

# Thermopile©

## D'leteren site: treatment test

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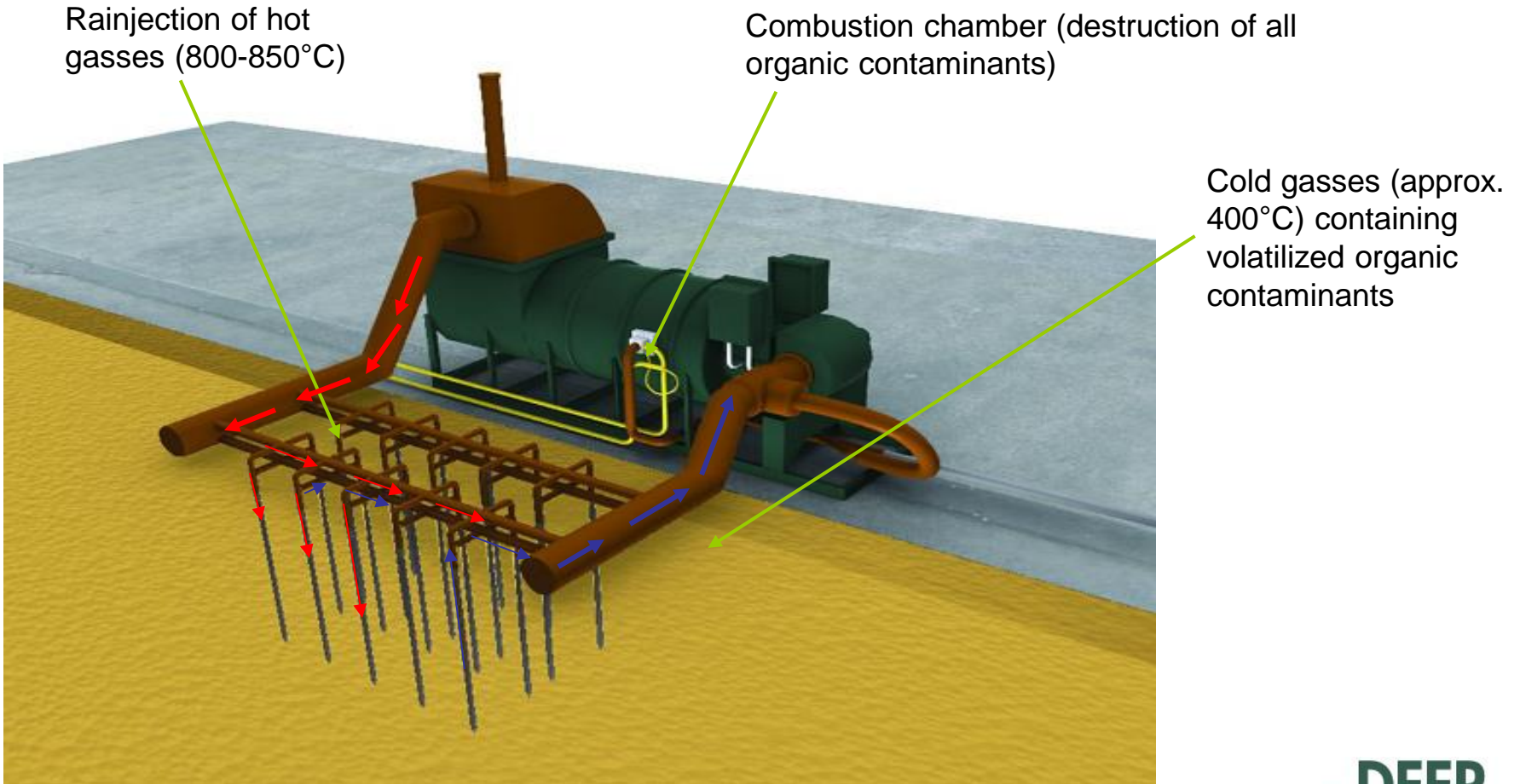
[www.deep-green.com](http://www.deep-green.com)

