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Electrical Flow Paths and the Application of the Resistivity Method to the Evaluation of Landfill's Lining Systems

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Summary

Results from two ERT performed on an empty small-scale pilot plant are presented illustrating the electrical current pathways in the presence of a conductive layer electrically insulated and partially insulated from the surrounding environment by a geomembrane. An ERT acquired on an operating cell of a real landfill where electrical connection is present between the inner medium (leachate, waste and covering soil) and the outside environment is also presented. Both results draw attention to the need of considering the slope of cell walls when interpreting ERT models from a survey performed on an operating landfill, since it is possible that the conductive bottom layers couldn't be related with a hole or other sort of defect on the geomembrane, which could facilitate the environment contamination, but with the deviated electrical pathways through waste and leachate. In this case a good topographical mapping before and after the cell's exploration is a key factor.

Introduction

As it is well known electrical current only flows through electrical conducting materials each with its own electrical resistivity. The higher conducting is the material the lower is its corresponding electrical resistivity. Since leachate resulting from the degradation of waste is rich in ions it has a low electrical resistivity thus contrasting with that of the surrounding environment. So, electrical resistivity is a powerful tool to investigate environment problems related with leachate identification that escapes from landfills.

Landfills are engineering facilities, composed by one or more cells, designed and constructed with a barrier system (lining system) which objective is to assure the protection of the environment. This system includes active and passive barriers (Mota et al. 2011). The active barrier includes, among other materials, a geomembrane. The effectiveness of lining systems in service conditions depends, above all, of the performance of the geomembrane. A critical issue on their performance is the defects, which, unfortunately, seems to be unavoidable, especially in the construction phase (Peggs 1996, Nosko and Touze-Foltz 2000; Rollin et al. 2002; Rollin et al. 2004; Peggs and Wallance 2008). Since geomembrane is an insulator material to electrical current transmission, several methods were developed based on this feature to evaluate the integrity of the geomembrane after the construction phase (see, for example, ASTM D7007 and Mota et al 2013). The basic principle is very simple: if there is a hole, electrical current flows between inside and outside the theoretically insulated cell. When the landfill is on its exploration phase, or after cell closing, it is difficult, if not impossible, evaluating the integrity of the geomembrane, when some signs of leachate is identifiable on the surrounding environment.

In the present paper, results from two Electrical Resistivity Tomographies (ERT) performed on an empty small-scale pilot plant are presented. Data gathered on an operating cell of a real landfill are also presented. Both results have the goal of drawing attention to the need of considering the slope of cell walls when interpreting ERT models from a survey performed on an operating landfill.

Material and methods

In the aim of a research project a set of three cells of approximately 10m×10m×1m was constructed at LNEC's campus. Figure 1 presents an overview of cells construction. Each cell was designed taking into account the lining systems typically used in different landfills in Portugal. For the present work only the central cell (Figure 1) was used. The cells include several layers, of both soils and geosynthetics, having the central one the following characteristics, from bottom to top:

- 0.5 m thick layer of compacted clayey soil as passive barrier;
- geomembrane as active barrier (HDPE, 2 mm thick);
- geotextile to protect the geomembrane against puncturing (polypropylene, 300 $g.m^{-2}$);
- 0.2 m thick layer of sand (0.18/2.0 mm), to simulate the drainage layer.

***Figure 1** Pilot cells construction at LNEC's campus. Right photo – detail of drainage layer (sand) installation.*

When evaluating the efficacy of the developed equipment (see Mota et al. 2013 and Barroso et al. 2013) several holes, on different stages, were performed on each cell. Presently, central cell has two holes. The resulting electrical potential map is presented on Figure 2.

