Integrated Geolectric and Hydrochemical Investigation for Environmental Impact Assessment of the Area around some Ancient Dumpsites in Akure Metropolis, Southwestern Nigeria.

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ABSTRACT

Geophysical, hydrogeological, and hydrochemical investigations have been used to assess the impact on soil and groundwater of some ancient dumpsites in Akure Metropolis. One hundred and seventy one (171) Vertical Electrical Sounding (VES) and dipole – dipole profiling along six (6) profiles were carried out. Seventy (70) water samples were collected from hand dug wells for chemical analysis within a radius of about 600 m from the centre of the ancient dumpsites.

The geoelectric sections and the inverted 2-D resistivity structures delineate three subsurface geological units consisting of the topsoil, weathered layer and the fractured/fresh basement rock. The weathered layer constitutes the main aquifer unit. The 2-D resistivity structures show that within the premises of the dumpsites, the topsoil and the weathered basement aquifer unit are characterized by relatively low layer resistivity values of <40 ohm-m and <20 ohm-m respectively. The relatively low resistivity values are suspected to be due to conductive leachate from the dumpsites. Results of chemical analysis of water samples from hand dug wells in the study area show that water samples from the area around the dumpsites are characterized by relatively higher electrical conductivity (1000 – 2361 µs/cm), chloride concentration of > 250 mg/l and nitrate concentration of > 10 mg/l which confirm groundwater pollution. It can be concluded that the soils and the groundwater in the areas around the investigated dumpsites have been polluted. The polluted zone has a depth extent of about 2.5 – >7.5 m and lateral extent of about 250 m north and up to 500 m south of the dumpsites.

(Keywords: geophysical, hydrogeological, hydrochemical, dumpsites, groundwater pollution)

INTRODUCTION

Some old dumpsites exist within the Akure Metropolis and have been in use for more than 40 years. The Metropolis is underlain by Precambrian Basement Complex rocks with the weathered/fractured basement constituting the aquifer units. The wastes at the dumpsites are composed of vegetable matters, domestic wastes, human and animal wastes, organic and inorganic matters, wood, paper, cloth, glass, plastic of various types, unclassified metal scraps, human and animal faces, partially empty cans of various chemicals (like paints, batteries, insecticides and so on) and other house hold trash. The biodegradation of these wastes would have generated leachate plume which may have impacted the groundwater. A significant proportion of the inhabitants of the Metropolis depend mainly on groundwater from hand-dug wells for their domestic use. There is therefore the need for a hydrogeological assessment of the quality of the groundwater and the extent of impact of the dumpsites.

This study employed geoelectric, hydrogeological and hydrochemical measurements to investigate the environmental impact of the dumpsites. Similar investigations have been carried out in both sedimentary and basement terrains of Southwestern Nigeria (Olayinka and Olayiwola, 2001; Adepelumi et al, 2005, Ayolabi and Peters, 2005 and Obase et al, 2009).

SITE DESCRIPTION

The study area is situated between longitudes 5^0 09 E and 5^0 14 E, and latitudes $7^0$13 N and $7^0$17 N. It covers an areal extent of about 13 km^2 (Figure 1).

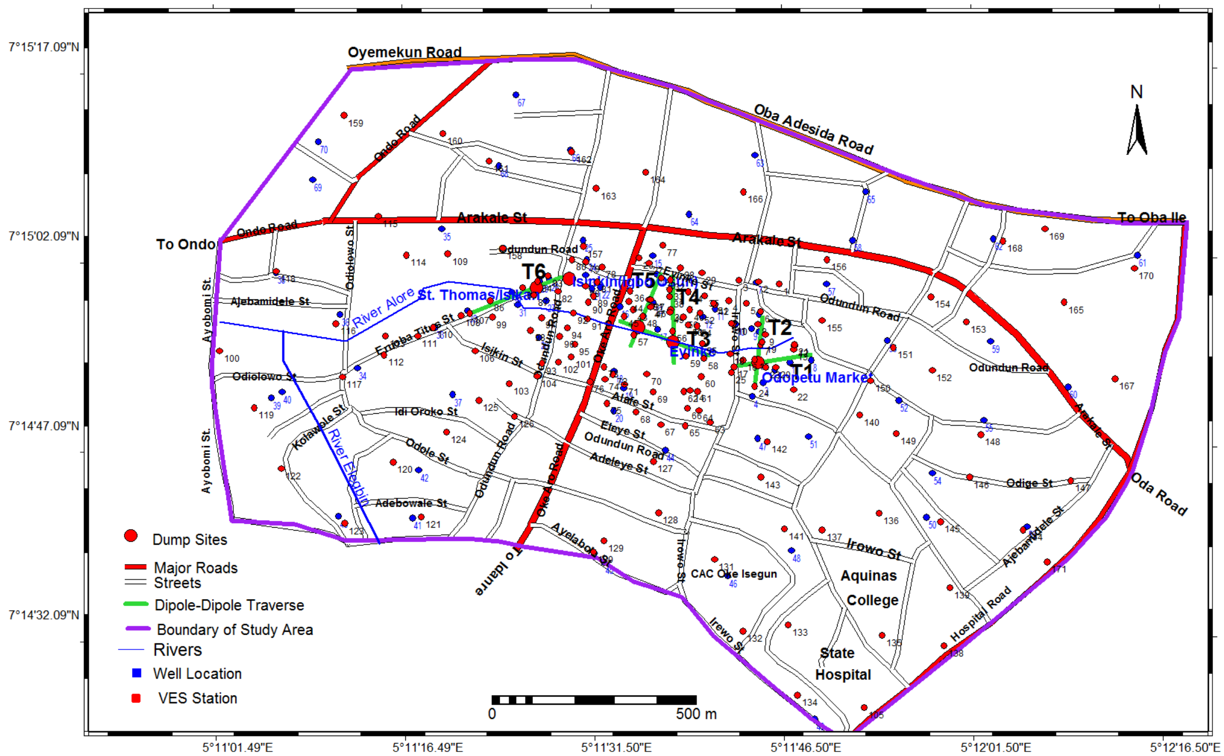

Figure 1: Location and Data Acquisition Map of the Study Area.

The five selected dumpsites for this study are the Odopetu dumpsite, Eyinke dumpsite, Isinkin (Igbo-Osun) dumpsite and the St. Thomas dumpsite. Topographic elevations in the study area vary between 260 m (853 ft) and 400 m (1312 ft) above mean sea level. The area is drained by River Elegbin and River Alore. Rivers Elegbin and Alore are seasonal. The two rivers are tributaries of River Ala which dominates the drainage system of Akure Metropolis. The area experiences a tropical climate with a dry season between the months of November and March and a wet season between April and October.

GEOLOGY AND HYDROGEOLOGY

The study area is underlain by migmatite gneiss, quartzite, granite gneiss and granitic rocks of the Precambrian Basement Complex of Southwestern Nigeria (Rahaman 1976). Migmatite gneiss is the predominant rock unit which underlies the waste dumpsites (Figure 2).

