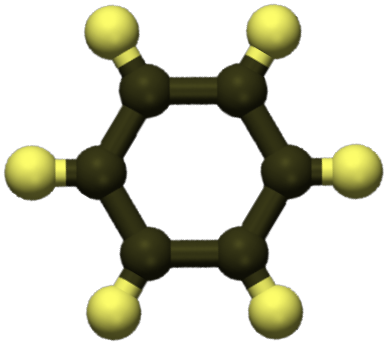
Groundwater Fact Sheet
Benzene



Constituent of Concern
Benzene

Synonym
Annulene, Benzol, Phene, Phenyl hydride, Pyrobenzole, Cyclohexatriene

Chemical Formula
C_6H_6

CAS Number
71-43-2

Storet Number
34030

Summary
Benzene is a regulated chemical with an established California State Maximum Contaminant Level (MCL) in drinking water of 1 µg/L. Benzene is a colorless highly flammable liquid that evaporates quickly into air and dissolves slightly in water. It is widely used and found in crude oils and as a by-product of oil-refining processes. In industry, benzene is used as a solvent, as a chemical intermediate, and is used in the synthesis of numerous chemicals. It also occurs naturally in volcanic gases and smoke resulting from forest fires. Benzene can get into drinking water from industrial discharge, gas storage tank leaching, and landfills. It can evaporate from soil and groundwater into a gas or vapor, which then can enter buildings by traveling through soil or cracks in bedrock or concrete. The Environmental Protection Agency (EPA) classified benzene as a known human carcinogen for all routes of exposure.

Based on State Water Resources Control Board (SWRCB) data from 2007 to 2017, 8 active and standby public water supply wells (of 8,997 tested, 17 detections) had at least one detection of benzene above the MCL.

REGULATORY WATER QUALITY LEVELS[1]

BENZENE

Type	**Agency**	**Concentration**
Federal MCL	EPA[2]	5 µg/L
State MCL	SWRCB[3]	1 µg/L
Detection Limit for Purposes of Reporting (DLR)	SWRCB[3]	0.5 µg/L
Public Health Goal (PHG)	OEHHA[4]	0.15 µg/L
Cancer Potency Factor ($1/10^6$ cancer risk)	OEHHA[4]	0.35 µg/L

[1]These 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).
[2] EPA – United States Environmental Protection Agency
[3]SWRCB - State Water Resources Control Board
[4]OEHHA – Office of Environmental Health Hazard Assessment

BENZENE DETECTIONS IN PUBLIC WATER WELL SOURCES[5]	
Number of active and standby public water wells with benzene concentrations > 1 µg/L [6]	8 of 8,997 wells tested with 17 detections
Top counties with benzene detection in public wells above the MCL	King County (2), and 1 well from each of the following counties: Fresno, Kern, Los Angeles, San Joaquin, Sonoma, and Yuba

[5] Based on 2007-2017 public standby and active well (groundwater sources) data collected by the SWRCB.
[6] Water from public active and standby public groundwater sources 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	502.2	8260/524.2	8020
Detection Limit (µg/L)	0.01	0.04	0.2
Notes	Gas chromatography with photoionization and electrolytic conductivity detectors	Gas chromatography/mass spectrometry - EPA Method 8260 is used at Leaking Underground Fuel Tank (LUFT) sites	Gas chromatography with photo-ionization detector
Known Limitations to Analytical Methods	Sample must be cooled to 4 °C upon collection, analyzed within 14 days and free of air bubbles. EPA Method 8020 can detect benzene but may yield false positives when other volatile organic compounds are present and co-elute in the same chromatographic range. The presence of benzene should be confirmed by EPA Method 524.2 or Method 8260 prior to use of Method 8020 for a long-term monitoring program.		
Public Drinking Water Testing Requirements	Benzene is a regulated chemical for drinking water sources, with monitoring and compliance requirements (Title 22, Section 64431, et seq.).		

Benzene Occurrence

Anthropogenic Sources

Benzene is a naturally occurring chemical found mostly in crude oil and gasoline. Benzene in unleaded gasoline is typically around 1 percent of the total volume. By 2007, the worldwide annual demand for benzene was approximately 40 million tons. Most of it is used to produce styrene and

cumene: chemicals used in the manufacturing of plastics, resins, adhesives, and nylon. It is estimated that approximately 6 million tons of benzene was used annually in the USA in the 1990s.

