DETECTION OF LEACHATE POCKETS IN EXPERIMENTAL CELL OF MUNICIPAL SOLID WASTE WITH AID OF GEOPHYSICS

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DETECTION OF LEACHATE POCKETS IN EXPERIMENTAL CELL OF MUNICIPAL SOLID WASTE WITH AID OF GEOPHYSICS

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SUMMARY: Some geophysical methods have been used to detect and monitor the contamination generated by percolated liquids from industrial and urban waste disposal, being one of them the Electrical Resistivity (ER) method. This method was applied in an experimental cell constructed on a municipal sanitary landfill, located in the city of Campinas, state of São Paulo, Brazil, in order to detect leachate concentration zones within the waste mass. The leachate levels measured within 5 piezometers installed in the experimental cell during the period of 2 ½ years were used to aid the interpretation of the geophysical tests. On the surface of the experimental cell, 6 dipole-dipole profile lines with 5 meters spacing and 10 investigation levels were performed, covering the entire cell area, including piezometers. The results interpreted in some profiles indicated areas with low resistivity (<10 ohm.m), which suggested the presence of leachate concentration zones, close to piezometers with leachate levels at about 1.4m to 2.8m. Where the level of leachate was zero, the interpreted results did not indicate these zones of concentration. In addition, the ER method was able to detect a high resistivity range, below the leachate concentration zones, represented by the high-density polyethylene (HDPE) geomembrane, installed at the base of the cell.

1. INTRODUCTION

The significant increase in the world population has generated great impacts and challenges for the next generations, being the production and disposal of solid wastes some of them. The generation of this waste in the world is around 12 billion tons / year and, in 2020, the estimated volume is 18 billion tons / year (UNEP-EEA, 2007).

The experimental cells have been used in research to analyze the hydro-geotechnical behavior and the biodegradation of municipal solid waste (MSW). These cells must have

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minimum dimensions to avoid interference of environmental conditions in biological processes and to represent the composition, heterogeneity and particle-sizes of the MSW.

Geophysical tests are auxiliary tools that aid in the investigation of subsurface materials. Applied geophysics consists of a set of methods and techniques widely used in environmental studies. It is important to highlight the geoelectric methods are known as non-invasive, since they do not affect and do not destroy the underground (Atekwana et al., 2000; Sauck, 2000; Stanton & Schrader, 2001 and Soupios et al., 2007).

Some geophysical methods have been used to detect and monitor the contamination generated by percolated liquids from industrial and urban waste disposal. Due to the chemical characteristics of these wastes, which are usually reflected in changes in the electrical conductivity at the place where they are disposed, geoelectrical methods are mainly used with good results (Benson et al., 1982). The application of these geoelectric methods in studies related to soil and groundwater contamination is widely reported in the literature (Hyoung-Soo & Yeonghwa, 1997 and Meju, 2000).

The geoelectric methods use direct currents or alternating low frequency currents to investigate the electrical properties of subsurface. Among these methods can be highlighted the methods of electrical resistivity, induced polarization and spontaneous potential. The first method is used in the study of horizontal and vertical discontinuities in the electrical properties of the soil and also in the detection of three-dimensional bodies of anomalous electrical conductivity (Kearey et al., 2002).

The electrical resistivity method allows several techniques for the execution of the tests, such as the vertical electrical sounding (VES) and electrical profiling (EP) techniques, in which a wide variety of possible electrode configurations exist, what makes it a very versatile method. With the data obtained through the VEs, it is possible to investigate the subsurface vertically. When the objective is to observe the lateral variation of resistivity, the EP is used, which data make possible to obtain images of the subsoil in depth and laterally (2D imaging).

However, few studies have attempted to determine the relationship between electrical resistivity, biological and physical chemical processes, and their relationship with the production of leachate and biogas in landfills (Georgaki et al., 2008).

Leachate plumes formed by municipal solid waste usually present high salt ion concentrations, such as chloride and sulphide. High salinity concentration shows very low electrical resistivity values (1-10 ohm.m). In the other hand, geomembrane are made of electrical insulating materials.

