Investigation of the Effect of Highway Runoff along Lagos-Badagry Expressway Using Electrical Resistivity Tomography and Physiochemical Methods

ABSTRACT

Geophysical and physiochemical investigations were carried out along Lagos-Badagry Expressway, Southwest, Nigeria on three locations dominated by highway runoff, with a view to monitoring the effect of highway runoff on nearby groundwater. The locations were: Iyana Isashi, Iyana Era and Agbara. An overview of the subsurface resistivity distribution was achieved employing Vertical Electrical Sounding (VES) using Schlumberger array and 2D resistivity imaging (Wenner array). The ABEM SAS 1000 terrameter was used for both VES and 2D resistivity surveys and the data were analysed using RES2DIN and IPi2win respectively. The VES results showed up to four geoelectric layers consisting of sand, clayey sand, clay and sandy soils. The resistivity at Agbara was found varying from 3.52 Ωm-11 Ωm. This low resistivity value showed a high level of infiltration of highway runoff into the subsurface, thereby causing contamination of the groundwater. Iyana Isashi and Iyana Era have a relatively moderate resistivity value ranging from 103 Ωm-178 Ωm. Physiochemical analysis of groundwater samples collected at each location revealed high electrical conductivity, total dissolved solids and pH values. The results of the borehole sample taken at 32 m away from the profile point at Agbara produced higher values of electrical conductivity and total dissolved solids than those of other locations, hence validating the electrical resistivity surveys, indicating that the groundwater sample from the survey point at Agbara is contaminated.

Keywords: Groundwater, Runoff, Resistivity, Physiochemical and Conductivity.

INTRODUCTION

Runoff is the flow of water that occurs when excess storm water, melt water, or other sources flow over the earth's surface (Chiew et al., 2000). Runoffs from highway or road can be a significant non-point source of pollutants. These arise from the release of a range of toxic contaminants such as heavy metals, Polycyclic Aromatic Hydrocarbon (PAH) from vehicles, road wear and road maintenance activities. Additional contaminants may arise majorly from the release of large amount of pollutant during a traffic accident and de-icing salt applied in cold climate region (Benson et al., 2014).

Heavy metals are produced from vehicular corrosion, tire treads, brake linings. Sources of PAH include asphalt leaching, particles from tire abrasion, automobile exhaust, leakage of petrol and engine oil. Runoff contains a complex mixture of potential toxicants with diverse impact on the environment if discharged untreated. The potential effect of road runoffs on quality environment depends on several factors which include traffic volume, frequency of rainfall, size of receiving surface and groundwater.

Several factors constitute pollution in highway runoff but the parameters frequently monitored include sediments and metals (Yonge et al., 2002). Metals could be either total metals or dissolved metals. Some of these metals such as copper, lead, iron and zinc are very poisonous and injurious to human’s health. Lead interferes with a variety of body processes and it is toxic to many organs and tissues including the heart, bones, intestines, kidneys and reproductive systems. Copper also when dissolved with water can result in gastrointestinal distress and haemolytic anaemia (Patrick, 2002).

Highway runoffs are caused by several factors. One of the major causes of highway runoff in Nigeria is road failure; at every point where there are potholes there is usually runoff (Irish et al., 1998). Another cause of highway runoff is lack of good drainage system. Where there is no good drainage system, the flood resulting from rainfall will not be properly channelled and so result in highway runoff. Excessive rainfall is another cause of highway runoff (Barbosa, 1999).

Pollution from non-point sources such as highway runoff has continued to be a major source of concern for environmental regulatory bodies and other stakeholders all over the world, as they contribute to the pollutant load of the receiving environment, in most cases the water bodies and farmlands. This results to a gradual degradation of the receiving water quality and an eventual impairment of the beneficial uses of such receiving environment (Pitt et al., 1995). The Nigerian situation is further exacerbated by the reality of increasing large-scale importation of old/fairly used vehicles for use on the Nigerian highways.

Lagos is the commercial capital of Nigeria and it's the fastest growing metropolis in Nigeria (and probably in sub-Saharan Africa) with the nation's largest population and network of highways (Ariyo et al., 2013). Hence, there is need for a comprehensive study on the effect of runoff from these highways on the proximate environment.

A wide range of pollutants have been shown to be present in highway runoff with about 75% (by dry weight) of these pollutants derived directly or indirectly from vehicles, road surface degradation, atmospheric sources and road maintenance (Ellis and Revitt, 1991). Heavy metals among others are constantly being studied and monitored in highway runoffs because of their probable mobilization to useable water systems, such as the beaches and underground water, where at elevated concentration levels could cause public health risks (Dwight et al., 2002). As these heavy metals and other pollutants are continuously mobilized to such water bodies and exposed land mass, they ultimately lead to soil and water pollution (Perdikaki and Mason, 1999). The level of the contamination depends on the nature of civil works on the highway, the duration of the antecedent dry period before the rainfall, size of the rainfall, volume of traffic per day of the study site and nature of land use of the adjoining area (Driscoll etal., 1990).

Globally, the concentration, transport and fate of some of these pollutants are usually difficult to generalise in most runoff studies (Grenato and Smith, 1999). Nevertheless, persistent efforts directed at monitoring these pollutants have shown that zinc, lead, copper, cadmium and nickel along with some other heavy metals could all be found in urban and highway runoffs (Marsaleket al., 1997; Mangani*et al*., 2005). Other pollutants that could be found in highway runoff include hydrocarbons and bacteria of human origin such as faecal coliforms (Barret et al., 1993).

Atmospheric deposition refers to substances that are deposited on land surfaces from the air. This deposition can contain pollutants such as nutrients, particulates, PAHs and heavy metals. Deposition can be classified as dry deposition, when pollutants settle out from the surrounding air, and wet deposition, which carries pollutants from the sky through precipitation. Metals are emitted from near and distant industrial sources. Incomplete combustion of fossil fuels contributes nutrients and PAHs in deposition materials. Most of the pollutants associated with vehicles in highway usually originate from engine wear and exhaust, lubricants, rusting, and tire wear. Brake pad wear is a source of copper and zinc, which are the metals most commonly found in highway runoff; tyres contain zinc; some older brake contain lead; and wheel-balance weights are made primarily of lead.

The monitoring of the composition of wet deposition (e.g., rain, sleet, snow) on urban highways and its effects on urban pollution has been an important part of environmental studies in many countries (Manganiet al., 2005; Backstrometal., 2003), where rich data have been generated on the composition of highway and other urban source runoff.

Electrical resistivity method has been successfully applied in exploring several related environmental problems to identify the presence and level of pollutant (Loke, 1999); and to trace and determine time-lapse variations in flows. The method has also been used to monitor groundwater contamination. The measurement is relatively rapid, cheap and non-destructive and provides data coverage both in vertical and horizontal directions. The resistivity values for the dissolved metals in highway runoff can be used as tracer for monitoring highway runoff. Although the other metallic pollutants could theoretically give anomaly to resistivity measurement, the concentrations are very small to practically contribute to conductivity increase in groundwater in the soil.

2.0 MATERIALS AND METHODS

Description of Study Area

The site investigated exists within Lagos-Badagry Expressway, Lagos, Nigeria. Badagry lies on the North bank of Porto Novo creek, an inland waterway that connects Lagos and Republic of Benin. Lagos-Badagry expressway also links toAgbara and Igbesa in Ogun State. Badagry rapidly became a major residential suburb of Lagos after the opening of an Expressway in 1976. There was an automotive assembly plant along the road, and has both Secondary and higher Institutions, such as Lagos State University, Ojo, AdeniranOgunsaya College of Education, Ijanikin and National Postgraduate Medical College, Ijanikin. The presence of higher Institutions along the road increases the level of traffic.

The highway is characterised by several points of runoffs due to road failures. The major points to be studied are Agbara, Iyana Era and Iyana Isashi. The points are dominated by highway runoff due to the potholes on the highway.

Geology of Study Area

The study area is along Lagos – Badagry expressway and is located in Ojo and Badagry Local Governments, within Lagos West in the Southwest part of Nigeria. The geological setting of the study area reveals that it lies solely within the extensive Dahomey basin, the basin extending almost from Accra to Lagos. The littoral and lagoon deposit of recent sediment underlies the area. The coastal belt varies from about 8 km near the Republic of Benin border to 24 km towards the Eastern end of the Lagos Lagoon (Nton, 2001). The area consists of sediment of clay, unconsolidated sands and mud, with a varying proportion of vegetable matter along the coastal areas, while the alluvial deposit consists of coarse claying unsorted sand with clay lenses and occasional pebble beds (Alabi et. al., 2010).The study area falls into the ecological zone of wetland soils and lies on the coast where inland water empties into the Atlantic Ocean. It has a geologic origin of deltaic basis and tidal flats (Nton, 2001).

