Asian Journal of Physical and Chemical Sciences

6(4): 1-11, 2018; Article no.AJOPACS.45413
ISSN: 2456-7779

Application of Electrical Resistivity and Geochemical to Monitor Soil and Groundwater Pollution at Tifinmadza, Mokwa Town, Niger State, Nigeria

T. U. Yusuf[1*], E. E. Udensi[2], K. A. Salako[2], P. C. Eze[3], A. A. Rafiu[2], A. Mohammed[1] and D. U. Alhassan[2]

[1]*Niger State College of Agriculture, Mokwa, Nigeria.*
[2]*Department of Physics, Federal University of Technology, Minna, Nigeria.*
[3]*Department of Soil Science, Federal University of Technology, Minna, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOPACS/2018/45413
Editor(s):
(1) Dr. Suresh Kumar Patra, Professor, Institute of Physics, Sachivalaya Marg, Bhubaneswar, India.
Reviewers:
(1) E. O. Joshua, University of Ibadan, Nigeria.
(2) Tajudeen Olugbenga Adeeko, University of Abuja, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/27665

Original Research Article

Received 13 September 2018
Accepted 26 November 2018
Published 08 December 2018

ABSTRACT

Vertical Electrical Sounding (VES) and physicochemical analysis techniques were carried out at TifinmadzaMokwa to investigate the degree and impact of the waste dumpsite on the quality status of soil and groundwater. Thirty Vertical Electrical Sounding points were investigated. The schlumberger array with a maximum electrode spread of 150 m was employed in all the points. Results from the sounding data indicated that the area was generally underlain by three to four geoelectric layers which included top soil, Clay Sandstone, Weathered basement, and Fresh basement. Based on the result obtained, the fractured and the weathered basement constituted the aquifer zones within the study area. Both the unsaturated overburden and the aquifer zones were characterised by dominant low resistivity anomaly associated to the delineated leachate plumes which implied very poor soil and groundwater quality. The results from both soil and groundwater analysis also revealed contamination by Lead, Chromium and Cadmium with concentration

**Corresponding author: E-mail: tklokogoma@gmail.com;*

exceeding the Canadian Soil Quality Guideline (CSQG), World Health Organization(WHO) and Standards Organization of Nigeria(SON) regulated guidelines. This implied a very strong correlation with the VES results and thus a very clear showcase of the dumpsite impact on both the soil and groundwater quality status. Therefore, the poor quality status of both the soil and the groundwater had made it unviable for farming activities, human consumption and other domestic uses.

Keywords: Cadmium; contamination; geophysical survey; leachate; farming; hydro-chemical; weathered basement; unprotected dump-site.

1. INTRODUCTION

Human induced soil and groundwater contamination via open dumps is among the major undesirable human activities which have brought about unending agricultural land use problems, soil and groundwater quality challenges among others around the study area. These Open dumps are generally unsanitary and constitute malodorous places in which disease-carrying vermin such as rats and flies proliferate [1].

Also, farmer's recent practice of indiscriminate choice of farm lands, most especially dumpsites, due to lack of specific principles for the crop management based on the variability of soil and groundwater properties can seriously affect the sustainability and profitability of agricultural practices. This can lead to waste of energy, time, cost and other resources which could be used to maximise the crop production. Contaminant plumes that ooze and seep down as leachates through dumpsites ultimately reach the soil, and ground water. Studies have shown that such leachates contain high load of organic matter, high nitrogen content and mass flux of transported contaminants which had impacted on plants heavily by entering the food chain through vegetation around the dumpsite [2]. Hazardous materials such as heavy metals, pesticides and hydrocarbons that are dissolved in these leachates often contaminate soil and water [3]. [4] suggested that continuous disposal of wastes on soil may lead to increase in heavy metals in the soil and surface water that would be inimical to both feeding plants and humans. Heavy metals such as arsenic, cadmium, lead, chromium, nickel, cobalt and mercury are of concern primarily because of their ability to harm soil organisms, plants, animals and human beings [3]. More emphatic are the untreated dumplings that rapidly increase soil toxicity making such dumpsites areas potentially hazardous for agricultural purposes. Yet these workers [4]; [3] also indicated that municipal waste dumpsites bear soils that are sufficiently rich in organic matter that would be acceptable for feeder plants and humans.

Therefore, this study is aimed at providing the physical and chemical quality status of the farmer's farmsite during the growing season using the most convenient geophysical methods. This farmer's knowledge about his farm site is very instrumental for any sustainable and profitable agricultural practice which guarantees food security for any viable nation. The choice of these geophysical methods for this research is due to its ability to offer the optimum convenience of achieving a very fast and extensive data measurement within the field without destroying or disturbing the soil at very economic survey cost. Also in addition, it offers the convenience of providing a more accurate and reliable soil and hydro-geophysical models which on proper implementation are capable of inducing a very high crop yield.

The study area (Fig. 1) is located in a humid tropical, wetland area where high rainfall and temperatures favour rapid degradation of organic materials [5]. This has attracted the public concern on soil and groundwater pollution and thus invited the focused attention on the disposal of wastes and its impact on soil and groundwater. Hence, this study intends to characterise both the soil and groundwater especially in relation to the concentrations of heavy metals (copper, zinc, iron, lead, chromium and cadmium)in the dumpsite soil and groundwater at the study area in view of its suitability for crop production and other uses.

