Journal of the Nigerian Association of Mathematical Physics
Volume 52 **(*July & Sept., 2019 Issue*), pp253 – 266**
© J. of NAMP

GEOELECTRICAL INVESTIGATION OF THE IMPACT OF THE USE OF INJECTION WELL TO CONTROL FLOOD AT IHAMA ROAD, BENIN CITY, NIGERIA

Okanigbuan P.N.[1] and Alile O.M.[2]

[1]Department of Physical Sciences, Benson Idahosa University Benin City, Nigeria.
[2]Department of Physics, University of Benin, Nigeria.

Abstract

The well injection is located at Ihama Road, by military hospital and there are over 45 boreholes inside the injection well. The purpose of the use of injection well is to control flood but because the well is almost drilled to the aquifer and is covered with just wire gauze, it becomes a concern to geophysicists as the suspected plumes are migrating. The subsurface imaging was done by engaging the dipole dipole configuration using PASI Earth Resistivity Meter. The Vertical Electrical Sounding (VES) was done by engaging the Schlumberger configuration using Petrozenith terrameter to determine the depth to the aquifer. The 1-Dimensional results from Military hospital showed that the depth to aquifer is 100m. Low resistivity values were seen in the Inversion Images of 2-D Resistivity Profiles, which could be as a result of the presence of contaminant plumes from the well injections. In addition, the Hydrophysicochemical analysis was carried out which further proved that the area of study has been contaminated. The study has proved that the use of injection well to control flood is a direct contamination on groundwater in the study area, instead good drainage system should be adopted or flood should be channelled to a nearby river.

1. Introduction

The subsurface imaging was done by engaging the dipole dipole configuration using PASI Earth Resistivity Meter. The Vertical Electrical Sounding (VES) was done by engaging the Schlumberger configuration using Petrozenith terrameter to determine the depth to the aquifer. The 1-Dimensional results from Military hospital showed that the depth to aquifer is 100m.

The DIPRO (Directed Probabilistic) software and the RES2DINV software were used for the interpretation of the 2-D resistivity data. Low resistivity values were seen in the Inversion Images of 2-D Resistivity Profiles, which could be as a result of the presence of contaminant plumes from the well injection.In addition, the Hydrophysicochemical the chlorine content in the area exceeded the maximum permitted level, Electrical conductivity exceeded the maximum permitted level, the total dissolved solids (TDS) exceeded the maximum permitted level, Hardness of water samples exceeded the maximum permitted level, Iron (Fe) content exceeded the maximum permitted level, and Magnesium (Mg) content exceeded the maximum permitted level by the Nigerian standard for drinking water quality, (NSDWQ).

Hence this could be as a result of the injection well which allow direct flow of flood to the aquifer without restriction.

It has proved that the use of injection well to control flood is a direct contamination of groundwater in the study area, instead good drainage system should be adopted or flood should be channeled to a nearby river.

Background of Study

Groundwater is the water that flows below the ground surface contained in pore spaces [1]. The most important use of groundwater, is to add to surface water for human consumption and it is becoming very common and reliable source of suitable water all over the country [2]. It helps a significant amount of agricultural activity and it is vital for domestic and stock uses.

The part of the ground that is filled with water is known as the saturated zone, water table is at the top of the zone while the part that stores water is called Aquifer.Aquifer is an underground layer of water-bearing rock[1]. Groundwater, can be gotten from precipitations that go down the soil and enter cracks [3].There are different types of aquifer, namely; Confined aquifer, Unconfined aquifer, Leaky aquifer, Multi-layered aquifer [10].

Corresponding Author**:** Okanigbuan P.N., Email: pokanigbuan@biu.edu.ng, Tel: +2348032724951, +2348061624117 (AOM)

Groundwater contamination occurs when human activities and chemicals penetrate inside the groundwater and the water turns to be unsafe for human beings. There are about four sources of ground water contamination which are geophysical aspects, chemical aspects, microbial aspects and man-made aspects [4]. In Nigeria, high population concentration, industrial and agricultural activities, environmental pollution and in discriminate disposal of all kinds of wastes are suspected to cause pollution in the urban areas [5, 6, 7, 8, 9, 10, 11]. The quality of ground water can be as a result of natural processes, and anthropogenic activities [12, 13, 14].Flood is referred to a situation that occurs when rain falls and water flows on the path ways and on the street, sometimes it stays there for days and weeks. It is a state when water flows out of its riverbed and lays at the riverside [15, 16]..

Flood is same everywhere in Nigeria and the rest of the world. In Nigeria, flooding have driven millions of people from their homes, destroyed businesses, polluted water resources and increased the risk of diseases [17, 18, 19, 20]. Flooding has occurred in many states in Nigeria ranging from northern, western, eastern and southern states.

Injection well can be defined as a well that is drilled to discharge fluids underground. When we inject fluids into the ground without regulation, it can contaminate groundwater and drinking water sources. Because contamination of groundwater can be difficult to remediate, it is important to ensure that contaminants do not enter groundwater.

There are different types of injection wells, namely; Class I, Class II, Class III, Class IV, Class V. Electrical Resistivity Imaging is a geophysical technique for imaging subsurface structures from the measurements made at the surface electrically. Electrical survey is important because it is used to determine how resistivity is distributed on the surface by measuring the ground surface. The measurements are made by injecting current into the ground via two current electrodes and measuring the resulting voltage difference at the two potential electrodes. Apparent resistivity value can be calculated from the current (I) and voltage (V) values.

$$\rho_a = \frac{kV}{I} \qquad (1.0)$$

Where k is the geometric factor

ρ_a = apparent resistivity

V = voltage

I = current

Using a computer programme, the true resistivity is obtained.