In this study, the leachate levels within an experimental cell and the interpretation of geoelectrical tests, using the electro-resistivity method, performed in this same cell, are presented and analyzed simultaneously with the objective of evaluating the concentration zones of leachate within the mass of wastes in the monitoring period from 2013 to 2014.

2. THEORETICAL FOUNDATION

The method of eletrical resistivity aims to make measurements of electrical resistivity, the physical property of materials that can be understood as the greater or lesser facility of a material to propagate an electric current. The resistivity parameter depends basically on the nature and physical state of the material, factors such as texture, shape and distribution of pores in the soil and rock, as well as the presence of liquids and gases in these pores make the resistivity of geological materials (Milson, 2003).

Based on Ohm's Law, the electrical resistivity method is first defined by the electrical resistivitance (R) measured in Ohm, in a ratio between the intensity of the electric current (I) flowing through a material (measured in amperes) and the necessary voltage (V) to propagate it (measured in volts) (Equation 1).

$$V = R.I \qquad \text{(Equation 1)}$$

The value of the electrical resistance (R) varies according to the dimensions of the material such as length (L) and cross-sectional area (A), values measured in meters, and thus, the electrical resistivity value (ρ) can be acquired by means of Equation 2.

$$\rho = \mathrm{R}\left[\frac{A}{\mathrm{L}}\right] \qquad \text{(Equation 2)}$$

In homogeneous media the obtained value represents the true resistivity of the medium. However, the geological environment is composed of heterogeneities and therefore the resistivity measures in this case represent a weighted average of true resistivities, whose calculated product is called apparent resistivity (ρ_a) (Equation 3).

$$\rho_a = \mathrm{K}\left[\frac{\Delta v}{\mathrm{I}}\right] \qquad \text{(Equation 3)}$$

The setting of the current and potential electrodes is called arrangement and defines the geometric factor (K), measured in meters, in the determining of resistivity. Therefore, the objective of generating and measuring an electric potential field is to determine the spacial distribution of ρ_a (Ω.m) in the subsurface (Vogelsang, 1995).

The acquisition of electrical resistivity data is based on the introduction of an electric current in the subsoil at different depths of investigation by two electrodes, called A and B, to measure the potential generated in two other electrodes called M and N (Figure 1) .

