INTERGEO
ENVIRONMENTAL TECHNOLOGY - BRANCHES WORLDWIDE
INTERGEO Greece – Offices in Thessaloniki
INTERGEO General Profile

• Has been founded in 1987
• Over 10,000 investigation projects
• Over 3,000 soil and groundwater remediation projects
Region of intervention of Municipality of Evosmos
Location points of the industrial units and of disposed waste and garbage within the investigation area

- Meandrou street
- Smirnis street
- Olimpiados street

Surface: ~500,000 m²

- Industrial unit
- Uncontrolled disposal of waste and garbage
Future uses of the ground uses of the area of intervention
Places of investigation boreholes and monitoring wells that have been executed in the field of research
<table>
<thead>
<tr>
<th>Drilling Diameter (mm)</th>
<th>Drilling Depth (m)</th>
<th>Lithology</th>
<th>Thickness (m)</th>
<th>Colour</th>
<th>Soil Sample</th>
<th>Soil Gas Sample</th>
<th>Water Sample</th>
<th>Soil Analysis TPH in mg/kg</th>
<th>Soil Gas Analysis in mg/m³</th>
<th>Water Analysis TPH in mg/l</th>
<th>Groundwater level</th>
<th>Remarks</th>
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<td>1,4</td>
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**Drill-log**

**Borehole Nr7**
Cross section in the research area according to the boreholes data and the information from the relative bibliography

South

North

Depth below the surface in meters
Distribution of the concentration of total hydrocarbons in the soil in the area of research in three different levels below the surface of the ground
Relation of the concentration of total hydrocarbons (TPH) with the sampling depth in the investigation borehole 19 in the research area in Evosmos
Distribution of the concentration of total hydrocarbons (TPH) in the groundwater in the area of research of Evosmos
Soil vapor extraction system

- Activated carbon filter
- Vacuum pump
- Water separator
- Perforated tube
- SVE-well
- Contaminated soil
Remediation system of the unsaturated zone with the bioventing system

- activated carbon filter
- vacuum pump
- water separator
- perforated tube
- Air infiltration well
- Soil vapor extraction borehole
- contaminated soil
- groundwater
Affected ray of the recovery wells that were achieved during the pilot test
Schematic representation of the pollution of the contaminated ground with the “on site” method

GROUND PLAN

6 m

screens of diameter 2"

30 m

Soil vapor extraction

SECTION

Soil vapor extraction

30 m

impervious cap from PVC

1.5 m

Contaminated soil

Impervious bottom from PVC

screens of diameter 2"

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Suggestion of remediation for the contaminated soil with hydrocarbons with “In situ” and “On site” methods

Contaminated soil
With hydrocarbons
that needs remediation

Soil vapor extraction

Absorption drilling
of underground air and
vapor of the underground

Deposition area
of contaminated soil
from the areas H, G, F and A
for "on site “remediation

Suggestion of remediation for the contaminated soil with hydrocarbons with “In situ” and “On site” methods

Contaminated soil
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that needs remediation

Soil vapor extraction

Absorption drilling
of underground air and
vapor of the underground

Deposition area
of contaminated soil
from the areas H, G, F and A
for "on site “remediation
Progress of the course of the soil remediation in unit 3 (in situ processing) in Evosmos, Thessaloniki. Duration: 1/11/98 - 13/7/99

Technique: BIOVENTING

were recovered 359 Kg Hydrocarbons

Total quantity of recovered hydrocarbons in Kg

Concentration of hydrocarbons

Concentration of hydrocarbons in mg/m³

Operation in days

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On site Soil Venting
In situ Soil Vapor Extraction
CASE STUDY DESCRIPTION

SITE FEATURES (1)

1. Location: Island in Aegean Sea with limited water resources
2. Site Operation: Depot terminal of power plant
3. Source: Leakage of underground oil product conveyance pipeline
4. Amount of released product: 1,5 m³ Diesel
5. Geology: Till 15-20 m unconsolidated permeable sediments (sand, gravel, silty sand)
6. Bedrock: granodiorit
7. Piezometric groundwater level: ~ 3 m b.s.l
CASE STUDY DESCRIPTION

SITE FEATURES (2)

8. Hydr. Conductivity of aquifer: 3-8 X 10^-5 m/s (permeable)

9. Condition of the aquifer: Unconfined

10. Mean hydraulic gradient: 1-3 %

11. Drinking water: Water wells located in 120 m distance (supply for 2000 people)

12. Environmental Risk: Very high

13. Amount of released product: 1,5 m3 Diesel

14. Groundwater impact in the drinking wells: 2,1 mg/l TPH concentration after 15 days of the incident
Case study: Groundwater flow conditions

Groundwater table and movement direction of the groundwater under static and dynamic conditions.
Case study: Groundwater flow dynamic conditions 3D

Groundwater table under dynamic conditions on 3-4/11/98
Case study Geological cross-section along the groundwater flow direction

Geological cross-section along the groundwater flow direction

Absolute height in m a.s.l.