# Thermopile©: Principles

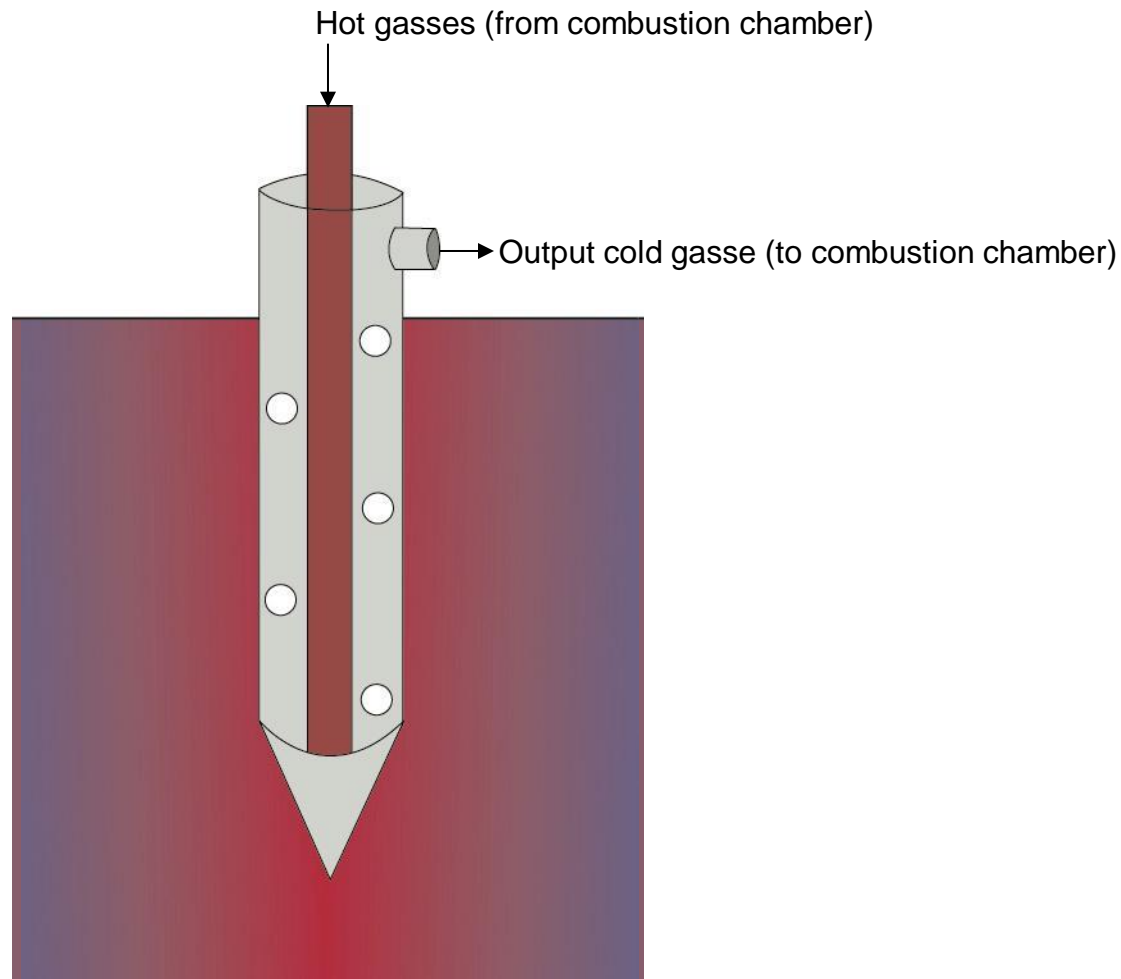
- Thermopile© is a specific application of **Thermal Desorption**:
  - Step 1: Transfer of the pollution from the soil into the gas phase by evaporation (mainly)
  - Step 2: Destruction of the pollution by thermal oxydation (combustion).
- Compared to classical thermal desorption:
  - Reduced fuel consumption (and emissions) – factor 2 to 10
  - In situ applications possible (no excavation)
  - Much higher score on sustainable development
  - Lower cost

# Thermopile<sup>©</sup>

## How does it work?



# Heating the soil



# Applications



**DEEP  
Green**  
FOR A CLEAN FUTURE

# Size of equipment – T1



# Size of equipment – T2



# Case study – in situ remediation of LNAPL

- D'leteren-site / Belgium
- Test objectives
- Thermopile© installation
- Operating conditions
- Test results

