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Comparisons of 2D- and 3D-Inverted Resistivity Data As Well As of Resistivity- and IP-Surveys on a Landfill

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SUMMARY

This extended abstract will focus on a CVES-investigation on an old abandoned landfill in Ekeboda, in the south of Sweden. The purpose of the investigation was to compare 2D and 3D inversions of resistivity data from a 2D-survey and to compare resistivity- and IP-surveys as methods for mapping landfills. To fulfil the purposes, CVES-measurements with following numeric inverse modelling of resistivity and induced polarization were conducted. The measurements were made using a modified version of the ABEM Lund Imaging System.

The investigation found that the 3D inversion generally gave better resolution and detail in the models than in the 2D models. Further more, the 3D inversion seem to handle disturbances in the subsurface better than the 2D inversion does.

The comparison of resistivity and IP surveys shows that, in general, the latter is better at delimiting the horisontal limits and the top of the landfill masses. The IP-survey is also able to define the covering layer in a better way. The resistivity survey, how ever, is better at distinguishing different materials.

Introduction

There are often several issues that need to be resolved concerning old, buried and poorly documented landfills due to environmental protection demands. The extent of the buried wastes coverage and depth is often unknown. The same is true for the covering layer. The subsurface material is often contaminated as a result of leakage from the waste, which could be a threat to the groundwater quality. The combination of resistivity and time domain induced polarisation (IP) has been shown to be a powerful tool to get an overview of landfills (Iliceto and Morelli 1999; Carlson et al 2001; Leroux and Dahlin 2007). Further more, Dahlin et al (2007) has shown that 3D inversions of 2D datasets can increase the resolution of the resistivity survey.

The aim of this investigation was to map potential leachate plumes, delimit the extension of the landfill as well as the thickness and quality of the covering layer. Furthermore, the purpose was to compare 2D and 3D inversions of resistivity data from a 2D-survey and to compare resistivity- and IP-surveys as methods for mapping landfills. To fulfil the purposes, CVES-measurements with following numeric inverse modelling of resistivity and induced polarization were conducted. To characterize the water in terms of possible contamination, samples were taken for chemical analysis. This paper will focus on the CVES-investigations.

Site Description

The Ekeboda landfill has an area of about 20 000 m^2 and is situated in a small valley in the municipality of Hörby in southern Sweden. The landfill was in use between 1965 and 1978, with illegal dumping continuing until the mid 1980's. The landfill contains domestic waste, construction, demolition and industrial waste as well as other hazardous waste such as pesticides and mineral oils. The major part of the waste was burned during the early years, but later on it was deposited. The waste has been deposited on natural ground, comprised of sandy till with underlaying bedrock of sandstone or possibly gneissic rock (SGU 2000). The covering layer consists of various soils, of which no precise record has been kept. At present, the leachate is collected and transported to the local water treatment facility.

Survey Method and Equipment

Twelve profiles were measured (1-2 and 4-13), see Figure 1. Multielectrode gradient array was used for all profiles. For the 3D inversions of profiles 4 to 13 a bipole-dipole array was used as well to try to get better depth penetration in the outer parts of the survey area. The electrode spacing used was two meters in profiles 1 and 2 and five meters in profiles 4 to 13. The topography along the profiles was surveyed and taken into account when inverting the data.

The resistivity- and IP-surveying data acquisition was made using a modified version of the ABEM Lund Imaging System. In this system the measurements are taken by the instrument RIP924, which in

