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Self Potential Investigation of Contaminants in a Dumpsite, University of Port Harcourt, Nigeria

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ABSTRACT

Self potential method was used to investigate the subsurface in a dumpsite and a neutral environment in Abuja campus, University of Port Harcourt, Nigeria. The self potential values ranges from -7.0 to 2.5 milliVolts within the dumpsite and 0. 1 to 9.5 miliVolts in the neutral site. The dumpsite is dominated with negative values which is attributed to electrochemical and electrokinetic processes. The electrochemical process is due to biodegradation of solid waste material which results in generation of leachate that modified the groundwater. The electrokinetic component is due to ground water flow. Positive values in the control site is due to low grasses and sand lithology. Possible direction of groundwater flow in the dumpsite is towards the stream in southwest while flow in the neutral area is toward the centre. Comparison of the two results showed that biodegradation of solid waste in the dumpsite modified the subsurface properties.

***Keywords*:** Dumpsite; Waste Materials; Self-Potential; Biodegradation; Leachate

1. INTRODUCTION

In most developing countries the management of solid waste disposal is a major environmental problem and challenges as a result of open dump sites which cause groundwater contamination. Geophysical techniques are widely used for evaluating and determining changes in physical properties of the subsurface in the present of contaminants. Environmental geophysicists are mainly concern with the detection of changes in the properties of the subsurface due to circulation of leachate and residence of contaminant in the subsurface. The contrast in the observed physical and chemical properties between the assessed locations and the surrounding areas with natural characteristics is normally used to delineate contaminated areas (Chen et al., 2012; Ramalho, 2013, Himilton, 2000; Okan, 2005; Mcneill, 1990; Kaya et al., 2007). Knowledge of the modifications of the subsurface physical and chemical properties due to the present of contaminants is very crucial for groundwater quality assessment. Self-potential methods of geophysicist has been used for evaluating contaminants in groundwater.

Geophysical techniques are continuously being used for assessing the nature of solid waste in dumpsites. The geophysical methods are simple, efficient and non-hazardous. They are used for mapping the boundaries of a landfill site, fill thickness, and fluid flow direction. These methods can be used to determined physical properties distribution in the subsurface and for obtaining useful chemical information about the subsurface (Meju, 2000; Benson et al., 1997). The geophysical techniques include electrical resistivity, electromagnetics and self potential methods.

The self potential method is based on the measurement of electrical potential which occurs between two points on the earth surface without injecting any electric current the earth. The self potential method is simple, quick and cheap. It is a passive method of Geophysics. The self potential method is carried out by using a high impedance multimeters and unpolarizable electrodes. Self potential can occur in the subsurface as a result of buried ore body, groundwater flow, biochemical reactions and vegetable biological processes.

Some geoscientists have used self-potential measurements for detecting and quantifying contaminants in groundwater (Baker and Cull, 2004; Naudet et al., 2003 and 2004). The self potential method has been widely used for investigating water movement, especially in monitoring leakages in dams (Corwin, 1990). Self potential method is classified into electrochemical potential, electrolytic and mineral potential based on the method of generation (Randall- Roberts, 1995 and 2001). The mineral potential is generated in the subsurface due to geochemical redox reaction in an ore body. Electrochemical potential occurs as a result biodegradation of organic matters deposited in landfill. The dumpsite is associated with physical and chemical reductions condition which lead to proliferation of anaerobic microorganism colonies. The difference between reduction in dumpsite and oxidation reaction in substratum produces measurable electric potential.

Naudet et al. (2003 and 2004) used the self potential and redox potential measurements to evaluate the evolution of a contaminant plume from a landfill. They observed that the electric potential decreases progressively in the aerobic zone and increases greatly in the redox front and finally reaches the standard of the study area when it achieve the oxidation zone. The result also showed a good correlation between self-potential and redox potential measurements. Natural electric potential and current have also been associated with degradation processes of organic compounds accumulated in solid waste landfills. Self potential method is also used for hydrogeological investigation for groundwater level tracing, soil moisture and salinity (Corwin, 1990; Fournier, 1989). The equipment consist of pair of electrodes, connected by a wire to a high impedance multimeter. The multimeter measures the natural background potential difference between the two buried electrodes.

