Mo 24B 11

Monitoring of In Situ Remediation with the Direct Current Time-Domain Induced Polarization Method

A. Nivorlis[1]*, T. Dahlin[1], M. Rossi[1], H. Wei[1]

[1] Lund University

Summary

In Alingsås, a dry-cleaning facility was operated for many years, and huge amounts of the solvent PCE was spilled into the ground. This contributed to an increasing concentration of PCE over the years until the use of PCE was stopped, resulting in the formation of a DNAPL plume beneath the building. Treatment of contaminated soils in Sweden often includes excavation and landfilling, however in Alingsås this is not applicable. In situ remediation methods (thermal, biological, chemical) are the only alternative however, there is a need for tools to monitor the effectiveness of those methods. One method of particular interest in this context is the Direct Current time-domain Induced Polarization (DCIP). For that purpose, a fully autonomous and automatic monitoring system was installed in Alingsås, to perform frequent automated measurements and to provide information about the changes in the subsurface. The geophysical data should be ideally acquired, analyzed and verified with automated routines as part of a larger monitoring system. It is of great importance, especially in the early stage, to verify events that appear to show interesting changes with sampling data to evaluate the level of reliability of the system.

Introduction

Important work has been done in locating and characterizing contaminated ground with the use of geophysical methods (Naudet, 2014). The use of geophysics, in connection with geotechnical (drilling) and hydrological (sampling) methodologies, can provide more efficiently accurate, spatially distributed data. Further work has been done in using geophysics to monitor dynamic processes like leachates (Oliver, 2016) and the natural degradation of the contaminants (David, 2017). Geophysical methods provide continuous models of the subsurface, in space and time, and can be used as a tool to interpolate the punctual information from other methodologies, increasing the success of building an accurate model.

It is common that remediation takes place by excavating and moving the contaminated soils however first this only migrates the problem and second it can be costly. Furthermore, this option may not be appropriate in cases where the contaminated mass is rather huge in volume and/or located in a significant depth. Additionally, very often the contaminated mass is located in urban or industrial environments, with the latter being the case in this study. In such cases, in situ remediation techniques appear as the only viable option. There are however concerns about how to control the result of in-situ remediation and a need for new methods with good spatial coverage arises.

A lot of studies have been done about the characterization of the subsurface, especially when it comes to the contaminants, however our main interest is the changes that take place due to the remediation. This project aims to use geophysical methods for continuous measurements (monitoring) of in-situ remediation to evaluate the results of such activities, by analyzing the geophysical signal and compare it directly with the concentration information. One method of particular interest in this context is the Direct Current resistivity and time-domain Induced Polarization (DCIP).

Conceptual Model

In Alingsås (Central Sweden), a dry-cleaning facility was operated for many years, and huge amounts of the solvent PCE were spilled in the ground. This contributed to an increasing concentration of PCE over the years until the use of PCE was stopped, resulting in the formation of a DNAPL plume beneath the building. The plume is migrating towards the NNW direction (Figure 1) and for that reason, a pilot in-situ remediation program was launched in November 2018, by the direct push injection in the area in the north side of the laundry building.

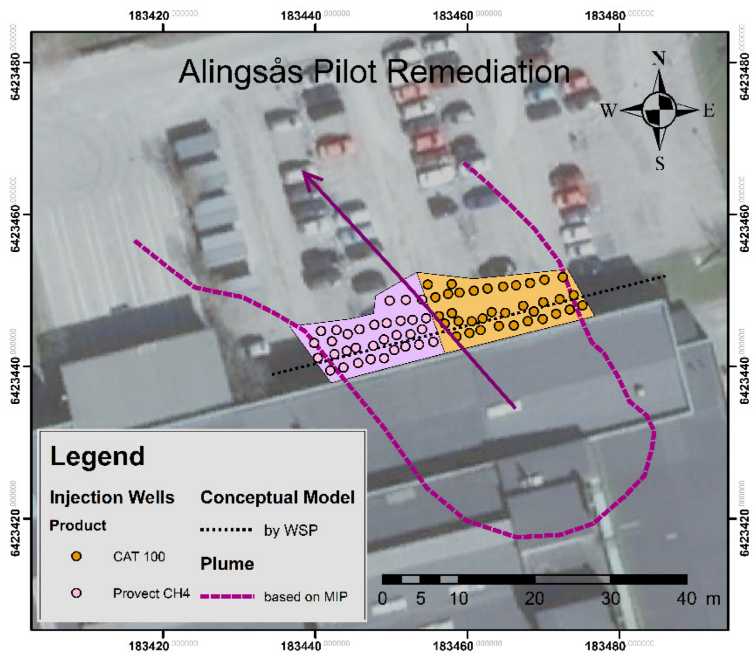


Figure 1. Alingsås contamination plume and remediation plan.