In basement complex area, groundwater is contained within the weathered and or fractured/jointed basement columns. The near-surface nature of the aquifer system makes them vulnerable to surface/near surface pollutants such as leachate from a waste dump.

METHOD OF STUDY

One hundred and seventy one (171) Schlumberger Vertical Electrical Soundings (VES) were carried out in the study area (Figure 3). The electrode spacing (AB/2) was increased from 1 m to a maximum of 100 m.

The VES curves were interpreted using the conventional partial curve matching technique. The obtained geoelectric parameters (layer resistivities and thicknesses) were used as starting model parameters for a 1-D computer aided forward modeling interpretation involving the RESIST 1.0 software (Vender Velper, 1988). Six (6) dipole-dipole horizontal profilings were conducted with a dipole-dipole expansion factor n, varying from 1 – 5 m and dipole spacing of (a = 5 m). The dipole-dipole profiling was carried out along approximately two orthogonal directions with respect to each dumpsite (Figure 1).

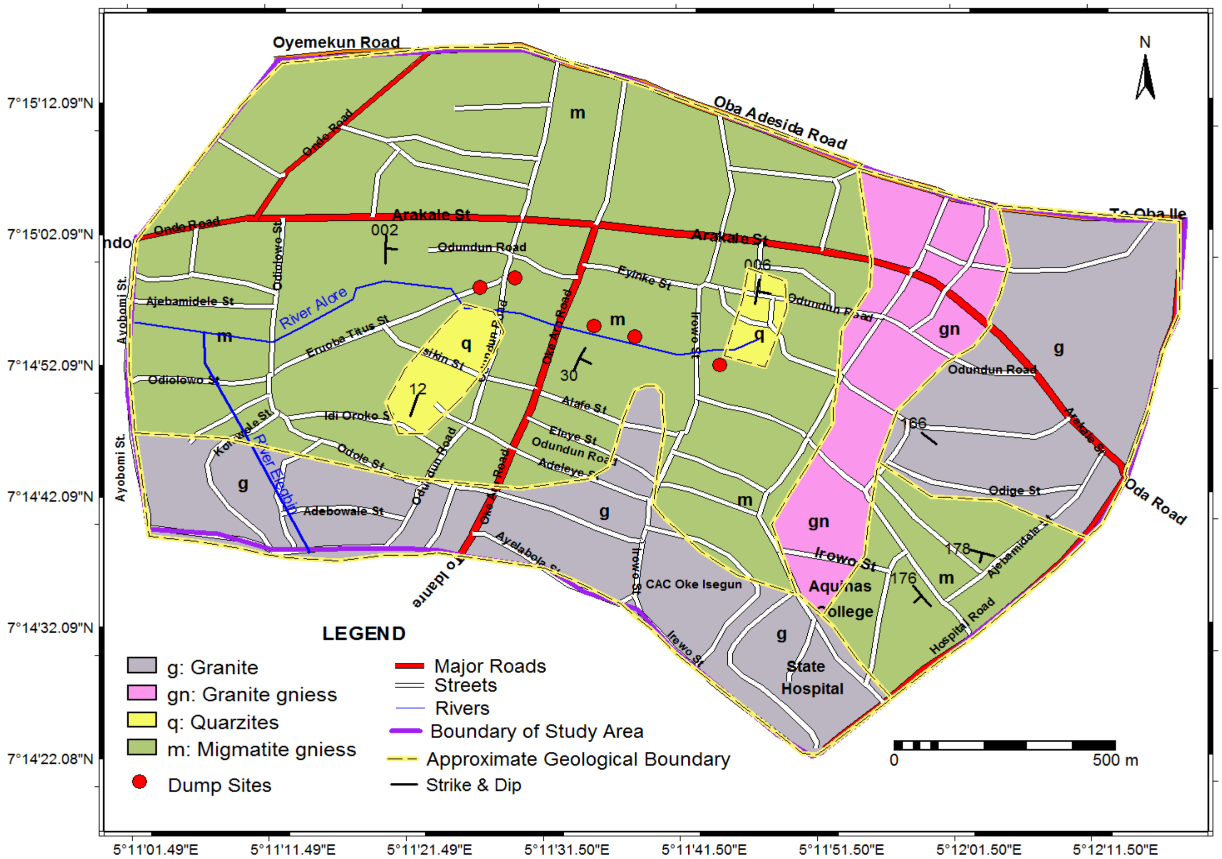

Figure 2: Geological Map of the Study Area.

The dipole-dipole data were inverted into a 2-D resistivity structure using the DIPRO (2001) software. The geoelectric models that evolved from VES interpretation results were used to constrain the inversion of the dipole-dipole data.

Seventy (70) water samples were collected from hand dug wells for hydrochemical analysis. The samples were collected between the months of February and March, and analyzed for electrical conductivity (EC), chloride (Cl^-) and nitrate (NO_3^-) concentrations. Static water level measurements were also carried out on all the seventy hand dug wells to enable the determination of the groundwater flow directions.

RESULTS AND DISCUSSION

The depth sounding curves vary from simple A and H type curve, to a more complex QH, HA, KH, HK, and HKH type. The H-type is the dominant type curves with a percentage frequency of occurrence of 79.5%.

Figures 3(a - c) display the geoelectric sections developed for the investigated dumpsites. The geoelectric parameters obtained at the different dumpsites are contained in Table 1. Three subsurface layers comprising the topsoil, weathered layer and the basement bedrock were delineated Bayode et al., (2010). Table 1 shows that the area around the dumpsites is characterized by relatively low resistivity topsoil and weathered layer. It is suspected that leachates generated at the dumpsites may have migrated downward from the topsoil into the weathered layer.

The 2-D resistivity structures obtained from the inversion of the dipole-dipole data along profiles 1 – 6 are presented in (Figure 4(a - f)).

