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Time-domain IP and Resistivity Sections Measured at Four Landfills with Different Contents

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SUMMARY

Four IP and resistivity sections measured in four landfills with different contents but in comparable geological settings are compared. The normalized chargeability makes it possible to distinguish waste from natural geological materials and to solve ambiguities remaining when the sole direct-current resistivity is used. The amplitude on the IP response is more important on the two landfills containing large amounts of biodegradable organic matter and disseminated metals. It is weaker when these materials are absent. It also appears larger when the moisture content is high. Some uncertainties remain concerning the depth of investigation but high normalized chargeability seems to extend to possibly contaminated sediments below the landfills.

Introduction

Several purposes can motivate geophysical investigations at landfills. One may for example want to assess soil stability or possibility for contaminant spreading in order to reclaim soils that have become enclosed in urban areas. Landfill mining is another application requiring identification of the buried materials. Landfills present specific difficulties to the surveyor: they are usually very heterogeneous in three dimensions and documentation is often poor, inadequate or outdated. Due to biodegradation, their geometry and properties may have changed significantly compared to the original state. Boring and sampling is costly and can only be used to a limited extent. Geoelectrical methods are suitable because electrical properties are strongly related to water content, salinity and porosity. Induced polarisation in particular has been used successfully for distinguishing buried waste from its surroundings. The origin of the higher polarisability often observed in refuse is however still disputed. A part of it is probably due to metal content (e.g. Angoran et al, 1974, Slater et al, 2006) but there are some indications that the presence of biodegradable organic matter also is significant (see Carlson et al, 2009). This paper describes and compares the results of resistivity and IP measurements at four landfills with different contents, which are all situated within a 2 km radius in Helsingborg in Southern Sweden.

Measurement and processing methods

Resistivity and time-domain induced polarization have been measured using successive versions of the modified ABEM-Lund multielectrode system. The gradient array with a 5 m spacing was used everywhere except at the bioreactor where a 2 m spacing was used. Only a few negative resistivity data were removed and all data were processed using Res2DInv (Loke and Barker, 1996) and the L1-norm option. After inversion the inverted chargeability for the 10-110 ms window was simply divided by the inverted resistivity, thus yielding the normalized chargeability, after Slater and Lesmes (2002).

Bioreactor landfill, very high organic content

The bioreactor landfill was filled between 2002 and 2004 with sorted and grinded household waste lying on a 0.5 m thick clay layer. Its dimensions are 120 x 60 m and its original depth is 15 m. Despite waste sorting, the metal content can probably be estimated to a few percents in mass. The content in organic matter is high, since the bioreactor was intended for accelerating its biodegradation and producing gas. It is covered by 0.5 m clay and a plastic liner. The measurements presented here were taken in 2006 at its surface, through the liner. Just after they were performed the bioreactor was excavated to install drainage pipes and the groundwater level was observed between 5 and 10 m depth.

A first thin and relatively conductive layer is observed on the resistivity section (Figure 1a) probably corresponding to the soil cover. Just below, a resistive layer with values over 70 Ω.m is visible, which is probably representative of drier, unsaturated waste material. 5 to 10 m below the ground surface the waste is saturated with water and exhibits much lower resistivity (below 40 Ω.m). Low resistivity is also observed on the left edge, outside the bioreactor. The saturated waste cannot be distinguished from its clayey bottom, neither from its clayey surroundings with resistivity. The normalized chargeability section (Figure 1b) shows relatively large values, above 15 mS/m, apparently confined to the saturated waste down to the expected bottom of the bioreactor at about 15 m depth. High chargeability is also visible on the left of the section, outside the bioreactor landfill, but still inside the waste management site.