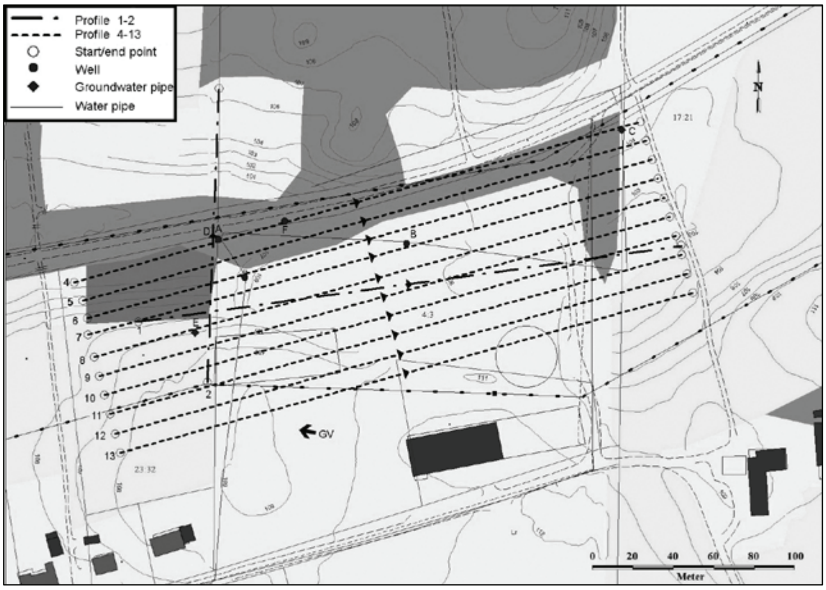

Figure 1. Map over the survey area (profiles 1-2 reconnaissance investigation, profiles 4-13 used for 3D inversion).

combination with an ES10-64 relay switch allows seven simultaneous readings of resistivity and chargeability to be carried out for each injection of current into the ground. The system was controlled via a PC type field computer. The galvanic contact with the soil was in general good and enabled the Terrameter Booster SAS2000 to transmit 100 to 200 mA current. Standard electrode cables for resistivity imaging were used in standard layout mode. The measuring sequence was designed to minimize charge up effects (Dahlin 2000). A 10 ms delay after the current was turned off was used for the IP-measurements and the potential was integrated as chargeability in ten time windows of 100 ms each.

The inversions of the results were carried out with half the electrode spacing, using only one IP time window due to software limitations. The 2D inverted models were created using the software Res2Dinv, and the results are presented as cross sections. Res3Dinv were used to create the 3D inverted models with the results presented as horizontal slices using the software Surfer. Depth slices were extracted also from combined 2D inversion models for comparison.

Results and Discussion

The model to the left in Figure 2 was made with 2D inversion of the resistivity data and the one to the right with 3D inversion. The low resistivities, in the middle of the models in the sections from 95 m.a.s.l. to 103 m.a.s.l. are interpreted as the wet part of the old landfill. This area appears to have a greater extension in the 3D-inverted model in the section for 95 m.a.s.l., than in the 2D inverted model. On top of the landfill, there is an inspection well that goes down into a culvert which is situated directly under the waste at 100 m.a.s.l.. The fact that low resistivities can be found under this level, is possibly due to downward transportation of leachate into the underlying sediments and bedrock. The low resistive area in the section 95 m.a.s.l. is not as big in the 2D model as in the 3D model. This could be explained by the fact that the 3D inverted model might have a bigger problem with equivalence, since it also has a bigger error in depth compared with the investigation well, mentioned earlier. It might also be because the 2D-model is unable to resolve the downward transportation.

