# DPT Jet Injection for Remediation in Clay Till: Full-Scale Case Study Results from over 3 Years of Treatment

***Chapman Ross*** (cross@geosyntec.com) and Dylan Eberle (Geosyntec Consultants, Acton, MA, USA), Neal Durant (Geosyntec Consultants, Washington, DC, USA), William Slack and Drew Baird (FRx, Inc., Cincinnati, OH, USA), Torben Højbjerg Jørgensen and Eline Begtrup Weeth (COWI A/S, Odense, Denmark), Peder Johansen (Capital Region of Denmark, Hillerød, Denmark)

**Speaker Bio:** Chapman Ross is a senior remediation engineer with Geosyntec Consultants in the Boston, Massachusetts area. Mr. Ross has 17 years of experience in in situ remediation design and technology development. His practice is focused on innovative remediation methods, including advanced treatment methods for low-permeability formations, and novel data visualization tools such as 3-D printed conceptual site models.

**Background.** Direct-Push Technology Jet Injection (DPT-JI) is an amendment delivery method that was developed to overcome the challenges of treating chlorinated solvents in low-permeability formations. This novel injection method combines high pressure jetting (10,000 psi) and controlled hydraulic fracturing for emplacement of amendments into geologic matrices where remediation is limited by contact between reagents and solvents trapped in the matrix. A former industrial facility in Nivå, Denmark (the Site) was impacted with chlorinated volatile organic compounds (CVOCs) in clay till over approximately 750 $m^2$ and 6 to 12 meters below ground surface. Trichloroethene (TCE) is the primary contaminant of concern, with baseline (pre-treatment) soil concentrations as high as 83 mg/kg. Following the demonstration of controlled emplacement of 49 tonnes of zero valent iron (mZVI) into the TTZ for chemical reduction of CVOCs in November 2014, a 5-year performance monitoring program was initiated to evaluate treatment over time. Here we present the results of soil and groundwater sampling conducted over the first three years of this program.

**Methods.** Progress toward treatment of CVOCs in the TTZ has been documented with groundwater monitoring every 6 months, soil sampling every 12 months, and 2 membrane interface probe (MIP) investigations. Groundwater sampling events have included analyses for CVOCs and degradation products (e.g., ethane, ethene). Soil and groundwater data have been incorporated into a 3-D model of the TTZ using Environmental Visualization System (EVS) software. EVS was used to calculate the total CVOC mass in soil and groundwater within the TTZ. The mass of CVOCs in groundwater discharging from the TTZ was calculated using the transect method.

**Results.** Strongly reducing conditions have been observed within the TTZ throughout three years of groundwater sampling events. After 30 months, the estimated mass of TCE in TTZ soils decreased by approximately 92% from 29 kg to 2.3 kg, and the total CVOC mass in soil decreased by 82% over the same period. Groundwater data from 36 months post-injection indicate that the total CVOC mass discharge from the TTZ has decreased by over 89%. After 30 months, up to 7.8 mg/L of ethane was detected in groundwater and the total estimated mass of ethane and ethene in TTZ groundwater (6.8 kg as TCE) was found to be higher than the remaining total chlorinated solvent mass (5.5 kg as TCE). These findings demonstrate complete in situ degradation of TCE throughout the TTZ. Although 1.5 more years of performance monitoring are planned, findings to date show that remediation amendments delivered using DPT-JI can achieve significant degradation of chlorinated solvents in low-permeability soils that are largely inaccessible to conventional injection technologies. The next soil and groundwater sampling event will be performed in June 2018, and these 3.5-year post-injection results will be presented.