The dumpsite used for this study is one of the sites in the University of Port Harcourt that accommodate daily amounts of solid waste generated within the campus. This dumpsite is not well developed and it is open. These refuse dumped produces liquid of leachate that seep into the subsurface and contaminate the groundwater. The landfill is located in a relatively permeable sand and as a result the leachate migration results in contamination over a large area. To predict the extent of contamination from the dumpsite, we carried out self potential survey within the area. The objectives of this study is to map the lateral extent of contamination at an open solid waste disposal site using self potential method of geophysics. The self potential method is economical and non-invasive for investigation of groundwater contaminant because the leachate from the solid waste is related to the electrical conductivity of the medium (McNeill, 1990; Dahlin, 1996; Oluwafemi, 2012; Dawson et al., 2002; Monteiro et al., 2002)

Self-potential method involves the measure the natural electrical potentials which occurs in the subsurface due to electrochemical or electrofitration phenomenon. The natural voltage difference that develop in the subsurface due to chemical disequilibria is known as the spontaneous polarization while the electrokinetic effect related to the migration of fluid containing ions through the subsurface is known as streaming potential. The self-potential method has find applications in mineral exploration, geothermal studies and leakages in in landfill sites and dams (Naudet et al., 2000; Fitterman and Corwin, 1982). The objectives of this study is to evaluate the results of natural self potential measurements in a solid waste dumpsite and a control site and to evaluate the extent of contaminants plume within the environment.

2. SUMMARY OF THE GEOLOGY OF THE STUDY AREA

The dumpsite (Figure 1) used for this study is located within the Abuja Campus, University of Port Harcourt, Nigeria. Figure 2 shows the locations of the dump site and the control sites where the self potential readings were taken. The landfill is sited close to a stream that is always dried up during dry season and fill with water during rainy season. Most of the materials are domestic and solid waste obtained from students' hostels, staff quarters, laboratories and offices. The dumpsite has been in existence for more than ten years now.

The geology of the area is typical of the Niger Delta which is the youngest sedimentary basin within the Benue Trough system.

The development of the basin began after the Eocene tectonic phase. The overall thickness of the Niger Delta sedimentary basin is approximately 12 km. Major part of the sediments are being supplied by Rivers Niger and Benue.

There are three lithostratigraphic units in the Tertiary Niger Delta. The basal Akata Formation which is mainly marine prodelta shale is overlain by the paralic sand/shale sequence of the Agbada Formation. The Agbada Formation is made up of alternation of sand and shale sequence. The topmost section is the continental upper deltaic plain sands – the Benin Formation. The underground water in the area is mainly obtained from the aquiferous Benin Formation.

The Benin Formation is made up of sands which are mostly medium to coarse grained, pebbly, moderately sorted with lenses of poorly cemented sands and clays (Ekweozor and Daukoru, 1994; Kulke, 1995; Doust and Omatsola, 1990). The hydrocarbon accumulations in the Niger Delta occur in the sands and sandstones of the Agbada Formation where they are trapped by rollover anticlines related to growth fault development.

Fig. 1. Dump site used for the survey

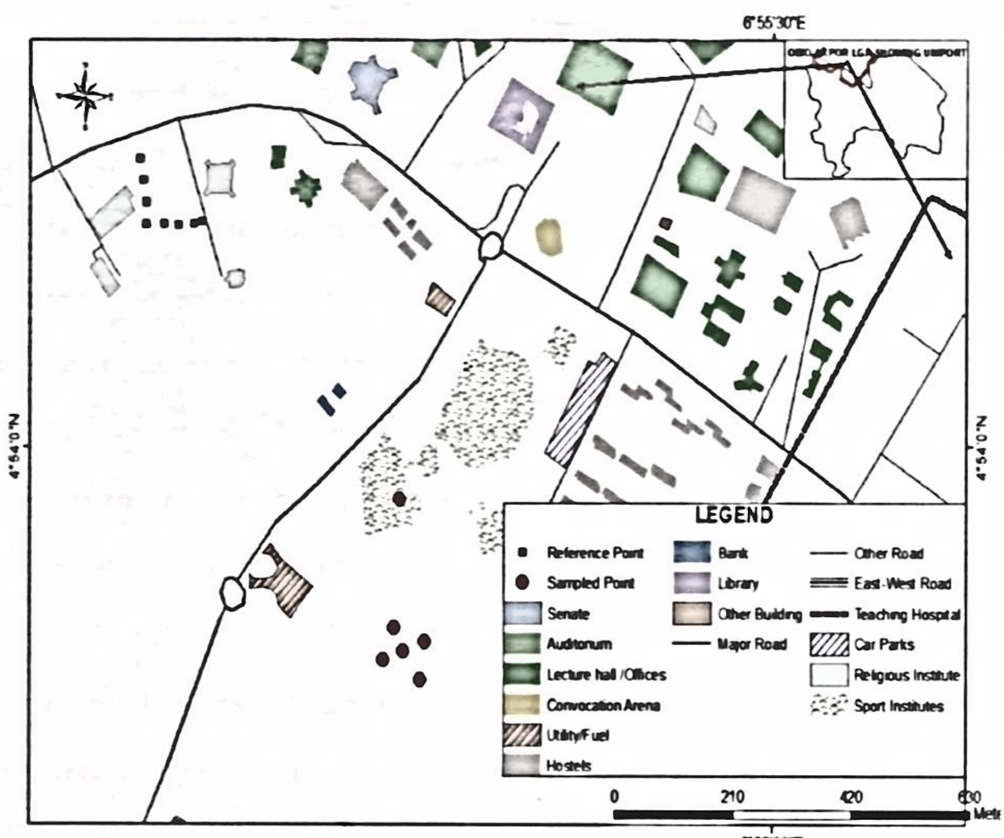

Fig. 2. Map of Abuja Campus, University of Port Harcourt showing the Studied Areas.