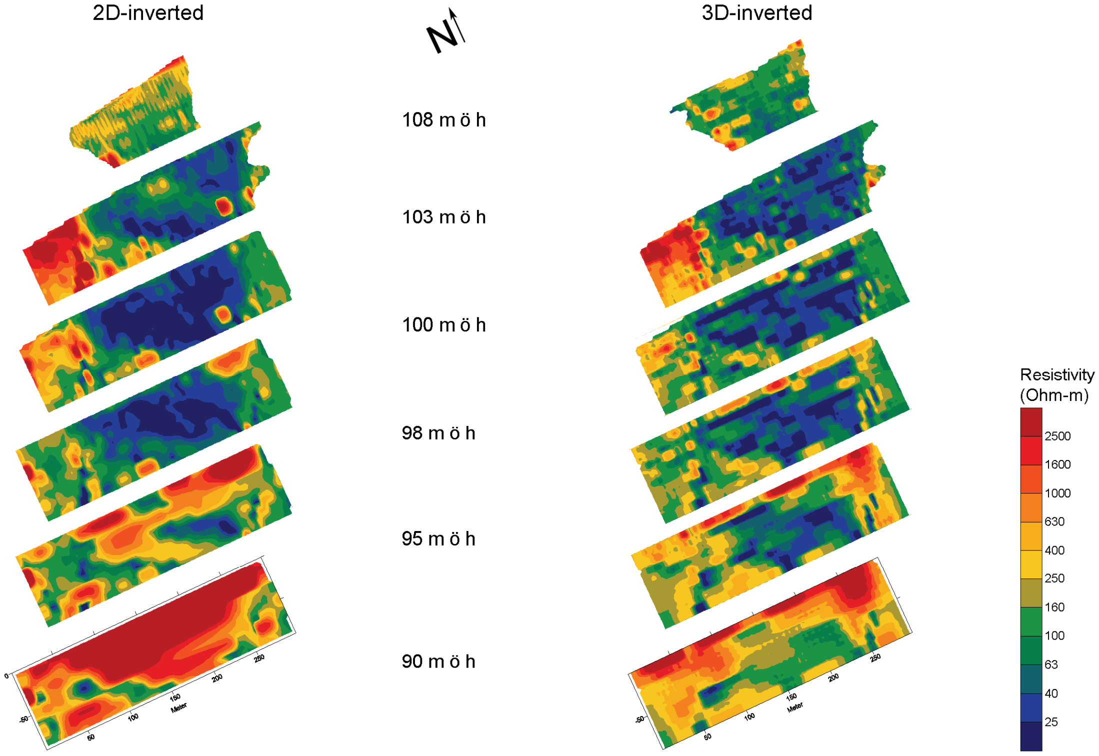

Figure 2. Resistivity results from profiles 4-13, presented as depth slices at different levels above mean sea level.

It seems as if 3D inversion gives a better resolution in the models, than the 2D inversion does. This can be observed, especially in section 98 m.a.s.l.. Here a culvert, which redirects a small brook, lies buried in the eastern part of the investigation area, and it is better defined in the 3D model. The same can be said about the pipe going from the leachate collection well in the north western corner of the landfill. This pipe shows as a stretch in a south westerly direction in the models. The difference in resolution can also be seen in the section for 90 m.a.s.l., where the high resistive area (interpreted as sandstone) is not very well defined towards the lower resistivities. This could also explain the fact that this area of high resistivity appears shallower in the 2D inverted model.

When the 3D inverted model is studied, it is obvious that it suffers from artefacts. These are probably due to the inversion routine. The artefacts could possibly be avoided by using a harder damping factor in the y-direction (north) of the model. It could also be avoided by using a smaller distance between the lines, when the measurements are carried out in the field.

In the sections for 100 and 103 m.a.s.l. there are two smaller areas with high resistivity in the northern part of the model. These are due to grounding cables that goes down into the ground here. These probably cause disturbances in the measurements. These disturbances are not as widespread in the 3D inverted model, which seems to be able to concentrate the resistivities to a smaller area.

When comparing the methods of resistivity and IP as tools to investigate old landfills, there is much to gain with a combination of the two, concerning the interpretation. For example, in the resistivity section of profile 1, low resistivities were found between 90 and 100 m.a.s.l. (figure 3a) and has been interpreted as the wet part of the waste. Higher resistivities were found on top of this, but it is not possible to distinguish the dry part of the waste from the covering layer. The thickness of the covering layer is however quite distinct in the IP section (figure 3b), where material with very little IP effect is visible in the uppermost layer. The IP section reveals that the covering layer is about 3-5 m thick and that it is thinner towards the outer parts of the landfill. Chargeable material was found at depths that correspond well with the waste. When it comes to delimitation of the extent of the waste, the IP-sections have some difficulties to identify the bottom of the landfill. This might be explained by the nature of the IP phenomenon and its relation to the resistivity. However, the

