Potential of geoelectrical resistivity methods for localizing gas at landfills

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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 (see e.g. Svensson et al.), detecting and mapping pollution plumes (see e.g. Rosqvist et al.), and to follow the spreading of leakage water in several experiments of leachate recirculation to accelerate biodegradation at bioreactors (e.g. Rosqvist et al, 2005, 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.

Three experiments were then conducted at Filborna landfill in Helsingborg to test this assumption.

Experiments: resistivity monitoring and relation to gas emissions, weather data and soil moisture.

Resistivity: depends on several parameters

The electrical resistivity of soil materials generally depends on the moisture content, on the temperature, on the porosity, on the pore water salinity. One can simply refer to Archie's law (1942), which is maybe not the most well-suited for clayey landfill material but is well-known and clearly illustrates the difficulty of discriminating the different parameters' influence on resistivity. That means that a higher resistivity is probably in most cases a necessary indicator of the presence of gas, but that it is in general not sufficient.

As a consequence of the expected sequential nature of the release of gas in the atmosphere, we expect that the 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.

Experiment of december 2007

Eleven parallel resistivity lines have been measured seven times with time intervals varying between 6 hours and a week. On the same area, gas concentration has been measured with laser and the flux has been estimated with 6 gas collecting chambers.

Measurements on BCR1 (bioreactor with plastic cover) in May-June 2008

Nine parallel resistivity lines have been monitored under nearly two months with a remote controlled system. The weather has been recorded locally at the same time. Temperature and salinity have been measured in two nearby groundwater wells and the pore pressure has been measured on two points.

Measurements on ”Filbornadeponi” in July-August 2008

Nine parallel resistivity lines have been monitored under nearly two months with a remote controlled system. The weather has been recorded locally. Gas samples were collected in six gas collecting chambers under two separate weeks, several times a day, together with the soil temperature to estimate the flux of the emissions and their variations. Methane concentration was measured in the air at the end of the experiment, and pore pressure was measured in two points there also. The moisture in the top layer was estimated punctually with a few TDR probes.

Results:

All resistivity measurements were acquired using the ABEM-Lund imaging system and processed with Res3Dinv (see www.geoelectrical.com for information). In all three cases very large variations in resistivity have been observed that are not likely explained by the sole influence of soil moisture (due to atmospheric precipitations) or temperature. We have then interpreted them as due to the presence of gas. However, some influence of the inversion method is not completely excluded, since no time-lapse inversion is implemented in Res3Dinv yet.

The correlation with gas emissions has been difficult, but it is not completely unexpected. Flux measurements with gas collecting chambers are very localized, both in time and space, and cannot cover the whole area. Measurements of methane concentration in the air with laser is often difficult, since the method is sensitive to wind velocity and methane is a light gas quickly mixing and raising in the atmosphere. It is therefore not completely contradictory that the resistivity measured under the ground surface, the emissions on the ground and the concentrations in the air should not exactly match each other in a spatial sense.

The full results of the study are not yet available at the time of writing, but the use of resistivity seems promising in that application, provided it is complemented by a few other measurement like (e.g.) temperature and moisture.

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Rosqvist et al. (2008) this workshop / Svensson et al (2008) this workshop.