Bioremediation in a Combined Remedial Strategy for a Complex Contaminated Site with Ecologically Sensitive Receptors in Brazil

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Authors

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Background

At a chemical industry site located in the State of São Paulo, Brazil, contamination of soil, groundwater, and soil vapor by tetrachloroethene (PCE) and its daughter products (trichloroethene [TCE] and cis-1,2-dichloroethene [cDCE]) was identified at two source areas. cDCE was detected in groundwater within the main source area at concentrations up to 141 milligrams per liter (mg/L). Groundwater impacts extended to a nearby spring and river, and its associated natural preservation area, located about 200 meters (m) downgradient of the source areas. PCE and TCE concentrations were detected in soil vapor up to 6,500 milligrams per cubic meter (mg/m^3) and 1,300 mg/m^3, respectively, exceeding regulatory threshold values by 3 to 4 orders of magnitude.

Figure 1. cDCE baseline plume in the shallow level of the sedimentary aquifer

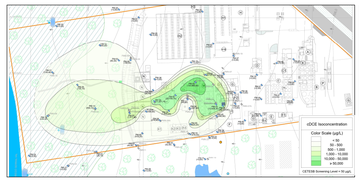


Figure 2. cDCE Baseline plume in cross-section

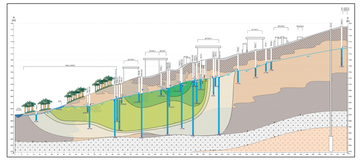


Figure 3. cDCE plume in cross-section after ~2,5 years of remediation

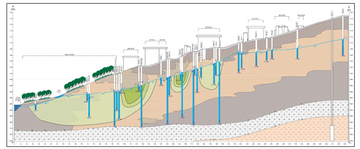
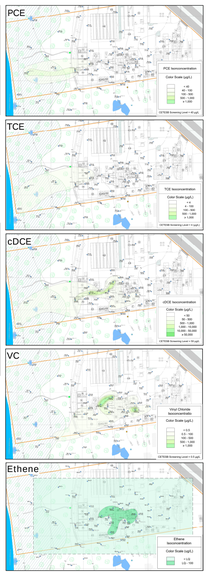


Figure 4. PCE, TCE, cDCE, VC and ethene current plumes



Intervention measures

In response to vapor intrusion risks, Ramboll installed an initial soil vapor extraction system (SVE Phase I) as an emergency measure in March 2017. The SVE system was expanded in June 2018 (Phase II) and September 2019 (Phase III).

For the protection of the spring area, a sustainable approach was adopted – the treatment system consists of a small pre-existing artificial reservoir connected to four activated carbon adsorption columns, driven by gravity (without the use of electricity).

In 2017, bench and pilot tests of in situ bioremediation (ISB), in situ chemical reduction (ISCR) and air sparging were performed at the plume edge, and an in situ chemical oxidation (ISCO) pilot test was performed in one of the hotspot areas

Excavation one of the source areas was performed in January 2019 to remove the impacted soil, when pumping and recirculation tests were also conducted.

Figure 5. SVE systems layout

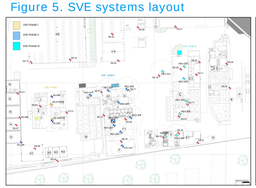


Figure 6. Full-scale remedial system layout

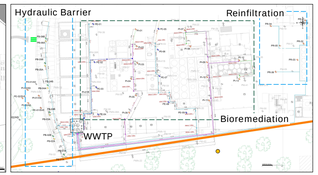


Figure 7. PCE plumes in soil vapor (baseline, after the implementation of SVE Phase I, and Phase II + Phase III)

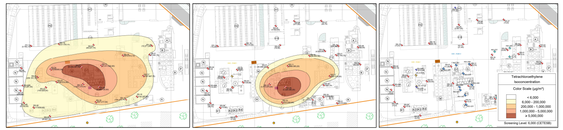
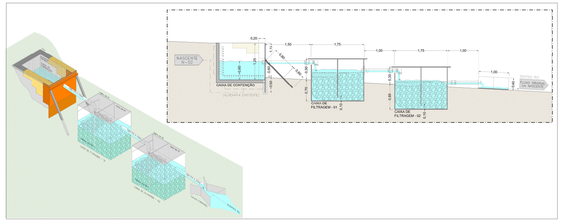


Figure 8. Spring treatment system



The results of bench and pilot tests indicated that both ISCO and ISB techniques would be feasible. Because site groundwater is predominantly anaerobic such that dechlorination product cDCE was the contaminant with the highest concentrations, Ramboll recommended ISB as the preferred remedial approach.

The operation of the full-scale remediation system started in May 2020. The system is composed of an ISB recirculating system with 9 extraction wells and 13 reinjection wells, adding 1,500 liters (L) of 5% sodium lactate solution as carbon substrate on a weekly basis; a hydraulic barrier with 12 pumping wells in order protect the river and its preservation area; a groundwater treatment plant for both the hydraulic barrier and the recirculating system; and a groundwater reinjection system with 6 wells installed upgradient of the plumes, to avoid offsite effluent water discharge.

Figure 9. Biogeochemical indicators After 1 year of remediation

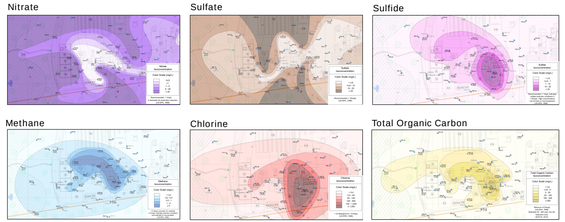
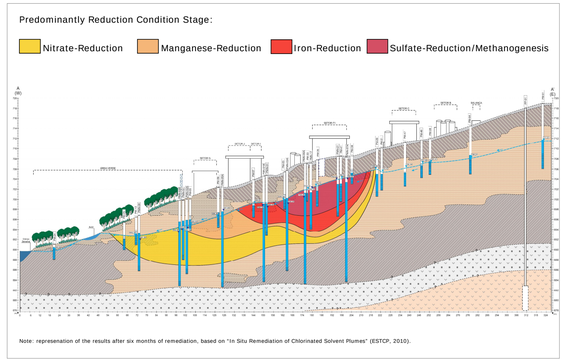


Figure 10. Representation of the biogeochemical indicators after 1 year of remediation in cross-section



Results and conclusions

- The vapor intrusion control systems provided an immediate reduction of PCE and TCE concentrations in sub-slab vapor, meeting the acceptable limits, in addition to maintaining a sub-slab minimum vacuum of 0.9 millimeters of water (mmH2O) required by the local environmental agency.
- The spring treatment system proved to be effective in contaminant adsorption and, since its installation, the spring has met applicable regulatory standards.
- After two years of ISB operations, PCE and TCE are almost no longer detected in the industrial area groundwater and have achieved remediation goals. Based on the most recent groundwater sample results, dechlorination product vinyl chloride (VC) is present in 3 wells above the remediation goal.
- Terminal product ethene was detected throughout the treatment area after only one year of operations, where the prevalence of ISB-induced sulfate reducing, and methanogenic conditions are observed.
- Water level monitoring confirmed that the hydraulic containment induced by the hydraulic barrier is preventing the migration of contaminants to the preservation area.
- Post-injection groundwater monitoring data interpretation will be presented, along with discussions of rationales regarding injection approaches and next steps.

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