1.1 Site Description

The study area (Fig. 1) is a dumpsite located at the frontage of Federal Road Safety Staff Quarters beside a transformer along Tifinmadza primary school road, Mokwa Local Government of Niger State, Nigeria(latitudes $9^{o}17'$ to $9^{o}18'$) N and longitudes $5^{o}03'$ to $5^{o}04'$) E). It covers an area of 60,000 $m^{2}$and lies within

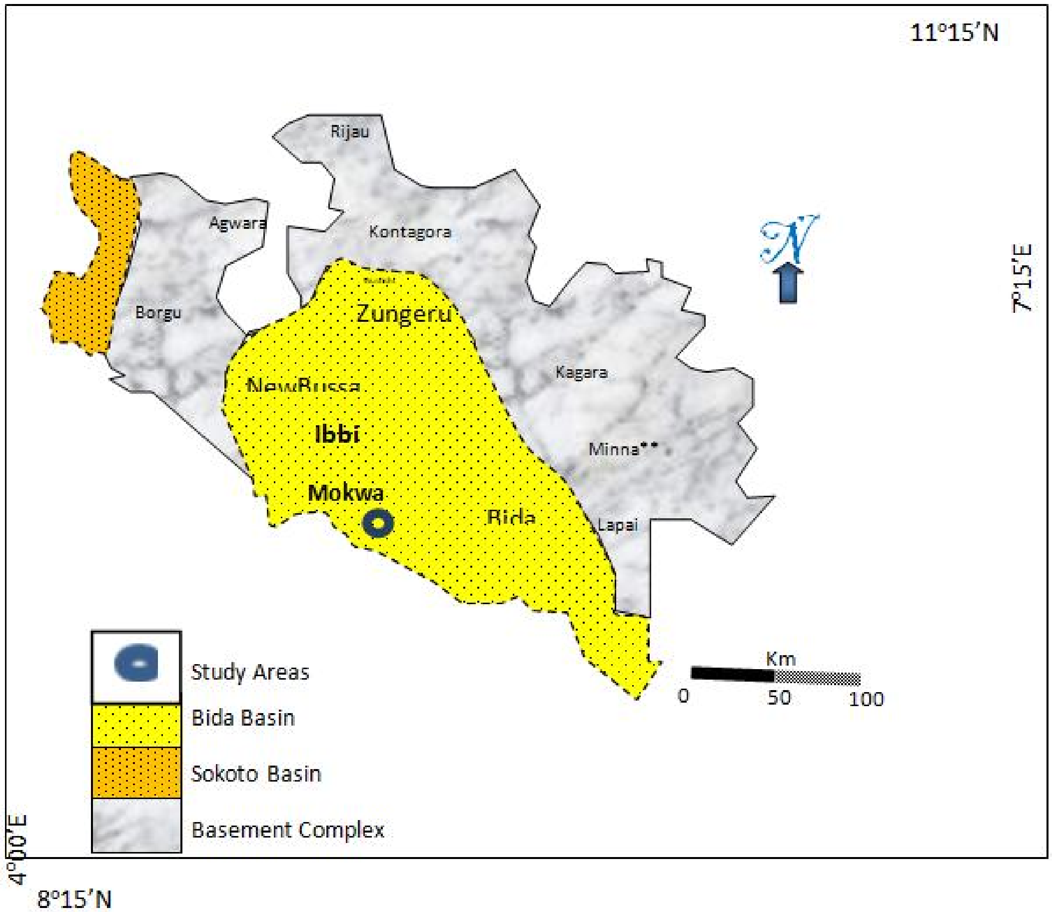


Fig. 1. Study location in Bida basin and Geology map of Niger State (Geology Department, Federal University of Technology, Minna), 2015.

the Bida Basin which is a NW–SE trending intracratonic sedimentary basin extending from Kontagora in Niger State of Nigeria to areas slightly beyond Lokoja in Kogi State. The Bida Sandstone is the basal sediment of the Middle Niger Basin, and it consists mainly of fine to coarse grained sandstone, conglomerates, siltstone and claystone [6]. It has an area of 4,338 km² and a population of 244,937 (2006 census). The sandstone which underlie the Mokwa and Kontagora plains are generally angular to sub-angular, well sorted to poorly sorted and very fine to very coarse and pebbly [7].

2. METHODOLOGY

ABEMTerrameter SAS 4000 was used for Vertical Electrical Soundings (VES). The area comprised of four profiles within the dumpsite and two other profiles outside the dumpsite. Thirty VES points were probed, out of which twenty points were within the dumpsite while the other ten points were within an area 500 m away from the dumpsite (control site) using Schlumberger electrode configuration. The resistance values displayed by the terrameter were recorded in recording sheets which were later used to compute apparent resistivity. The apparent resistivity was computed using equation (1):

$$\rho = \left(\frac{V}{I}\right)\left(\frac{A}{L}\right) = RK \quad (1)$$

Where ρ is the apparent resistivity, $R = \left(\frac{V}{I}\right)$, the earth resistance and $K = \left(\frac{A}{L}\right)$ is the geometrical factor. The apparent resistivity values obtained from equation (1) were plotted against the half current electrode separation spacing using IPI2WIN software to generate geoelectric model where layer resistivity, depth and thickness were obtained.