Plate1.1: The inside view of the injection well in military hospital

Aim and Objectives

The aim of the study is to carry out geoelectrical imaging of the impact of flood injection on groundwater, which satisfy the following objectives:

1. carryout Vertical Electrical Sounding to ascertain the depth of aquifer using Schlumberger array.
2. carryout 2D Electrical Resistivity Tomography (ERT), to determine the extent of contaminant plumes if any to collect water samples from the existing boreholes using clean water bottle in the study areas
3. Carryout hydro physicochemical analysis on the water samples collected in the study areas.
4. carryout geoelectrical interpretation of the resistivity data using Res2Dinv and Diprofwin soft wares, to visualise the resistivity distributions along the contour lines.
5. correlate the hydro physicochemical analysis results with the results of Electrical Resistivity Imaging.

Methodology

The method used was Resistivity method and the equipment used was PASI Earth Resistivity Meter for (2-D) and Petro zenith Terrameter for (1-D) for geophysical measurements. Hydrohysicochemical analysis was also carried out to check for contaminant plumes present in the study areas.

The following gives the data and the interpretation of the data acquired using

6. Ip2win software for 1-Dimension.
7. DIPROFWIN and RES2DINV softwares for 2-Dimensional inversion.
8. Hydrophysicochemical analysis of water samples in the study areas.

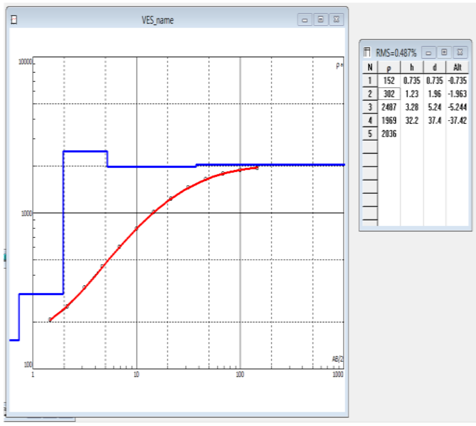

Figure 1: 1-D VES for Military Hospital

This is the 1-D VES for Military Hospital and it shows the depth of groundwater as 37.4m. It has A- type VES curve.

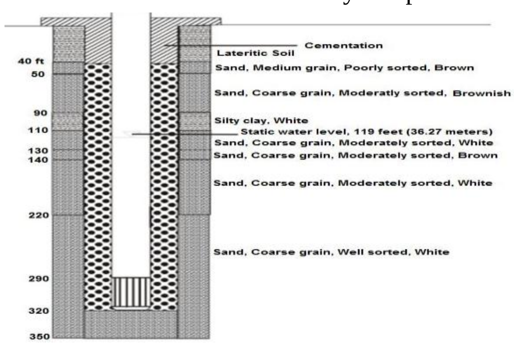

Figure 2. Borehole Lithology for Ihama / Boundary road

This is the borehole lithology for Ihama/Boundary road. It shows different stones found underground as one drills into the ground as Lithology is the study of stones. From figure 2, it can be seen that at the depth of 36.27m, static water level was observed and at 320ft which is 97.6m, the depth of groundwater was realized. The depth of groundwater realized with iteration method above, for 1-D VES which is 100m, is in line with the depth of groundwater, 97.6m, realized from the lithology of existing borehole around Ihama/Boundary road.

The Survey Diagrams

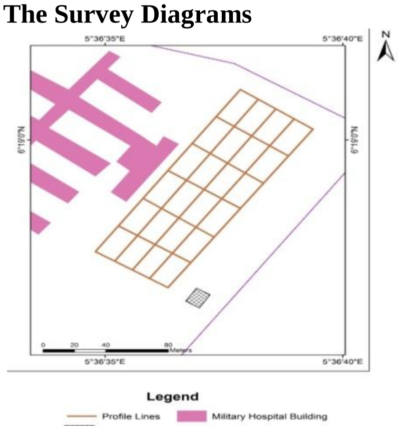

Figure 3: Rectangular Gridlines of Military Hospital

This is the survey diagram showing the rectangular gridlines at Military hospital. The readings were taken along the vertical and horizontal lines of the grid. There are about seven (7) vertical lines and five (5) horizontal lines which make up twelve (12) profiles in military hospital.

Theory of Resistivity

Resistivity is the inverse of conductivity and it is an electrical property of rocks that is related to rock lithology which has controlling factors like bulk rock porosity, pore structure, e.t.c. it is possible to convert the resistivity data into a geological picture by knowing the typical resistivity values and geology of the surveyed area [21]. The resistivities of Laterite and lateritic soil are from 120 - 750Ωm and 800 - 1500Ωm respectively [22].

Resistivity method is observed to be the oldest geophysical technique [23]. The law used in resistivity surveys is Ohm's Law which governs the flow of current in the ground. The equation for Ohm's Law in vector form is given by

$$J = \sigma E \qquad (1)$$

σ is the conductivity, J is the current density and E is the electric field intensity. At the field we measure the electric field potential.

$$E = -\nabla\phi \qquad (2)$$

From equations(1)and(2), we get

$$J = -\sigma\nabla\phi \qquad (3)$$

$$\nabla . J = \left(\frac{I}{\Delta V}\right)\delta(x - x_s)\delta(y - y_s)\delta(z - z_s) \qquad (4)$$

where δ is the Dirac delta function. Therefore equation (3) can be rewritten as

$$-\nabla . [\sigma(x, y, z)\nabla\phi(x, y, z)] = \left(\frac{I}{\Delta V}\right)\delta(x - x_s)\delta(y - y_s)\delta(z - z_s) (5)$$

This is the basic equation.

The equipotential surfaces have a hemisphere shape, and the current flow is perpendicular to the equipotential surface. The potential in this case is given by

$$\phi = \frac{\rho I}{2\pi r} \qquad (6)$$

Where r, is the distance of a point in the medium from the electrode.

$$\phi = \frac{\rho I}{2\pi}\left(\frac{1}{r_{c_1}} - \frac{1}{r_{c_2}}\right) \qquad (7)$$

where$r_{c_1}$and$r_{c_2}$are distances of the point from the first and second current electrodes. Where a ≠ b ≠ c ≠ d ≠ e ≠ f.

