GROUNDWATER INFORMATION SHEET

Perchlorate

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

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: ammonium 7790-98-9, potassium 7778-74-7, magnesium 10034-81-8, and sodium 7601-89-0
Storet No.	A-031
Summary	The California Department of Public Health (CDPH) has adopted a maximum contaminant level (MCL) for perchlorate 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. As of June 2010, 302 active and standby public drinking water wells (of 9,224 sampled) had concentrations above the MCL. Most perchlorate detections above the MCL have occurred in Los Angeles, San Bernardino, and Riverside Counties.

REGULATORY AND WATER QUALITY LEVELS[1]		
Type	**Agency**	**Concentration**
Federal MCL	US Environmental Protection Agency (EPA) Region 9	No MCL set
State MCL	CDPH	6 μg/L
Detection Limit for Purposes of Reporting (DLR)	CDPH	4 μg/L
Others:		
Preliminary Remediation Goal Tap Water	US EPA, Region 9	3.6 μg/L
Public Health Goal (PHG)	Office of Environmental Health Hazard Assessment (OEHHA)	6 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* (Marshack, 2008).

SUMMARY OF DETECTIONS IN PUBLIC DRINKING WATER WELLS[2,3]	
Detection Type	**Number of Groundwater Sources**
Number of active and standby public drinking water wells with detections (above 4 μg/L)	467 of approximately 9,227 sampled
Number of active and standby public drinking water wells above MCL (above 6 μg/L)	302 of approximately 9,227 sampled
Top 4 counties having public drinking water wells with perchlorate detections	Los Angeles, San Bernardino and Riverside

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

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

ANALYTICAL INFORMATION	
Analytical Test Methods	US EPA Method 314.0
Method Detection Limit	1 µg/L
Known Limitations to Analytical Methods	Ion chromatography (IC) is the state-of-the-art technology for perchlorate analysis. Historical methods based on gravimetry, spectrophotometry, or atomic absorption lack the selectivity, specificity, and sensitivity for perchlorate that IC analysis provides. Before 1997, the IC method used to analyze for perchlorate (Aerojet method) had a method detection limit (MDL) of 100µg/L. In 1997, the CDPH developed and introduced what became US EPA Method 314.0, which has an MDL of 4µg/L. In 1998, the Dionex AS-11 method was developed by the Air Force Research Laboratory/Operational Toxicology Branch (AFRL/HEST), which has an MDL of <1µg/L. These methods depend upon retention time in a standard to identify any peak with the same or similar retention time as perchlorate in a water sample. The robustness of the existing IC methods for perchlorate in water analysis with high total dissolved solids is questionable. Research is underway that will evaluate the variability, reproducibility, accuracy and precision of the IC methods across laboratories and to determine the appropriate concentration ranges for measurement.
Public Drinking Water Testing Requirements	In January 1997, perchlorate was identified by CDPH as an unregulated chemical requiring monitoring. As a result, public water systems began monitoring for perchlorate in their drinking water supplies. In October 2007, CDPH finalized the MCL for perchlorate at 6 µg/L. According to the CDPH website, between 2002 and 2007 approximately 6,300 drinking water sources in California were sampled for perchlorate.

PERCHLORATE OCCURRENCE	
Anthropogenic Sources	Perchlorate originates as a contaminant in the environment from the release of solid salts of ammonium, potassium, or sodium perchlorate. The vast majority (approximately 90 percent) of locations where perchlorate has been detected in the groundwater are associated with the manufacturing or testing of solid rocket fuels for the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA), and with the manufacture of ammonium perchlorate. Perchlorate salts are also used in: fireworks; matches; automotive air bag inflators; nuclear reactors; electronic tubes; lubricating oil; the tanning and finishing of leather; as a fixer for fabric and dyes; electroplating; aluminum refining; rubber manufacture; and the production of paints and enamels. Perchlorate is also reported to have been present in certain types of fertilizers. In addition, perchlorate has been detected at hazardous waste sites. 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 is reported to be present in some caliche formations in Chile that are used to produce nitrate fertilizers.
History of Occurrence	In February 1997, perchlorate was first detected in drinking water wells near the Aerojet site in Sacramento County. Aerojet has used perchlorate as a solid rocket propellant. Perchlorate was initially detected in drinking water wells in Los Angeles County in April 1997. Since then, several sites have been identified as potential sources of contamination, including Aerojet (Azusa), Whittaker-Bermite (Santa Clarita), and Jet Propulsion Laboratory (Pasadena).