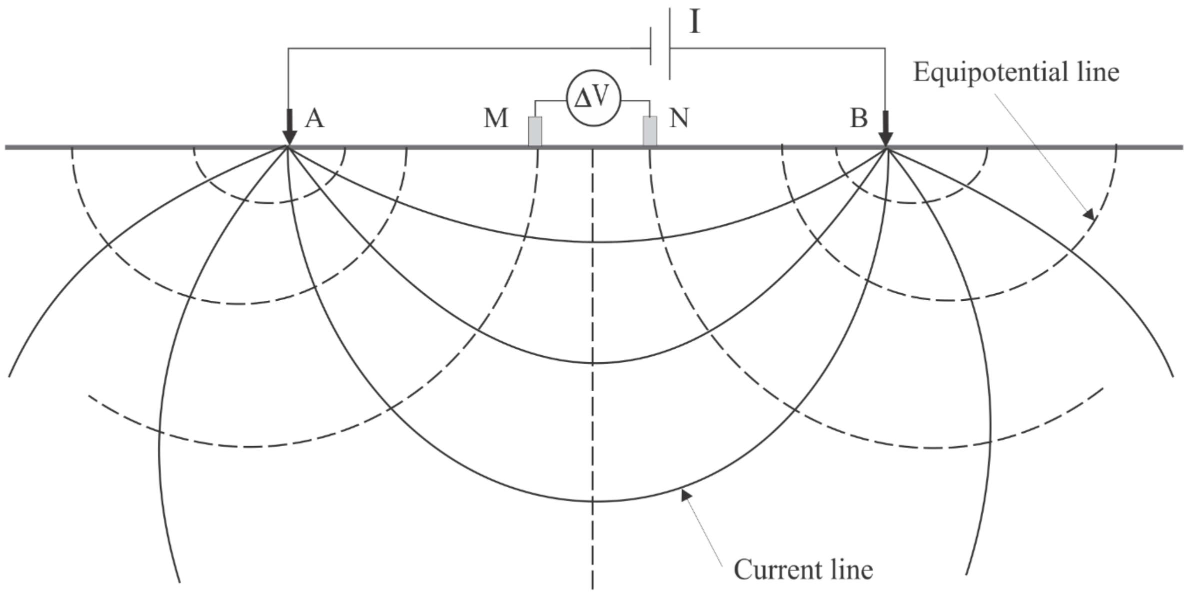

Figure 1. Field acquisition of resistivty data. Modified from Telford et. al., 1990.

3. STUDY AREA

The experimental cell studied in this research was built on the Delta A, a municipal landfill, located in the city of Campinas, southeast region of Brazil, with a population of approximately 1,080,000 inhabitants spread over an area of 795,000 km^2.

This experimental cell has a useful height of 5.0m MSW, occupies an area of 5,080m^2 and has liner system, leachate and gas drainage systems and cover system (Figure 2).

The liner system consists of a 50 cm thick mineral layer (clayed silt compacted) under a 1.0 mm thick the high-density polyethylene (HDPE) geomembrane and a nonwoven geotextile (300 g/m^2) and a 10 cm thick protective soil layer. During the execution of the mineral layer, a central channel (2 m wide and 30 cm deep) was constructed, sloping 1.5% and diagonally of the cell, to assist the drainage of the leachate to the outside of the experimental cell. The geomembrane, geotextile and the layer of protection soil also cover this channel.

The leachate drainage system consists of a 30 cm thick stone layer on the protective soil, arranged in the area of the cell including the central channel. The slope of this stone layer is 1.5% towards the central channel.

In addition, the experimental cell is instrumented with five piezometers (LL1, LL2, LL3, LL4 and LL5), forty surface benchmarks and five settling plates supported at its base. Details on the construction of this experimental cell can be seen in Benatti et al (2013).

The location of the piezometers as well as their locations in relation to the leachate central drainage channel are shown in Figure 3.