In practice, it is the potential difference between two points that is measured. A typical arrangement with 4 electrodes is shown in Figure4.

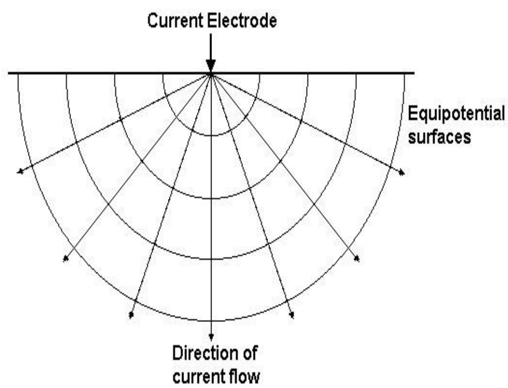

Figure4: The flow of current radially [24].

The figure above shows how current is distributed radially under the ground when geophysical survey is being carried out in the field.

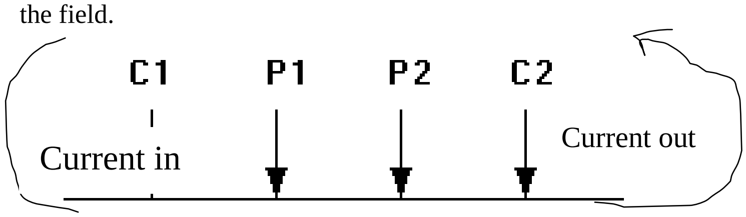

Figure 5: Current and Potential electrodes. [24]

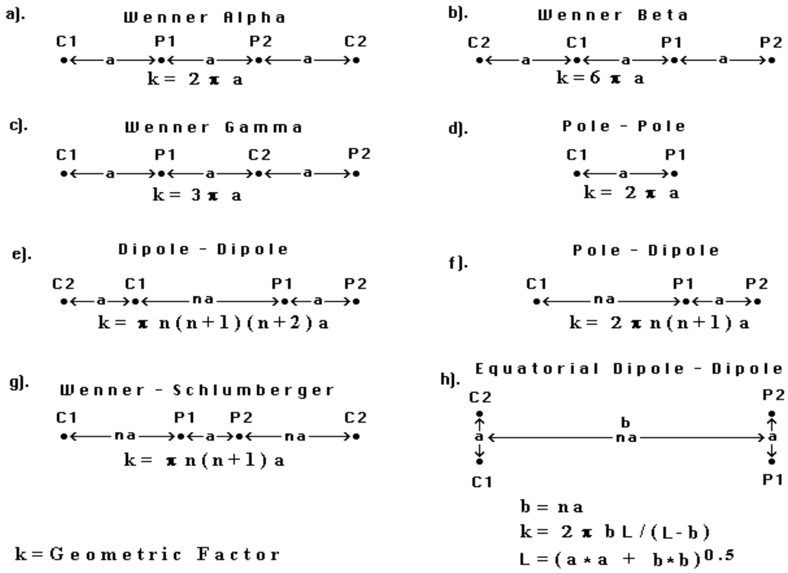

Figure 6: Some array diagrams with geometric factors. [24]

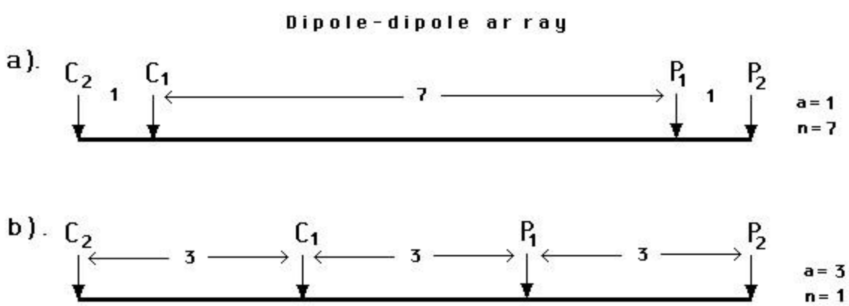

Figure7: Dipole dipole arrangements [24]

RESULTS AND DISCUSSION

This area does not experience natural purification as it contains injection wells which are cased since casing hinders natural purification to take place. In addition, being that it is a military environment, there might be presence of some metals as parts of weapon used in wars which in turn might have effect on the groundwater around the environment.

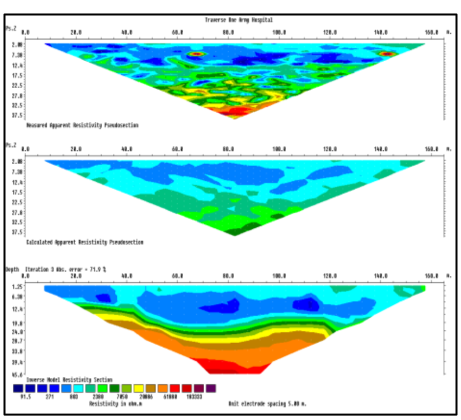

Figure 8. Inversion image of 2-DResistivity for Military Hospital Profile One using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile one using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes lie between 27m-115m electrode spacing and 6.38m-12.4m depth. The depth of groundwater from 1-D VES for military hospital is 37.4m. This shows that the plumes are migrating and the area is being contaminated as years go by.