History of Occurrence (cont.)	Perchlorate has been detected in drinking water wells associated with a TCE plume at the former operation site of the Lockheed Propulsion Company (San Bernardino and Riverside County). Perchlorate has been detected in several wells located in the Rialto area of San Bernardino County. Potential sources of contamination in Rialto include fireworks manufacturing, military contractor 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: • an explosives manufacturing facility near Lincoln (1,200 and 67,000 µg/L). • United Technologies in Santa Clara (up to 180,000 µg/L). • Whittaker Ordnance 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. Perchlorate and concentrated solutions of perchlorate are denser than water which allows it to sink. 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.

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 Aerojet 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 from75 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 Aerojet, 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 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, the process is slow and involves safety concerns.

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, 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. For these effects, the US EPA (1992) identified a no observed adverse effect level (NOAEL) of 0.14 mg/kg/day and a 1000-fold uncertainty factor (UF). Later, US EPA reviewed its earlier report and material submitted by the Perchlorate Study Group, and maintained the earlier 1000-fold UF, but also included a 300-fold UF (US EPA, 1995). The US EPA evaluations of perchlorate corresponded to an acceptable range of 4 to 18 µg/L in drinking water. CDPH, in cooperation with OEHHA, reviewed the US EPA perchlorate evaluations, and established an acceptable limit (AL) of 18 µg/L in 1997. CDPH reduced its AL level from 18 µg/L to 4 µg/L, equal to the analytical quantitation limit in 2002. OEHHA released a final Public Health Goal for perchlorate of 6 µg/L in March 2004. In October 2007, the final MCL was set by the CDPH at 6 µg/L. Perchlorate concentrations at or below 6 µg/L are not considered by CDPH and OEHHA to pose a health concern for the public, including children and pregnant women and their developing young.

KEY REFERENCES

1 State Water Resources Control Board. GeoTracker GAMA http://www.waterboards.ca.gov/water_issues/programs/gama/geotracker_gama.shtml
2 California Department of Public Health. *Perchlorate in Drinking Water* http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Perchlorate.aspx *Regulations page* http://www.cdph.ca.gov/services/DPOPP/regs/Pages/R-16-04-PerchlorateinDrinkingWater.aspx
3 California Environmental Protection Agency. Office of Environmental Health Hazard Assessment. Public Health Goal for Perchlorate in Drinking Water http://www.oehha.ca.gov/water/phg/perchphg31204.html (March 2004).
4 California Environmental Protection Agency / Regional Water Quality Control Board, Central Valley Region.. *A Compilation of Water Quality Goals*. Prepared by Jon B. Marshack. http://www.swrcb.ca.gov/rwqcb5/available_documents/wq_goals/index.html (August 2003).
5 U.S. Environmental Protection Agency. Groundwater and Drinking Water. *Drinking Water Contaminant List: Perchlorate* http://www.epa.gov/safewater/perchlorate/perchlorate.html (January 2003).
6 U.S. Environmental Protection Agency. Contaminant Focus: Perchlorate (CLU-IN.ORG) http://clu-in.org/contaminantfocus/default.focus/sec/perchlorate/cat/Overview/ (March 2004).
7 General Electric, Osmonics Technology Web Library http://www.osmonics.com/library/library.htm (March 2004).
8 Calgon Carbon Corporation, http://www.perchlorateinfo.com/index.html (June 2003).
9 U.S. Environmental Protection Agency. *What Techniques Will Work?* Prepared by Edward T. Urbansky http://www.epa.gov/safewater/ccl/perchlorate/pdf/urban.pdf.
10 *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 (May 2000).
11 Aerojet Sacramento Perchlorate Activities (Fact Sheet supplied through Groundwater Resources Association Website) http://www.grac.org/Aerojet_Perchlorate_Solutions.pdf (May 2003).

