IN-PILE THERMAL DESORPTION OF PAHs, PCBs AND DIOXINS/FURANS IN SOIL AND SEDIMENT

[Short Title: In-Pile Thermal Desorption of Soil and Sediment]

Ralph S. Baker[1], John LaChance[1] and Gorm Heron[2]

[1]TerraTherm, Inc.
356 Broad Street
Fitchburg, MA 01420 USA
(978) 343-0300
Fax: (978) 343-2727
rbaker@terratherm.com

[2] TerraTherm, Inc., Keene, CA

ABSTRACT:

Current overall treatment costs for soil and sediment heavily contaminated with Semi-Volatile Organic Compounds (SVOCs) such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and polychlorinated dibenzodioxins and furans (PCDD/Fs) can be as high as $550-770 per metric tonne. This paper focuses on an innovative thermal treatment method that is likely to be highly effective at full-scale costs of less than one third ($110-330 per metric tonne depending on total volume).

TerraTherm's In-Pile Thermal Desorption (IPTD) technology is an ex-situ version of In-Situ Thermal Desorption (ISTD), by which TerraTherm utilizes simultaneous

Preprint: To be presented at the International Symposium and Exhibition on the Redevelopment of Manufactured Gas Plant Sites (MGP2006), Reading, England, April 4-6, 2006. Submitted for publication in *Journal of Land Contamination and Reclamation*.

application of thermal conduction heating and vacuum to treat contaminated soil without excavation. With IPTD, the contaminated solids are placed in covered piles, interlayered with heater pipes and vapor extraction screens. The piles are then heated and treated using electrical heaters, which bring the temperature up to the target, typically around 330ºC for SVOCs, depending on the nature of the contaminants. The applied heat volatilizes both water and organic contaminants within the soil/sediment, enabling them to be carried in the air stream toward vacuum extraction wells for destruction within the soil/sediment and transfer of the remaining vapor to an air quality control (AQC) unit. Based on demonstrated ISTD results of eight field-scale SVOC projects, very low or even non-detect concentrations are a feasible goal if required.

KEY WORDS:

Soil Remediation

Sediments Remediation

In-Situ Thermal Desorption

Thermal Remediation

Polycyclic Aromatic Hydrocarbons

Polychlorinated Biphenyls

Dioxins/Furans

INTRODUCTION:

TerraTherm's In-Pile Thermal Desorption (IPTD) technology is an ex-situ version of In-Situ Thermal Desorption (ISTD), by which TerraTherm utilizes simultaneous application of thermal conduction heating and vacuum to treat contaminated soil without excavation (Stegemeier and Vinegar 2001). Both the IPTD and ISTD processes are designed to remediate soil and sediment contaminated with a wide range of organic compounds. Heat and vacuum are applied simultaneously to the soil with an array of vertical or horizontal heaters, under imposed vacuum. Heat flows through the soil primarily by thermal conduction from electrically powered heating elements. Because their temperature can be easily controlled, much like the burners on an electric stovetop, they can be operated at any desired temperature between ambient and 870°C, allowing the heating process to be tailored to the needs of the particular project.

Both IPTD and ISTD remediation technologies employ a network of thermal wells to achieve the clean-up standards within the targeted soil. Typically, for ISTD applications, approximately one-quarter of the thermal wells within the limits of the TTZ are configured as heater-vacuum (producer) wells to allow collection of the volatilized contaminants, and the remaining wells function as heater-only wells. A thermal heat front advances radially outward from the heater wells through the adjacent soils, with most of the heat transfer occurring via thermal conduction. For IPTD applications, a combination of heater-only and heater-vacuum or heater-only and vacuum extraction wells may be used depending on the constituents being treated, the remedial objectives, and the off-gas treatment requirements.

