Effect of Landfill Leachate on Groundwater Contamination: A case study of Obio-Akpo Local Government Area, Rivers State, Nigeria

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ABSTRACT: This research investigates the effect of landfill leachate on the groundwater in "Odum", a community that plays host to a dumpsite along Choba/Alakahia road in Obio/Akpor Local Government Area (L.G.A.) of Rivers State, Nigeria. Five vertical electrical soundings (VES) were conducted using the Schlumberger configuration and also five horizontal profiling were done using the Wenner configuration. The field data were acquired using ABEM tarrameter SAS 300C, and processed using the IP TWO WAY software. The results showed that the area is composed of sandstone, clay, laterite, sandy clay, and sand. Also, from careful analysis and interpretation of the processed data it was observed that contaminated zones have low resistivity (high conductivity). Strikingly, areas of low resistivity such as 11.9 Ωm and others with high resistivity up to greater than 1818 Ωm do exist. The results show that groundwater around this landfill contaminated area contains highly conductive leachates like sulphur, methane, ammonia gas at depths > 16 m. This indicates that the study area is not a good aquifer zone.

Several works have been done on different dumpsites in many parts of the world, and also, in Nigeria that show how the quality of groundwater and human health is affected by leachate percolation into underground water bodies. Such works, among others include those of Udom and Esu 2004; Udom *et al*. 1999; Rosqvist *et al*. 2003; Ibe and Njoku 1999; Inichinbia and Sule 2018a; Inichinbia and Sule 2018b; Olayinka and Olayiwole 2000; Ehirim *et al*. 2009a; Ehirim *et al*. 2009b; Adebibu, 1985; Agbemuko *et al*. 2017; Ajadike 2007; Ige and Ogunsanwo 2009; Adekunle and Kehinde 2008; Eshimiakhe *et al*. (2019). The total amount of water in the earth is virtually constant but its distribution over time and space varies to a great extent. Wherever people live, they must have a clean and continuous supply of water as a primary requirement for human existence. The assessment of the quality, supply and renewal of water is quite a well-known problem, but it is becoming critical with the growth of population and rapid industrialization. The rising population of Nigeria of about 180 million requires knowledge of the proper disposal of wastes. This is because wastes are dumped recklessly with little environmental regards in major cities of many states in Nigeria including Rivers State. Increase in population, changes or improvement in wages, massive expansion of the urban areas and the changing lifestyle or better standard of living, as well as improvement in technology in Nigeria has encouraged solid waste generation. Although solid waste is an asset when properly managed, its volume has continued to increase tremendously in recent times. In Nigeria, much has been, and is still being invested on municipal solid waste management in cities. But little progress has been made because of severe financial, technological and institutional constraints within the public and the private sectors. Waste could be defined as any material lacking direct value to the producer and so must be disposed of. Similarly, waste is any material that is thrown away as unwanted material. The term "solid waste" means any garbage, refuse, or sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded materials, including solid, liquid, semi-solid, industries, mining etc. Solid waste can however be classified into different types, depending on their source; household waste is generally classified as municipal waste; industrial waste as hazardous waste, and biomedical waste or hospital waste as infectious waste. The trend of indiscriminate or uncontrolled and haphazard construction of groundwater facilities particularly shallow wells and boreholes in the residential areas close to refuse dumpsites is of great health concern, as this may contribute significantly to groundwater pollution. This results to an adverse impact on the aquifer as a result of overdependence and over abstraction with attendant negative effects. The Odum

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dumpsite is not well managed over the years and has contaminated the aquifer with leachate. As a matter of fact people within this settlement have been drilling boreholes from this very contaminated zone as a result of ignorance, thereby endangering their lives. Also the decomposition of municipal solid waste causes serious airborne diseases and releases methane a greenhouse gas contributing to climate change. The objective of this paper is to evaluate the effect of landfill leachate on groundwater contamination within the study area.