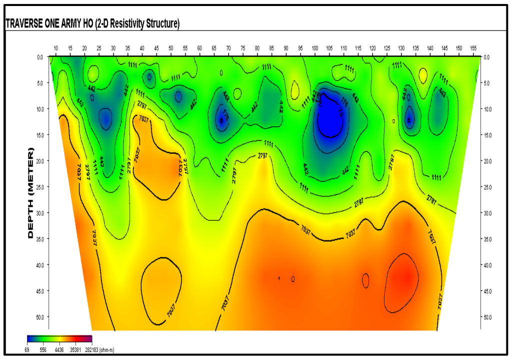

Figure9:InversionImageof 2-DResistivity for Military Hospital Profile one using DIPRO Software

The inversion images of 2-D resistivity for military hospital, EDHA, and Agbor Park profiles using DIPRO software show similar results with Res2D software but the plumes lie around the contour lines.

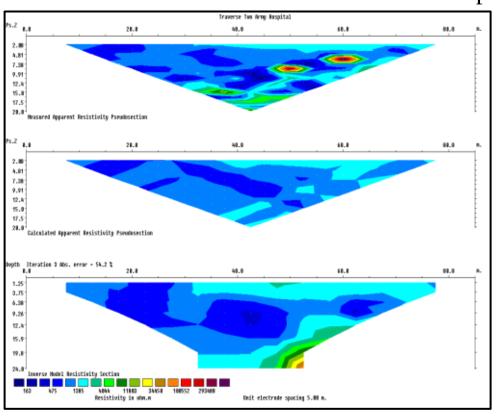

Figure10.Inversionimageof 2-DResistivity for Military Hospital Profile Two using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile two using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes lie between 15m - 67m electrode spacing and 1.25m – 12.4m depth. The depth of groundwater from the lithology or existing boreholes around military hospital is 100m. This shows that the plumes are migrating and the area is being contaminated as years go by.

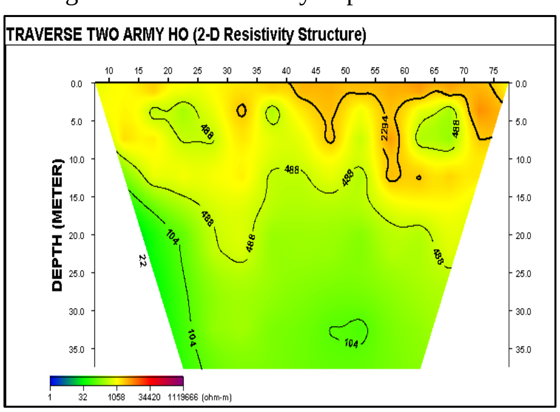

Figure11: Inversion Image of 2-DResistivity for Military Hospital Profile two using DIPRO Software

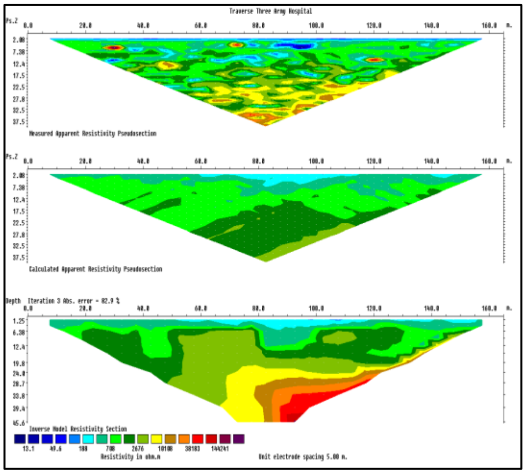

Figure 12: Inversion image of 2-D Resistivity for Military Hospital Profile three using Res2Dinv software.

This is the inversion image of 2-D resistivity for military hospital profile three using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes are not visible though the plumes are present but at very low depth.

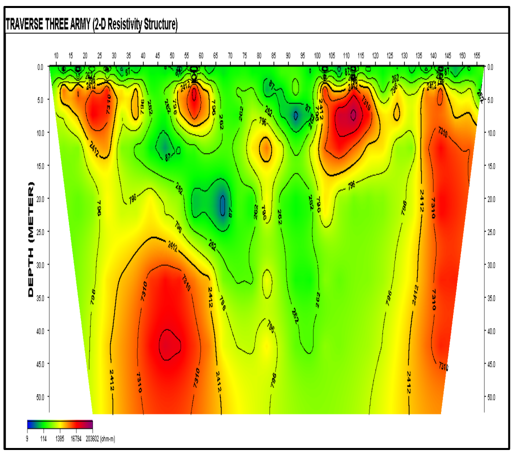

Figure13: Inversion Image of 2-DResistivity for Military Hospital Profile three using DIPRO Software

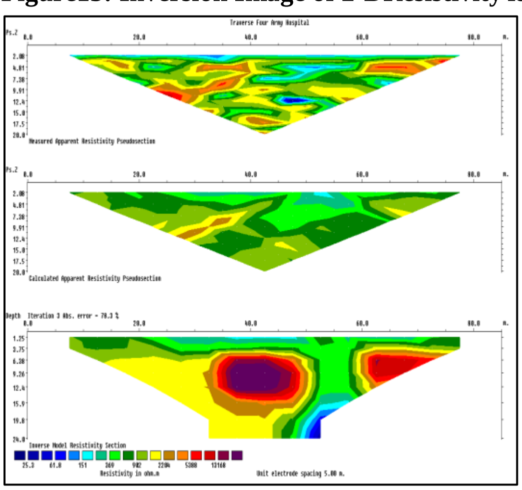

Figure14: Inversion image of 2-DResistivity for Military Hospital Profile four using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile four using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes lie between 50m - 55m electrode spacing and 19.8m – 24.0m depth. The depth of groundwater from the lithology or existing boreholes around military hospital is 100m. This shows that the plumes are migrating and the area is being contaminated as years go by. Besides, from 6.38m – 12.4m depth and 35m - 45m electrode spacing, it can be seen that there is a hollow at the centre.

