

Thermal Conductive Heating/ In-Situ Thermal Desorption (ISTD)

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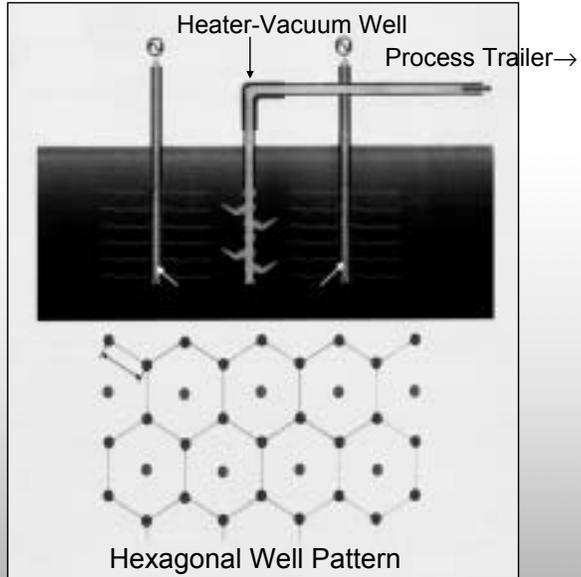
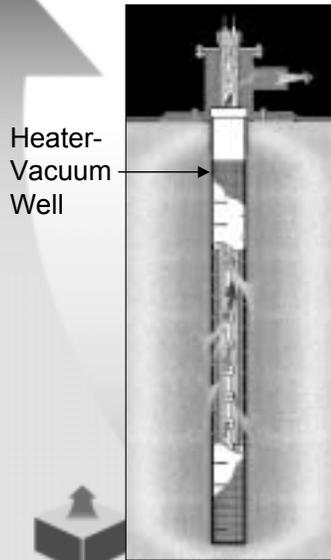
Program Manager

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ISTD: Simultaneous Application of Heat and Vacuum



