Source Zone
Treatment of CVOCs and DNAPL

One Partner. Many Solutions.

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ADT

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Content

Thermal Remediation Technologies

- Thermal Conduction Heating
- Electrical Resistance Heating
- Steam Enhanced Extraction

Cascade Chemistries

- SourceKill™

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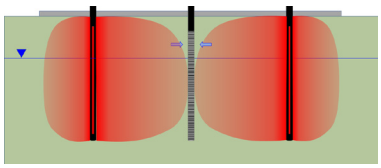
Our Thermal Technologies

OVERVIEW

THERMAL CONDUCTING HEATING

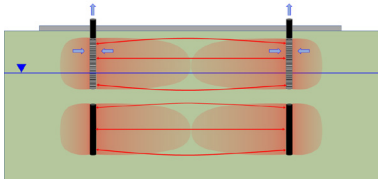


We offer low, moderate, and high temperature thermal remediation solutions using **Thermal Conduction Heating (TCH)**. Depending upon the targeted contaminants, remedial goals, and timeframe, we can select the optimal thermal treatment approach to reliably and safely cleanup your site. Chemicals TCH can treat include VOCs, CVOCs. BTEX, SVOCs, PAHs, PCB, dioxins, PFAS and even mercury. It is also an ideal remedy for LNAPL and DNAPL.

TCH is a straightforward heating technology that relies on one of the least varying properties of soil and bedrock, thermal conductivity. During TCH, heat radiating from hot thermal wells warms the treatment volume to the desired remedial temperature over a period of 60 to 90 days. Heating can target, 35, 80, 100, 250, 350, 400°C, or any temperature in between.

TCH is ideal for both in situ soil and groundwater remediation and the ex-situ treatment of stockpiled soil and sediments and has been applied successfully to depths of over 150 feet below grade.

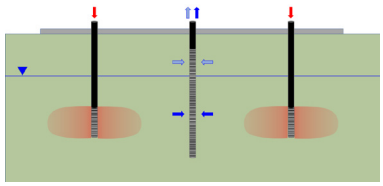
ELECTRICAL RESISTANCE HEATING



Electrical Resistance Heating (ERH) is highly effective at treating contaminants that require heating to 100°C, including: VOCs, BTEX, CVOCs, Naphthalene's, Chlorobenzenes, and LNAPL. ERH works by applying alternating voltages and current (AC) to electrodes placed in a grid pattern across the treatment area. As the soil matrix resists the flow of current between the electrodes, the treatment volume is heated by Joule heating. The upper temperature limit for ERH is 100°C. If the water is boiled off, heating stops.

Our ERH systems are specially engineered and designed to safely address a wide range of conditions that may be present at your site, including working in, around, and beneath buildings and infrastructure. We use discrete length electrodes and power control strategies customized to your site's geology.

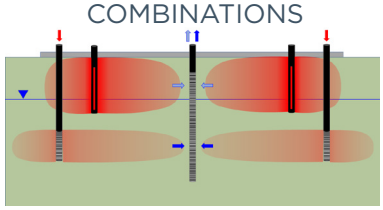
STEAM ENHANCED EXTRACTION



Steam Enhanced Extraction (SEE) is the most cost-effective way to heat the subsurface. Simple energy transfer from the injected steam to the subsurface intervals it is flowing through produces the desired heating results.

SEE is not an ideal technology for treating low permeability lithologies containing clay or silts. However, because SEE can effectively heat permeable units, it is an ideal heating technology for saturated geologic units with moderate to high groundwater flux. Typical contaminants targeted with SEE include: VOCs, BTEX, CVOCs, Naphthalene's, Chlorobenzenes, and LNAPL.

COMBINATIONS



For sites with complex geologies and both low and high permeability and high groundwater flux, we combine heating technologies to provide the optimized solution to effectively and thoroughly heat and treat the targeted interval. Typical technology combinations include the use of ERH or TCH in shallower tight soils and SEE in an underlying flowing aquifer, as well as using ERH to selectively target interbedded silty or clayey units and SEE to target the permeable sands.