Physiography and Climate of the Study Area

Lagos State is located in the south-western coast of Nigeria, approximately between latitudes $6^{0}22^{'}$N and $6^{0}52^{'}$N and longitudes $2^{0}42^{'}$E and $3^{0}42$’E (Odumosu , et. al., 1999). It is bounded on the west by the Republic of Benin while the southern boundary of the state is formed by the 180 km long Atlantic coastline. Its northern and eastern boundaries are shared with Ogun State. Lagos is the largest city in Nigeria and loosely classified into two main geographical areas – the "Island" and the "Mainland" and was the capital city of the country before it was replaced with Abuja on 12th December, 1991. It remains the commercial nerve centre of Nigeria. The city is a typical example in the history of growth and development of urban areas in Nigeria. The main occupations of the people of the study area are farming and fishing.

Two main seasons exist in the study areas. These are rainy and dry seasons; rainy season existsbetween April to July (heavy rainy season) and October to November (milder rainy season) while a very brief dry season occurs in August and September, and long dry season spell occurs from December to March.

The study area has wet equatorial climate with mean annual rainfall above 1800 mm and experiences an average annual temperature of 27^{0}C. Humidity is high in the rainy season and drops to its lowest level during December due to harmattan butgenerally high and rarely below 70% throughout the year. The vegetation cover is dominated by swamp forest, wetlands and tropical swamp forest comprising of fresh waters and mangrove. Generally, the pattern of relief in the study area reflects the coastal location of the state. Water is the most significant topographic feature in the study area. Water and wetlands cover over 40% of the total land area within Lagos State and an additional 12% is subject to seasonal flooding (Iwugo et. al., 2003).

Sites Description and Accessibility

The major points studied areIyana Era, Iyana Isashiand Agbara and its environs.Agbara is under Ado-Odo/ Ota Local Government Area, Ogun State and is easily accessible from Mile 2. Other routes include the LASU-Iba and the Atan-Ota roads. There are two commercial areas; one located along Abeokuta Road, one of the primary roads on the estate and, the other area is a strip of land backing the Lagos-Badagry expressway. On the former is located the town centre, which accommodates a shopping arcade (already completed but presently belongs to Messrs First Medical Industries Limited) and a number of community facilities.

Iyana Era and Iyana Isashi are both under Ojo Local Government Area, Lagos. The points are along Lagos-Badagry expressway. The highway is characterised by several points of runoffs due to road failure. They are known for regular vehicular traffic due to the bad nature of the road. We can link the Lagos- Badagry expressway from Ikeja, which is the capital of Lagos State, by going throughOshodi to Mile 2 and from Mile 2 to Lagos-Badagry expressway.

Data Acquisition Method

In this study, three methods were adopted: Vertical Electrical Sounding (VES), Two-Dimensional (2D) electrical resistivity survey, and physiochemical methods. The combination is aimed at enhancing better information of the subsurface.

ABEM terrameter SAS 1000 and its accessories were used for the electrical resistivity serveys and powered by a 12V Direct Current (DC) power source, while HACH 44600-00 Conductivity/TDS meter was used for water analysis. The pH was determined using a HACH sensor 3 pH meter.

Nine profiles were established for the electrical resistivity method, and each had a length of 200 m. Three profiles were established in each location. The electrode spread (Wenner array configuration) for data collection along the three profiles in each of the locations used electrode spacing of 10 m, 20 m, 30 m and 40 m.

For the physiochemical method, two samples of water were collected from each location. At Iyana Isashi, the first borehole sample was taken at Bimpy petrol station, Iyana Isashi Bus- Stop and was 25 m away from the survey point. The second sample of water was taken from a borehole at Number 8, Oloruntoyin Street, Amosun Community Mebamu, Iyana Isashi Bus Stop, 100 m away from the survey point.

At Iyana Era, the first sample of water was taken from a borehole at Talatu Food Canteen, Iyana Era Bus-Stop, about 20 m away from the survey point while the second sample was taken from Number 10, Onijanikin Street, Iyana Era Bus stop, 120 m away from the survey point

At Agbara, the first water sample was taken at Jeba's stores, 22m away from the survey point, opposite Agbara market, while the second sample was taken at The Redeemed Christian Church of God, Rose of Sharon, Jida road Agbara, about 150 m away from the survey point. For each sample of water collected, the P^H, Electrical Conductivity (EC), Total Dissolved Solid (TDS) and temperature were tested.

Fig.1: Location Map of Iyana Isashi showing the survey points.

Fig. 2: Location Map of Iyana Era showing the survey points

Fig. 3: Location map of Agbara showing the survey points

Data Analysis

The Wenner data was analysed using RES2DIN software which is a 2D forward modelling program which calculates the apparent resistivity pseudo section for a user defined 2D subsurface model. The program helps to choose the method to calculate the apparent resistivity values. It indicates the contours in the simulated section produced by the different arrays over the same structure. The Vertical Electrical Sounding data was analysed using Ipi2win, while the water samples data were analysed using Microsoft office excel.

3.0 RESULTS AND DISCUSSION

Three (3) 2D electrical resistivity tomography and three (3) Vertical Electrical Soundings were established at each location and the results are displayed in Figure 4 to Figure 21.The inverted resistivity images made it possible to obtain information on the variations of resistivity to a depth of about 30 m. The upper image is the pseudo section data, while the lower one is the inverted image of the raw data.

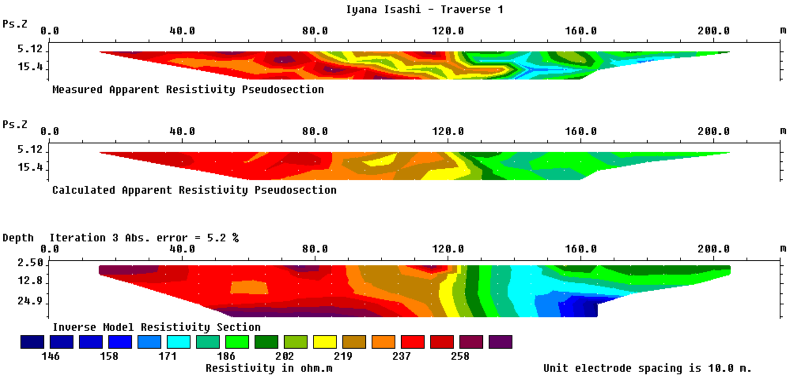


Fig. 4: Profile 1 at Iyana Isashi

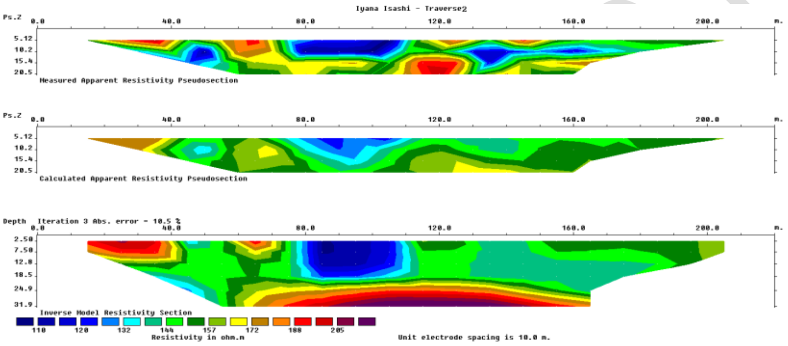


Fig. 5: Profile 2 at Iyana Isashi

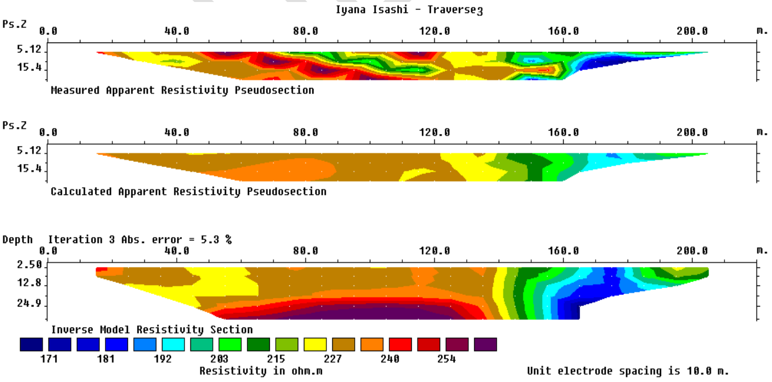


Fig. 6: Profile 3 at Iyana Isashi

Three profiles were established at Iyana Isashi, and the results are shown in Figure 4-6.. For profile 1 (Fig. 4), the lateral extent is 200 m. At the lateral distance of 15 m to 120 m, to a depth of 24.9 m, a formation of clayey sand was observed with resistivity value ranging from 219 Ωm to 237 Ωm while clay settlement with resistivity slightly above 50 Ωm is confined within the sand from a depth of 2.5 m to 25 m at the lateral distance of 120 m to 160 m. At the lateral distance of 40 m to 90 m, to a depth of 30 m, a formation of sand was observed with resistivity value of 258 Ωm.