ISTD Processes

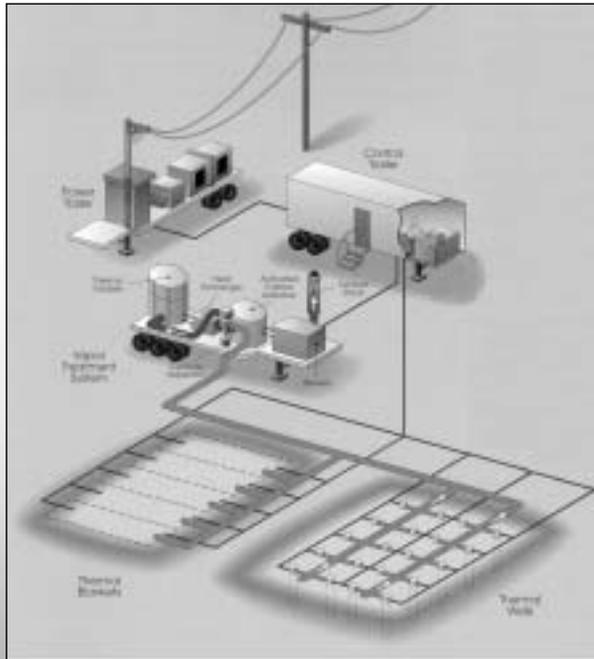
Thermal Conduction into Soil

Vaporization of Fluids and Contaminants within Soil

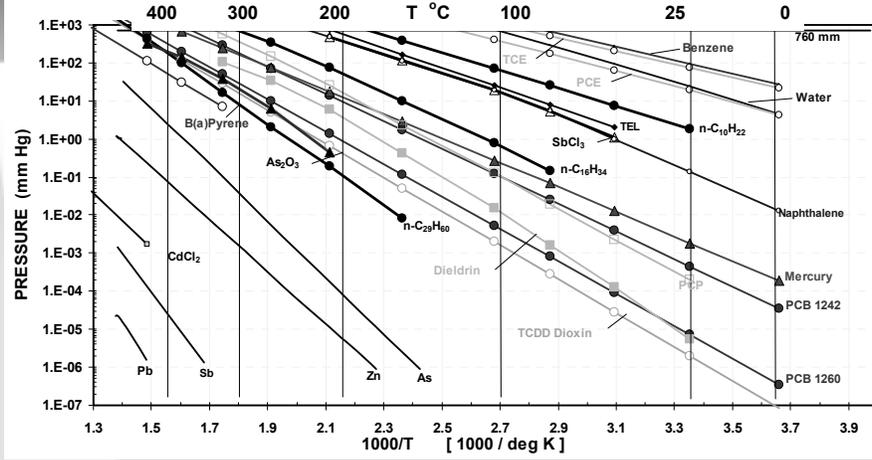
Collection of Vapors

In-Situ Oxidation and Pyrolysis - >95-99% In-Situ Destruction

Aboveground Treatment of Vapors (may be simpler than illustrated)



Vapor Pressure of Contaminants



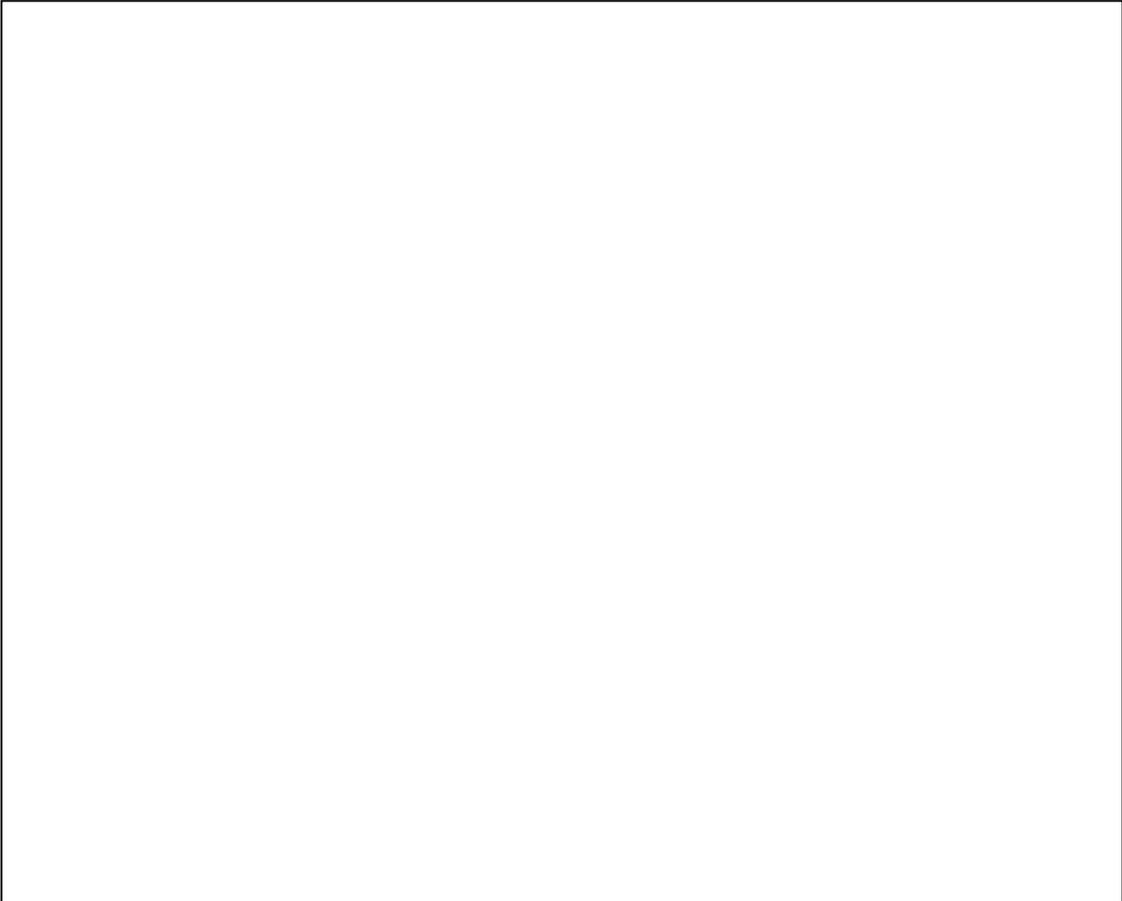
(Stegemeier and Vinegar, 2001)