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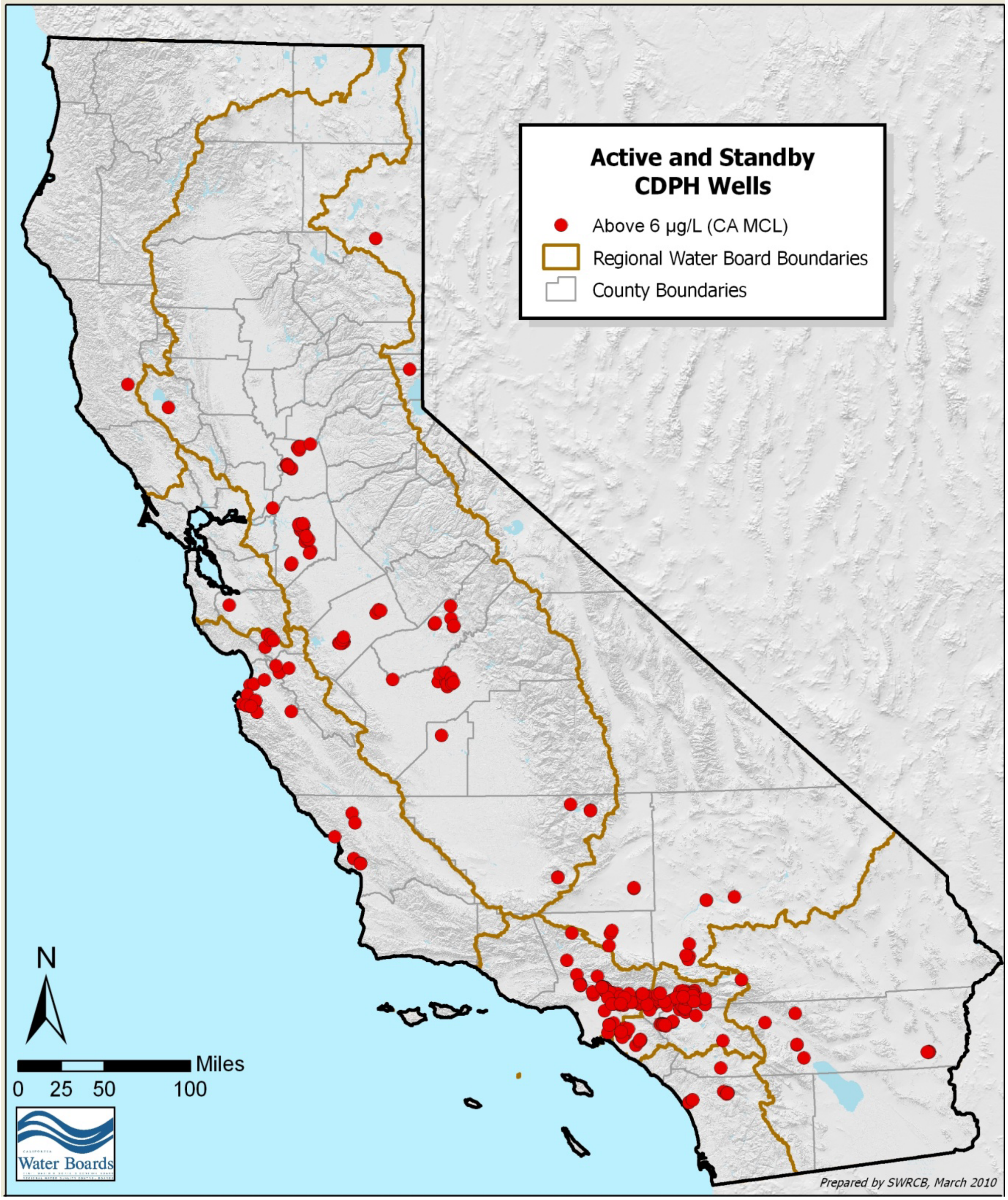

Active and Standby CDPH Regulated Public Drinking Water Wells with at Least One Detection of Perchlorate above the MCL .
(9,227 wells sampled, 439 wells reported detections, 302 above the MCL)

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

Abandoned, Destroyed and Inactive CDPH Regulated Public Drinking Water Wells with at Least One Detection of Perchlorate above the MCL.
(943 wells sampled, 142 wells reported detections, 99 above the MCL)

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