There are no important variations in the elevation and the geology is rather simple, with the water table being about 2 meters below ground surface. Below the filling material (0-1m) there is a layer of clay with varying thickness from 6 to 8 meters. A thin layer of sand can also be found in some locations with a maximum thickness of about a meter, between the crystalline bedrock and the clay (Figure 2).

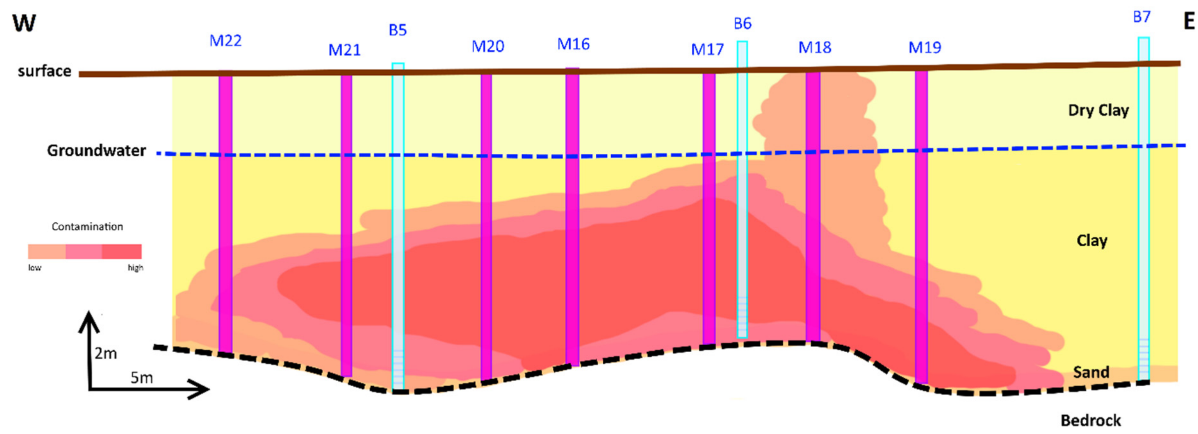


Figure 2. Simplified conceptual model (provided by WSP).

Monitoring System

A fully autonomous and automatic monitoring system was installed in Alingsås, to perform frequent automated geophysical measurements and to provide information about the changes in the subsurface. For that purpose, a permanent DCIP installation which includes 4 surface layouts (with 5x5cm stainless steel plate electrodes) and 4 boreholes (with stainless steel ring electrodes) had to be made (Figure 3). Apart from the DCIP data the system has the potential to monitor several other parameters (soil temperature/moisture, rainfall, air temperature, groundwater level, water conductivity, redox potential, etc.) by using external sensors, to make it possible to obtain a better understanding about changes caused by other processes (i.e. rainfall) and how they can affect the measurements.

The electrode spacing for the surface layout is 1m, with the outer electrodes having 2m separation, with a total of 64 electrodes in place. For the boreholes, the ring electrodes where installed around the plastic casing of the well every 0.25m, starting from the bottom all the way to the top. Daily measurements are performed for every surface profile and for the two cross-hole tomography pairs (LU1-LU2 and LU6-LU7). Since the installation is planned to remain in place for a long time, all the cables are buried, approximately to 0.40cm depth and they end up in the inside of the building (Figure 3, red square) where all the equipment is being stored safely.

The data are being transferred daily on our server in Lund and are being processed to evaluate the data quality and extract useful information about changes in the subsurface.

By evaluating the complimentary data, provided by the external sensors, we can take changes from external processes into account. The remaining events should then be compared with sampling data, such as isotope analysis, to verify our hypothesis.

