Ozone as a cleanup tool

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Ozone treatment has “evolved” from water treatment to remediation. Recently, ozone has been used to clean up sites containing polycyclic aromatic hydrocarbons (PAHs); soils and groundwater contaminated with benzene, ethylbenzene, toluene, and xylene (BTEX); and methyl *tert*-butyl ether (MTBE).

“The reason for using ozone is to target those compounds that are not biodegradable,” says Susan Masten, associate professor of civil and environmental engineering at Michigan State University. Although many hydrocarbon compounds will biodegrade if they are dissolved, these contaminants are “not readily biodegraded by microorganisms” if they are on soil particles, she explains. Ozone is pumped into sites from ozone generators via injection wells.

Kevin Wheeler of Resource Control Corp. in Rancocas, NJ, points to a number of examples demonstrating ozone’s effectiveness against MTBE in remediating several sites in New Jersey and Pennsylvania. At a bulk storage terminal, ozone reduced MTBE concentrations by 90% over seven months. And at a toll road service plaza, where remediation is still in progress, ozone has dropped MTBE concentrations by 65%. Wheeler sees a fairly broad application for ozone, noting that it has been effective in various media. The bulk storage facility was above glacial soils and organic peat; the service plaza was over coarse quartz and sand.

Julie Hoffman, an environmental engineer with TriMedia Consultants in Marquette, MI, has used ozone to treat BTEX contamination at a county garage in northern Michigan. “We have seen 99% reduction of contaminants by ozone—that’s pretty incredible removal efficiencies,” she states. From the start of ozonation at this site in September 1999 to March 2001, BTEX concentrations dropped from 49,000 ppb to 335 ppb, says Hoffman.

In what California regulators call “one of the largest in situ applications of ozonation”, the technique was used in Long Beach on a parcel of land contaminated with PAHs from a manufactured gas plant during the early 20th century. After the land was treated for three months with injected ozone, contamination levels ranging from as high as 912,000 ppb for total petroleum hydrocarbons, 4820 ppb benzene, 20,000 ppb napthalene, and 340 ppb benzo(*a*)pyrene were cut in half on the site, says Megan Cambridge, unit chief for expedited remedial action programs at the California EPA.

The oxidizing agent attacks double bonds in PAHs and generates smaller compounds, such as 4-carboxy-5-phenanthrene-carboxyaldehyde, dihydroxy-naphthalene, and benz[*a*]anthraquinone, which can be further degraded by ozone or biodegraded, explains Masten.

Cambridge says that an in situ remedy was selected because the network of water pipes and utility lines through the site made it impossible to excavate the contaminant-laden soil. Early this year, after evaluating the site's condition and finding that it was cleaned to residential standards, which are more stringent than industrial standards, the agency concluded that it posed no health risk.

According to Cambridge, ozonation would be least effective in hard clays and tight soils, which would interfere with the movement of ozone. Another limitation, says Chris Nelson, an environmental engineer with ISOTEC, of Englewood, CO, is that the cost of ozone generators can be high, making this a potentially expensive method compared to other oxidation techniques such as the use of Fenton's reagent (a combination of iron and hydrogen peroxide). Wheeler, however, argues that the costs are comparable. He estimates a figure of around $20 per cubic yard for the MTBE-contaminated gas station. Moreover, if the amount of contamination is underestimated, he says, it is a relatively simple matter to continue running the ozone generators. With other methods, such as Fenton's, if there is an underestimate, "you're back to square one. You have to repurchase the equipment, and practically double your cost to do a second application," says Wheeler.

Ozone, however, doesn't react quickly with all organic compounds. One way around that problem, says Christopher Miller, assistant professor of civil and environmental engineering at the University of Akron, is to add a metal such as manganese, either by means of a wall of sand coated with the metal or colloidal manganese pumped into the site to coat the soil. Ozone is injected as the groundwater passes through the metal-coated soil.

Miller, whose work is reported in *Environmental Engineering and Science* (in press), successfully used this technique in laboratory tests on dinitrotoluene (DNT). He says he is not "100% sure," but it appears that ozone reacted with manganese to produce the highly reactive OH radical.

— HARVEY BLACK