INTEGRATED TREATMENT OF 1,4-DIOXANE IN GROUNDWATER USING ENHANCED AEROBIC BIOREMEDIATION AND PHYTOREMEDIATION TECHNOLOGIES

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Background/Objectives:
Shallow groundwater at a former warehouse site has been impacted by 1,4-dioxane due to historical wastewater discharges from pack parts cleaning operations. Initial concentrations of 1,4-dioxane reached as high as 60,000 micrograms per liter (µg/L). While source mass removal and a pilot phytoremediation system installed in 2007 reduced concentrations to 11,000 µg/L by 2021, the rate of contaminant decline and mass flux reduction remained slower than desired. The project team initiated an expanded pilot study to enhance natural attenuation processes and integrate engineered remedies, leveraging the naturally-occurring microorganism, *Pseudonocardia dioxanivorans* BERK-1, which is capable of aerobic metabolic biodegradation of 1,4-dioxane.

Approach/Activities:
The expanded pilot study included the installation of an engineered aeration trench across the 1,4-dioxane plume core to introduce atmospheric oxygen into the subsurface, stimulating microbial biodegradation. The trench featured slotted air sparge wells and a sand-and-gravel backfill, and in situ sensors for real-time monitoring of oxidation-reduction potential (ORP) and water levels. A TreeWell® phytoremediation system was installed downgradient of the aeration trench to enhance mass removal of 1,4-dioxane and to provide hydraulic control downgradient of the aeration trench. This phytoremediation technology enables trees to target, extract, and treat groundwater from the deeper anoxic saturated zone and enhances natural biodegradation in the rhizosphere. The combined system aims to minimize plume migration and accelerate contaminant mass removal. Analyses including microbial adenosine triphosphate (ATP) assays, quantitative polymerase chain reaction (qPCR) targeting 1,4-dioxane degraders, and compound-specific isotope analyses (CSIA) and supporting laboratory studies were conducted to evaluate natural attenuation processes and the relationship between oxygen availability, microbial activity, and contaminant degradation.

Results/Lessons Learned:
Preliminary site characterization results indicated that naturally occurring aerobic biodegradation of 1,4-dioxane is limited to the shallow, oxic portion of the aquifer, with deeper anoxic zones requiring engineered enhancements to stimulate bioremediation. Early lessons highlight the importance of optimizing oxygen distribution, integrating monitoring tools, and tailoring system designs to site-specific conditions. The combined approach is intended to significantly reduce source area contributions, enhance natural attenuation downgradient, and accelerate overall remediation timelines. Data on system performance, tree growth, groundwater monitoring, and lessons learned from initial operations will be presented. The significance of this project is the novel application of an engineered aeration trench for enhancing in situ aerobic biodegradation of 1,4-dioxane, employed in combination with established phytoremediation methods.

About The Author

Kristi Diller is a Principal Member of Technical Staff for Parsons, based in Colorado. She holds a B.S. and M.S. in Geological Sciences from the University of Idaho and Arizona State University, respectively, and is a registered geologist in California, Oregon, and Wyoming. She has over 19 years of environmental consulting experience concentrated in site characterization and remediation, specifically in-situ groundwater remediation. In recent years, her work has focused on emerging contaminants including 1,4-dioxane and PFAS.