S. Glens Falls, NY Drag Strip (PCBs)

Waste oil sprayed on soil

Sharp boundary of ISTD treatment zone



Missouri Electric Works (MEW) 12-Well ISTD Demo

Superfund site in Cape Girardeau, MO

PCBs (Aroclor 1260)

Boiling Point: 730 - 780 °F

Depth of contamination: 10 ft.

Soil Type: Clay

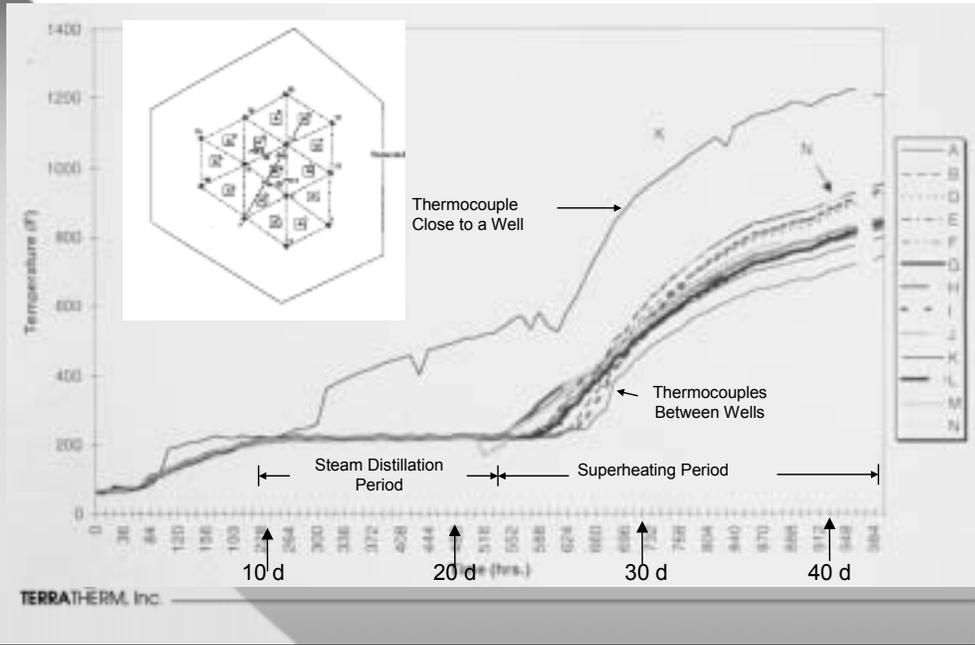
Maximum Concentration: 20,000 mg/kg (\Rightarrow NAPL)

Mean Concentration: 782 mg/kg (n=92)



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MEW - Soil Temp. History at 2 m Depth



Results - MEW, Cape Girardeau, MO

PCBs reduced from mean of 782 mg/kg (n = 92), to mean of <0.033 mg/kg (n = 83)

Treatment temperatures and results demonstrate 100% sweep efficiency

Stack testing showed 99.999998% DRE

No evidence of contaminant migration

Dioxins in treated soil below background level (< 6 ppt)