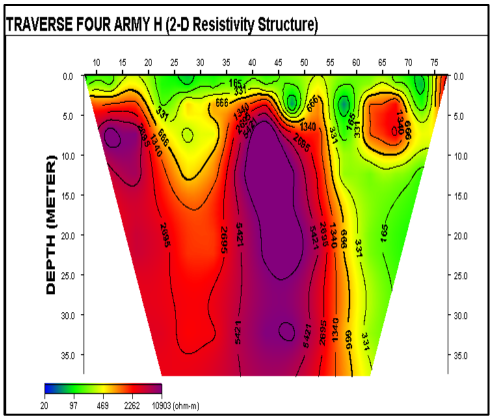

Figure15: Inversion Image of 2-DResistivity for Military Hospital Profile four using DIPRO Software

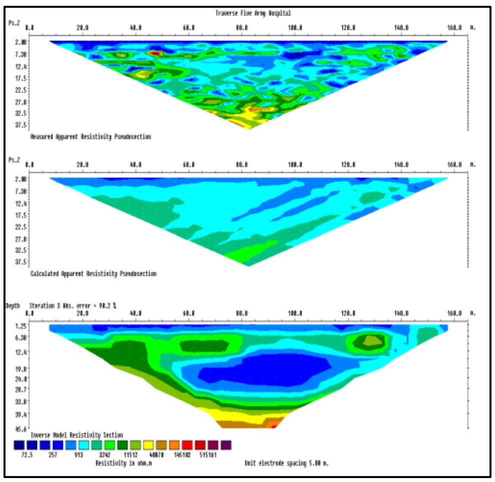

Figure16: Inversion image of 2-DResistivity for Military Hospital Profile five using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile five using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes lie between 25m - 135m electrode spacing and 1.25m – 24.8m depth. The depth of groundwater from the lithology or existing boreholes around military hospital is 100m. This shows that the plumes are migrating and the area is being contaminated as years go by.

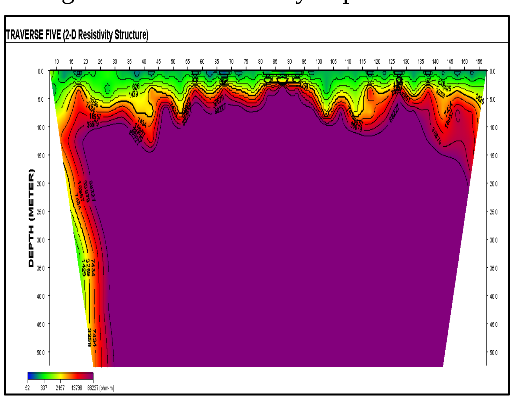

Figure17: Inversion Image of 2-DResistivity for Military Hospital Profile five using DIPRO Software

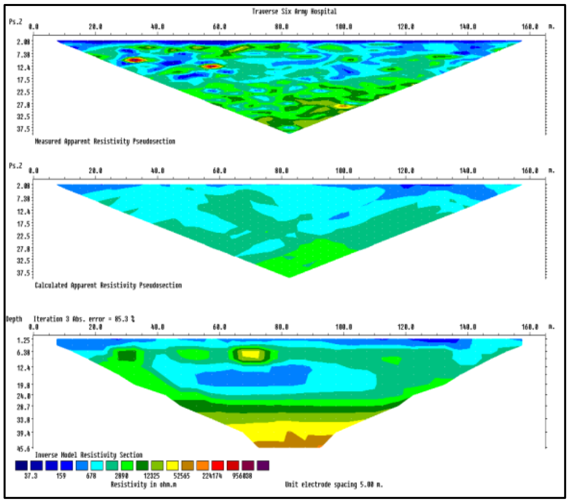

Figure18: Inversion image of 2-DResistivity for Military Hospital Profile six using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile six using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes lie at a shallow depth of 1.25m but spread horizontally between 25m - 135m electrode spacing. The depth of groundwater from the lithology or existing boreholes around military hospital is 100m. This shows that the plumes are migrating and the area is being contaminated as years go by.

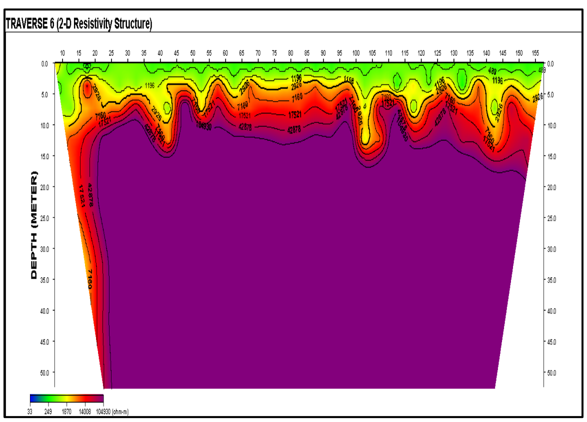

Figure19: Inversion Image of 2-DResistivity for Military Hospital Profile six using DIPRO Software

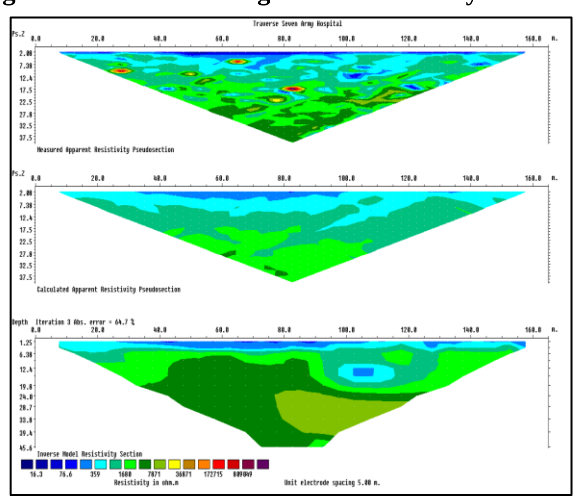

Figure20: Inversion image of 2-DResistivity for Military Hospital Profile Seven using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile six using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes lie at a shallow depth of 1.25m but spread horizontally between 40m - 90m electrode spacing. The depth of groundwater from the lithology or existing boreholes around military hospital is 100m. This shows that the plumes are migrating and the area is being contaminated as years go by.

