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Geophysical Monitoring of Initiated In-Situ Bioremediation of Chlorinated Solvent Contamination

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Summary

Contaminated ground is a severe problem which is present in many countries, and it is of great importance to find efficient solutions to deal with it. In Sweden, there is a trend in the industry to move towards alternate remediation methods and on that scope in-situ bioremediation has received a lot of attention. The main challenge with in-situ bioremediation is to verify that the treatment has the intended effect, and it is hence important to understand the changes that happen in the subsurface and monitor them over time. The scope of our work is to use geophysics to extrapolate the punctual information from groundwater and soil samples and acquire a better understanding of the changes in the subsurface during in-situ bioremediation of the contaminated soil. In this work we have made a permanent installation in one of our field sites, in Alingsås, where a pilot bioremediation test is taking place to treat the contaminated soil. The autonomous system can measure the resistivity and chargeability distribution in the subsurface. The results indicate promising correlations with the geophysical signature and the contaminant. Currently we are investigating the correlations between the groundwater samples and the time-lapse imaging acquired while working towards real-time monitoring.

Introduction

Contaminated ground is a severe problem which is present in many countries, and it is of great importance to find efficient solutions to deal with it. The most common way to treat the contaminated mass in Sweden is by excavation and treatment, which is associated with a high cost, especially if the contaminated mass has great volumes or it is deep. Furthermore, the approach creates a risk for secondary exposure to the contaminant and requires destruction of any properties sitting on the land, which is very often the case especially when the contaminated mass is located in urban environments.

There is a trend in the industry to move towards alternate remediation methods and on that scope in-situ bioremediation has received a lot of attention. As opposed to excavation and treatment, this method is more cost efficient and prevents secondary exposure if done with care.

The main challenge with in-situ bioremediation is to verify that the treatment has the intended effect, and it is hence important to understand the changes that happen in the subsurface and monitor them over time. To achieve this a number of monitoring wells are normally placed sparsely in the area, and groundwater and soil samples are taken for analyses over a period of time. The scope of our work is to use geophysics to extrapolate the punctual information from groundwater and soil samples and acquire a better understanding of the changes in the subsurface during in-situ bioremediation of the contaminated soil.

In this work we have chosen to use the Direct Current time-domain Induced Polarization (DCIP) method to acquire daily measurements of the resistivity and chargeability distribution in the subsurface. For that reason, a fully autonomous system was developed and installed in the field site, which takes care of the data acquisition and data handling.

Area of investigation

Alingsås is located in western Sweden in close proximity to the city of Gothenburg. A former dry-cleaning facility spilled large amounts of PCE in the 1970’s. The accumulation of PCE in the subsurface led to the formation of a plume which is outlined in Figure 1.

A simplified geological conceptual model (Figure 2) shows that clay is dominant in the area (0.5m to 6m depth) and most of the highest concentration of the contaminant can be found in that clay layer. A rather thin (0-1m) layer of sand can be found between the clay and the granite bedrock.

To treat the subsurface a small-scale pilot in-situ bioremediation plan was executed in 2017 by performing direct push injection of two different products (Table 1).