2.1 Groundwater and Soil Samples Collection

Three Groundwater samples were collected from the untreated wells around the dumpsite. Groundwater sample from the control site at 500 m distance from the dumpsite was also collected. The samples were collected using a fetch bucket that was cleansed with distilled water which were transferred into two plastic bottles (100 cl and 75 cl) that had also been cleansed with distilled water and tightly capped and clearly labeled. The temperature (in ^{O}C) and electrical conductivity (µS/cm) of all the samples were also measured and recorded using a Jenway 4010 Conductivity meter. An Oyster Series pH meter was used to measure the pH of all the samples. The alkalinity of all samples were determined using the volumetric analysis of the samples using equation (2).

$$\text{Total Alkalinity} = (\text{Volume of } H_2SO_4 \times \text{Molarity} \times 100{,}000 / \text{Volume of Sample}) \quad (2)$$

Six soil samples within the waste dumpsite were collected from the six profile pits dug. Each of the profile pit had dimension of Length = 2 m, Breadth = 2 m and Depth = 2 m. The samples were collected randomly at the depth interval of (0.30 – 1.80) m. 15 to 20 soil samples from various points within each of profile pit were randomly taken and bulked to give a composite sample. A sub sample of the composite soil from each profile pit was thereafter obtained and put in an already prepared 75 Cl plastic bottles. The bottles were then tightly capped and properly labeled. The concentrations of the heavy metals (zinc, lead, iron, copper, chromium and cadmium) in the soil and groundwater samples were then determined using a 210 VGP Buck Scientific Atomic Absorption Spectrophotometer as described by [8].The samples' temperatures, (^{O}C), electrical conductivity (µS/cm) and pH were determined at time of sampling on the field [9].

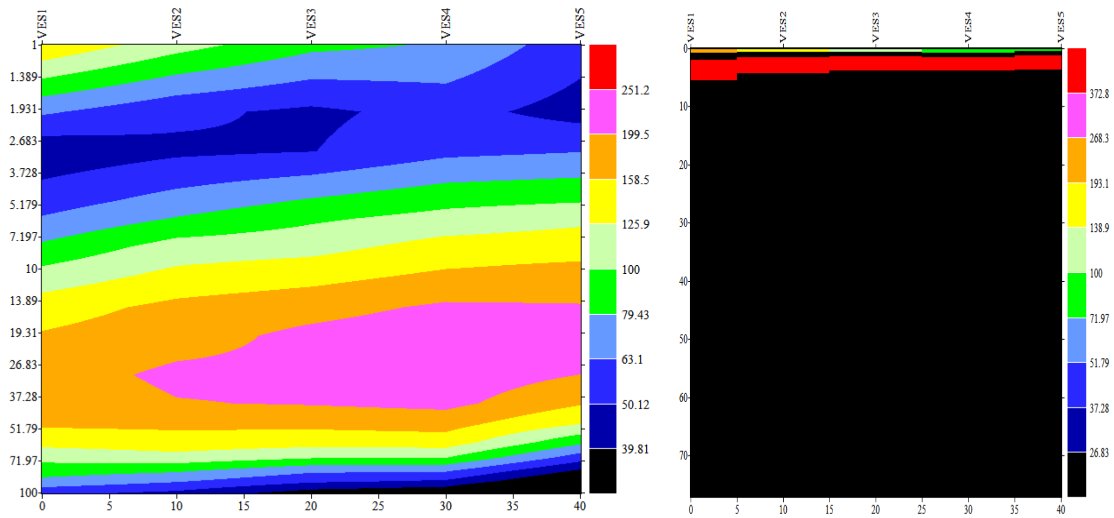
3. RESULTS AND DISCUSSION

3.1 Dumpsite

Figs. 2 (a) and (b) showed the pseudo cross sections and resistivity cross sections for VES points 1-5 along Profile 1 which was at the eastern edge of the study area and it runs north-south direction. Three geologic zones were delineated beneath this profile where the first zone exhibited moderately low apparent resistivity values varied (443.9 – 488) Ω-m. The second geologic zone was a moderately low resistivity zone (varying blue colorations) with apparent resistivity values ranged (478.9 – 523) Ω-m which started from the depths ranged (3.728 to 7.179) m and cut across all the VES point. The third geo-electric zone was a zone of extremely high resistivity values ranged (950 – 1173) Ω-m which started from the depths ranged (2.863 - 3.728) m and towards the west between VES points 1, 2, 3 and eastwards at VES point 5. This delineated extremely lowest apparent resistivity zone widen in thickness towards the eastern section (VES point 5) and its narrowed up through VES points 1, 2, 3 up to 4 as well. In the second Profile (Figs 3 (a) and (b)) three geologic zones were also delineated. The first zone was a zone that exhibited resistivity values ranged (77.56 – 443.9) Ω-m. This zone was observed around.