3. MATERIALS AND METHODS

The self potential (SP) geophysical method used for this study is simple and cheap. The equipment and materials used are; one pair of non-polarizing electrodes (porous pots), wire, high-impedance multimeter, surveying tapes to measure distance, a compass to measure location, base maps and tools to dig holes. The porous pots were planted firmly in small holes dug by a trowel for good contact with the ground. The electrodes were made of copper that were placed in a saturated copper sulphate solution which percolate through the base of the porous pot into the subsurface in order to make good electrical contact with the ground. This is to minimize electrons polarisation between the electrodes and the ionically conducting ground. The non-polarisable porous pot electrodes were connected to the high impedance multimeter by the wires. The multimeter has a precision voltmeter used for recording the voltages between the two electrodes. The field techniques involved keeping one of the electrodes at a base station while the other electrode is moved to each of the other stations. The measured self-potential values are then posted on the 2-D grid of the survey area. The posted values were latter contour using surfer-10. Due to the complexity of self potential data, qualitative interpretation was applied.

4. RESULTS AND DISCUSSION

The self potential measurement was carried out at a dumpsite and a control site which are about 500 metres apart. Self-potential method of geophysics was carried out to detect the spread of groundwater contaminations and to locate the leachate plumes direction that resulted from open waste disposal site. The results of the self potential measurements for the two locations are plotted in a 2D maps as shown in Figures 3 and 4 respectively.

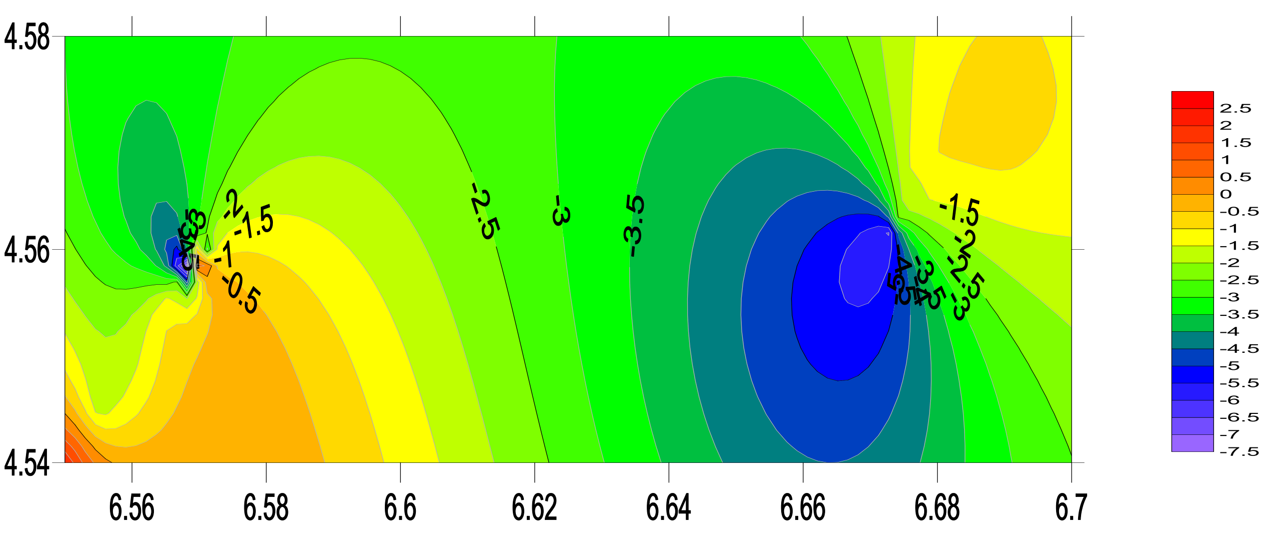

Fig. 3. Self potential map over the dumpsite.

