



The Self-Potential (SP) method applied for investigating the contamination in the vicinity of the Estrutural city landfill, in Brasilia-DF.

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Abstract

This paper presents the self-potential (SP) method results and the comparison of this results with electrical resistivity data in delineation of potentially impacted areas by leachate flow from Jockey Club Landfill, located at Estrutural City, Brasília-DF. The survey was made at the south part of landfill boundary, near of Brasilia National Park. The probable leachate plume is prolonged to out of landfill boundaries and, in general, those plumes have the same directions of the groundwater flow. The SP method application aims to infer the subsurface leachate flow direction. The results obtained showed a good correlation with electrical resistivity data. The self-potential method has proved to be an important tool for assessing the environmental quality in Landfills.

Introduction

It is estimated that Brazil produces about 240 tons of waste daily in their cities. It is waste in solid state from industrial activities, domestic, hospital, commercial, agricultural and service sweeping and included sludge treatment systems water, liquids with hazardous characteristics making it impossible to launch the public sewers or water bodies (ABNT, 1987). In most cases, the residues are buried in landfills.

When the rain's water percolates between the mass of buried waste, which are in decomposition, a fraction of the biological materials and the chemical constituents is loaded into the solution (HAMADA, 1997). As a result of this process arises the leachate: a dark liquid and acid that contains high concentrations of organic and inorganic compounds. This liquid may contain high concentrations of heavy metals such as cadmium (Cd), Lead (Pb), copper (Cu), chromium (Cr), manganese (Mn), Mercury (Hg), zinc (Zn), and organics compounds metabolized by biological action.

In areas close to landfill sites, the risk of soil and groundwater contamination is permanent. This risk prompted the local government to adopt a series of measures to try to combat the harmful effects of wrong deposition of urban solid waste. In the management of contaminated areas, the geophysical is the best non-invasive method to monitoring the leachate flow from landfills. Among the geophysical methods applied to environmental survey there is the Self-Potential (SP).

Self-potential geophysical surveys measure the difference in potential between any two points on the ground produced by small, naturally currents that occur beneath the Earth's surface. The SP method is passive, non-intrusive and does not require the application of an electric current. Small potentials of order of a few millivolts are produced by two electrolytic solutions of differing concentrations that are in direct contact, and by the flow of electrolytic fluids through porous materials. SP anomalies are generated by flows of fluid, heat, ions in the earth, so SP investigations have been used to help locate and delineate sources associated with such flows (CORWIN, 1990). In the case of environmental studies, the main application of the SP method is to determine the sense of the groundwater flow (GALLAS, 2005).

The most common mechanisms that originate SP anomalies are potential generated by the flow of fluids in the porous space ("streaming potential"), diffusion potential, potential membrane due to the effect of clays ("shale potential") and the potential due to the presence of conductors (GALLAS *et al.*, 2000).

Different types and/or dissolved ions concentrations in the water's porous space rise up the subsurface's diffusion potential. Ions with different polarities have different mobilities and thus occur a difference in the diffusion rate (GALLAS, 2005). This dynamic makes a formation of ions concentrations with opposite signs, thereby generating a potential difference in the soil, which can be expressed as follows:

$$\Delta V = \frac{u - v RT}{u + v n F} \ln \frac{C_1}{C_2} \quad (1)$$

Which:

u,v = mobility of cations and anions, respectively;

n = valence of the ions;

$R = 8,314 \text{ joules/mol.K}$;
 $T = \text{absolute temperature}$;
 $F = 96.487 \text{ Coulombs/mol (Faraday's constant)}$;
 $C_1, C_2 = \text{electrolytes concentration in contact}$.

Streaming potential is due to the water flow containing dissolved solutes with certain electrical properties passing through the medium porous with different electrical properties (WIGHTMAN *et al.*, 2003). The clay fraction of the soil, which consists of mineral clay particles less than $2 \mu\text{m}$ in diameter, has an unbalanced negative electrical charge at the surface. Electrostatic attraction exists between the clay particles surface, the polar soil-water molecules, and solutes dissolved in the soil water. So, this negative charge is balanced by positively charged cations that are attracted to the surface of clay minerals (FETTER, 1993).

When the solute enters in the porous space channel, its anions are attracted by the porous space walls. Those, in turn, attract cations, forming an electrostatic double layer. Figure 1 illustrates that dynamic.

