PERFORMANCE RELATIVE TO DIOXINS OF THE IN-SITU THERMAL DESTRUCTION (ISTD) SOIL REMEDIATION TECHNOLOGY

Ralph S. Baker and John C. LaChance

TerraTherm, Inc., 356 Broad St., Fitchburg, MA 01420

Introduction

Thermal technologies have seen widespread use for the treatment of soil, sludge and sediment containing chlorinated hydrocarbons such as polychlorinated biphenyls (PCBs), pentachlorophenol (PCP), chlorinated solvents such as trichloroethylene (TCE) and tetrachloroethylene (PCE), and organochlorine pesticides (OCPs). Historically, concerns have been raised regarding the potential for thermal technologies, such as incineration or ex-situ thermal desorption, to generate potentially toxic products of incomplete combustion (PICs), which in turn can lead to the formation of polychlorinated dibenzodioxins and furans (PCDD/Fs), either as air emissions or particulates collected in the off-gas treatment system (e.g., bag house dust), or as residual remaining in the soil. This short paper addresses the potential for PCDD/Fs to be released or generated as a result of an innovative remediation technology termed In-Situ Thermal Destruction (ISTD), also known as In-Situ Thermal Desorption (ISTD). Also, the potential for PCDD/F-contaminated soils to be treated by ISTD is documented.

The ISTD technology treats soil contaminated with volatile, semivolatile and non-volatile organic compounds in place, through a combination of heat and vacuum [1]. The soil is heated conductively by means of an array of vertical or horizontal thermal wells, about one-third of which are typically operated as heater-vacuum wells, and the remainder as heater-only wells. The electrically powered heating elements are operated at temperatures of up to 800°C (1500°F). For treatment of PCB- and dioxin/furan-contaminated soils, the heater wells are typically installed at 6' to 7' spacing, with an impermeable liner installed at the soil surface. Heat flows through the soil from the heating elements primarily by thermal conduction, resulting in a gradual increase in the temperature of the soil located in between the heater wells. As a consequence of this heating, water, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs) in the soil are vaporized due to evaporation, steam distillation, and boiling, and a region of very hot soil (i.e., >500°C [>900°F]), a meter or so in diameter, is created around the heater vacuum wells. As the vaporized water and contaminants are drawn counter-current to the heat flow, into the heater-vacuum wells, the region of very hot soil around the heater vacuum well acts similarly as a packed-bed reactor and the organic compounds (VOCs and SVOCs) are destroyed in situ by oxidation and pyrolysis. For typical sites, the residence time for vapors traveling through the very hot region around the heater vacuum wells is several hours, which is sufficient time for the oxidation and pyrolysis of most of the contaminants [2].

In practice, most (e.g., 95-99%) of the contaminants are destroyed within the soil, before the soil vapor reaches the extraction wells and is conveyed to the surface. Contaminants that have not been destroyed in-situ are removed from the produced vapor stream at the surface with an air quality control (AQC) system.

The AQC system used with ISTD usually consists of a thermal oxidizer, heat exchanger, acid-gas scrubber (typical for chlorinated sites), granular activated carbon (GAC) adsorbers, and vacuum blowers. With this system, a destruction and removal efficiency (DRE) for PCBs of 99.9999998% ("8-nines") has been achieved in the stack effluent. For the four fully documented sites where ISTD was used to treat PCBs, the mean stack gas concentration of dioxin/furan was between 0.0055 and 0.0003 ng 2,3,7,8-tetrachlorodibenzodioxin (TCDD) Toxicity Equivalence Quotient (TEQ)/dry standard cubic meter (DSCM). Based on the results of seven completed ISTD remediation projects conducted at contaminated sites and numerous treatability studies, the ISTD technology has been proven to be highly effective in removing a variety of contaminants including dioxins and furans, PCBs and other chlorinated hydrocarbons, coal tars, and heavy and light petroleum hydrocarbons, typically within an overall treatment timeframe of one to three months [1]. Achievement of non-detect levels of contaminants of concern (COCs) throughout the treatment zone is typical, which is unprecedented for an in-situ remediation technology.

ISTD is fundamentally different than conventional ex-situ treatment technologies like low- and high-temperature thermal desorption and incineration [3]. With these ex-situ thermal technologies, the soil or waste being treated is exposed to high temperatures only briefly – typically for seconds or at most minutes. In addition, off-gases tend to be generated at such high rates and temperatures that best available technology such as adsorption on GAC, either as the primary vapor treatment or for polishing, is often too expensive to be utilized. Thus, conditions may exist where PICs and compounds such as PCDD/Fs can sometimes be created and not fully treated. With ISTD, by contrast, even the coolest portions of the treatment zone are heated to target temperatures for days, at a minimum. Not only are dioxins and furans not created, treatability and field data indicate they too are destroyed in-situ [1]. PCDD/Fs that remain in the extracted vapor are treated in the above-mentioned AQC system. ISTD has been demonstrated to be more robust and efficient with respect to treatment of PCDD/Fs than either ex-situ thermal desorption or incineration.

