



TECHNICAL FACT SHEET – PERCHLORATE

At a Glance

- ❖ White crystalline solid or colorless liquid.
- ❖ Both naturally occurring and man-made.
- ❖ Sampling at current federal sites as well as Formerly Used Defense Sites detected perchlorate primarily in association with sites historically involved in the manufacture, maintenance, use, and disposal of ammunition and rocket fuel.
- ❖ Highly soluble in water; migrates quickly from soil to ground water.
- ❖ Primary pathways for human exposure include ingestion of food and contaminated drinking water.
- ❖ Short-term exposure to high doses may cause eye and skin irritation, coughing, nausea, vomiting, and diarrhea.
- ❖ Health-based goals or drinking water standards developed by various states.
- ❖ Various detection methods available include ion chromatography, liquid chromatography, mass spectroscopy, and electrospray ionization.
- ❖ Common treatment technologies include ion exchange, bioreactors, and in situ bioremediation.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a brief summary of the contaminant perchlorate, including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information.

Perchlorate is a persistent contaminant of concern that has presented a number of issues to the government, the private sector, and other organizations and interested parties. These issues include health effects and risk, regulatory standards and cleanup levels, degradation processes, and treatment technologies (EPA FFRRO 2005). This fact sheet provides basic information on perchlorate to site managers and other field personnel who are addressing perchlorate contamination at cleanup sites or in drinking water supplies.

What is perchlorate?

- ❖ Perchlorate is a naturally occurring and man-made anion (ClO_4^-) that consists of one chlorine atom bonded to four oxygen atoms (EPA FFRRO 2005; ITRC 2005).
- ❖ Perchlorate may occur naturally, particularly in arid regions such as the southwestern United States (Rao 2007).
- ❖ Manufactured forms of perchlorate include perchloric acid and salts such as ammonium perchlorate, sodium perchlorate, and potassium perchlorate (EPA FFRRO 2005; ITRC 2005).
- ❖ Perchlorate is found as a natural impurity in nitrate salts from Chile, which are imported and used to produce nitrate fertilizers and other products (EPA FFRRO 2005; ITRC 2005).
- ❖ Perchlorate is commonly used as an oxidizer in solid propellants, munitions, fireworks, airbag initiators for vehicles, matches, and signal flares (EPA FFRRO 2005; ITRC 2005). It is also found in some disinfectants and some herbicides (ITRC 2005).
- ❖ Of the domestically produced (high grade) perchlorate, 90 percent is estimated to be used in the defense and aerospace industries in the form of ammonium perchlorate (GAO 2005; ITRC 2005).
- ❖ Perchlorate has been used by the U.S. Department of Defense (DoD) as an oxidizer in munitions and missiles since the 1940s (Mendiratta et al. 1996).

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Exhibit 1: Physical and Chemical Properties of Perchlorate Compounds
(EPA FFRRO 2005; ITRC 2005; NIOSH 2007)

Property	Ammonium Perchlorate	Sodium Perchlorate	Potassium Perchlorate	Perchloric Acid
CAS Numbers	7790-98-9	7601-89-0	7778-74-7	7601-90-3
Physical Description (physical state at room temperature)	White orthorhombic crystal	White orthorhombic deliquescent crystal	Colorless orthorhombic crystal or white crystalline powder	Colorless liquid
Molecular weight (g/mol)	117.49	122.44	138.55	100.47
Water solubility (g/L at 25°C)	200	2,096	15	Miscible in cold water
Melting / Boiling point (°C)	Melting Point: 65.6 to 439	Melting Point: 482	Melting Point: 400	Melting Point: -112 Boiling Point: 19
Vapor pressure at 25°C (mm Hg)	Not available	Not available	Not available	6.8
Specific gravity	1.95	2.52	2.53	1.664
Octanol-water partition coefficient (log K _{ow})	-5.84	-7.18	-7.18	-4.63

Notes: g/mol – grams per mole; g/L – grams per liter; mg/L – milligrams per liter; °C – degrees Celsius; mm Hg – millimeters of mercury.

What are the environmental impacts of perchlorate?

- ❖ Perchlorate is highly soluble, relatively stable and mobile in water. As a result, perchlorate plumes in ground water can be extensive. For example, the perchlorate plume at a former safety flare site (the Olin Flare Facility) in Morgan Hill, California, extends more than 9 miles (EPA 2009a; ITRC 2005).
- ❖ Perchlorate compounds and the perchlorate anion do not volatilize from water to air (EPA IRIS 2005; ITRC 2005).
- ❖ High concentrations of perchlorate have primarily been detected at current and Formerly Used Defense Sites historically involved in the manufacture, testing, and disposal of ammunition and rocket fuel (ITRC 2005).
- ❖ Types of military and defense-related facilities with known releases include missile ranges and missile/rocket manufacturing facilities. However, due to unavailable site specific documentation and historical uncertainties, it is generally difficult to determine which specific military sites have known perchlorate releases (ITRC 2005).
- ❖ In addition, the past disposal of munitions in either burial pits or by open burning and open detonation has the potential to result in releases to the environment. The amount of perchlorate released can vary depending on the length of use and types of munitions disposed (ITRC 2005).
- ❖ Recent surveys have detected perchlorate in food crops and milk (FDA 2008).
- ❖ Perchlorate has been detected in the ground water at 54 federal facilities and 29 private (Superfund or RCRA) sites in 26 states. (EPA FFRRO 2011).