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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:

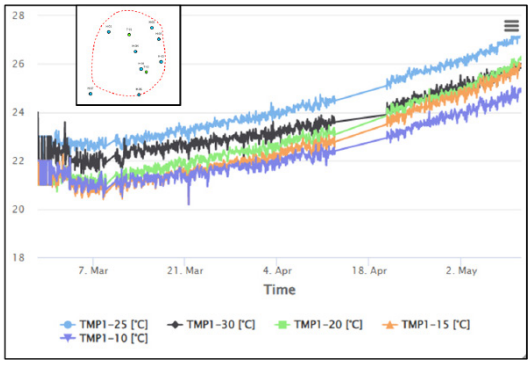
- Increasing the temperature to between 35 and 40°C can result in a 4-fold increase in the aerobic and anaerobic biological reaction rates.
- Increasing the temperature to 60 to 90°C can increase abiotic hydrolysis reaction rates and reduce the half-lives for some CVOCs by 4 to 6 orders of magnitude (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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Thermal Treatment in Bedrock

OVERVIEW

Treating fractured bedrock can be complex, and effective remedial options are limited. Due to the fractured nature of rock, it is difficult to reliably delivery amendments and reaction chemicals to where the mass is located. Fortunately, thermal remediation using Thermal Conduction Heating (TCH) overcomes these limitations and is a cost-effective, safe, and reliable means of treating fractured bedrock.

TCH uses simple electrical heaters suspended inside a bore-hole to deliver heat to the surrounding formation. The heat migrates away from the heater borings primarily by thermal conduction driven by the temperature gradient. For lots of sites, heating the targeted bedrock zone and the overlying overburden to 100°C is an effective approach for treating VOCs, CVOCS including DNAPL although lower temperatures can be effective too, if thermally enhanced hydrolysis or biodegradation is the targeted remediation mechanism.

When heating to boiling, the fractures are utilized as the pathways for the generated vapor (steam and contaminants) to escape and be captured by the vacuum extraction system. Every TCH heater, spaced approximately 15 ft apart, is typically supplied with a vapor recovery point. This ensures good connection with the fracture network, that the entire treatment zone is kept under a vacuum, and that the mobilized contaminants are effectively captured.

TCH has been successfully used to treat contaminants in a wide range of bedrock types and hydrogeologic settings, to depths as great as 170 ft below ground surface. Characteristics of the bedrock, such as porosity and saturation, play a key role in the heat-up rates and overall performance of treatment. Even with all the variables of a fractured bedrock site, TCH can achieve thorough heating of the matrix and fractures, prevent unwanted condensation of steam and vapors, and capture and remove the mass liberated from the bedrock and unconsolidated deposits.

TerraTherm has successfully and safely completed more than 10 bedrock sites around the world including the deepest site to date at 170 ft. Contact us to learn more and discuss options for treating your contaminated bedrock site.

PROJECT SNAPSHOT

Thermal Treatment of SRSNE Superfund Site

TCH

Location: Southington, CT

Client: deMaximis

Contamination: CVOCs, VOCs, DNAPL and NAPL
Volume: 57,770 cy

Goal: NAPL and Mass Removal. Targeted COC goals
Number of Heaters: 607

Duration: 9 months of operation

Mass Removed: 496,400 lbs.

WHAT MAKES THIS PROJECT UNIQUE?

To address the large amount of contaminant mass (estimated to range between 0.5 and 1M lbs), the wellfield was operated in two phases with an overlap in the middle to minimize the size of the vapor treatment system and optimize utilization of treatment capacity. Daily peak contaminant loading ranged around 10,000 lbs./day.

Important Project Details

- **Approach:** A total of 607 thermal conduction heaters, 551 vapor extraction wells, and over 300 linear feet of horizontal vapor extraction wells were installed to heat and capture the volatilized contaminants. Heating and treatment were staged over two overlapping treatment periods to manage peak mass removal rates and make the design and procurement of the off-gas treatment system practical.
- **Challenges:** During the installation of the thermal wells, it was discovered that the bedrock surface elevation varied much more than previously anticipated. To address the variances in the bedrock depth, all heater borings were installed and then heaters were custom designed and fabricated the appropriate lengths.
- **Results:** The project was successfully completed with over 496,000 lbs of VOC contamination removed. This resulted in >99% reduction in COC mass and achievement of all soil cleanup goals.

