Use of the Combined OIHPT Probe to evaluate the Distribution and Efficiency of a Remediation Agent supplemented with a Fluoresceine Tracer

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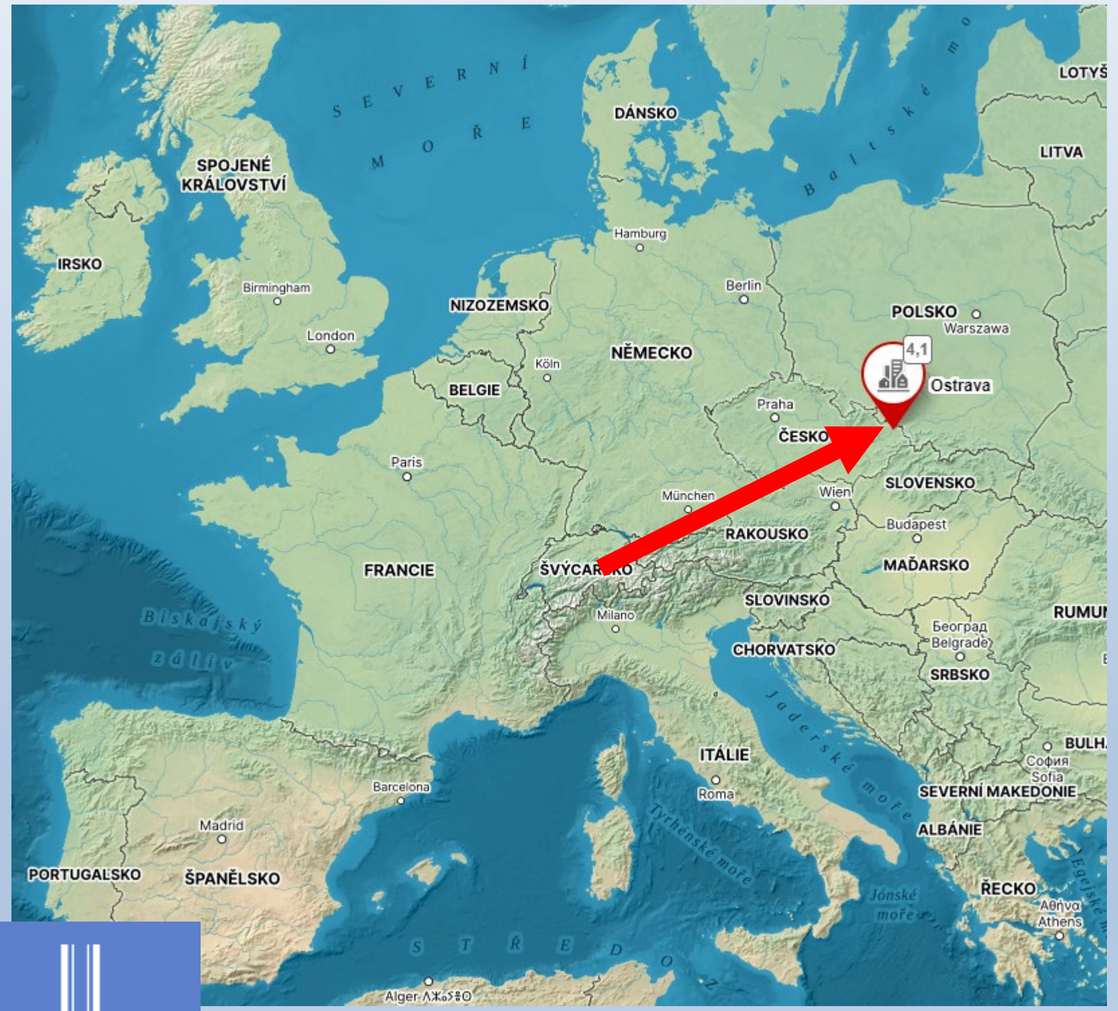
Ostramo Lagoons: Site Overview



- **Landfill Usage:** The Ostramo Lagoons were used as a landfill for dumping residual petrol waste from a former refinery that produced mineral oils.

- **Waste Sludge**: Most of the waste sludge, which contained a mixture of petroleum residues and sulfuric acid, was excavated and incinerated earlier.

- **Groundwater Contamination**: Despite these efforts, the aquifer remains highly contaminated. The contamination includes both petrol waste residues and heavy acidic brines, which create a distinct phase in the lower parts of the aquifer.