Filborna landfill, high organic content

The Filborna landfill was filled with unsorted household, industrial and construction waste for about 50 years from 1950 until 2008, being one of the largest and oldest landfills in Sweden. In later years, almost exclusively household and sorted industrial refuse was deposited.
The waste was laid directly on the natural ground on either sides of a small stream that was later diverted. The natural geological soil consists of glacial sediments of varying nature and thickness (up to about 20 m in an erosion channel) on the heavily weathered and possibly faulted Triassic sandstone (Dittrich, 1997).
The organic content of the waste is high, although it is lower than in the bioreactor landfill as evidenced by the significant amounts of biogas still produced today. Compared to the bioreactor the landfill probably contains more metal and it is not all divided in small pieces but can be present in objects of varying sizes and nature. On the other hand the parts filled with construction waste contain less metals and possibly only little wood. The metal content probably decreases for the most recent layers due to sorting practices. The measurements presented here were taken in 2006, before the landfill was all covered and closed.
On the inverted resistivity section shown in Figure 2a the discontinuous soil cover is apparent as a heterogeneous and globally resistive superficial layer. On the left hand-side of the landfill, inside the waste management site, a track of compacted inert soil materials appears with higher resistivity. On the right hand-side of the landfill the natural soil also appears with higher resistivity. Inside the landfill the resistivity decreases progressively and following an irregular pattern at depth probably reflecting different materials, increasing water content at depth, locally perched water tables and possibly variations in salinity. No clear transition is observed between the water saturated waste and glacial sediments which should occur at about 45 m above sea level, whereas the unweathered sandstone appears clearly as is expected around 15 m above sea level. The former bed of the diverted stream is apparent around x=400 m. Figure 2b shows small superficial polarisable bodies just below the soil cover. Extended areas with normalized chargeability above 16 mS/m are clearly visible in the saturated waste body, but also on the sides, below the track and below the slope on the right side. Large normalized chargeability is also observed at depth possibly corresponding to glacial sediments, but not in the fresh sandstone.

Old Filborna landfill, low organic content

The old Filborna landfill was first active before 1951, and then during 1967-1973. No precise records were kept about the waste deposited at the landfill. It was covered with soil material until its contents were finally excavated, sorted, and the whole landfill reshaped in 2006, some of the material being transferred. Many construction materials were found almost everywhere, like bricks, stones, concrete blocks, asphalt and creosote impregnated wood. Ashes were found, as well as oil contaminated materials. A number of metal objects, often corroded and often of larger dimensions were found, like metal beams, concrete reinforcement bars and bicycles. The biodegradable organic content was low and consisted mainly of wood. A number of different groundwater levels and units coexisted in the landfill, some places being dry, other saturated with water, or even showing artesian pressures. The measurements presented here were taken in 2002 before the landfill was excavated and when it was still covered with a soil layer.
Figure 3a shows higher resistivity in the heterogeneous soil cover on the landfill and also the most superficial waste materials. The underlying waste shows lower values (below70 ohm.m) and comparable to the values observed in the natural clay tills on the right. These were saturated with water at the time of the measurements. The sandstone here too shows larger resistivity, but the low resistivity seems to extend below the waste in the natural geological materials below the landfill. The normalized chargeability section on Figure 3b shows no polarisability in the natural geological materials outside the landfill and much lower levels in the waste than at the two sites described above. Here too, high normalized chargeability seems to extend below the waste.

Rökille landfill, no biodegradable organic content

The Rökille landfill, now closed and partly covered with soil material, was used from the 1980's for landfilling of waste from the local chemical industry. Mostly gypsum was deposited, and towards the end of the active period, also sludge mixed with gypsum for stability. The sludge has a relatively high metal content (Cd, Cr, Ni, Zn, As, Pb and Cu). The oldest sludge also contains organo-chlorides. No biodegradable organic waste was deposited here.

On the inverted resistivity section (Figure 4a) the waste is clearly marked by lower resistivity (between 1 and 10 Ω.m) below the more resistive and heterogeneous cover. It is also clearly distinct from the underlying natural geological materials and the limit between low and high resistivity at depth seems to follow the original topography. However a fault or fracture zone is apparent around x=250 m and some contamination of the upper sediments is possible and signalled by lower resistivity. On Figure 4b polarisability appears restricted to the waste but with much lower levels than at the two first sites. Here too, it seems to extend below the waste.