MATERIALS AND METHODS

Study Area: The study area is Obio-Akpo Local Government Area of Rivers State Nigeria (Figure 1).
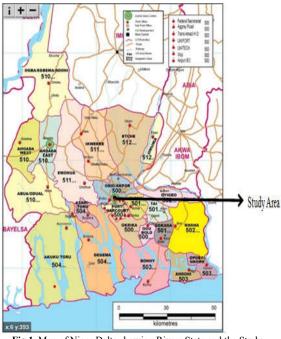

Fig 1. Map of Niger Delta showing Rivers State and the Study Area

Methodology: The geophysical method used was the resistivity method employing both Schlumberger electrode configuration (VES) and the Werner electrode configuration for profiling. Electrical Resistivity Tomography (ERT) are surface geophysical methods in which an electrical current is injected into the ground through electrodes and voltages on the surface are measured revealing the direction and amount of current flow in the subsurface. The data is used to image the subsurface resistivity. Observed measurements of the current and voltages are converted into apparent resistivity, a weighted average of the resistance of earth materials to current flow. Variations in fluid saturation, fluid resistivity, rock type, porosity, and permeability affect resistivity values and are often revealed with the electrical resistivity methods.

Data Analysis and Interpretation: The data obtained from the field survey were processed using the IP TWO WAY software, analysed and interpreted using modern techniques demonstrated by Inichinbia and Sule 2018a; Inichinbia and Sule 2018b; Olayinka and Olayiwole 2000; Ehirim *et al*. 2009a; Ehirim *et al*. 2009b; Adebibu, 1985; Agbemuko *et al*. 2017; Tamuno and Inichinbia, 2019; Eshimiakhe *et al*. (2019) and a host of other authors. The results are presented in appropriate sections and table and discussed in the results and discussions section.

RESULTS AND DISCUSSION

Profile 1 (see Figure 2) was acquired 10 m away from the landfill. The inverse model resistivity section has resistivity values ranging from less 1.67 Ωm to greater 541.00 Ωm. There is a zone of anomalously low resistivity in the inverse model section of depth ranging from 1.25 m to 15.90 m and at surface points from 25.00 m - 85.00 (> 65.00 m) the zone of low resistivity (> 10.20 Ωm) at the upper point of the inverse model section could be associated with highly conductive leachate contaminant plume originating from the decomposition of the various wastes due to the landfill seeping into the aquifer and also indicate contamination of the surrounding soil. Under the low resistivity zones are layers of increasing resistivity (yellow and green) with resistivity values ranging from 25.20 Ωm – 62.30 Ωm at depths ranging from 9.26 m to greater than 16.00 m and at surface points ranging 17.00 m to greater than 95.00 m (>70.00 m). These layers are interpreted as permeable sandy formation of varying grain sizes, thicknesses and moisture content. Above the zone of increasing resistivity is a zone of anomalously high resistivity greater than 941.00 Ωm at a depth between 3.75 m to greater than 15.9 m which could be interpreted as dissolved landfill gas produced as a result of the decomposition of the landfill waste. The extremely high resistivity portions (red), and >1256.00 Ωm, are probably hard rocks transported and buried over time as a result of construction works (Inichinbia and Sule, 2018a&b). These materials are found at depths ranging <2.00 m to >9.00 m and at surface locations 20.00 m to 35.00 m, 45.00 m to 55.00 m, 60.00 m to 75.00 m and 80.00 m to about 95.00 m, across the field. Profile 2 (see Figure 3) was acquired 25.00 m away from the landfill. The inverse model resistivity section has resistivity values ranging from less than 11.90 Ωm to greater than 1818.00 Ωm. There is a zone of anomalously low resistivity (deep blue) in the inverse model resistivity section at depths ranging from 1.25 m to greater than 12.50 m and at the surface

points ranging from 15.00 m to greater than 30.00 m, between 45.00m and 50.00 m, and 75.00 m to greater than 95.00 m (> 65.00 m). The zone of low resistivity (50.20 Ωm) at the upper part of the inverse model resistivity section could be associated with highly conductive leachate, since contaminant plume originating from the decomposition of the various wastes dumped on the site has seeped into the aquifer and possibly caused the contamination of the surrounding soil too. The upper zone and layers have decreasing resistivity (green to yellow) with resistivity