As summarized in Table 1, TerraTherm's proprietary ISTD/IPTD technology has been used successfully at 5 field-scale projects treating PCBs, of which three were demonstration-scale (General Electric Co., Glens Falls, NY; Missouri Electric Works Superfund Site, Cape Girardeau, MO; and US Navy BADCAT, Vallejo, CA), and the remaining two projects were full-scale (US Army Corps of Engineers, Saipan, W. Pacific; and US Navy, Centerville Beach, CA). Note that while pre-treatment PCB concentrations ranged as high as 20,000 mg/kg, post-treatment concentrations were close to the detection limit, and well below remedial goals.

TerraTherm recently completed a full-scale ISTD project at a former wood-treatment (i.e., creosote-contaminated) site operated by Southern California Edison Co. (SCE) in Alhambra, CA (Bierschenk et al. 2004). A total of 12,615 m^3 of predominantly silty sand soil was treated to as deep as 32 m. Due to SCE's desire that there be no restrictions as to future land use, they adopted the following stringent soil cleanup goals: PAHs (expressed as benzo(a)pyrene [B(a)P] equivalents): 65 μg/kg; and PCDD/Fs (expressed as 2,3,7,8-tetrachlorodibenzodioxin equivalents, TEQ): 1 μg/kg. Over the course of the project, TerraTherm reduced mean B(a)P and TEQ concentrations in soil from 30,600 μg/kg and 18 μg/kg (pre-treatment) to 59 μg/kg and 0.11 μg/kg (post-treatment), respectively; thereby meeting the remedial goals. Attainment of such stringent soil treatment goals with an in-situ technology is unprecedented.

To achieve these results, both the IPTD and ISTD processes employ the same thermal treatment mechanisms, including vaporization, boiling, oxidation and pyrolysis (Stegemeier and Vinegar, 2002). When a combination of heater-only and heater-vacuum wells are used, the vaporized water and contaminants are drawn counter-current to the heat flow into the vacuum extraction wells. As the vapors move into the close proximity of the heater-vacuum wells, they encounter superheated soil at ~500-600°C, at which oxidation and pyrolysis reactions occur with half-lives of seconds to minutes.

In practice, most (e.g., >95-99%, or more) of the SVOCs are destroyed within the soil, before they reach the extraction wells, after which the extracted vapors are conveyed to the aboveground AQC system. Contaminants that have not been destroyed within the soil are removed from the produced vapor stream with the AQC system. Repeated rounds of source testing have indicated that the off-gas emissions remained well below the required standard (Table 2).

IPTD DESCRIPTION:

With the patented IPTD process, the contaminated soil or sediments are placed in covered piles, interlayered with heater pipes and vapor extraction screens (Figure 1). Each pile would contain the following:

- A bermed area with a vapor-and liquid-tight bottom and sides, with a leachate collection system. This is needed because as the soil is heated, drainage of water, and potentially of non-aqueous phase liquids (NAPL) may occur.
- Horizontally- or vertically-oriented heater elements, air injection and vapor extraction wells distributed throughout each soil pile.
- A vapor cap used to contain fugitive emissions and allow for application of a vacuum to each pile.
- Surface insulation over each soil pile to reduce heat losses during treatment.
- Thermocouples and pressure transducers at select locations to document heating progress and vacuum conditions, respectively.

Compared to the in-situ treatment times listed in Table 1, the IPTD version of this technology can achieve similar treatment goals in a shorter timeframe, due to the ability to locate the heaters closer together than for typical in-situ applications. Typical IPTD treatment times will be on the order of 30-45 days per pile.

A variant of IPTD, In-Barge Thermal Desorption (IBTD may be attractive for treatment of contaminated material at dock-side locations (Figure 2).