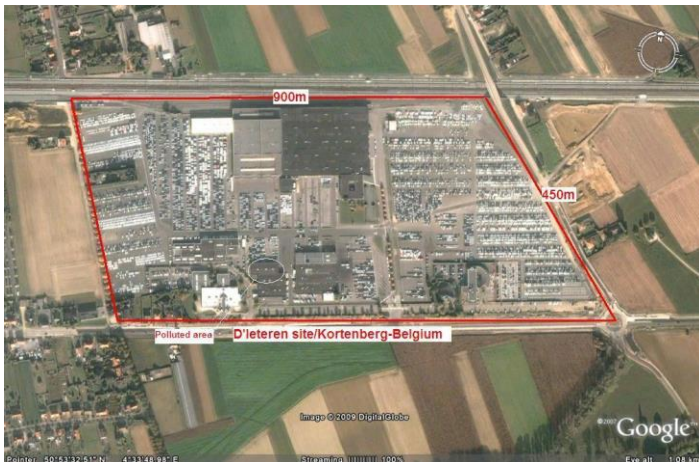


# Thermopile©

## D'leteren site: treatment test

### D'leteren-site/Belgium

- Size: 40 hectares;
- Polluted area: 2000m<sup>2</sup> (3.5m depth) → >12kTons;
- Soil (gravel-sand-clay);
- Underground water at 2.65-3m;
- Pollutant: - LNAPL layer (20-80cm thick)
  - BTEX, HCT, HAP (vadose/saturated zones and ug-water)



D'leteren site

↓

Sample	BTEX (mg/Kg)	C10-C40 (mg/Kg)	PAH (16) (mg/Kg)
Soil (at 1m)	<0.25	97.4	0.06<x<0.81
Soil (at 2m)	<0.25	---	<0.8
Soil (at 4m)	<0.25	848	1.46<x<1.91
Sample	BTEX (µg/L)	C10-C40 (g/L)	HAP (16) (µg/L)
Liq(water)	414	1.3	740

Table. Soil and water pollution

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- D'leteren-site /Belgium
- **Test objectives**
- Thermopile© installation
- Operating conditions
- Test results

### Test objectives

- To evaluate the effectiveness of the technology
- To estimate the time and the cost of treatment

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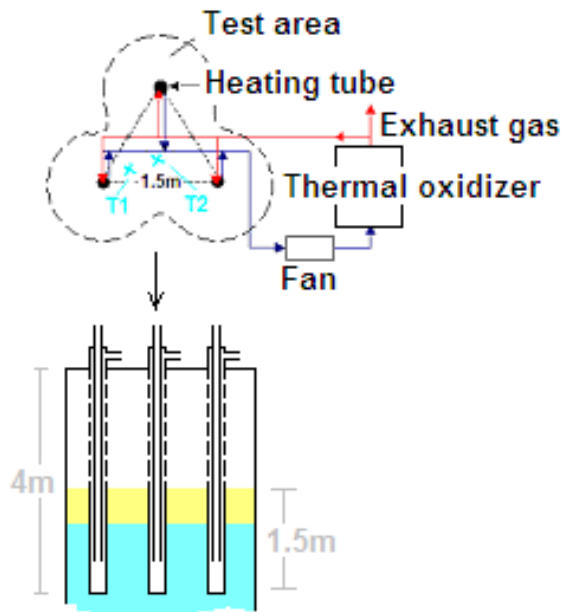
- D'leteren-site /Belgium
- Test objectives
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# Thermopile©

## D'leteren site: treatment test

### Thermopile© installation

- 3 heating pipes (1.5m, equilateral triangle);
- Test area: ~5m<sup>2</sup> (3.5 m depth) → 30 Tons;
- 15 K-thermocouples (soil+gas circuit);
- 3 control wells (5m depth) were dug → Evolution LNAPL layer



Thermopile© installation

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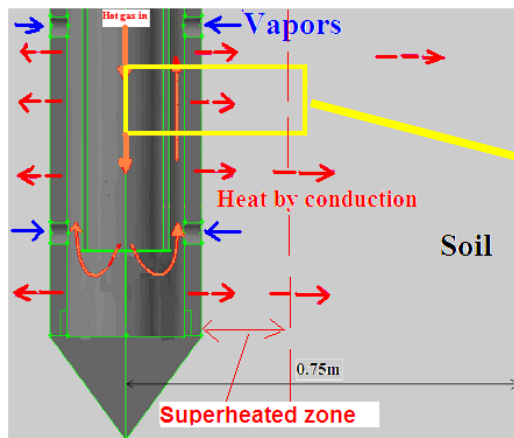
- D'leteren-site /Belgium
- Test objectives
- Thermopile© installation
- **Operating conditions**
- Test results