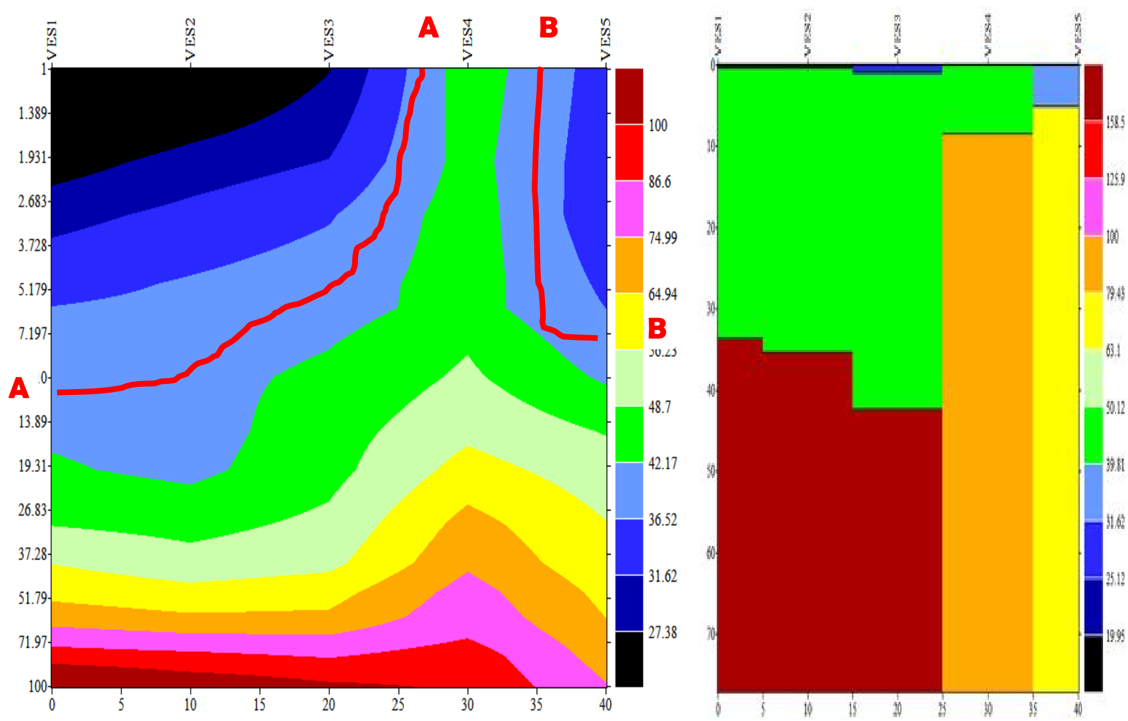
VES points 1, 2 and 3. It was very narrow under VES point 3 and progressively increased in thickness towards VES 2 and 1 the depth ranged (0.25 – 2.54) m. Also, a very sharp resistivity drop was delineated from (443.9 to 112.56) Ω-m between the first and second layers across VES points 1 & 2, and 4 & 5 denoted by (A-A^1 and B-B^1). The second layer had the lower resistivity values ranged (112.56 – 478.9) Ω-m with thickness ranged (4.63 to 17.29) m and depth varies between (7.02 and 18.11) m. The third zone was a zone of highest apparent resistivity values ranged (1347 – 2085) Ω-m. It occurred to the western section of the profile with thickness ranged (10.21 - 14.20) m and depths ranged (12.05 – 67) m at VES stations 3 and 5.Profile 3 (Figs 4 (a) and (b)) exhibited very low resistivity zone (black colour) with apparent resistivity value ranged (29.39 – 78.83) Ω-m at shallow subsurface with thickness ranged (0.21 – 3.33) m and depths ranged (0.28 – 4.09) m. The second zone had resistivity values ranged (64.39 – 113.83) Ω-m. This was the aquifer zone (represented by green, grey and yellow). It occurred around VES points 1 - 4 with thickness ranged (6.04 – 13.33) m and depths varies between (7.34 and 13.27) m. The third zone was the zone with highest resistivity value which varied (1239 – 1846) Ω-m with thickness ranged (12.01 – 21.15) m and depth ranged (13.08 – 48.02) m at VES points 2, 3, and 4.Profile 4 (Fig. 5 (a) and (b) probed had its first layer having extremely very low resistivity zone (49.75 –

443.9) Ω-m occurred around VES 1, 2 and 3 (black coloration) at relatively shallow topsoil with depth ranged (0.77 – 4.90) m. The second layer was characterised by very sharp horizontal strange pattern in soil indicated by a sharp fall in resistivity values from (443.9 to 84.75) Ω-m. This implied a fractured zone which can facilitate leachate percolation into soil. The third layer was the highest resistive zone with resistivity values ranged (1135 – 1510) Ω-m with thickness ranged (4.66 – 14.40) m and depth ranged (13.00 – 14.05) m [10].



