GROUNDWATER INFORMATION SHEET

Perchlorate

The purpose of this groundwater information sheet is to provide general information regarding a specific constituent of concern (COC). The information provided herein relates to wells (groundwater sources) for public drinking water, not water served at the tap.

GENERAL INFORMATION	
Constituent of Concern	Perchlorate
Aliases	Dissociated anion of perchlorate salts. Includes: ammonium, potassium, magnesium or sodium perchlorate
Chemical Formula	ClO_4^-
CAS No.	Perchlorate 14797-73-0 Perchlorate: ammonium 7790-98-9, potassium 7778-74-7, magnesium 10034-81-8, and sodium 7601-89-0
Storet No.	A-031
Summary	Perchlorate is a regulated drinking water contaminant with an established State Maximum Contaminant Level (MCL) of 6 micrograms per liter (µg/L). Common anthropogenic (man-made) sources of perchlorate include perchlorate salts used in industrial and military applications. Perchlorate is highly soluble in water, highly mobile, and once released is persistent in groundwater. Based on SWRCB data from 2007 to 2017, 230 active and standby public water supply wells (of 9,341 wells sampled) had at least one detection above the MCL. Most wells with detections occurred in three counties, Los Angeles (88), San Bernardino (62) and Riverside (23).

REGULATORY AND WATER QUALITY LEVELS[1]		
Type	**Agency**	**Concentration**
Federal MCL	US EPA[2]	EPA placed perchlorate on Contaminant Candidate List (CCL3) and is evaluating possible regulation
State MCL	SWRCB[3]	6 µg/L
Detection Limit for Purposes of Reporting (DLR)	SWRCB[3]	4 µg/L
Others: Public Health Goal (PHG)	 OEHHA[4]	 1 µg/L

[1]These levels generally relate to drinking water. Other water quality levels may exist. For further information see *A Compilation of Water Quality Goals,* 17th Edition (SWRCB, 2016).
[2]US EPA – United States Environmental Protection Agency
[3]SWRCB – State Water Resources Control Board.
[4] OEHHA – Office of Environmental Health Hazard Assessment

SUMMARY OF DETECTIONS IN PUBLIC WATER WELLS[5]	
Detection Type	**Number of Groundwater Sources**
Number of active and standby public water wells that had at least one detection of perchlorate[6] above the MCL >6 µg/L.	230 of 9,341 wells sampled.
Top counties with perchlorate detections in public standby and active wells above the MCL >6 µg/L.	Los Angeles (88), San Bernardino (62) and Riverside (23)

[5]Based on 2007-2017 public and standby well (groundwater sources) data collected by the SWRCB.
[6] Water from active and standby public wells is typically treated to prevent exposure to chemical concentrations above the MCL. Data from private domestic wells and wells with less than 15 service connections are not available.

ANALYTICAL INFORMATION	
Analytical Test Method	US EPA Method 331.0
Method Detection Limit	0.005 µg/L by LC/MRM or 0.008 µg/L by LC/SIM
Known Limitations to Analytical Methods	Liquid chromatography electrospray ionization mass spectrometry (LC/ESI/MS) is the state-of-the-art technology for perchlorate analysis in drinking water. Historical methods based on gravimetry, spectrophotometry, or atomic absorption lack the selectivity, specificity, and sensitivity for perchlorate that LC/ESI/MS analysis provides. Before 1997, the Ion Chromatography (IC) method used for perchlorate detection had a method detection limit (MDL) of 100 µg/L. In 1997, the DDW (formerly CDPH) developed and introduced what became the US EPA Method 314.0, which has an MDL of 4 µg/L. In 1998, the Dionex AS-11 method was developed by the Air Force Research Laboratory/Operational Toxicology Branch (AFRL/HEST), which has a MDL less than 1 µg/L. In 2005, EPA published the 331.0 (LC/ESI/MS) method that allows perchlorate detection at the parts per trillion level. The method can use either Selected Ion Monitoring (SIM) or Multiple Reaction Monitoring (MRM) detection.
Public Drinking Water Testing Requirements	In October 2007, the DDW (formerly CDPH) established the MCL for perchlorate at 6 µg/L. Testing of all public drinking water sources is required. Perchlorate concentrations in drinking water provided to the public cannot exceed the MCL.

