In situ Chemical Oxidation for Treatment of Contaminated Groundwater

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In situ chemical oxidation (ISCO) is the delivery of a chemical oxidant to contaminated soil and groundwater to destroy target contaminants and convert them to innocuous compounds such as water and carbon dioxide. The rate and extent of the degradation of contaminants are dictated by their chemical and physical properties, including susceptibility to oxidation. Additionally, soil and groundwater conditions such as pH, temperature, and the concentration of other oxidant-consuming substances such as natural organic matter and reduced minerals, affect the degradation of contaminants. Contaminants that are amenable to treatment by ISCO are listed below.

- benzene, toluene, ethylbenzene, and xylenes (BTEX)
- methyl *tert*-butyl ether (MTBE)
- total petroleum hydrocarbons (TPH)
- chlorinated solvents (chlorinated ethenes and ethanes)
- polyaromatic hydrocarbons (PAHs)
- polychlorinated biphenyls (PCBs)
- chlorinated benzenes
- phenols
- organic pesticides (insecticides and herbicides)
- munitions (RDX, TNT, and HMX)

Currently, there are five oxidants that are used for soil and groundwater remediation and include permanganate, persulfate, peroxide, percarbonate, and ozone. Other common oxidant names that are used in industry include sodium permanganate, potassium permanganate, $KMnO_4$, sodium persulfate, Fenton's reagent, and RegenOx^{TM}. Each oxidant involves a slightly different chemistry, health and safety, and field application, and has its own advantages and limitations. Not all oxidants are capable of treating all of the contaminants listed above. For example, permanganate is not effective at treating benzene and therefore is not typically used at fuel or petroleum hydrocarbon sites.

Generally, the main benefits of using ISCO over conventional treatment technologies such as pumping include, 1) large volumes of waste material are not usually generated, and 2) treatment is implemented over a much shorter time frame. General limitations to the technology include 1) the inability to treat all contaminants in cases where a mixed plume is present, and 2) unfavorable geologic and hydrogeologic conditions that limit distribution, and therefore effective treatment.

The effectiveness of ISCO is limited by the extent of subsurface distribution and the need to establish good oxidant-contaminant contact, which is required for contaminant destruction. When the subsurface is heterogeneous or of low permeability, it is very difficult to deliver the oxidizing solution to all areas of contamination and multiple liquid injections are generally required to achieve treatment goals. In low permeability aquifers, distribution can be enhanced by chemical diffusion.

Implementation of a chemical oxidant is typically accomplished through injection of a liquid reagent, or gas for ozone applications. Additionally, potassium permanganate has been delivered as a solid slurry because of its low solubility. Permanent or temporary vertical wells, horizontal wells, temporary direct push boreholes, and hydraulic fractures have been used to apply oxidants. Injection can be achieved using gravity feed, or applied pressure. Regardless of which injection system is used, multiple application events separated by periods of groundwater monitoring are typically required due to the disruption in the mass balance of the sorbed and dissolved contaminant phases in groundwater.