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In Situ Treatment of Chlorinated Volatile Organic Hydrocarbons by Fracture-Emplacement of a Micro-Iron/Carbon Amendment

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An in situ pilot remediation project was carried out on behalf of the US Army Corps of Engineers (Omaha District) at the F.E. Warren Air Force Base (AFB) Former Atlas "E" Missile Site No. 12 (Atlas 12) in Colorado, that featured an innovative application of drilling, treatment, fracture-emplacement, and geophysical technologies to mitigate impacts from chlorinated volatile organic hydrocarbons.

The former missile site complex is located outside of Windsor, Colorado, and is underlain by silty sandstone bedrock sediments impacted by trichloroethene (TCE) exceeding 2,000 micrograms per liter (µg/L) and associated volatile organic hydrocarbons. The origin of the chlorinated aliphatic hydrocarbons was from operational disposals of TCE during 1960-1965. The purpose of the Pilot Test was to evaluate the performance of technologies prior to developing the proposed remedy. Two pilot test areas (source area and dissolved plume area) were selected to evaluate the effectiveness of biotic and abiotic in situ chemical reduction (ISCR) for reducing trichloroethene concentrations to less than maximum contaminant levels (MCLs).

The pilot work involved the emplacement of over 100 tons of a micro-iron/complex carbon treatment amendment ("EHC") into deep bedrock sediments to attain optimal distribution throughout the contaminant plume, including underneath the former Launch and Service Building. A total of 206,000 lb. of EHC amendment was emplaced at 9 locations within the pilot test areas. Hydraulic fracturing was conducted in pre-drilled boreholes to deliver the amendment slurry at 5 ft. increments between depths of 35 ft. to 55 ft. in bedrock. Between 6,000 lb and 32,000 lb of micro-iron/carbon amendment was emplaced at each borehole by mixing it as a biodegradable, linear protein gel slurry to carry the amendment in a uniform suspension. Upwards to 6,400 lb. of the treatment amendment was delivered in each fracture in this manner. Tiltmeter geophysics was used to verify the final distribution and geometric configuration of the micro-iron fractures placed. Field observations and tilt response showed that the radius of fracture-emplacement in the bedrock was upwards to 60 ft., with a typical fracture overlap of 30 to 50%.

Following placement of EHC into the subsurface environment, a number of physical, chemical and microbiological processes combine to create very strong reducing conditions that stimulate the chemical and microbiological dehalogenation of chlorinated hydrocarbons. Groundwater quality monitoring is underway to evaluate groundwater redox conditions, longevity of EHC amendment, geochemical parameters, contaminant and degradation byproducts, and microbial quantification of Dehalococcoides to determine the viability of the native microbial populations and evaluate if a bioaugmentation approach may be beneficial.

Mr. Gordon Bures, P.Eng., M.Eng.
Gordon is a professional engineer and a Principal at Frac Rite Environmental Ltd. based in Calgary, Alberta. He earned a Bachelor of Science Degree in Geological Engineering at the University of Manitoba in 1985, and a Master of Environmental Engineering Degree at the University of Alberta in 1993.

Gord is an experienced practitioner in the in situ design and implementation of remediation systems at contaminated industrial and commercial sites across Canada, the USA, Europe, and Africa. For the last fifteen years, he has specialized in the enhanced remediation of low permeability soils using soil hydraulic fracturing and amendment delivery techniques. Gord is developing applications of fracture-enhanced bioremediation and in situ chemical oxidation with vendors and consulting partners, and is a co-patent holder of the BIO FRAC™ process.

Ms. Joanna Moreno, PHG.
Joanna has more than 25 years of experience in using mathematical models to optimize groundwater remedial designs and resource management for industry and government projects worldwide. She co-authored the John Wiley book: A Practical Guide to Groundwater and Solute Transport Modeling. She provides groundwater-related remediation design analyses and modeling services to support Adventus' remedial solutions and products. Joanna's areas of technical expertise include: groundwater fate and transport modeling, groundwater remediation, multiphase flow and transport, water supply modeling, and software development.