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DETECTION OF WATER AND GAS MIGRATION IN A BIOREACTOR LANDFILL USING GEOELECTRICAL IMAGING AND A TRACER TEST

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SUMMARY: In this paper we describe field investigations of leachate recirculation at a bioreactor landfill using geoelectrical imaging technique (i.e., electrical resistivity) combined with a tracer test. The use of geoelectrical imaging techniques is an established practice for environmental investigations and monitoring of various landfill processes and in recent years also the bioreactor landfill concept has been emphasised. In the study, the electrical resistivity technique was evaluated and the possibility to detect water and gas migration in the waste mass was investigated. Results showing moisture migration through the bioreactor landfill, during leachate flushing and during a tracer test, are presented. Also results indicating the resistivity technique being useful for biogas detection are shown.

1. INTRODUCTION

The bioreactor concept was developed to reduce and control the environmental impact of landfills and to utilise the energy potential of the waste, and in recent years the interest for bioreactor landfill techniques have been at a high level (Barlaz and Reinhart, 2004). The main principle of the bioreactor concept is to enhance waste biodegradation by recirculation of leachate in the waste mass, and consequently, the potential long-term risks will be reduced, and post operation costs will be decreased. Moreover, the enhanced waste biodegradation leads to an increase of biogas production for energy utilisation. Spatial distribution of moisture content is recognised to be of great importance to the biodegradation and methane production in a bioreactor. The overall objective of the project was therefore to investigate the spatial distribution of water flow within a bioreactor landfill with leachate recirculation.

The use of geoelectrical imaging techniques is an established practice for environmental investigations and monitoring of various landfill processes (e.g., Bernstone and Dahlin, 1997, Rosqvist et al, 2003, Cardelli and Di Filippo, 2004), and in recent years also the bioreactor landfill concept has been emphasised (Guerin et al, 2004, Moreau, et al., 2004, Rosqvist et al, 2005). In the study, the electrical resistivity technique was evaluated and the increase in moisture content as a result of the start of leachate recirculation was investigated. In this paper we describe field investigations of water recirculation at a bioreactor landfill using a geoelectrical imaging technique (i.e., resistivity) combined with a tracer test.

2. MATERIALS AND METHODS

2.1 The Bioreactor landfill

The field campaign was carried out at a bioreactor landfill at the Filborna landfill site, Helsingborg, Sweden, which was 120 by 60 meter, with a depth of approximately 16 meter. The bioreactor landfill was isolated from the surroundings by the use of low permeable clay as a bottom liner. During the construction of the bioreactor landfill it was built up in 5 meter layers, each layer covered with an intermediate cover of compost. Horizontal pipes for leachate recirculation were placed in trenches filled with wooden chips, together with gas collection pipes. The pipes for leachate recirculation were installed at the bottom of the trenches and the gas collection pipes in the upper part. Altogether 7 trenches for leachate recirculation and biogas collection pipes were installed with a 20-meter distance between the trenches (see Figure 1). At the bottom of the bioreactor landfill, a leachate collection system was installed and in the interior horizontal pipes for gas collection was installed.

2.2 The geoelectrical-imaging techniques

Geoelectrical imaging techniques are envisaged to have three major applications in connection with ground and groundwater contamination around landfills: mapping for identification and delineation of contaminants, quality control of soil stabilisation/contaminant immobilisation, and long term monitoring. Leakage from municipal and mining waste deposits is generally associated with high ion concentrations and hence very low resistivities. This makes geoelectrical imaging techniques particularly interesting for leachate migration inside, and around, landfills. In the study presented here the use of geoelectrical imaging techniques for bioreactor landfill process monitoring have been addressed. The electrical resistivity is suitable for monitoring of water fluxes in landfills since it links with moisture content and ionic content in the water, as pointed out in Guérin et al., (2004).

