TerraTherm

Thermal Treatment of PFAS, Dioxins, PCBs, Pesticides/Herbicides

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PFAS REMEDIATION

Overview

Per-and polyfluoroalkyl substances (PFAS) compounds include thousands of individual chemicals that are the subject of an increasing levels of regulatory scrutiny due to their persistence and potential adverse health effects.

Much of the science with respect to their health effects, occurrence and behavior in the environment, as well as how to sample and analyze for them is still being developed. In addition, clear remedial goals or regulatory limits for soil, water, and air have not been promulgated. This has created much uncertainty around how to characterize, treat, and dispose of PFAS contaminated media.

What is certain is that thermal treatment using thermal conduction heating (TCH) to raise the temperature of soils to 400°C, is highly effective in removing PFAS. This can be accomplished in situ using TerraTherm's proven and safe In Situ Thermal Desorption (ISTD) technology or ex situ in above ground constructed soil piles using our In Pile Thermal Desorption® (IPTD®) technology. Note, in situ treatment would be limited to PFAS source zones located above the water table, as the presence of water would prevent achieving temperatures above 100°C). Importantly, TerraTherm's patent pending thermal treatment approach removes the PFAS compounds that are regulated today as well as those that may be regulated in the future, eliminating the specter of long-term liability. The following provides some answers to often asked questions about using thermal remediation to treat soil and sediment impacted with PFAS.

What are the remediation mechanisms for PFAS in soil at 350 to 400°C?

At temperatures between 350 to 400°C, the PFAS present in the soil undergoes a combination of removal mechanisms: 1) degradation, defluorination, and mineralization of the PFAS, 2) volatilization of some of the degraded PFAS, and 3) direct volatilization of shorter chain volatile PFAS such as perfluroalkyl carboxylic acids (PFCAs). What is left in the soil following heating at these temperatures for several weeks is inorganic fluoride and metal fluorides such as calcium fluoride bound to the soil. Importantly, the off-gas extracted from the soil heated to 350 to 400°C may contain: volatized PFAS and products of incomplete degradation (PIDs) such as volatile fluorinated compounds (VFCs), which will need to be subsequently treated using a combination of thermal oxidation or thermal catalytic oxidation and acid gas scrubbing to remove hydrogen fluoride (HF) formed from the mineralization of the HF. The degree of complete mineralization and volatilization depends on the target temperature, nature of the PFAS, and minerology and geochemistry of the soil and water. For example, heating soils impacted with PFAS to 400°C that have naturally occurring calcium carbonates will result in more complete mineralization than heating soils with little calcium carbonates to 350°C.

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Have there been any laboratory studies supporting thermal remediation of soil impacted with PFAS?

Laboratory studies performed by TerraTherm and our European partner Kruger, have closed the fluorine mass balance, tracking and accounting for 100% of the fluorine associated with the starting PFAS in soil. These studies indicate that when soil containing PFAS is heated to 350 to 400°C, between 40% and 100% of the fluorine remains in the soil as inorganic fluoride and metal fluorides from the mineralization of the PFAS. Depending on the target temperature and nature of the soil and PFAS, between 0 to 60% of the fluorine leaves the soil as a combination of HF and volatile PFAS (likely as PIDs and VFCs).

Thermal catalytic systems were also tested that resulted in the complete mineralization of the volatized PFAS and fluorinated compounds present in the vapor stream extracted from the heated soil. The PFAS in the vapor stream was mineralized leading to the formation of metal fluorides and HF, with less than 0.01% of the fluorine from the PFAS starting in the soil emitted as target PFAS compounds.

Have there been measurements of PFAS precursors and/or total oxidizable/total organic fluorine before and after TCH on PFAS-impacted soils?

Yes, and results from these analyses indicate removal of both target and precursor PFAS to below detection limits, following heating to temperatures of 350°C and greater.

Are air emissions a potential issue with this treatment technology?