Ostramo Lagoons: Site Overview

- Brines have **pH below 2.5**, sulphates up to 150 g/l, iron and aluminum above 3 g/l, plus other toxic metals.

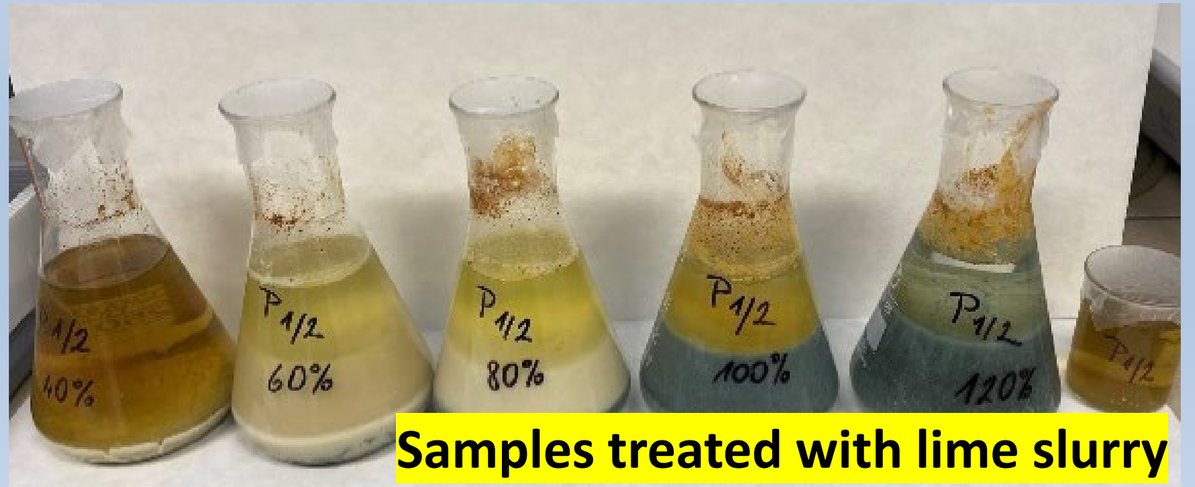
- **Underground sealing wall failure:** The installed wall does not work properly.

Ostramo Lagoons: Remedy

- **Raising pH - previous** research and geochemical modeling show that raising the aquifer's pH can cause minerals like gypsum and ettringite to form, which helps reduce the spread of contaminated groundwater.
- **Full-scale Remediation** - the plan was to use direct push lime slurry injections to neutralize and stabilize the aquifer.
- **Pilot Test Results** - pilot tests were unsuccessful as the aquifer's pH was not sufficiently neutralized.

WHY?

And that is where our story begins. We need to find out what is going on underground.



Samples treated with lime slurry

Methodology

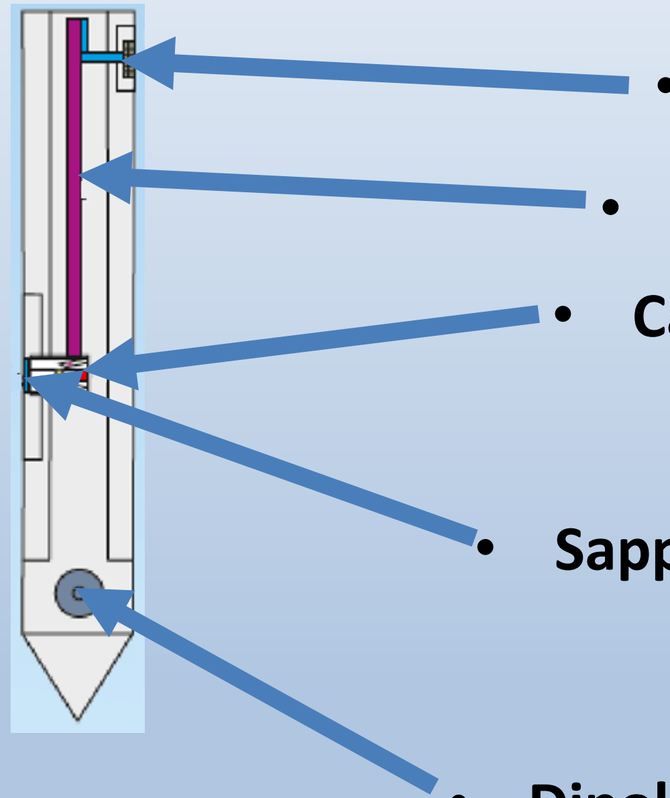
- **Adding Tracers** - the lime slurry was supplemented with several tracers (fluorescein dye and strontium aluminate).
- **Pre- and post-injection investigations** - (OIHPT, Dual Tube soil sampling) were conducted to:
  - **Assess the actual distribution and** preferential migration of the injected agent in the aquifer and
  - **valuate the stability** of the treated parts of the aquifer regarding the transition back to acidic conditions (rebound effect).
  - **Analyze Soil Changes** - determine changes in soil permeability and conduct soil analysis.