# Thermopile©

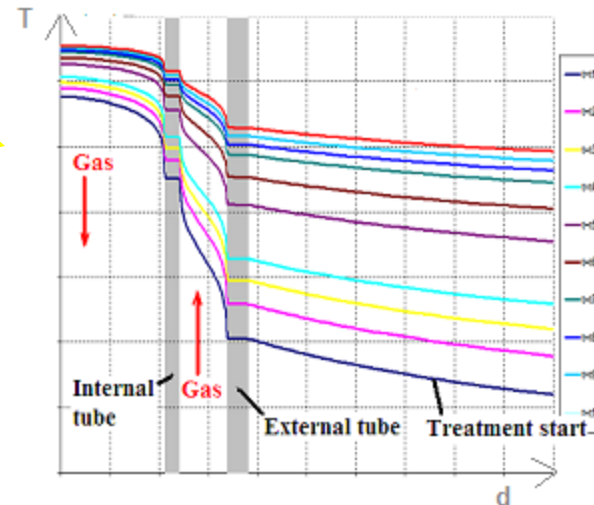
## D'leteren site: treatment test

### Operating conditions

- Turbulent flow ( $Re \gg$ ) → Good heat exchange gas/tubes
- Gas flow first through inlet tube → small  $\Delta T_{axial}$
- Heating temperature (inlet pipe)  $>700^{\circ}\text{C}$



### Gas/soil temperatures



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- D'leteren-site /Belgium
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# Thermopile©

## D'leteren site: treatment test

### Test results

#### Heating time

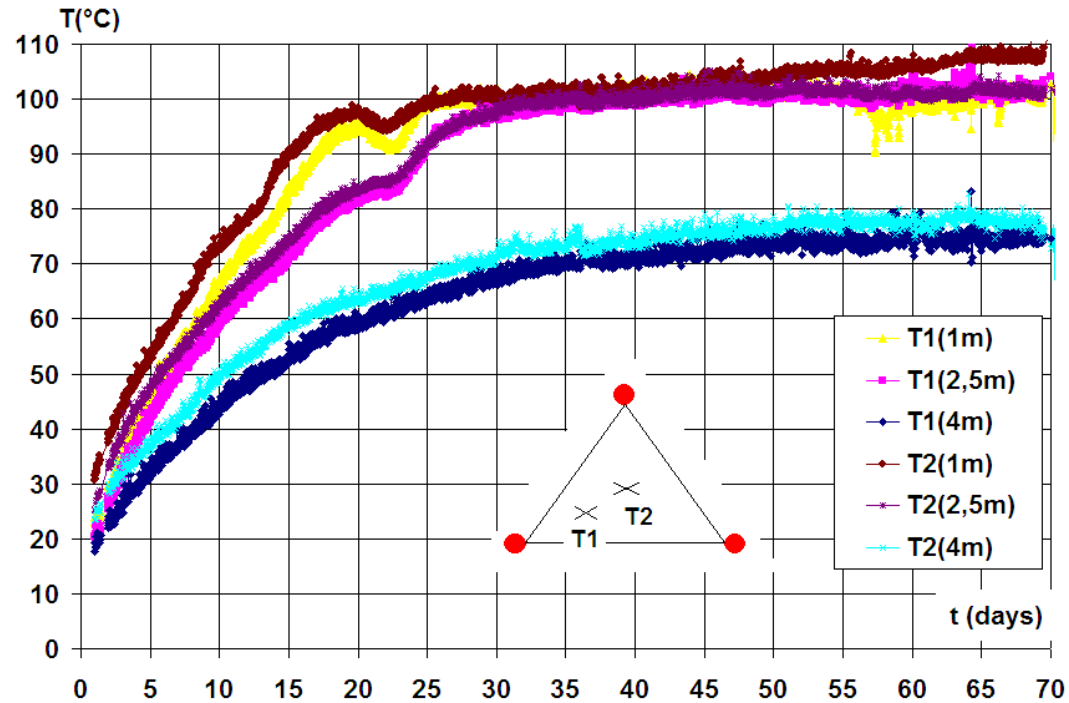
➤ 70 days

#### Soil temperature

➤ Phase1: ~20 days → Soil 'T' rises to 100°C (boiling point of water).

➤ Phase2: ~50 days → Soil 'T' remained at 100°C (except SHZ) →

most energy yielded → to evaporate water+contaminants

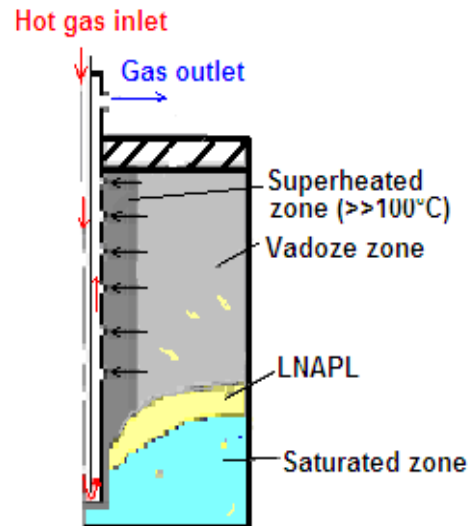


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## D'leteren site: treatment test

