

GROUNDWATER INFORMATION SHEET

Arsenic

The purpose of this groundwater information sheet is to provide general information regarding a specific constituent of concern (COC). The following information, compiled by staff of the Groundwater Ambient Monitoring and Assessment (GAMA) Program, is pulled from a variety of sources and data relates mainly to drinking water. For additional information, the reader is encouraged to consult the references cited at the end of the information sheet.

GENERAL INFORMATION	
Constituent of Concern	Arsenic (As)
Aliases	“Arsenic Black”, “Colloidal Arsenic”, “Grey Arsenic” (numerous additional aliases exist for the compound forms of arsenic)
Chemical Formula	As Arsenic exists in oxidation states of -3, 0, 3 (arsenite), and 5 (arsenate)
CAS No.	7440-38-2
Storet No.	01002
Summary	Arsenic is widely distributed throughout the earth's crust, most often as arsenic sulfide or as metal arsenates and arsenides. The California Department of Public Health (CDPH) regulates arsenic as a drinking water contaminant. In January 2006, the US Environmental Protection Agency (EPA) revised its MCL from 50 µg/L to 10 µg/L. California revised its arsenic MCL to 10 µg/L in November of 2008. As of June 2010, 1375 drinking water wells (of 10,425 sampled) have had concentrations of arsenic above the MCL. Most arsenic detections above the MCL in have occurred in Kern, San Joaquin and San Bernardino Counties.

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REGULATORY AND WATER QUALITY LEVELS¹		
Type	Agency	Concentration
Federal MCL	US EPA, Region 9	10 µg/L
State MCL (effective November, 2008)	CDPH	10 µg/L (EPA MCL of 10 µg/L enforceable in California since 2006)
Detection Limit for Purposes of Reporting (DLR)	CDPH	2 µg/L
Others: CA Public Health Goal Cancer Potency Factor (1/10 ⁶ cancer risk) IRIS Reference Dose (non-cancer health effect)	CDPH OEHHA US EPA, Region 9	0.004 µg/L 0.023 µg/L 2.1 µg/L

¹These levels generally relate to drinking water, other water quality levels may exist. For further information, see *A Compilation of Water Quality Goals* (Marshack, 2008).

Important Regulatory Dates for Arsenic in California:

- *July 1, 2002* – Public water supply systems that detect between 5 and 10 µg/L arsenic must include an educational statement in their yearly Consumer Confidence Reports (CCRs). Systems that detect between 10 and 50 µg/L of arsenic must include specific health effects information in their annual CCRs.
- *January 23, 2006* – The USEPA MCL of 10 µg/L became enforceable.
- *December 31, 2007* – All groundwater drinking water sources were to have completed initial monitoring.

SUMMARY OF DETECTIONS IN PUBLIC WATER WELLS^{2,3}	
Detection Type	Number of Groundwater Sources
Number of active and standby public drinking water wells with arsenic concentrations > 10µg/L.	1,375 of approximately 10,425 sampled
Top 3 Counties with active and standby public drinking water wells with arsenic concentrations > 10 µg/L.	Kern, San Joaquin and San Bernardino

²Based on CDPH database query dated June 2010 using GeoTracker GAMA.

³In general, drinking water from active and standby wells is treated or blended so consumers are not exposed to water exceeding MCLs. Individual domestic wells and wells for small water systems not regulated by CDPH are not included in these figures.

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ANALYTICAL INFORMATION	
Analytical Test Method	US EPA Methods: 200.7 (ICP), 200.8 (ICP/MS), and 200.9 (AA - Platform) ASTM Methods: D-2972-93C (AA – Furnace) and D-2972-93B (Hydride AA) APHA Standard Methods: 3120B (ICP), 3113B (AA – Furnace), 3114B (Hydride AA)
Detection Limit	Most methods can attain the 2 µg/L DLR. Gaseous/Hydride Atomic Absorption Spectrometry (EPA method 1632), is able to achieve sub-µg/L detection limits and speciate the arsenic components present in samples.
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.).

OCCURRENCE	
Anthropogenic Sources	Almost all of the arsenic used 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 released to the environment. Commercial and industrial uses include alloying agents in the manufacture 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

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	<p>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.</p>
<p>History of Occurrence</p>	<p>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.</p>
<p>Contaminant Transport Characteristics</p>	<p>In water, the most common valence states of arsenic are As(V), or arsenate, which is more prevalent in well-oxygenated (aerobic) surface waters, and As(III), or arsenite, which is more likely to occur in anaerobic groundwater or deep lake sediments (reducing environments). The solubility, mobility, and toxicity of As in the environment are dependent upon its oxidation state, and increases 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.</p>

REMEDATION & TREATMENT TECHNOLOGIES

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; and,
- Membrane filtration, including reverse osmosis, and electro dialysis reversal.