For profile 2 (Fig. 5), at a lateral distance of 15 m to 40 m to the depth of 12.8 m from the surface, a formation of clayey sand was observed with resistivity value ranging from 188 Ωm to 205 Ωm. At the lateral distance of 80 m to 100 m to the depth of 18.5m from the surface, a formation of clay was observed with resistivity value ranging from 50 Ωm to 100 Ωm. At the lateral distance 110 m to 200 m to a depth of 24 m from the surface, a formation of sand was observed with resistivity value ranging from 132 Ωm to 144 Ωm, while a formation of clayey sand was observed at the depth of 31.9 m with resistivity of 205 Ωm.

Figure 6 shows profile 3 at Iyana Isashi. At a distance of 60 m to 140 m to a depth of 24.9 m, clayey sand was observed with resistivity value ranging from 227 Ωm to 248 Ωm, while a formation of clay content was observed at a lateral distance of 160 m to 180 m, to a depth of 30 m from the surface with the resistivity value of 100 Ωm. From lateral distance of 40 m to 140 m to a depth of 24 m to 30 m, a formation of clayey sand was observed with the resistivity value of 254 Ωm.

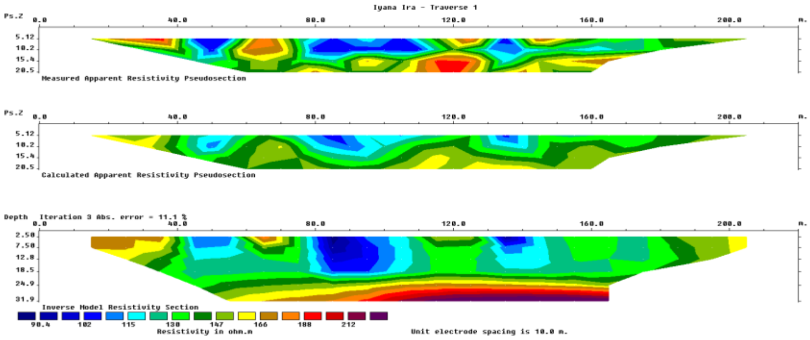


Fig. 7: Profile 1 at Iyana Era

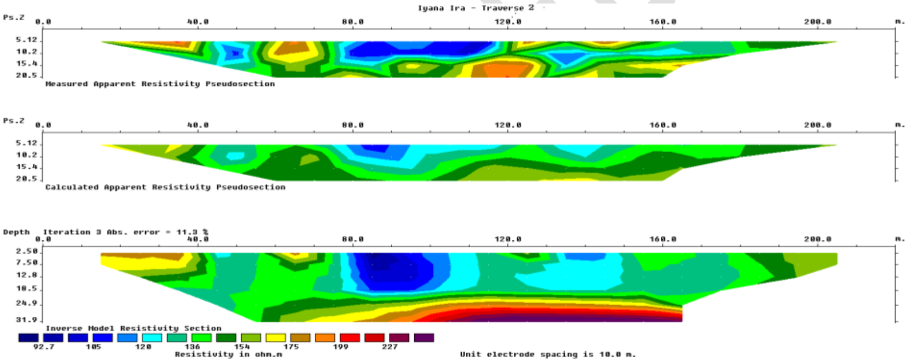


Fig. 8: Profile 2 at Iyana Era

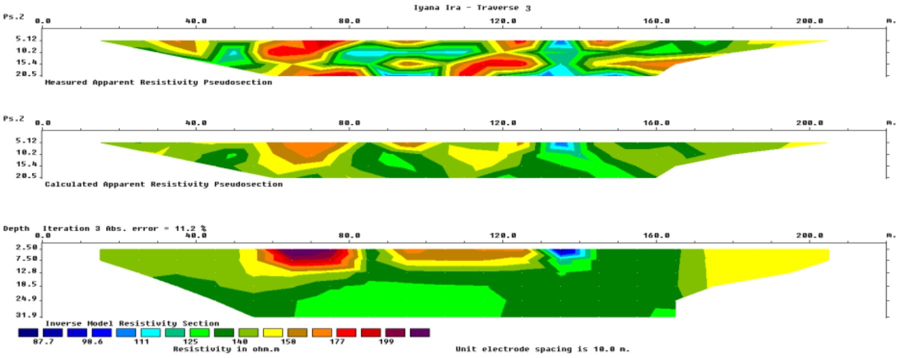


Fig. 9: Profile 3 at Iyana Era

Figure 7 is profile 1 at Iyana Era. It depicts low resistivity value of 92.4 Ωm at a lateral distance of 80 m to 100 m to a depth of 25 m from the surface, indicating clay formation, while a formation of sand with resistivity value ranging from 130 Ωm to 147 Ωm was observed between 40 m to 200 m along the profile to a depth of 24.9 m from the surface. A relatively low resistivity value ranging from 166 Ωm to 212 Ωm was also observed from 90 m to 160 m at 25 m to 31.9 m depth.

Figure 8 is profile 2 at Iyana Era. This profile is dominated by dry clay, mud and sand from 40 m to 200 m at depth about 31.9 m from the surface with the resistivity ranging from 136 Ωm to 154 Ωm, but clay sediment is formed within the sand and mud at 80 m to about 105 m, along the profile at depth 18.5 m from the surface with the resistivity ranging from 92.7 Ωm to 120 Ωm. At 15 m to 40 m and from 80 m to 170 m on the profile at depth 2.5 m to 7.5 m and 31.9 m from the surface are characterized by relatively low resistivity, ranging from 175 Ωm to 227 Ωm. This was observed to be clayey sand formation.

Figure 9 is profile 3 at Iyana Era. At 15 m to 165 m along the profile from the surface up to 31.9 m depth is characterized by low resistivity, varying from 125 Ωm to 140 Ωm. Confined within this sandy clay formation, are clay formation with low resistivity value of 87.7 Ωm to 100 Ωm at lateral distance of 120 m to 130 m to a depth of 7.5 m from the surface and sandy and clayey sand with resistivity values ranging from 177 Ωm to 199 Ωm at 55; 158 Ωm at 90 m to 125 m respectively

