Use of Magnetic Susceptibility to Map Amendment Distribution in the Subsurface

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It has been said that one of the challenges of in-situ remediation is that "it's dark underground". We inject various remedial amendments into the subsurface and often have limited means to assess where they go, despite the fact that amendment distribution can have a major impact on remedial performance. It is critical to document that amendments are going where we expect them to go.

***Figure 1**: EHC® injection process with injection rod shown in the foreground and mixing unit with a pallet of EHC® in the background.*

OBG is tackling this challenge by applying a novel method to determine the distribution of one particular amendment. EHC® is a solid amendment that combines a plant-based carbon source with microscale zero valent iron (ZVI) to support both biological and abiotic degradation of chlorinated ethenes. OBG employs this amendment in less permeable soils (e.g., silts and clays) where injection of soluble electron donors is problematic. The EHC® can be injected using a number of techniques, including direct injection or hydraulic or pneumatic fracturing.

Regardless of the injection approach, it is important to evaluate the distribution of the amendment in the soil. OBG uses magnetic susceptibility (MS) measurements for this purpose. Ferromagnetic materials like ZVI have very high values of MS, a property that is commonly measured in investigations of earth materials. MS measurements are highly sensitive, quantitative, objective, and easily applied in the field using hand-held MS sensors/meters that are commercially available for purchase or rental (Arnason, et al., 2014).

Figure 2: *MS measurements being obtained on soil core.*

OBG recently used MS measurements to map the distribution of EHC® obtained during a pre-design pilot study at an industrial facility with clay-rich overburden soil impacted by chlorinated ethenes. The purpose of the work was to determine an appropriate injection spacing for the full-scale design.

EHC® injections were performed at seven locations on 10-foot centers using a direct injection process **(Figure 1)**. At each location up to four EHC® injections were performed at discrete depth intervals from 6 to 15 feet below ground surface. Injection pressures varied from 250-600 psi to force the EHC® slurry into the formation. Nine soil cores were obtained in PVC sleeves at various distances and directions from the injection points.MS measurements were collected in 2-inch increments on two sides of each soil core using a hand-held MS sensor **(Figure 2)**. Each measurement took less than 5-minutes. Calibrations standards were prepared in the field to relate MS measurements to known EHC® concentrations in soil from the site.

The MS measurements demonstrated that the direct injection technique utilized during the pre-design pilot study resulted in consistent EHC® distribution 5 to 7 feet from the injection points, indicating the 10-foot injection spacing is appropriate for this site **(Figure 3)**. This information is being used to design the full-scale injection program.

REFERENCES

Arnason, J.G., Harkness, M., Butler-Veytia, B., Evaluating the Subsurface Distribution of Zero-Valent Iron Using Magnetic Susceptibility, Groundwater Monitoring Remediation, 34(2): 96-106, 2014.