The passage of this solute through paths in the porous spaces produces a potential difference at the ends (GALLAS, 2005). The potential difference between the beginning and the end points of this path can be represented by the following equation:

$$\Delta V = \frac{dP\varepsilon}{n\sigma} \quad (2)$$

Which:

- $d = \text{electrostatic double layer potential difference}$;
- $\varepsilon = \text{dielectric constant}$;
- $\sigma = \text{conductivity}$;
- $n = \text{solute viscosity}$;
- $P = \text{hydrostatic pressure difference}$;

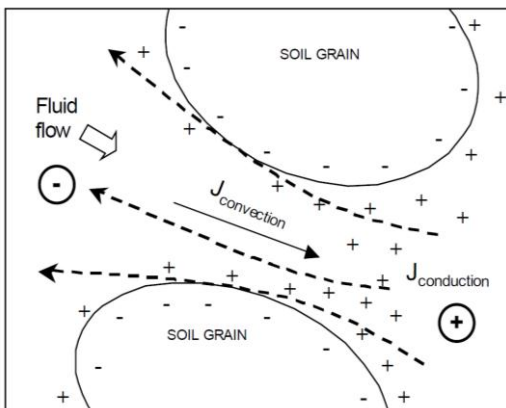


Figure 1 - Convection and conduction currents in a saturated pore channel (SHEFFER, 1995).

The urban waste disposal Estrutural city (figure 2), also known as *Jockey Club* landfill, was created in the 1950's, at the beginning of the urban city development. Today, the waste disposal covers an area of, approximately, 1.93 km^2 . Currently, about 2000 tons of non-recycled domestic waste material is deposited superficially per day. The affected area for the waste deposition was extended from the south to the north and covers an area about 190 hectares. The location contains no base sealing, no drainage system, and no waste water treatment, which dramatically increases the risk of soil and groundwater contamination.

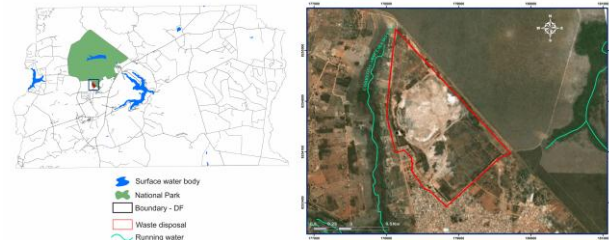


Figure 2 – Landfill localization map.

It is highlighted that the subsurface contamination both inside and near this landfill was observed by previous geophysical studies (FRANCO, 1996; CARNEIRO, 2002; CAVALCANTI *et al.*, 2011; STOLLBERG *et al.*, 2011; SOUSA *et al.*, 2012). Those studies characterized areas that were possibly contaminated by leachate from the landfill, but were inconclusive about the direction of subsurface contaminant's flow.

Aiming to help characterize the influence/contamination zone of *Jockey Club's* landfill as well as the contaminants's direction flow in the subsurface, it is proposed the use of the method in areas where previous studies (STOLLBERG *et al.*, 2011; CAVALCANTI *et al.*, 2011; SOUSA *et al.*, 2012) have indicated the presence of contaminant (figure 3).

The SP caused by potential flow due to infiltration of rainwater into the soil is used in studies aimed at determining the subsurface flows such as groundwater contamination originating from landfills, dumps, and other chemicals (GALLAS, 2005).

If both diffusion and streaming potentials are generated, it is highly probable that a measurable SP anomaly will be present at the landfill boundaries (REYNOLDS, 1997).

In most cases, landfills containing significant volumes of highly conductive leachate which may leak through the margins are known to generate significant SP anomalies (COLEMAN, 1991).



Figure 3 – Map showing the study area of this work. The red line indicates the profile comparison between the SP and resistivity data.

Method

Survey profiles were set in the landfill south boundary (see figure 3). We used one pair of Cu-CuSO₄ non-polarizable porous pot electrodes which were manufacturing by one of the authors of this paper (Figure 4).



Figura 4 – Cu-CuSO₄ electrodes made for this survey.

Cu-CuSO₄ electrodes used in this study were made up of a copper electrode dipped in a saturated copper sulphate solution with can percolate through the porous base to the pot in order to make an electrical contact with the ground.

Non-polarisable porous-pot electrodes were connected to a precision multimeter with input impedance greater than 10⁸ Ohms. Resolution of 0.1mV is sufficient for SP field measurements, ad a range of +/- 10 VDC will cover even large anomalies generated by DC current grounds (CORWIN, 1990).

