TerraTherm

Sustainable Thermal Treatment of Source Zones

Low Temperature Thermal Remediation

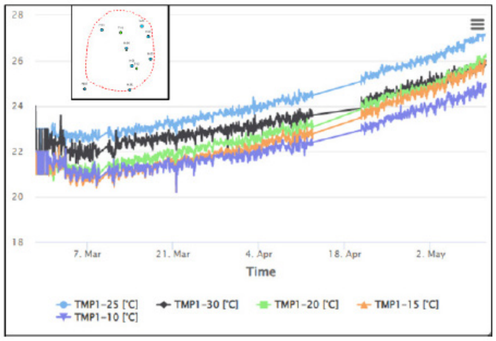
TERRATHERM
a Cascade Company

www.terratherm.com

TerraTherm

Low Temperature Thermal

Overview



Our low temperature thermal technology utilizes simple, inexpensive, and easy to install electrically powered heaters to gradually and gently heat soil and water.

We use our highly controllable low temperature thermal technology to uniformly heat the targeted soil and water to the desired temperature range to enhance the rate of biotic or abiotic chemical reactions:

- Increasing the temperature to between 35 and 40°C can result in a 4-fold increase in the aerobic and anaerobic biological reaction rates.
- Increasing the temperature to 60 to 90°C can increase abiotic hydrolysis reaction rates and reduce the half-lives for some CVOCs by 4 to 6 orders of magnitude (e.g., from a half life of 1,000,000 days to 10 days).
- ISCO, ISCR, and other chemistry-based injection technologies can also be enhanced by increasing the temperature.

Site Applications

- Petroleum Hydrocarbon Sites/Gas Stations (biotic destruction)
- CVOCs (biotic and abiotic destruction)

Considerations

- Low cost
- Small diameter heaters, 1 or 2-inch diameter
- Simple to install using direct push technologies
- Easy to install below grade
- Heaters can be operated unobtrusively 24/7
- Highly sustainable!

Learn More About

- **Integrated applications** with Cascade's injection and chemistries technologies for source zone and plume treatment
- **How to enhance performance** with our Low Temperature Thermal Technology to achieve:
  - More uniform treatment, and
  - Faster clean-up times

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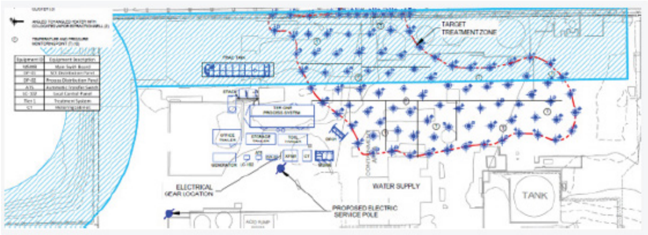
Thermally Enhanced Hydrolysis of Carbon Tetrachloride

Case Study



In late 2021, a low temperature thermal remediation (LTTR) project was completed at a site in the eastern half of the United States that focused on the degradation of carbon tetrachloride (CT) through hydrolysis, including removal of CT DNAPL. The remedial approach was to increase the subsurface temperatures in the TTZ from ambient (~10°C) to between 60 and 80°C in order to increase hydrolysis reaction rates of CT. Increasing the temperature by this amount significantly speeds up the hydrolysis reaction rates of CT by two to three orders of magnitude. As a result, the half-life of CT decreases from 60,000 days at ambient temperatures to approximately 60 days at the desired target temperatures. Importantly, by limiting temperatures in the TTZ to less than 100°C, boiling and subsequent vapor production can be avoided, which limits the need for vapor extraction and treatment.

The project remedial objectives were to remove CT DNAPL and reduce the CT present in the TTZ to a site-wide average concentration of less than 100 mg/kg, which was established to be protective of a nearby waterbody. Site conditions included silts and clays to 30 ft bgs with a water table present between 10 and 15 ft bgs. The overall treatment volume was ~8,000 cubic yards and a total of 105 low temperature heaters were installed with ~15 foot spacing. During low temperature heating, an average of 60 W/ft of energy was injected into the subsurface over the length of each heater. After nearly 150 days of operations, the TTZ averaged a temperature of 68°C with temperatures ranging between 47 and 85°C depending on depth.