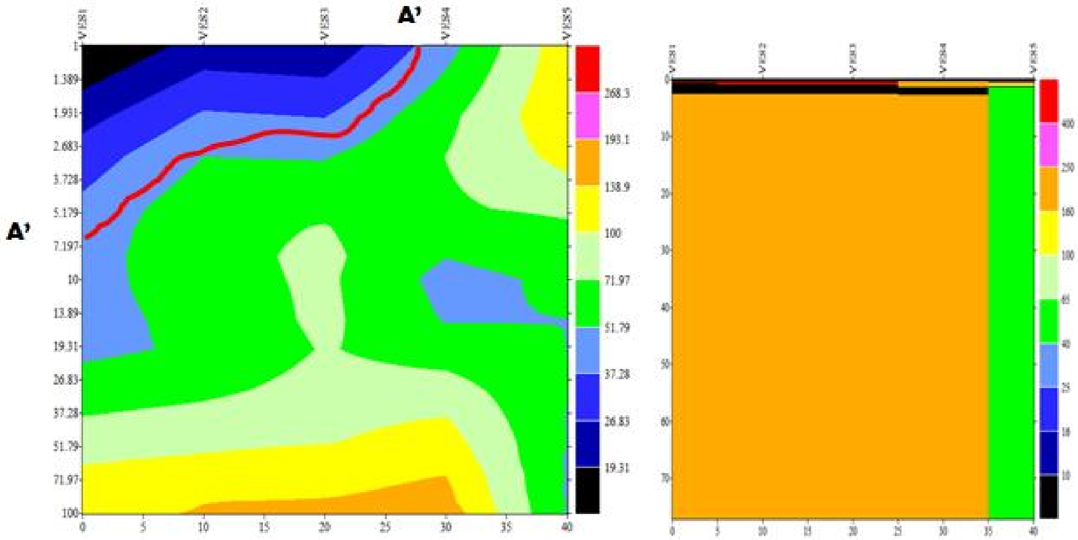
(a) Pseudo cross-section (b) Resistivity cross-section

Fig. 2. (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 1



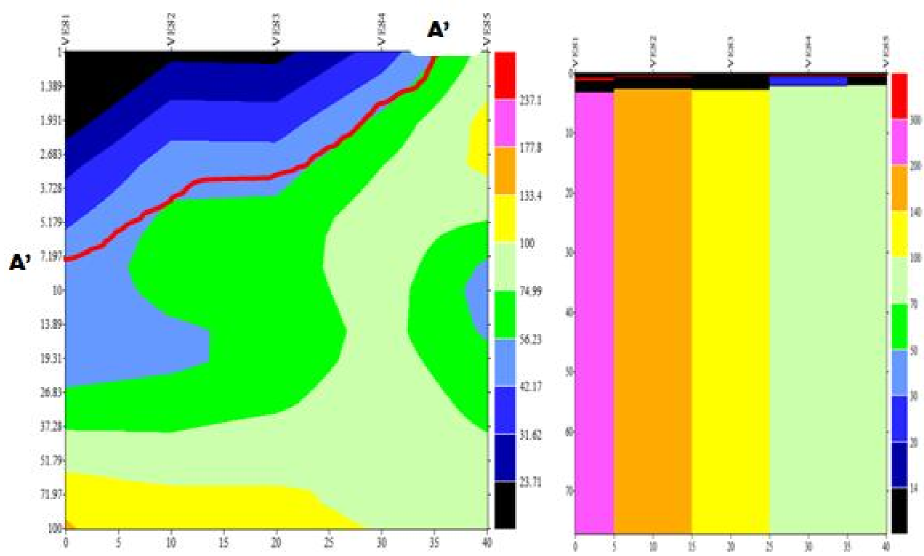
(a) Pseudo cross-section (b) Resistivity cross-section

Fig. 3. (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 2



(a) Pseudo cross-section **(b) Resistivity cross-section**

Fig. 4. (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 3.



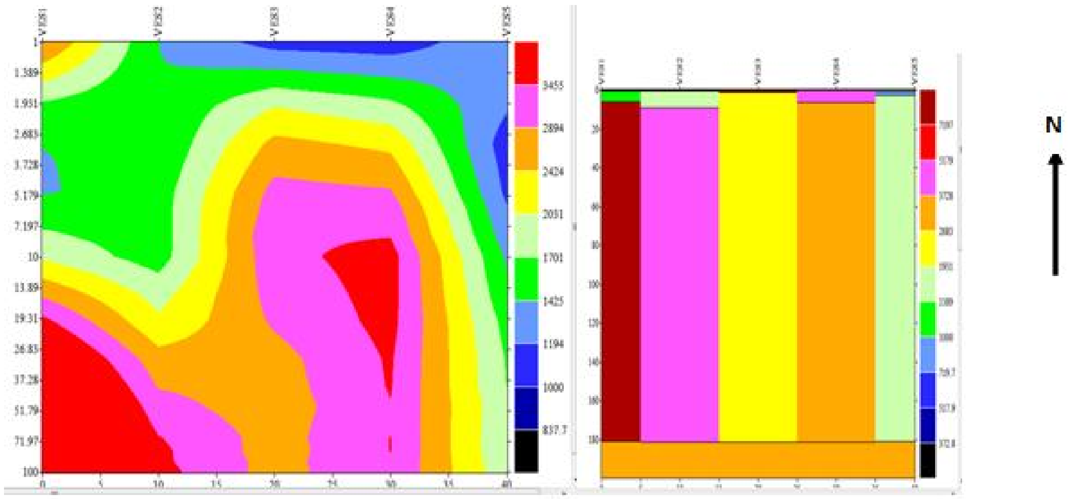
(a) Pseudo cross-section **(b) Resistivity cross-section**

Fig. 5. (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 4.