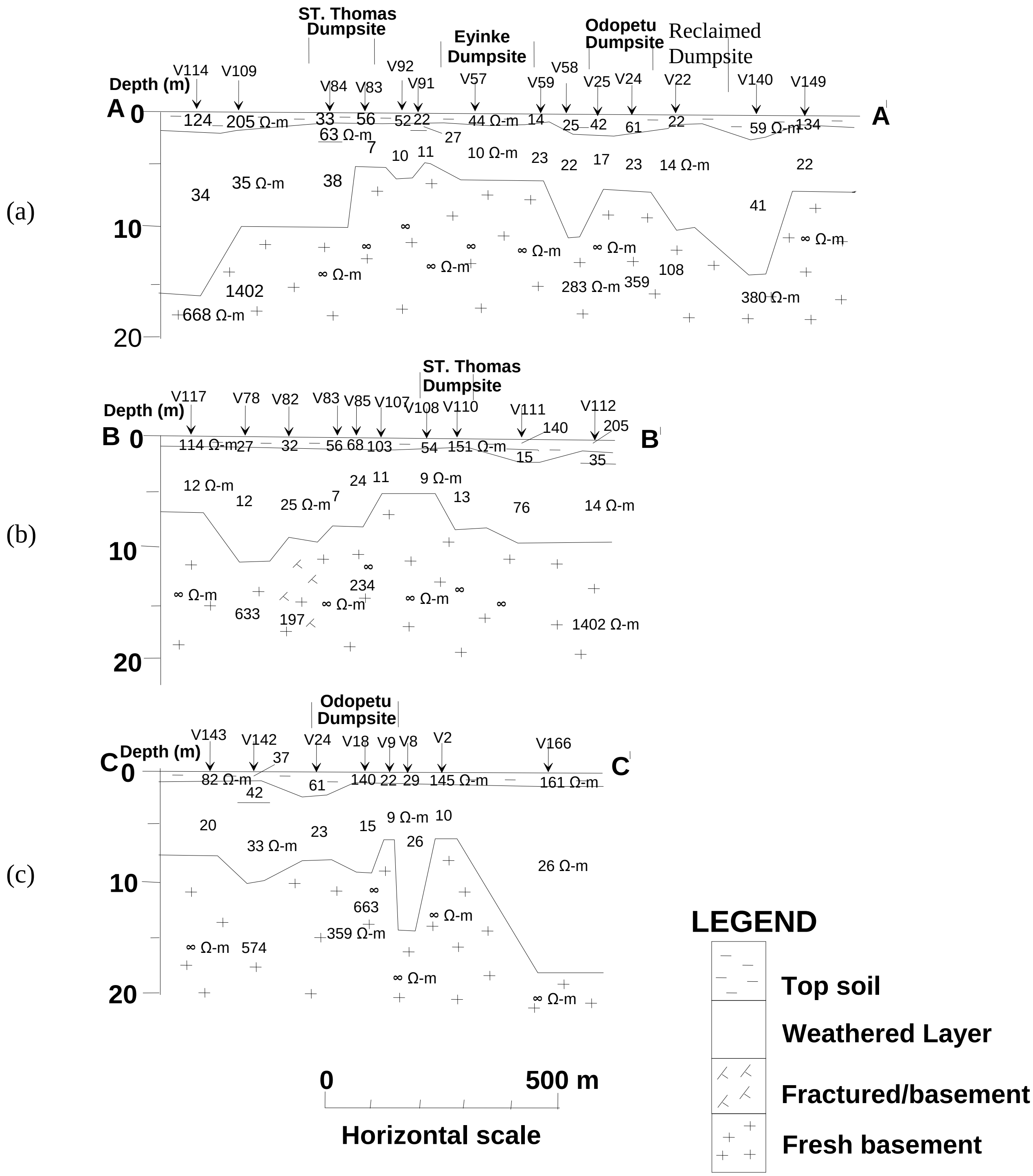

Figure 3(a-c): Geoelectric Section Along Sections (a) AA', (b) BB' and (c) CC' Across the Study Area.

Table 1: Geoelectric Characterization of the Investigated Dumpsites from VES Interpretation Results.

Layering	Resistivity Range (ohm-m)	Resistivity within Dumpsite Area (ohm-m)	Thickness (m)	Lithologic Description
ODOPETU DUMPSIE				
Topsiol	19 – 144	19 – 66	0.4 – 2.1	Made ground, fill materials, clay and sandy clay.
Weathered layer	9 – 36	9 – 14	2 – 12.8	Clay
Basement Bedrock	108 – ∞	108 – ∞	2.1 – 14.6	Fractured/Fresh Basement.
EYINKE DUMPSIE				
Topsiol	6 – 461	6 – 40	0.4 – 2.1	Made ground, clay, sandy clay and clayey sand.
Weathered layer	10 – 35	6 – 27	2 – 9.5	Clay
Basement Bedrock	102 – ∞	102 – ∞	2.0 – 10.3	Fractured/Fresh Basement.
ST. THOMAS DUMPSITE				
Topsiol	21 –103	21 – 68	1.0 – 2.4	Made ground, clay, and sandy clay.
Weathered layer	11 – 38	11 – 24	5.0 – 7.0	Clay
Basement Bedrock	234 – ∞	234 – ∞	5.9 – 10.1	Fractured/Fresh Basement.

*Depth to Bedrock varies from 2.1 to 14.6 m

The resistivity structures show that the topsoil has virtually merged with the weathered layer because of overlapping low resistivity values and the relatively small thickness. Very low resistivity (< 10 - < 25 ohm-m) zones with light bluish color band occur between stations 10 and 33 (50 – 165 m) along Profile 1, and between stations 7 – 24 (35 – 100 m) along Profile 2 (Figures 4a and b); between stations 2 – 5 (10 – 25 m); 17 – 47 (85 – 235 m) and particularly between stations 17 and 25 (85 – 125 m) along Profile 3 (Figure 4c); stations 2 – 9 (10 – 45 m) and 24 – 33 (120 – 165 m) along Profile 4 (Figure 4d); and between stations 2 – 15 (10 – 75 m) along Profile 5 (Figure 4e) and beneath stations 2 – 19 (10 – 95 m) along profile 5 (Figure 4f) Bayode et al, (2010). The low resistivity topsoil within the identified zones above may have been polluted by leachate from the dump.

The second layer, characterized by green color band is the weathered layer. The layer resistivity values are generally less than 50 ohm-m along Profiles 1 – 5 (Figures 4a - e) and less than 90 ohm-m along Profile 6 (Figure 4f). The resistivity structures show that the thickness of the weathered layer ranges from about < 2.5 m to > 7.5 m. The weathered layer contains patches of very low resistivity (< 10 - < 25 ohm-m beneath profiles 1 – 5) zones with light to deep bluish colour bands suspected to be leachate polluted areas.

The third layer which has moderately high resistivity (of up to 1102 ohm-m) with yellowish – red colour band is the fresh/fractured basement bedrock. Depths to the basement bedrock vary from about < 2.0 to > 7.5 m.

The correlation of the geoelectric sections with the corresponding 2-D resistivity structures (Figures 3 and 4) shows that the weathered layer which constitutes the main aquifer units contains zones with characteristically very low layer resistivity values (< 10 ohm-m) that may have been precipitated by conductive leachate from the waste dumpsites Bayode et al., (2010). It is therefore suspected that the groundwater may have been polluted beneath the current dumpsites and the reclaimed area. The depth of migration of suspected leachate ranges from 2.5 m to > 5 m along Profiles 1, 2, 4, 5 and 6 (see Figures 4 (a, b, d, e, and f)) while it is between 2.5 m to > 7.5 m along Profile 3 (Figure 4c).