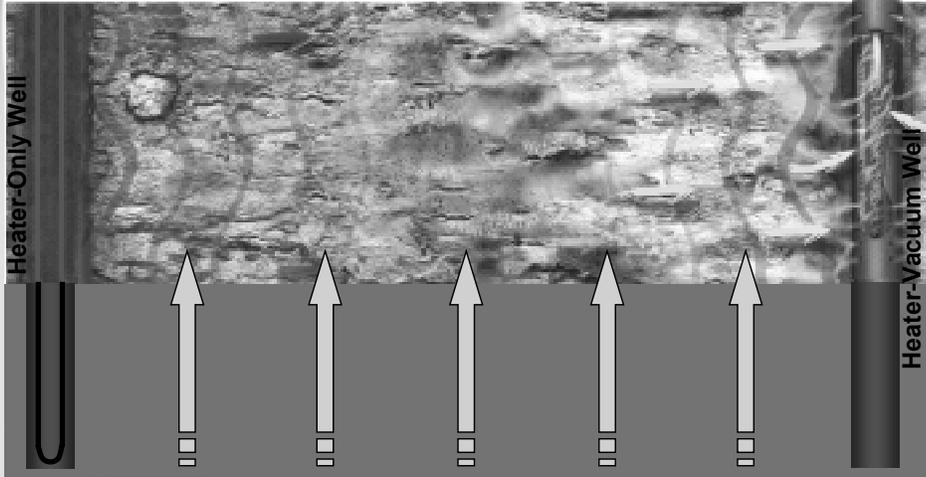
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(Vinegar et al., 1997; France-Isetts, 1998)

Zones of In-Situ Thermal Desorption and Destruction

Vadose Zone – permeability is created:
SVOCs: 150 – 600°C (very rapid reaction rates)
VOCs: 100 – 600°C

Below water table:
SVOCs: 150 – 600°C
VOCs: 100°C



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ISTD at Former Shell Bulk Storage Terminal, Eugene OR



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ISTD at Eugene, OR (cont.)

Diesel Range Organics (DRO), gasoline and benzene:

- ◆ in soil and groundwater to depths up to 12 feet bgs;
- ◆ maximum soil concentrations of 9,300 mg/kg (DRO), 3,500 mg/kg (gasoline); and in groundwater, 1,300 µg/l (benzene);
- ◆ as much as 7.9 ft of free product in monitoring wells.

Gravel layer 1-4', over silt to ~11-16' bgs.

Perched groundwater encountered in the unconfined top gravel and silt layers.

Project goal was removal of free product and benzene, and closure of the site under RBCA UST program with Oregon DEQ.



(Conley et al., 2000)

Eugene, OR ISTD Project Results

Free phase LNAPL removed from the entire 1-acre site.

Estimated 200,000 lbs of hydrocarbons removed and treated during the 120-day heating cycle.

All confirmation (post-remediation) soil and groundwater samples were below the ODEQ's Tier 1 Risk-Based Concentrations:

- ◆ Benzene concentrations in groundwater within the treatment area were reduced from 1,300 µg/L to ≤2.50 µg/L.
- ◆ All post-treatment off-site groundwater samples (4 quarterly rounds) were below the analytical detection limit (i.e., <0.5 µg/L).

Oregon DEQ issued a "No Further Action" letter for the site on March 14, 2000

- ◆ Closure 2 ½ yr after startup (incl. 1-yr post-treatment monitoring).



ISTD at Former Molded Plastics Manufacturing Facility, Portland, IN

7500 sq.ft. x 18 ft = 5000 CY Treatment Zone

PCE as high as 3,500 mg/kg

- ◆ IDEM Voluntary Tier II industrial cleanup goal (< 8.01 mg/kg for depths > 2 ft)