3.2 Control Site

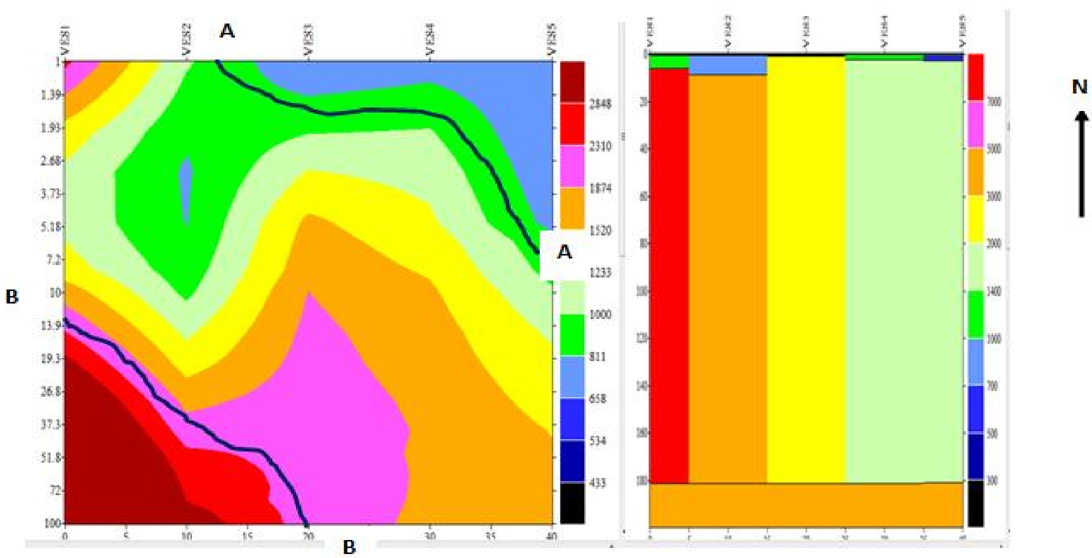
Figs. 6 (a) and (b) showed the pseudo cross sections and resistivity cross sections for VES points (1-5) 500 m away from the dumpsite across profile 1. It showed a high resistivity zone (400 - 427) Ωm of the first layer, with thickness ranged (0.23 – 5.00) m and depth ranged (1.10 – 5.00) m. The second layer was characterised by higher resistivity values which varied (420 – 448) Ωm with thickness ranged 3.71 – 15.74) m and depth ranged (7.01 – 15.74) m. The third layer exhibited the highest resistivity zone with values ranged between (925 and 1618) Ωm with thickness ranged (1.25 – 21.43) m and depth ranged (13.02 – 91.05) m.

Figs. 7 (a) and (b) is the resistivity model for profile 2 which exhibited high resistivity zone (426 - 465) Ωm at shallow depth (topsoil) around VES 1, with thickness ranged (0.72 – 4.98) m and depth ranged (0.88 – 5.30) m. The second layer was characterised by high resistivity values which varied (454 – 500) Ωm with thickness ranged (6.32 – 14.14) m and depth ranged (12.03 – 15.38) m, this zone was the aquifer zone. While the third layer exhibited the highest resistivity values ranged (717 – 1700) Ωm with thickness ranged (11.14 – 32.23) m and depth ranged (13.22 – 43.11) m.



(a) Pseudo cross-section (b) Resistivity cross-section

Fig. 6. (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 1 (control site 300 m away from the Dumpsite)



(a) Pseudo cross-section (b) Resistivity cross-section

Fig. 7. (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 2 (control site 300 m away from the Dumpsite)

3.3 Chemical Properties of Soil Samples at Dumpsite

The results (Table 1) for the soil samples analysed indicated that the measured pH value at the dumpsite and the control site ranged (6.34 – 7.23) and were within the Canadian Soil Quality Guide (CSQG) standard (Table 1). The mean soil pH of 6.76 at dumpsite indicated a neutral pH zone. The standard deviation also ranged (1.23 – 31.31) which indicated a skewed distribution. The results revealed the presence of the toxic hard metals (Zn, Pd, Fe, Cu, Cr and Cd) in the dumpsite soil. However, it was observed that samples from both the dumpsite and the control site had concentrations of Zinc, Lead, Iron Chromium and copper that fall within the CSQG standards with the exception of the dumpsite samples which had concentrations of Chromium above the CSQG standards (Table 1). The left skewed observed deviations of the toxic hard metal concentrations from the edge of the Dumpsite eastward depicted the trend of the leachate movement direction along wells A and C.

3.4 Physicochemical Properties of Groundwater Samples

The groundwater analysis results (Table 2) revealed the temperature of groundwater from Wells A and C to be 25.3ºC and 23.2ºC respectively which were below WHO and (SON) allowable limits while well B and the Control site Well has temperatures of 36.0 and 37.5 ^{O}C respectively which fell within the WHO and (SON) standards. The Wells around the dumpsite were all sited at distance ranged (75 - 152) m which was less than the recommended step-back distances of (480 - 960) m. The Groundwater pH values for the three Wells averaged 7.46, while pH value for Control Well was 7.60. The pH values for all the three Wells as well as the Control Well met the WHO and (SON) standards. The value of alkalinity for Wells A and C were above WHO and (SON) limits. The values for Well B as well as that of the Control Well were both within allowable limits.