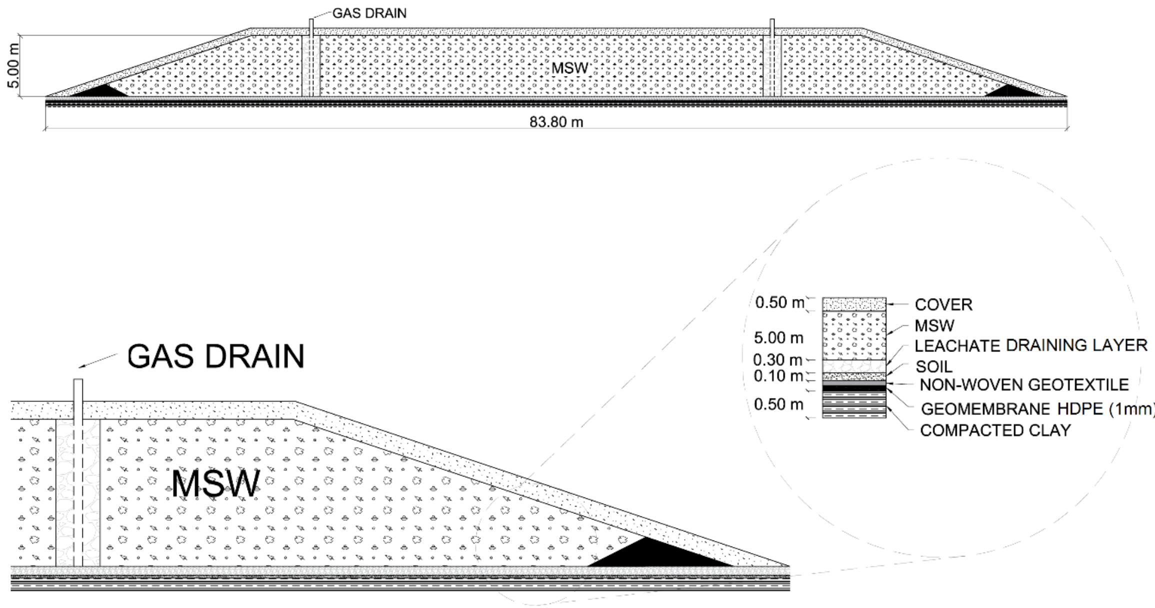

Figure 2. Cut and detail of the experimental cell

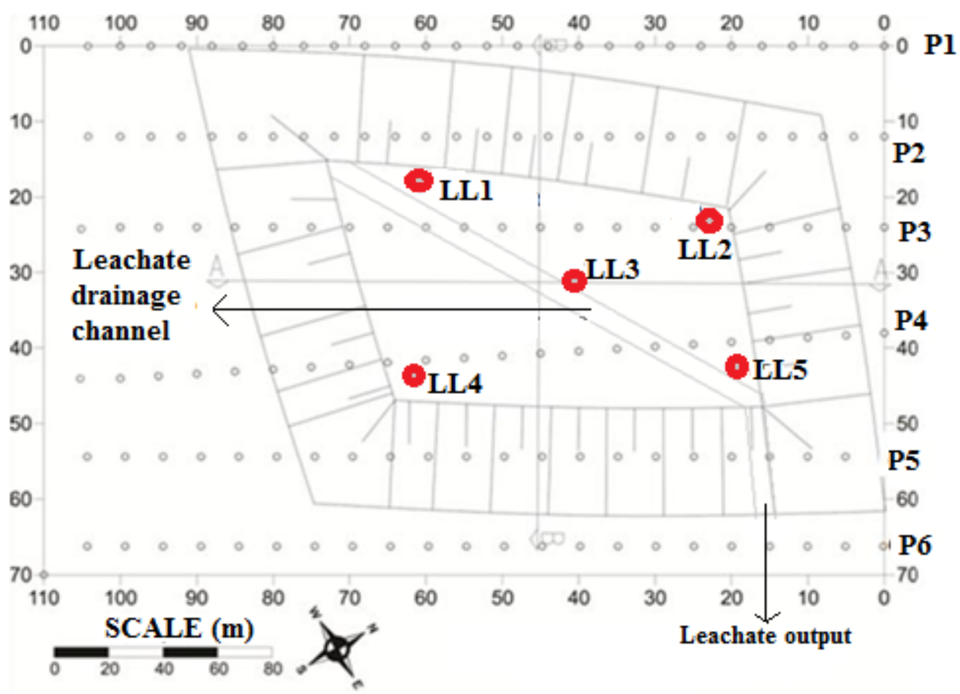

Figure 3. Location of piezometers of the experimental cell

4. METHODS

Monitoring of leachate level within the cell was done monthly by the five piezometers installed using Sonlist® equipment for level measurement, electrical conductivity and temperature. The equipment is inserted inside the tube of the piezometer until reaching its bottom, that is, in contact with the stone layer. Throughout the data collection procedure the equipment is connected to a computer via a USB cable, where the data is transmitted in real time. The occurrence of the end of the data collection of each point is considered when the data reading is stabilized, meaning that at least 3 consecutive data have the same values of temperature, conductivity and piezometric level.

The tests with the electrical resistivity (ER) method were performed between the first semester of 2013 and the second half of 2014. Six ER profiles with dipole-dipole array (5 m spacing and ten investigation levels) were performed. The ER profiles were named P1, P2, P3, P4, P5 and P6, as shown in Figure 3. Profiles P3 and P4 passed through the piezometers LL2 and LL4, respectively.