COMPARISON OF IPTD TO CONVENTIONAL THERMAL TREATMENT:

IPTD differs from conventional ex situ thermal desorption (TD) and incineration systems in a number of essential respects, as follows:

- IPTD, being a batch process, is able to handle a wide variety of materials, including debris and rocks less than approximately 1 ft in diameter. Typical TD and incineration systems must exclude objects >2” in diameter because they cannot pass through the conveyance and treatment equipment.
- IPTD is relatively insensitive to moisture content, fines content, variability in particle size distribution, elevated humic content, coarse fragments, and the presence of fill materials including ash, clinkers, cinders, brick, glass, metal, and wood fragments. Such materials can represent a problem for TD and incineration systems, and can therefore require separate treatment strategies. The need to employ off-site disposal of excluded material is therefore minimal with IPTD.
- IPTD systems can operate in close proximity to neighbors with minimal noise impacts. Although the heavy materials handling that occurs during construction and dismantling of soil piles can be confined to weekday daylight hours, the IPTD treatment process itself can operate 24 hours per day, 7 days per week at very low noise levels consistent with residential neighborhoods. Three full-scale ISTD

systems with similar equipment have been operated immediately adjacent to occupied residences without any adverse impacts or complaints. By comparison, TD systems have noisy conveyance systems that need to operate continuously whenever TD treatment is underway and that are difficult to shut down and restart without losses of efficiency.

- IPTD/ISTD has a demonstrated ability to destroy, not create dioxins, furans or other products of incomplete combustion. The gases being collected from the soil piles are passed through heated and insulated pipelines to prevent condensation upstream of the thermal oxidizer, which operates at 930°C. Furthermore, the heat exchanger is placed immediately downstream of the thermal oxidizer, and in a fraction of a second cools the gas exiting the oxidizer to make its temperature compatible with GAC treatment. There is no baghouse as is often the case with TD and incineration systems. IPTD is not incineration. Thus the conditions that might give rise to *de novo* formation of PCDD/Fs are not present (Baker and LaChance 2002). Such may not be the case with TD and incineration systems.
- IPTD soil piles can be designed to operate within a designated timeframe. If, for example, the entire site must be remediated within two years to hasten the ability to redevelop the site, more soil piles can be constructed and operated simultaneously. Mobile and stationary TD and incineration systems, by contrast, are limited to the design throughput of the equipment.
- As a result of these advantages, full-scale costs (treatment volumes >15,000 metric tonnes) for difficult-to-treat contaminant matrices are estimated to be less

than one third those for TD or incineration systems ($110-330, relative to $550-770 per metric tonne).

Compared to excavation and disposal, IPTD has the major advantage that the contaminants are completely removed and destroyed. The treated sediments are non-hazardous, and will not present a long-term liability at a disposal facility such as a landfill.

CONCLUSIONS:

The IPTD process is similar to its proven in-situ counterpart technology (ISTD), allowing cost-effective remediation of a wide range of organic contaminants in soil and/or sediment that have already been excavated or can readily be consolidated into piles. For treatment of PAHs, PCBs and PCDD/Fs, IPTD offers many potential advantages relative to conventional TD systems or off-site disposal.

REFERENCES:

Baker, R.S. and LaChance, J.C. (2003) Performance Relative to Dioxins of the In-Situ Thermal Destruction (ISTD) Soil Remediation Technology. In: *Proceedings of the 23rd International Symposium on Halogenated Organic Pollutants and Persistent Organic Pollutants (Dioxin 2003)*, (G. Hunt, ed.), Boston, MA, Aug. 24-29, 2003.

Bierschenk, J.M., R.S. Baker, R.S., Bukowski, R.J., Parker, K., Young, R., King, J., Landler, T. and Sheppard, D. (2004) Full-Scale Phase 1a Results of ISTD Remediation at

Former Alhambra, California Wood Treatment Site. In: *Proceedings of the 4th International Conf. on Remediation of Chlorinated and Recalcitrant Compounds*, Monterey, CA, May 24-27, 2004. Battelle, Columbus, OH.

Stegemeier, G.L., and Vinegar, H.J. (2001) Thermal Conduction Heating for In-Situ Thermal Desorption of Soils. In: *Hazardous and Radioactive Waste Treatment Technologies Handbook* (ed. C. Oh), pp. 1-37. CRC Press, Boca Raton, Florida.

