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Looking Deep to Remediate Perchlorate

Tracing its roots back to 1789, the U.S. Department of Defense (DoD) is charged with safeguarding America's citizens, interests, and infrastructure. Today, DoD is also carrying out a life-saving mission of a different sort—protecting our drinking water supplies from potentially adverse health effects of perchlorate. Perchlorate contamination arises primarily from the manufacture and disposal of ammonium perchlorate—an oxidant found in solid rocket fuel, flares, and munitions that have been used by the U.S. defense and space programs since shortly after World War II. Perchlorate is known to inhibit iodide uptake by the thyroid. While the health effects of low-level perchlorate exposure are controversial, perchlorate is an especially sensitive issue due to its high solubility and mobility in groundwater.

Above right: Going higher sometimes creates deeper problems: Solid rocket fuel, fireworks, and flares are just a few sources of perchlorate soil and groundwater contamination.

Going to Great Depths to Protect Drinking Water

To date, perchlorate contamination has been documented at more than 100 DoD and government contractor sites in the United States. While many of these locations have shallow soil contamination, which can be effectively treated using excavation, many sites have perchlorate deep in the vadose zone, the soil located above the water table. Soil contamination at this depth represents a significant long-term source of continuing groundwater contamination—due to perchlorate's leachability and the impractical and costly remediation challenge of using deep excavation methods.

"Since perchlorate is readily biodegradable by bacteria, *in situ* bioremediation stands out as an affordable and effective treatment option for perchlorate far below ground," explains Dr. Pat Evans, CDM perchlorate remediation specialist. Water containing electron donors (food)—such as ethanol (alcohol) or acetic acid (vinegar)—is effective in stimulating certain bacteria to grow and simultaneously convert perchlorate to harmless water and chloride salt.

"Specialized anaerobic bacteria consume this food and use perchlorate much in the same way humans use oxygen for energy. However, this method has its limits for deep soil," notes Evans.

Harnessing Innovative Gaseous Technology

To optimize the biodegradation process in the deep vadose zone, CDM has developed a new *in situ* bioremediation technology called gaseous electron donor injection technology (GEDIT). "This innovative process involves the injection of electron donors as a gas, rather than as liquid, into the soil to stimulate anaerobic, biological reduction of perchlorate," continues Evans, who invented the patent-pending GEDIT process. "*In situ* methods involving water injection are unlikely to succeed because the liquids are not easily distributed through the soil. GEDIT may be the only technology that is capable, practical, and effective for treatment of perchlorate in deep soil."

GEDIT is based on, but the reverse of, bioventing—a common *in situ* remediation process used for remediation of fuel hydrocarbons, such as gasoline and jet fuel. Bioventing involves injection or drawing of air into the ground to provide oxygen to promote biodegradation of hydrocarbons.

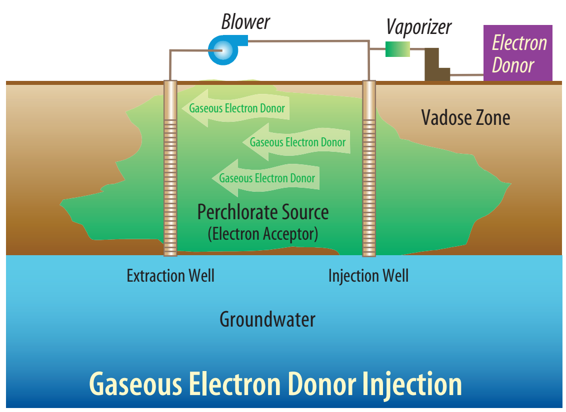
Achieving Significant Cost Savings

Currently, pilot testing of GEDIT is being initiated at a perchlorate-contaminated site and is funded under the DoD Environmental Security Technology Certification Program (ESTCP–www.estcp.org). Several process factors are being evaluated, including delivery method, soil moisture, nutrients, and electron donor type. "One of the most important determining factors is the delivery method, which is dependent on the soil type and specific electron donor candidates, such as hydrogen and ethyl acetate," says Evans. "ESTCP funding has been instrumental in demonstrating this innovative technology with its potential for significant cost savings compared to more traditional methods."

Dr. Andrea Leeson, ESTCP program manager for environmental restoration, who is overseeing ESTCP's perchlorate program, is optimistic about GEDIT's achievable savings. "This project will demonstrate and validate a necessary and cost-effective *in situ* bioremediation technology for perchlorate in soil," states Leeson.

According to Evans, it is estimated that average DoD savings per site could be $6.6 million over excavation and disposal, and $2.6 million over excavation and *ex situ* bioremediation. "Based on a conservative estimate of 20 applicable sites, the estimated total savings could range from $50 million to $130 million!"

Evans believes the benefits will extend far beyond DoD implementation. "Military contractors will benefit, as well, because they also have sites with significant perchlorate contamination. GEDIT provides these contractors with another tool that may be used for more cost-effective site cleanup," states Evans.



Left: Since gas transports through soil (especially deeper soil) more effectively than liquid, electron donors are injected as a true gas—not as mist—to efficiently treat perchlorate in the vadose zone.

Below: Deep-soil perchlorate contamination is a significant ongoing source of groundwater contamination, and expensive to treat ex situ. *GEDIT, an* in situ *bioremediation technology, has the potential for per-site savings of $6.6 million over excavation and disposal.*

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