Geoelectrical Monitoring for Mapping of Gas and Water Migration in Landfills

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Introduction

Buried waste in old landfills is an increasing problem as cities expand and grow into areas with former waste deposits. In order to be able to manage and as far as possible reclaim land in such areas, better tools are needed for mapping and characterisation of buried waste and contaminated land. Combined resistivity-IP surveying has shown great potential for this (e.g. DAHLIN et al., 2010). Another problem associated with landfills is methane emissions. Methane is a powerful greenhouse gas and a growing concern regarding global climate changes. Landfill gas is regarded as one of the major sources for methane migration to the atmosphere. The migration of methane and carbon dioxide from a specific landfill depends on several aspects, such as the nature of the soil cover system, the gas collection system, and daily management.

A short term 3D resistivity and time-domain induced polarisation (IP) monitoring field experiment was carried out over part of a Municipal Solid Waste (MSW) landfill, the Filborna landfill site, Helsingborg, Sweden. Short term monitoring experiments have been conducted at the Filborna landfill site on several occasions during 2008, 2009 and 2011 (e.g. ROSQVIST et al., 2011). The objective was to detect variations in gas and fluid content due gas migration in the landfill. In this paper we present results from a short term monitoring performed in 2011.

Method

An area measuring 40 by 22 meter was monitored during a couple of weeks in June-July 2011. A grid with 21 x 12 electrodes was monitored, with an electrode spacing of 2 m in both directions (Fig. 1). A remote controlled data acquisition system based on ABEM Terrameter LS with 12 measuring channels complemented by 3 external relay switches, lightning protection, internet modem, etc was employed. In addition to the resistivity-IP monitoring the weather was recorded locally. The data acquisition was done measuring induced polarisation (IP) as well as resistivity using a duty cycle with 1 second current-on and current-off, where the timing is a compromise between acquisition speed and ability to capture the IP characteristics. In this way eight 3D resistivity-IP data sets were recorded daily, but only the resistivity data results are presented here. It can be noted that even if only resistivity data were measured, shorter measurement cycle times lead to underestimation of the measured resistivity due to the large IP-effects associated with waste. Res3dinv was used for time-lapse inversion of the resistivity data.

