Journal of the Nigerian Association of Mathematical Physics
***Volume32,(November, 2015*), pp 431 – 436**

Geoelectric Imaging of the Subsurface Using Non Invasive Technique in Uwalor-Oke, Uromi, Esan North East Local government Area, Edo State

[1]Ezomo F. O. and [2]Biose O.

[1]Department of Physics, University of Benin, Benin City, Nigeria.
[2]National Centre for Energy and Environment (Energy Commission of Nigeria), Benin City, Nigeria.

Abstract

The 2D resistivity tomography was used to delineate the extent of leachate plume in the subsurface in Uwalor-oke community, Esan North Esat Local Government Area, Edo State. The petrozenith earth resistivity meter was utilized for data acquisition and the wenner-schlumberger electrode configuration was employed, Zondre2D and Surfer 11 softwares for data interpretation were adopted. The result from 2D resistivity tomography revealed that the leachate plume is laterally located between 35m and 37m and extends vertically to a depth of 5.0m, it was also observed from the topographic setting that lateral migration of the plume is towards the hand dug well location which is 28m away from the plume location and if flow continues, region down gradient from it might be contaminated. Water samples collected from hand dug well also revealed high nitrate concentration of 4.38mg/l as against 3.0mg/l recommended permissible limit of World Health Organisation (WHO) drinking water benchmark which is in agreement with the presence of leachate plume. The presence of nitrate in drinking water can be hazardous to health especially for infants and pregnant women. It is recommended that hand dug wells should not be cited close to potential pollution sources and also reverse osmosis can be used to treat well contaminated with nitrate.

Keywords: Blue Baby Syndrome (BBS), Hand dug well, World Health Oragnisation (WHO), Tomography

1.0 Introduction

Water pollution is a major problem in the global context, and it has been suggested that it is the leading worldwide cause of deaths and diseases [1]. Human activities during the last century have polluted most of the groundwater in Nigeria [2]. Water on the earth can be said to be enormous in quantity when it is considered that more than two-thirds of the earth surface is covered by water [3]. It is not sufficient merely to have access to water in adequate quantities, the water also needs to be of adequate quality to maintain health and it must be free from harmful biological and chemical contamination [4]. It was observed that as surface water becomes increasingly polluted, people turn to groundwater for alternative supplies [5]. Therefore the development and efficient management of groundwater resources is of particular concern.

Nitrogen-based fertilizers and pit latrine are the most commonly identifiable pollutant in groundwater in rural areas [6]. Nitrogen in the form of dissolved nitrate is the major nutrient for vegetation, when applied some nitrate is retained by plants and soil particles. However, if applied in excessive amounts, the excess nitrate not consumed by plants can be flushed down to groundwater. Although nitrate is relatively non-toxic it can cause certain conditions, a serious blood disorder in infants [7]. The greatest danger associated with drinking water is that, it may be polluted by human or animal waste and leads to ingestion of dangerous pathogens. Sanitation units, such as septic system and latrines are designed to discharge domestic waste water into the sub-surface. The necessity of obtaining portable water within an environment is pertinent [8]. This paper therefore aims to locate and delineate plumes migrating from the surface sources down to the underlying aquifers using geo-

Corresponding author: Ezomo F. O., E-mail: ezomofriday@yahoo.com , Tel.: +2348054470436, 8062151153(B.O)

electric method and to ascertain the health status of the hand dug well in the study area.

2.0 Methodology

In the research work, the Wenner schlumberger array electrode configuration was adopted. The basic field equipment utilized for data acquisition was the **PETROZENITH EARTH RESISTIVITY METER MODEL PZ-02**. This meter consists of a power supply with a 100mA output 12V DC power supply, analog to digital converter (ADC-voltage to frequency converter switching circuit), display system, and a processor (i.c) memory, other accessories to the earth resistivity meter include cables, electrodes, measuring tape, cutlass and hammer for driving the electrodes into the ground