Fluorescein tracer in the field

Strontium aluminate under normal and UV light

Methodology - OIHPT

Optical Image Profiler + **Hydraulic Profiling Tool** (Geoprobe, USA)



- **HPT injection port**
- **Trunkline cable**
- **Camera with visible/UV light**
- **Sapphire glass window**
- **Dipole for electric conductivity measurements**

- **OIP** = a direct push tool used for the delineation of non-aqueous phase liquid (NAPL) hydrocarbon fuels and oils using camera system under UV and visible light
- **HPT** = a port utilising measuring the pressure required to inject a set flow of water into the soil – the pressure data serves as an indicator of soil permeability
- **EC** = electric conductivity data provides lithologic information of soil conductivity

Methodology - OIHPT

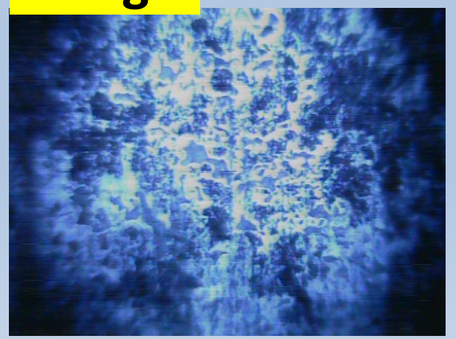
Tracer Colors - The tracers used have different colors compared to the blue color of petroleum compounds commonly monitored using the Optical Image Profiler (OIP).

New Software Development - We developed new software capable of monitoring different colors and creating graphic columns of stacked pictures taken by the OIHPT.

Column created of stacked UV light pictures

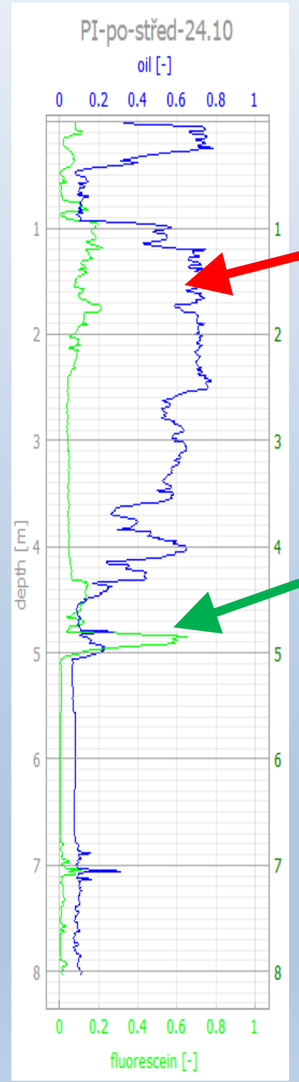
Picture taken by OIHPT under: visible light

