Mapping landfills with Time Domain IP: The Eskelund case study.

Gazoty, A., Fiandaca, G., Pedersen, J., Auken, E., Christiansen, A.V.

The field case

The area of interest, Eskelund, is a former landfill active from 1950 to 1980. It is located in the vicinity of Aarhus (Denmark), and the site was established in the meadows adjacent to Aarhus creek. The landfill has been uncontrolled, and was established without any kind of membranes, leachate capture or isolation systems. The waste mainly consists of domestic waste, but also industrial waste including oils and chemical waste. The nature of the waste can be very different from one place to another within the landfill, as they were first stored according to their content, and burnt afterwards at some places. Previous geochemical surveys and underground water samples evidence a contamination resulting from water seepage through the landfill. By a dense coverage in IP/DC of the area, this study aims at delineating the waste body by mapping it in 3-D and gain knowledge upon the overall geological settings. By performing a correlation between ground-based measurements and in-situ IP/DC measurements from an electrical logging (hereafter el-log), we intend to improve the characterization of the waste body and obtain reliable values for the chargeability of the waste layer.

Measurements of DC resistivity and Time-Domain Induced Polarization

The overall area was investigated with the collection of 13 IP/DC profiles with lengths ranging from 355 m to 700 m, and with a minimum electrode spacing of 5 m. In addition, an el-log drilling was performed, which is an electrical logging tool mounted near the drill head allowing for in-situ measurements of the electrical resistivity (Sørensen and Larsen 1999). The el-log enabled to link between lithology, resistivity and induced polarization of the layers. While only a resistivity and a gamma log is measured with the traditional el-log system we have in this study replaced the resistivity instrument with the Iris Syscal-Pro resistivity meter allowing for also measuring the IP decays. The measurements were performed every half meter, down to a total drill depth of 24 m. The use of the el-log aims at providing a very accurate correlation between the geology and the geophysical measurements, and enables to allocate in-situ values of chargeability and resistivity to the waste layer. To our knowledge this is the first time such kind of induced polarization data have been collected. The surface measurements were inverted using a new code developed by Fiandaca et al. (2011), where the time domain forward response is computed for a layered medium via a Hankel transform of the frequency-dependent Cole-Cole impedance. The inversion part is performed using the 1D-LCI implementation (Auken *et al.* 2005), for retrieving the four Cole-Cole parameters (resistivity, c, τ and M_0), for each layer. This new code presents the main advantage that it uses the full IP decay curve for retrieving the spectral content of the IP phenomenon, allowing an accurate description of the sub-soil.

Results

Figure 1 shows some representative results in IP/DC of a profile crossing the landfill North-South, and extending outside the landfill boundaries. It displays a clear discontinuity in IP and DC at the south boundary of the landfill, with a resistive body and a low chargeable unit outside the area. Within the landfill, the inverted section clearly shows a chargeable unit of several hundreds of mV/V, in agreement with the waste layer identified in the boreholes, matching both the thickness and the depth. It is important to note that at some places, the waste layer is saturated, and hence displays a signature in both IP and DC, e.g. at the northern part around borehole B1. However, the DC section cannot be used to identify the waste layer which is clear from the lateral variations seen in the profile. Contrary, the IP section displays a systematic signature in IP throughout the waste layer. This example demonstrates the complementarity of IP and DC resistivity, as the joint application of both allows the shape of the waste body to be delineated with high accuracy and reliability. In this example, the lateral thickness variations of the waste body can also be retrieved all along the section, which is verified by the three boreholes. Comparing the results from M_0 for all sections containing boreholes, the presence of the waste is identified by all the induced polarization sections, and matches the borehole information near perfect wherever present (not shown here). Also, the 1-D code is able to restore the layer at the right location, even when quite strong lateral variations are present, which is a very promising result. Further comparisons with el-log measurements in IP/DC indicated that the el-log validates the results from the surface measurements and confirms the magnitudes of parameters obtained by the two methods.