Theory

Most surveys on modern electrical resistivity aim to obtain the true resistivity values of subsurface structures because the true resistivity is geologically significant. Resistivity imaging technique depends on ohm's law, which states that the electric current (I) in a material is proportional to the potential difference across it. The linear relationship between these two variables is expressed by the following equation:

$V = IR$ (1)

Where (I) is the current (V) is the potential difference, and (R) is the resistance. The above equation is the linear relationship between (V) and (I). For a given material, resistance is proportional to length (L) and inversely proportional to the cross sectional area (A) of the conductor. These relationships are expressed in the following equation:

$R = \rho L/A$ (2)

The proportionality constant (ρ) is the resistivity of the conductor. Resisitivity, a physical property of materials, is the ability to resist a flow of charges; it is the measurement of how strongly a material resists the flow of electric current [9].

Ohm's law states that, "for many materials (including most metals), the ratio of the current density to the electric field is a constant σ that is independent of the electric field producing the current" [10].

$J = \sigma E$ (Ohm's Law) (3)

The constant of proportionality (σ) is the conductivity of the material, (J) is the current density, and (E) is the electric field. The inverse of conductivity is resistivity (ρ):

$E = \rho J$ (4)

For a homogeneous area with one electrode, the potential separates radially away from the current source, where the area (A) is a half sphere ($2\pi r^2$) with radius (r). Equation (2) is rewritten as

$\rho = RK$, (5)

Where $K = 2\pi r$ for a half sphere. Equation (5) consists of two parts. The first part is resistance (R) and the second part is geometrical factor (K), which describes the geometry of the electrodes configuration.

The geological structures of the ground are inhomogeneous, and the obtained values of resistivity represent apparent resistivity instead of true resistivity [11, 12]. Therefore, the resistivity (ρ) in Equation (5) changes to apparent resistivity (ρ_a) in an inhomogeneous area:

$\rho_a = RK$. (6)

Where $K = \pi n (n + 1) a$

This is a new hybrid between the Wenner and Schlumberger arrays [13] arising out of relatively recent work with electrical imaging surveys. The classical Schlumberger array is one of the most commonly used array for resistivity sounding surveys. This array (Fig. 1) is moderately sensitive to both horizontal and vertical structures.

C1 —— na ——→ P1 - a → P2 —— na —— C2

Fig. 1: Wenner-Schlumberger array method

The Wenner-Schlumberger spread was carried out for acquisition of data. In each line location, electrodes numbered 0- 30 were staked into the ground at intervals of 5m along the line. Each time measurement were to be taken, array of four electrodes are selected manually and connected to the Petrozenith Earth Resistivity Meter via single core cable. The longitude, latitude and altitude of begin and end of the survey line were measured using the Global Positioning System device.

In this survey, a maximum current spread of 150 meters was used to map the subsurface of the study area. For the first measurement, electrodes number 0, 1, 2 and 3 are used. Electrode 0 was used as the first current electrode C1, electrode 1 as the first potential electrode P1, electrode 2 as the second potential electrode P2 and electrode 3 as the second current electrode C2. For the second measurement, electrodes number 1, 2, 3 and 4 were used for C1, P1, P2 and C2 respectively. This was repeated down the line of electrodes until electrodes 21, 22, 23 and 24 are used for the last measurement with "1a" spacing .After completing the sequence of measurements with "1a" spacing, the next sequence of measurements with "2a" electrode spacing was carried out. First electrodes 0, 2, 3 and 5 were used for the first measurement. The electrodes were chosen so that the spacing between C1-P1, P2-C2 electrodes are "2a". 'The same process was repeated for measurements with "3a", "4a", "5a", "6a" and "7a" spacings respectively.

Groundwater quality was evaluated from test on sample from hand dug well from Uwalor-oke community in Uromi, Esan North East of Edo State. Polythene bottles containers were used for the collection of water samples at each location these bottles were rinsed by the water from which samples were to be taken. The laboratory analysis of the sampled water revealed the chemical composition of water. The groundwater samples were analysed in Quality Analytical Laboratory and data obtained were compared with the World Health Organisation (WHO) benchmark of drinking water [14]. The chemical characteristics include, pH, Total Dissolved Solids (TDS), Electric Conductivity (EC), Total Suspended Solids (TSS), Hardness, Colour, Turbidity, Alkalinity, Nitrate (NO_2), Nitrite (NO_3), Zinc (Zn), Copper (Cu), Calcium (Ca), Lead (Pb), Iron (Fe), Phosphate (PO_4), Magnesium (Mg), Manganese (Mn) based on the procedures outlined in [15, 16, 17].

