Resistivity monitoring for detection of landfill gas migration

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Geoelectrical Resistivity Monitoring for Localizing Gas at Landfills

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SUMMARY

In order to assess the potential of electrical resistivity for imaging gas migration at landfills, two relatively well-known sites - one bioreactor landfill and a conventional landfill - have been monitored successively. A three-dimensional resistivity image could be constructed every two hour on both sites. Meteorological parameters were monitored at the same time, with one measurement taken every hour. Methane concentration was measured in the air at several occasions, the pore pressure was monitored at two locations and some relative estimations of moisture in the top layer were made at the second site. The results show imperfect but interesting correlations between the different parameters and give a hint of how the method could be refined. The resistivity depends on several parameters, but the areas where the resistivity is most variable seem to be clearly related to higher gas emissions.

Introduction

Landfill gas consists of about 40-60% methane and 60-40% carbon dioxide, and contains about one to a few percent other gases. Methane can be used for heating, being in that respect a valuable resource, but it is also a powerful greenhouse gas. Growing concern regarding global climate changes over the last few years has pointed out the need to quantify and control the leaking of gas from landfills into the atmosphere.

Gas appears to be transported mainly horizontally at landfills, under the compacted layers, following the paths of highest permeability until the gas eventually finds its way into the atmosphere, generally through fissures and cracks. The rate of emission depends on several factors like the humidity in the topsoil, as well as the temperature and the atmospheric pressure (O'Leary and Walsh, 2002). It has been observed that slopes present higher rates of leakage (Ljungberg et al., 2008); because of settlement and more difficult compaction, cracks easily open there.

Resistivity has been widely used at landfills for various purposes like mapping landfill cover (e.g. Leroux et al. 2007), detecting and mapping pollution plumes (e.g. Rosqvist et al. 2003), and to follow the spreading of leakage water in several experiments of leachate recirculation to accelerate biodegradation at bioreactors (e.g. Rosqvist et al, 2007). In these experiments growing resistive anomalies were observed at the same time as the moisture spread, and the presence and accumulation of gas was one plausible explanation for them. In that case, resistivity could be used for detecting and localizing landfill gas. Experiments were then conducted at Filborna landfill in Helsingborg to confirm this assumption, which had been tested in an earlier study (Dahlin et al., 2008).

The electrical resistivity of soil materials generally depends on the moisture content, on the temperature, on the porosity, on the pore water salinity. A higher resistivity is probably a necessary indicator of the presence of gas, but high resistivity may have causes as well.

As a consequence of the expected sequential nature of the release of gas in the atmosphere, we expect that zones where the landfill gas concentration is high will signal themselves by large variations in resistivity. It is also expected that the variations in resistivity will be related to soil temperature and moisture as well as to atmospheric conditions: that is to the rate of gas emission, even if they might not be well correlated to gas emissions in a spatial sense.

Method

In each of the two experiments described below resistivity monitoring was carried out along nine parallel lines with the ABEM Lund Imaging multi-electrode System. The sites were monitored successively, each during 2 months with a remote-controlled system. The time for the 50% duty injection cycle was 1s, sufficiently short to make it possible to measure all the lines within less than 2 hours, but sufficiently long to make it possible to correct for charge-up and polarisation effects, that are notoriously important at landfills (Carlson et al. 1999; Leroux et al.2007). All data for each complete set of measurements were inverted together, but separately for each measuring occurrence using Res3Dinv, and a true 3D-model was computed for each time, using the same parameters and the same geometry..

The first experiment comprised measurements on a bioreactor landfill with plastic cover (BCR1) in May-June 2008. Temperature and salinity were measured in two nearby groundwater wells. The bioreactor landfill is filled with homogeneous moulded and mixed material and is equipped with a system of watering pipes, used in the first year but now only occasionally.

In the second experiment measurements were made on the Filborna landfill site in July-August 2008. The test site was covered with older, now inert waste, which was removed for the purpose of the experiment. Gas samples were collected in six gas collecting chambers under two weeks, several times a day, along with soil temperature to estimate the flux of emissions and their variations. Methane concentration was measured in the air at the end of the experiment. The moisture in the top layer was estimated punctually with a few TDR probes.

On each site, the weather was recorded locally and the pore pressure was measured in two points, and there is a system of vertical and horizontal pipes that collects the biogas.

Results

Resistivity

The measurements analysed for the first site were taken during a very sunny and dry week, and the results presented for the second site were taken during a week with constant rainy weather, both during summer.

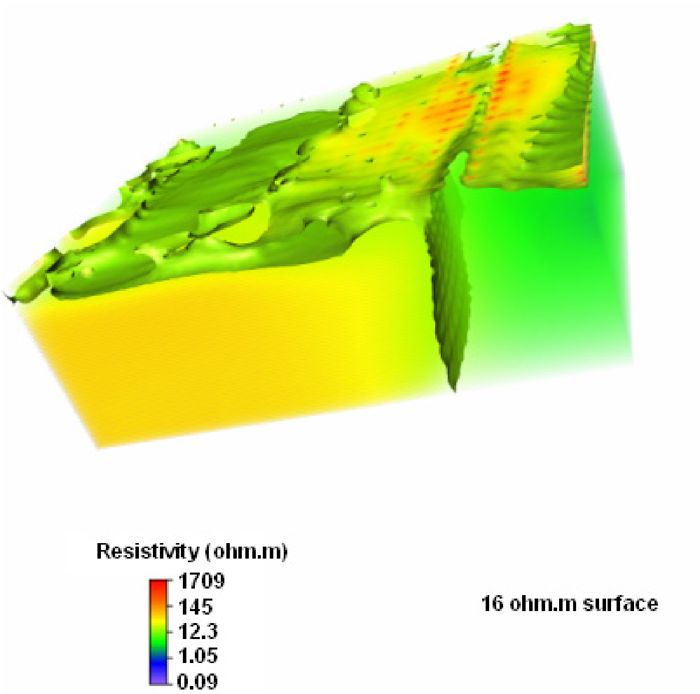

Figure 1. View of resistivity at Filborna landfill test site 18 August 2008 10:00 – 12:00.