Methods and Materials

The data reported herein are derived from the following completed ISTD projects, the detailed methods and materials of which are presented in the referenced reports: Missouri Electric Works (MEW) Superfund Site, Cape Girardeau, MO [4,5]; U.S. Naval Facility Centerville Beach (NFCB), Ferndale, CA [6]; Southern California Edison (SCE) Former Pole Yard, Alhambra, CA [7]; and S. Glens Falls, NY [8]. PCDD/F analyses in soils were by EPA Method 8280[4,7], except for NFCB[6], where EPA Method 8280A was employed. Stack emissions were measured for 2,3,7,8-TCDD TEQ isokinetically using an XAD-2 sorbent trap in accordance with EPA Method 23 [4,5,6,8]. In accordance with EPA Method 23, prior to the sorbent trap, a series of impingers was used to cool the sample stream. The sorbent trap and impingers were submitted for analysis by High Resolution combined Gas Chromatograph/Mass Spectrometer (HR GC/MS).

Results and Discussion

Evidence that ISTD Does Not Create, or Release Dioxins and Furans Below Ground

Table 1 summarizes the results of soil sampling and analyses for both PCBs and PCDD/Fs before and after ISTD treatment. These field-scale ISTD projects have demonstrated that PCDD/Fs in post-ISTD treatment soil samples were reduced to below "background" concentrations for North

American soils [1,9]. The post-treatment soil concentrations are clearly much lower than the pre-treatment concentrations. Data from a treatability study of PAH- and dioxin-contaminated soil [7] are included in Table 1 for comparison.

Table 1. Pre- and post-ISTD PCB and dioxin soil concentrations (n = number of samples).

LOCATION	MEAN PCB SOIL CONCENTRATION		MEAN DIOXIN SOIL CONCENTRATION	
	PRE-TREATMENT (µg PCB/kg)	POST-TREATMENT (µg PCB/kg)	PRE-TREATMENT (µg TEQ/kg)	POST-TREATMENT[1] (µg TEQ/kg)
Cape Girardeau, MO Thermal Well Demo (PCBs)	649,000 (n = 111)	22 (n = 101)	6.5[2]	0.0032 (n = 4)
Centerville Beach, CA Thermal Well Demo (PCBs)	302,000 (n = 6)	85 (n = 16)	1.7 (n = 2)	0.011 (n = 10)
Alhambra, CA Treatability Study (PAHs)	N/A	N/A	1.23 (n = 1)	0.061 (n = 6)

[1] For comparison, background level in uncontaminated North American soils = 0.0079 µg TEQ/kg (per Reference 3).
[2] Estimated value (assumes that PCDD/Fs are typically present in PCB Aroclor mixtures at a concentration of 10 ppm).

Evidence that ISTD Does Not Create, or Release Dioxins and Furans Aboveground

ISTD systems are designed to prevent emission of dioxins or furans or their formation in aboveground treatment units. The combined destruction and removal efficiency of the in-situ processes and the off-gas treatment achieved using ISTD for the treatment of PCB sites has been demonstrated to be >99.999999% (Table 2). The discharge rate of 2,3,7,8-TCDD TEQ was less then 0.0055 ng/dscm during these projects, or approximately 100 times less than the Maximum Acceptable Control Technology (MACT) standard of 0.2 ng/dscm established by the USEPA for the treatment of dioxin-like substances [10]. Note that these data are from highly contaminated sites, e.g., the pre-ISTD concentrations of PCBs in soil treated at MEW were as high as 2% by weight [4]. These data provide evidence that PCDD/Fs were not released to the atmosphere during these ISTD projects.

There is no evidence that ISTD results in the formation or release of PCDD/Fs, either in the treated soils or in the off-gas. Quite to the contrary, the evidence indicates that ISTD applied to sites with high levels of chlorinated hydrocarbon contamination exceeded the soil cleanup objectives and reduced levels of PCDD/Fs in treated soils to near background levels, while achieving air emissions of PCDD/Fs well below mandated MACT standards.

Patent Notice: Within the U.S., ISTD is covered by 22 U.S. patents and patents pending, with all rights reserved by the University of Texas at Austin and TerraTherm, Inc. Outside the U.S., international patents on ISTD are pending, with all rights reserved by Shell Oil Co. and TerraTherm, Inc.

Table 2. Dioxin stack emissions measured during ISTD projects. Air quality control systems consisted of a flameless thermal oxidizer, heat exchanger, and granular activated carbon.

LOCATION	MEAN AIR FLOW RATE (SCMM[1])	MEAN OXIDIZER BED TEMPERATURE (°C)	MEAN EMISSION RATE (g TEQ/hr)	MEAN STACK GAS CONCENTRATION[2] (ng TEQ/dscm)
S. Glens Falls, NY Thermal Blanket Demo (PCBs)	42.5	960	1.2×10^{-08}	0.004
Cape Girardeau, MO Thermal Well Demo (PCBs)	2.1	1027	3.47×10^{-10}	0.00291
Cape Girardeau, MO Thermal Blanket Demo (PCBs)	2.6	1027	4.51×10^{-11}	0.000289
Centerville Beach, CA Thermal Well Demo (PCBs)	4.9	927	1.84×10^{-09}	0.00547

[1] SCMM = standard cubic meters per minute.
[2] ng TEQ/dscm = nanograms 2,3,7,8-Tetrachlorodibenzodioxin Toxic Equivalency per dry standard cubic meter.

References

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