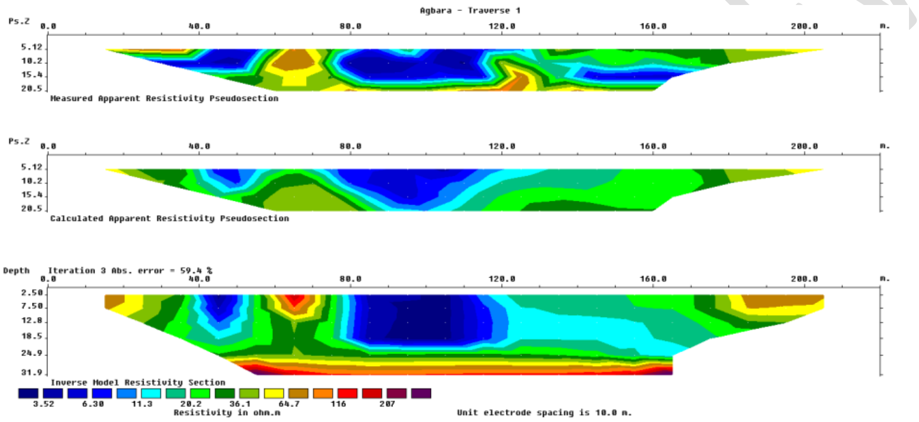


Fig. 10: Profile 1 at Agbara

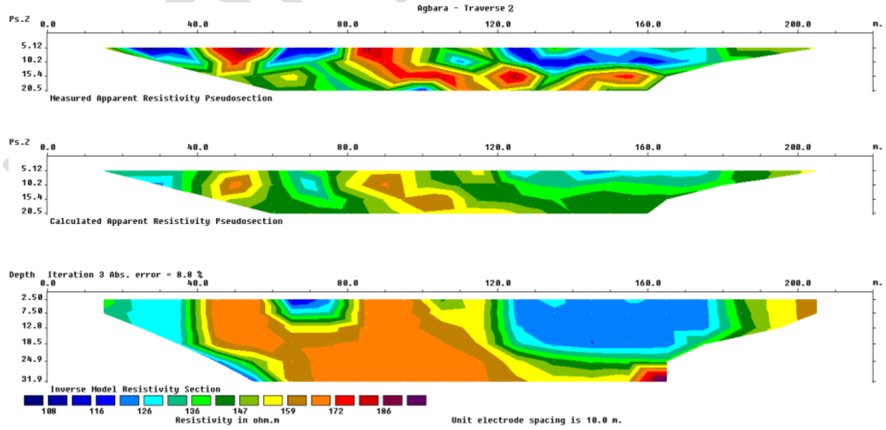


Fig. 11: Profile 2 at Agbara

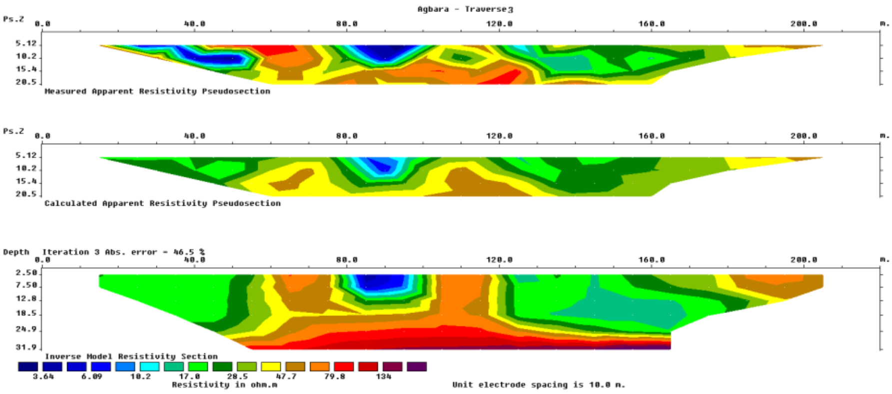


Fig. 12: Profile 3 at Agbara.

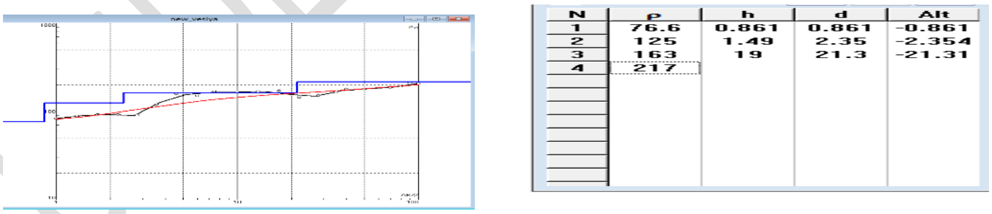
For profile 1 at Agbara (Fig. 10), there is low resistivity ranging from 3.52 Ωm to 11.3 Ωm at lateral distance of 80m to 120m to a depth of 24.9m from the surface.This was observed to be peat mixed with clay. A large formation of clayey sand is observed at the depth of 30 m to 31.9 m with resistivity from 116 Ωm to 287 Ωm, from 40 m to 160 m spread along the profile. Above this formation is a layer of relatively low resistivity.

Figure 11 is profile 2 at Agbara. From of 120 m to 180 m spread and to a depth of 24.9 m from the surface, is a relatively low resistivity with value ranging from 110 Ωm to 116 Ωm. This could be as a result of clay compacted. From 40 m to 100 m lateral spread, is a zone of resistivity ranging from 159 Ωm to 186 Ωm. This was observed to be sandy clay formation. Confined within this zone, is a local zone of relatively low resistivity of 110 Ωm to 116 Ωm at 60 m to 80 m spread and to a depth of 7.5 m from the surface.

For profile 3 at Agbara (Fig 12), the spread from 60 m to 120 m, from the surface to 18.5 m depth was characterized by resistivity in the range of 47.7Ωm to 79.8 Ωm. This was observed to spread from 40m to 160 m from 34.9 m depth to 31.9 m with resistivity from 79.8Ωmto 134 Ωm, indicating sandy clay. Within this zone, is a zone of low resistivity ranging from 3.44 Ωm to 18.2 Ωm, from 80 m to 100 m spread and to a depth of 18.5 m from the surface. This was observed to be peat mixed with clay.From 120m spread up to 180 m and to a depth of 24.9 m from the surface, is a zone of relatively low resistivity of 17.8 Ωm to 22.5 Ωm. This was also observed at 15 m to 55 m along the profile.

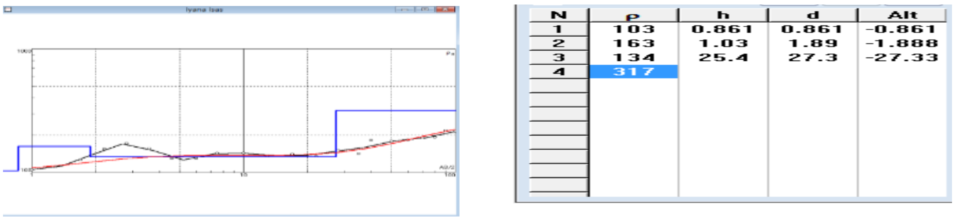
Vertical Electrical Sounding Results

The 1D geoelectric sections resulting from the interpretation of the resistivity data comprise VES 1- 3 in each location. These results revealed four geoelectric layers each as depicted in Figure 13 – 21.



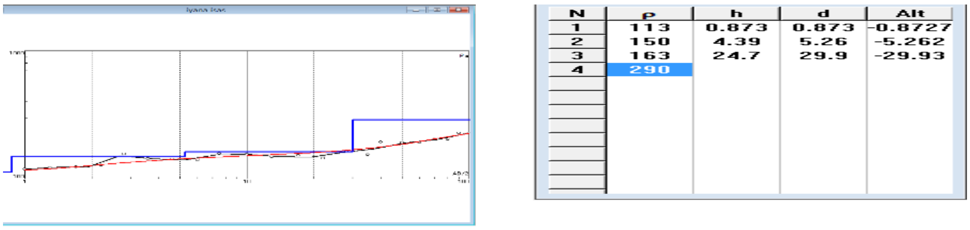
N	ρ	h	d	Alt
1	76.6	0.861	0.861	-0.861
2	125	1.49	2.35	-2.354
3	163	19	21.3	-21.31
4	217			

Fig . 13: VES 1at Iyana Isashi



N	ρ	h	d	Alt
1	103	0.861	0.861	-0.861
2	163	1.03	1.89	-1.888
3	134	25.4	27.3	-27.33
4	317			

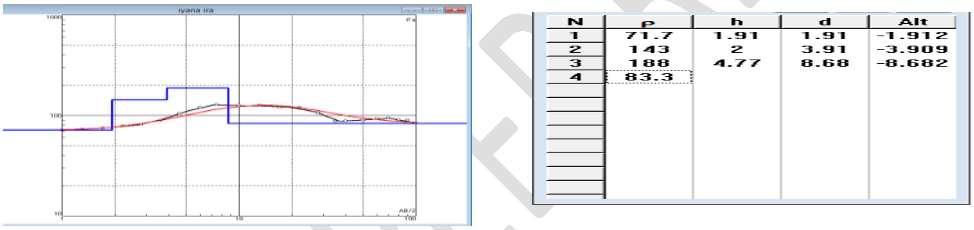
Fig. 14: VES 2 at Iyana Isashi



N	ρ	h	d	Alt
1	113	0.873	0.873	-0.8727
2	150	4.39	5.26	-5.262
3	163	24.7	29.9	-29.93
4	290			

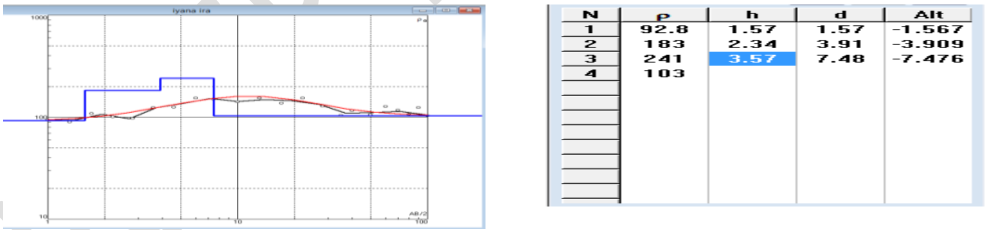
Fig . 15: VES 3 at Iyana Isashi

VES 1 in the first location (Iyana Isashi) are characterized with low resistivity of 76.6 Ωm at the first layer and thickness of 0.8 m, indicating clay formation. At the third layer, at a depth of 21.3 m, the resistivity is relatively high with a value of 163 Ωm. This layer has a high thickness of 19 m which may serve as good protective layer for the underlying rock. The fourth layer of VES 1 has a resistivity but the thickness and depth could not be determined as the current terminated within this layer. The geo-electric section of VES 2 and VES 3 are closely related; their first layers are characterized by relatively low resistivity of 103 Ωm and 113 Ωm respectively, which depicts alluvium soil, while their third layers are characterized by high thickness at the depth of almost 30 m.