PERCHLORATE OCCURRENCE	
Anthropogenic Sources	Perchlorate is a manufactured compound that includes perchloric acid and salts such as ammonium, potassium, and sodium perchlorate. Sources include the manufacturing or testing of solid rocket fuels and the manufacturing of ammonium perchlorate, fireworks, and certain types of fertilizers. Perchlorate has also been detected at hazardous waste sites. Perchlorate is present in matches, automotive air bag inflators, nuclear reactors, electronic tubes, and lubricating oils. It is used in the leather tanning and finishing chemicals, as a fixer for fabric and dyes, electroplating, aluminum refining, rubber manufacturing, and in the production of paints and enamels. Potassium perchlorate has been used therapeutically to treat hyperthyroidism resulting from an autoimmune condition known as Graves' disease. Diagnosis of thyroid hormone production has used potassium perchlorate in some clinical settings.
Natural Sources	Perchlorate also occurs naturally and is reported to be present in sodium-nitrate deposits of Chiles' Atacama Desert that are used for the production of nitrate fertilizer. Perchlorate was detected in salts accumulated in thick unsaturated zones in the southwestern USA. Isotopic data suggest an atmospheric origin for the perchlorate in these arid environments, and perchlorate is present in precipitation.

History of Occurrence	In February 1997, perchlorate was first detected in drinking water wells near a Rancho Cordova site in Sacramento County. Perchlorate was used there as a solid rocket propellant. Perchlorate was also detected in drinking water wells in Los Angeles County in April 1997. Since then, several sites using perchlorate have been identified as potential sources of contamination including sites in Azusa, Santa Clarita, and Pasadena. Perchlorate has been detected in drinking water wells associated with a TCE plume at a former industrial site in San Bernardino and Riverside counties, and in several wells located in the Rialto area of San Bernardino County. Potential sources of contamination in Rialto include fireworks manufacturing and landfill sites. In addition, perchlorate has been found in 24 agricultural wells located in San Bernardino County at concentrations ranging from 11 to 221 µg/L. Colorado River water sampling has shown perchlorate concentrations ranging from 5 to 9 µg/L. The Colorado River is an important source of California's drinking and agricultural irrigation water. These perchlorate detections are associated with contamination from perchlorate manufacturers near Las Vegas, Nevada. Other locations in California showing groundwater contamination by perchlorate: • Explosives manufacturing facility near Lincoln (1,200 and 67,000 µg/L) • Industrial facility in Santa Clara (up to 180,000 µg/L) • Industrial facility near Hollister in San Benito County (up to 88 µg/L); an agricultural well in the vicinity (34 µg/L); and a private well (810 µg/L).
Contaminant Transport Characteristics	Perchlorate is highly soluble and mobile in groundwater, and is resistant to degradation. The persistence of perchlorate in groundwater results primarily from its chemical stability (very inert) and its relative resistance to biodegradation (stable at low concentrations).

REMEDIATION & TREATMENT TECHNOLOGIES

Treatment of perchlorate contamination in water is complicated because conventional filtration, sedimentation, and air stripping technologies cannot remove the perchlorate anion. Since 1997, much progress has been made in perchlorate treatment technologies. However, no single treatment technique is effective in every case and the best solution may be a combination of treatment technologies. Perchlorate treatment technologies may be generally classified into categories of destruction or removal technologies. The optimum treatment technology for a given perchlorate occurrence may depend on several factors, including perchlorate concentration, other water quality parameters (pH, alkalinity, organic matter, total dissolved solids (TDS), metals, etc.), and geochemical parameters (nitrate, sulfate, chloride, dissolved oxygen, redox potential, etc.). The presence of perchlorate-reducing microbes will also influence perchlorate treatment technology effectiveness. For in situ treatment of perchlorate contamination, variables related to the site hydrogeological setting, such as depth to and distribution of contaminants, soil permeability, groundwater flow velocity, etc. are also additionally important.

Physical Removal Technologies

Ion Exchange – A process with two similar applications of the same technology:

- *Water softening* - removes ions from the water and replaces them with sodium (Na^+) and chloride (Cl^-) ions. This technique is employed at the site in Sacramento.

- *Deionization* - ions are removed and replaced with hydrogen (H^+) and hydroxyl (OH^-) ions, which can combine to form water.

Ion exchange treatment has been successful in reducing perchlorate concentrations in water from 75 µg/L to less than detectable levels at the San Gabriel Valley Superfund sites. This process concentrates the perchlorate into brine, which must be disposed or treated. Ion exchange is the preferred large-scale treatment method used by most utilities.

Membrane Techniques:

- *Reverse Osmosis and Nanofiltration (RO and NF) -* A semi-permeable membrane is used, allowing the water to pass through it, while retaining perchlorate. RO and NF can be costly due to the energy use and perchlorate disposal. This method is typically used on small-scale systems.

- *Electrodialysis -* An electrically driven membrane separation process that separates ions from water. This process is based on the property of ion exchange membranes to selectively reject anions or cations.