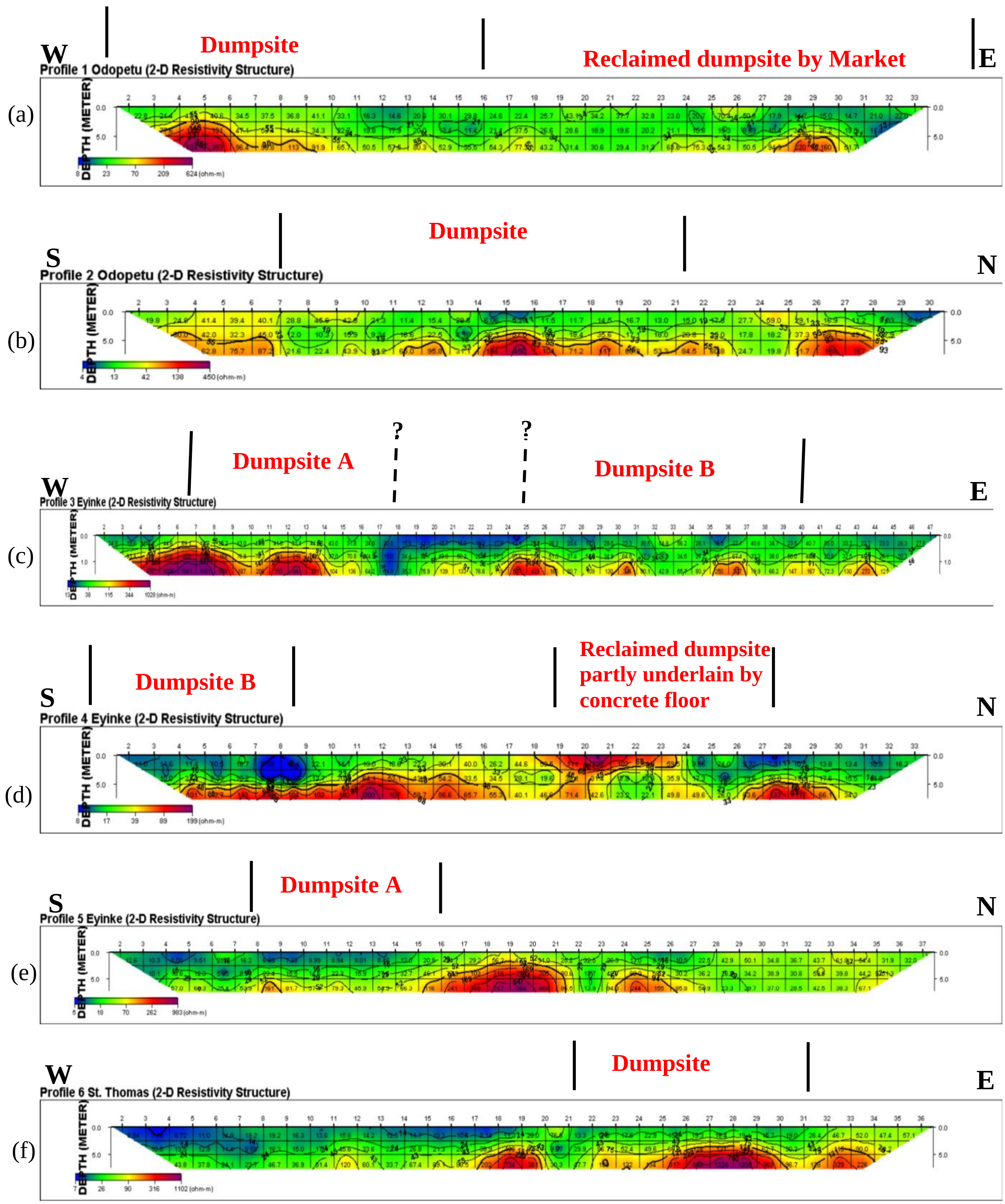

Figure 4 (a-f): Dipole–Dipole 2-D Resistivity Structure Along (a and b) Profiles 1 and 2: Odopetu Dumpsite, (c-e) Profiles 3 – 5: Eyinke Dumpsite and (f) Profile 6: St. Thomas Dumpsite.

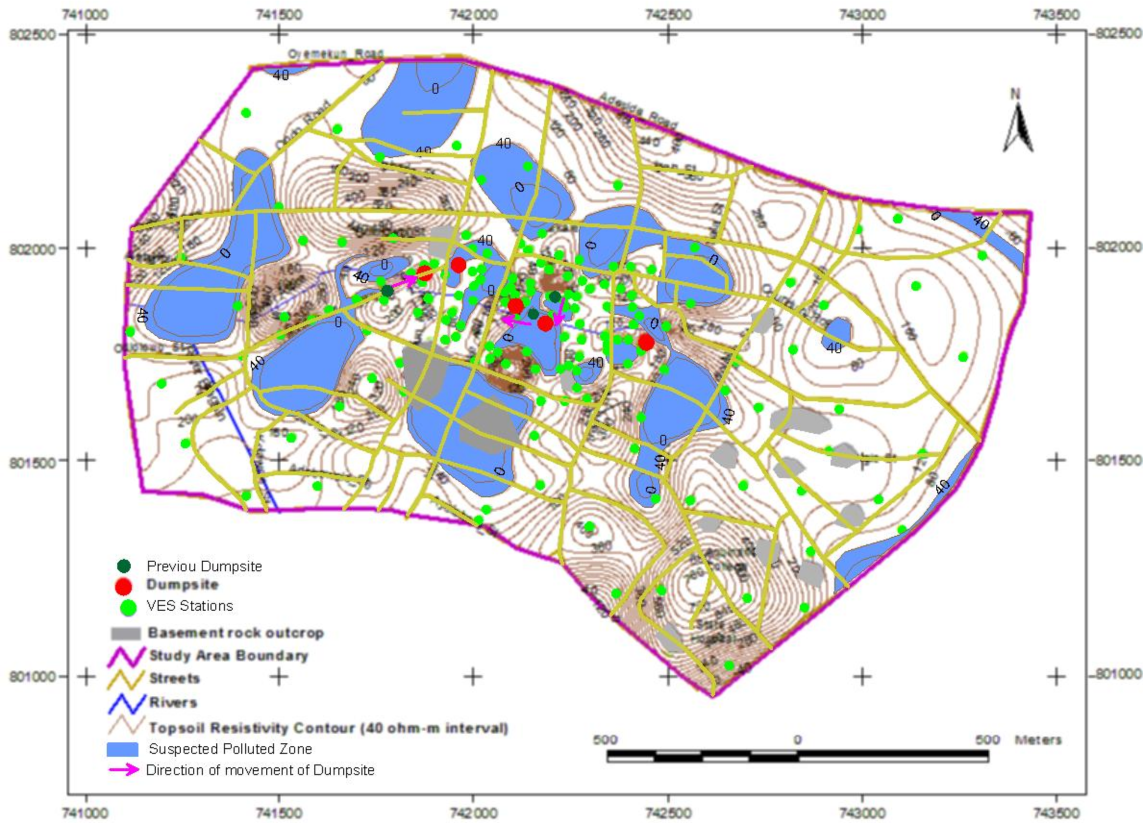

Figure 5: Topsoil Resistivity Map of the Study Area

RESISTIVITY MAPS

Resistivity maps were generated for both the top soil and the weathered layer across the study area. The topsoil resistivity contoured map (Figure 5) shows topsoil resistivity values generally varying from 6 – 2108 ohm-m. Relatively low resistivity values of < 100 ohm-m mostly characterize the area around the dumpsites. The synthesis of geoelectric sections and 2-D resistivity structures from the dumpsites shows that the resistivity values of polluted topsoil/weathered layer are generally < 40 ohm-m. The topsoil within these low resistivity zones, (shaded in the map) may have been saturated with leachate, and hence can be considered polluted. The topsoil resistivity values generally increase away from the dumpsite. This further confirms the fact that the topsoil within the immediate surroundings of the dumpsites may have been polluted.