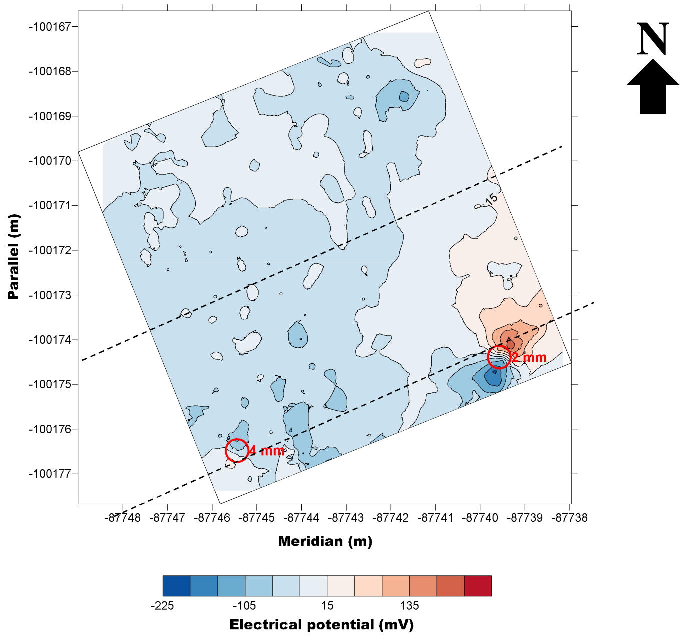

***Figure 2** Electrical potential map of central cell as a result from the survey performed with Geosave equipment (Mota et al. 2013 and Barroso et al. 2013). Dash black lines mark both ERT positioning performed to for the present work.*

To illustrate the electrical current pathways and the resulting resistivity profiles on a site insulated with a geomembrane two profiles were performed crossing the central cell of LNEC's pilot plant. One profile was performed crossing by the middle of the cell and the second one was executed passing over both holes (see Figure 2). The survey was performed with an ABEM SAS4000 resistivity meter equipped with a Lund system. Both profiles were gathered with 41 electrodes in a Wenner configuration with 0.5 m of dipole distance for a total acquisition line of 20 m, in order to have several dipoles outside both edges of the cell. The only electrical connection between inside and outside the cell was through both holes performed on the geomembrane.

On a real landfill cell, already closed (filled with waste and leachate) but without a covering geomembrane on its top, a set of profiles were gathered using both dipole-dipole and Wenner configurations. One of them, acquired with dipole-dipole configuration near the edge of the cell, and parallel to one of cell's slope, is used to illustrate the results on a real environment. In this case there was an electrical connection between outside and inside the cell through the covering soil. Figure 3 tries to illustrate the expected relative positioning of both the ERT and the geomembrane, if the electrical pathway could pass through the geomembrane in order to be arranged in a 2D ''pseudo-section'' plot (Edwards, 1977).

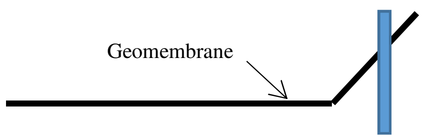

***Figure 3** Cross-section scheme (view from the beginning of the profile to its end) of the relative positioning of the ERT (vertical blue line) and the closed cell bottom geomembrane.*

ERT models were produced with version 3.55 of Res2dinv software.

Results and discussion

ERTs performed on LNEC's pilot plant are presented on Figure 4. From the observation of the results the following features can be highlighted: very high resistivity below the geomembrane and a deeper conductive layer on the profile acquired over the holes, due the electrical connection between the covering sand and the soil bellow the geomembrane.

