Pervasive Perchlorate - Rocket fuel isn't the only source of this emerging contaminant

** Timothy Peschman*

Perchlorate (C104), an anion remnant of highly oxygenated salts, isn't just a problem for the U.S. Department of Defense (DoD). So far, this pollutant has been found in surface water, groundwater, and potable water wells in 42 states. While researchers are still determining the extent of the contamination, they now know it isn't solely the result of rocket manufacturing and maintenance operations.

Representatives of industry, DoD, and the U.S. Environmental Protection Agency (EPA) have been meeting to determine the public health risk of perchlorate. Researchers from the Ammonium Perchlorate Advisory Group, composed of representatives from DoD and the National Aeronautics and Space Administration, have found that ingested perchlorate can inhibit proper thyroid function in humans. Experts agree that a maximum contaminant level (MCL) for perchlorate, based on human studies, is needed to protect those primarily at risk - pregnant women, fetuses, and toddlers. So, what are the other sources of perchlorate? What is the MCL likely to be? What treatment options are available?

Sources

At first, experts suspected that rocket fuel was the primary source of perchlorate-contaminated groundwater. But as they found more sites unrelated to DoD activities, they learned that perchlorate contamination also is the result of above- and belowground blasting activities (to remove rock), as well as water and wastewater treatment processes.

For example, when sodium hypochlorite (bleach) is used to disinfect water, it leaves behind perchlorate residuals. The chloralkali process for generating chlorine leaves behind levels of residual chlorate that, over time, eventually revert into perchlorate.

The wastes from perchloric acid cleaning and bleaching generate strong perchlorate concentrations (g/L) that generally flow untreated through wastewater treatment plants, contaminating the receiving waterbodies. Downstream municipalities that use these waterbodies as drinking water sources can expect to find perchlorate in their water treatment plant influent.

Regulations

EPA is expected to need 2 to 5 years to develop an MCL for perchlorate. (Typically, the National Pollutant Discharge Elimination System limit is 50% of the MCL.) Meanwhile, California, Maryland, Massachusetts, New Jersey, Texas, and other affected states are developing their own limits, based an the U.S. National Academy of Sciences' reference-dose determination of 0.0007 mg per kilogram of perchlorate. The state rules would help bridge the regulatory gap until the federal regulation is promulgated.

Treatment Options

Currently, biological treatment, membrane filtration, and ion-exchange systems are used to remove perchlorate from contaminated groundwater and wastewater.

Biological. Field research has proven that indigenous bacteria can reduce perchlorate to chloride and oxygen, if given the right environment. With the addition of nutrients or an electron donor to the process, bacteria can readily reduce perchlorate in an anoxic biological reactor.

Ex situ biological methods involving fixed- and fluidized-bed reactors have been proven to treat groundwater effectively at aerospace and military armament sites in the United States. In a fixed-bed reactor, the treatment bacteria grow on a solid surface. In a fluidized-bed reactor, countercurrent flow is used to suspend a bed of sugar sand or granular activated carbon on which the treatment bacteria grow.
In situ biological methods are used to clean up strongly contaminated groundwater. In this case, treatment system designers must understand the hydrogeologic properties of the contaminated groundwater system so the plume can be properly contained, the added nutrients or electron donors will be properly mixed, and treatment will be complete.

To date, biological treatment has been used successfully in nonpotable applications but has not been accepted for potable water treatment because of perceptions that the treatment bacteria are toxic. At press time, California had approved the use of biological treatment for potable water treatment, but it had yet to be used.

Membrane filtration. Synthetic, semipermeable membranes work well in removing perchlorate from potable water, but the high perchlorate levels in the wastestream (concentrate) make its final disposal problematic. To date, they have been used in point-of-use (low-flow) applications, and the Small volume of concentrate generated generally has been mixed with water from the user's septic system.

Membranes also have been used to treat perchlorate-contaminated groundwater for potable use. In Utah, for example, groundwater is treated via electrodialysis reversal, in which a semipermeable membrane is electrically charged to concentrate anions and cations an either side of it. As the groundwater passes through the membrane, the charged ions are attracted to their opposing charge side, where they are concentrated and removed. In addition, membranes are used for smallscale treatment. In California, several point-of-use reverse osmosis systems have been NSF-certified, approved for use, and operate as under-the-sink drinking water treatment systems.

Ion exchange. Ion-exchange systems are commonly used to remove perchlorate from groundwater and potable water. Ion-exchange costs have dropped as ion-exchange resin manufacturers have optimized the perchlorate removal mechanism and used this information to develop better resins.
Two types of perchlorate-specific resins are available: single-use and reusable. Single-use resins are burned alter use - an easy and elegantly simple way to dispose of the concentrated perchlorate.

Reusable resins are more problematic. At press time, consultants and equipment manufacturers were still investigating cost-effective methods for treating or disposing of spent brine regenerant (and concentrated perchlorate). Options evaluated to date involved incompatible metallurgies or reduction chemistries.

Bacteriological technologies are being tested, but growing perchlorate-reducing bacteria in a highly concentrated (4% to 6%) spent brine regenerant stream has proven difficult and requires a significant reaction time (and significant brine storage) to work effectively.

Present Day Costs for Treatment

Technology	**Minimum ($/ac-ft)**	**Maximum ($/ac-ft)**
Bacteriological	75	125
Ion exchange (one use)	100	250
Ion exchange (regenerable)	250	450
Membrane	350	700

1 ac-ft = 326,000 gal = 1234 m^3

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