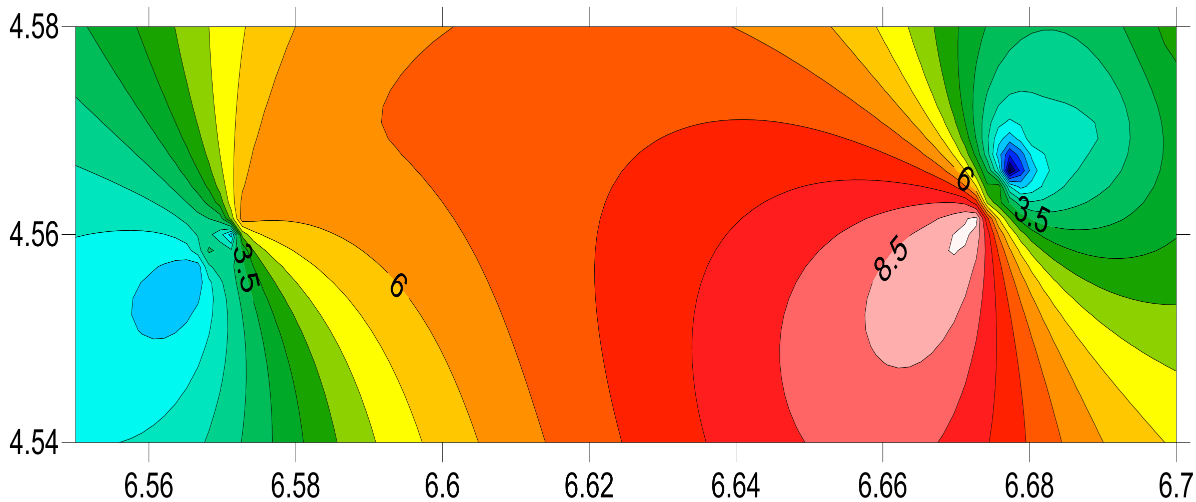

Fig. 4. Self potential map over the control site (nuetral site)

The self potential data observed within the dumpsite shows negative values ranging from -8 to 1.5 mV within the dumpsite (Fig. 4). The negative values can also be attributed to the redox reaction processes due to biodegradation of the contaminants which deplete the oxygen content in the landfill area. The dumpsite environment is highly conductive because of the leachate flowing from the dumpsite. The negative values obtained is in confirmation with the findings of others researchers (Vichabian et al., 1999; Christensen et al., 2000; Naudet et al., 2002). The self potential values increase towards the edges of the site especially in the southwest and north east regions where the values are positive.

The self potential values can be attributed to two major phenomenon: an electrokinetic and electrochemical components. The electrochemical effect can be attributed to electrochemical gradient in the subsurface due to the presence of leachate from the biodegradable materials of the dumpsite. The sources of the negative self potential anomalies are the redox processes associated with the biodegradation of the solid waste materials which deplete oxygen in the areas of contamination. The electrochemical processes of the organic contaminants and their interactions with bacterial in the subsurface make it feasible for the self potential method. Many researchers (Naudet et al., 2003; Nimmer and Osiensky, 2002; Corry, 1985; Vichabian et al., 1999; Greenhouse and Harri, 1983; Baba and Cull, 2004; Baba et al., 2004) have investigated the self potential anomalies associated with oxidation – reduction processes in contaminated sites and have observed negative values within the leachate plumes.

The electrokinectic effect is as a result of groundwater flow in the subsurface. This fluid is likely to be underground water flowing towards the stream in the southeast. This process result in positive self potential anomaly in the flow direction. The self potential anomaly is used for delineating the flow direction. The self potential due to the fluid flow increases from upstream to downstream and the intensities are function of the hydraulic pressure in the area. The flow direction is from the lower to the higher potential. This means that the leachate is flowing toward the south east where the values are positive. The positive values in the northwest may be due the presence of sand lithology upstream. The negative values is also as a result of clay lithology in the downstream area.

The self potential readings in the control (neutral) site is dominated with positive values which ranges from 0 to 9.5 mV. The causes of the positive signals are mainly due to presence of low grasses, sand lithology and groundwater flows. The grasses causes ionic water in the subsurface to flow thereby causing self potential anomalies. Low vegetation are usually associated with positive self potential anomalies. Sandy soil are also associated with positive anomalies. The difference in soil type affect sp anomalies due the mineral contents and the water retained in it.

Comparison of the self potential maps from the two sites shows that the chemical and physical properties of the subsurface are not the same. The neutral region has more positive ions than the contaminated dump site. The biodegradation of the materials in the dumpsite has led to the production of leachate while migrate into the groundwater thereby modifying its physical and chemical properties.

5. CONCLUSIONS

Self potential method was carried out in an open dump site and a neutral site. The self potential method was simple, fast, economical and reliable. The results shows that the dumpsite is highly associated with negative self potential values while the neutral site is associated with positive potential. The negative values in the dumpsite was attributed to biodegradation of the solid waste thereby producing leachate which modified the groundwater.

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