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PROJECT SNAPSHOT

Remediation at Hamilton Labree Superfund Site

ERH/SEE

Location: Chehalis, WA

Client: AECOM/USACE/EPS

Contamination: PCE

Volume: ~12,000 cy

Goal: Reduce PCE concentrations in soil to less than or equal to 10 mg/kg
Number of Electrodes/Steam Wells: 82 Electrodes in 49 locations/ 49 in 40 locations
Duration: 5 months of operation

Mass Removed: 7,795 lbs.

WHAT MAKES THIS PROJECT UNIQUE?

Site remediation was performed in two phases. The source area was remediated during phase 1, and Phase 2 addressed the large downgradient dissolved phase plume. Phase 1 was accomplished using Electrical Resistance Heating (ERH) combined with Steam Enhanced Extraction (SEE). In Phase 2, warm water from the now clean source area was used to enhance bioremediation of the downgradient plume. A stream running through the source area significantly complicated the site remediation.

Important Project Details

- **Approach:** The deployment of both ERH and SEE was required to treat the heterogeneous subsurface lithology where some depth intervals were too tight for SEE and groundwater flow in other intervals too high for ERH. Once the source remediation was complete, clean and warm water was pulled through the downgradient plume to enhance the effectiveness of bioremediation approach.
- **Challenges:** The site was located between a major interstate and a service road requiring trenching and installation of utilities across the road the location of the extraction and treatment system and steam boiler. The stream running through the source area had to be isolated and insulated to protect it during heating (temperature impacts and COC migration). The ERH/SEE design included multiple steam injection and ERH intervals combined with co-located SVE wells, MPE wells, and HVEWS and an insulated vapor cover integrated into a stream re-location channel. Once Phase 1 was complete, the stream was restored to preexisting conditions.
- **Results:** After 150 days of heating, all 101 soil confirmation samples collected at various depths across the site met the thermal remediation goals (<10 mg/kg PCE). Total contaminant mass removed from the site was 7,800 lbs, which was more than triple the estimated starting mass.

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PROJECT SNAPSHOT

SEE/TCH Remediation at an Active Manufacturing Facility

TCH/SEE

Location: Florida

Client: Confidential

Contamination: CVOCs

Volume: 104,000 cy

Goal: Eliminate NAPL in the source zone.

Heaters and SEE Wells: 413 TCH and 40 SEE Wells

Duration: 8 months of operation

Mass Removed: 4,800 lbs.

WHAT MAKES THIS PROJECT UNIQUE?

The combined TCH and SEE system was implemented to treat contaminated soils and groundwater at a site where 90% of the target treatment zone (TTZ) was located beneath a building. SEE was combined with TCH to address high permeability groundwater flow zones within a low permeability silt layer. The TTZ encompassed an area with a footprint of approximately 70,000 ft^2 extending from ground surface down to a maximum depth of 55 ft bgs.

Important Project Details

- **Approach:** The TTZ was located within and outside a building. 413 TCH wells and 40 SEE injection wells were installed. A Fourier Transform InfraRed (FTIR) field analytical package was used for continuous system and air discharge monitoring.
- **Challenges:** Approximately 90% of the TTZ was located beneath a building. Although the building was vacant, partition walls, drop ceilings, and existing utiliites existed within the limits of the TTZ. An Ambersorb treatment system was operated to remove 1,4-dioxane, mobilized by the thermal system.
- **Results:** The total mass removed was approximately 4,000 lbs in the vapor phase and another 800 lbs in the liquid phase and as NAPL. Biotic and abiotic processes were also found to have removed substantial amounts of mass due to the idling of the heaters and gentle low-temperature heating for several months prior to full operation.

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Cascade Chemistries

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WHAT IS CASCADE CHEMISTRIES?

Cascade Chemistries is a new line of amendments for in situ groundwater remediation, designed to help you reach site closure faster and cost-effectively. The products are exclusively offered by Cascade Environmental, and include a colloidal zero valent iron, emulsified zero valent iron, colloidal activated carbon, and encapsulated enzymes.