Total Dissolve Solid and Total Hardness were lower than WHO and (SON) allowable limits (Table 2). Consequently, the groundwater from Well A was found to be contaminated by Zinc, Lead, Chromium and Cadmium while Well C was contaminated by only Cadmium because levels of their concentrations exceeded WHO and (SON) regulated guidelines. Well B was found to be free from contamination because its values fell within the WHO and (SON) allowable limits. This result correlated fine with the delineations on the Electrical Resistivity pseudo-sections for the profile 1 VES 1 probed at the dumpsite (Fig. 2) which was attributed to its depth (deepest 13.22) m and proximity (416) m to the dumpsite edge at VES point 1 of profile 1 which

Table 1. Chemical properties of soil samples at dumpsite at depth range of (0 - 2) m

Profile Pit	pH	Zn	Pb	Fe	Cu	Cr	Cd
			←	(mg/Kg)	→		
TM1	6.89	6.41	36.46	6.77	63.40	119.00	9.49
TM2	6.56	5.54	20.23	6.377	51.00	82.32	6.46
TM3	6.34	4.83	19.24	5.76	36.50	60.70	4.75
TM4	7.08	4.28	9.82	5.17	25.30	40.67	1.83
TM5	7.01	3.40	9.53	3.37	13.20	40.67	1.61
TM6	6.35	2.76	9.53	1.679	13.20	25.83	0.307
Min	6.34	2.76	9.53	1.68	13.20	25.83	0.31
CSQG	6 - 8	200	70	400	270	6.4	1.4
Max	7.08	6.41	36.46	6.77	63.40	119.00	9.49
Mean	6.71	4.54	17.47	4.85	33.77	61.53	4.08
S.D	0.30	1.23	9.63	1.79	18.71	31.31	3.18
TMC1	6.39	2.01	0.00	0.53	0.00	6.63	0.01
TMC2	7.23	1.55	0.01	0.85	1.04	2.62	0.001
TMC3	7.22	0.47	0.17	0.80	2.14	3.16	0.002
Min	6.39	0.47	0.00	0.53	0.00	3.16	0.001
Max	7.23	2.01	0.17	0.85	2.14	6.63	0.005
Mean	6.95	1.34	0.06	0.72	1.06	4.14	0.003
S.D	0.39	0.65	0.08	0.14	0.88	1.78	0.002

TM: Tifinmadza, TMC: Tifinmadza Control, CSQG: Canadian Soil Quality Guideline, SD: Standard Deviation.

Table 2. Physiochemical analysis on the groundwater from hand-dug wells around the dumpsite

Parameter	Unit	Well A	Well B	Well C	Control Well	WHO	NSDWQ
Distance from Dumpsite (m)		125	416	250	525	500	500
Measured Watertable Depth	M	12.47	13.22	12.91	12.91		
Temp	^{O}C	25.3	36.0	23.2	37.5	35 - 40	NS*
Ph		7.36	7.38	7.65	7.60	6.5 - 9.2	6.5-9.2
Conductivity	µS/cm	778	87	765	96	100	100
Alkalinity	mg/l	310	170	420		200	200
Acidity	mg/l	24	37	38	40	NS*	NS*
TDS	mg/l	1400	501	1100	480	500 - 550	500
Total Hardness	mg/l	56	43	63	32	500	500
Zinc	mg/l	4.08	2.06	0.07	0.002	3.0	3.0
Lead	mg/l	0.19	0.0008	0.00	0.00	0.001	0.001
Iron	mg/l	0.07	0.002	0.03	0.01	0.3	1.0
Copper	mg/l	0.25	0.00	0.00	0.00	2.0	1.5
Chromium	mg/l	0.73	0.004	1.08	0.005	0.05	0.05
Cadmium	mg/l	0.02	0.002	0.07	0.0001	0.003	0.005

TDS Total Dissolved Solids, NS = Not specified, WHO= World Health Organization, NSDWQ= Nigerian Standard for Drinking Water Quality.*

indicated no leachate invasion. The wells A and C corresponded to the contaminant plume observed in (Figs. 2 – 5) due to their location which was below the allowable setback distance from the dumpsite [11]. Such facilitated the aquifer invasion by leachates resulting into elevation in concentrations of Lead, Zinc, Chromium and Cadmium in soil and aquifer exceeding the permissible limits. This also agreed with the observed contaminations of both the soil and the groundwater as also revealed by Electrical Resistivity results [12]. These contaminants (Zinc, Lead, chromium and Cadmium) observed in both soil and groundwater remained a very serious challenge to the health quality of both plants (e.g. vegetables) and human as long as the dumpsite cultivation for agriculture and secured sources of domestic water supply were not redressed [13].

