Combining Strategies for Remediation of Different Gas Work DNAPL and LNAPL Groundwater Contaminants

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Background/Objectives. In the north-eastern part of central Stockholm, Norra Djurgårdsstaden has historically been a large industrial area which is now being redeveloped. The City of Stockholm engaged RGS Nordic to undertake pilot tests with several in situ methods to find viable solutions to the problem, as well as designing in situ remediations for the entire Gasworks area. The Gaswork activities have left a very complex mix of contaminants impacting the soil, groundwater and shoreline sediments. One of the more challenging problems is the contaminated groundwater at great depth down to 20 m below ground level (approximately 18 m below groundwater level).

Approach/Activities. Three sets of pilot tests were carried out during the summer of 2017 focusing on in situ chemical oxidation (ISCO), enhanced aerobic biodegradation (ENA) and enhanced desorption. For the ISCO tests RGS Nordic trialled three different oxidants (hydrogen peroxide, RegenOx® and PersulfOx®) targeting areas with high concentrations of PAH compounds. The ENA trials were focused on areas impacted with lower dissolved phase concentrations of benzene and naphthalene; ORC-Advanced® and PermeOx. For areas where gross PAH/BTEX soil impact an enhancing desorption reagent, PetroCleanze®, was applied in combination with pumping to desorb and remove contaminants from the soil. These pilot tests were performed in coarse sandy soils with gravel/bolder material, with the exception of the ORC-Advanced® pilot test which was performed in clay. All reagents were applied using direct push injection. A subsequent larger trial using PersulfOx® was completed in 2018 to further evaluate the efficacy of the full-scale ISCO works.

Results/Lessons Learned. The ENA pilot test using PermeOx in coarse soil showed >99% reduction of benzene and PAH's in groundwater. The pilot test using ORC-Advanced in clay, yielded a sustained reduction of naphthalene, but less for benzene, which then increased to baseline levels probably due to its mobility in clay and continual influx into the pilot area. PAH-M and PAH-H's were reduced by >98 %.

The enhanced desorption facilitated by PetroCleanze® pilot showed a reduction in dissolved phase benzene by approximately 70%. For the PAH's the result was less significant since the baseline concentrations of the soil bound levels were lower than expected.

The highly reactive nature of hydrogen peroxide made utilising the reagent difficult to perform on site with additional health and safety risks to site personnel. To mitigate this risk citric acid was added to the hydrogen peroxide to slow the reaction. However, this slowed the reaction down so much that the rate of remediation was negligible. RegenOx®, however, yielded an 80% reduction in benzene concentrations in the groundwater. Most of the PAHs showed increasing levels, probably due to large amounts of soil bound contamination desorbing into the ground water post treatment. The pilot test using PersulfOx yielded a >90 % reduction of benzene and PAH-Ls, e.g. naphthalene by >95 % and about an 80 % reduction of PAH16.

The combined evaluation shows that there are in situ techniques for all parts of the Gasworks site. For the full-scale remediation, a combination of techniques have been proposed, mainly ISCO and ENA. Also, for the treatment of clay, stabilization/solidification is being considered as a co-method to preserve the required geotechnical properties.