The geoelectrical imaging method is based on measurement of the potential distribution arising when electric current is transmitted to the underground via electrodes. The data acquisition was done as two-dimensional (2D) resistivity imaging, using the ABEM Lund Imaging System. The system is computer controlled and consists of a resistivity-IP instrument, a relay-switching unit, four electrode cables, connectors and steel electrodes. The 2D imaging layouts used comprises around 80 electrodes, and measurement lines can be expanded via a roll-along technique. A multiple gradient array electrode configuration was used in order to get good resolution and fast data acquisition. The measured data was processed with inverse numerical modelling (inversion) to produce model cross-sections of the resistivity and chargeability distribution of the ground using the software Res2dinv.

2.3 The experimental set up

A 2-D resistivity and IP survey was performed in which three parallel lines, each 160 m long, were measured perpendicular to the leachate distribution pipes (Figure 1). The electrode distance was 2 m and multiple current source gradient array was used. A number of resistivity and IP-surveys were carried out with the cable layout in fixed positions. In this paper only the resistivity measurements are shown.

A flushing experiment started in March 2006 and continued for 85 days. To get a picture of the bulk resistivity of the waste material in the bioreactor the fieldwork started with a set of background measurements. The irrigation system was started after the background measurements had been carried out, and seven further measurements were carried out during the experimental period. During the experiment, in all 922 m³ of water was introduced to the bioreactor landfill, corresponding to less than 2 mm/day.

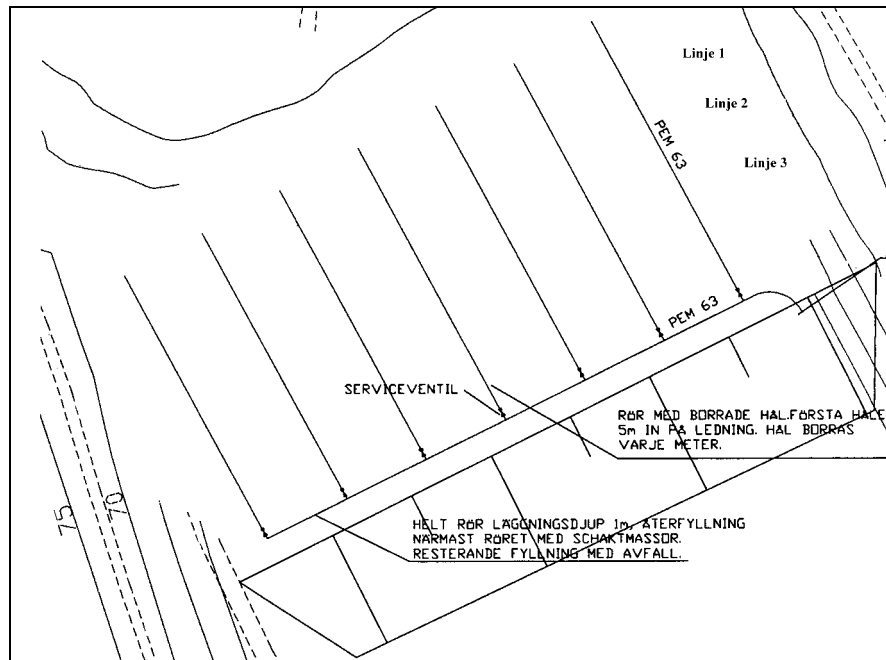


Figure 1. Plan of the bioreactor landfill showing the distribution pipes for leachate and the lines for resistivity measurements (Line 1 – 3).

When the tracer test was started, the irrigation system was turned off and a one cubic meter Lithium Bromide tracer pulse was introduced to one of the leachate circulation pipes. Once the tracer pulse had been introduced to the waste mass, all leachate circulation pipes were put back in normal use. The tracer pulse was diluted in the leachate recirculation system before it reached the distribution pipe and consequently, the tracer concentration in the pulse entering the waste mass was not known.