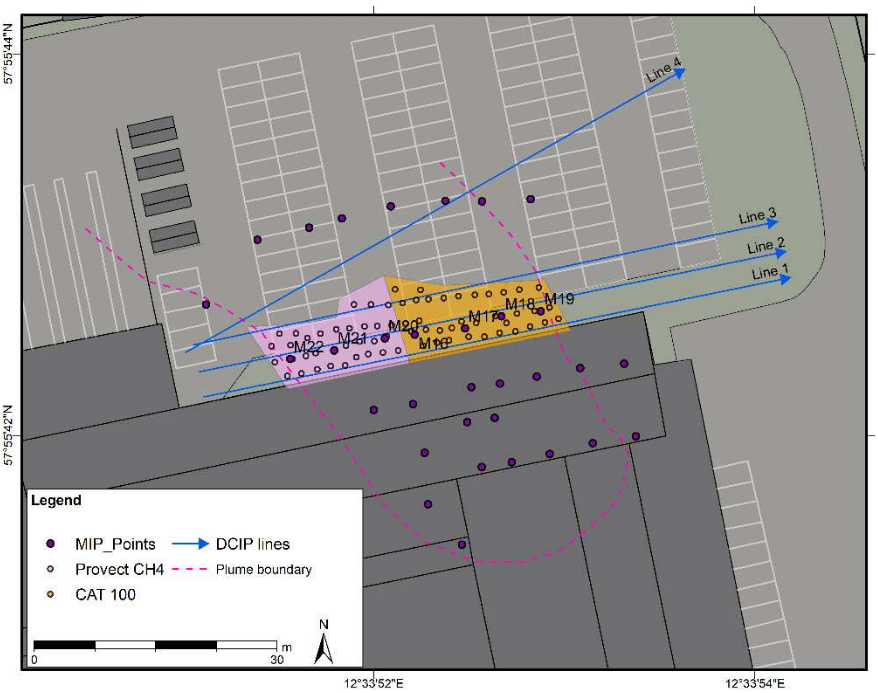

Figure 1. Overview map showing location of contaminant plume, DCIP lines, MIP soundings and pilot in-situ bioremediation injection points.

	Product name	# injection points
East area (orange)	CAT™100	37
West area (purple)	Provect™ ERD-CH 4	32

Table1. Information about the direct push injections (product name and number of points).

In order to follow changes due to the remediation 4 DCIP lines were permanently installed in the area by burying the electrode cables and stainless-steel plate electrodes. The measurement system is installed in the building and makes continuous daily measurements since a week ahead the start of the bioremediation. The data are acquired using a multiple gradient array, and the 100% duty cycle is used (Olsson et al. 2015) for more time efficient acquisition, and the full waveform data are saved to processed as proposed by Olsson et al. (2016).

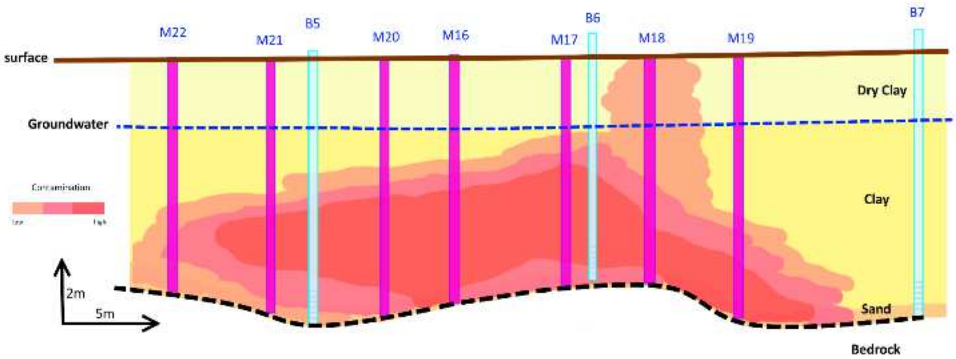

Figure 2. Simplified geological model based on the MIP sounding (provided by WSP).

Baseline survey

The baseline survey data were acquired immediately after the system was installed, one week in advance of the start of the pilot in-situ bioremediation. The data were processed to evaluate the efficiency and stability of the system, which showed that the data are of good quality and give very low residuals after inversion (Figure 3). The resistivity results from Line 3 and Line 4 show an increase in resistivity associated with the sediment-bedrock interface, at depths of around 6 m, which matches prior knowledge from the MIP soundings and monitoring wells in the area. An increase in the resistivity in the sediments correlates with the plume boundaries and the high concentration measured with the MIP soundings. It is expected that the plume will give a rise in the resistivity as descripted in Johansson et al. (2015).

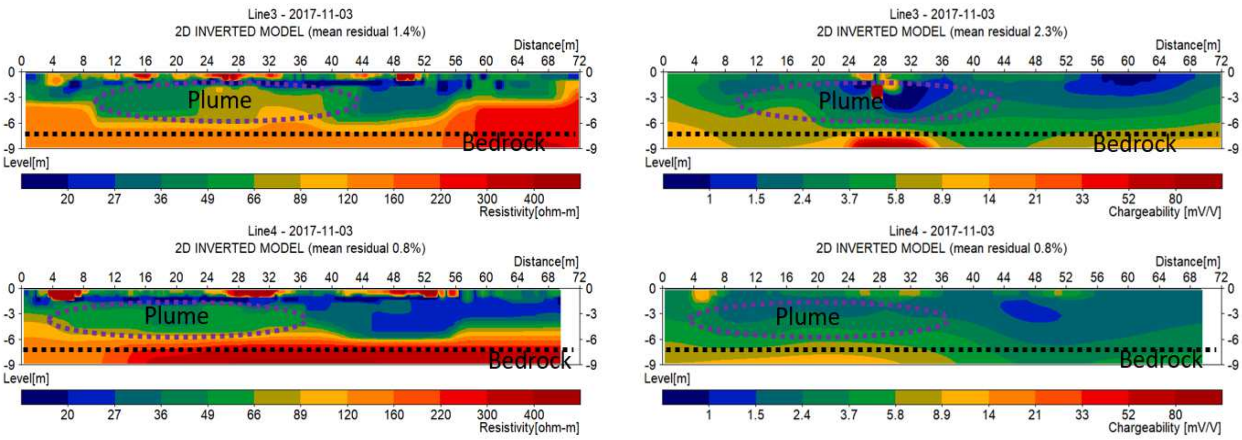

Figure 3. Results from the baseline measured with the autonomous system. Resistivity results (left) and chargeability results (right).