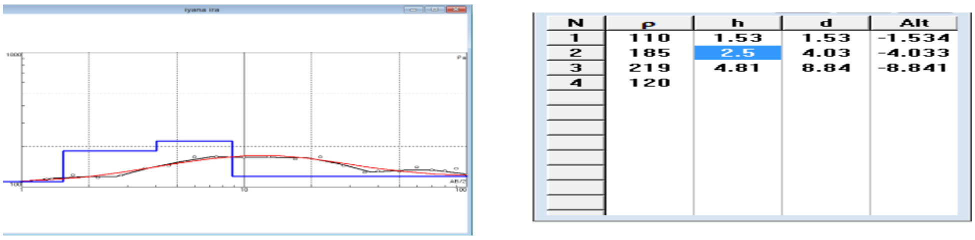
N	ρ	h	d	Alt
1	71.7	1.91	1.91	-1.912
2	143	2	3.91	-3.909
3	188	4.77	8.68	-8.682
4	83.3			

Fig. 16: VES 1at Iyana Era



N	ρ	h	d	Alt
1	92.8	1.57	1.57	-1.567
2	183	2.34	3.91	-3.909
3	241	3.57	7.48	-7.476
4	103			

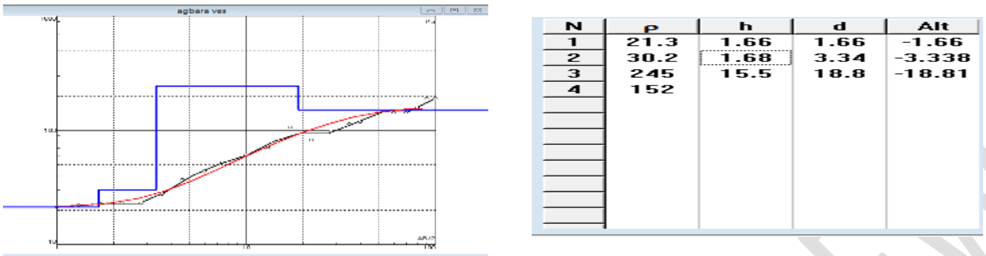
Fig. 17: VES 2 at Iyana Era



N	ρ	h	d	Alt
1	110	1.53	1.53	-1.534
2	185	2.5	4.03	-4.033
3	219	4.81	8.84	-8.841
4	120			

Fig . 18: VES 3 at Iyana Era

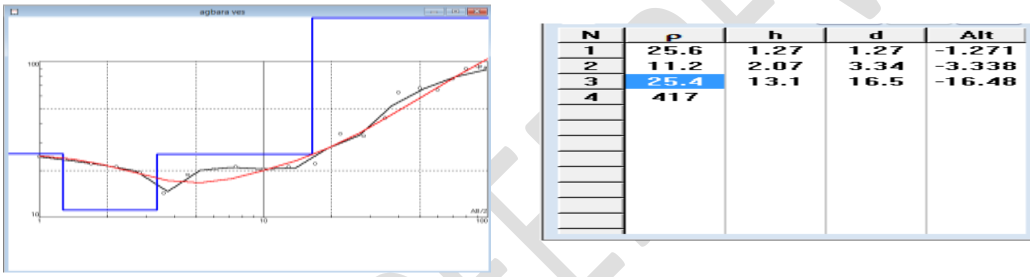
For location 2 (Iyana Isashi), the first layers of VES 1 and 2 are characterized by relatively low resistivity of 71.7 Ωm and 92.8 Ωm respectively which may delineate the presence of clay content with average thickness of 3.91m. The third layers of VES 1 and 2 are relatively high, indicating the presence of alluvium soil. The first layer of VES 3 also has a relatively low resistivity of 110 Ωm at a depth of 1.53 m, while that of the second layer is 185 Ωm at a depth of 4.03 m, and the third layer has a resistivity of 219 Ωm with the thickness of 4.81m. This delineates the presence of clayey sand soil.



N	ρ	h	d	Alt
1	21.3	1.66	1.66	-1.66
2	30.2	1.68	3.34	-3.338
3	245	15.5	18.8	-18.81
4	152			

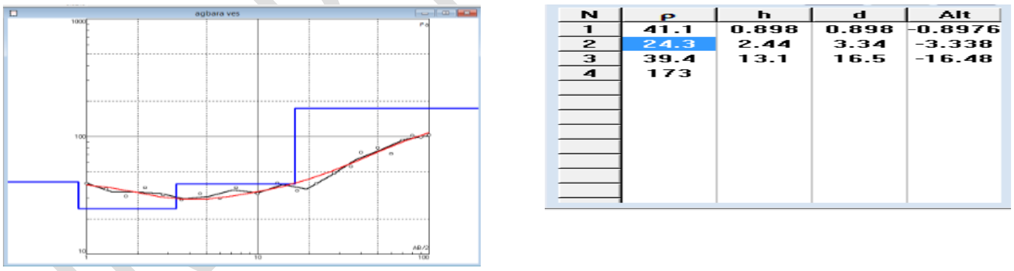
Fig. 19: VES 1 at Agbara

.



N	ρ	h	d	Alt
1	25.6	1.27	1.27	-1.271
2	11.2	2.07	3.34	-3.338
3	25.4	13.1	16.5	-16.48
4	417			

Fig. 20: VES 2 at Agbara



N	ρ	h	d	Alt
1	41.1	0.898	0.898	-0.8976
2	24.3	2.44	3.34	-3.338
3	39.4	13.1	16.5	-16.48
4	173			

Fig. 21: VES 3 at Agbara

For location 3 (Agbara), the first layer of VES1 is characterized by low resistivity of 21.3 Ωm at a depth of 1.66 m and thickness of 1.66 m. VES 2 is characterized by low resistivity value of 25.6 Ωm, the second layer of VES 2 has a very low resistivity of 11.2 Ωm at a depth of 3.34 m, indicating a zone of possible contamination. The third layer for VES 2 has a resistivity of 25.4 Ωm and thickness of 13.1m at the depth of 16.1 m. This is also a zone of possible contamination, which could be as a result of the infiltration of runoff at the location. At the third layer of VES 1, the resistivity is relatively high with a value of 245 Ωm, at a depth of 18.8 m and thickness of 15.5 m, which could be as a result of clay formation.

The geo-electric sections of the 3 locations are shown in Figure 22 – 24.

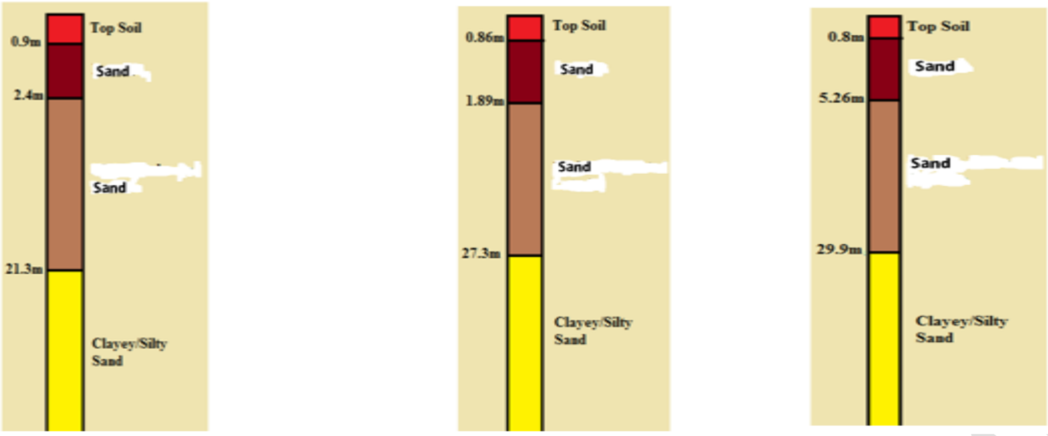


Fig. 22: Geo-electric sections of VES 1-3 at location 1 (Iyana Isashi)