Prior to the application of low temperature thermal, a total of 45 soil samples were collected that indicated concentrations of carbon tetrachloride within the TTZ ranged between 102 and 144,000 mg/kg with an average concentration of 4,393 mg/kg. Following the application of low temperature thermal, a total of 95 soil samples were collected that found soil concentrations within the TTZ had been reduced to between non-detectable levels and <100 mg/kg for all but one sample. Although one sample had a concentration of 198 mg/kg of carbon tetrachloride, the average concentration of 7.52 mg/kg was well below the site remedial goal of 100 mg/kg and the LTTR project was determined to have met the low temperature thermal remediation objectives for the site.

Overall, the project demonstrated the effectiveness of LTTR of chlorinated ethanes and other CVOCs which undergo degradation through hydrolysis. Even with carbon tetrachloride being present as DNAPL, the dissolution rate of DNAPL was orders of magnitude faster than the hydrolysis degradation rate of carbon tetrachloride, which ultimately supported a low temperature approach targeting hydrolysis degradation and a successful completion of the project.

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PROJECT SNAPSHOT

Thermally Enhanced Bioremediation for Xylene Using Thermal Conduction Heating to 35°C

Location: New York

Client: Confidential

Contamination: Xylenes, Ethylbenzene, Toluene and Naphthalene

Volume: 17,611 cy

Goal: Reduce soil concentrations of all COCs to below 1000 mg/kg

Duration: 18 months of operation

Heaters: 143

Mass Removed: 3,651 lbs.

WHAT MAKES THIS PROJECT UNIQUE?

This project demonstrated how thermal conduction heating (TCH) was very effective in heating the subsurface to a modest temperature in the 30-40°C range, and to stimulate biological degradation. Combined with a targeted investigation of permeability, and a system to deliver oxygen for the aerobic reactions, very substantial rates of biodegradation, and eventually site closure, was attained.

IMPORTANT PROJECT DETAILS

- **Approach:** To stimulate biological degradation, oxygen needed to be delivered to the target volume, and gentle heating to temperatures between 30 and 40°C was shown to greatly enhance rates. The subsurface was heated while air was pulled into the xylene-rich zones, facilitating bioremediation. Interim soil sampling was used to track the progress.
- **Challenges:** The first interim soil sampling round revealed that the goals had been met in more than 75% of the volume, with two hotspots remaining – xylene concentrations remained above 1,000 mg/kg. System enhancements were made to improve the distribution of heat – and more time allowed for the remediation.
- **Results:** Subsequent soil sampling events in the two smaller areas showed significant progress towards the goals, and eventually the completion of the remedy.

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PROJECT SNAPSHOT

ERH Combined with Low Temperature Bioremediation

Location: Bothell, WA

Client: City of Bothell

Contamination: PCE and TCE DNAPL

Volume: 4,759 cy

Goal: PCE (soil): 0.05 mg/kg, PCE (groundwater): 5 ug/L

Duration: 5 months of operation

Heaters: 36

Mass Removed: 1,466 lbs.

WHAT MAKES THIS PROJECT UNIQUE?

Electrical Resistance Heating (ERH) was used for source zone mass removal and combined with a biostimulation/warm-water recirculation system. The biostimulation system utilized residual heat energy from the ERH project to enhance dehalorespiration rates in the larger dissolved phase plume. The overall combined remediation strategy tied the two technologies and project phases together spatially and temporally, in order to optimize projects costs, schedule, and efficiency, while maximizing the downgradient impacts of ERH treatment on bioremediation efforts.

IMPORTANT PROJECT DETAILS

- **Approach:** The target treatment zone (TTZ) extended to 55 ft below grade, requiring the simultaneous heating of layered alluvial, till, and outwash geological units. The entire TTZ was heated to boiling and then held at boiling for 90 days. Residual heat from the ERH zone was recovered and used to heat the downgradient plume to enhance biodegradation.
- **Challenges:** Uniform heating of different geologic layers located at significantly different depths below ground surface (bgs). For example, the entire TTZ was heated to a depth of 25 ft bgs, while heating of the outwash to 55 ft was only performed in a small portion of the TTZ where a deep DNAPL pool was created by the dry cleaners disposing PCE into a deep well.
- **Results:** Confirmatory soil and groundwater samples verified all remedial goals had been achieved and that PCE concentrations in soil and groundwater had been reduced by over 99.99%.

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