The chargeability results identify a minor increase in the interface between the sediments and the bedrock, just beneath the plume, for both Line 4 and Line 3. Unfortunately, the buried infrastructure objects introduce some artifacts in the inversion of Line 3 but the results from Line 4 are very promising for the efficiency of the monitoring downstream the injection area.

Time-lapse results

The results from the period during the injection was evaluated to understand the signature of the fluids. In Figure 4 the resistivity difference (as percentage) between the baseline and just after the injections had been completed. Based on the result for Line 3, changes in the clay layer (3-6m) can be seen that are clearly different in the two areas. The western area (Provect) shows an increase in the resistivity whereas in the eastern area (CAT100) the resistivity has decreased. The sand layer which is located at around 6 meters depth show some increase in the resistivity after the injection.

Line 4 is located further out so most of the changes can be seen in the sand layer because of the higher hydraulic conductivity but changes due to the injection in the clay are expected to take place soon. The changes in the very shallow part (0-2m depth) observed in both lines are interpreted to be caused by displacement of water and changes in temperature due to the direct pushing injections.

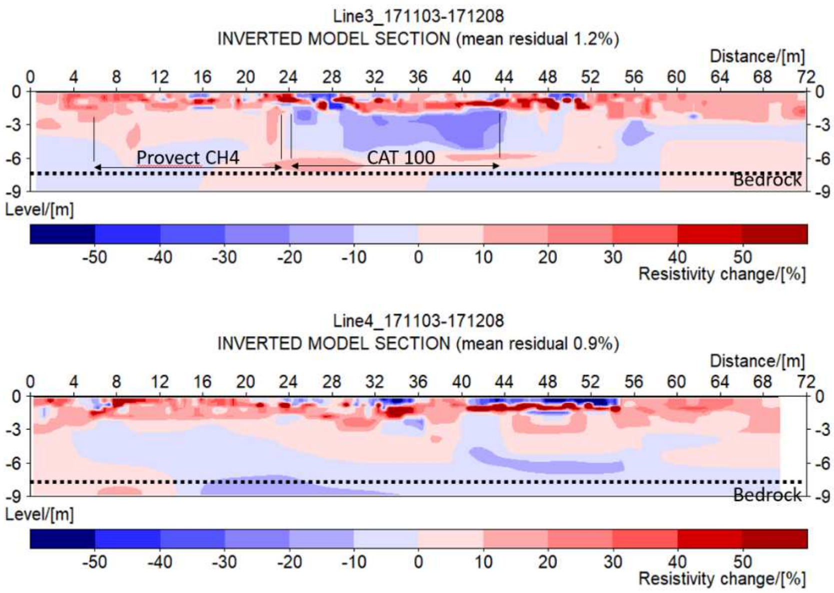

Figure 4. Time-lapse results showing the effects right after the injection. The areas where the injection took place are marked in Line 3 and are projected into Line 4.

Future work

While collecting daily measurements has great potential to identify the changes in the subsurface, it is almost impossible to process the large amounts of the generated data. Therefore, stable and advanced routines for the automation of the data processing part are needed, especially in case multiple sites are being monitored.

Currently, the main focus is to develop routines for automatic data filtering so we can generate the models of the changes in the subsurface automatically. Furthermore, the correlation between changes in the geophysical signatures and the groundwater chemistry are being evaluated to achieve a better understanding of the processes. However, those processes expected to be rather slow (up to 4 years) therefore a longer time series needs to be processed in order to distinguish seasonal variation from the result of the remediation.

Conclusions

The evaluation of the results for a short period after the injection appears promising for identification of changes in the subsurface due to the initiated in-situ bioremediation. The burden of data collection has been lifted as the autonomous system is robust and automatically takes care of the data collection and data handling procedure for us. It is of great importance to establish routines to handle the data processing and inversion automatically, and ideally to obtain the monitoring results as close to real-time as possible.

Acknowledgements

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