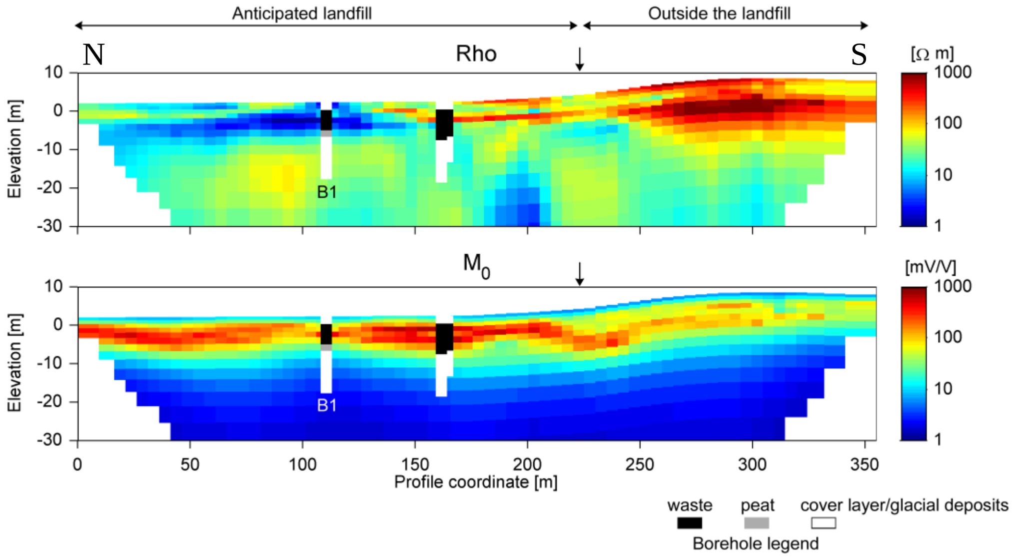

Figure 1 *Results from a 1-D Laterally Constrained Inversion for a section in-between the landfill area, with superimposed boreholes. Top: resistivity, bottom: chargeability* M_0.

The results from all 2-D sections have been merged to provide an estimate of the 3-D body and to check the inter-profile consistency (Figure 2). The depths and thicknesses of the chargeable unit agree very well between all the sections. Furthermore, because it is observed that the chargeability value varies 2 to 3 times within the waste layer, some relevant chargeability isovolumes have been computed and superimposed on aerial pictures taken at different stages of the waste deposit. From this, it seems that there is a straightforward correlation between the magnitude of the IP signal and the waste content. Therefore, we cannot only delineate the waste body itself, but also distinguish the waste content within the waste layer, and track the spatial advancement in time of the landfill.

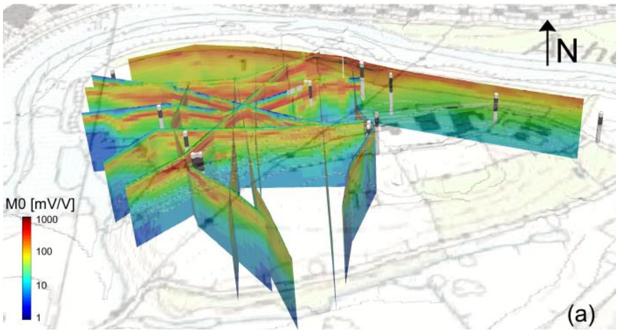

Figure 2 *Gathered 2-D sections in chargeability with superimposed boreholes, allowing a 3-D characterization of the landfill area.*

Conclusion

The Eskelund study clearly shows the complementarity of IP and ERT. The joint application allows pointing out the shape of the waste body with a high accuracy and in perfect agreement with borehole information. With the el-log, it was possible to make an accurate correlation between the geology and the geophysics, and to determine the chargeability of the waste layer. Moreover, the inversion of the IP data also shows that it is possible to discriminate the different waste contents within the waste body.

References

Auken, E., et al. "Piecewise 1D Laterally Constrained Inversion of resistivity data." Geophysical Prospecting 53 (2005): 497-506.

Fiandaca, G., et al. "Time domain induced polarization: full decay forward response modeling and direct inversion for Cole-Cole parameters." Submitted to Geophysical Journal International (2011).

Sørensen, K.I., and Larsen, F. "3-in-one method for hydrogeological data collection." Ground water monitoring and remediation 19.4 (1999): 97-101.