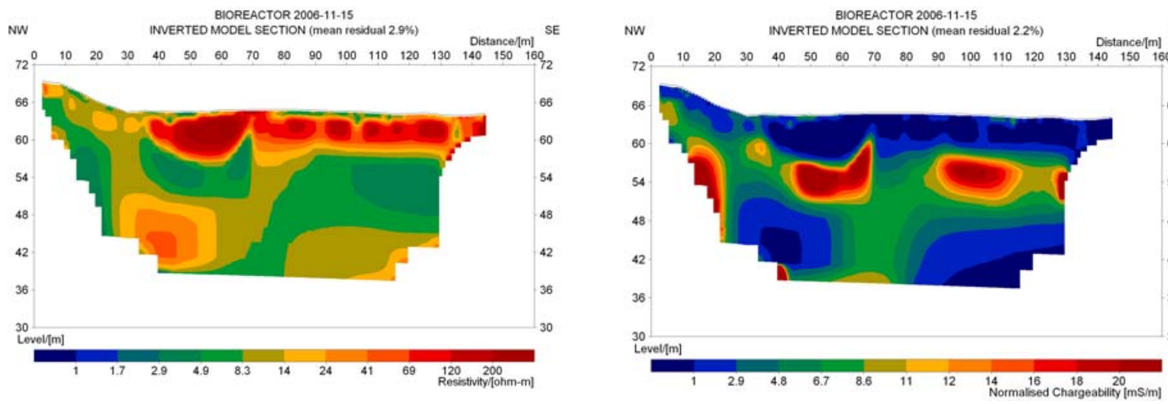

***Figure 1** Resistivity (a) and normalized chargeability (b) at the bioreactor landfill.*

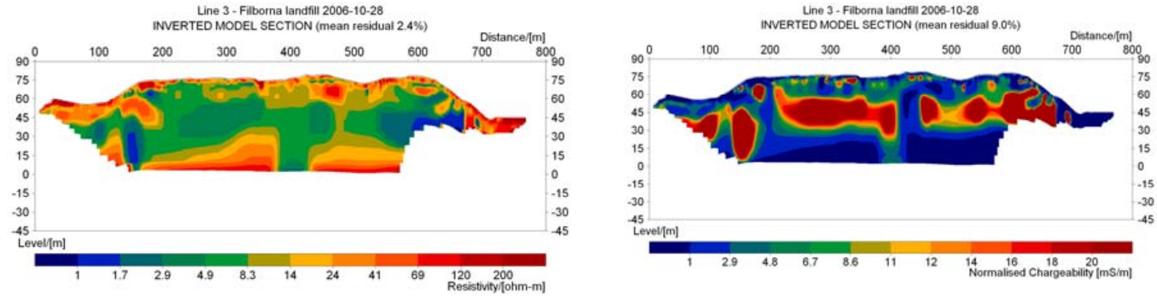

***Figure 2** Resistivity (a) and normalized chargeability (b) at Filborna landfill.*

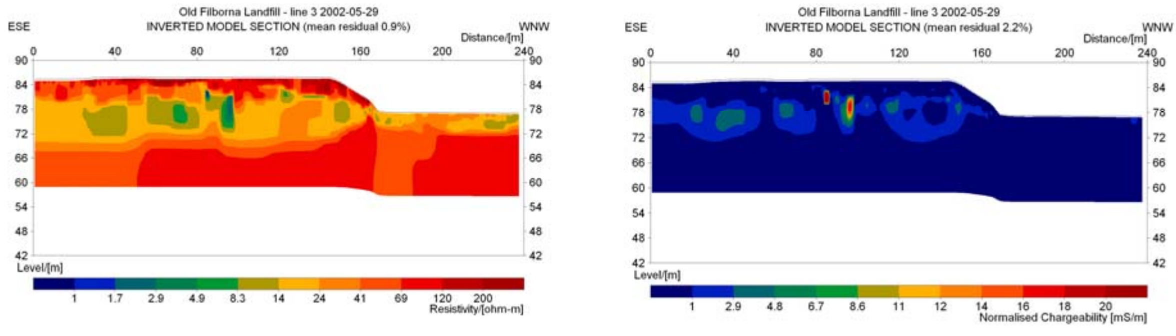

***Figure 3** Resistivity (a) and normalized chargeability (b) at the old Filborna landfill.*

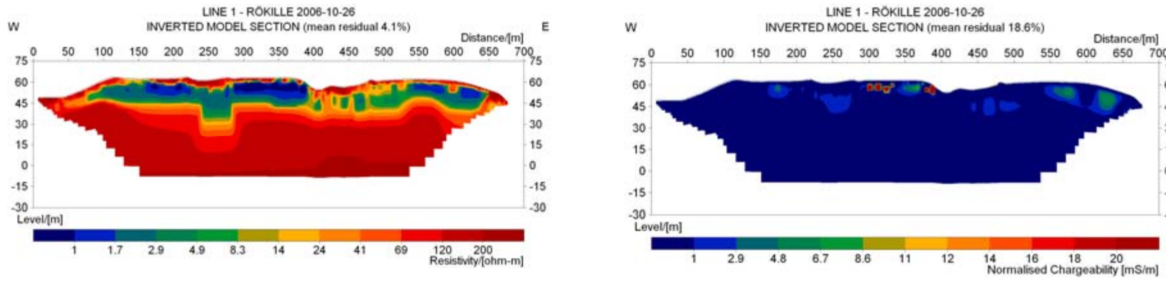

Figure 4 *Resistivity (a) and normalized chargeability (b) at Rökille landfill.*

Conclusions

The resistivity and induced polarisation profiles measured at four different landfills show that induced polarisation makes it possible to distinguish waste from natural geological materials, at least when these are not polarisable or only weakly. IP helps solving ambiguities that sometimes remain when only the direct-current resistivity is used. The amplitude of the polarisability observed is also dependent on the kind of material deposited and probably to their biodegradable matter and/or disseminated metal content. The water content also seems important since high normalized chargeability appeared mainly in saturated or nearly saturated materials.
There are some indications at the second and third site that higher normalised chargeability can also be a characteristic of contamination in natural geological materials. However some uncertainties remain relative to the depth of investigation and the geometrical resolution in such heterogeneous media as landfills, especially when 2D imaging is used.

