

USING BATCH- AND PILOT-SCALE TESTING TO IMPROVE DESIGN OUTCOMES FOR THE IN SITU CHEMICAL OXIDATION AND ENHANCED AEROBIC BIOLOGICAL DEGRADATION OF BENZENE AND ATRAZINE

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Background/Objectives:

Persistent low-level concentrations of benzene and atrazine (i.e., approximately 5 micrograms per liter [$\mu\text{g/L}$] greater than the Maximum Contaminant Level [MCL]) downgradient from a former agriscience manufacturing facility require treatment. A microcosm study was developed to evaluate the feasibility for in situ treatment of benzene and atrazine in the saturated zone. The primary objective of the study was to determine the most effective remedial approach for both compounds from a range of amendments and aerobic and anoxic remedial processes including enhanced biological degradation and/or in situ chemical oxidation (ISCO).

Approach/Activities:

A microcosm study was completed to evaluate and compare several potential oxygen-releasing amendments, including calcium peroxide (CaO_2), hydrogen peroxide (H_2O_2), and Klozur®CR (mixture of Klozur®SP [alkaline activated sodium persulfate] and PERMEOX®Ultra [calcium peroxide]), and anaerobic biodegradation, including enhanced microbial sulfate reduction with calcium sulfate (CaSO_4) or co-metabolically with CaSO_4 plus emulsified vegetable oil (EVO). Microcosms were prepared with soil and groundwater collected from the downgradient plume and spiked with the target compounds to provide starting concentrations representative of historical in situ conditions while providing a starting point sufficient to demonstrate degradation. Select geochemical parameters were analyzed to understand their potential impact and ensure they were addressed in the design of the study; for example, soil oxygen demand was taken into consideration in determining appropriate test doses of aerobic amendments. Unamended microcosms were prepared to provide a point of comparison and abiotic controls using sterilized soil were prepared to account for potential changes not attributable to biodegradation.

Results/Lessons Learned:

All aerobic treatments (Klozur® CR, calcium peroxide, and hydrogen peroxide) were highly effective for reducing benzene concentrations in microcosms relative to untreated controls. Calcium peroxide and hydrogen peroxide were also effective at degrading atrazine, but not nearly as effective as Klozur® CR. Anoxic amendments including calcium sulfate alone and augmented with EVO were somewhat effective at degrading benzene and were not effective to any significant degree for degrading atrazine. Klozur® CR was the most demonstrably effective amendment for degrading both benzene and atrazine. Based on manufacturer information, Klozur® CR incorporates both a slow-release oxygen compound to enhance biodegradation as well as persulfate to act as a chemical oxidant. Based on monitoring performed during the study, the pH of the microcosms prepared with Klozur® CR was maintained at biologically-optimum levels. However, the degree of degradation attributable to biological degradation versus chemical oxidation was not definitively determined in the study, as the results of Quant Array Petro analysis did not definitively indicate the presence of a microbial community capable of aerobically degrading benzene and/or atrazine. The most effective amendment tested in the batch study was selected for the pilot study, which was designed to determine the amendment injection approach and evaluate the treatment efficacy of benzene and atrazine in groundwater at low-level concentrations using the combined approach of ISCO and enhanced aerobic biological degradation. The pilot study was designed with Klozur®CR and will be implemented in 2025. Lessons learned during the implementation of the pilot and performance monitoring results will be presented at the conference.

About The Author

Dr. Leslie is the Technical Director for Environmental Remediation, managing a team of approximately 30 geologists, scientists, and engineers. She has provided technical guidance and leadership as the Technical Lead at numerous government and private sites. Dr. Leslie is a subject matter expert in environmental remediation, with experience at sites with non-aqueous phase liquids, dissolved organics, dissolved inorganics, mine waste, and emerging contaminants such as 1,4-dioxane and PFAS. Her work leverages an interdisciplinary academic and research background in geochemistry, microbiology, geology, and engineering in the development, design, and implementation of innovative remedial strategies. Dr. Leslie holds a doctorate in biogeochemistry from the University of Kansas and a bachelors of geological engineering from Queen's University.