TABLE LEGENDS:

Table 1. Summary of ISTD/IPTD Projects with PCB- and/or Dioxin Contaminated Soils.

Table 2. Dioxin Stack Emissions of ISTD Projects Relative to Goals (as determined by independent source testing).

FIGURE LEGENDS:

Figure 1. Schematic Illustrating an In-Pile Thermal Desorption (IPTD) System with a Number of Piles Operating Sequentially or According to a Staggered Schedule.

Figure 2. Schematic Illustrating an In-Barge Thermal Desorption (IBTD) System Located Dock-Side.

TABLES:

1.

LOCATION	CONTAMINANT	MAX. INITIAL CONCENTRATION (mg/kg)	FINAL CONCENTRATION (mg/kg)	m^3 TREATED	YEAR COMP-LETED	HEATING PERIOD (days)
S. Glens Falls, NY	PCB 1248/1254	5,000	< 0.8	6	1996	~60
Cape Girardeau, MO	PCB 1260	500	< 1	161	1997	42
	PCB1260	20,000	< 0.033			
Vallejo, CA	PCB 1254/1260	2,200	< 0.033	132	1997	37
Tanapag, Saipan	PCB 1254/1260	10,000	< 1	1017	1997	330*
Ferndale, CA	PCB 1254	800	< 0.17	765	1999	90
Alhambra, CA	Dioxin (TEQ)	0.194	< 0.00001	12,615	2005	300**

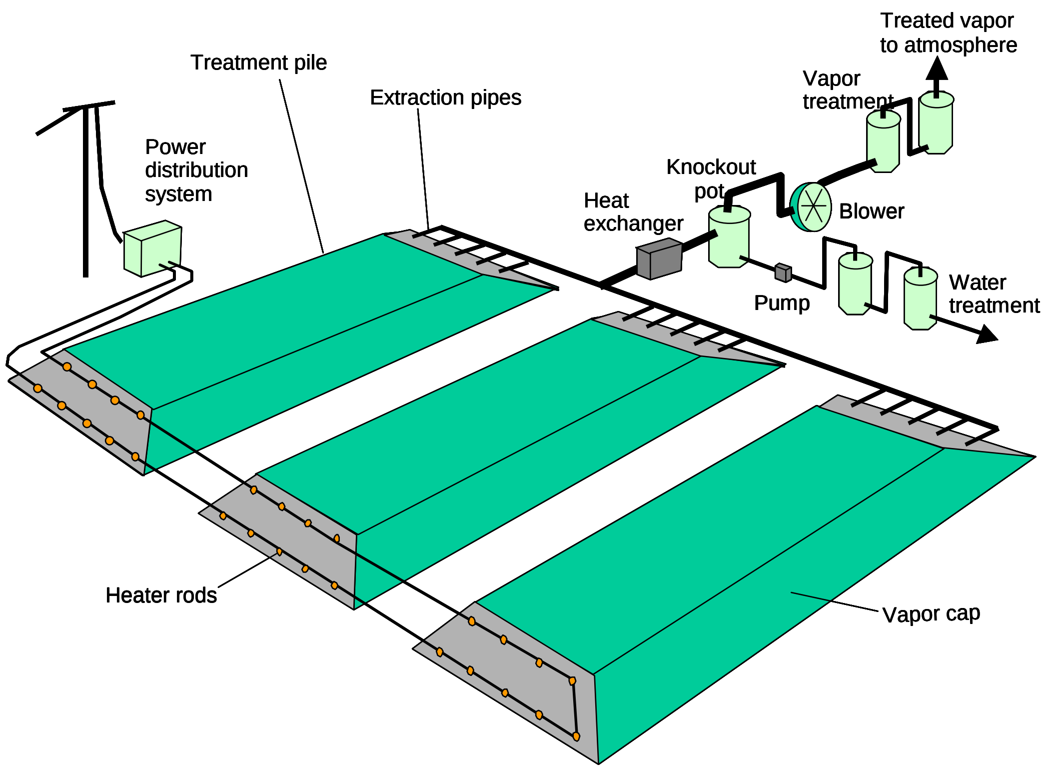
*Overall time required to heat many small batches using an early version of IPTD; **For each of two phases.