3. RESULTS

3.1 Flushing test

In Figure 2 the resistivity measurements at line 1 from day no 8 to 85 are presented as the relative difference between the measurements at day one and the current day. The scale in Figure 2 is -0.1 to $0,1$ which stands for a 10% increase and decrease in resistivity, respectively. In Figure 2 also the input of water to the bioreactor landfill are shown. In all, 922 m³ of water was introduced to the bioreactor landfill during the experimental period.

In Figure 2 the moisture migration in the waste is shown as a decrease in resistivity. It is shown that after 8 days the migrating water results in a scattered pattern of lowering of the resistivity (blue/dark) zones near the surface. These zones are interpreted as a non-uniform water flow through the upper layer of the waste. As the water input continued, the zones with decreased resistivity showed a more uniform pattern, which is interpreted as higher moisture content. At the end of the experimental period (day 85), the low resistivity zone showed a relatively homogenous pattern reaching to a depth of almost 10 meter.

In Figure 2 also an increase in resistivity has been recorded in irregular zones at various locations during the experimental period. The appearance of high resistivity zones could not be

experimentally evaluated. However, the most probable explanation for the irregular pattern of high resistivity zones is migration of gas in the bioreactor landfill.

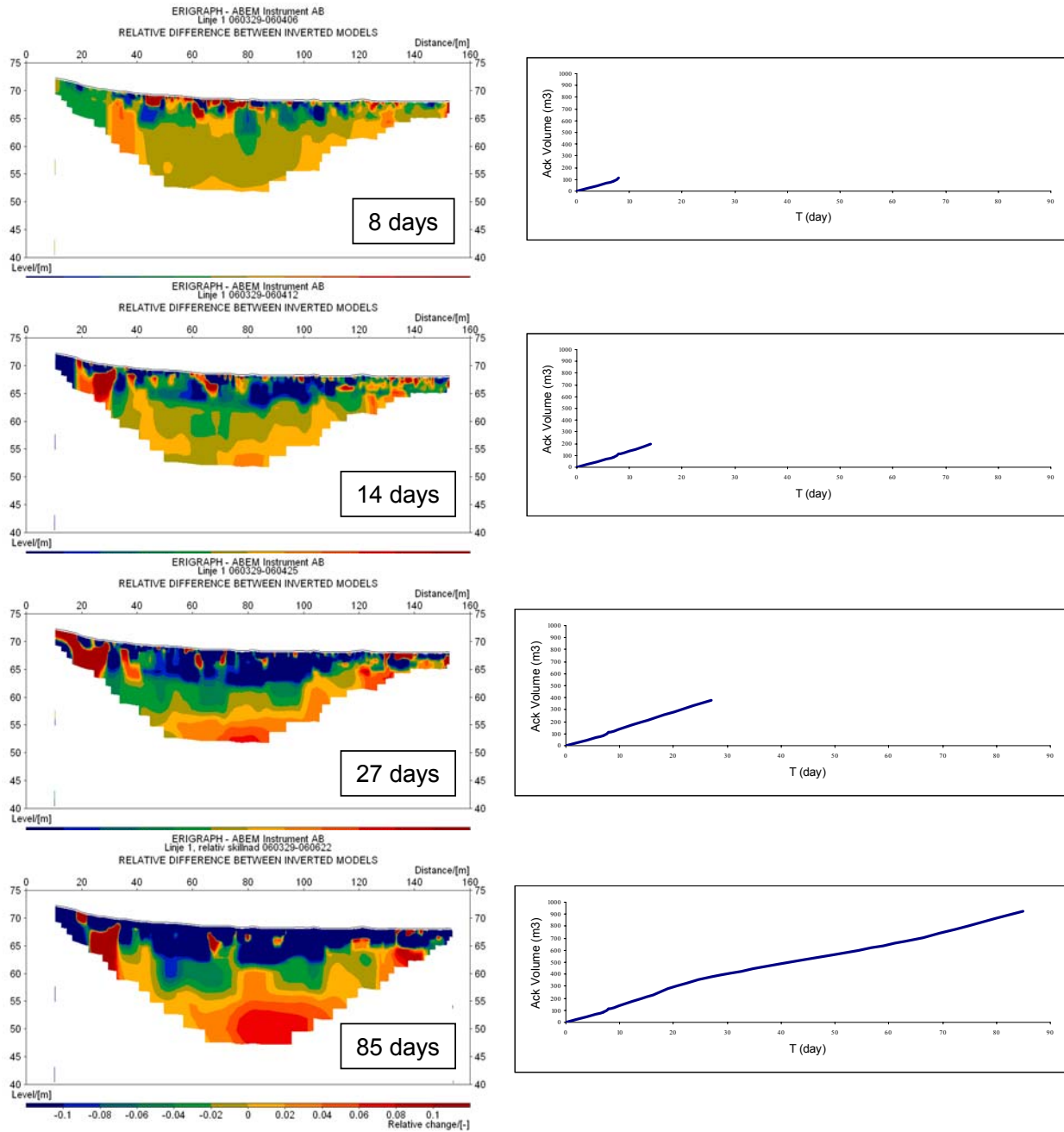


Figure 2. Inverted resistivity sections for line 1 presented as relative change from day no 8 to 85, and the accumulated input of water to the bioreactor landfill.

3.2 Tracer test

In Figure 3 the resistivity measurements at line 3 during the tracer test are shown. The figure shows the relative differences in resistivity from the start of the experiment and the current day. The relative differences are presented in two scales of relative differences, +/- 10 and 50 percent, respectively. To the left in Figure 3 the +/- 50 percent scale, and to the right the +/- 10 percent scale, are shown.