What are the health effects of perchlorate?

- ❖ Primary pathways for human exposure to perchlorate are ingestion of food and contaminated drinking water (EPA FFRRO 2005).
- ❖ At high enough exposures, perchlorate can interfere with iodide uptake into the thyroid gland, disrupting the functions of the thyroid and potentially leading to a reduction in the production of thyroid hormones. Thyroid hormones play an important role in regulating metabolism. Thyroid hormones are critical for normal growth and development in fetuses, infants, and young children (NAS 2005).
- ❖ Potassium perchlorate was historically used to treat hyperthyroidism and Grave's Disease because of its ability to inhibit thyroid iodide uptake (NAS 2005).

What are the health effects of perchlorate? (continued)

- ❖ Studies conducted on rodents showed that perchlorate concentrations below that required to alter thyroid hormone equilibrium is unlikely to cause thyroid cancer in human beings (EPA IRIS 2005).
- ❖ The chronic oral reference dose (RfD) is 0.0007 milligrams per kilogram body weight per day. (Note: A reference dose is an estimate [with uncertainty spanning perhaps an order of magnitude] of a daily oral exposure to the human population [including sensitive subgroups] that is likely to be without appreciable risk of deleterious effects over a lifetime) (EPA IRIS 2005).
- ❖ Short-term exposure to high doses may cause eye and skin irritation, coughing, nausea, vomiting, and diarrhea (NIOSH 2007).

Are there any federal and state guidelines and health standards for perchlorate?

- ❖ EPA has decided to regulate perchlorate under the Safe Drinking Water Act. EPA has initiated the process of proposing a national primary drinking water regulation (EPA 2011).
- ❖ EPA established an Interim Drinking Water Health Advisory of 15 micrograms per liter ($\mu\text{g/L}$) in water (EPA 2009b).
- ❖ The Office of Solid Waste and Emergency Response (OSWER) has established a preliminary remediation goal (PRG) at National Priority List sites of 15 $\mu\text{g/L}$. PRGs are developed based on readily available information and are modified, as necessary, before final cleanup goals are established, based on information that becomes available during the remedial investigation/ feasibility study (EPA 2009b).
- ❖ Numerous states have promulgated enforceable standards for perchlorate in drinking water. For example, Massachusetts (2 $\mu\text{g/L}$) and California (6 $\mu\text{g/L}$) have established enforceable standards for perchlorate in drinking water (CDPH 2010; Massachusetts DEP 2006).
- ❖ California EPA released Draft California Human Health Screening Levels (CHHSLs) for Perchlorate. The draft CHHSLs for perchlorate is 28 parts per million (ppm) soil for residential property and 350 ppm soil for commercial/industrial property (Cal EPA 2009).
- ❖ Certain states have also developed advisory levels or health-based goals ranging from 4 to 51 $\mu\text{g/L}$ (ITRC 2005).

What detection and site characterization methods are available for perchlorate?

- ❖ The following methods can be used to analyze for perchlorate in drinking water, ground water, surface water, and irrigation water:
 - EPA Method 314.0—Ion Chromatography (EPA OGWDW 2011).
 - EPA Method 314.1—Inline Column Concentration/Matrix Elimination Ion Chromatography with Suppressed Conductivity Detection (EPA OGWDW 2011).
 - EPA Method 332.0—Ion Chromatography with Suppressed Conductivity and Electrospray Ionization/Mass Spectrometry (EPA FFRRO 2005).
 - EPA Method 331.0—Liquid Chromatography/Electrospray Ionization/Mass Spectrometry (EPA OGWDW 2011).
- EPA Method 6850—High Performance Liquid Chromatography/Electrospray Ionization/Mass Spectrometry (EPA 2007).
- EPA Method 6860—Ion Chromatography/ Electrospray Ionization/Mass Spectrometry (EPA 2007).
- ❖ The presence of high amounts of other anions, such as chloride, sulfate, or carbonate may interfere with the analysis of perchlorate (EPA 1999).
- ❖ Researchers have demonstrated the ability to distinguish man-made and natural sources of perchlorate using chlorine and oxygen stable isotope analysis (Böhlke et al. 2005).

What technologies are being used to treat perchlorate?

