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Recentregs.html
4. California State Water Resources Control Board - A Compilation of Water Quality Goals. 17th Edition, (SWRCB, 2016).
http://www.waterboards.ca.gov/water_issues/programs/water_quality_goals/docs/wq_goals_text.pdf
5. National Environmental Methods Index (NEMI). Trace elements.
https://www.nemi.gov/methods/keyword/?keyword_search_field=trace+elements
6. National Research Council (US) Subcommittee on Arsenic in Drinking Water. Arsenic in Drinking Water. Washington (DC): National Academies Press (US); 1999.
<https://www.ncbi.nlm.nih.gov/books/NBK230885/>
7. State Water Resources Control Board. GAMA GIS online tools.
http://www.waterboards.ca.gov/water_issues/programs/gama/geotracker_gama.shtml
8. US Environmental Protection Agency. Technical Fact Sheet: Final Rule for Arsenic in Drinking Water. (January 2001). <https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=20001XXE.txt>
9. US Environmental Protection Agency. Contaminated Site Clean-up Information, Arsenic. Treatment Technologies. https://clu-in.org/contaminantfocus/default.focus/sec/arsenic/cat/Treatment_Technologies/
10. US Environmental Protection Agency. Implementation Guidance for the Arsenic Rule. EPA-816-K-02-018. <https://www.epa.gov/dwreginfo/state-implementation-guidance-arsenic-rule>
11. US Geological Survey. National Water-Quality Assessment Program. Trace Elements National Synthesis Project. Arsenic in groundwater of the United States.
<http://water.usgs.gov/nawqa/trace/arsenic/>

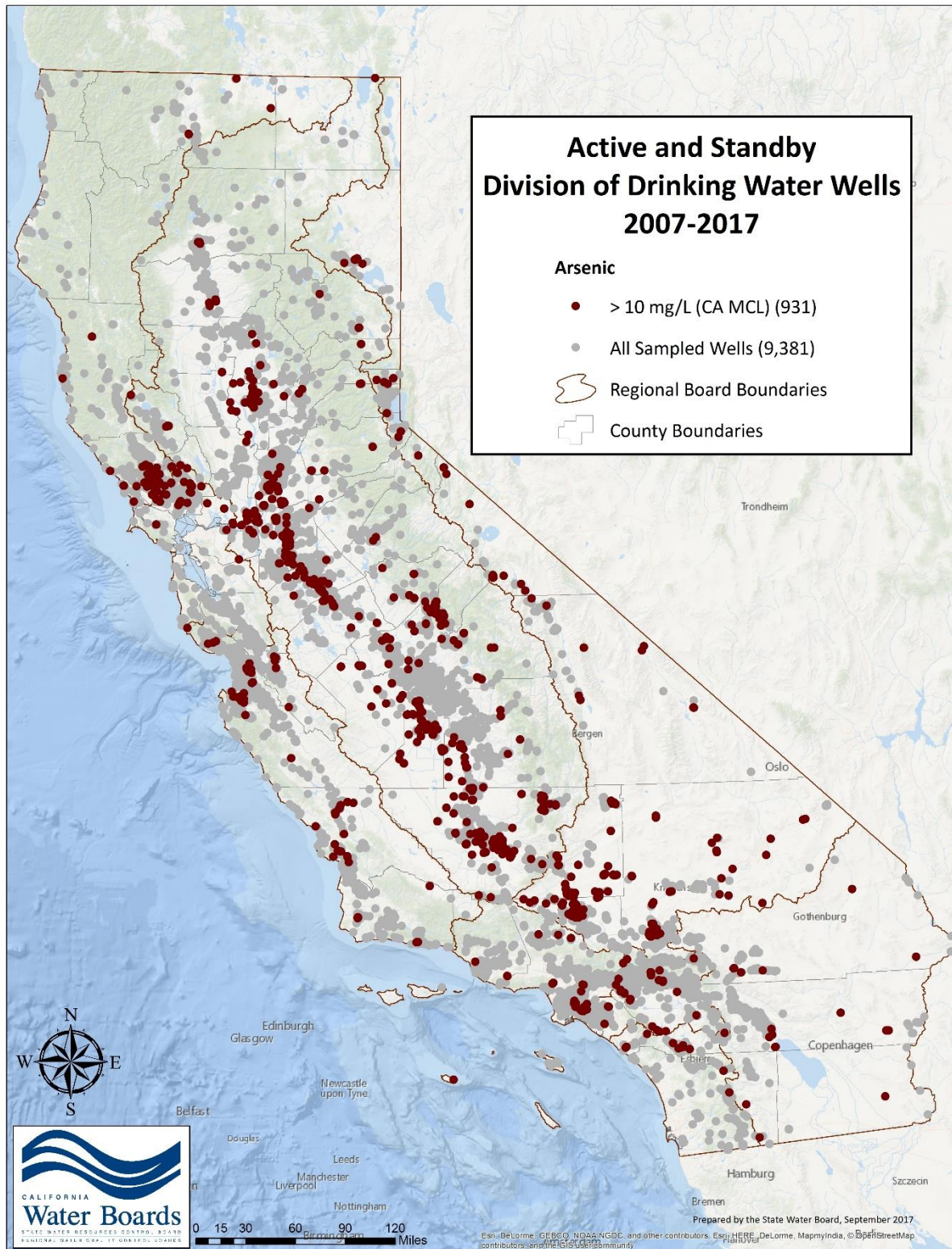


Figure 1. Active and standby public drinking water wells that had at least one detection of arsenic above the MCL, 2007-2017, 931 wells. (Source: Public supply well data in GAMA GIS).