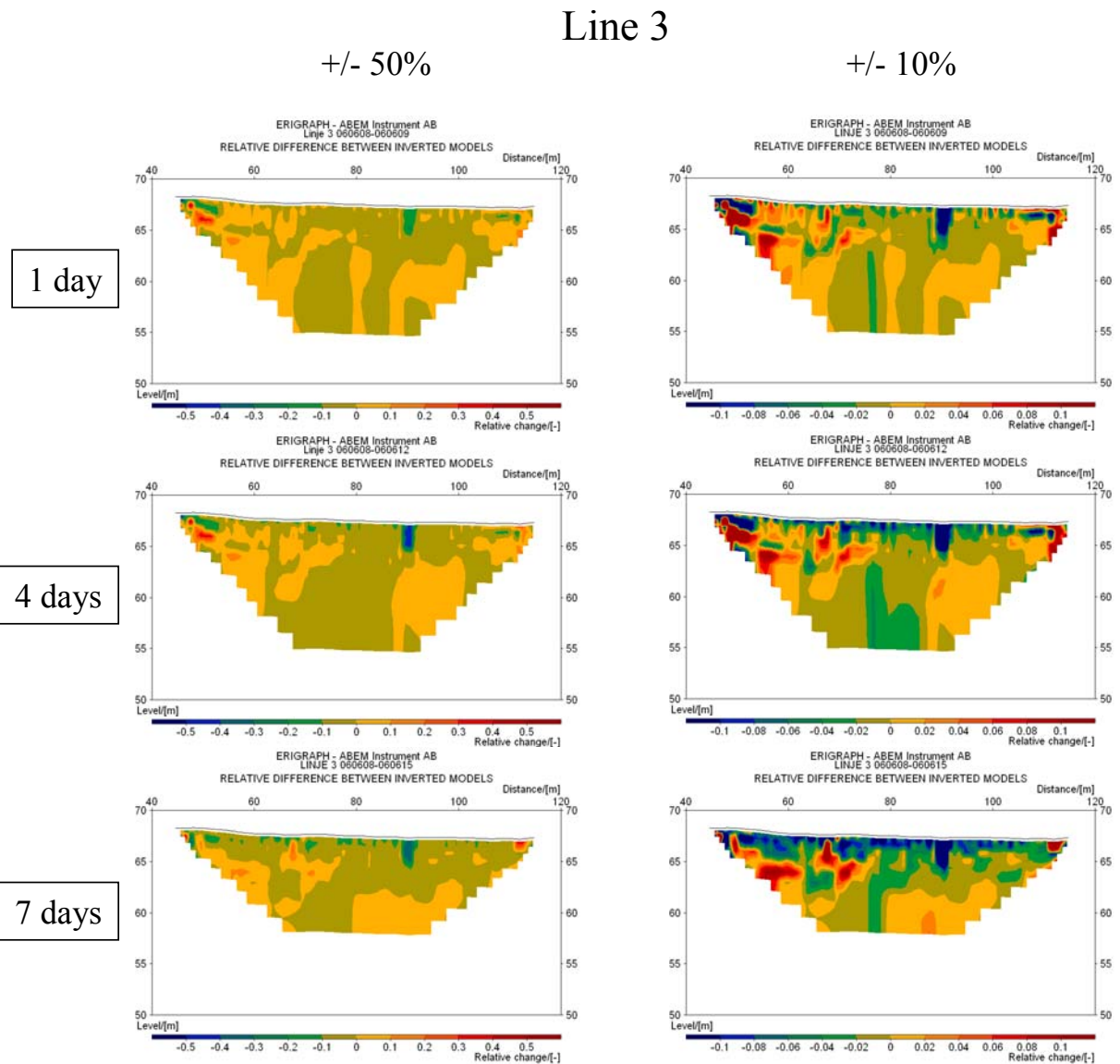


Figure 3. Inverted resistivity sections for line 3, presented as relative change during the tracer test.

As described above, the tracer pulse was introduced through a leachate recirculation pipe at the distance of approximately 88 meter (see sections in Figure 3). As shown in all six sections in Figure 3, the tracer pulse appears at the 88-meter point as a clear decrease in resistivity (dark blue) in a zone propagating down from the surface. After one day only, the low resistivity zone reached to a depth of approximately 2 to 3 meter, and after seven days no significant changes in the depth of the low resistivity zone could be observed. However, in Figure 3, the +/- 50 percent shows that the relative changes in resistivity had decreased from over 50 percent (day 4, blue) to approximately 30-40 percent (dark green) after 7 days. It was thus indicated that the tracer pulse was diluted from day 4 to 7.

In Figure 3 an increase in resistivity has also been recorded in irregular zones at various locations during the experimental period. In particular in the interval between approximately 45 and 80 meters irregular zones are appearing, most clearly in the sections showing +/- 10 percent change. These zones are showing large changes in resistivity with time, resulting in a gradual change in positions. The appearance of high resistivity zones could not be experimentally evaluated.

4. DISCUSSION AND CONCLUSIONS