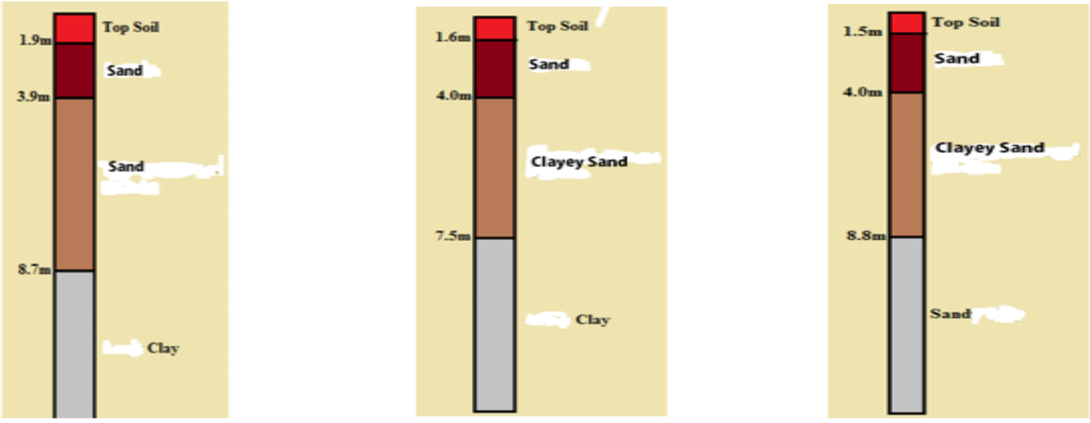


Fig. 23: Geo-electric sections of VES 1-3 at location 2 (Iyana Era)

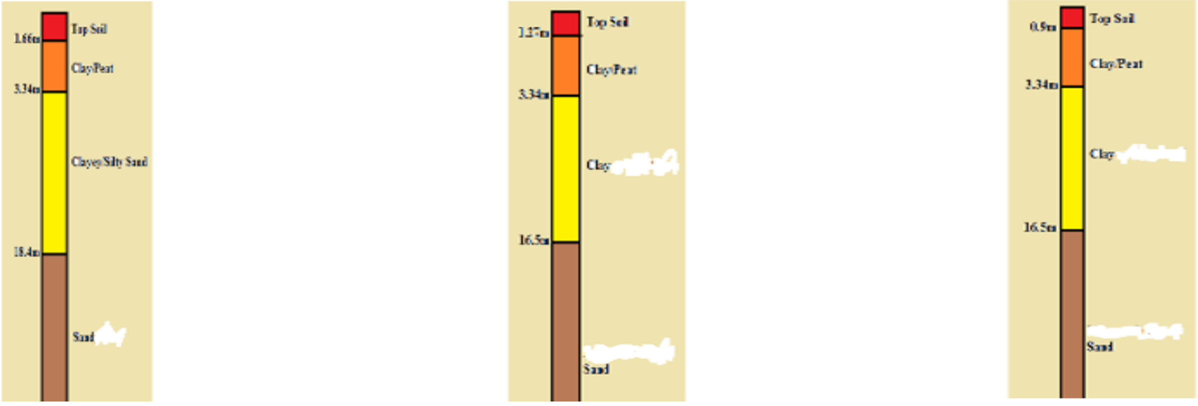


Fig. 24: Geo-electric sections of VES 1-3 at location 3 (Agbara)

Table 1: Summary of the Curve types obtained, true resistivity value, number of layers, thickness, depth and lithological units of each VES point.

Number of Sounding	Number of Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithological unit	Curve Type
VES1 (Iyana Isashi)	1	76.60	0.90	0.86	Topsoil	AA
	2	125.00	1.49	2.40	Sand	
	3	163.00	19.00	21.30	sand	
	4	217.00	-	-	Clayey Sand	

VES1 (Iyana Isashi)	1	103.00	0.86	0.90	Topsoil	KH
	2	163.00	1.00	1.89	Sand	
	3	134.00	25.40	27.30	Sand	
	4	317.00	-		Clayey Sand	
VES3 (Iyana Isashi)	1	113.00	0.87	0.87	Topsoil	AA
	2	150.00	4.39	5.26	Sand	
	3	163.00	24.70	29.90	Sand	
	4	290.00	-	-	Clayey Sand	
VES1 (Iyana Era)	1	71.10	1.91	1.91	Topsoil	AK
	2	143.00	2.00	3.91	Sand	
	3	188.00	4.77	8.68	Sand	
	4	83.30	-	-	Clay	
VES 2(Iyana Era)	1	92.8	1.57	1.60	Topsoil	AK
	2	183.00	2.34	4.0	Sand	
	3	241.00	3.57	7.50	Clayey sand	
	4	103.00	-	-	Clay	
VES3 (Iyana Era)	1	110.00	1.53	1.53	Topsoil	AK
	2	185.00	2.50	4.03	Sand	
	3	219.00	4.81	8.84	Clayey sand	
	4	120.00	-	-	Sand	
VES1(Agbara)	1	21.30	1.66	1.66	Topsoil	AK
	2	30.20	1.68	3.34	Clay/Peat	
	3	245.00	15.50	18.40	Clayey sand	
	4	152.00	-	-	Sand	
VES2 (Agbara)	1	25.60	1.27	1.27	Topsoil	HA
	2	24.30	2.44	3.34	Clay/Peat	
	3	39.40	13.10	16.50	Sand	
	4	173.00	-	-	Sand	
VES3 (Agbara)	1	41.10	0.90	0.90	Topsoil	HA
	2	24.30	2.44	3.34	Clay/Peat	
	3	39.40	13.10	16.50	Clay	
	4	173.00	-	-	Sand	

Physiochemical Results

A water quality test was carried out on the samples which include the Total Dissolved Solids, Electrical Conductivity as against temperature, and pH of the samples.

Total Dissolved Solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal solution) suspended form (WHO, 2007). It comprises inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates) and some small amounts of organic matter that are dissolved in the water; this is suggested to be sourced from the metallic host rock for the water bodies.

Electrical Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulphides and carbonate compounds (Fondriest, 2018).

P^H is a measure of how acidic/basic water is. The range goes from 0 - 14, with 7 being neutral. P^H values less than 7 indicate acidity, whereas a pH value greater than 7 indicates a base. P^H is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water (United State Geological Survey, 2018).

Three locations were considered for this study; two samples were collected from each location making a total of six samples.

The following are the codes for the samples:

ISA-A ----------------- First Sample at Iyana Isashi

ISA-B ----------------- Second Sample at Iyana Isashi

IIR-A ---------------- First Sample at Iyana Era

IIR-B ---------------- Second Sample at Iyana Era

AGB-A ---------------- First Sample at Agbara

AGB-B ---------------- Second Sample at Agbara

The results obtained from the samples above have been compared with the World Health Organisation Standard (WHO, 2004) and United States Environmental Protection Agency (USEPA, 1995).

The test was carried out using a 3-in-1 Water Analysis meter and a high accuracy pH Meter which was calibrated using Buffer Solution 4.6 and 6. 0.

Water quality refers to the chemical, physical, biological and radiological characteristics of water. It describes the condition of the water; including chemical, physical and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking or swimming.

Laboratory Analysis Results

Definition of Terms

EC – Electrical Conductivity (µs/cm)
Temperature: ^{0}F
pH – Potential of hydrogen
TDS – Total Dissolved Solids (ppm)

Table 2: Location 1 (Iyana Isashi)

		SAMPLE ISA-A			**SAMPLE ISA-B**		
S/N	**READINGS**	**pH**	**EC**	**TDS**	**pH**	**EC**	**TDS**
1	1^{ST} READINGS	6.8	216	325	6.7	255	355
2	2^{ND} READINGS	6.8	252	354	6.8	214	322
3	3^{RD} READINGS	6.9	255	320	6.7	213	354
4	AVERAGE	6.8	254	354	6.7	214	322

Table 3: Location 2 (Iyana Era)

		SAMPLE IER-A			**SAMPLE IER-B**		
S/N	**READINGS**	pH	**EC (29^0F)**	**TDS (29^0F)**	**pH**	**EC (29^0F)**	**TDS (29^0F)**
	1^{ST} READINGS	7.0	276	544	6.7	250	532
2	2^{ND} READINGS	6.9	279	540	6.6	251	528
3	3^{RD} READINGS	6.8	275	544	6.6	250	533
4	AVERAGE	6.9	276	542	6.6	250	532

Table 4: Location 3 (Agbara)

		SAMPLE AGB-A			**SAMPLE AGB-B**		
S/N	**READINGS**	**pH**	**EC (29^0F)**	**TDS (29^0F)**	**pH**	**EC (29^0F)**	**TDS (29^0F)**
	1^{ST} READINGS	6.2	291	659	6.1	265	653
2	2^{ND} READINGS	6.1	289	656	6.1	266	653
3	3^{RD} READINGS	6.1	290	657	6.1	266	653
4	AVERAGE	6.1	290	657	6.1	265	653

The conductivity, total dissolved solid and P^H values of the samples of water vary for different locations. For Isashi, the average conductivity is 254 µs/cm for the first sample of water and 214 µs/cm for the second sample, thus showing variation in the conductivity. The total dissolved solid is 354 ppm and 322ppm for the first and second samples respectively. The average P^H value for the first and second samples are 6.8 and 6.7 respectively. These values do not exceed the WHO standard for safe drinking water.

