An overview of time domain induced polarisation for characterisation of underground structures and point source contaminations – large research projects in Denmark and Sweden

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Two large research projects in which the time domain induced polarisation method plays a key role are underway in Sweden and Denmark, focusing on characterising underground structures in geotechnical engineering contexts and description of percolate flows from old landfills to surface water and streams respectively. Both projects involve development of new codes, instruments, field methodology etc. Scientists and engineers with multi-disciplinary backgrounds and from both universities are jointly involved in the projects.

Research and development on data acquisition techniques of DCIP (DC resistivity and induced polarisation) for environmental and engineering applications has been carried out at Lund University for over 10 years (e.g. Dahlin et al. 2002; Dahlin and Leroux 2012). Much of the research has focused on mapping, characterisation and monitoring of landfills (e.g. Dahlin et al. 2010), see example in Fig. 1, in later years within the MaLaGa project[1].

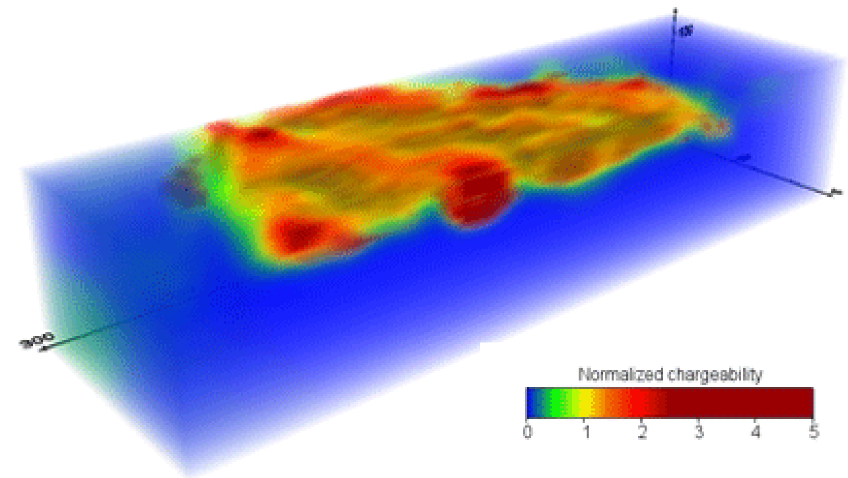

Fig. 1: 3D normalised chargeability model showing extent of waste in the Ekeboda buried landfill in Sweden (Dahlin et al. 2010).

During the last six years there have been two large projects in Denmark funded by the Danish Council for Strategic Research in which DCIP has been the key geophysical method. The first project focused on the mapping of landfills and percolate outflow to underlying groundwater reservoirs (Gazoty et al. 2012a, 2012b). Among other things this project allowed the development of efficient field methodologies for measuring IP in the time domain (Gazoty et al. 2013) and the development of the first modelling code where the entire decay curve including waveform and instrument transfer function could be modelled using e.g. the Cole-Cole model (Fiandaca et al. 2012) . This code was based on the 1D LCI formulation. In the second project we could expand this code to a 2D solution (Fiandaca et al. 2013), and hardware was developed to a fully automated measurement system where 384 electrodes were set up in a time lapse experiment measuring full decay time domain IP and DC data (Auken et al. 2014). This experiment lasted almost 6 months and a clear correlation between Cole-Cole parameters and tracer metals released by CO_2 injected into the shallow aquifer was seen.

The on-going Swedish project is part of the Geoinfra-TRUST framework that is working towards developing techniques for more cost efficient underground construction in urban areas[2]. This project aims at development and adaptation of DCIP imaging for use in urban environments and demonstration and evaluation of geoelectric mapping in this context. Establishing how well

[1] *http://malagageophysics.com*
[2] *http://www.trust-geoinfra.se/*

engineering and environmental key parameters can be estimated from models based on time-domain spectral IP is another aim. One part of the work is 3D data acquisition methodology and strategies, including different electrode arrays and combinations of surface and borehole electrode arrays. Adaptation and evaluation of data acquisition equipment is included, where the evaluation comprises synthetic examples from numerical modelling as well as field experiments. Development of software for 3D inversion of spectral time-domain IP data is a key part of the project. Ways of integrating other types of data in the inversion process are also part of the task. The possibility of establishing a more accurate characterisation of engineering and environmental key properties, based on models derived from inversion of spectral time-domain IP data, will also be investigated. This includes soil and rock properties, tectonic structures, existence and character of buried waste and derelict industrial areas, as well as water and contaminant occurrence and transport.

Lately a new consortium consisting of, among others, two Danish regions and a private consulting company has received funding from the Danish Council for Strategic Research for development of an efficient methodology for characterisation of outflow of percolate from old point source contaminations to surface water. The geophysical part of this project is to develop new prototype DCIP equipment further and describe a more quantitative relation between the pore water chemistry and the Cole-Cole model parameters.

In later years the two research groups at Lund University and Aarhus University have joined forces to boost the developments of hardware, software, methodologies and applications. The Swedish and the Danish projects have clearly shown that DCIP measured in the time domain is a strong alternative to measuring in the frequency domain. Field procedures are simple and the equipment is stable and (more or less) off the shelf. The key parameter has been to understand how to measure reliable data in the field and the development of the new inversion codes in 1D and 2D. In our opinion the methodologies are so robust that they can be used in real field scale production surveys with a greatly enhanced resolution of geological structures as well as of a suite of contaminations.

References

Auken, E., Doetsch, J., Fiandaca, G., Christiansen, A.V., Gazoty, A., Cahill, A.G. and Jakobsen, R., 2014. Imaging subsurface migration of dissolved CO2 in a shallow aquifer using 3-D time-lapse electrical resistivity tomography. *J. Appl. Geophys.*, 101, 31-41.

Dahlin, T., Leroux, V. and Nissen, J., 2002. Measuring techniques in Induced Polarisation Imaging. *J. Appl. Geophys.*, 50, 279-298.

Dahlin, T., Rosqvist, H. and Leroux, V., 2010. Resistivity-IP for landfill applications *First Break*, 28(8), 101-105.

Dahlin, T. and Leroux, V., 2012. Improvement in time-domain induced polarisation data quality with multi-electrode systems by separating current and potential cables. *Near Surface Geophys.* 10, 545-565.

Fiandaca, G., Auken, E., Gazoty, A. and Christiansen, A.V., 2012. Time-domain induced polarization: Full-decay forward modeling and 1D laterally constrained inversion of Cole-Cole parameters. *Geophysics*, 77, E213-E225.

Fiandaca, G., Ramm, J., Binley, A., Gazoty, A., Christiansen, A.V. and Auken, E., 2013. Resolving spectral information from time domain induced polarization data through 2-D inversion. *Geophys. J. Int.*, 192, 631-646.

Gazoty, A., Fiandaca, G., Pedersen, J., Auken, E. and Christiansen, A.V., 2012a. Mapping of landfills using time-domain spectral induced polarization data: The Eskelund case study. *Near Surface Geophys.*, 10, 575-586.

Gazoty, A., Fiandaca, G., Pedersen, J., Auken, E., Christiansen, A.V. and Pedersen, J.K., 2012b. Application of time domain induced polarization to the mapping of lithotypes in a landfill site. *Hydrol. Earth Syst. Sci.*, 16, 1793-1804.

Gazoty, A., Fiandaca, G., Pedersen, J., Auken, E. and Christiansen, A.V., 2013. Data repeatability and acquisition techniques for Time-Domain spectral Induced Polarization. *Near Surface Geophys.*, 11, 391-406.