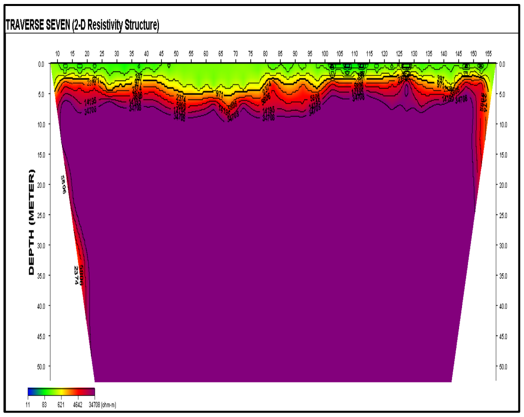

Figure21: Inversion Image of 2-DResistivity for Military Hospital Profile Seven using DIPRO Software

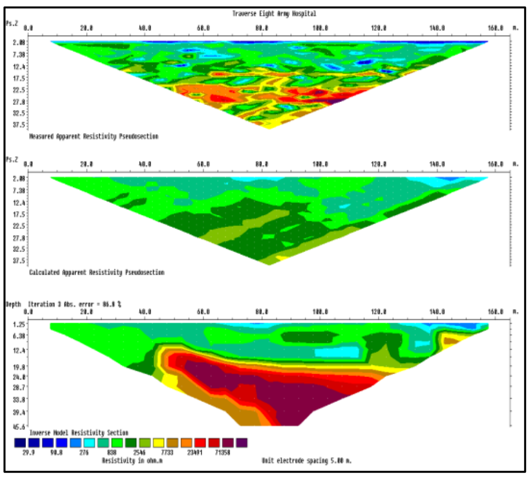

Figure22: Inversion image of 2-DResistivity for Military Hospital Profile Eight using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile eight using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes are not visible though the plumes are present but at very low depth.

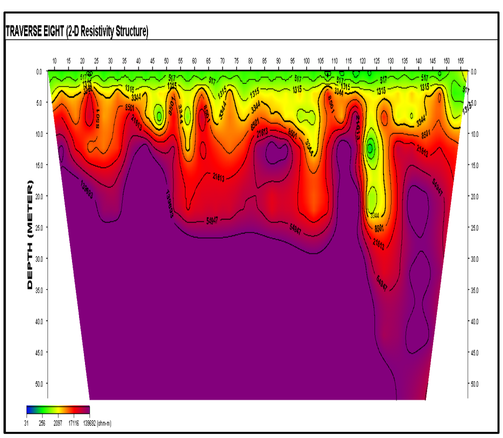

Figure23: Inversion Image of 2-DResistivity for Military Hospital Profile eight using DIPRO Software

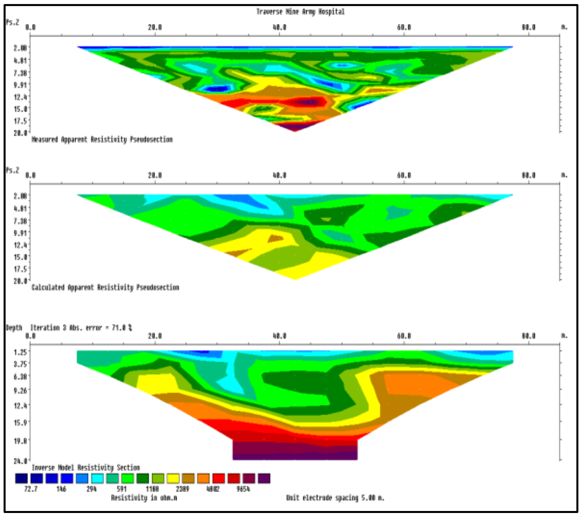

Figure24: Inversion image of 2-DResistivity for Military Hospital Profile Nine using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile nine using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes lie at a shallow depth of 1.25m but spread horizontally between 25m - 28m electrode spacing. The depth of groundwater from the lithology or existing boreholes around military hospital is 100m. This shows that the plumes are migrating and the area is being contaminated as years go by.

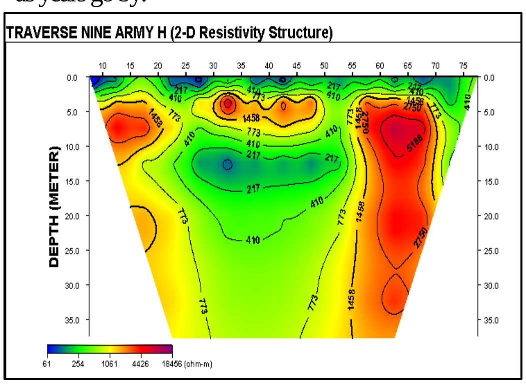

Figure25: Inversion Image of 2-DResistivity for Military Hospital Profile Nine using DIPRO Software

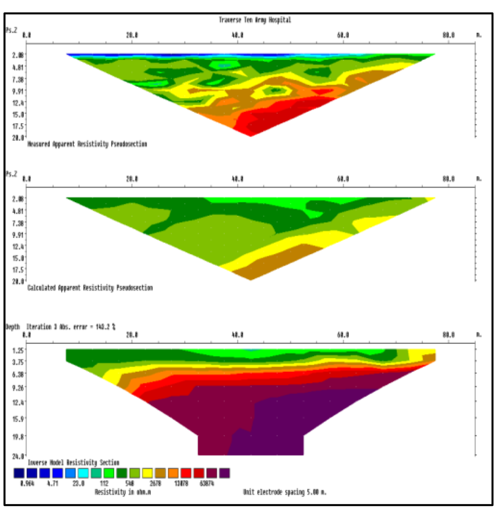

Figure26: Inversion image of 2-DResistivity for Military Hospital Profile Ten using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile ten using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes are not visible though the plumes are present but at very low depth.

