HIGH-ENERGY INJECTION IN GLACIAL GEOLOGY: PERMEABLE REACTIVE TRANSECTS FOR TREATMENT OF HEXAVALENT CHROMIUM

ABSTRACT

Historical industrial processes resulted in hexavalent chromium impacts to soil and groundwater at a former manufacturing facility in the Northeast United States. Groundwater remediation was conducted as part of several environmental remedies for various sections and depths at the site, including soil excavation, soil mixing, pump and treat, and in situ chemical reduction. For several areas within the lower overburden groundwater plume, as an interim remedial measure (IRM), installation of a viscous slurry reactant (FerroBlack®, a mackinawite structured iron sulfide) was chosen to reduce hexavalent chromium to trivalent chromium.

Here, a viscous slurry was installed in a silty-sand unit and a glacial till unit at significant depth without using soil mixing or hydraulic fracturing. This transect application was a contemporary modification to conventional source treatment and permeable reactive barrier (PRB) options and was preferred for this phase of the project compared to other alternatives, such as excavation and direct mixing.

PROJECT SNAPSHOT

- **Key Dates**
  - Soil and Groundwater Sampling, Evaluation, and Bench Scale Testing: 2019-2020
  - GeoTAP: September to October 2021
  - Triplex Injections with FerroBlack: October 2021
- The impacted groundwater was measured between 8 and 13 feet bgs, residing within silty sands, sandy silts, fine- to medium-grained gravelly sands, and sandy gravels
- **Lithology:** Silty sand overlain by varved sands, silts, and clays; underlain by gravelly silt (glacial till)
- **Depth to Groundwater:** 8 feet below ground surface (ft-bgs.)
- **Contaminant:** Hexavalent chromium, up to 10 mg/L (pre-injection baseline)

CHALLENGES & OBJECTIVES

Due to the heterogeneity of the overburdened soil unit, it had been difficult or impossible to access various geologic zones of the site with commonly available direct push technology (DPT). Compounding access issues at depth, glacial till and fluvial glacial outwash units were pervasive at the site. Specifically, the targeted groundwater treatment intervals typically comprised some part of each unit, and the unit varied in thickness and depth, typically thickening and/or plunging moving westward.

To concisely target this zone, a sequential combination of drilling methods, soil logging, and an engineered borehole backfill process known as GeoTAP™ allowed environmental practitioners to target and treat this zone using DPT injection and FerroBlack.

APPROACH

The remedial design characterization (RDC), which evaluates soil and groundwater mass and mass flux, indicated that a significant mass of reactant was needed to construct reactive transects in the phreatic zone. This was predicated on a minimum 30-year lifespan for these reactive transect—approximately the time it would take the most upgradient, impacted groundwater to reach the transect and react with the injectate. The RDC process was critical to calculating the necessary FerroBlack loadings to install at each transect.

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APPROACH (CONTINUED)

Site geology precluded traditional DPT from being utilized for injection due to dense silty sands, gravels, and glacial till at depth. An innovative proprietary drilling and injection process (GeoTAP) was used to access targeted depths. This process also provided a complete vertical soil profile, which determined succinct top and bottom injection spans for each injection point within the transect, as the geologic interval varied laterally across each transect.

Injection locations were installed using roto-sonic ("sonic") drilling technology, which allowed for expeditious advancement of borings. After logging and photographing the soil to target depth at each location, the evacuated borehole was backfilled in lifts with an engineered hydrated bentonite blend to prepare the borehole for high-energy injections.

Depending on the location and product loading, injection point spacing was determined by the transect-specific groundwater flux (from the RDC) and injectate slurry loadings. The spacing of injection points was typically 15 to 30 feet apart, depending on product loading.

INJECTION

Sonic drilling and backfill activities took five weeks to complete and were conducted with a four-week lead time over injection activities. To deliver injectate, a DPT rig was used to drive 2.25" injection rods, fitted with a geology-specific injection tip, through the bentonite column to the targeted injection interval (typically 30 to 70 ft-bgs). Installation was completed using a custom high-flow/high-energy Triplex injection system capable of flow rates up to 280 gallons per minute (gpm) and sustaining injection pressures as high as 2,000 pounds per square inch gauge (psig).

Approximately 34,600 gallons of FerroBlack were installed across five transects, totaling 2,340 linear ft (lf), during four weeks of injection activities. Injectate distribution was assessed by placing pressure transducers in existing monitoring wells and temporary wells (installed specifically for the injection event) and by monitoring changes in groundwater geochemistry using these same sentinel wells. Colorimetric evaluation was also simple, as the FerroBlack product is a dark gray color; groundwater samples showed visual influence as further evidence of product distribution. Using these groundwater monitoring techniques, field emplacement of material was affirmed successful in creating the transect design. Currently, groundwater monitoring continues at the site to observe performance.