Controlling Contaminant Migration

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In situ thermal remediation (ISTR) is a robust suite of technologies used to treat volatile and semi-volatile organic compound (VOC and SVOC) source zones. Most projects involve heating the target zone to around 100°C, a temperature at which water boils, and below which the liquid and sorbed phase VOCs efficiently transfer to the gas phase. The generated steam acts as a carrier gas, bringing the contaminant vapors to extraction wells screened across the treatment zone, where ISTR practitioners extract and treat them conventionally at the surface, usually with granular activated carbon or thermal oxidizers.

Often, source zones have complex geology and heterogeneity, making hydraulic or pneumatic capture efforts challenging (Munholland et al. 2016).

Reasonable questions include:

- What is the process that ensures complete contaminant capture?
- How is this documented?

In this paper we discuss the most important issues related to contaminant migration.

Make sure the source is properly delineated

Knowing where the contaminant mass is prior to ISTR is essential. Applying heat in a target zone will generate steam and vapors. The temperature immediately outside of the installed infrastructure (i.e., perimeter heaters, electrodes or injection wells) will increase, too. If contaminants of concern (COCs) (known or unknown) are present outside of the perimeter, some mass may move inward for extraction, while some may move outward.

Fortunately, during the installation of the subsurface components, the data density of the treatment volume increases dramatically, improving the conceptual site model (CSM). If perimeter sampling indicates high concentrations of contaminants, TRS Group (TRS) recommends advancing additional borings, thus expanding the perimeter, until encountering low concentrations.

Heaters and electrodes function as extraction wells

Using extraction well screens co-located with heaters or electrodes is a good way to minimize the risk of spreading contaminants. By applying a vacuum to each source of heat, TRS creates a preferential flow pathway for the steam and COC vapors, which is especially important in tight overburden and rock matrices. Vapor capture mechanisms in tight clay were discussed by Heron et al. (2013).

Collect data on pressure and water level gradients

Hydraulic and pneumatic control is difficult to prove; however, gradient data is useful for documenting that the overall movement of fluids is inward towards the source zone. While measuring water levels in hot environments can be challenging (it is not advisable to open a well in a hot zone), TRS has developed methods to get the crucial data. Common practice includes collecting water levels and vadose zone pressure daily or weekly.

Injecting steam at steam enhanced extraction sites

When applying steam enhanced extraction (SEE), the injected steam can travel longer distances than the in-situ steam generated by electrical resistance heating (ERH) or thermal conduction heating (TCH), increasing the risk of pushing contaminants outside of the capture zone. Further, VOCs can move ahead of the condensation/steam front and condense (Davis 1997). As discussed earlier, it is imperative to have an accurate CSM. TRS recommends placing perimeter steam injection wells 5 to 15 feet outside the non-aqueous phase liquids (NAPL) treatment zone boundary, so that the injected steam will push the COCs inward for subsequent extraction.

For sites where the perimeter of the source zone is poorly defined, TRS recommends placing extraction wells at the perimeter to minimize the risk. These outer extraction wells pull fluids in from the outside, while also extracting the hot fluids from the steam injection wells.

Provide backup systems for fluids extraction

While it is unusual to have backup power for the heating equipment, it is common practice to ensure near continuous extraction of fluids. Backup power generators with automatic transfer switches provide power to vacuum blowers and pumps when the power goes out. Spare blowers and pumps are kept ready in the event of failure of the operating components. Up-times in excess of 99% are typical.

Monitor outside the source zone

Contaminants escaping outside of the treatment region will result in an increase in soil, water or vapor concentrations. We may also see an increase in temperature. Small changes in COC concentrations can occur without a significant change in temperature; however, major escapes of heated fluids will lead to temperature increases. Temperature is easy to monitor, and you can collect data from multiple depths in real time, making temperature sensing a convenient method for scanning the perimeter. If TRS observes an unanticipated increase in temperature outside of the treatment zone, operators can make near real-time adjustments and collect discrete soil, water or vapor samples.

Plan for the unknown

As even robust characterization inevitably will have data gaps, TRS recommends contingency budgeting for finding COCs on the perimeter or outside of the treatment volume. Further, the heating and treatment system should have additional capacity to deal with an unexpected increase in the estimated load. It is common to size the treatment equipment for 10-25% extra flow capacity.

Precautions for high-risk scenarios

Some site conditions call for extra care and attention to prevent contaminant from spreading. These include:

- Fractured bedrock where fluids flow preferentially in the secondary porosity: Extraction from all heated boreholes helps ensure capture.
- Karst geology, where the voids can be difficult to locate (Beyke et al. 2014): The degree of fracturing and potential for karst features are important risk drivers. Using geophysical tools can help ensure contact between extraction wells and voids.
- Clay layer in vadose zone underlain by high permeability zone: Since the steam and vapors can migrate up and down from a clay layer, TRS recommends vapor extraction from both sides.
- NAPL in high-permeability band between tight layers: Separate extraction wells help minimize the risk of steam pressure build-up and lateral migration.
- Deep sites: When the treatment zone is thick, multiple screened sections in each extraction well improve control and capture.
- Confined aquifers: Generated vapors tend to rise in aquifers and may accumulate near the top, and if not extracted, may migrate laterally (Munholland et al. 2016). TRS recommends using dedicated extraction wells to lower the pressure locally and encourage steam and COC vapors to migrate towards them. This may include water pumping to establish inward gradients and lower pressure.
- Fast flowing aquifers: Loss of hydraulic control can lead to escape of dissolved COCs (Hegele and McGee 2017). TRS recommends using hydraulic barriers (walls or pumping wells) to minimize this risk, as implemented at East Gate Disposal Yard, Washington (US Army Corps of Engineers, 2007). Further, it may be prudent to use steam injections to heat the permeable zones, as implemented at several sites by Steamtech and TerraTherm (Heron, 2017).

As stated earlier, knowing the site well is crucial. The design of the capture system is just as important as selecting the most appropriate heating technology. With good site data and our experience from treating more than 160 sites, TRS can prevent spreading COCs with proper system design.

References

Beyke, G.L., B.A. Hodges, G.N. Jones. 2014. Electrical Resistance Heating of Volatile Organic Compounds in Sedimentary Rock. Remediation, Vol. 25 (1), Winter 2014: 53-70.

Davis, E. L. 1997. How Heat Can Accelerate In-situ Soil and Aquifer Remediation: Important Chemical Properties and Guidance on Choosing the Appropriate Technique. US EPA Issue paper, EPA/540/S-97/502.

Hegele, P.R and B.C. McGee. 2017. Managing the negative impacts of groundwater flow on electrothermal remediation. Remediation, 27, 29–38.

Heron, G., J. LaChance, and R. Baker. 2013. Removal of PCE DNAPL from Tight Clays using In Situ Thermal Desorption. Ground Water Monitoring and Remediation, 33(4): 31-43.

Heron, G. Steam Enhanced Extraction (SEE). 2017. http://erwiki.net/index.php?title=Thermal_Remediation_-_Steam.

Munholland, J.L., K.G. Mumford, B.H. Kueper. 2016. Factors affecting gas migration and contaminant redistribution in heterogeneous porous media subject to electrical resistance heating. Journal of Contaminant Hydrology, 184, 14–24.

US Army Corps of Engineers Seattle District. 2007. Cost and Performance Report. In Situ Thermal Remediation (Electrical Resistance Heating), East Gate Disposal Yard, Ft. Lewis, Washington. August 17, 2007.