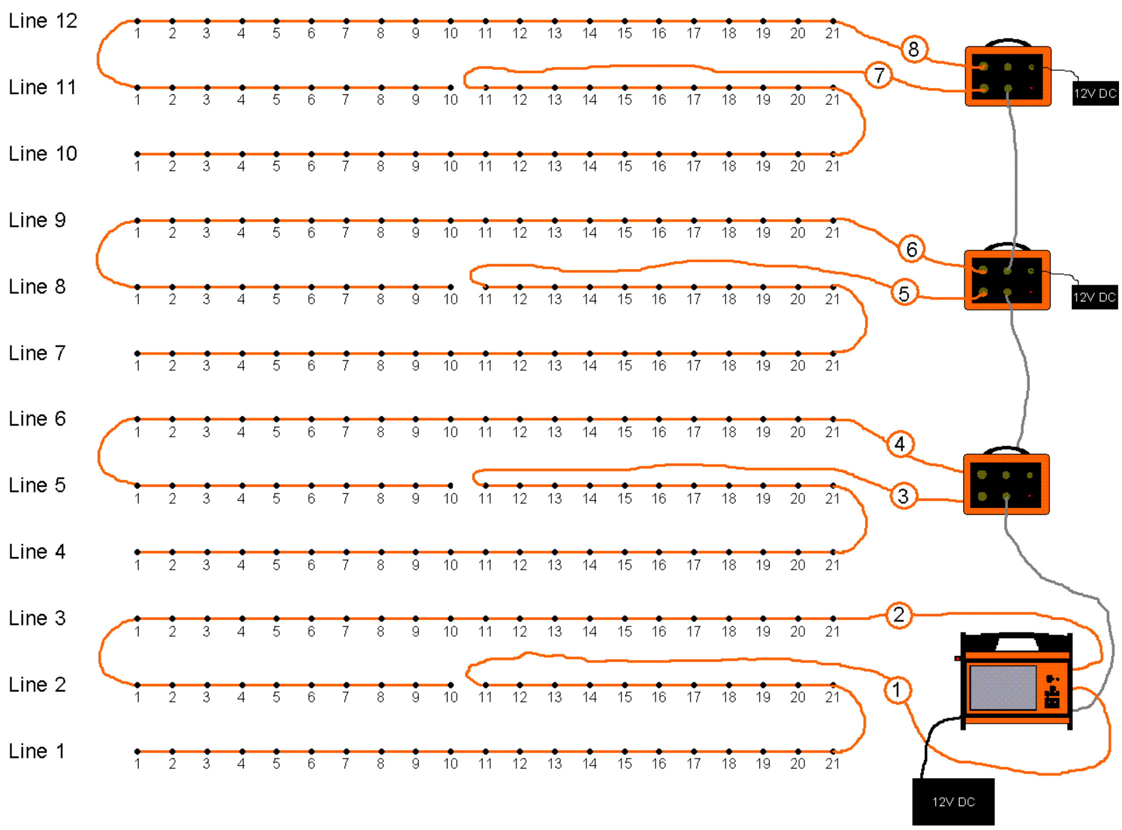


Fig. 1: Sketch of short term monitoring setup with 12 x 21 electrodes.

Results

The predominant material in the investigated volume in the short term monitoring is mixed waste, with a layer of cover material on top. According to the waste company the cover material consists of 0.4 m compost, 0.8 m excavation masses, 0.3 m gravel and 0.3 m clay, plus possibly 0.1 to 0.2 m compost, under which there is waste. The groundwater level is expected at some metres depth according to observations in the surrounding areas. The waste is underlain by sedimentary rock dominated by sandstone at depths beyond the depth penetration of the investigation presented here.

The inversion model used cells of 1 metre width so that large near surface resistivity variations could be more accurately modelled. Higher damping factors were also used for the first two layers as well as a diagonal roughness filters to reduce banding effects in the inversion (LOKE and DAHLIN, 2010). The resistivity model from one time step is shown in Fig. 2, where a strong decrease in resistivity is seen at around 4 metres depth which is interpreted as due to the groundwater surface. The IP results (see example in Fig. 3) show a strong increase in chargeability a couple of metres below the decrease in resistivity. This is interpreted as a change in type of material, and that there is mixed waste below this level which gives rise the high chargeability.

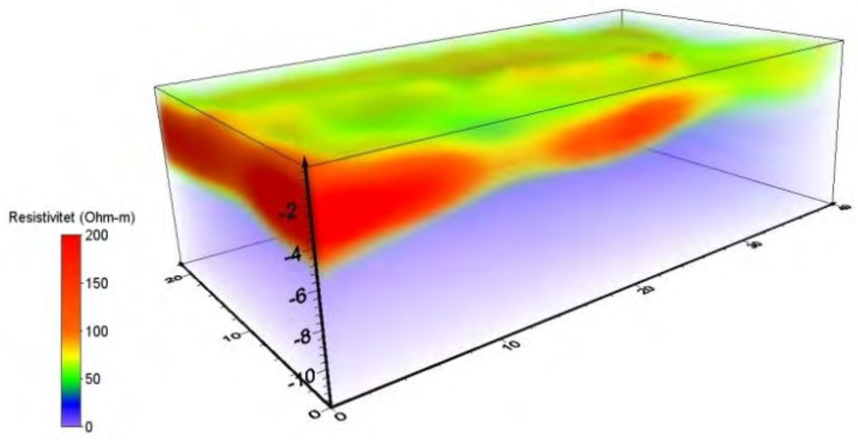


Fig. 2: Example resistivity model from short term monitoring (distances are in metres).