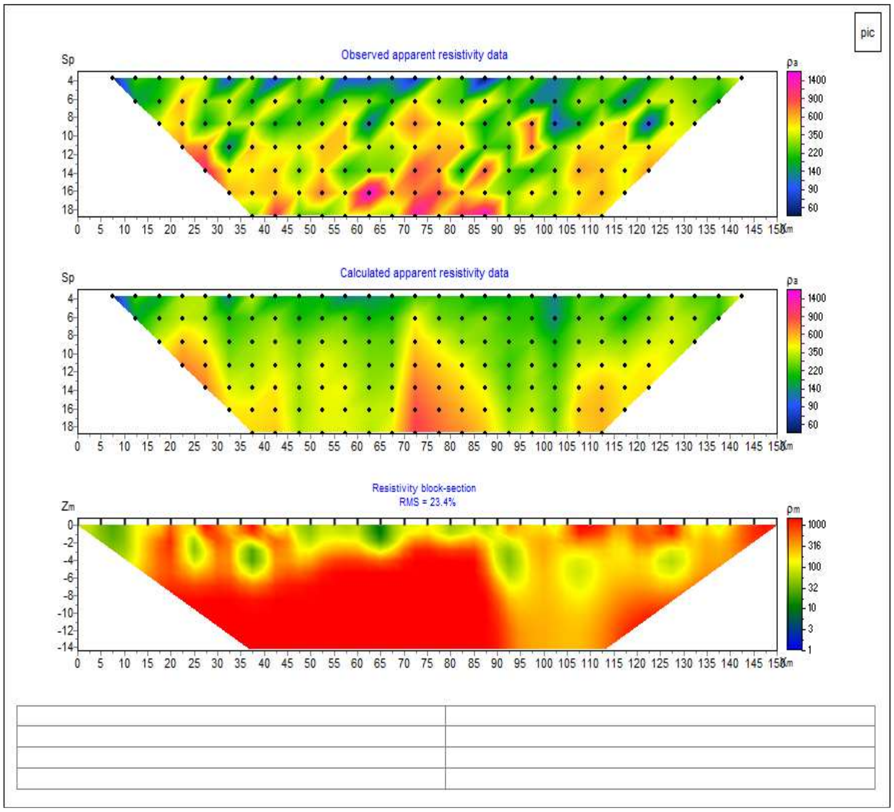
3.0 Results and Discussion

The result of the geoelectrical survey employing the electrical resistivity tomography (ERT) and utilizing the Zondres2D software and Surfer 11 software for data analysis are shown in figures 2-4. The physicochemical parameters of water samples collected in the study are shown in Table 1. The aim is to identify the pollutants and also ascertain the health status of the hand dug well in the study area.

Table 1: Test Results of Physicochemical Parameters

Parameters	Units	Sample 1	WHO Limit
pH		6.60	6.5-8.5
EC	$\mu s/cm$	218.0	1000
TDS	Mg/l	136.0	1000
TSS	Mg/l	Nil	N/A
Total Hardness	Mg/l	2.50	100-500
Turbidity	FAU	1.0	5.0
Colour	Mg/l Pt/Co	2.0	5.0
Alkalinity	Mg/l	96.0	500
Fe	Mg/l	0.01	0.3
Zn	Mg/l	0.23	5.0
Mg	Mg/l	0.23	50
Mn	Mg/l	BDL	0.1
Cu	Mg/l	BDL	1.0
Ca	Mg/l	0.92	75.0
NO_2	Mg/l	**4.38**	3.0
NO_3	Mg/l	0.02	10.0
Pb	Mg/l	BDL	0.05
PO_4	Mg/l	0.14	N/A

