Biodegradation of a Chlorinated Solvent Plume Enhanced by Reducing Chemical Conditions beneath a Former Landfill

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Background/Objectives.
Burns & McDonnell is conducting investigation/feasibility study/remediation of a confidential closed landfill site in California. A site investigation including the delineation of potential on- and off-site groundwater contamination sources, forensic source evaluation, and contaminant fate and transport analysis was conducted to support the development and evaluation of potential remedial options for the former landfill.

Approach/Activities.
Evidence of upgradient, off-site source(s) of chlorinated volatile organic compounds (CVOCs), the primary contaminants of concern at the site, has been generated during recent site investigation efforts. This evidence includes TCE (trichloroethene) concentrations of up to 2,600 ug/L, the highest concentrations reported at the site, in deep monitoring wells located along the upgradient boundary of the site. These elevated concentrations are found within deeper groundwater within a confined sand unit, rather than in the uppermost groundwater unit as would be expected for an on-site source. In addition, CVOC concentrations in the downgradient portion of the landfill, within the same aquifer unit, are far lower. This evidence prompted a detailed investigation of on- and off-site groundwater conditions to assess the presence of potential sources and evaluate contaminant transport and degradation mechanisms, including reductive dechlorination under chemically reducing conditions.

Results/Lessons Learned.
Off-site investigation results identified an upgradient source of CVOCs in groundwater at a nearby industrial site that that historically used large amounts of chlorinated solvents. The site had undergone a separate investigation and PCE (tetrachloroethene) concentrations indicative of dense non-aqueous phase liquids (DNAPL) were reported in groundwater. Concentrations of PCE and TCE in groundwater beneath the upgradient site, approximately 800 feet from the landfill, are up to 25,000 ug/L and 40,000 ug/L respectively, and 10 to 100 times the maximum concentrations found beneath the landfill.
Strongly reducing conditions beneath the former landfill create an environment that is favorable for reductive dichlorination of CVOCs. Methane concentrations ranging from 1% up to 60% by volume are commonly recorded in soil vapor above and below the waste. In groundwater beneath the landfill, dissolved oxygen concentrations (<0.5 ug/L) and ORP values (-50 to -260 mv) are favorable for reductive dechlorination.
As the CVOC plume flows downgradient within the confined sand unit beneath the former landfill, concentrations of PCE decrease from 85 to <1 ug/L, and TCE decreases from 2,600 to 57 ug/L. Concentrations of *cis*-1,2-dichloroethene, a reductive dechlorination product, also decline from 900 to 38 ug/L, while vinyl chloride (VC) decreases from 85 to 6 ug/L. The observed decreases are consistent with a reductive dechlorination model whereby the parent products (PCE and TCE) are transformed to 1,2-DCE and VC; those in turn decrease in concentration, suggesting degradation of 1,2-DCE and VC to ethene and chloride occurs, within zones that may range from moderately- to weakly-reducing conditions, as can exist beneath landfills. The presence of the former municipal waste landfill provides an ample source of

electron donors and nutrients to bacteria in the groundwater, which would facilitate a reductive dechlorination process.
The updated conceptual site model, including recognition of the upgradient CVOC source and the substantial natural attenuation of the CVOC plume as it flows beneath the former landfill, is vitally important to managing the risks and liabilities of the site effectively. Supporting evidence for the mixed plume and natural biodegradation processes will be presented.