Other Treatment Technologies

Biological - An effective and fast-reaction treatment technology that has been successful in reducing concentrations in water from 75 µg/L to less than detectable levels at the San Gabriel Valley Superfund and Sacramento sites. Biological fluidized bed reactors (FBR) use naturally occurring microorganisms to convert perchlorate molecules to oxygen and chloride while attached to a hydraulically fluidized bed of sand or granular activated carbon media. Regulatory barriers and the hardiness of the bacteria have been considered problematic, but additional microbe removal using oxidation and/or granular activated carbon has been effective when added downstream of the FBR.

Biochemical - A highly effective and fast-reaction technique that produces no toxic by-products; however, biochemical reduction requires a high degree of maintenance and is difficult to implement. In addition, the enzymes used in the reaction are expensive and unstudied.

Chemical - A reducing agent transfers electrons to the chlorine atom (of perchlorate anion) converting it to chloride. Chemical reduction is expensive, slow, and it produces toxic by-products that are hard to remove.

Electrochemical - A well-known technique producing non-toxic by-products; however, construction costs are high. It requires large amounts of power to electrolize the water and the process is slow and involves safety concerns.

In-Situ - treatment methods rely mostly on bioremediation techniques, phytoremediation or monitored natural attenuation.

HEALTH EFFECT INFORMATION

In the body, perchlorate interferes with the uptake of iodine by the thyroid gland, causing disruption of thyroid hormone production. Thyroid hormones help to regulate the body's metabolism and physical growth. Inhibited thyroid function can result in hypothyroidism and, in rare cases, thyroid tumors. Pregnant women and their developing fetuses may suffer the most serious health effects from perchlorate contamination in drinking water, particularly in the first and second trimesters of pregnancy. During this period, the fetal thyroid is not yet fully functional, so the mother's thyroid must be able to produce enough extra hormones to enable her baby's brain to develop properly. Because pregnancy already places a strain on the maternal endocrine system, pregnant mothers and their fetuses are particularly susceptible to perchlorate's inhibition of iodine intake. Women with critically low levels of iodine can miscarry, or their developing fetuses can suffer congenital hypothyroidism, which may stunt the fetus's physical growth and impede proper development of its central nervous system. Even moderate to mild iodine deficiency during pregnancy has been linked to impaired brain development and lower IQs for children born under these conditions (OEHHA, 2002).

Following the initial detections in 1997, DDW (formerly CDPH) informed drinking water utilities that US EPA had evaluated the health effects of perchlorate as part of its Superfund activities (US EPA, 1992, 1995). US EPA used studies on humans to evaluate the health risks of perchlorate and to establish a "provisional" reference dose (RfD). Data were derived from medical patients given perchlorate to treat hyperactive thyroid glands (Graves' disease). The release of iodine from the thyroid and inhibition of iodine uptake by the thyroid were the most sensitive indicators of perchlorate effects. In 2005, the EPA assigned perchlorate a chronic oral reference dose (RfD) of 0.0007 milligrams per kilogram per day (mg/kg/day), which equates to a Drinking Water Equivalent Level (DWEL) of 24.5 µg/L. In 2012, the EPA established an Interim Lifetime Drinking Water Health Advisory Level of 15 µg/L. Perchlorate at this concentration is not expected to cause any adverse effects for a lifetime of exposure. EPA's tap water screening level was calculated at 11 µg/L in 2013.

In October 2007, the final MCL was set by the DDW at 6 µg/L. Perchlorate concentrations at or below 6 µg/L are not considered to pose a health concern for the public, including children and pregnant women, and their developing young. In 2015 OEHHA updated the previous Public Health Goal (PHG) of 6 µg/L (2004) for perchlorate in drinking water to 1 µg/L. In response to the revised PHG, DDW will determine if the state MCL should be considered for revision.

KEY REFERENCES

1 Biological Treatment of Perchlorate-Contaminated Groundwater Using Fluidized Bed Reactors, prepared by Paul B. Hatzinger, http://www.clu-in.org/download/contaminantfocus/perchlorate/Envirogen1.pdf

2 California Environmental Protection Agency. Office of Environmental Health Hazard Assessment. Public Health Goal for Perchlorate in Drinking Water https://oehha.ca.gov/media/downloads/water/chemicals/phg/perchloratephgfeb2015_0.pdf

3 State Water Resources Control Board. GeoTracker GAMA http://www.waterboards.ca.gov/water_issues/programs/gama/geotracker_gama.shtml