The physicochemical analysis from Table 1 shows that all the parameters analysed for water sample collected from hand dug well were within the World Health Organisation (WHO) drinking water benchmark apart from nitrite with a high value of 4.38mg/l as against 3.0mg/l World Health Organisation (WHO) benchmark for drinking water.
Sample 1 = Uwalor-oke FAU = Formazin Attenuation units, **µs/cm** = Micro second per centimetre, **Mg/l** = Milligram per litre, **ptCo** = Platinum cobalt scale, **BDL** = Below Detectable limit, **N/A** = Not Available



Survey Aim: To locate contaminant leachates plumes

Site Description: Uwalor Oke

State/Town/ LGA: Edo/Uromi/Esan North East

Begin/End Coordinates: N06^{0} 66.792′, E006^{0} 63.199

Fig. 2: Geoelectric Image of Uwalor-Oke

Three different colour shades, green, yellow and red are seen in the resistivity block section model section. The green 6.5-66 Ωm (on the average 36 Ωm), yellow 66-658 Ωm (on the average 362 Ωm) and red 658-1500 Ωm (on the average 1079 Ωm).This probably shows three different geoelectric materials. The geological interpretation of the resistivity anomalies are shown in the form of geoelectric section (Fig 2).

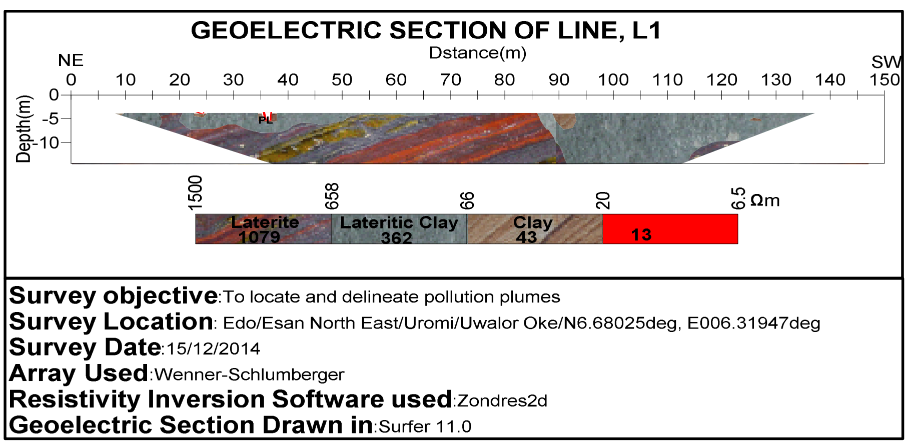


Fig. 3: Geoelectric Section of Profile Uwalor Oke

The average resistivities 43, 362 and 1079 Ωm inferred to be clay, lateritic clay and laterite. Resistivity anomaly, labelled PL lie between 6.5Ωm and 20Ωm (on the average 13Ωm) indicating leachate plume is observed. PL1 is 1.5m by 2.0m in cross section, it laterally located between 35 m and 37m marks, and extends vertically to a depth of 5.0m.

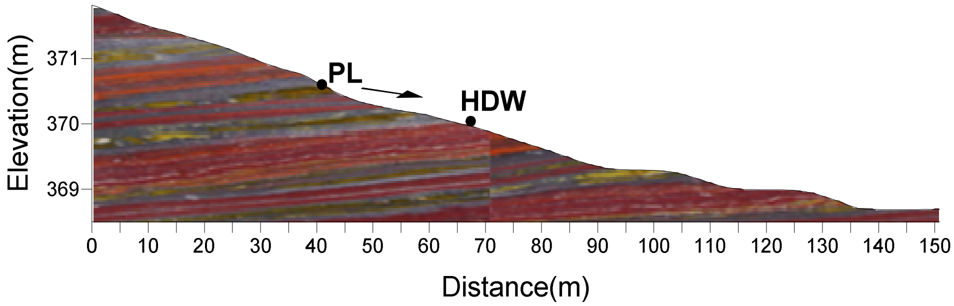


Fig. 4: Topographic Cross Section across Plume, PL and Hand dug well Location Uwalor Oke

The plume, PL is located up elevation of the hand dug well location, which is 28m away from the plume location (Fig. 4). From this topographic setting, it could be suggested that lateral migration of the plume is towards the hand dug well location, and if flow continues, region down gradient from it might be contaminated. The topographic cross section tie the topographic information with leachate plume i.e predicts the direction of flow of plume.