ranging from 103.00 Ωm – 170.00 Ωm at depths ranging from 6.30 m to a depth greater than 16 m and at surface points ranging from 15.00 m to greater than 95.00 m (>80.00 m). These layers are permeable sand Formation of varying grain sizes, thicknesses and moisture contents (Tamuno and Inichinbia, 2019; Eshimiakhe *et al*., 2019). This site is no longer has a good aquifer zone because of the impact of the leachate from the dumpsite.
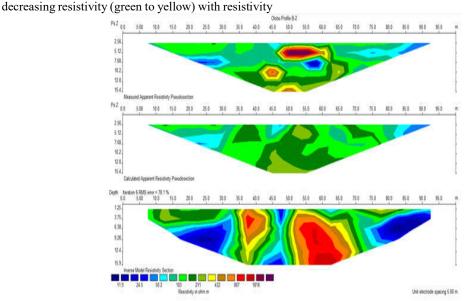

Fig 2. Inverse model resistivity section of profile 1. The model is the result of the simultaneously processed horizontal profiling and vertical profiling data.
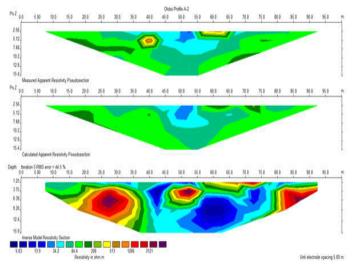

Fig 3. Inverse resistivity model section of profile 2. The section is the result of the simultaneously processed horizontal profiling and vertical profiling

From the results of the 2D resistivity imaging it is clear that the top soil and groundwater around the landfill site to depth exceeding 16m which is within the

aquifer in the study area, have been contaminated by the leachate. The results of the 2D resistivity imaging isolated three zones in each profile mapped around the

landfill site. These are the zones of anomalously low resistivity which are regarded as highly conductive leachate contaminated zones and contain pathogens that causes health problems. Secondly, a zone of anomalously high resistivity as fill wastes and thirdly, a zone of increasing resistivity layers which is interpreted as permeable sandy formation of varying grain sizes, thicknesses and moisture contents.

Hydrogeological features of the study area show that leachate derived from the landfill sites seeps into the vulnerable sand aquifer and hence contaminates the groundwater. This research project has demonstrated that 2D resistivity imaging can be used to investigate pollutions of top soils and groundwater as well as the lateral extents of the contamination of the leachate plumes from the waste (medical, domestic and industrial) disposal area.

Table 1 shows the interpretation of the processed field data for VES obtained at Olobo environs of Choba/Alakahia and revealed five (5) geoelectric layers of resistivity values ranging from 47.10 Ωm – 148.30 Ωm and depth to the layers also ranging from 1.95 m – 35.28 m . the resistivity of layers of depth and thickness beyond 35.28 m had poor resolution.

Table 1. Interpretation of processed VES data 2

No of layers	RES (RΩ)	Depth (m)	Thickness (m)	Lithological Unit
1.	47.10	1.95	1.95	Top Soil
2.	78.95	4.75	2.80	Sand Stone, laterite
3.	166.20	13.59	8.85	Clay/Sandy
4.	248.60	35.28	21.69	Coarse, Weak Aquifer
5.	148.30	-	-	Indurate

Conclusion: Dumping of waste (domestic, industrial, and medical) in urban or rural settlements without environmental precautions leads to serious health issues. Quality water management is an issue that must be given top priority in our state and country. The hydrogeological features of the vulnerable sandy aquifer are not suitable for waste disposal as contaminants easily seep into the groundwater. Therefore construction of landfill sites must include solutions to landfill problems, such as thick concrete floor, bagging waste in waterproof bags, creating public awareness and immediate recycling.

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