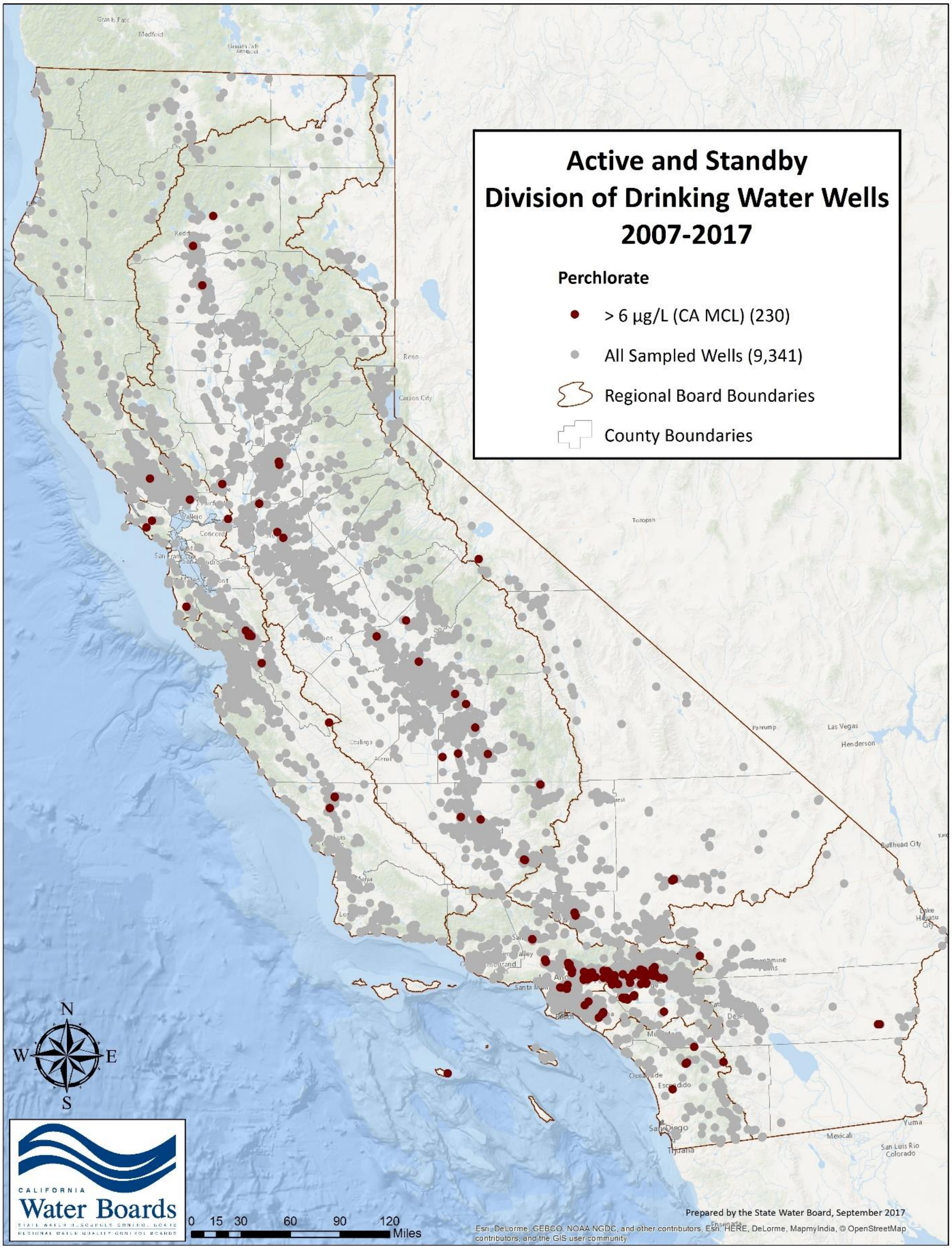
4 State Water Resources Control Board. A Compilation of Water Quality Goals, 17th Edition, (SWRCB, 2016). http://www.waterboards.ca.gov/water_issues/programs/water_quality_goals/docs/wq_goals_text.pdf

5 State Water Resources Control Board-Division of Drinking Water. Perchlorate in Drinking Water http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Perchlorate.shtml

6 U.S. Environmental Protection Agency. Contaminant Focus: Perchlorate (CLU-IN.ORG) http://clu-in.org/contaminantfocus/default.focus/sec/perchlorate/cat/Overview/

7 U.S. Environmental Protection Agency, Technical Fact Sheet-Perchlorate, http://www.epa.gov/sites/production/files/2014-03/documents/ffrrofactsheet_contaminant_perchlorate_january2014_final.pdf

8 Urbansky, E.T., Schock, M.R., Issues in managing the risks associated with perchlorate in drinking water, Journal of Environmental Management, (1999) 56,79-95, https://clu-in.org/download/contaminantfocus/perchlorate/urbansky1.pdf



Active and standby public drinking water wells that had at least one detection of perchlorate above the MCL, 2007-2017, 230 wells. *(Source: public well data in GeoTracker GAMA).*