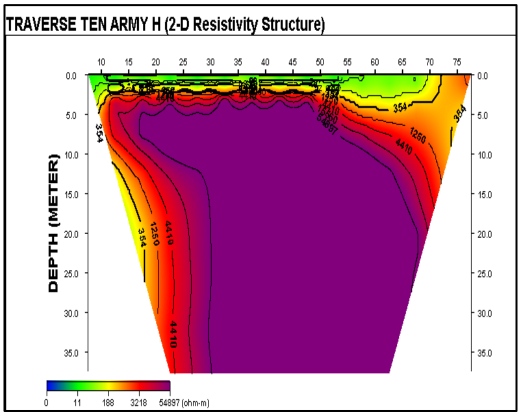

Figure27: Inversion Image of 2-DResistivity for Military Hospital Profile Ten using DIPRO software

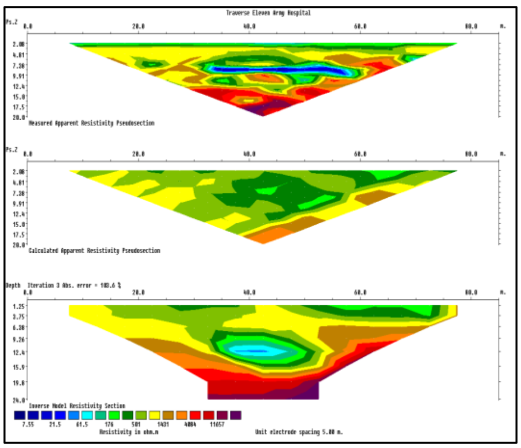

Figure 28: Inversion image of 2-DResistivity for Military Hospital Profile Eleven using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile eleven using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes are not visible though the plumes are present but at very low depth.

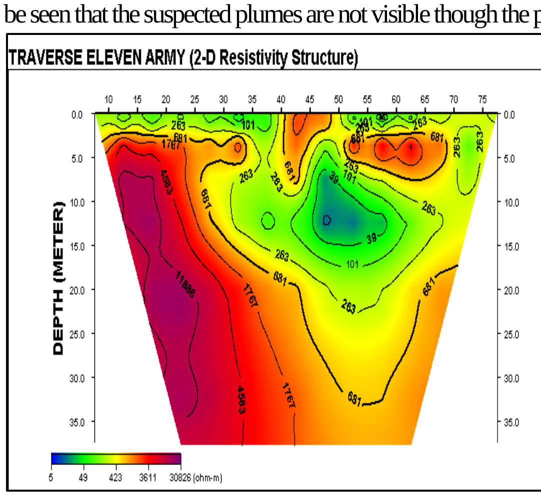

Figure29: Inversion Image of 2-DResistivity for Military Hospital Profile Eleven using DIPRO software

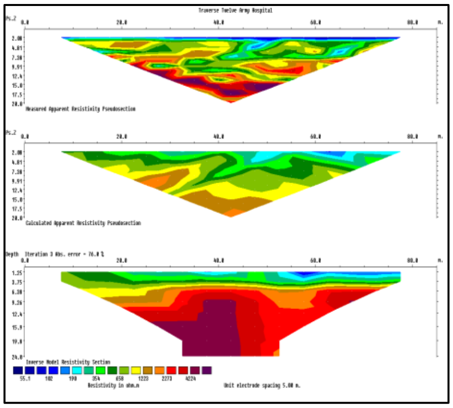

Figure 30: Inversion image of 2-DResistivity for Military Hospital Profile Twelve using Res2Dinv software

This is the inversion image of 2-D resistivity for military hospital profile twelve using Res2D software. From the inverse model resistivity section, it can be seen that the suspected plumes lie at a shallow depth of 1.25m but spread horizontally between 55m - 60m electrode spacing. The depth of groundwater from the lithology or existing boreholes around military hospital is 100m. This shows that the plumes are migrating and the area is being contaminated as years go by.

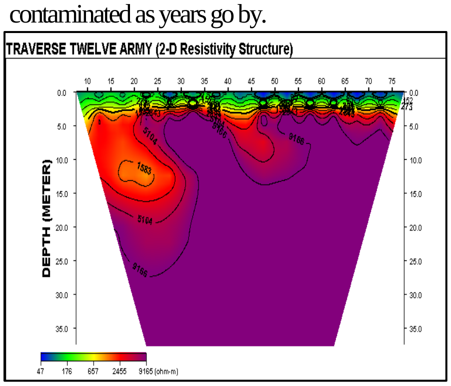

Figure31: Inversion Image of 2-DResistivity for Military Hospital Profile twelve using DIPRO software

Results of Hydrophysico Chemical Analysis of water

Table 1: Hydrophysico Chemical Analysis of water

S/N	PARAMETER	UNIT	MILITARY BASE	NSDWQ (maximum permitted level)
1	TURBIDITY	NTU	1.9	5
2	SO_4^{2-}	mg/L	6.872	100
3	NO_3 - N	mg/L	0.749	50
4	Colour	Pt.Co	11	15
5	Cl	mg/L	999.69	250
6	Electrical Conductivity	µS/cm	25000.0	1000
7	TDS	mg/L	12500.0	500
8	Hardness	mg/L	513.40	150
9	Fe	mg/L	0.397	0.3
10	Cu	mg/L	0.002	1
11	Pb	mg/L	<0.009	0.01
12	Cd	mg/L	<0.001	0.003
13	Cr	mg/L	<0.001	0.05
14	Ni	mg/L	<0.001	0.02
15	Mn	mg/L	<0.002	0.2
16	Zn	mg/L	0.125	3
17	Mg	mg/L	79.352	0.20

(NSDWQ, 2011)