UV light



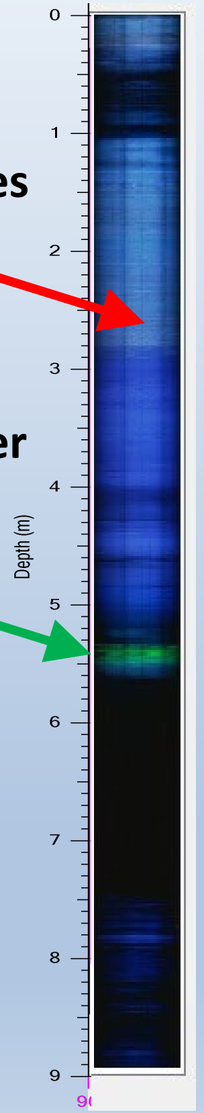
How to interpret the data

OIP graph – to quantify blue and green fluorescence



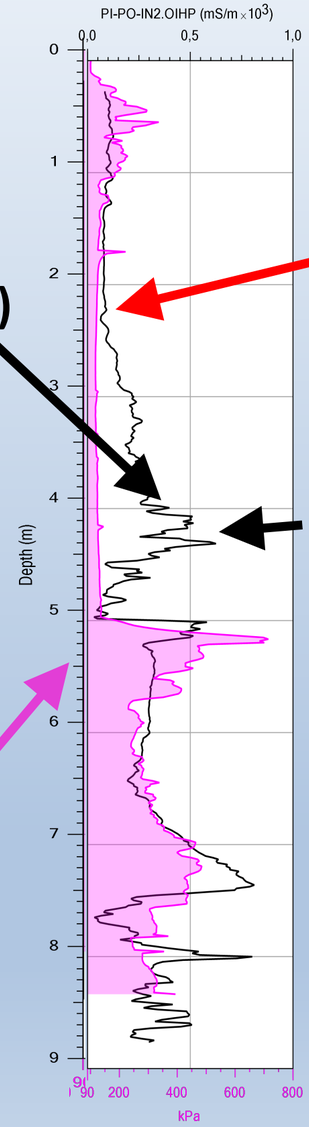
Petrol waste residues

Horizon with a tracer and lime slurry



Column created of stacked UV light pictures

HPT graph



Fine sands

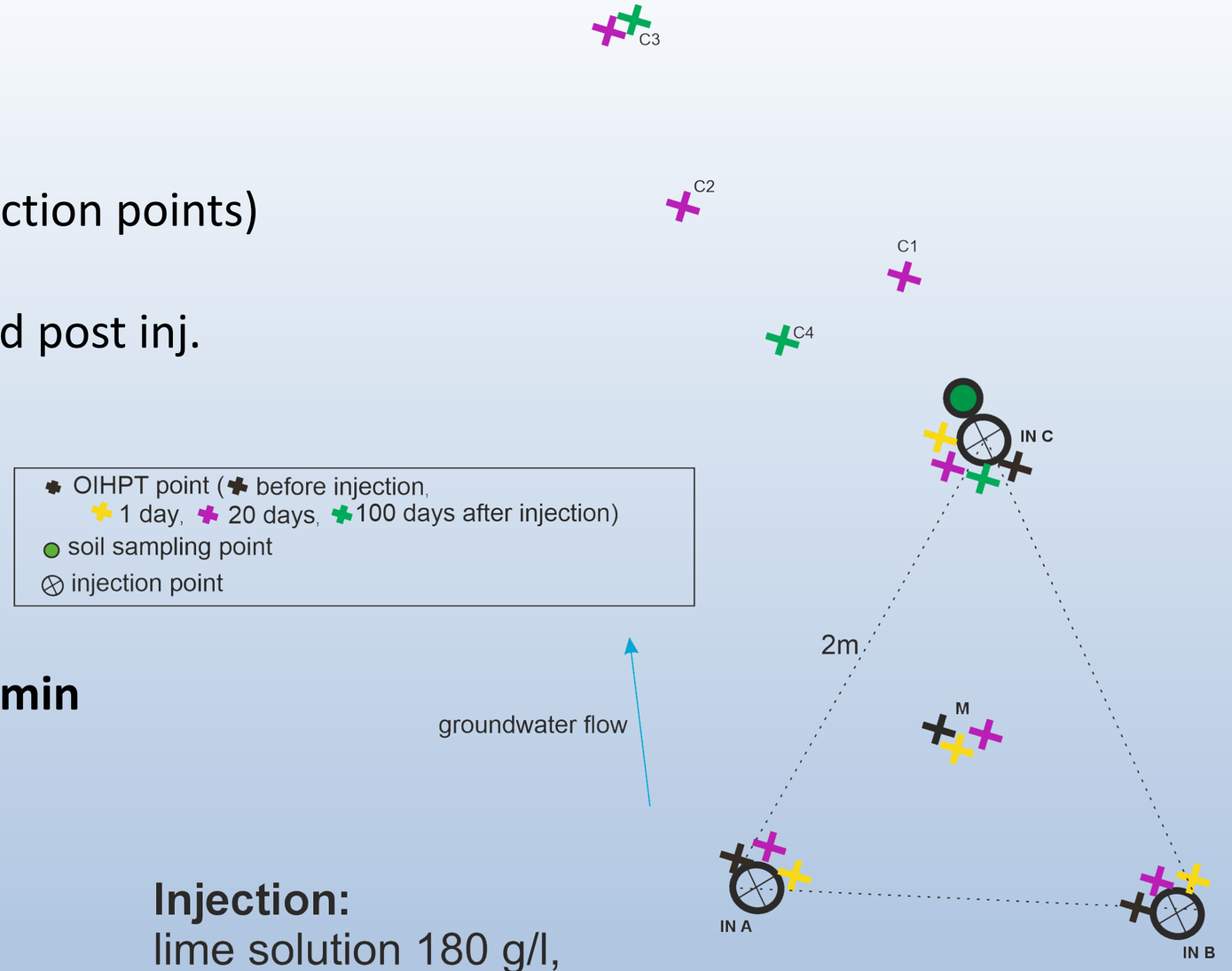
Electric conductivity (mS/m)