The resistivity structure of both test sites was relatively stable in its overall appearance, but the resistivity values were highly variable at both sites, see example from Filborna landfill in Figure 1. Known built structures inside the waste are clearly visible at both test sites, like for example a compost ridge (see Figure 1). The highest rates of variations were observed over well-delimited zones, in relation to the known existing structures.

In the example from in Figure2 there is a distinct band of large variation that follows the extension of the compost ridge, and there are some isolated spots with large variation at shallow depths. The large variations recorded at the ridge are interpreted as being caused by variations in gas concentration in the ground, as it is difficult to explain by the sole influence of soil moisture due to precipitation and drying, or temperature. The compost ridge is also expected to be active in terms of gas production and transmission since it contains organic matter and is likely to be relatively transmissive. The soil temperature was also higher there.

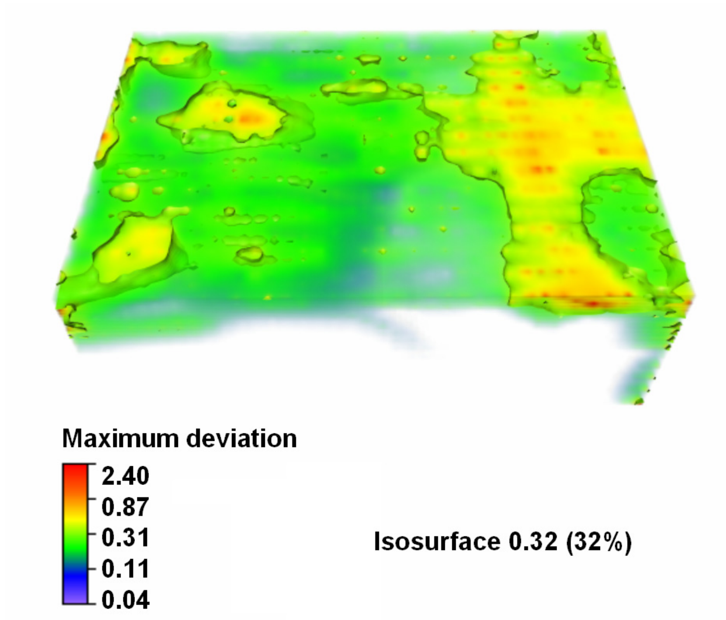

Figure 2. **Relative variation at Filborna landfill test site 18 – 22 August 2008.**

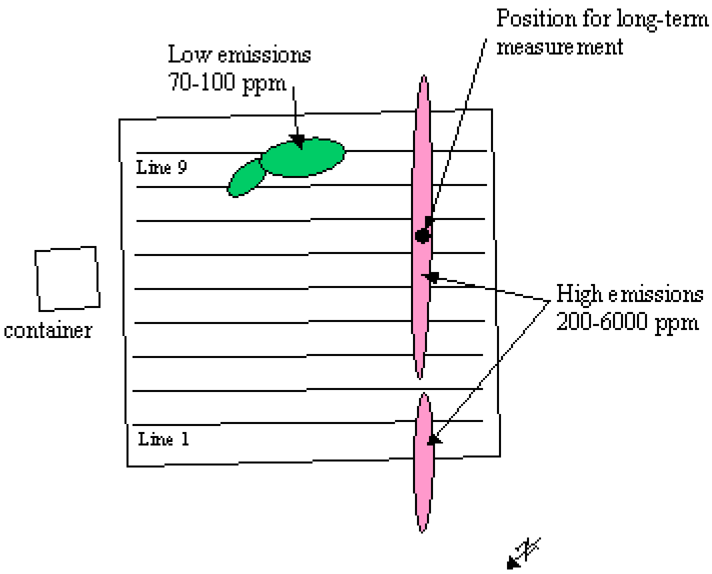

Figure 3. **Laser scanning results for NSR2 test site (the orientation is the same on the previous figures, with the container placed left to the lines).**

<u>Correlation with other data</u>

Laser scanning results showed high levels of gas emission along the compost ridge (Figure **3**), and emissions at lower levels in two spots at the test area. Locations of elevated gas flux measured with the laser method thus correspond well with the zones where high variability in resistivity was recorded. Correlation with gas emission measurements has, however, generally been difficult, which is not surprising. Laser measurement of methane concentration in the air is difficult, where a drawback with the method is its sensitivity to wind velocity. Furthermore, methane is a light gas quickly mixing when rising into the atmosphere. Gas flux measurements with static chambers confirmed high emissions at the compost ridge.

Conclusions

Relatively resistive as well as conductive structures were identified, that could, in most cases, be related to known existing structures inside the landfills, such as ditches, compost walls, pipes or clay layers. Large temporal variations in the measured and interpreted resistivity were observed at shallow depths. At bioreactor landfill and Filborna landfill, the most important variations seem to be observed in the most resistive structures. It is likely that large variations in resistivity are related to gas migration, since higher or lower gas content modifies the temperature, the moisture content, the pore pressure and possibly the chemical composition in the material. We have not been able to devise any other explanation for the large observed variations in resistivity, but the relationship between gas contents and resistivity appears to be complex and site-dependent. However, given a good combination of information, it appears to be possible to image migration of gas inside a landfill.

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