TCE as high as 79 mg/kg

- ◆ IDEM cleanup goal < 25 mg/kg

Silty-Clay Soil (Till), < 2.5×10^{-8} cm/s

Water Table at 22 ft BGS

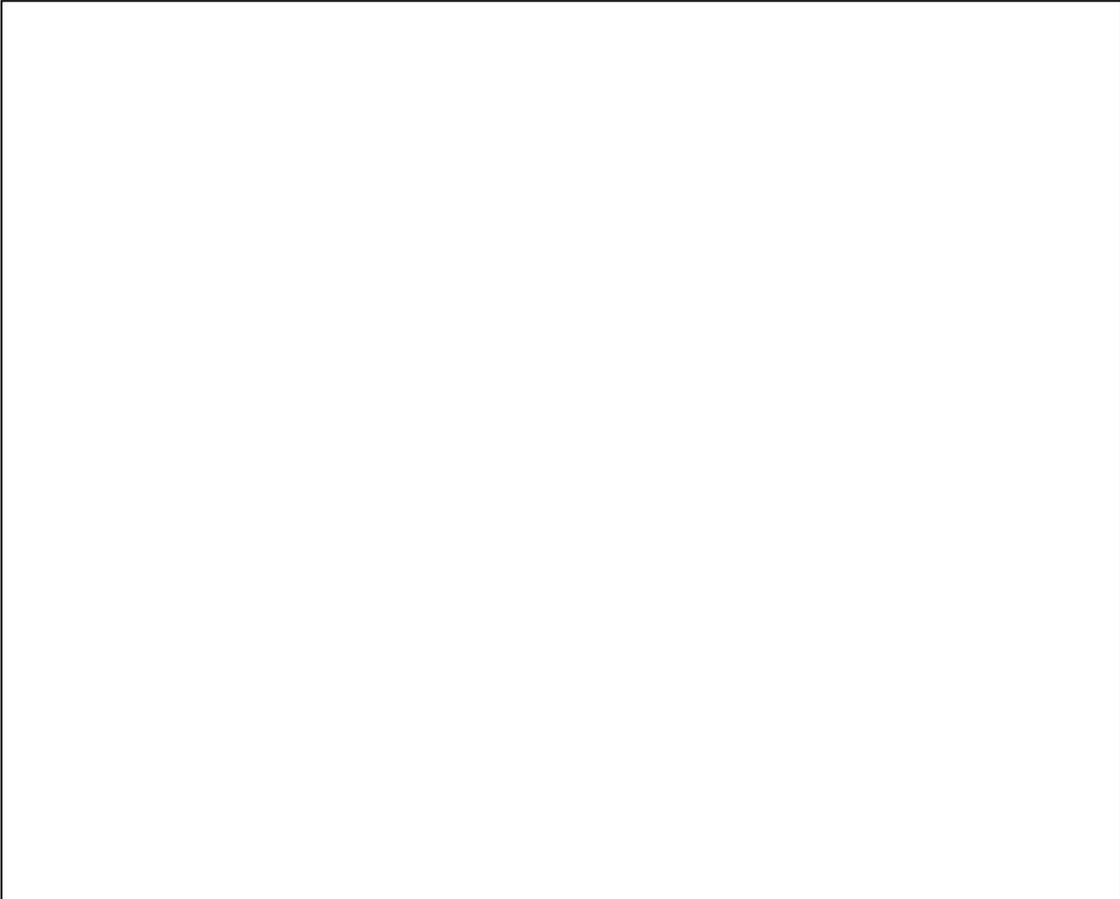


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Adjacent Residences, Portland, IN



**ISTD
Well
Field**



Portland, IN Site Closure by IDEM, 2000 Removal Action Summary:

Location	Depth (feet)	Pre-Heating (mg/kg)	Post-Heating (mg/kg)
SA4	4 to 5	PCE = 23	PCE = 0.530
		TCE = 0.25	TCE = ND
SB20	4 to 5	PCE = 2.9	PCE = 0.046
		TCE = 0.67	TCE = ND
SA13	9 to 10	PCE = 3500	PCE = 0.011
		TCE = 79	TCE = 0.020
SB19	12 to 14	PCE = 76	PCE = 0.048
CS12*		TCE = 1.6	TCE = ND
GP31	15 to 16	PCE = 570	PCE = 0.18
		TCE = NA	TCE = 0.008