Gravel aquifer with brine

HPT pressure (kPa) - decreased permeability due to treatment

Results – 1st pilot test

- Injection polygon – triangle (2m between injection points)
- Only Sodium fluoresceine tracer
- OIHPT investigation – 4 different times pre and post inj.
- Soil sampling – 20 days after injection



Injections using - high pressure hydraulic piston pump (Filamos, Czechia) – up to 80 bars and 70l/min

Geoprobe rig 7822DT and adjusted Geoprobe injection system with a hose inside the rods

Injection:
lime solution 180 g/l,
fluoresceine 20 mg/l
3,2; 3,5; 3,8; 4,1 mgb
IN A - 5000 l
IN B - 5000 l
IN C - 4000 l

1st Pilot Test

Results 1st pilot

Lime Slurry Distribution was suboptimal, with significant preferential migration observed around 3 bgs.

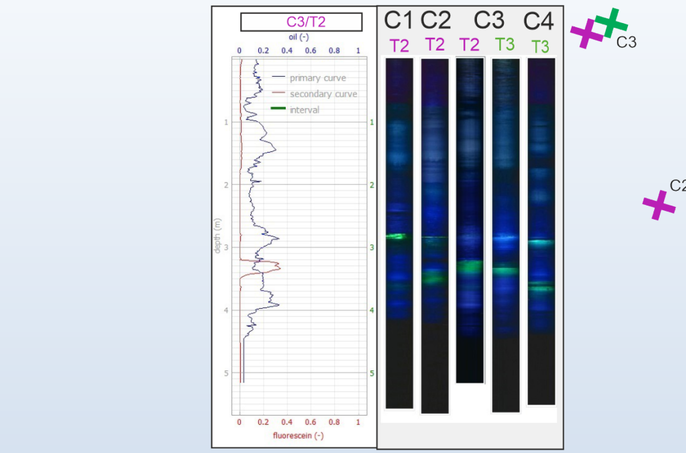
The fluorescein disappeared in the treated zone over time, as it is only stable in neutral pH and degrades in acidic pH.

→ the amount of lime provided was not sufficient to neutralize the aquifer long-term, causing the treated zones to become acidic again.

→ Additional laboratory tests revealed that the soil itself has a high acidifying potential.

→ **Recommendations:**

- Increased lime dosing
- Explore new injection methods to improve lime distribution.



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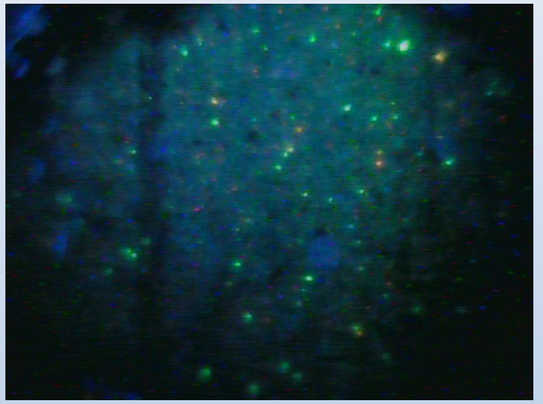
Successive pilot tests

We conducted 6 additional pilot tests with different setups to address the findings from our initial tests.

These setups included:

- Higher concentrations of lime solution with limestone marl and quarry ash
- Injections into cased wells
- Enhancement of the slurry distribution using pneumatic fracturing
- Two tracers approach (addition of strontium aluminate that is stable even in acidic pH)

Mixture of strontium aluminate and fluorescein caught by OIHPT 2 days after injection