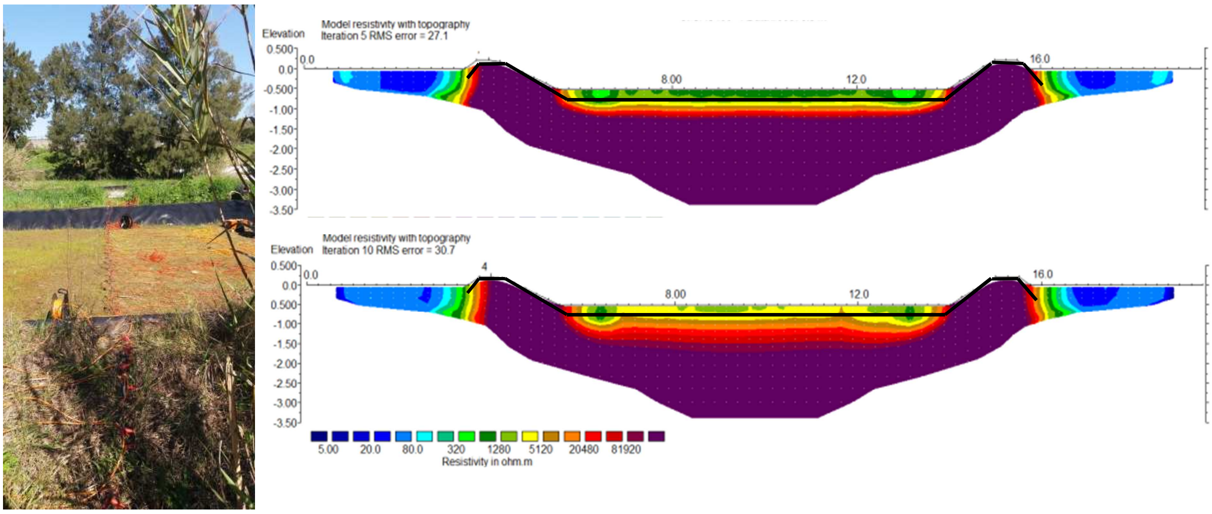

Figure 4 *Left – view from SW to NE of profile performed by the cell's centre. Right Top – ERT crossing the cell's centre; Right down – ERT crossing the holes.*

Figure 5 illustrates the ERT acquired on the real cell. It was expected that the high values of resistivity present on the left, approximately until x=50 m, would be present along all the profile. Due to the presence of the waste and of the leachate electrical pathways were distorted and the real positioning of the cross-section is that approximately represented on Figure 6.

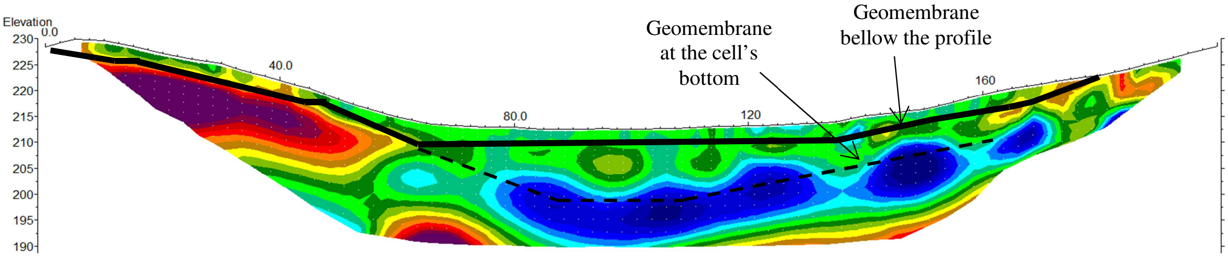

Figure 5 *ERT acquired with dipole-dipole configuration on the edge of a closed cell.*

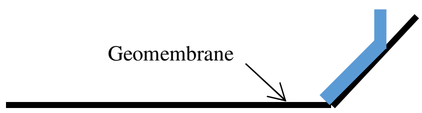

Figure 6 *Cross-section scheme (view from the beginning of the profile to its end) of the real representation of the ERT (blue line) and the closed cell bottom geomembrane.*

Conclusions

Results from two ERT performed on an empty small-scale pilot plant were presented illustrating the electrical current pathways in the presence of a conductive layer electrically insulated and partially insulated from the surrounding environment by a geomembrane. An ERT acquired on an operating cell of a real landfill where electrical connection is present between the inner medium (leachate, waste and covering soil) and the outside environment was presented. Both results draw attention to the need of considering the slope of cell walls when interpreting ERT models from a survey performed on an operating landfill, since it is possible that the conductive bottom layers couldn't be related with a hole or other sort of defect on the geomembrane, which could facilitate the environment contamination, but with the deviated electrical pathways through waste and leachate. In this case a good topographical mapping before and after the cell's exploration is a key factor.

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