Accorfing to Telford et. al. (1990), in the dipole dipole array, the current and the potential electrodes are separated by a fixed distance "a". The dipoles are displaced by an increasing distance "na" in order to investigate deeper levels (Figure 4).

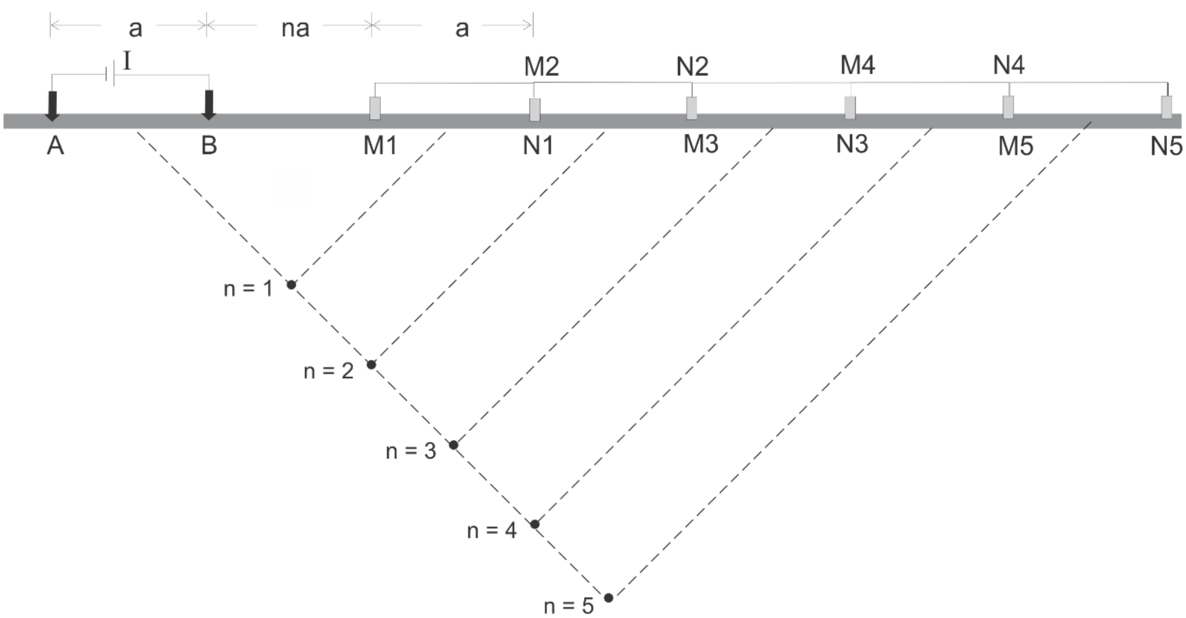

Figure 4. Dipole dipole array.

5. RESULTS AND DISCUSSION

The results of the monitoring of the leachate levels performed in the esperimental cell in the period from 2012 to 2015 are presented in Figure 5, as well as the on-site precipitation data, however, in the period from 2014 to 2015.