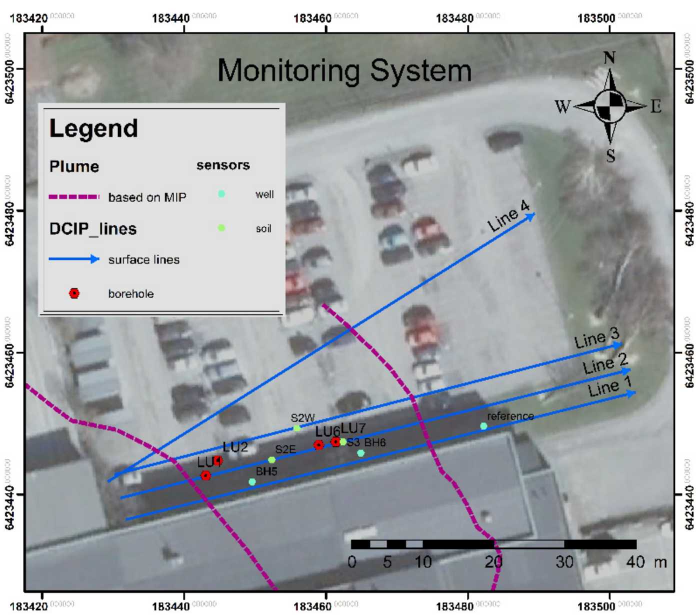
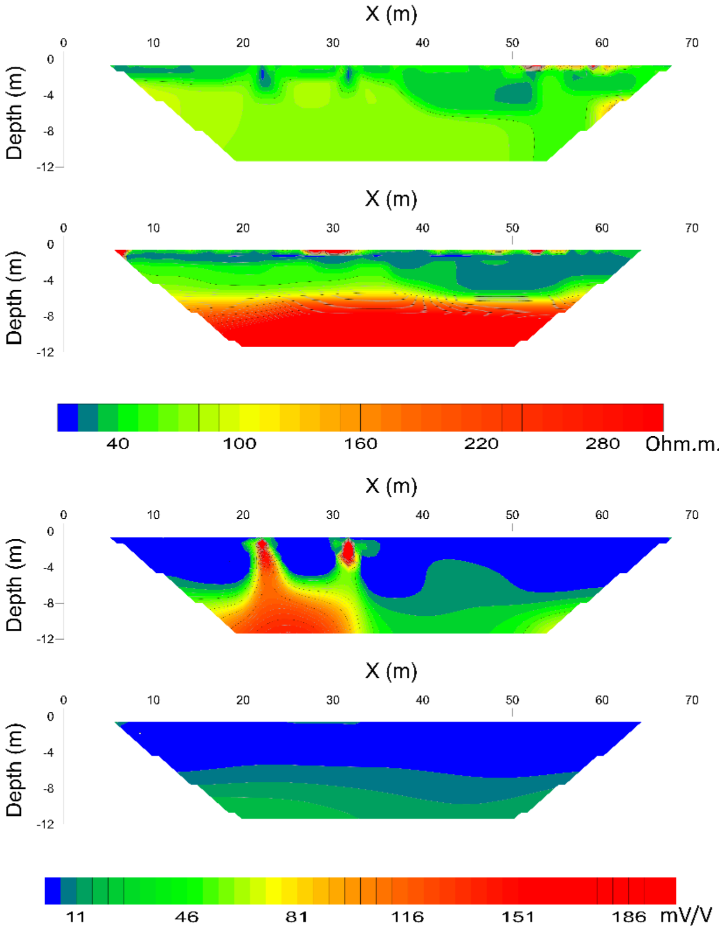


Figure 3. Monitoring system installations.

Baseline Survey



Prior to the launch of the pilot, a rather long field survey took place to make the necessary installations. That field campaign was a great chance to collect baseline data for acquiring a better understanding of the incoming signals.