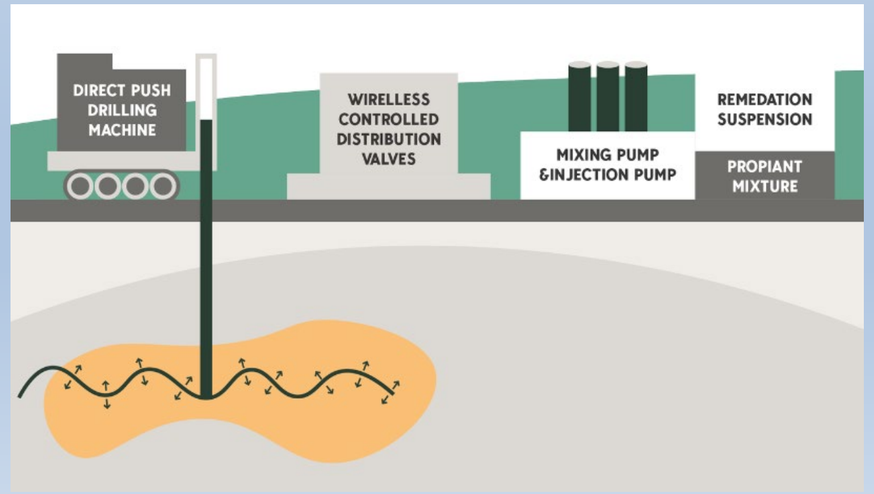


Same spot 7 days after injection with no fluorescein, while strontium aluminate can still be seen as white dots

Successive pilot tests

- Best results observed with pneumatic fracturing coupled with injection of a mixture of lime slurry and calcareous saliva

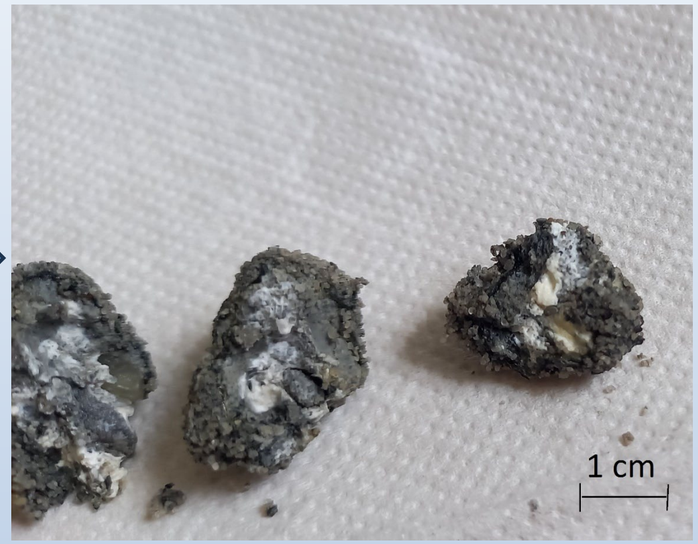
- Limestone marl reacts with GW to produce carbon dioxide that bubbles trough the formation and enhance the distribution



Setup for hydraulic fracturing

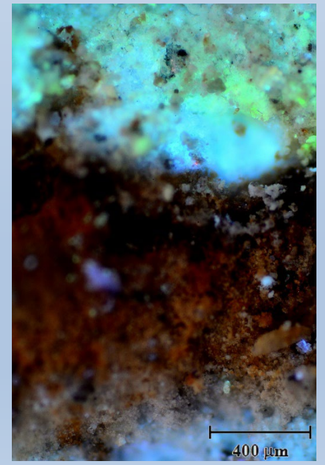
- High pressure pump Filamos and automatic distributor for remediation agent and air
- Cubic tank equipped with mixer
- Mixer with a hopper
- Air compressor
- Electrical unit

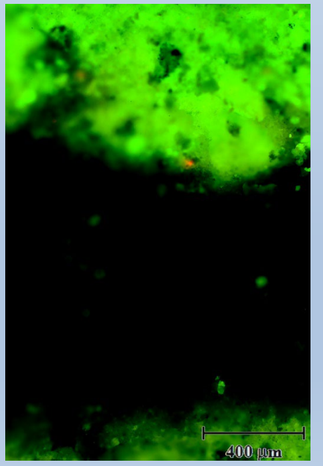
Results - Soil sampling and analysis



Optical and Fluorescence Microscopy

- Samples containing lime were collected in a form o separated conglomerates in the gravel aquifer
- Optical and Fluorescence Microscopy
- Scanning Electron Microscopy (SEM)
- X-Ray Powder Diffraction





Takeaways

- OIHPT could be used for tracing fluorescein and other UV actives tracers and assess the distribution of remediation agents in the aquifer
- Strontium aluminate can be used as a solid-state inert tracer
- Pneumatic fracturing can be used to enhance the remediation agent distribution in well permeable aquifers
- Limestone marl is a cheap and reactive neutralization agent that produce CO_2 bubbles that can further enhance the remediation agent distribution
- Aquifer soil needs to be always taken in to account when lab testing

Thank you for your attention

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