The fieldwork was performed under good conditions resulting in high quality field data showing a fairly consistent picture of the waste mass in the bioreactor landfill. In the bioreactor the resistivity of the relatively wet waste mass at depth was measured to be in the range of 3 to 30 Ωm , which is in the same range (Gu erin et al., 2004) or somewhat lower (Bernstone and Dahlin, 1997), than results presented elsewhere. High water content and ionic content, and high organic content in the bioreactor can partly explain the relatively low resistivity. Also the temperature may influence the outcome of the measurements (Gu erin et al., 2004).

The main objective with the study was to investigate the spatial distribution of recirculated leachate in a bioreactor landfill at field scale. It was concluded that the experiment could successfully detect the distribution of recirculated leachate through the waste mass by comparing interpretations of resistivity measurements at different time steps (i.e., relative differences) in 2-D resistivity sections.

After 8 days of irrigation non-uniform water flow through the upper layer of the waste was indicated by the resistivity measurements. As the water input continued zones with decreased resistivity showed a more uniform moisture flow pattern and after 85 days a uniform low resistivity zone indicated increase in moisture content. It is concluded that the use of different plotting scales for the inverted resistivity sections or relative difference sections is beneficial for the interpretation, since different information can be extracted at different plot intervals. In our study +/- 10 and +/- 50 percent variation was shown to be the most appropriate levels.