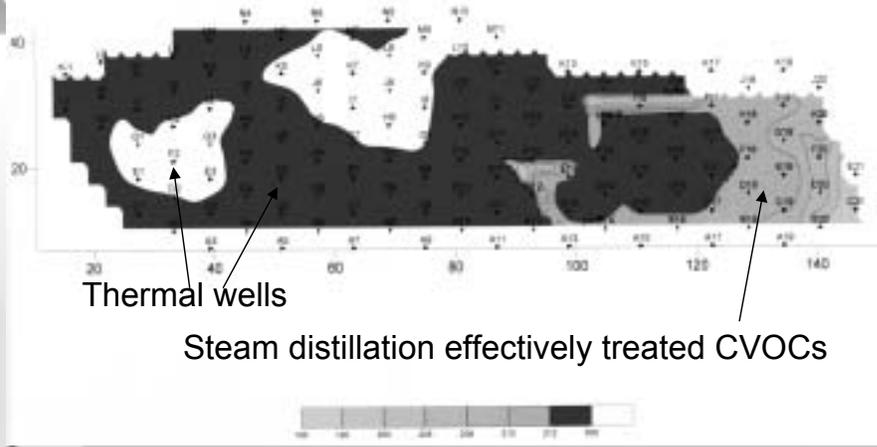


ND – non-detect; NA – not available; *8 ft away from SB19

(Vinegar et al., 1999)

Portland, IN ISTD Temp. Distribution

13 Ft BGS, 11/2/97



(Vinegar et al., 1999)

Summary of Completed Thermal Conduction/ISTD Field Projects

Location	Contaminant	Initial Max. Concentration (ppm)	Final Concentration (ppm)
S. Glens Falls, NY	PCB 1248/1254	5,000	< 0.8
Cape Girardeau, MO	PCB 1260	20,000	< 0.033
Vallejo, CA	PCB 1254/1260	2,200	< 0.033
Portland, IN	PCE	3,500	< 0.5
	TCE	79	< 0.02
Saipan, NMI	PCB 1254/1260	10,000	< 1
Eugene, OR	Benzene Gasoline/Diesel	3.3 3,500/9,300 + free product	< 0.044 250,000 lbs. free product removed
Ferndale, CA	PCB 1254	800	< 0.17



(Stegemeier and Vinegar, 2001)

Current ISTD Projects

Southern California Edison, Alhambra, CA – Former Pole Yard (*PAHs, PCP, dioxins*); 15,000 CY silty sand to 100 ft depth; clean-up goals: < 0.033 mg/kg B(a)P TEQ and < 1 µg/kg TCDD TEQ; May 2002 – Dec. 2003

Confidential Site, OH – Active Manufacturing Facility (*CVOCs*); 11,000 CY clay till to 15 ft depth; clean-up goal: 1 mg/kg TCE; July 2002 – June 2003

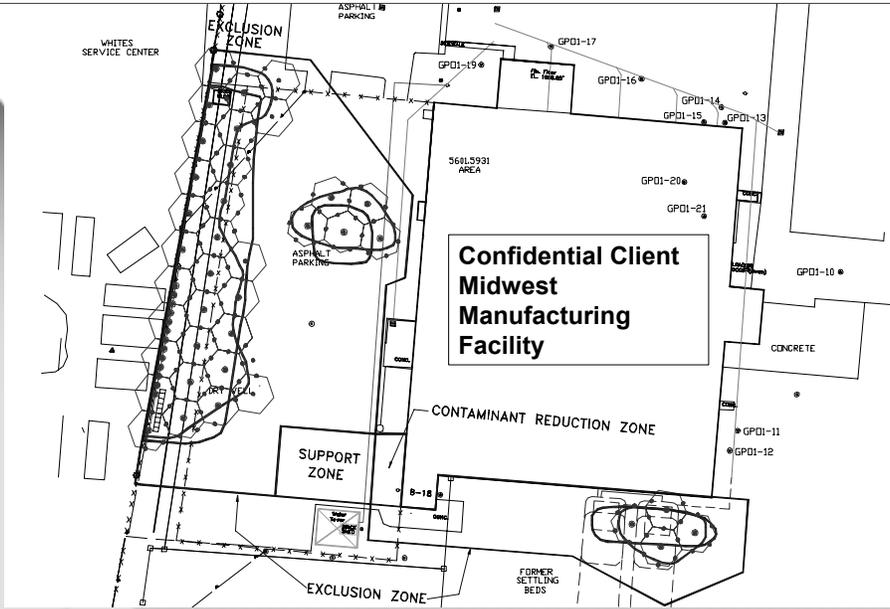


Confidential Client, CA – Former Manufacturing Facility (*CVOCs*); Thermally-enhanced dual-phase extraction; 8,000 CY silty-clay soil, above and below water table, to 37 ft depth; clean-up goal: 1 mg/kg DCE; Sept. 2002 – Aug. 2003