For Iyana Era, the P^H is 6.9 for first sample and 6.6 for the second. Electrical conductivity is 276 µs/cm for the first sample and 250 µs/cm for the second sample of water. Also, while the Total dissolve solid is 542 ppm for the first sample, it is 532 ppm for the second sample.

Agbara shows a higher variation of Electrical conductivity and Total dissolve solids. The average electrical conductivity is 290 µs/cm for the first sample while it is 265 µs/cm for the second sample; although the P^H values are the same. The total dissolved solids is 657 ppm for first sample and 653 ppm for the second sample. The electrical conductivity of Agbara is higher when compared to other locations but it is still in the permissible state as compared to World Health Organization's standard.

Table 5: World Health Organization regulatory standards for water (WHO, 2007).

Level of TDS (milligrams per litre, mg/L)	**Rating**
Less than 300	Excellent
300 - 600	Good
600 - 900	Fair
900 - 1,200	Poor
Above 1,200	Unacceptable

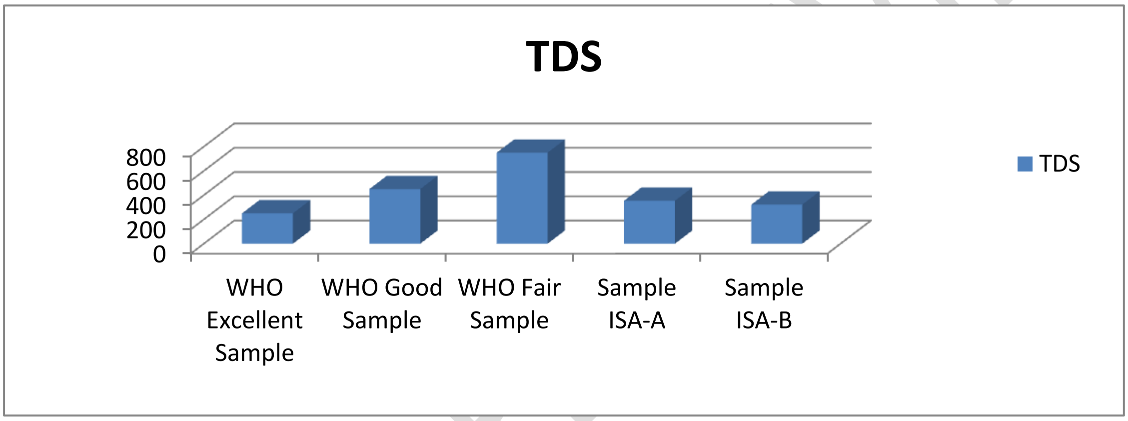


Fig. 22: Microsoft Excel Chart showing the Total Dissolved solid compared to WHO at Location 1(Iyana Isashi)

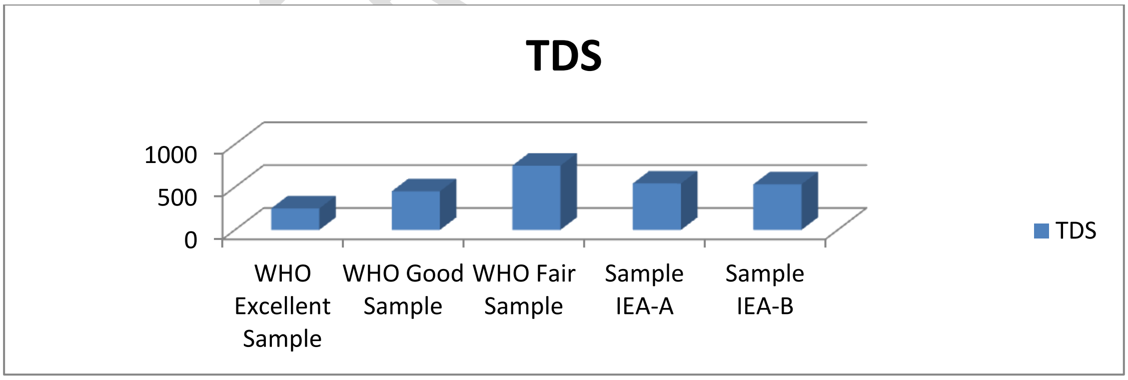


Fig. 23: Microsoft Excel chart showing the Total Dissolved solid compared to WHO at Location 2 (Iyana Era)

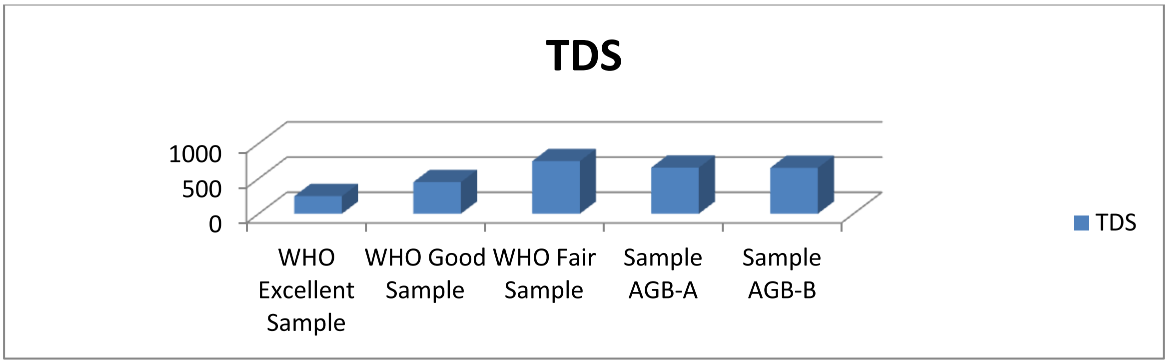


Fig. 24: Microsoft Excel chart showing the Total Dissolved solid compared to WHO at Location 3 (Agbara)

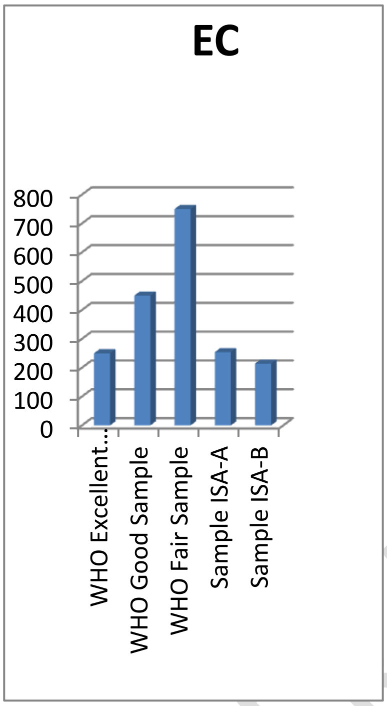


Fig. 25: Chart showing the Electrical conductivity compared to WHO at Location 1 (Iyana Isashi)

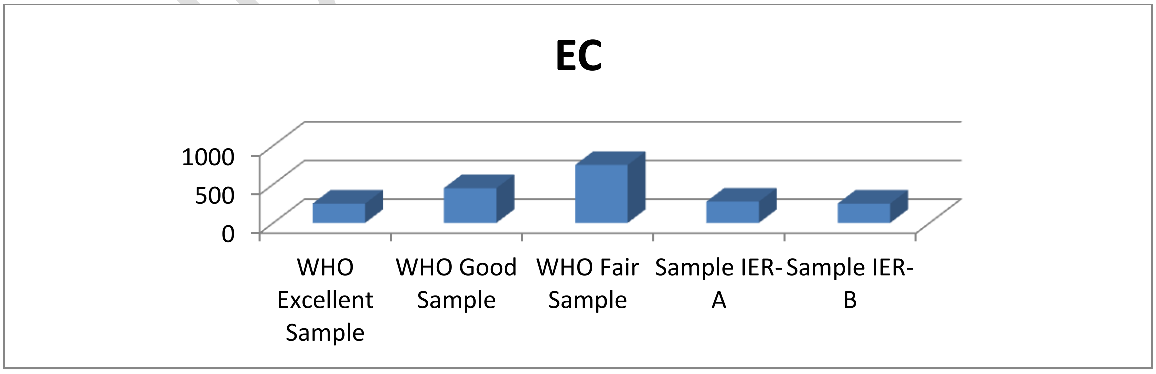


Fig. 26: Microsoft Excel chart showing the Electrical conductivity compared to WHO at Location 2 (Iyana Era).

