In-Pile Thermal Desorption® (IPTD®) of Dioxin Contaminated Soil and Sediment

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Overview

- IPTD® Background and Concepts
- ISTD/IPTD® Treatment of Dioxins
- SCE - Alhambra ISTD Case Study
- MOE Japan IPTD® Demonstration
- USAID – Da Nang Airport Project
- New IPTD® Patent
ISTD for In-Situ Source Removal

IPTD® for Ex-Situ Soil Remediation
In-Pile Thermal Desorption® (IPTD®)

• Like ISTD, uses thermal conduction heating (TCH) and vacuum extraction to provide within-the-soil remediation;

• Can be designed to treat any organic contaminant; and

• Eliminates the need for offsite disposal or incineration of contaminated soils and sediments.

U.S. Patents 6,881,009; 7,004,678; 7,534,926; and 8,348,551; International patents issued and pending.
First IPTD® Application: Saipan (PCBs)

1998 Technology Merit Award - issued by the Army Corps of Engineers for TerraTherm's Saipan ex-situ remediation project.
Sketch of IPTD® with Horizontal Wells
Corinna, ME
(Chlorobenzenes, Dioxins)

(Baker et al. 2002)
Early IPTD® Concept Utilizing Vertical Wells
Dioxins and Furans

- Structure, example:

\[
\begin{align*}
\text{Cl} & \ \text{O} & \ \text{Cl} \\
\text{Cl} & \ \text{O} & \ \text{Cl} \\
\end{align*}
\]

2,3,7,8-Tetrachlorodibenzodioxin (TCDD)

- Low vapor pressure, high boiling point, high \( \log K_{ow} \), low aqueous solubility
- Known human carcinogens
- Stable in the environment, highly recalcitrant to most remedial techniques
The vapor pressures of contaminants increase exponentially due to thermal conduction heating during the IPTD® process.
ISTD/IPTD®: Where Does Removal and Destruction Occur?

Heater-Only Well: 700°C to 800°C

Volatilization and Destruction of Contaminants 100°C to 500°C

Very Hot Thermal Destruction Zone 500°C to 700°C

Off-Gas Residence Time Several Hours

To Off-Gas Treatment Unit

Heater-Vacuum Well: 700°C to 800°C

Vertical cross-section between two thermal wells
Examples of ISTD and IPTD® field project results for the remediation of dioxin in soil and sediment

(Heron et al. 2010; Baker et al. 2007; USEPA 1998; Conley and Lonie 2000)

<table>
<thead>
<tr>
<th>Site</th>
<th>Target Media</th>
<th>Average Pre-Treatment Concentration</th>
<th>Average Post-Treatment Concentration</th>
<th>Exhaust Gas Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yamaguchi, Japan</td>
<td>Sediment</td>
<td>1,800</td>
<td>67.75</td>
<td>0.000018</td>
</tr>
<tr>
<td>Alhambra, California USA</td>
<td>Soil</td>
<td>18,000</td>
<td>110</td>
<td>0.0071</td>
</tr>
<tr>
<td>Cape Girardeau, Missouri USA</td>
<td>Soil</td>
<td>6,500</td>
<td>3.2</td>
<td>0.0029</td>
</tr>
<tr>
<td>Ferndale, California USA</td>
<td>Soil</td>
<td>3,200</td>
<td>7.3</td>
<td>0.0055</td>
</tr>
</tbody>
</table>
ISTD Case Study: Southern California Edison, Former Pole Yard, Alhambra, CA (PAHs, PCP and Dioxins)

Phase 1

Phase 2

Designed, built, operated by TerraTherm, Inc.

(Baker et al. 2007)
Alhambra Air Quality Control System

- Continuous Emissions Monitoring (CEM) of Off-Gas
- 4 Stack Tests
Alhambra Target Treatment Zone:
- Heterogeneous fine silty sands
- $2,800 \text{ m}^2$
- $12,400 \text{ m}^3$
- Avg. depth 6 m; max. depth 32 m
- Water Table $>82 \text{ m}$
Alhambra ISTD Design Features

- Target temperature (treatability results) of 335°C, maintained for 3 days
- 2.1-m thermal well spacing
- 785 thermal wells, total (131 heater-vacuum and 654 heater-only wells)
- Insulated surface seal
- Two treatment phases
Attainment of Target Temperature (Phases 1 and 2)

335°C
Confirmatory sampling in well field

Auger cuttings oxidation vs. pyrolysis

Coke from product zone

~18’bgs  ~9’bgs  ~1’bgs

Alhambra Confirmatory Soil Sampling
Alhambra Treatment Results

B(a)P Equivalent
Dioxins (2,3,7,8-TCDD TEQ)

Cleanup Goals
65 μg/kg B(a)P
1 μg/kg Dioxin or 1,000 pg TEQ/g

Mean Concentration (μg/kg)

Pre Treatment
N = 47
30,600
18

Post Treatment
N = 60
59
0.11

(Baker et al. 2007)
Alhambra
No Further Action Letter:

"DTSC has determined that the AOC-2 portion at this Site has been remediated to allow for unrestricted land use and that No Further Action is required."

Unprecedented outcome for an in-situ remediation technology!

⇒ Also, less expensive than excavation.
IPTD® Demonstration 2009
Sponsored by Ministry of Environment (MOE), Japan

A joint project of TerraTherm, Inc. and SheGoTec Japan, Inc.