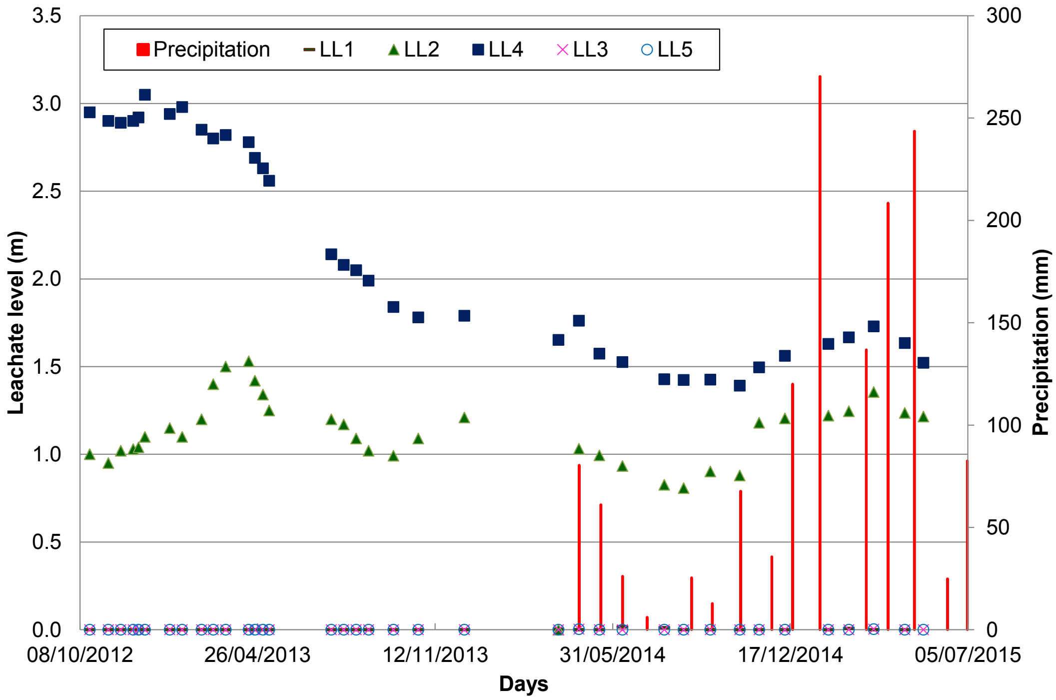

Figure 5. Variation of leachate level in the piezometers and precipitation

The piezometers located in the central drainage channel LL1, LL3 and LL5 did not present a piezometric level, regardless of the variation in the amount of rainfall, which suggests that the drainage of the leachate through the channel has been efficient (Figure 5).

At LL2 and LL4, just after the beginning of the collection of piezometric levels of the experimental cell, October 08, 2012, leachate levels were close to 3.0m for LL2 and 1.0m for LL4, decreasing over time, but varying around 1.4m and 2.8m, depending on the precipitation variation, as observed in Figure 5.

The interpreted results of ER profiles P3 e P4 are presented in Figure 6, where it is possible to identify the geomembrane (resistivity values > 500 ohm.m) and the mass of the waste (10 to 75 ohm.m).

The geomembrane does not show its real shape and resistivity because the electric current does not pass through the insulant material. Zones with very low resistivity (< 10 ohm.m) suggest the presence of leachate accumulation. In the profiles P3 and P4, which are close to the piezometers LL2 and LL4 (Figure 3), were observed these zones, interpreted as leachate pockets.