The short answer is, potentially yes, practically no. Thermal remediation of PFAS involves heating the impacted material to 350 to 400°C. Most of the PFAS will be broken down and/or destroyed at these temperatures directly within the soil. Vapors removed from the soil during heating and treatment could contain low levels of target PFAS compounds and some degradation products (PIDs and VFCs), as well as HF. Thus, our patent pending technology also includes a vapor treatment step to complete the destruction of the fluorinated compounds and neutralize any HF that is generated, such that vapor emissions meet relevant air emissions standards.

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PFAS REMEDIATION

Related Experience

TerraTherm has successfully completed 19 high temperature PFAS related soil remediation projects using both ISTD and IPTD (in situ and ex situ) to treat similar recalcitrant compounds (e.g., dioxins, PCBs, PAHs).

In addition, we have completed several innovative laboratory studies demonstrating the removal of PFAS compounds from soil when it is heated to temperatures ranging from 250 to 500°C. This groundbreaking work showed that the targeted PFAS was eliminated from the soil through both mineralization (complete destruction) and evaporation of PFAS pre-cursers and degradation products.

Currently we are working on a SERD/ESTCP funded project (ER23-8372) to demonstrate our high temperature approach for treating PFAS impacted soils. Our portion of the project includes using a specially designed heated container utilizing our thermal conduction heating technology to treat ~2 cy (~1/2 a drum) of soil and sediment at the Peterson SFB outside Colorado Springs. The system demonstration is planned for the fall of 2024.

Importantly, we have the experience required to design safe and reliable systems for the total treatment of PFAS. This includes proven effective methods for construction and heating of in situ source zones and constructed soil piles to ensure thorough heating to the required treatment temperature and safe and effective removal and treatment of the produced vapors.

When your project is ready for Total Treatment of PFAS impacted soil (or sediments and soil washing fines), and elimination of all future liability, contact our experts to explore your options for safe, effective PFAS remediation.

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High Temperature Thermal Treatment

Overview

Treatment of soil impacted with high boiling point recalcitrant SVOC contaminants such as PFAS, PCBs, dioxins, and PAHs requires heating from 300 to 350°C (high temperature thermal remediation). Thermal conduction heating (TCH) is the only thermal remediation technology that can heat soil to these temperatures. TCH can even treat mercury contaminated soil.

Electrical resistance heating (ERH) and steam enhanced extraction (SEE) cannot achieve these temperatures or effectively treat these compounds because they both require the presence of water to deliver energy to the subsurface. Once the water is boiled off, which is required first to achieve temperatures greater than 100°C, their heating mechanisms stop. This also means that sites with recalcitrant SVOCs that extend below the water table must include some provisions for isolating the treatment zone and controlling groundwater influx if they require high temperature thermal treatment. Continued groundwater flux will prevent achieving temperatures above 100°C.

High-temperature TCH can be performed both in situ or in specially engineered above-grade soil piles. The use of TCH to heat and treat soil piles is also known as In Pile Thermal Desorption (IPTD®), one of our patented technologies. With the application of higher temperatures the soil before reaching the surface. This substantially reduces the loading and size of the treatment system. Contaminants that have not been destroyed in situ are removed from the heated soil in the vapor phase through vacuum extraction wells and subsequently treated to appropriate emission standards in a state-of-the-art, high efficiency treatment system.

TerraTherm is the only thermal vendor in the world to have successfully implemented multiple high-temperature TCH projects for a variety of high boiling point contaminants such as PCBs, dioxins, PAHs, TPH, and MGP waste. To date, we have completed 19 such projects, using both in situ as well as IPTD approaches. Along the way, we have perfected the technology for safely and efficiently heating soils to high-temperatures and for extracting and treating the targeted contaminants. This gives our clients the confidence that we know what we are doing when it comes to high temperature treatment of contaminants such as PFAS, PCBs, dioxins, and PAHs, and that our high temperature designs will meet project expectations for safety, schedule, performance, and cost.