2.

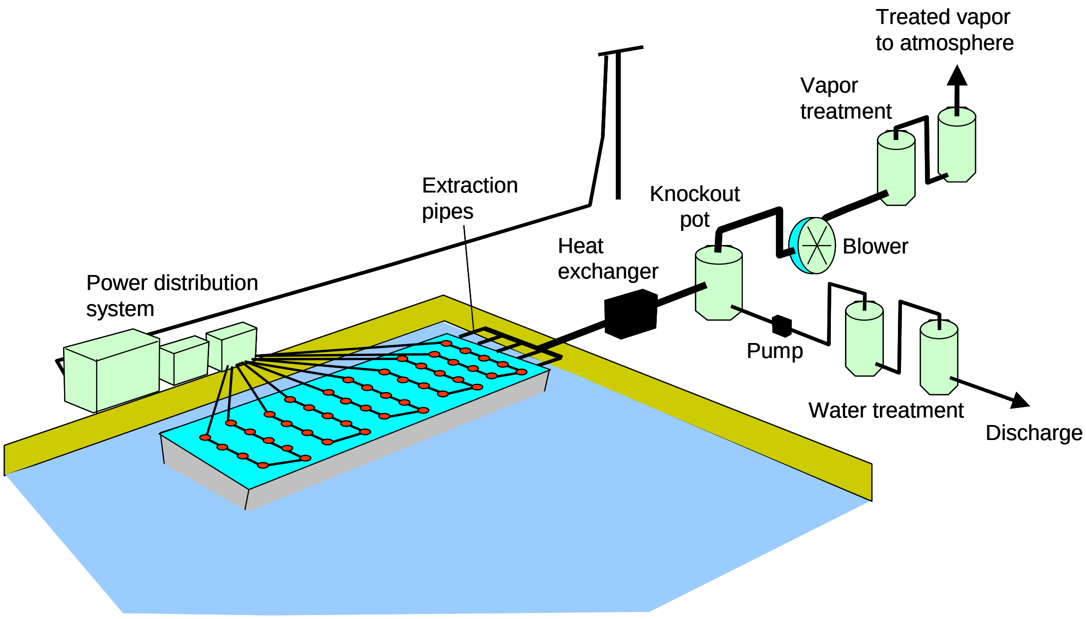
LOCATION	MEAN AIR FLOW RATE (SCMM)	MEAN OXIDIZER BED TEMPERATURE (°C)	MEAN EMISSION RATE (g TEQ/hr)	MEAN STACK GAS CONCENTRATION (ng TEQ/dscm)
Cape Girardeau, MO Thermal Well Demo (PCBs)	2.1	1027	3.47×10^{-10}	0.00291
Cape Girardeau, MO Thermal Blanket Demo (PCBs)	2.6	1027	4.51×10^{-11}	0.000289
Alhambra, CA Full Scale (PAHs, PCDD/Fs)	**31.9**	**798**	**1.61×10^{-8}**	**0.0084**
Maximum Acceptable Control Technology (MACT) Standard for Treatment of Dioxin-Like Substances				**0.2**

FIGURES:

1.


Treated vapor
to atmosphere
Vapor
treatment
Treatment pile
Extraction pipes
Power
distribution
system
Knockout
pot
Heat
exchanger
Blower
Water
treatment
Pump
Heater rods
Vapor cap

2.


Treated vapor
to atmosphere
Vapor
treatment
Extraction
pipes
Knockout
pot
Blower
Heat
exchanger
Power distribution
system
Pump
Water treatment
Discharge