Two promising arsenic removal processes are granular ferric hydroxide (GFH) and zerovalent 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 well head 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, lung 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 US 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.

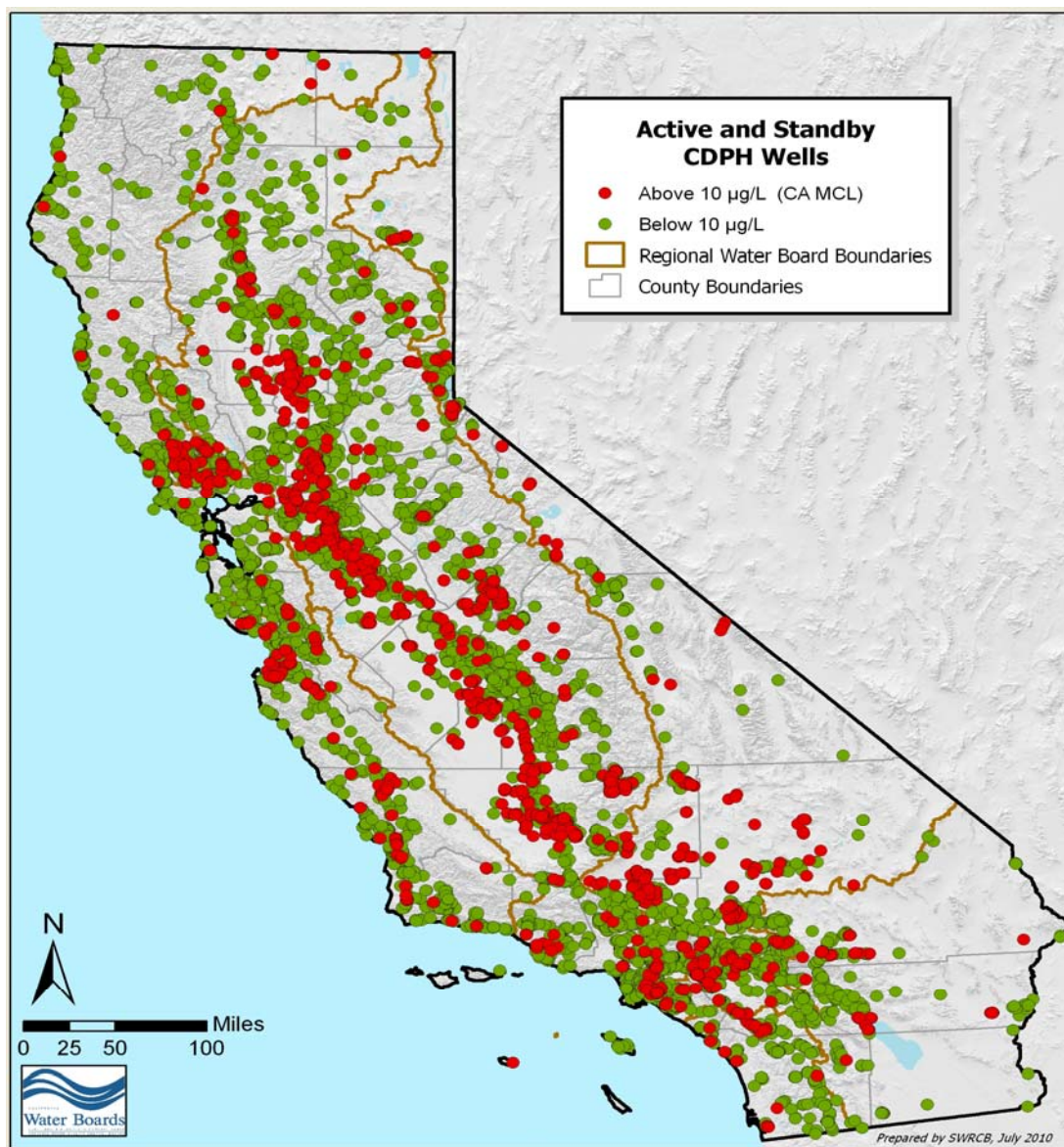
Inorganic arsenic has been recognized as a human poison since ancient times, with large oral doses (above 60,000 µg/L in food or water) producing death. Ingestion of moderate to elevated levels of inorganic arsenic (greater than 300 µg/L) may cause irritation of the stomach and intestines, with symptoms 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 develop into skin cancer.