The weathered layer resistivity map (Figure 6) shows resistivity values varying from 4 – 280 ohm-m. Relatively low resistivity values of < 20 ohm-m characterize the weathered layer beneath the area around the dumpsites. These low resistivity zones, shaded in the contoured map, are suspected to have been impregnated with leachate generated at the dumpsites.

STATIC WATER LEVEL AND GROUNDWATER FLOW PATTERN

Figure 7 shows the static water level map. The static water level varies from 0 – 6.5 m. There is a generally high static water level (0.5 – 1.5 m) at the central portion and around the dumpsites and along River Alore and River Elegbin. Judging from the estimated depth of suspected leachate migration (2.5 – 7.5 m) from the modeled resistivity structures, the groundwater in this area may have been impacted. High static water level is also obtained in the Northeastern, Southeastern and the Northwestern parts of the study area. The Southwestern, Northern, and Eastern parts are characterized by low static water levels varying from 2.0 – 7.0 m.

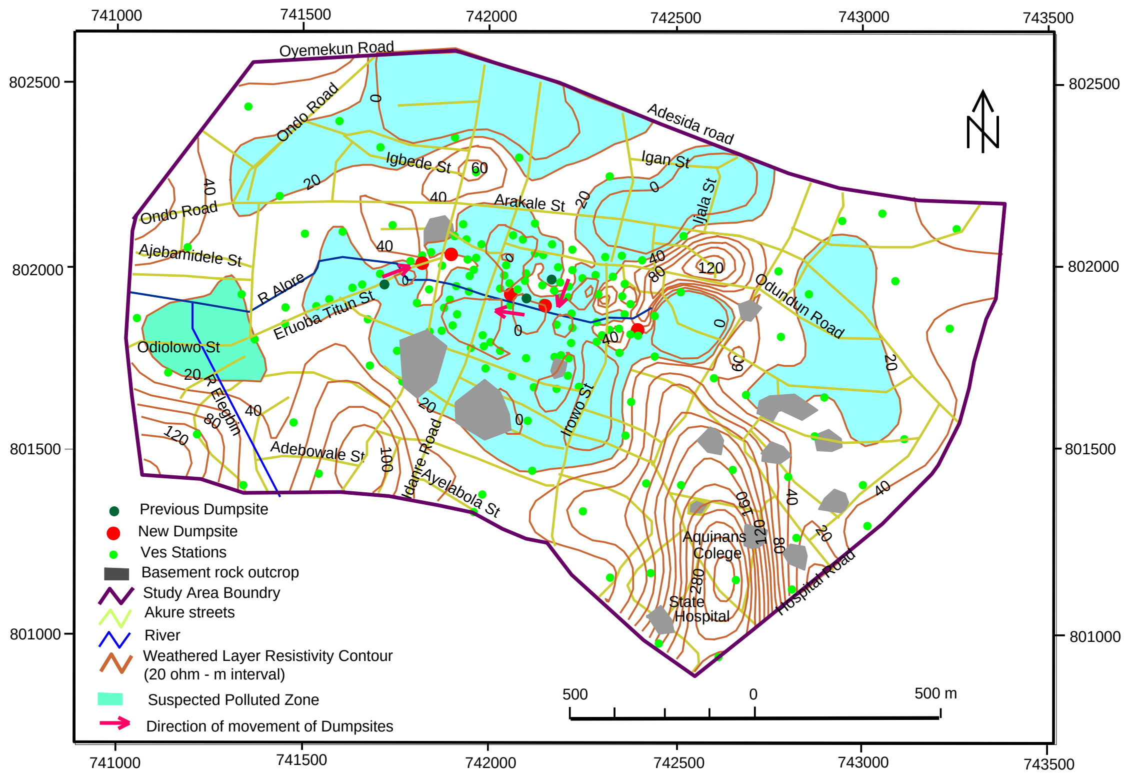

Figure 6: Weathered Layer Resistivity Map of the Study Area.

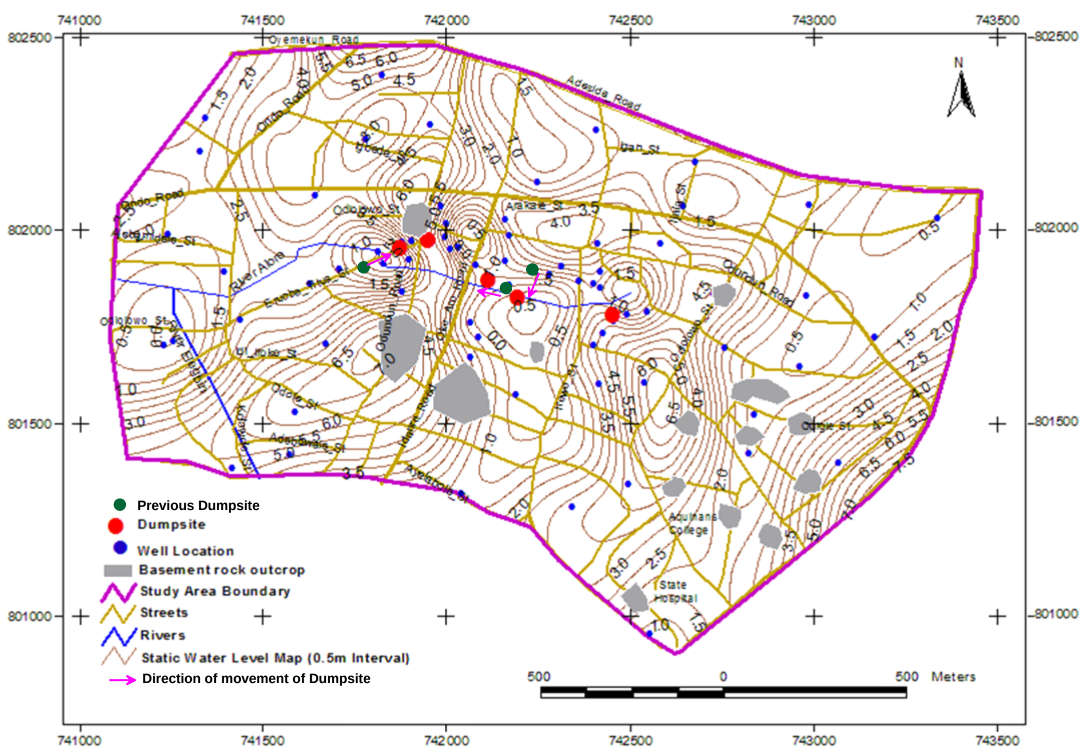

Figure 7: Static Water Level Map of the Study Area.

