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Practical Review and Guidance on 1,4-Dioxane Field-Scale Biodegradation Potential and Characterization

Dora Chiang, Ph.D., P.E (AECOM, Atlanta, GA, USA)
Claudia Walecka-Hutchison, Ph.D. (CWaleckaHutchison@dow.com) (The Dow Chemical Company, Midland, MI, USA)

Background/Objectives. Biodegradation potential of 1,4-dioxane has been evaluated since the early 2000s. A large-scale 1,4-dioxane plume which likely underwent natural attenuation was first documented in 2008, but this case study raised questions as to the attenuation mechanisms and the biological evidence of such attenuation. Research and development of 1,4-dioxane biodegradation in laboratory settings has exponentially increased to evaluate rates under different environmental conditions, microbial populations, and concentration levels. Recently, natural attenuation potential was documented based on the U.S. Air Force and California Geotracker data's statistical review. A series of molecular biological tools (MBTs) to confirm degradation potential have also been developed to help verify 1,4-dioxane biodegradation occurrence. However, engineered field applications attempting to duplicate the success of microcosm studies are extremely limited. With all these developments and lack of field-based case studies, in-situ biodegradation of 1,4-dioxane is still considered "conceptual". The lack of technical guidance on when, where and how to consider 1,4-dioxane biodegradation also drives the conservancy of implementing the approach. This paper intends to summarize the latest developments on demonstrating 1,4-dioxane biodegradation and to provide preliminary guidance on selecting field parameters and tools to validate 1,4-dioxane biodegradation based on site specific data evaluation.

Approach/Activities. The authors selected ten 1,4-dioxane sites with more than 5 years of dioxane monitoring datasets to screen against environmental conditions that are favorable for 1,4-dioxane biodegradation. A couple of promising sites were selected to go through comprehensive microbial characterization with MBTs and isotopic tools. The results were used to correlate 1,4-dioxane degradation trends and to guide the selection of the most relevant field parameters, microbial and isotopic tools for confirming 1,4-dioaxne biodegradation potential at field scale.

Results/Lessons Learned. The collected data will fill in the following knowledge gaps:

- Case studies assessing and demonstrating 1,4-dioxane plume stability
- Geochemical indicators to characterize attenuation of 1,4-dioxane
- Usefulness and applicability of MBTs for evaluating 1,4-dioxane biodegradation
- Cost and technology benefits of treating CVOCs and 1,4-dioxane concurrently or sequentially
- Feasibility of MNA for 1,4-dioxane

MBTs and compound specific isotopic tools have changed the way for researchers to confirm degradation mechanisms and for practitioners to optimize treatment systems. This paper summarizes the current tools and evidence available for confirming 1,4-dioxane biodegradation. Biological treatment and attenuation continue to be considered as a promising remedial option to reduce social, economic and environmental risks associated with the releases of 1,4-dioxane.