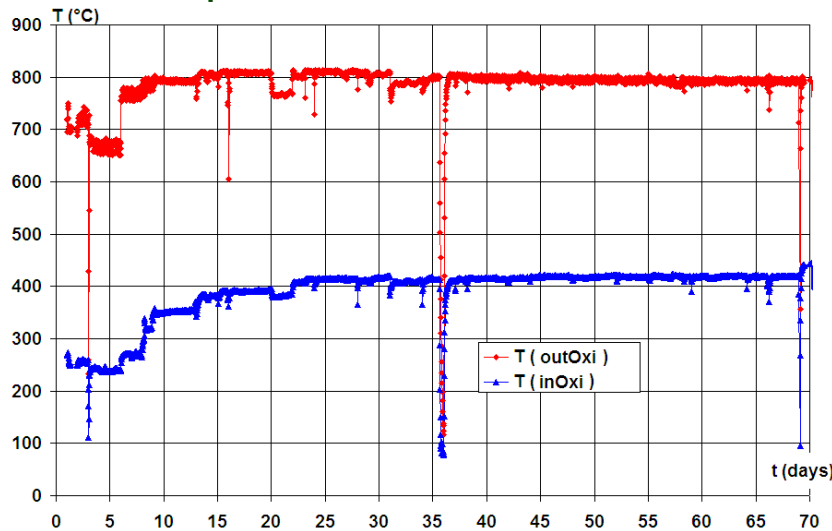
### Treatment mechanisms

- Soil at 100°C → Forced convection of steam →  
Steam distillation of organic compounds occur
- SHZ (>>100°C) close to pipes (few cm thick) →  
Oxidation, Pyrolysis and Hydrolysis Reactions occur
- SHZ is a form of well → fast elimination of LNAPL layer

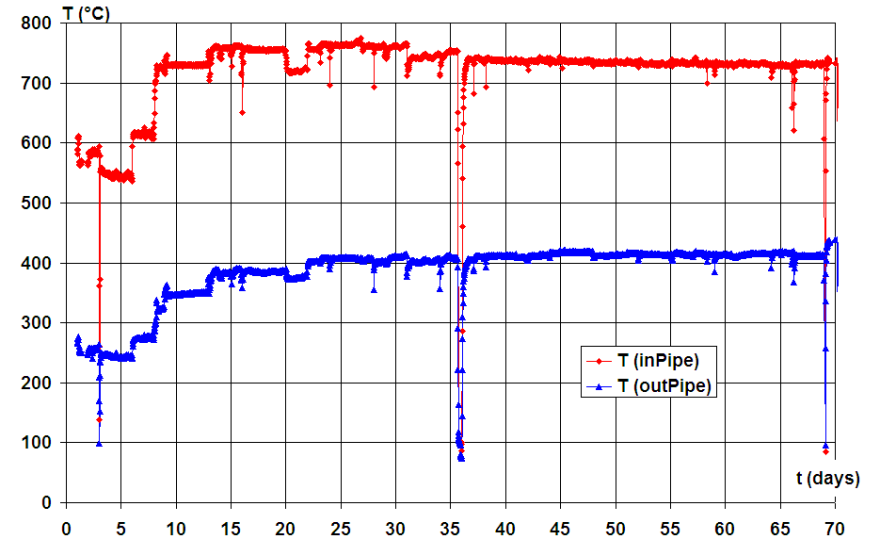


### Energy balance

Gas temperature in/out Thermal Oxidizer



Gas temperature in/out pipe



Energy provided by gas:

$$\dot{Q} = \int_0^{t_f} \dot{m}(T) \cdot C_g \cdot [T_{out}(t) - T_{in}(t)] dt$$

### Energy balance

During 70 days:

- ~1000W/m (pipe length) were injected in soil
- ~ 17MWh were used to heat soil, evaporate water and contaminants
- ~ 30% of this energy were provided by contaminants

# Thermopile©

## D'leteren site: treatment test

### Post-treatment soil and water analysis

- Treated area → LNAPL layer became non-existent
- BTEX: total elimination in soil and more than 91% in water  
(414µg/L → <40µg/L)
- TPH (HCT): elimination >79% in soil and >99.5% in water
- PAH (HAP): elimination >60% in soil and > 98% in water  
(1.91mg/Kg → 0.8mg/Kg in soil and 740µg/L → <11µg/L in water)