Benzene can be released into groundwater from leaking underground fuel storage tanks and piping, atmospheric deposition, fuel spills during transportation, and leaks at refineries. Underground storage tanks or piping releases make up most of the releases that have impacted groundwater. Studies have shown that atmospheric deposition of benzene results only in trace concentrations in surface waters. In contrast, point sources of benzene contamination such as underground storage tank sites may result in benzene concentrations in the milligrams per liter (mg/L) range.

Natural Sources

Benzene occurs naturally in the environment as a product of incomplete combustion of carbon-rich materials. Benzene is also present in petroleum oil deposits and in gases associated with volcanic eruptions and forest fires.

History of Occurrence

Benzene replaced lead as a gasoline additive for its anti-knock properties. Concerns about negative health effects related to air quality led to the limitation of benzene content in gasoline to about 1 percent. EPA regulations had further lowered the benzene content to 0.62 percent in 2011. Based on a SWRCB data query in March 2017 using the Groundwater Ambient Monitoring and Assessment Program's Groundwater Information System (GAMA GIS), 20 active and standby public water wells out of approximately 100,000 sampled had benzene detections above the State MCL at least once since 1984. The maximum measured concentration was 180 µg/L.

Contaminant Transport Characteristics

Benzene can volatilize into air from soil and water. Once in the atmosphere, benzene breaks down (biodegrades) within a few days. In soil and groundwater, the biodegradation process is slower. Benzene is slightly soluble in water and can migrate through the soil column into groundwater. Because benzene is a light non-aqueous phase liquid (LNAPL) it can collect on top of the water table. Benzene biodegradation in groundwater can take days to years, depending on oxygen concentration, temperature, and the presence of favorable bacteria.

Remediation and Treatment Technologies

Soil and Groundwater Remediation

Several effective remediation technologies remove benzene and other gasoline compounds from soil and groundwater.

These include:

Soil Vapor Extraction (SVE)

Effective in reducing benzene in the unsaturated zone due to the high vapor pressure.

Air Sparging

Used in conjunction with soil vapor extraction. This can also oxygenate the groundwater and stimulate biodegradation of dissolved contaminants.

In-situ Oxidation

Relies on the capacity of certain chemicals (e.g., hydrogen peroxide combined with iron) to rapidly oxidize organic molecules in water.

Bioremediation
Most effective under aerobic conditions.

Flushing (Pump and Treat)
Extracts contaminated groundwater and treats at the surface using air stripping, activated carbon, or advanced oxidation systems.

Drinking Water and Wastewater Treatment
For drinking water, the most common treatment options are air stripping, activated carbon filters, and advanced oxidation (combinations of ultraviolet light, chemical oxidants, and catalysts). There are other emerging technologies for the remediation and treatment of benzene and gasoline compounds including permeable reactive barriers and thermal treatment.

Health Effect Information
Exposure to benzene can occur through the lungs (inhalation), gastrointestinal tract (ingestion), and through skin (dermal contact). Health effects depend on two main factors: length of exposure and concentration (amount of benzene a person is exposed to).

Brief exposure to very high levels of benzene in air can result in death, while breathing lower levels can cause drowsiness, confusion, dizziness, headaches, tremors, and unconsciousness. The major effect of benzene exposure is to the blood. Long term exposure to benzene can affect the body's ability to produce red blood cells. When the bone marrow is affected, the result is usually a form of leukemia. It can also cause blood (hematologic) diseases, anemia, and cancers of blood-forming organs. The most common long-term health effects associated with benzene exposure are:

- Acute Myelogenous Leukemia (AML) in which cancer cells are present in the blood and bone marrow.
- Acute Lymphocytic Leukemia (ALL) in which cancer affects the cells that make the lymphocytes for the bone marrow.
- Chronic Myelogenous Leukemia (CML) in which leukemia develops from the white blood cells reducing the body's ability to fight disease and infection.

