

In situ groundwater treatment is experiencing rapid growth at contaminated sites, so consultants, environmental engineers, hydrogeologists, and regulators must not only stay abreast of emerging remedies, they must strive to objectively select the most natural and cost-effective solutions available.

# In situ bioremediation technology tested in Northern Italy

The famous Italian natural philosopher and mathematician, Galileo Galilei (1564-1642) wrote in his diary that “All truths are easy to understand once they are discovered; the point is to discover them.” Oftentimes, in the science of environmental remediation it can be difficult to navigate the best path forward in a noisy environment of competing technological claims. For this reason, the environmental engineering firm TRS Servizi Ambiente S.r.l. of Turin, Italy, carried out laboratory and field tests to determine the effectiveness of In Situ Chemical Oxidation (ISCO) and In Situ Chemical Reduction (ISCR) bioremediation technologies for severely polluted groundwater at an operating petrochemical facility in Northern Italy, before implementing a full-scale, remediation course of action. Adventus Europe and TRS collaborated on the design of these tests.

Groundwater and soil on the site is contaminated with high concentrations of 1,2-dichloroethane (1,2-DCA;  $C_{max} = 11,000$  mg/L,  $C_m = 300$  mg/L) and vinyl chloride (VC;  $C_{max} = 130$  mg/L,  $C_m = 0.5$  mg/L). These substances are distributed in an area of about 7,000 m<sup>2</sup> and affect a thickness of 7 to 13 meters. The primary contamination source zone is located next to an old, deteriorated process water tank (cracking of 1,2-DCA to VC) that caused significant pollution. The remediation system was divided into two phases because of the high degree of contamination. Pump-and-treat technology is used to remove free-phased product to reach the average values found in the area. The second (and final) phase includes use of EHC®, a patented ISCR™ technology, in order to reach the Italian regulator's Site Specific Target Levels (SSTL) for the entire area.

A series of rigorous laboratory and field tests led to technology selection and final planning for the second remediation phase. ISCO and ISCR were considered during the laboratory-testing phase. For ISCR, EHC (www.adventus.eu) was used, which is an innovative formulation of zero-valent iron and natural sources of organic carbon. The laboratory tests focused on the reagents selected to assess their efficiency, establish optimal rates, and determine their effects on the site's geochemical conditions. For each test representative samples of soil and groundwater were taken directly from the contaminated site through the use of direct push equipment (Geoprobe®), characterized, and homogenized in the laboratory. The test related to chemical oxidation was divided into two distinct phases. The first phase was carried out on uncontaminated water coming from the site, in order to calculate the Soil Oxidant Demand (SOD), which is the amount of oxidant consumed from soil matter and therefore not available for the degradation of contaminants dissolved in the aqueous phase. In the second phase, the contaminated soil and groundwater were treated using the reagent amount calculated on the base of previously measured SOD, and of the Stoichiometric demand related to the maximum contaminants' concentration.

The relatively longer reaction time required for ISCR made it practical to conduct the tests in a single phase, performed on a sample of saturated matrix taken from the site. Adventus assessed the optimal dosing of the reagent on the basis of site geochemical characteristics and profile of contaminants on site. For the field test, a specific area of about 50 m<sup>2</sup> was selected, considering that it should be representative of the overall site con-

ditions. EHC was injected throughout the targeted using direct-push technology and four monitoring wells were placed to monitor water quality.

## Test results

The first phase of laboratory testing for chemical oxidants demonstrated that in the presence of sodium persulfate (with activator), the concentration of all contaminants in the water and soil dropped quickly to reach values close to the SSTL concentrations.

During the next phase of laboratory tests for sodium persulfate, it was observed that the use of alkaline activation (NaOH) led to a solubilization of some metals, and in particular to the oxidation of Cr (III) to Cr (VI); a contaminant very soluble in water and not naturally present in the site groundwater. Additional tests were carried out using different doses of reagent and activator to identify the optimal amount and ratio of reagent/activator, and to ensure oxidation of COI while minimizing the solubilization of metals, especially oxidation