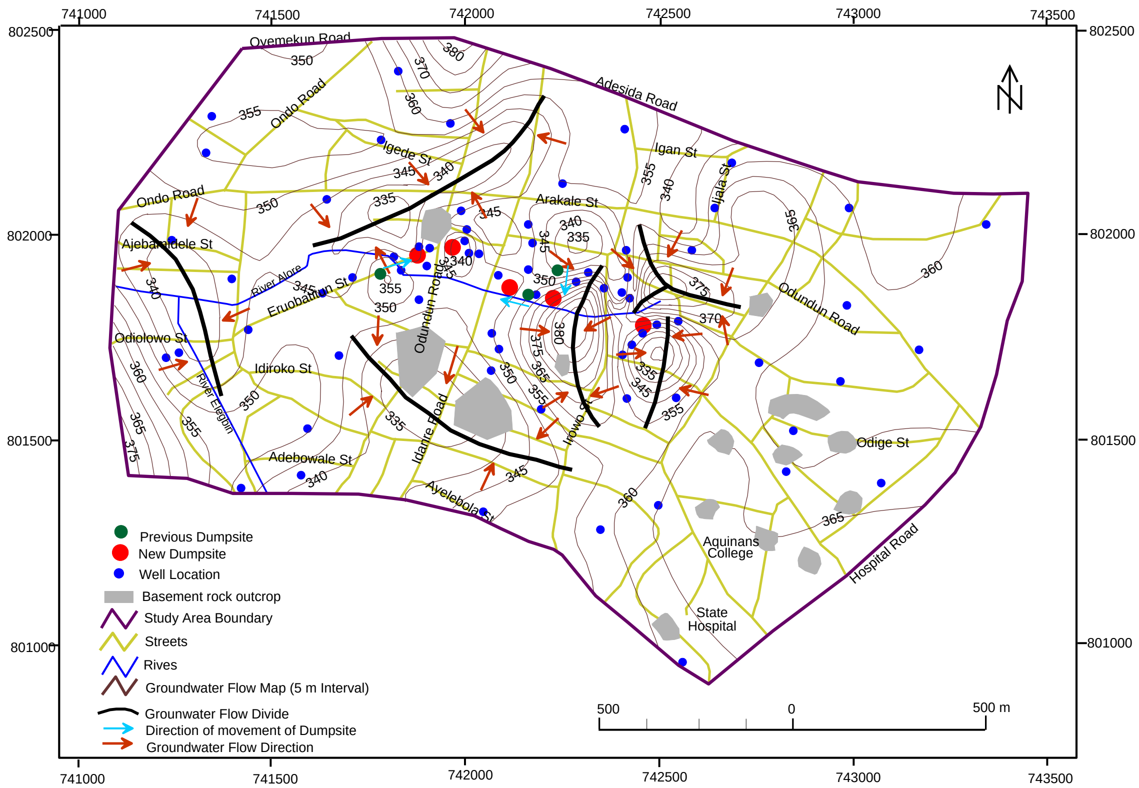

Figure 8: Groundwater Head Map of the Study Area.

There were few dry wells in the study area at the time the data were collected, suggesting that the wells obtain their water mainly from the weathered layer aquifer and at shallow depth.

Figure 8 shows the groundwater flow map for the study area. The red arrows on the map show the multiple groundwater flow directions typical of the discontinuous nature of basement aquifer system. The map shows that groundwater generally flows away from the clustered dumpsites thereby aiding a radial direction of leachate migration. The predominant flow is towards the south.

HYDROCHEMICAL ANALYSIS

Hydrochemical analysis of water samples collected from 70 hand dug wells located around 600 m radius from the dumpsites were carried out and the results are presented in Table 2. The results show that the water samples collected around the waste dumpsites have higher concentrations of the analyzed parameters.

The electrical conductivity (EC) ranges from 145 – 2361 µS/cm (Table 2) and (Figure 9). The lowest EC value of < 200 µS/cm was obtained from a well located far away from the dumpsites while the EC values of >1000 – 2361 µS/cm (shaded in the contoured map), obtained in the immediate surroundings of the dumpsites and at the dumpsites are higher than the WHO, (1995). FEPA, (1991) recommended safe values of less than 1000 µS/cm for drinking water. The relatively high conductivity values around the dumpsites are also generally higher than the values obtained in a typical basement complex area of Nigeria (see Table 3). The high electric conductivity values are indicative of pollution arising from the release of leachate generated at the dumpsites as also observed by Olayinka and Olayiwola (2001) and Tijani et al., (2002). These high EC values are corroborated by the low resistivity values obtained for both the topsoil and the weathered layer at and around the dumpsites (Figures 3, 4, 5, and 6)

The chloride (Cl^-) concentration levels range from 46 – 677 mg/l (Figure 10).

Table 2: Chemical Parameters of Groundwater from the Study Area.

Well No	Cond. µS/cm	Cl^- mg/l	NO_3 mg/l	Well No	Cond. µS/cm	Cl^- mg/l	NO_3 mg/l
1	1210	333	6.0	36	1197	284	5.0
2	1495	436	7.0	37	522	163	2.4
3	680	280	4.0	38	1031	287	2.0
4	1082	397	10.6	39	485	106	2.4
5	1235	269	4.4	40	682	167	4.0
6	1481	500	3.0	41	457	167	2.4
7	1931	496	3.4	42	145	46	2.2
8	2361	819	4.0	43	614	202	6.0
9	1605	404	4.0	44	1640	454	3.2
10	1632	397	3.8	45	1337	430	4.0
11	1760	500	5.0	46	328	96	3.0
12	2042	557	2.4	47	635	199	4.0
13	1023	248	3.0	48	236	89	52.0
14	770	103	3.0	49	276	64	2.4
15	894	152	8.0	50	1160	167	2.4
16	1686	425	3.0	51	632	394	4.4
17	1702	269	7.0	52	1500	468	3.0
18	1492	433	3.0	53	705	195	3.0
19	1557	216	2.0	54	729	305	4.6
20	2112	638	3.0	55	957	241	5.0
21	1689	408	2.0	56	921	259	3.8
22	1380	337	3.0	57	1680	475	3.0
23	1578	394	4.0	58	1794	418	4.0
24	2010	500	3.0	59	1932	677	3.0
25	1767	423	18.0	60	759	167	6.4
26	1770	518	6.0	61	832	305	3.6
27	1610	316	10.0	62	1037	223	6.0
28	1657	674	1.6	63	1790	184	4.4
29	1401	319	1.6	64	1020	206	4.0
30	1683	507	30.0	65	1466	323	3.0
31	1933	323	7.6	66	1874	507	5.6
32	1140	308	1.4	67	1545	436	10.0
33	535	149	2.4	68	1203	415	5.0
34	484	128	6.4	69	968	273	5.0
35	1570	386	8.0	70	730	227	3.8

Chloride values are generally high for some samples and are above the WHO (1999) recommended acceptable limit of 250 mg/l (Egereonu and Emeziem, 2006) and background values for basement complex area of Nigeria (Table 3). The groundwater in areas with high chloride concentrations (> 250 mg/l) shaded in the contoured map (Figure 10), may have been polluted. Similarly high chloride concentrations (> 250 mg/l) were obtained around basement complex underlain dumpsites in Ibadan, southwestern Nigeria (Tijani et al., 2002). The high chloride content is suspected to have resulted from anthropogenic activities and degradation of refuse at the dumpsites and septic tank effluent. The chloride levels generally decrease south and east of the dumpsites.