The results of the combination of a tracer test and resistivity measurements clearly suggest this technique to have potential for detecting and quantifying subsurface moisture movement in landfills. Further research is however required for optimisation of the approach and a more comprehensive understanding of the results. It is suggested that future experiments combining resistivity measurements with tracer tests should facilitate for water sampling in order to detect the migration of the tracer pulse. The results suggest the tracer pulse to migrate to a depth of 2-3 meter in less than one day, indicating the water migration to occur as a fast vertical flow. The occurrence of fast vertical flow have been reported in previous studies to be due to non-uniform flow in the physically heterogeneous waste mass e.g., Rosqvist and Destouni (2000).

In recent years a study addressing gas migration in landfills has been reported (Moreau, et al., 2004). In Moreau, et al., (2004) variation in electrical resistivity indicated biogas migration and an interpretation of leachate recirculation effects on biogas migration were proposed. An

increase in resistivity was recorded in irregular zones at various locations in the waste mass during the experimental period. The appearance of high resistivity zones could not be experimentally evaluated. However, the most probable explanation for the irregular pattern of high resistivity zones is migration of gas in the bioreactor landfill. Therefore it is concluded that the resistivity measurement could be a viable method for detection of gas migration in landfills. It is therefore suggested that the use of resistivity should be further investigated in order to develop systems for landfill gas monitoring.

Based on the results of the geo-electrical measurements, it is suggested that the technique provide an interesting possibility for development of bioreactor and MSW landfill monitoring and process control. For future R&D, it is suggested that moisture and gas migration through the waste mass should be investigated and clarified. For a better understanding experiments in laboratory and pilot-scale landfills are suggested. For example, in an experiment combining a tracer test with resistivity measurements in lab-scale, experimental conditions such as, moisture content, temperature, and tracer concentrations, can be kept under control.

REFERENCES

- Barlaz, M.A., and Reinhart, D. 2004. Bioreactor landfills: progress continues. Editorial, *Waste management*, 24, 859 – 860.
- Bernstone, C., and Dahlin, T. 1997. DC resistivity mapping of old landfills: two case studies. *European Journal of Environmental and Engineering Geophysics* 2, 121-136.
- Cardelli, E., and Di Filippo, G. 2004 Integrated geophysical surveys on waste dumps: evaluation of physical parameters to characterise an urban waste dump (four case studis in Italy). *Waste Manage Res.* 2004: 22: 390-402.
- Guérin, R., Munoz, M.L., Aran, C., Laperrelle, C., Hidra, M., Drouart, E., and Grellier, S. 2004. Leachate recirculation: moisture content assessment by means of a geophysical technique. *Waste Man*, 24, 785 – 794.
- Moreau, S., Bouyè, J-M., Duquennoi, C., Barina, G., and Oberti, O. 2004. Electrical resistivity survey to investigate biogas migration under leachate recirculation events. *Waste 2004; Integrated waste management and pollution control policy and pracyice, research and solutions*, Stratford-upon-Avon, September, 2004.
- Rosqvist H., and Destouni G., 2000. Solute transport through preferential pathways in municipal solid waste. *J. Cont Hydrol.* 46, 39-60.
- Rosqvist, H., Dahlin, T., Fourie, A., Rohrs, L., Bengtsson, A., and Larsson, M. 2003. Mapping of leachate plumes at two landfill sites in South Africa using geoelectrical imaging techniques. *Proc. Ninth International Waste management and landfill symposium*, Cagliari, Sardinia, Italy.
- Rosqvist, H., Dahlin, T., and Lindhé, C (2005). Investigation of water flow in a bioreactor landfill using geoelectrical imagining techniques. *Proceedings Sardinia-05, Tenth International Waste Management and Landfill Symposium*, Cagliari, Sardinia, Italy.