KEY REFERENCES

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13. World Health Organization. Fact Sheets. *Arsenic in Drinking Water*.
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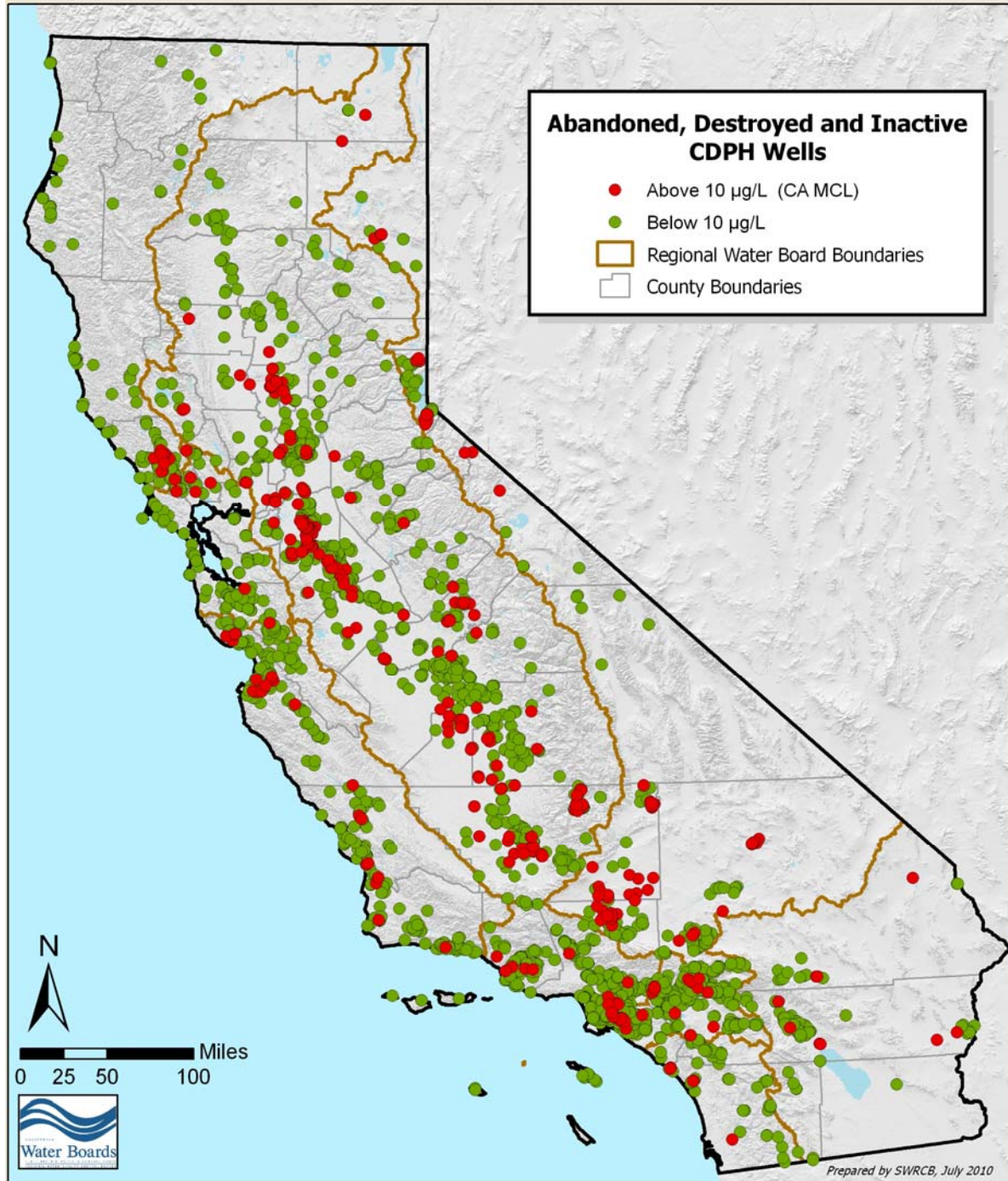
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Active and Standby CDPH Regulated Public Drinking Water Wells with at Least One Detection of Arsenic above the MCL (1,375).

Source: June 2010 well query of CDPH data using GeoTracker GAMA

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Abandoned, Destroyed and Inactive CDPH Regulated Public Drinking Water Wells with at Least One Detection of Arsenic above the MCL (399).

Source: June 2010 well query of CDPH data using GeoTracker GAMA