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References

Angoran Y. E., Fitterman D. V., Marshall D.J. [1974] Induced Polarization: A Geophysical Method for Locating Cultural Metallic Refuse. *Science, New Series*, **184**, 4143, 1287-1288.

Carlson N.R., Mayerle C.M. [2009] Changes in IP effects over time resulting from accelerated degradation processes at a landfill, *International workshop on induced polarization in near-surface geophysics*, Bonn University, Germany, 30 Sept- 1 Oct.

Dittrich and Partner Hydro-Consult GmbH Bannewitz [1997] Groundwater monitoring system, Filborna landfill, *technical report commissioned by NSR AB, Helsingborg*.

Jönsson A.-K. [2002] Resistivity and induced polarisation measurements as a tool in environmental geophysics, *Master of science thesis, Lund university, Sweden. ISRN LUTVDG/TVTG—5083—SE.*

Linders F. [2006] Geoelektrisk undersökning av BCR 2002/04 i samband med gasbrunnsborrning, november 2006, *Unpublished report, NSR, Helsingborg, Sweden*. (In Swedish.)

Loke M. H., Barker R. D. [1996] Rapid least squares inversion of apparent resistivity pseudosection by a quasi-Newton method, *Geophysical Prospecting*, **44**,131–152.

Slater L., Ntalargiannis D., Wishart D. [2006] On the relationship between induced polarization and surface area in metal-sand and clay-sand mixtures, *Geophysics*, **71**, 2, A1-A5.

Slater L., Lesmes D. [2002] IP interpretation in environmental investigations, *Geophysics*, **67**, 77-88.