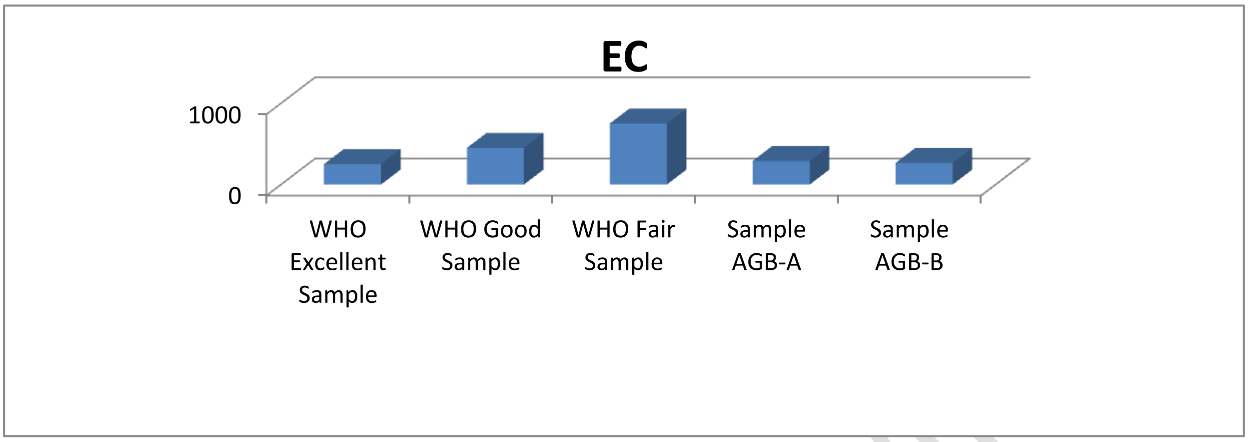


Fig. 27: Chart showing the Electrical conductivity compared to WHO at Location 3 (Agbara).

4.0 CONCLUSION

In this work, Electrical resistivity and physiochemical methods were used in monitoring highway runoff at Iyana Isashi, Iyana Era and Agbara, along Lagos-Badagry Expressway. The same methods were adopted for these locations having known their geologies.

The major conclusions drawn from this work are:

1. The study area is characterized dominantly by four geoelectric layers: topsoil, clay, clayey sand and sand.
2. The result of the Vertical Electrical Sounding correlated positively with the electrical resistivity imaging.
3. The sample of water collected very close to survey indicated relatively high electrical conductivity value and Total Dissolved Solid as compared to sample of water collected far away from the survey point. The lowest resistivity values are estimated around the runoff points.
4. The presence of sandy materials near the surface suggests easy infiltration of highway runoff.
5. The low resistivity value observed at Agbara shows the infiltration of highway runoff which must have contained some measure of pollutants. Although the physiochemical results revealed that the boreholes close to the three locations are still safe for drinking but if the highway runoff in these locations persists, the boreholes would be prone to contamination with time.
6. This paper on the effect of highway runoff on groundwater will therefore serve as a guide for those trying to drill boreholes and wells around the study locations.

5.0 REFERENCES

Alabi ,A .A., Bello, R. Ogungbe, A.S., Oyerinde, H.O. (2010).Determination of ground water potential in Lagos State University, Ojo using Geoelectric methods (vertical electrical sounding and horizontal profiling). 2(5): P.12

Ariyo, S.O, Omosanya K.O, Oshinloye B.A (2013) Electrical resistivity imaging of contaminant zone at Sotubo dumpsite along Sagamu- Ikorodu Road, Southwestern Nigeria. African Journal of Environmental Science and Technology 7:312–320

Backstrom, K. I, Auken, E., Christensen, N. ,Pellerin,. L (2003) An integrated approach for hydrogeophysical investigations: New technologies and a case history. In: Bulter DK (ed) Near-surface Geophysics. Society of Exploration Geophysicists, Tulsa, USA, pp 585–597

Barbosa, A. E (1999) Highway runoff pollution and design of infiltration ponds for pollutant retention in semi-arid climates. Ph.D. Thesis, Environmental Engineering Laboratory, Aalborg University.

Barrett, M., R. Zuber, E., Collins, J., Malina, J. R., and Ward, G (1993) A review and evaluation of literature pertaining to the quantity and control of pollution from highway runoff and construction. Centre for Research in Water Resources, Bureau of Engineering Research, University of Texas, Austin, TX.

Benson, C.H., Chiang, I., Chalermyanont, T., Sawangsuriya, A. (2014). Estimating van Genuchten parameters α and n for clean sands from particle size distribution data. In Iskander, M., Garlanger, J.E., Hussein,M.H., (Eds), From soil behaviour fundamentalis to innovations in geotechnical engineering.
ASCI, Geotechnical s.ed, 233

Chiew, F. S., Duncan H. P., Smit H. W (2000) Modelling pollutant build up and wash off: keep it simple, Proceedings of the 24th International and Water Resources Symposium, pp.131-136, Aukland, New Zealand Hydrological
Society.

Driscoll, E.D., Shelley, P.E., and Strecker,E.W. (1990). Pollutant Loadings and Impacts from Highway Stormwater Runoff—Volume III: Analytical Investigation and Research Report. FHWA-RD-88-008. FederalHighway Administration, Office of Research and Development,McLean,VA.

Dwight, R.H., C.S. Jan, C. S, Dean, B. B, and H.O. Betty, (2002) Association of Urban runoff with coastal water quality in orange county, California. Water Environ. Res., 74: 82-90.

Ellis, J.B. and Revitt, D. M (1991) Drainage from roads: Control and treatment of highway runoff. Report NRA, 43804/MID OR, Thames NRA, Reading.

Fondriest, K. H (2018) Contamination assessment of surface and groundwater within and around two dumpsites. International Journal of Environmental Science and Technology 7(2):367–376

Grenato, G.E. and Smith, K.P (1999) Estimating concentrations of road-salt constituents in highway runoff from measurements of specific conductance. U.S. Geological Survey Water Resources Investigation Report, 99-4077, pp: 22.

Irish, L.B., Barrett, M.E, Malina, J.F and Charbeneau, R. J (1998) Use of Regression Models for Analyzing Highway Storm-Water Loads. Journal of Environmental Engineering 124(10):987–993.

Iwugo, K. O., D'Arcy B., Andoh, R. (2003). Aspects of Land-based pollution of an African Coastal Megacity of Lagos.Proceedings of the International Specialized IWA Conference, Dublin, Ireland.

Loke, M.H.(1999) Electrical imaging Surveys for Environmental and Engineering Studies. A practical guide to 2-D and 3-D survey, Geotom Software, Malaysia.

Mangani, G., A. Berloni, F. Bellucci, F. Tatano and Maione, M. (2005) Evaluation of the pollutant content in road runoff first flush waters. Water Air Soil Pollution 160: 213-228.

Marsalek, J., B. Brownlee, T. Mayer, S. Lawal and G.A. Larkin, (1997) Heavy metals and PAHS in stormwater runoff from the Skyway Bridge, Burlington, Ontario. Water Qual. Res. J. Can., 32: 815-827.

Nton, M.E., (2001). Sedimentological and physiochemical studies of rock units in the eastern.

Patrick L. (2002). Mercury toxicity and antioxidants: Part 1: role of glutathione
and alpha-lipoic acid in the treatment of mercury toxicity. Altern Med Rev
7(6): 456–471

Perdikaki, K. and C.F. Mason, C.F, (1999) Impact of road runoff on receiving streams in Eastern England. Water Res., 33: 1627-1633.

Pitt, R., Field, R. M., Lalor, H. G and Brown, M., (1995) Urban stormwater toxic pollutants: Assessment sources and treatability. Water Environ. Res., 67: 260-275
United States Environmental Protection Agency (1995) Erosion, Sediment and Runoff Control for Roads and Highways.Washington, D.C.: Office of Water, U.S. Environmental Protection Agency

United States Geological Survey (2018): Science for changing the world.

WHO (2004). Guidelines for drink-ing-water quality. Recommendations. Vol.1, 3rd edition, WHO Geneva.

WHO (2007) Guidelines for drinking-water quality: fourth edition incorporating the first
Addendum

Yonge, D., Hossain, D. H., Barber, F. H., Chen, P. B., and Griffin, D. (2002) Wet Detention Pond Design for Highway Runoff Pollutant Control. National Cooperative Highway Research Program report.