Figure 4 illustrates the results from that survey, a couple of days before the pilot began, for Line 2 and Line 4. Line 4 is expected to provide reliable information about the subsurface since it is located away from the building it. On the other hand, Line 1 and Line 2 are expected to suffer from 3D effects from the building and underlying cabling in that area,

The resistivity results from Line 4 are in very good alignment with the conceptual model for the area. The first 8m can be identified as clay with resistivities around 40 Ohm.m., followed by a resistive layer which is interpreted as the bedrock. The chargeability for that line is very low, around 10 mV/V yielding no new information and verifying the previous analysis.

Figure 4. Baseline survey results from 4th of November for Line 2 (top) and Line 4 (bottom). Resistivity results can be seen on top and chargeability results on bottom.

The results from Line 2 shows reflects the artificial structures of the subsurface. The bedrock is not clearly identified in the resistivity results. The chargeability results are clearly affected by the cables and the storm water pipe in the area. Similar results and be seen in Line 1 (not shown here).

On-going work

The results from the baseline survey shows the complexity of the incoming signals and one of the challenges in this project would be the processing of such data to successfully identify changes in the subsurface due to the remediation.

The full waveform data are being recorded and processed with advanced signal processing schemes (Olsson, 2016; Rossi, 2018). The individual datasets are being analysed and the data quality is being assessed based on spatial statistical filtering (Kim, 2016) and the shape of the IP decay pattern to remove possible outliers. The time series of each measurement is being analyzed (Sjödahl, 2008) to identify and exclude extreme values from the whole data set.

The filtered dataset is then inverted by using advanced inversion algorithms, which introduce time and space regularizations (Karaoulis, 2013; Loke, 2014). Preliminary results, from the first months after the pilot in-situ remediation test, will be presented.

Conclusions

It is expensive and time consuming to control the remediation result via sampling and chemical analyses with high spatial resolution at regular intervals. With DCIP we can acquire dense data, in space and time, that hopefully can aid following and better understand the changes due to the remediation.

The geophysical data should ideally be acquired, analyzed and verified with automated routines as part of a larger monitoring system. It is of great importance, especially in the early stage, to verify events that appear to show interesting changes with sampling data to evaluate the level of reliability of the system.

Acknowledgements

This work is done within the MIRACHL project. Founding for this work was provided by the Swedish Research Council Formas – The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planing and SBUF – The Development Fund of the Swedish Construction Industry.

References

Caterina D., Flores Orozco A., Nguyen F. (2017). Long-term ERT monitoring of biogeochemical changes of an aged hydrocarbon contamination. Journal of Contaminant Hydrology 201, 19-29

Karaoulis, M.C., Revil, A., Tsourlos, P., Werkema D.D., Minsley, B.J. (2013). IP4DI: A software for time-lapse 2D/3D DC-resistivity and induced polarization tomography. Computers & Geosciences, 54, 164-170.

Kim, J. H., Supper, R., Ottowitz, D., Jochum, B., Yi, M.J. (2016). Processing of ERT Monitoring Data and Evaluation of Their Reliabilities. Proceedings of Near Surface Geoscience 2016

Kuras O. (2016). Geoelectrical monitoring of simulated subsurface leakage to support high-hazard nuclear decommissioning at the Sellafield Site, UK. Science of the Total Environment, 350-359

Loke, M.H., Dahlin, T., Rucker, D.F. (2014). Smoothness-constrained time-lapse inversion of data from 3D resistivity surveys. Near Surface Geophysics, 12, 5-24

Naudet V., (2014). 3D electrical resistivity tomography to locate DNAPL contamination around a housing estate. Near Surface Geophysics, 12, 351-360

Olsson, P.I., Fiandaca, G., Larsen, J. J., Dahlin, T., Auken, E. (2015). Doubling the spectrum of time-domain induced polarization by harmonic de-noising, drift correction, spike removal, tapered gating and data uncertainty estimation. Geophysical Journal International, 207(2), 774-784

Rossi, M., Dahlin, T., Olsson, P.I., Gunther, T. (2018). Data acquisition, processing and filtering for reliable 3D resistivity and time-domain induced polarization tomography in an urban area: field example of Vinsta, Stockholm, Near Surface Geophysics (Special Issue)

Sjödahl, P., Dahlin, T., Johansson, S., Loke, M.H. (2008). Resistivity monitoring for leakage and internal erosion detection at Hällby embankment dam. Journal of Applied Geophysics 65, 155-164