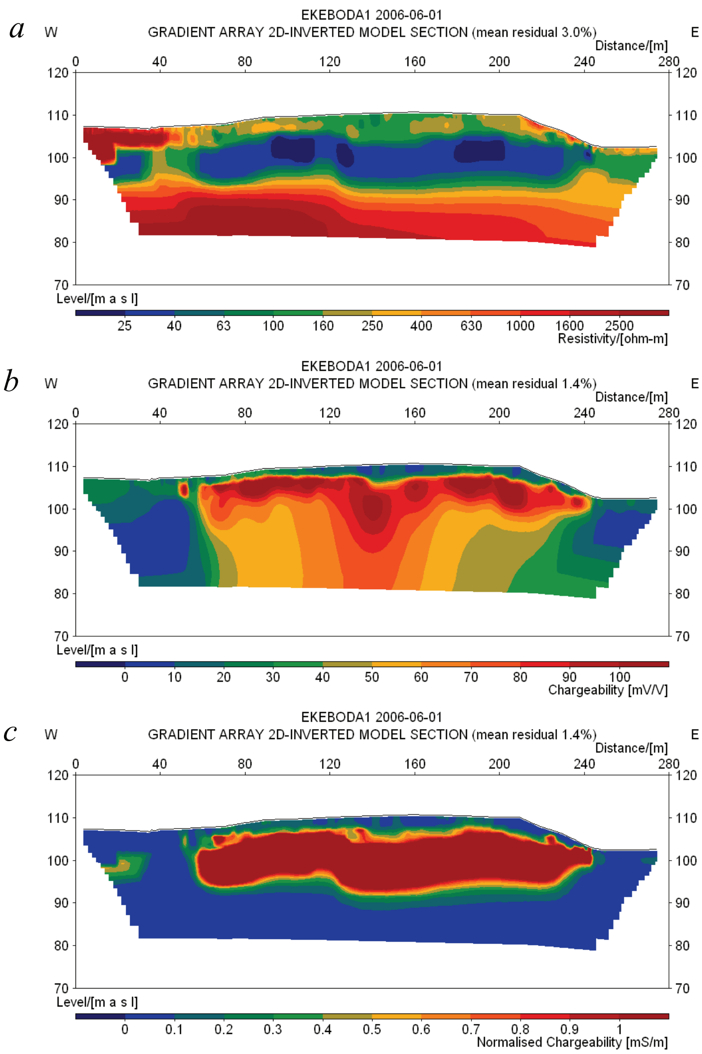

Figure 3. 2D-inverted data from the resistivity survey (a) and IP-survey (b) along profile 1. The normalized IP-model of the same profile is shown in (c).

problem with delimitation of the bottom of the landfill can be avoided using normalised IP, a parameter that quantifies the magnitude of surface polarization. The normalised IP section is able to clearly delimit the waste as can be seen in figure 3c. Using both the resistivity and IP section (Figure 3a and b), it is evident that the covering layer is comprised of material with higher resistivity and lower chargeability towards the outer parts of the landfill. This is probably medium grained to coarse grained soil material. In the middle of the model the covering layer consists of material with low resistivity and IP effects that are small compared to the waste. This is interpreted as consisting of more fine grained soils.

Conclusions

The comparison between 2D and 3D inversion of resistivity data shows that 3D inversion generally give better resolution and detail in the models. It also shows that 3D inversion seem to handle disturbances in the subsurface better than the 2D inversion does. This is evident where the grounding cables went down into the ground.

The comparison of resistivity and IP surveys shows that, in general, the latter is better at delimiting the horisontal limits and the top of the landfill masses. This is especially true for normalised IP. The IP-survey is also able to define the covering layer in a better way. Resistivity measurements are better at distinguishing different materials, but IP-measurements are a good complement to resolve ambiguities in the interpretation.

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