The nitrate (NO_3^-) concentration levels range from 1.4 – 52 mg/l (Table 2). Nitrate (NO_3^-) concentrations are higher in well located around the dumpsites as shaded in the contoured map (Fig. 11). The background nitrate concentration levels for the basement complex area of Nigeria ranges from none detectable – 22.94 mg/l (Table 3). Nitrate concentrations of greater than the 10mg/l maximum permissible level recommended by WHO (1999) were obtained from water samples collected around the dumpsites and are regarded as evidence of pollution.

Table 3: Baseline Concentration Values for Groundwater Conductivity, Chloride and Nitrate Obtained in Parts of the Basement Complex Area of Nigeria.

Parameter/ contaminant	**Basement Complex Area of Southwestern, Nigeria.** (Olatunji et.al 2001, Abimbola et.al 2002 and WATSAN Technical Reports from Ondo, Ekiti and Osun State).	**Basement Complex Area of North-Central, Nigeria.** (Olarewaju et. al., 1997)	**Basement Complex Area of Northwestern, Nigeria.** (Bala and Onugba, 2001)
	Range of values	**Range of values**	**Range of values**
Conductivity (EC)	19 – 909 µS/cm	25 – 800 µS/cm	90 - 680 µS/cm
Chloride (Cl^-)	0.0145 – 394 mg/l	0.3 – 22 mg/l	1.42 – 32.62 mg/l
Nitrate (NO_3^-)	None detectable – 8.89 mg/l	0.02 – 2.5 mg/l	9.30 – 22.94 mg/l

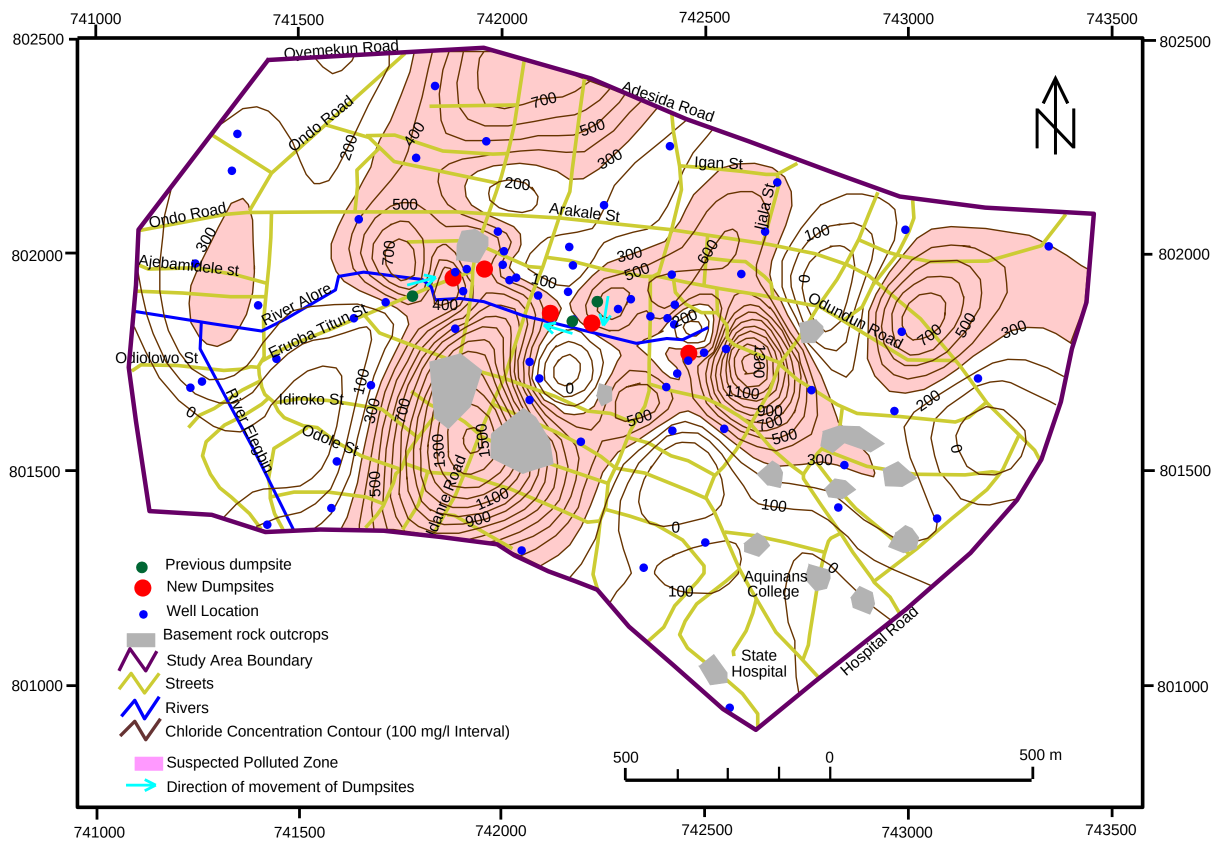

Figure 10: Chloride (Cl^-) Concentration Distribution Map of the Study Area.

High nitrate concentration values were also observed around the State Hospital and Aquinas College in the southwestern part of the study area (Figure 11). This may be due to sewage influence.

ESTIMATION OF EXTENT OF WASTE DUMPED INDUCED POLLUTION

The topsoil, weathered layer, water conductivity and chloride concentration maps (Figures 5, 6, 9, and 10) were used to generate the pollution map (Figure 12). The parameters that were used to generate the polluted zones are the topsoil resistivity values (< 40 ohm – m) and weathered layer resistivity values (< 20 ohm – m), water conductivity (> 1000 µS/cm), and chloride concentration (> 250 mg/l). The map shows that a significant part of the study area has been impacted. The impacted zone extends radially outward from the dumpsites and may have extended to about 500 m south and up to 250 m north of the dumpsites.