4. CONCLUSION

This research work revealed the soil and groundwater quality status of the study area. Geo-electrical imaging was very useful in mapping resistivity variations at dumpsite where leachate was inferred from the inverse model sections as well as the VES data. The results revealed leachate migration into the dumpsite soils and groundwater from mostly very shallow depth 0-3 m (plant root zones) down to the aquifer zones across profiles 1, 2, 3 and 4 [14]. The high potential clean groundwater with water table depth of about 51.79 m was at profiles 1. While profiles 2, 3 and 4, had shallower water tables at about 19 m which was characterised by fracture indicating that the groundwater at these profiles is vulnerable to leachate invasion. The Physicochemical soil and groundwater properties indicated elevations in the parameters analysed which implied pollution of the soil and groundwater by Zinc, Lead, Chromium and Cadmium with levels of their concentrations exceeded CSQG, WHO and SON regulated guidelines, while samples analysed from the control sites were within the tolerable limit, implying that the elevation observed around the dumpsite area was caused by the effect of dumps. The high conductivity of the subsurface materials and the fractured features were believed to have facilitated the movement of the leachates near and below the surface. This movement of leachates constituted a threat to the soil and groundwater system especially groundwater in the area since the area had a shallow aquifer overlain by weak zones and therefore, all the spotted wells around the dumpsite were dangerous for consumption. Consequently, these invaded soils and groundwater by leachates from dumpsites are therefore not viable for agricultural activities, domestic and industrial usage. This identified poor nature and quality status of both the groundwater and the soil viability constituted a very vital farmer's knowledge about his farm site, especially in relation to sustainable agricultural practices. This in addition is also a testimony that Agricultural geophysical researches remains the most simplest and rapid method in favor of quick farmer's knowledge and economic recovery.

5. RECOMMENDATIONS

Based on the result of this research work, it is recommended that:

Geophysical techniques should be adopted due to its economic convenience when determining the rate of leachate migration in order to educate farmers on the need to protect and plan for the unaffected soils and groundwater for the quality assurance in the area.

Sustainable treatment methods on these delineated leachates should be adopted to make it viable for agricultural activities because it contains other number of favorable characteristics for agriculture like; nitrogen (N), potassium (K), magnesium (Mg), and very low load in heavy metals that can be exploited.

Government should enact the enabling laws and its full implementations as it regards environmental protections.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bellebaum J. Between the Herring Gull Larus argentatus and the Bulldozer: Black-headed Gull Larus ridibundus feeding sites on a Refuse Dump. Ornis Fennica. 2005;82:166-171.
2. Weng HX, Zhang F, Zhu YM, Qin YC, Ji ZQ, et al. Treatment of Leachate from domestic landfills with three-stage physiochemical and biochemical technology. Environmental Earth Science. 2011;64:1675-1681.
3. Adelekan BA, Abegunde KD. Heavy metals contamination of soil and groundwater at automobile mechanic villages in Ibadan Nigeria. International Journal of Physical Science. 2011;6(5): 045-1058.
4. Anikwe MAN, Nwobodo KCA. Long term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, Nigeria. Journal of Biosource Technology. 2001;83(3):241-250.
5. Ayolagha GA. Survey and classification of Yenagoa-Meander Belt Soils in the Niger Delta.27th Proceedings of the Annual Conference of the Soil Science of Nigeria. November 5-9, 200, University of Calabar, Nigeria. 2001;10-16.
6. Adeleye DR. Sedimentology of the fluvial Bida Sandstone (Cretaceous), Nigeria. Journal of Sedimentary Geology. 1974;12(1):1-24.
   DOI:10.1016/0037-0738(74)90013-X
7. Olusola TO, Martin O, Eduvie I, Olaniyan O. Evaluation of groundwater resources of the Middle Niger (Bida) Basin of Nigeria. American Journal of Environmental Engineering. 2012;2(6):166-173.
   DOI:10.5923/j.ajee.20120206.04.
8. Zaura E, Elena AN, Bastiaan PK, Bart JF. Acquiring and maintaining a normal oral microbiome: Current perspective. Frontiers in Cellular and infection Microbiology; 2014.
   DOI:10.3389/fcimb.2014.00085
9. Rafiu AA, Mallam A. Investigation of contamination plumes at mechanic road, Bosso Waste Disposal site Using Geophysical and Geochemical Approach. Journal of Science Mathematics and Education. 2015;11(3).
10. Omolayo D, Fatoba JT. 2-D electrical imaging surveys for leachate plume migration at an old dump site in Ibadan South Western Nigeria: A Case Study. International Journal of Geophysics. 2014;2:1- 6. Article ID 879530.
11. Muhammad AI, Olugbenga BES, Adamu IH, Muhammad AC, Adamuadamu U. Parameters of water quality in hand dug wells (HDW) From Hardo Ward; 2015.
12. Awokunmi EE, Asaolu SS, Ipinmoroti KO. Effect of leaching on heavy metals concentration of soil in some dumpsites.

African Journal of Environmental Science and Technology (AJEST.). 2010;4(8):10-15.

13. Zauro SA, Dabai MI, Tsafe AI, Umar KJ, Lawal AM. Extent of some heavy metals contamination in soil of farmlands around Sokoto metropolis. European Scientific Journal. 2013;9(3). ISSN:1857 – 7881 (print) e - ISSN 1857- 7431 30.

14. Al Hagrey SA. Geophysical imaging of root-zone, trunk, and moisture heterogeneity. Journal of Experimental Botany. 2007;58:839-854.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/27665