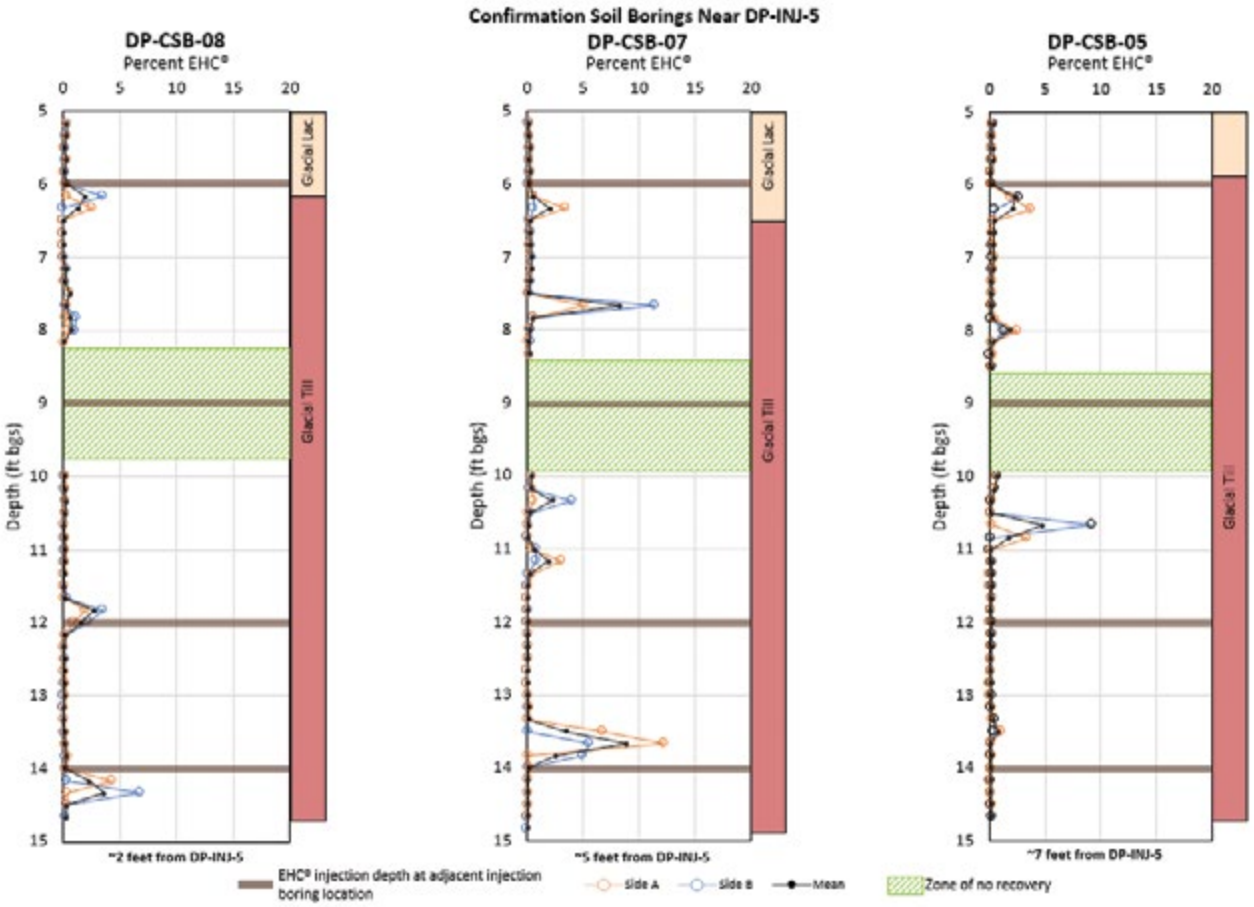

Figure 3: *Example MS measurements in three soil cores. DP-CSB-08 was obtained adjacent to injection location DP-INJ-5. Actual injection intervals in DP-INJ-5 are also shown. DP-CSB-07 and DP-CSB-05 were obtained five and seven feet from the injection location, respectively.*

About Mark Harkness:

Mark is a leader in remediation project design and management with extensive experience implementing a wide range of innovative, pragmatic, and cost-effective remedial technologies to address petroleum and chlorinated solvents in soil and groundwater.
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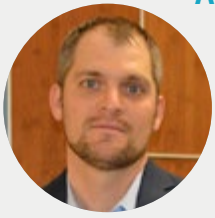

About Paul Freyer:

Paul is a professional geologist experienced in remedial investigation, site characterization, and bioremediation. Over his 12 year career, Paul has assisted clients through remedial and design investigations and has recently been involved with the design and implementation of several bioremediation pilot tests on chlorinated solvent impacted sites. Paul can be contacted at Paul.Freyer@obg.com.

About Luke Reusser, PhD:

Luke joined OBG following completion of his graduate work in geomorphology and geohydrology at the University of Vermont, focusing on quantifying human impacts on rates of landscape erosion. Luke has experience with various site characterization methods and has worked on bioremediation pilot tests that will support remedial design to address chlorinated solvent soil and groundwater impacts at a site in New York State. Luke can be contacted at Lucas.Reusser@obg.com.