(Heron et al. 2010)
Monitoring Program

- Exhaust through the dust traps
- Environmental Measurement (DXNs before, during and after demo, Noise and Vibration before and during)
- Exhausted to the air

- Analysis of the exhaust from the dust traps
- Analysis of the HEPA filters after the demonstration

- Work Place Measurement (DXNs, Dust, Noise, Vibration)
Monitoring the Surroundings

<table>
<thead>
<tr>
<th>Period</th>
<th>pg-TEQ/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Demo</td>
<td>0.007</td>
</tr>
<tr>
<td>During Demo</td>
<td>0.015</td>
</tr>
<tr>
<td>After Demo</td>
<td>0.0072</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>pg-TEQ/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Demo</td>
<td>0.0063</td>
</tr>
<tr>
<td>During Demo</td>
<td>0.016</td>
</tr>
<tr>
<td>After Demo</td>
<td>0.0088</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>pg-TEQ/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Demo</td>
<td>0.0053</td>
</tr>
<tr>
<td>During Demo</td>
<td>0.015</td>
</tr>
<tr>
<td>After Demo</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Environmental Std.: 0.6pg-TEQ/m³

A to D: DXN monitoring Points
P: Noise/Vibration monitoring Points

: Demonstration Tent
### Effectiveness of the IPTD® Technology

<table>
<thead>
<tr>
<th>Values expressing the effectiveness</th>
<th>Basis for the calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal Ratio</td>
<td>DXNs concentration before remediation (pg-TEQ/g)</td>
</tr>
<tr>
<td></td>
<td>96.24 %</td>
</tr>
<tr>
<td>Decomposition Rate</td>
<td>Total amount of DXNs in the treatment tank before remediation (ng-TEQ)</td>
</tr>
<tr>
<td></td>
<td>96.48 %</td>
</tr>
<tr>
<td>Decomposition Rate in the soil</td>
<td>Total amount of DXNs removed from the tank (ng-TEQ)</td>
</tr>
<tr>
<td></td>
<td>99.98 %</td>
</tr>
</tbody>
</table>

No changes in soil characteristics were observed.
Average TEQ in soil after treatment: 68 pg-TEQ/g (standard = 1,000 pg/g) relative to pre-treatment concentration of 1,800 pg-TEQ/g

⇒ **IPTD® approved for treatment of dioxin-contaminated soil or sediment in Japan**

Met environmental standard in off-gas: 0.6 pg-TEQ/m^3

Peak concentration in gas evolved from soil (before AQC) = 0.46 ng-TEQ/m^3
ISTD and IPTD® without Heater-Vacuum Wells

$\theta_1,\theta_2,\theta_3 = \text{temperature progression}$

$t_3 = 335^\circ\text{C}$
Da Nang Airport
(Sorenson et al. 2011)
Areas Requiring Excavation

Total Area: approximately 190,000 m²

Total Volume (with Pacer Ivy Storage Area to the south): 77,000 m³

Sen Lake and Wetland: 31,000 m³

Central Area: 6,000 m³

Drainage Ditch: 11,000 m³

Former Storage Area: 11,000 m³

Mixing and Loading Area: 17,000 m³

(Sorenson et al. 2011)
## Detailed Evaluation: Summary of EA Findings

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Final Remedy to Meet Clean Up Goals</th>
<th>Implementable</th>
<th>Potential Environmental Impact</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Action</td>
<td>No</td>
<td>Yes</td>
<td>Highest</td>
<td>Externalized</td>
</tr>
<tr>
<td>Active Landfill</td>
<td>Uncertain</td>
<td>Yes with challenges</td>
<td>Second highest</td>
<td>$31M</td>
</tr>
<tr>
<td>Passive Landfill</td>
<td>No</td>
<td>Yes with challenges</td>
<td>Third highest</td>
<td>$36M</td>
</tr>
<tr>
<td>ISTD/IPTD</td>
<td>Yes</td>
<td>Yes with challenges</td>
<td>Lowest</td>
<td>$34M</td>
</tr>
</tbody>
</table>
Da Nang Airport Treatability Testing
(Sorenson et al. 2011)

- Samples collected in August 2010 from MLA and Sen Lake
- Pre-treatment 2,3,7,8-TCDD concentrations
  - Soil: 130,000 ppt to 157,000 ppt (VN standard = 1,000 ppt)
  - Sediment: 5,970 ppt to 7,480 ppt (VN standard = 150 ppt)
- Post-treatment 2,3,7,8-TCDD concentrations
  - MLA Soil below soil cleanup goal after 10 days
  - Sen Lake Sediment below sediment cleanup goal after 7 days
Treatability Testing Results (Sorenson et al. 2011)
IPTD Pile Location  (Sorenson et al. 2011)

- Runway Extension
- Storage Area
- Mixing and Loading Area
- IPTD Pile
- Sen Lake
- Da Nang Airport
Vietnam: Environmental Remediation of Dioxin Contamination at Danang Airport

Progress Report: November 1, 2012 to November 30, 2012

CONSTRUCTION ACTIVITIES
Clearing and grading continued, and USAID contractors began importing fill material at the location for the thermal desorption treatment pile containment structure. Test pits were dug to ensure the integrity of the foundation below the pile containment structure. Contractors also began casting concrete masonry unit (CMU) blocks for construction of the pile structure – 644 of the eventual 33,000 CMU blocks were produced as of November 30, 2012.

Drive in / Drive out capability. Load / unload with no obstructions!


International patents pending.