SCE – Alhambra (under constr'n)

- 15,000 cy contaminated to 100' depth in silty sands
- TerraTherm currently installing \$5.3M ISTD project





- 11,000 cy of PCE- and TCE-contaminated soil (low-permeability clay till) to 15 ft depth; water table > 30 ft
- Total cost \$1.2 M, or ~\$110/cy treated.



TerraTherm's Approach for Chlorinated Solvents Sites

Employ Wider (e.g., 30 to 40-ft diameter) Well Patterns

Attain Steam Distillation Target Temperatures between Thermal Wells

Create Vapor Plenums to Enhance Vapor Collection, and Hot Floors (U.S. Patent No. 5,997,214) to Prevent Downward Migration of DNAPL

Simplify Off-Gas Treatment System:

- ◆ Condenser (if needed);
- ◆ No Oxidizer needed;
- ◆ Dry Scrubber and Carbon Adsorbers.



Soil Heating Requirements

Soil

◆ Mineral Grains $(1-\Phi) \rho_s C_s \Delta T$

Water Saturation

◆ Sensible $\Phi S_w \rho_w C_w \Delta T$

◆ Latent $\Phi S_w \rho_w h_v$

Inflow Water

Air

Power \approx 10-30% of overall cost

Where:

Φ = porosity

ρ = density

C = heat capacity

ΔT = change in
temperature

S = saturation

h_v = heat of
vaporization

s = solids

w = water



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ISTD Heating Requirements: Past and Present

Traditional Approach for SVOCs – boil off all water (latent heat of vaporization)

Traditional Approach for CVOCs – assume boil 1 pore volume (to offer guaranteed results)

Recent Work Suggests Less Power may be Sufficient

Thermal Conduction Heating is As Efficient as Other In-Situ Thermal Heating Methods



ISTD Price Range

PCBs, PAHs, Dioxins

- ◆ ~\$600/cy for small sites (1000 cy)
- ◆ ~\$100/cy for large sites (100,000 cy)

BTEX, VOCs

- ◆ ~\$170/cy for small sites (3000 cy)
- ◆ ~\$60/cy for large sites (100,000 cy)

Price considerations incl.: site access, air discharge limits, need to control recharge, electricity costs, depth of heating zone/length of heaters, regulatory oversight



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Attributes of ISTD

Widest heating range of any in situ thermal technology
— effective at sites with DNAPL, LNAPL, mixtures

Can clean to very low/non-detect residual levels in situ

Typically achieves >95% in-situ destruction of
contaminants ⇒ less loading to aboveground treatment

Past ISTD projects have all had emissions of <0.005 ng
TEQ/dscm; no evidence of dioxin formation.

Minimal risk of mobilization due to application of
vacuum and predictable heating



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Attributes of ISTD, cont.

Process is not hindered by subsurface heterogeneity

- ◆ Gas permeabilities range over many orders of magnitude
- ◆ Electrical conductivities range over 1-2 orders of magnitude
- ◆ Thermal conductivities range only by factor of ± 2

100% Sweep - Highly Predictable and Reliable

Can be rapid (e.g., 2-3 months operation)

Safe, quiet, odorless (perfect safety record)

Cost-Effective



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About TerraTherm, Inc.

Exclusive licensee of ISTD technology:

- ◆ Within the U.S., from the Univ. of Texas at Austin:
Protected by 20 U.S. patents, + patents pending
- ◆ Outside the U.S., from Shell Oil Co.: Protected by 5
patents pending

Offices in Fitchburg, MA and Houston, TX

- ◆ Currently 20 Employees

For more information, please visit

www.terra-therm.com



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