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In Pile Thermal Desorption

Overview

In Pile Thermal Desorption (IPTD®) uses thermal conduction heating (TCH) to provide ex-situ thermal remediation of soil and sediment that can be designed to treat any organic contaminant, streamlines material handling, and eliminates the need for off-site disposal of contaminated soils and sediment.

Our IPTD approach is highly flexible and easily customizable to optimize treatment of any soil volume, large or small. It involves placing contaminated soil and/or sediment within an engineered above-ground, fully covered and insulated treatment pile structure, and then heating the soil to the required temperature to destroy and/or remove the contaminants over periods of several weeks to several months. The design temperature and treatment period is dependent on the contaminants, and remedial goals. For example, treatment of soil contaminated with SVOCs such as PCBs or PFAS might require 250°C to 350°C for several months.

IPTD Treatment of Dioxin Contaminated Soil

IPTD is a good fit for shallow soil contamination, excavated soil, or IDW when off-site disposal is not an option. On-site IPTD can be a cost-effective option for total treatment of contaminants like PFAS, PCBs, dioxins, and PAHs, which importantly, eliminates the long-term liability of disposal of the soil in a landfill.

Extremely stringent soil standards can be achieved even for recalcitrant contaminants like PFAS, PCBs, dioxins, and PAHs.

We have treated soil volumes as little as 50 cy and up to 70,000 cy for our clients. The size of the pile depends on the volume of material to be treated, space available, electrical power available, and desired schedule. Over the past 20 years we have treated more than 135,000 cy of soil and sediment using IPTD and our patented TCH technology for difficult to remediate contaminants similar to PFAS such as PCBs, dioxins, and PAHs.

Between 2012 and 2016, we implemented the largest IPTD project in the world in Da Nang Vietnam, working with USAID and the Government of Vietnam. Over 120,000 cy of soil and sediments contaminated with dioxins associated with the disposal of agent orange were successfully and safely remediated in two consecutive treatment phases using one constructed pile. Extracted vapors and liquids were effectively captured and treated and all human health and environmental discharge, worker, and resident standards were met.

Largest IPTD for Treatment of Dioxins in Vietnam

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PROJECT SNAPSHOT

Dioxin Treatment at Da Nang Airport - Phase 1

Location: Da Nang, Vietnam
Client: USAID
Contamination: Dioxins (2,3,7,8-TEQ)
Volume: 43,348 m^3

Goal: 150 ppt for 2,3,7,8-TEQ
Duration: 15 months of operation
Heaters: 1,254
Pile Size: 105m by 70m by 6m

WHAT MAKES THIS PROJECT UNIQUE?

More than 49 years after the Vietnam War, during which Agent Orange was used for defoliation, a large area at the Da Nang airport remained heavily contaminated by residues of the chemicals, including dioxins such as 2,3,7,8-tetrachlorodibenzo-p- dioxin. U.S. Agency for International Development (USAID) funded and implemented this project in partnership with the Vietnam Ministry of National Defense. TerraTherm's role included design, construction, operation, and decommissioning of the in pile thermal desorption (IPTD®) treatment system and treatment of the contaminated soil and sediments in two sequential phases.

IMPORTANT PROJECT DETAILS

- **Approach:** For Phase 1, impacted soil was excavated and loaded into a pile the size of a football field and, 6m tall. With a required target temperature of 335°C for effective treatment, thermal conduction heating (TCH) was the only available heating technology. The soil was heated, treated, cooled, and used as clean fill for airport expansion after confirmatory sampling.
- **Challenges:** Heating was observed to be slowest at the top and bottom of the pile. This prolonged the first phase, and lead to improvements of the cover design, and a revised heating strategy for Phase 2, which was completed on schedule.
- **Results:** Contaminant concentrations were reduced from a range of 4,040 to 6,880 ppt to an average of 8.9 ppt. TerraTherm received the EBJ 2018 Business Achievement Award for Project Merit in Remediation.