Key Resources

1. 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/index.shtml
2. Office of Environmental Health Hazard Assessment-California Environmental Protection Agency Public Health Goal for BENZENE In Drinking Water https://oehha.ca.gov/media/downloads/water/chemicals/phg/benzenefinphg.pdf
3. State Water Resources Control Board, California Drinking Water-Related Laws http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Lawbook.shtml
4. State Water Resources Control Board, GAMA GIS Online Database http://www.waterboards.ca.gov/water_issues/programs/gama/geotracker_gama.shtml
5. US Environmental Protection Agency, Technologies-Remediation, http://www.clu-in.org/remediation/
6. US Environmental Protection Agency. 2012. Water, Benzene Health Advisory, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100N01H.PDF?Dockey=P100N01H.PDF

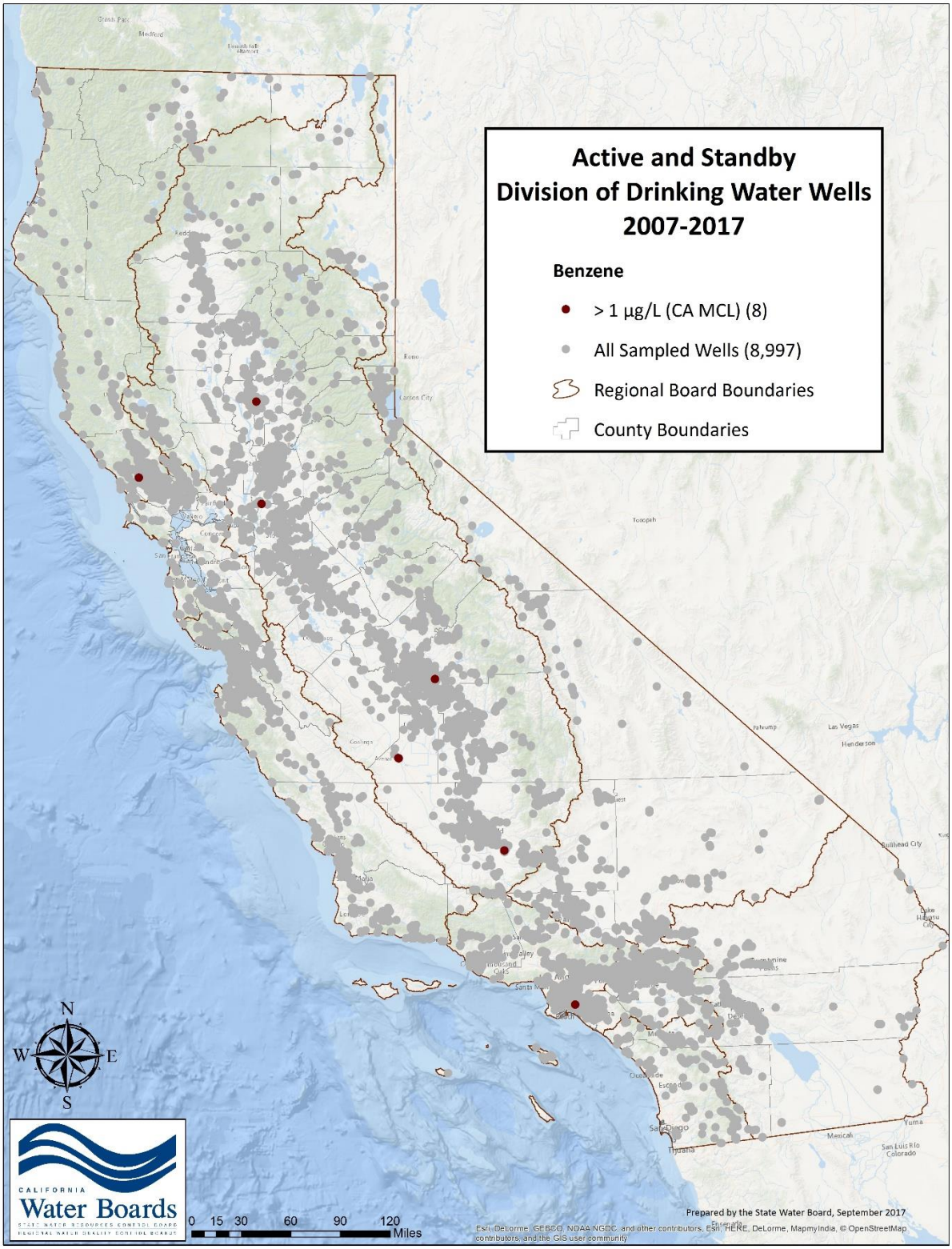


Figure 1. Active and standby public drinking water wells that had at least one detection of benzene above the MCL, 2007-2017, 8 wells. (*Source: Public supply well data in GAMA GIS*).