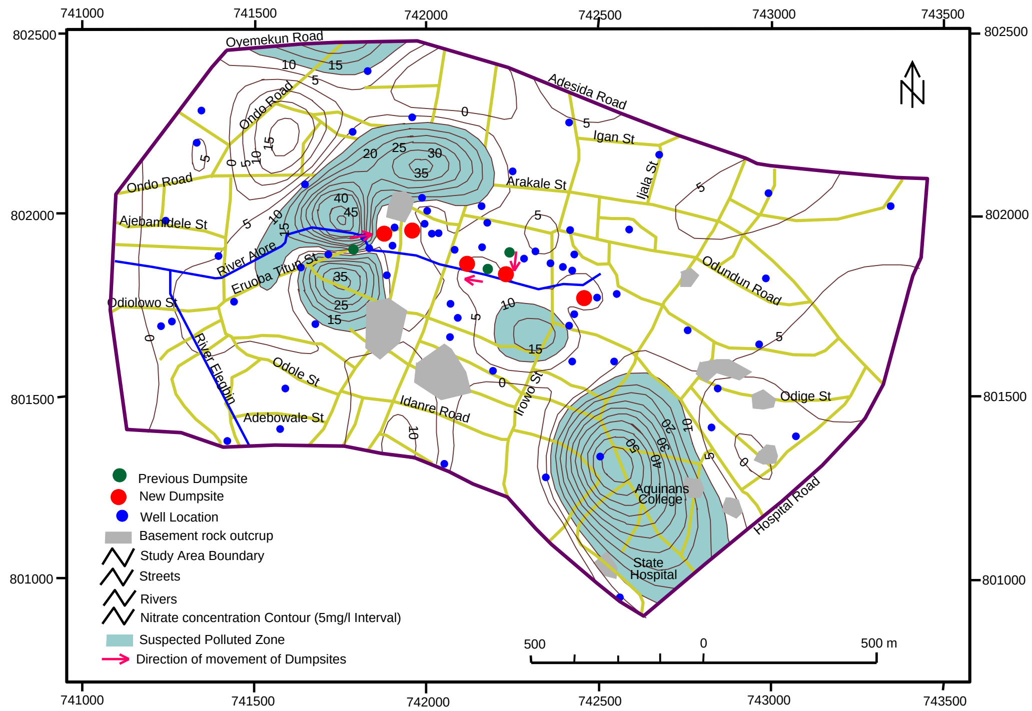

Figure 11: Nitrate (NO_3) Concentration Distribution Map of the Study Area.

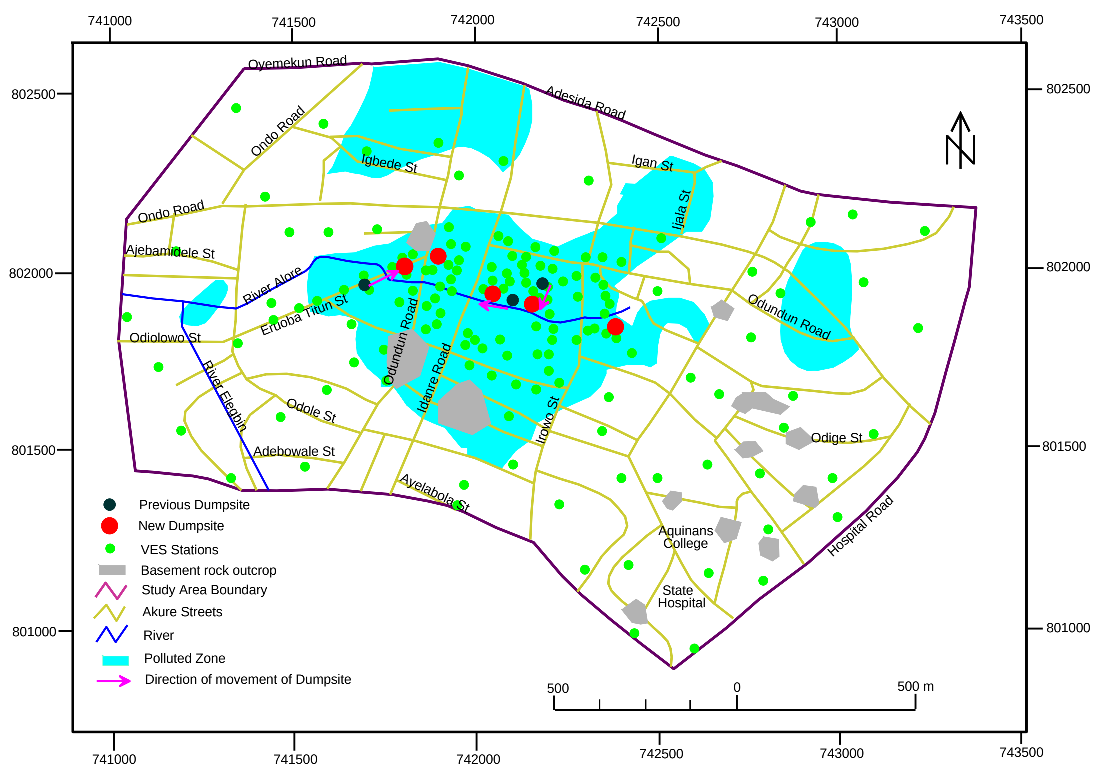

Figure 12: Pollution Extent Map of the Study Area.

The migration of the pollution plume is significantly southwards which corroborated the predominantly southward groundwater flow direction in the area (Figure 9). The identified suspected polluted zone in the far west may have emanated from a reclaimed dumpsite at Isinkan market. The polluted zone in the northwestern part was confirmed to be due to a reclaimed ancient dumpsites located at Igboyegun St. and Egbedi St., respectively.

CONCLUSIONS

Geophysical, hydrogeological and hydrochemical investigations have been used to assess pollution of soil and groundwater in the area around some selected ancient dumpsites located in the basement complex area of the Akure Metropolis, Southwestern Nigeria. The geoelectric section delineated a maximum of three subsurface layers. They are the top soil, weathered layer and the fractured/fresh basement rock. The weathered layer constitutes the major aquifer unit with characteristic low resistivity values of 6 – 38 ohm-m and thickness range of 2 -12.8 m.

The geoelectric section (Figure 3a - c), Table 1 and the 2-D resistivity structures (Figure 4 a - f) and resistivity maps revealed that both the topsoil and the weathered layer aquifer units have been contaminated by leachate released from the dumpsites. This is indicated by a topsoil resistivity of < 40 ohm-m and weathered layer resistivity values of < 20 ohm-m. Resistivity maps were generated for both the topsoil and the weathered layer.

The results of hydrochemical analysis of water samples from hand dug wells show that the electrical conductivity (EC) values generally range from 145 – 2361 µs/cm while the chloride concentration values range from 46 – 677 mg/l, and nitrate concentration levels conductivity (1000 – 2361 µs/cm), chloride concentration of > 250 mg/l and nitrate concentration of > 10 mg/l. These values are higher than the maximum permissible save values recommended by WHO, 1999 and FEPA, 1991 and hence a confirmation of groundwater pollution. The 2-D resistivity structures show that the suspected leachate depth of migration varies from about 2.5 – > 7.5 m beneath the dumpsites. The pollution migration has a predominantly southerly flow in line with the regional direction of the groundwater flow.

A pollution map was generated for the study area by adopting the following threshold values: topsoil resistivity value of < 40 ohm-m, weathered layer resistivity value of < 20 ohm-m, water conductivity of > 1000 µS/cm, and chloride concentration levels of > 250 mg/l. The generated pollution map (Figure 12) shows that a significant part of the area around the dumpsites has been impacted. The impacted zone has extended to about 250 m north and up to 500 m south of the dumpsites.

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