Photo Courtesy of USAID

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PROJECT SNAPSHOT

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Dioxin Treatment at Da Nang Airport - Phase 2

Location: Da Nang, Vietnam
Client: USAID
Contamination: Dioxins (2,3,7,8-TEQ)
Volume: 43,348 m^3

Goal: 150 ppt for 2,3,7,8-TEQ
Duration: 9 months of operation
Heaters: 1,254
Pile Size: 105m by 70m by 6m

WHAT MAKES THIS PROJECT UNIQUE?

More than 49 years after the Vietnam War, during which Agent Orange was used for defoliation, a large area at the Da Nang airport remained heavily contaminated by residues of the chemicals, including dioxins such as 2,3,7,8-tetrachlorodibenzo-p- dioxin. U.S. Agency for International Development (USAID) funded and implemented this project in partnership with the Vietnam Ministry of National Defense. TerraTherm's role included design, construction, operation, and decommissioning of the in pile thermal desorption (IPTD®) treatment system and treatment of the contaminated soil and sediments tin two sequential phases.

IMPORTANT PROJECT DETAILS

- **Approach:** For Phase 2, impacted soil was excavated and loaded into a pile the size of a football field and 6m tall. With a required target temperature of 335°C for effective treatment, thermal conduction heating (TCH) was the only available heating technology. The soil was heated, treated, cooled, and used as clean fill for airport expansion after confirmatory sampling.
- **Challenges:** Lessons learned from Phase 1 yielded improvements to design of the surface cover and modifications to heater element design, thereby completing IPTD heating two weeks ahead of modeled schedule. Higher organic content in Phase 2 sediment, particularly in NW corner of pile, caused locally slower heating and high benzene concentrations in vapor phase due to cracking of larger organic molecules. Installed 8 additional heaters in NW corner, and implemented scheduled VGAC change-outs in Level B PPE to manage high influent benzene concentrations.
- **Results:** Contaminant concentrations were reduced from a range of 2,461 to an average of 0.199 ppt. TerraTherm received the EBJ 2018 Business Achievement Award for Project Merit in Remediation.

Photo courtesy of USAID

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PROJECT SNAPSHOT

TCH Treatment of Creosote and SVOCs (PCP, PAHs and Dioxins) to 350°C at former Wood Treatment Facility

Location: Alhambra, California

Client: Southern California Edison

Contamination: Petrachlorophenol, PAHs, creosote, (wood) and dioxins

Volume: 16,200 cy

Goal: Achieve mass removal and <0.065 TDEQ

Duration: 15.5 months of operation (both phases)

Heaters: 785 (two phases)

Mass Removed: 870,000 lbs.

WHAT MAKES THIS PROJECT UNIQUE?

This is the largest high temperature ISTR project ever undertaken at a wood treatment site. The only alternative deemed capable of achieving the unrestricted land use goal was soil excavation followed by off-site incineration. The thermal solution was approximately 40% lower cost than the excavation/incineration alternative for this F-listed waste.

IMPORTANT PROJECT DETAILS

- **Approach:** TerraTherm installed 785 thermal wells, including 654 heater-only and 131 heater-vacuum wells at 7 ft spacing at the site. The target temperature to achieve destruction and removal of all COCs including dioxins was 335°C.
- **Challenges:** An extensive community involvement program was undertaken by Southern California Edison and TerraTherm, and in response to community concerns and additional contingencies were included in the system design, including redundant air treatment equipment, process blowers, stack testing events, and longer operator hours.
- **Results:** Over the course of the project, TerraTherm reduced mean B(a)P-E and TDEQ concentrations in soil from 30.6 mg/kg and 0.018 mg/kg (pre-treatment) to 0.059 mg/kg and 0.00011 mg/kg (post-treatment), respectively; thereby meeting the remedial goals, and resulting in a No Further Action letter from the Department of Toxic Substances Control.

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