- ❖ Ex Situ Treatment
 - Ion exchange using perchlorate-selective or nitrite-specific resins (Boodoo 2003; EPA FFRRO 2005; GWRTAC 2001).
 - Bioremediation using packed-bed or fluidized-bed bioreactors (EPA FFRRO 2005; GWRTAC 2001; Hatzinger 2005).
 - Membrane technologies (electrodialysis and reverse osmosis) (EPA FFRRO 2005; GWRTAC 2001; ITRC 2005).
 - Liquid phase carbon adsorption using granular activated carbon (GAC) to remove low levels of perchlorate; pretreatment may be necessary to prepare GAC for perchlorate removal (EPA FFRRO 2005; GWRTAC 2001; ITRC 2005).
- ❖ In Situ Treatment:
 - Bioremediation using perchlorate-selective microbes (EPA FFRRO 2005; GWRTAC 2001; ITRC 2005).
 - Permeable reactive barrier (EPA FFRRO 2005; GWRTAC 2001; ITRC 2005).
 - Phytoremediation may also be used, although the mechanism of phytoremediation of perchlorate is yet to be established (EPA FFRRO 2005; GWRTAC 2001).

Where can I find more information about perchlorate?

- ❖ Boodoo, F. 2003. POU/POE Removal of Perchlorate. *Water Conditioning & Purification*. Pages 1-4.
- ❖ Böhlke, J. K., N.C. Sturchio, B. Gu, J. Horita, G.M. Brown, W.A. Jackson, J. Batista, and P.B. Hatzinger. 2005. Perchlorate isotope forensics. *Anal. Chem.*, 77, 7838-7842.
- ❖ California Department of Public Health (CDPH). 2011. Perchlorate in Drinking Water. www.cdph.ca.gov/certlic/drinkingwater/Pages/Perchlorate.aspx
- ❖ California Environmental Protection Agency (Cal EPA). 2009. California Human Health Screening Levels for Perchlorate.
- ❖ Food and Drug Administration (FDA). 2008. U.S. Food and Drug Administration's Total Diet Study: Dietary intake of Perchlorate and Iodine.
- ❖ Ground Water Remediation Technologies Analysis Center (GWRTAC). 2001. Technology Status Report: Perchlorate Treatment Technologies. 1st edition.
- ❖ Hatzinger, P.B. 2005. Perchlorate Biodegradation for Water Treatment. *Environmental Science & Technology*. Vol. A. Pages 239-247.
- ❖ Interstate Technology Regulatory Council (ITRC). 2005. Perchlorate: Overview of Issues, Status, and Remedial Options. www.itrcweb.org/Documents/PERC-1.pdf
- ❖ Massachusetts Department of Environmental Protection (DEP). 2006. Perchlorate Information. www.mass.gov/dep/water/drinking/percinfo.htm#stds
- ❖ Mendiratta, S.K., R.L. Dotson, and R.T. Brooker. 1996. Kirk-Othmer Encyclopedia of Chemical Technology. Vol. 18. Pages 157-170.
- ❖ National Research Council of the National Academies (NAS). 2005. "Health Implications of Perchlorate Ingestion." www.nap.edu/catalog.php?record_id=11202.
- ❖ National Institute for Occupational Safety and Health (NIOSH). 2007. www.cdc.gov/niosh/ipcs/icstart.html
- ❖ Rao, B., Anderson, T. A., Orris, et al. 2007. Widespread natural perchlorate in unsaturated zones of the Southwest United States. *Environmental Science & Technology*. 41 (13), 4522 -4528, 2007.
- ❖ U.S. Environmental Protection Agency (EPA). 1999. Method 314.0 Determination of Perchlorate in Drinking Water Using Ion Chromatography. Revision.
- ❖ EPA. 2007. New Test Methods On-line. www.epa.gov/epawaste/hazard/testmethods/sw846/new_meth.htm
- ❖ EPA 2009a. Region 9. Perchlorate in the Pacific Southwest. www.epa.gov/region9/toxic/perchlorate/per_ca.html#olin
- ❖ EPA 2009b. Revised Assessment Guidance for Perchlorate. www.epa.gov/fedfac/documents/perchlorate_memo_01-08-09.pdf

Where can I find more information about perchlorate? (continued)

- ❖ EPA. 2011. Drinking Water Contaminants. Unregulated. Perchlorate. <http://water.epa.gov/drink/contaminants/unregulated/perchlorate.cfm>
- ❖ EPA Federal Facilities Restoration and Reuse Office (EPA FFRRO). 2005. Perchlorate Treatment Technology Update – Federal Facilities Forum Issue Paper. EPA 542-R-05-015.
- ❖ EPA FFRRO. 2011. Perchlorate and Other Emerging Contaminants. www.epa.gov/fedfac/documents/emerging_contaminants.htm.
- ❖ EPA Integrated Risk Information System (IRIS). 2005. “Perchlorate and Perchlorate Salts.” www.epa.gov/iris/subst/1007.htm.
- ❖ EPA Office of Groundwater and Drinking Water (OGWDW). 2011. www.epa.gov/safewater/methods/analyticalmethods_ogwdw.html
- ❖ U.S. Government Accountability Office (GAO). 2005. Perchlorate: A System to Track Sampling and Cleanup Results is Needed. GAO-05-462.

Additional information on perchlorate can be found at EPA's www.cluin.org/perchlorate.

Contact Information

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