4.0 Conclusion

The 2D electrical resistivity imaging successfully delineated the lateral and vertical extent of the contaminated zones as well as determining the subsurface migration pathway. The result of 2D resisitivity imaging has helped characterize the landfill subsurface such as landfill geometry and leachate plume in Uwalor-oke community. It is observed that the leachate plume was delineated within the resistivity range of about 1-20 Ωm which is laterally located between 35m and 37m and extends vertically to a depth of 5.0m. The topographic crossection helped to predict the flow of leachate plume direction. The test result of physicochemical analysis of hand dug well water samples revealed nitrite concentration which justifies the presence of leachate plume in the subsurface. The presence of nitrite in drinking water can be hazardous to health especially for infants and pregnant women (blue baby syndrome).

5.0 Reference

[1] World Resources (1998). A Guide to the Global Environment (WR 1) Part 1; Environmental Change and Human Health. pp 386.

[2] Osibanjo, O. 1994. Present Water Quality Status in Nigeria. Federal Environmental Protection Agency, Lagos.

[3] Abdulaziz, M. (2003). Spatial variation in Water Quality in Nguru urban. Unplished M.Sc. Project. University of Maiduguri, Nigeria.

[4] UNEP and WHO 1996. Water Quality Monitoring. An Imprint of Chapman and Hall, London.

[5] Dauda, A. M. (1993). A Comprehensive Approach in water Resources Management for the 21^{st} Century Environmental Bullets 12.

[6] Marte, A. M. (1983). The Groundwater Resources and Exploitation in the Chad Formation. Unpublished M.Sc. Project, Loughbough University of Technology.

[7] Offodile, M. E. (2002). Groundwater Study and Development in Nigeria, University of Ibadan Press. Nigeria

[8] Ezomo, F. O. 2010. Geophysical investigation of Groundwater in Oluku Village and its Environs of Edo State, Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences 2 (4). pp 610-614.

[9] Denchik, N., and Chapellier, D. (2005). 3D electrical resistivity monitoring during rainfalls. Paper presented at the 3^{rd} Swiss Geoscience Meeting.

[10] Serway, R. A., and Jewett, J. W. (2007). Physics for Scientists and Engineers (6 ed.): Thomson Brooks/Cole.

[11] Lowrie, W. (2007). Fundamentals of Geophysics (2 ed.): Cambridge University Press.

[12] Reynolds, J. M. (1997). An Introduction to Applied and Environmental Geophysics: John Wiley and Sons, Ltd.

[13] Pazdirek, O. and Blaha, V., (1996). Examples of resistivity imaging using ME-100 resistivity field acquisition system. EAGE 58th Conference and Technical Exhibition Extended Abstracts, Amsterdam.

[14] WHO. (2008). Guidelines for drinking - water quality, 3rd Ed. World Health Organisation, 20 Avenue Appia, 1211 Geneva 27, Switzerland. 688p.

[15] Lacatus, R. (2000). Appraising levels of soil contamination and pollution with heavy metals. European Soil Bureau, Research No.4.

[16] Aiyesanmi, A.F. (2008). Baseline Heavy metals concentration in River Sediments within Okitipupa South East belt of Nigeria bituminous sand field. *J. Chem. Soc .Nig.,* Vol.33, No.2, pp 29 – 41.

[17] Oyakhilome, G.I., Aiyesanmi, A.F., Adefemi, O.S. and Asaolu, S.S. (2013). Interrelationship of heavy metals concentration in water, sediment and fish samples from Owena Multi-purpose dam, Ondo State, Southwestern Nigeria. JETEAS, 4(2): 207-215