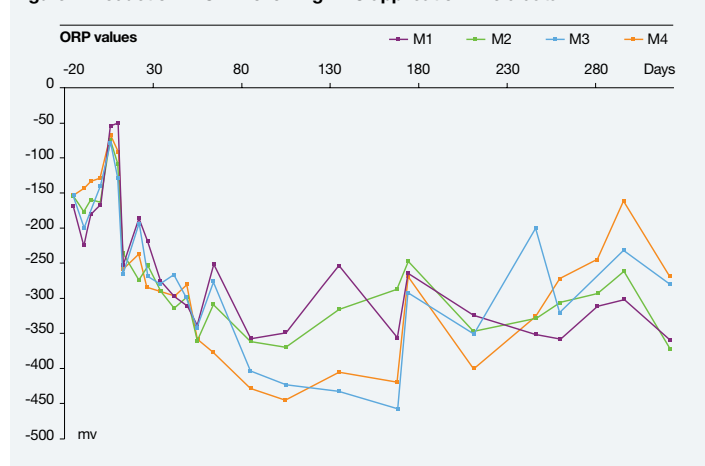
# 50

The specific area (square meters) that was selected for the field test considered to represent the overall site conditions.

# 21

The amount (tonnes) of EHC that will be injected during Phase 1 of the full scale implementation.

Figure 1: Reduction in ORP following EHC application - field data.



**Laboratory tests using EHC were carried out in a single phase, during which a sample of site soil and groundwater was treated for a period of 60 days.**

of Cr (III) to Cr (VI). The results of these tests showed that using just the reagent, without the activator, provided the best efficiency of the treatment with the least release of metals in water.

Laboratory tests using EHC were carried out in a single phase, dur-

ing which a sample of site soil and groundwater was treated for a period of 60 days. Intermediate samplings showed that the concentration of 1,2-DCA was greatly decreased after only 15 days, and that it achieved values near the analytical detection limit of at the end of the 60-day test. Also the last gas analysis collected during the test showed significant microbial activity and offered supporting evidence for the complete mineralization of the target contaminants without the accumulation of catabolic intermediates.

**Field scale testing of ISCR™ technology**

Laboratory tests showed a comparable efficiency between persulfate ISCO and EHC ISCR; however EHC was selected for field scale evaluation for several reasons:

- Lower geochemical impact on soil and groundwater conditions;
- Significant enhancement biogeochemical reduction;
- Longer time of reagents' persistence in groundwater/extended reaction time;
- Ease of application without any health and safety issues;
- And no potential for generation of secondary plumes or contaminants (mobilization of heavy metals).

Accordingly, 6,300 kg of EHC was

emplaced via nine injection points distributed within the 50m<sup>2</sup> area (700 m<sup>3</sup> soil). The EHC reagent was provided as a fine, dry powder that was mixed with site water to yield a slurry containing about 30% solids, which was subsequently injected in a bottom-up manner ( i.e. starting from the deepest point and progressing upward). An Adventus representative provided on-site technical support during the injection work.

Before injection, three monitoring campaigns were completed to evaluate average contamination levels in the area and to analyze main chemical-physical parameters. Subsequent monitoring of field data showed a significant decrease in ORP value (from -150 mV to -300mV) post EHC injection (Figure 1), which is indicative of a highly reducing environment.

The monitoring of other chemical parameters also showed positive results attributed to the addition of EHC. Most notably, after 300 days from the time of EHC injection nearly all groundwater samples collected from within the treated area showed concentrations lower than the respective remedial goals. Furthermore, VFA (volatile fatty acid) values higher than 100 mg/L were detected, as a natural by-product of organic carbon fermentation (organic carbon can be used by indigenous microorganisms

as an electron donor to further aid longer term COI reductions).

**Moving forward**

Engineers from Adventus Europe and TRS Servizi Ambiente are working on the design of full-scale site remediation using the EHC In Situ Chemical Reduction process for enhanced natural attenuation. Simultaneously, continued monitoring of the field site remains ongoing to verify effective reagent life and document lack of rebound, which is typical for many other remedial technologies. Full-scale implementation will employ 600 to 700 tonnes of EHC to treat an area measuring 7,000 m<sup>2</sup> and is planned for 2009 through 2011. Phase I of the full scale implementation will start before the end of 2009, and will consist of the injection of 21 tons of EHC through 90 injection points to treat an area measuring 750 m<sup>2</sup>.

**Authors' Note**

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