G4
G1
Mw3
Mw5

Sand-gravel
Vadose zone
Clay-sand
Saturated zone

Soil contamination in the vadose and saturated zone
Figure 3: Distribution of TPH concentration in the soil in three different levels - Contaminated site - Power plant close to drinking water extraction wells.
Case study TPH in the groundwater

Distribution of TPH concentration in the groundwater (date 16/12/98)

Floating free phase of oil product on the groundwater

TPH mg/l

0.0 1.0 2.5 5.0 10.0 15.0 20.0 25.0 30.0
Case study Remediation Action Plan
Synoptic presentation of the remediation action plan
Case study  Location of the remediation systems

Locations of the remediation systems at the contaminated Power plant site
Case study \( \text{O}_2 \) content in the groundwater before remediation

Distribution of \( \text{O}_2 \) content in the groundwater, date 14/2/99 before the start of groundwater remediation measures
Case study: O\textsubscript{2} content in groundwater shortly after the start

Distribution of O\textsubscript{2} content in the groundwater, date 06/04/99
shortly after the start of groundwater remediation measures
Case study O₂ content in groundwater after completion

Distribution of O₂ content in the groundwater, date 14/2/01 after completion of the remediation measures
Case study Soil Vapor Extraction Progress

Bioventing Borehole BB

SVE boreholes

Target of remediation

590 Kg

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Case study: Water quality in the drinking well

Graph showing changes in TPH over days of operation.
REMEDIATION RESULTS

• The soil remediation (source) was completed after 20 months implementation of the airsparging technology

• The groundwater TPH concentration was radically reduced below the drinking water standards after 16 months of system operation
Location of investigation drillings and groundwater monitoring wells at the depot terminal
## Drill-log from borehole BH9 in the depot terminal

<table>
<thead>
<tr>
<th>Lithological Description</th>
<th>Drilling Depth (m)</th>
<th>Lithology</th>
<th>Thickness</th>
<th>Colour</th>
<th>Soil Sample</th>
<th>Soil Gas Sample</th>
<th>Water Sample</th>
<th>Soil Gas Analysis in mg/m³</th>
<th>Water analysis TPH in mg/l</th>
<th>Groundwater level</th>
<th>Remarks</th>
<th>Drilling Diameter (mm)</th>
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</thead>
<tbody>
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<td>*carried materials 52</td>
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<td>2391 Arom. 895</td>
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<td>60 cm</td>
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<td></td>
<td>strong smell of product</td>
<td></td>
</tr>
</tbody>
</table>

: sample
Simplified geological cross section at the depot terminal
Distribution of TPH concentration in the soil of the vadose and of the saturated zone
Distribution of volatile hydrocarbon concentration in the soil-gas at the depot terminal
Depth to the groundwater at the site of the depot terminal

Depth to groundwater in m below surface

0.50    0.60    0.70    0.80    0.90    1.00    1.10    1.20    1.30    1.40    1.50    1.60    1.70    1.80    1.90    2.00
Estimated extent of floating free product on groundwater at the depot terminal (May ’98-Nov ’98)
Distribution of TPH concentration in groundwater & estimated extent of floating free product on groundwater table
Initial concept of the proposed decontamination technique for the subsurface in the installation

- Soil Vapor Extraction Unit 21
- Soil Vapor Extraction Unit 1
- Oil separator for the recovered oil product
- To underground disposal of the pumped groundwater

**Legend:**
- SVE1: Soil Vapor Recovery well
- Rw1: Groundwater Abstraction well + Oil Product recovery well
- Skimmer
- Submersible groundwater pump
Bioslurping technique for the subsurface in the installation

- Oil separator for the recovered oil product
- To disposal or further treatment (if necessary) of the pumped water
- Contaminated soil-zone
- Floating free phase of oil product
- Slurp tube
- Air liquid separator
- Air flow - Bioventing
- Extracted soil-gas
- Oil separator for the recovered oil product
- To Oil product holding tank
- To disposal or further treatment (if necessary) of the pumped water
- Groundwater table
- Bioslurping technique for the subsurface in the installation
Applied soil and groundwater
Decontamination measures at Depot terminal
Decontamination measures in the Depot Terminal

For the unsaturated soil:

Implementation of the in situ method of “Bioventing” in 4 areas within the installation

For the groundwater:

1) Installation of Skimming system for free product recovery [at least four (4) recovery wells]

2) Implementation of Bioslurping technique in 5 monitoring wells
Progress of soil decontamination procedure
Operation time of SVE unit 1: 25/7/1999-19/7/2000
at the Depot terminal

Decontamination completed

930 Kg

Total amount of eliminated hydrocarbons in Kg

Operation time in days

Hydrocarbon concentration in mg/m³

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Progress of soil decontamination procedure
Operation time of SVE unit 2: 25/7/1999-17/5/2000
at the Depot terminal

Decontamination completed

46 Kg

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Progress of soil decontamination procedure
at the Depot terminal

Total amount of eliminated hydrocarbons in Kg
7650 Kg

Hydrocarbon concentration in mg/m³

Operation time in days

Goal concentration in the soil-gas

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Progress of soil decontamination procedure
at an installation

Decontamination completed

Total amount of eliminated hydrocarbons in Kg

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28438 Kg
Progress of the oil product floating on the groundwater - Measurements in the recovery wells

<table>
<thead>
<tr>
<th>Time (in days)</th>
<th>Recovered oil Bioslurping (in m³)</th>
<th>Recovered oil by Skimming (in m³)</th>
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<tr>
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<tr>
<td>200</td>
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<td>360</td>
<td>12</td>
<td>9.1</td>
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Thickness of the oil product floating on the groundwater - Measurements in the Bioslurper wells