The porous pot is placed in the ground by digging a small hole with a trowel or pick, filling the hole with water, and implanting the pot firmly against the hole's bottom, making good contact with the hole's wetted portion (BUTLER, 2005)

The field technique used was the potential gradient method, also known as "leapfrog". This method was used for SP observation with electrode spacing of 5 meters, among which the potential difference measured is divided by the electrode separation to give a potential gradient (mV/m).

This configuration provides a non-polarizing contact which means that it provides a galvanic path for the received signals and is designed to prevent development of contact potentials and minimize electrode polarization between the electronically conducting metal electrode and the ionically conducting ground (BUTLER, 2005).

Results

The observed SP anomalies are shown in Figure 5. Along the SP profile several sharp and local SP anomalies are recognized. The profile was compared with the resistivity data to verify the possibility of realizing a correlation between anomalies of these two methods.

Both profiles present areas with anomalous behavior. Although is possible to associate, in resistivity profile case, the high conductivity areas to the presence of leachate plume. The same cannot be inferred from the SP data. The anomalous high amplitude behavior of different potential in the beginning of the profile (red bar), as well as the low amplitude standard related to the end of the same (yellow bar), present alternate potential values, which contrasts with the strongly negative behavior that would be expected for the presence of contaminant plume in the subsurface.

This difference in potential presented cannot be associated to streaming potential. It is related to the diffusion potential caused by the presence of buried debris at the study site. The differences in mobility and concentration of ions present in the subsurface would be causing the diffusion potential, as explained in equation 1.

Conclusions

The self-potential method was effective in environmental studies, especially when correlated with other geophysical methods. This type of methodology correlation can eliminate certain ambiguities in data interpretation.

Since both the diffusion as the streaming potential are present in the medium, in this case it was possible to observe the prevalence of diffusion potential.

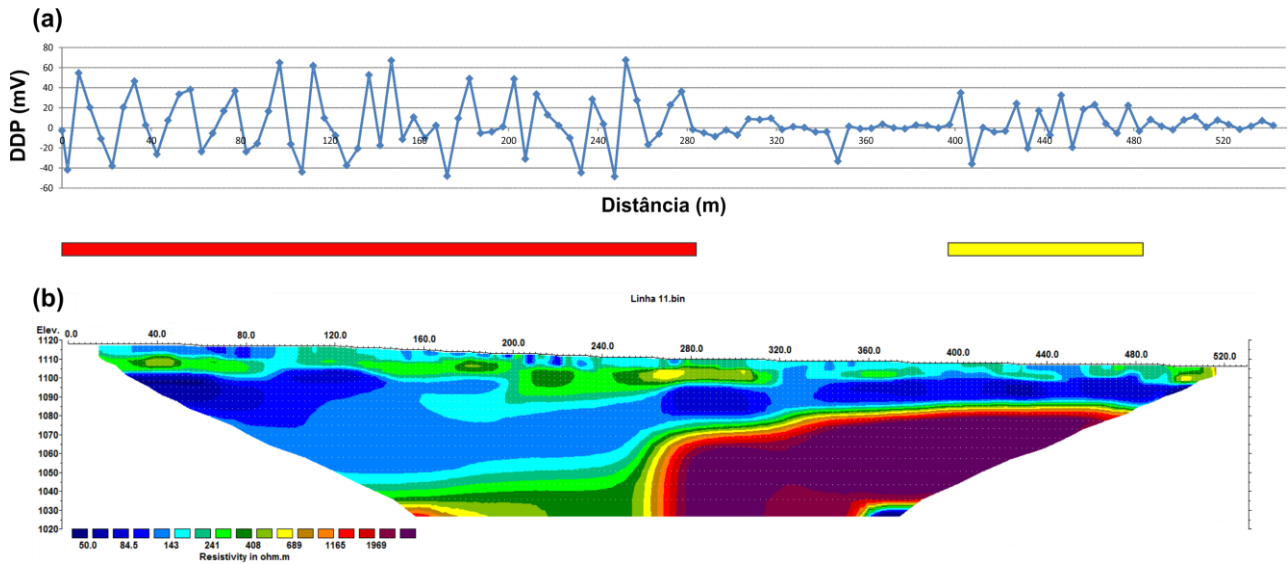


Figure 5 – Correlation between SP (a) and resistivity (b) profiles.

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