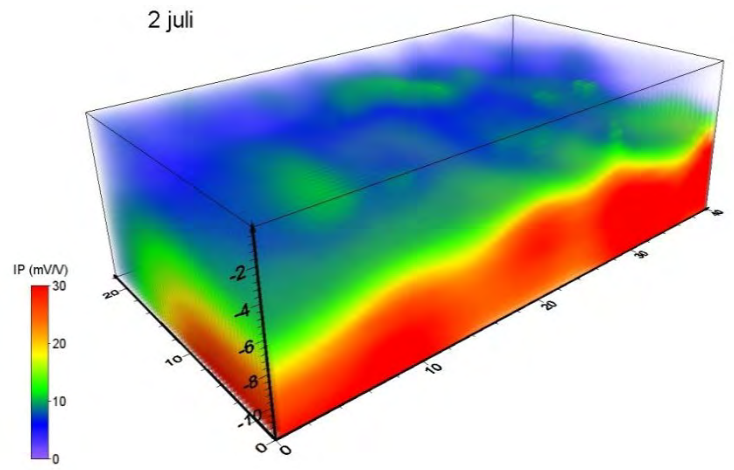


Fig. 3: Example chargeability (IP) model from short term monitoring (distances are in metres).

There were some rainfall events during the monitoring period, and the resulting change in resistivity is shown in Fig. 4. As can be seen much of the decrease in resistivity is very shallow, but there is a zone in the central part of the volume where it penetrates to some metres depth.

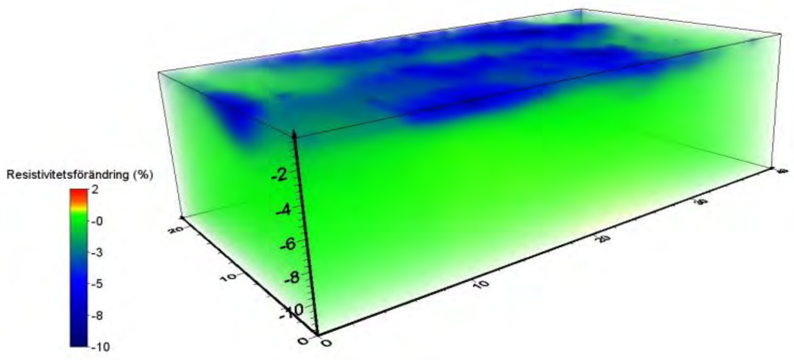
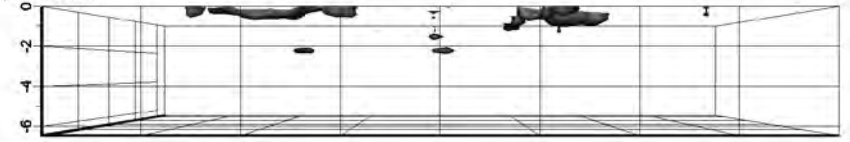
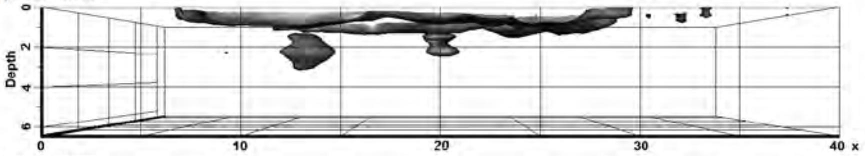


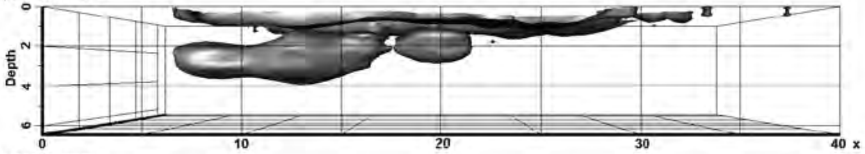
Fig. 4: Change in resistivity during the monitoring period (distances are in metres).



