TIME LAPSE ELECTRICAL IMAGING TO STUDY FLUID MOVEMENT WITHIN A LANDFILL

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The environmental acceptability of landfill as a waste disposal option depends on the prevention of uncontrolled emission of gas and leachate. With increasingly strict legislation governing the operation and monitoring of landfills and with progressively more emphasis on the controlled biodegradation of waste, a robust understanding of the physical and bio-chemical processes taking place within landfills is essential. Geophysical techniques are already playing an important part in achieving this understanding, both with the installation of below liner leak detection systems, and as a tool for tracking changes in water content in landfills. With many operators now realizing the potential benefits of running landfills as controlled bioreactors, where the introduction or recirculation of leachate into the site is actively encouraged to accelerate degradation and enhance landfill gas production rates, the tracking of moisture within the site has taken on increased significance. Where leachate is re-circulated into a site to increase gas generation, the aim is to raise the water content of as large a proportion of the waste mass as possible. However, the possibility that rapid short circuiting of large volumes of leachate from the injection infrastructure to the collection system could bypass a large proportion of the waste means that there is a real need to be able to monitor the movement of leachate.

This paper describes a field study that used time domain resistivity to monitor the effect of dewatering a landfill using horizontal wells over a period of 18 months. As such it represents one of the longest studies of this type in the literature.

This study of time-lapse electrical imaging applied at the field scale took advantage of a landfill leachate dewatering programme carried out on a landfill site in Essex and designed and implemented by the University of Southampton. The dewatering was to be achieved via three horizontal drains each 250m long and drilled into the base of the landfill. A comprehensive hydrogeological monitoring scheme, which would provide essential comparative results for the validation of the time-lapse electrical imaging, comprised piezometers at multiple levels and neutron probe access tubes installed in lines perpendicular to the horizontal drains. The use of horizontal drains and the degree of instrumentation installed provided a unique opportunity to assess the efficacy of 2-dimensional time-lapse electrical imaging to monitor fluid movement within the landfill. Three electrical imaging arrays, each with 50 electrodes at 5m inter-electrode spacing, were installed on the surface of the landfill perpendicular to the horizontal drains. The configuration of the horizontal drains means that the drainage pattern and hence changes in resistivity are also likely to be predominantly two-dimensional, thus reducing the potential for out of section artefacts in the interpretation of the electrical imaging results. The landfill surface was only partially capped with a plastic liner, with the majority of the surface capped only with a soil layer used as temporary cover.

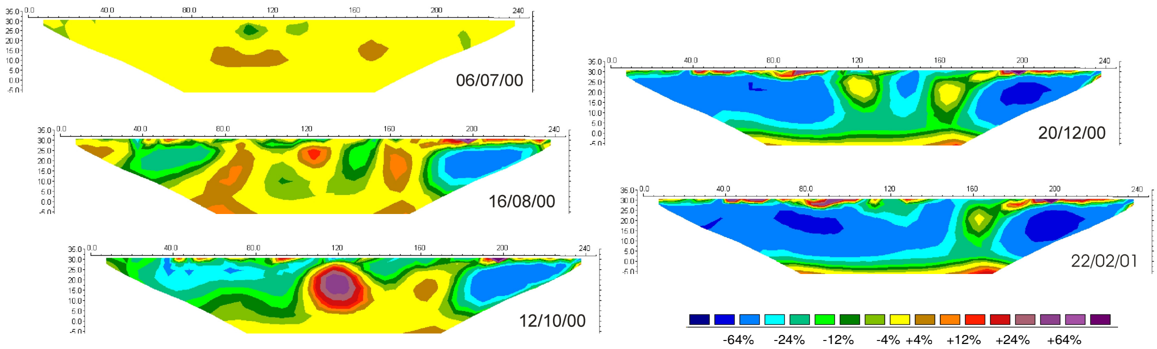

Figure 1. Sample of results from the time-lapse electrical imaging. Percentage change in resistivity recorded over the landfill, where a decrease in resistivity indicates an increase in moisture content and an increase in resistivity indicates a decrease in moisture content.

The results of the time-lapse imaging showed there to be:

1) no general dewatering of the waste by the horizontal wells, a finding backed up by an independent piezometric monitoring programme that indicated that although there had been considerable reduction in pore pressure of a confined layer within the waste, there had been no desaturation.

2) there was a net decrease in resistivity within the landfill over the 18 month monitoring period, that was attributable solely to an increase in the quantity of pore spaces filled with liquid and caused by high rainfall over the period. Seasonal variations in resistivity were detected indicating the drying of the surface layers during the summer.

3) an area of high resistivity developed directly above one of the horizontal wells soon after the start of pumping. This is attributed to the release of gas within the leachate and a consequential reduction in the water filled porosity in response to a pore water pressure reduction (caused by pumping).

The validation of the interpretation of the time-lapse images with the observation well data and Meteorological Office data supports the use of electrical imaging for the monitoring of leachate conditions and net changes in moisture content within a landfill.

A forward modelling program was used to investigate issues relating to image resolution. A simple two-layer basecase model was constructed as the starting model, with an upper resistivity of 60Ωm representing the waste material and a lower resistivity of 9Ωm representing a basal clay layer at a depth of 31 m. Infiltration was represented by discrete vertical channels (represented by a lower resistivity of 15Ωm) of varying thicknesses, geometries and spacings. The resulting time-lapse electrical image for each infiltration pattern is shown for each model, giving a direct comparison between a ground (or at least physical) truth and the calculated changes in resistivity. This method very clearly gives an indication of resolution, and the technique revealed that:

1) caution must be exercised in the interpretation of electrical imaging, particularly at depth as resolution decreases. The technique is able to identify the impact of discrete events that change the resistivity of the waste, but is not necessarily able to resolve the exact location or shape of what is causing the change.

2) the appearance of anomalous changes in resistivity in the model time-lapse images emphasises the importance of fully understanding the limitations of any monitoring technique. The merits of time-lapse electrical imaging in the monitoring of landfill processes are indisputable, but as with other more common methods of monitoring fluid in the subsurface, such as boreholes and piezometers, ambiguity in the interpretation exists and it is the responsibility of the skilled practitioner to make robust interpretations of the data.