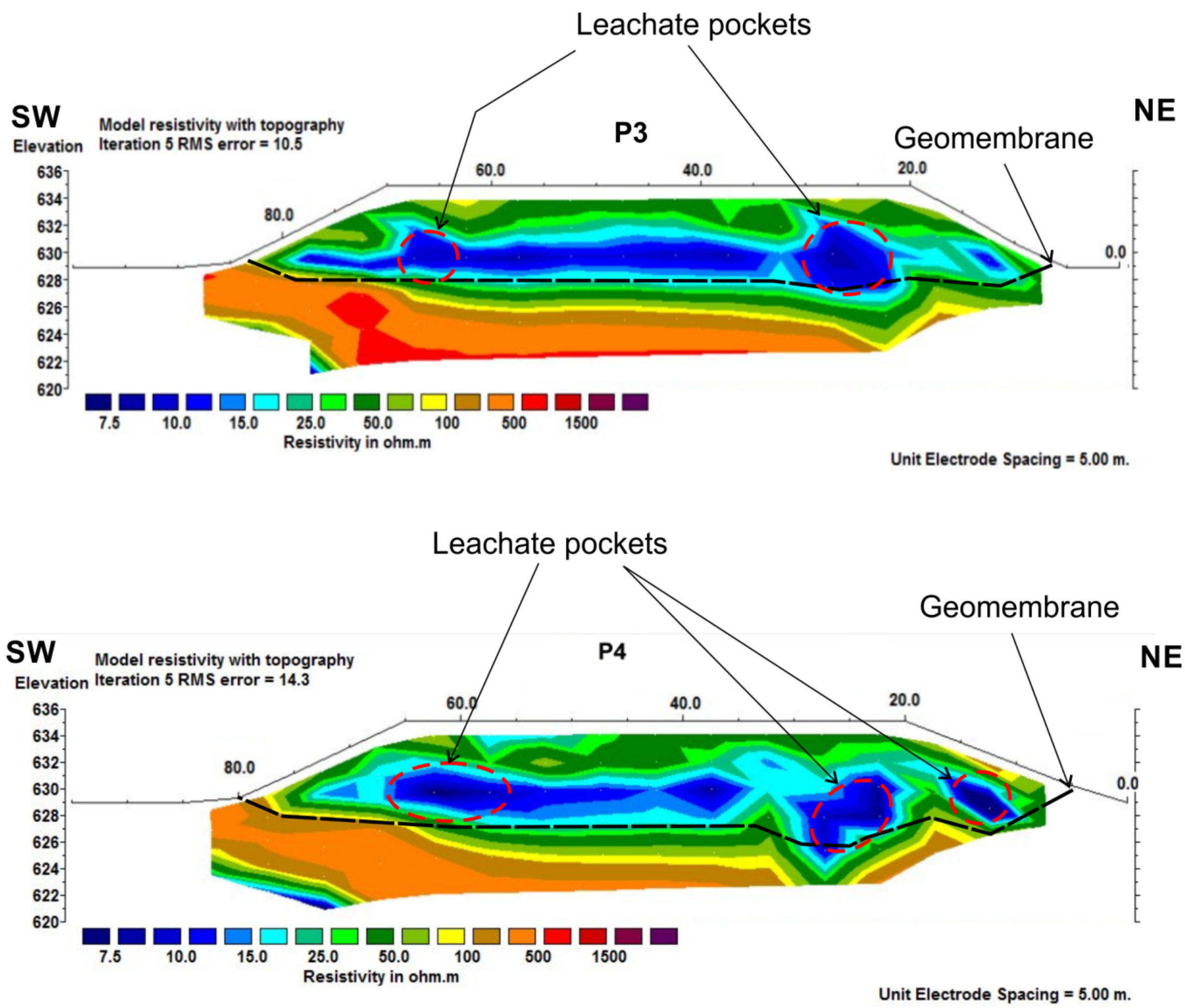

Figure 6. Apparent resistivity profile (ohm.m) of profile 3 (P3) and 4 (P4)

In the P3 profile (Figure 6), the presence of two pockets of leachate is noted. The first pocket approximately 7.5 m in length is closest to the piezometer LL2 (Figure 3), where a leachate level was measured around 1.4 m. The second pocket is located near the drainage channel (Figure 4) and is approximately 5.0 m long.

In the P4 profile three pockets of leachate were identified (Figure 6). The first two pockets are located near the beginning of the profile, each one being less than 5 m in length. These pockets are close to the LL5 piezometer and also to the drainage channel (Figure 3). In turn the third pocket is at the end of the profile, close to the LL4 piezometer and it is approximately 10 m long.

Profile P4 is distant about 3 m from piezometer LL5, which did not detect leachate level, because the leachate is being directed to the central drainage channel.

With the use of the electrical resistity method in the experimental cell, besides confirming the presence of pockets and being possible to compare them with the leachate levels read in the installed piezometers, the method allowed to dimension these pockets, avoiding the installation of new piezometers around.

6. CONCLUSION

The electrical resistivity tests, performed in an experimental cell of municipal solid waste, allowed the identification of zones of concentration of leachate within the waste mass and the resistive layer the (HDPE geomembrane). Some areas of very low resistivity were detected, suggesting that they represented these zones of concentration of leachate and confirming what indicated the readings of level performed within piezometers installed in the cell. Thus, it was possible to locate these zones and size them using a good resolution and not evasive method.

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