NSDWQ IS NIGERIAN STANDARD FOR DRINKING WATER QUALITY

This table shows the results of water collected from the study area. It is observed that some parameters exceeded the maximum permitted level by the Nigerian standard for drinking water quality, (NSDWQ). It was found that,

1. The chlorine content in all the area exceeded the maximum permitted level
2. Electrical conductivity in the area exceeded the maximum permitted level
3. The total dissolved solids (TDS) in the area exceeded the maximum permitted level
4. Hardness in the area exceeded the maximum permitted level
5. Iron content in exceeded the maximum permitted level.
6. Magnesium (Mg) content in the area exceeded the maximum permitted level

Conclusion

From the 1-Dimensional result, the depth of the Aquifer for Ihama/Boundary Road is 100m, which correlated with Ihama/Boundary Road Lithology or depth of existing borehole in the vicinity of 97m. Also, low resistivity values were seen in the Inversion Images of 2-D Resistivity Profiles, which could be as a result of the presence of contaminant plumes from the well injections since there was direct flow of flood to the aquifer. The Hydrophysicochemical analysis of the water samples in the study area showed that, the chlorine content in all the area exceeded the maximum permitted level, Electrical conductivity in the area exceeded the maximum permitted level, the total dissolved solids (TDS) in the area exceeded the maximum permitted level, Hardness in the area exceeded the maximum permitted level, Iron content in exceeded the maximum permitted level, Magnesium (Mg) content in the area exceeded the maximum permitted level.

REFERENCES

[1] Dawie Han, (2010). Concise Hydrology. Ventus Publishing APSISBN 978-87-7681-536-3

[2] Oyeku, O. T, and A.O. Eludoyin. (2010). Heavy metal contamination of groundwater resources in a Nigeria urban settlement, African Journal of Environmental Science and Technology, Vol. (2),pp.367-376.

[3] Okosun, E.A (1998): Review of the Early Tertiary Stratigraphy of South western Nigeria. Journal of Mining and Geology, 34, pp.27-35

[4] Alile O.M, Oranusi, S.A. and Airen, J.O. (2012). Subsurface Geophysical Investigation and Physiochemical Investigation and Physiochemical/Microbial Analysis of Groundwater contaminant in Ota, South western Nigeria.Volume2(6).Pp179-184.

[5] Kehinde, M.O. (1998). The impact of industrial growth on groundwater quality and availability in: Osuntokun, A(eds). Current Issues in Nigerian Environment, Ibadan Danidan Press.

[6] Adelana, S.M.A, Bale, R. Band M. Wu (2003). Quality of assessment of pollution vulnerability of ground water in Lagos metropolis, South western Nigeria in: proceedings of the aquifer vulnerability Risk Conference AURO3 SalameniaMexico,Vol2,pp.1-17.

[7] Adelana, S.M.A., Bale, R.B, and M.Wu (2004).Water quality in a growing urban centre along the coast of South western Nigeria In: Seilder, K,P. W and XI,R (eds). Research Basic and Hydrological planning, Balkama, The Netherlands, pp.83-92.

[8] Adelana, S.M.A., Bale, R.B., Olasehinde, P.I. and M.Wu (2005). The impact of anthropogenic activities over ground water quality of coastal aquifer in South western Nigeria. Proceeding son Aquifer.

[9] Ajala, O.(2005).Environmental impact of urbanization, culture and the Nigeria in: Fadare et al (eds.) Globalisation, Culture and Nigerian built Environment, Faculty of Environmental Design and Management, OAU,pp.192-199.

[10] Adelana, S.M.A., T. A. Abiye., D.C.W. Nkhuwa., C. Tindinugaya., and M.S. Oga (2008). Urban groundwater management and protection in Sub-Saharan Africa

[11] Eni, D.V., J .Obiefuna., C. Oko., and I. Ekwok. (2011). Impact of urbanization on sub- surface water quality in Calabar municipalty, Nigeria. International Journal of Humanities and Social Sciences, Vol.1, Issue 10, pp.167-172.

[12] Brassington,N.(1988).FieldHydrogeology.GeologicalSocietyofLondon,John Wiley.

[13] MacDonald, A., Davis, J., Calow and J. Chilton (2005). Developing groundwater: A guide to rural water supply, ITDGS Publishing. U.K.

[14] Sajad, M.M., S. Rahim., and T. Tahir. (1998). Chemistry of groundwater of Rawalpinli/Isalama, 24th Conference,Islamba.

[15] Hrelja,H.(2007). Inzenjerskahidrologija. Faculty of civil engineering, university of Sarajevo-Sarajevo.

[16] Prohaska, S. (2003). Hydrology. Faculty of mining and geology. Belgrade.

[17] Baiye, E., (1988). Numan in the Throes of Floods, in: The Guardian, Thursday, October8, pp:9.

[18] Akinyemi, T., (1990). Stemming the Tide of Lagos Floods, in: The Guardian, Friday, July20,pp:7.

[19] Nwaubani, C.(1991). Ogunpa River Leaves Bitter Aftertaste in Tragic Course Through Abeokuta; in: The Guardian, October 21, pp:9.

[20] Edward-Adebiyi, R. (1997). The Story of Ogunpa, in: The Guardian, Saturday, May 17,pp:5.

[21] Thomas, T., (2000). 2D Resistivity and Time – Domain EM-aquifer mapping: a case study, North of lake Naivasha, Kenya.

[22] Reynold, A.E. and Cahill, G.E., (1998). Handbook of Physiology: Adipose Tissue, American Physiological Society, Washington.

[23] Loke, M.H. (2011). Electrical resistivity surveys and data interpretation. in Gupta, H (ed.), Solid Earth Geophysics Encyclopaedia (2nd Edition) "Electrical & Electromagnetic" Springer-Verlag,276-283.

[24] Loke, M.H. (2014): T u t o r i a l : 2-Dand3-Delectricalimagingsurveys. pp28-40