CAPABILITIES

Addresses contaminants like chlorinated solvents (including DNAPL), petroleum, and emerging contaminants like PFAS

Provides sufficient contaminant contact in transmissive (high K) and/or storage (low K) zones thanks to integrated approach

Cascade's proprietary Inner-Hose was invented to improve distribution of chemistries and optimize their results.

HOW IT WORKS

Cascade's proprietary chemistries are applied to contaminated sites by Cascade's remediation experts, who have decades of experience in the integration of high resolution characterization design optimization (HRDO) with injection and fracturing. We provide consultants with the data needed to identify where and how to apply remedies for best results, implement the approved remediation design, and partner with the client to monitor for optimization opportunities.

This means you get an integrated solution that is cost effective, reduces risk, and is designed to provide an excellent return on your remediation investment.

To provide this integrated approach, we utilize multiple existing services in conjunction with the new chemistries, including but not necessarily limited to:

- HRDO
- 3D visualized targeted remediation plans
- Hydraulic testing of wells or DPT screens
- Design optimization testing (DOT) prior to full scale remediation
- Manifolding automated injection of liquid and colloidal amendments
- Pneumatic & hydraulic emplacement
- Downhole pulsing for delivery into highly heterogeneous and moderate K zones
- Post remediation troubleshooting

By leveraging new chemistries, the best technologies, and the most experienced experts, you'll achieve site closure faster and more cost efficiently.

Design optimization investigation allows a more targested injection of chemistries, leading to a more efficient and cost effective remedy.

Cascade **Chemistries**
SOURCEKILL[SM]

WHAT IS SOURCEKILL?

SourceKill is the most reactive and DNAPL specific chemistry on the market today. Offered exclusively by Cascade Environmental, it is manufactured by TEA Inc. the first and US leader to providing this engineered in situ chemistry solution for DNAPL.

HOW DOES IT WORK?

SourceKill involves placing micro-scale zero valent iron (ZVI) particles into a surfactant-stabilized, biodegradable water-in-oil emulsion. This emulsion is injected into the DNAPL-contaminated zones. The DNAPL is then pulled (sequestered) into the emulsion where the CVOC's react with the ZVI. Through a process known as chemical reduction, primarily through the beta elimination pathway, the DNAPL and its daughter products are degraded into ethene, ethane and other hydrocarbons. The by-products are finally broken down through biological activities in the subsurface.

CASCADE

Advantages for distribution, contact & residence time

SourceKill can be emplaced into target DNAPL zones, typically in a grid pattern through direct push, sonic or straddle-packered boreholes either by pneumatic or hydraulic fracturing into either lower and/or higher K zones.

Benefits of ZVI biotic/ abiotic reactions and...

- Injected as neat solution, at 10% to 20% of pore space while requiring no dilution.
- High persistence in the subsurface, 5 to 10 years (or more), to account for DNAPL diffusion into the EZVI.
- Optimized propriety manufacturing process resulting in EZVI consistent with the NASA patent.
- Can be integrated into combined spatial remedies with other chemistries including bioremediation, chemical oxidation/ reduction, or sequestration.

For more information, visit
www.cascade-env.com/
cascade-chemistries

Cascade **Chemistries**
SOURCEKILL[SM]

TURNKEY SOLUTIONS

While effective chemistries are a key part of successful remediation solutions, Cascade's turnkey solution meets the overall in situ remediation objective "to make contact with contaminant mass for a long enough period of time to achieve destruction." Cascade adds significant value to the application of SourceKill by providing:

- High resolution design optimization through our MiHPT subsurface technologies to identify target zones based on mass, lithology, and hydraulic conductivity.
- Screening of DNAPL sites using our expert rules framework
- Advanced pneumatic and hydraulic fracturing technologies with high flow and pressure pumping systems to optimize contact.
- Client design support for dosing and critical injection parameters, including spacing and injection volumes and concentrations based on geology and hydraulic conductivity. Bench-scale and field design optimization services available.

CASCADE

For more information, visit
www.cascade-env.com/cascade-chemistries

Ready to get results with Cascade Chemistries?
We're ready to help.
Call or email us to get started.

CASCADE

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