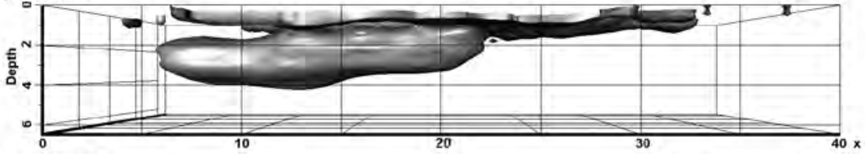
(a) At 21 hours



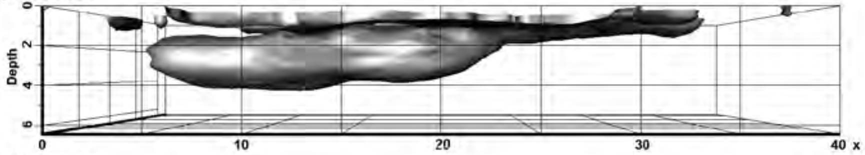
(b) At 27 hours



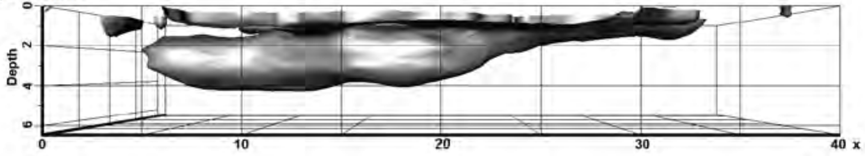
(c) At 33 hours



(d) At 39 hours



(e) At 51 hours



(f) At 75 hours

Fig. 5: 3-D iso-surface plots showing the positions of the -6% resistivity change boundary with time.

Fig. 5 shows iso-surface plots of the -6% resistivity change boundary with time, which provides a set of 3-D views of the movement of the rainwater. At 21 hours (Fig 5a), or about 10 hours after the start of the downpour, most of the water is still confined to near the surface. At 27 hours (Fig 5b) more of water has migrated downwards which then forms a significant plume reaching to 4 metres depth at 33 hours (Fig. 5c). At 39 hours (Fig. 5d) the bottom boundary of the plume has moved slightly below 4 metres accompanied by a greater lateral migration. There is a slight increase in the volume of plume at 51 hours (Fig. 5e), after which there were no significant changes up to the 75 hours mark (Fig. 5f).

The particularly heavy rainfall event that occurred 2nd July and that event tends to dominate the change during the period. However if the change in resistivity relative to the preceding day is plotted more subtle changes can be seen, as shown in Fig. 6 where the increase in resistivity can be interpreted as due to increase in gas contents below the water saturated horizons above.

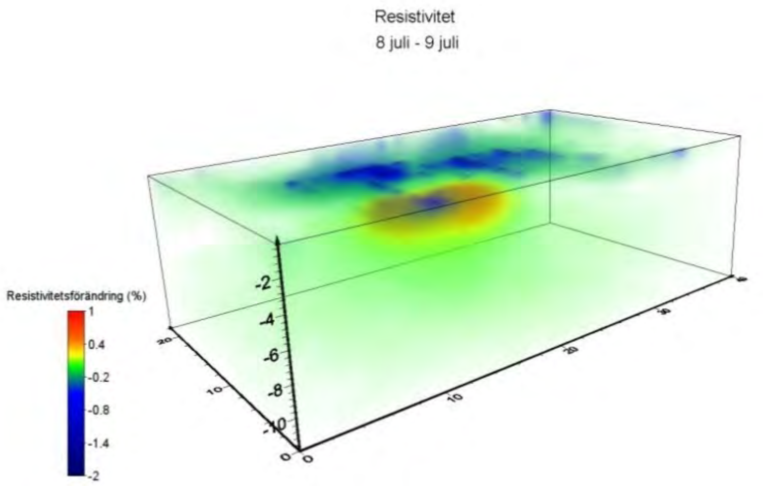


Fig. 6: Change in resistivity 8.–9. July (distances are in metres).

Conclusions

Internal landfill structure was successfully mapped using a combination of resistivity and time-domain IP. Variations in resistivity and chargeability are interpreted to be related to different types of materials. Continued evaluation against historical documentation of the landfilling is underway, and it is planned to do sampling by test pits or drilling as follow up.

Variations in resistivity that we interpret being linked to variation in fluid and gas content were captured by short term monitoring. A rainfall event that occurred during the monitoring period acts as an infiltration test and the changes in resistivity outlines the water migration pattern. After this event there are signs of gas increasing contents below the saturated zone, which is expected as the water will tend to act as a lit above the gas that is generated inside the landfill. The results show the potential of resistivity monitoring for tracing fluid migration in the ground, and also shows patterns that may be due to increasing gas contents in line with previous results.

Acknowledgements

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