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RESEARCH PAPER

Investigating Groundwater Quality and Soil Cultivation Viability Using Geophysical and Geochemical Approach at A Dumpsite in Mokwa, Niger State, Nigeria.

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ABSTRACT

Geophysical survey involving electrical resistivity method, soil and hydro-chemical analyses was conducted around Masallachi Idi dumpsite in (latitudes 9o18' N and longitudes 5o04' E) Mokwa, Niger State, Nigeria with the aim of investigating the degree and impact of the waste dumpsite on the quality of the groundwater and the recent farming activities observed in the study location. Forty Vertical Electrical Sounding survey were carried out at the study location. 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 location is generally underlain by three to four geo-electric sections which include top soil, Clay Sandstone, Weathered basement, and Fresh basement. Based on the results obtained, the fractured and the weathered basement constitute the aquifer zones within the study location. These zones are characterized by dominant low resistivity zones <75 Ωm due to the delineated leachate invasions up to the depth of 20 m which indicate very poor soil and groundwater quality. The results of the groundwater samples analyzed in this location revealed contamination by leachates containing Lead, Chromium and Cadmium whose average concentration levels (0.48, 1.06, and 0.04) mg/l respectively exceed the WHO and SON regulated limits. The results of soil analysis indicated that the soil samples collected in this dumpsite were also contaminated by the same elevated highest concentrations of Chromium 136 mg/kg and Cadmium 10.49 mg/kg implying that the poor quality state of both the soil and the groundwater had made it unviable for any agricultural activity or normal consumption. Immediate and appropriate law enactment on stoppage of farming activity within any dumpsite by the government is among the major recommendations.

Keywords: Heavy metals, Contamination, leachate, Farming, weathered basement.

INTRODUCTION

The increase in world population without corresponding available areas with fertile soils for agricultural production has mounted unending pressure on both agricultural lands and groundwater resources. As such careful soil and groundwater management for agriculture are required. The current rising population and growth in economic activities within Mokwa area and its environs too, has brought about insufficiency in fertile agricultural soils, greater demand for groundwater and decomposition of the generated huge waste matters into soil and groundwater contaminant leachates among the rest which are of great challenges to the qualities of soil and groundwater necessary for human and plants health as well as the entire environment. The selected Masallachi Idi Dumpsite which has served as a waste disposal facility for Mokwa market and its environs for over 30 years has now been regarded as a fertile soil used for cultivating fruits, vegetables, maize, guinea corn and other crops for consumption and economic purposes. Also the locally unprotected hand dug wells around the dumpsite were observed to be far below the recommended setback distances from the dumpsite. All these were being practiced

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without any regard to the risk/adverse effects of its possible contamination from the leachates absorption by those plants and its consumers. Studies have shown that leachates contain high load of organic matter, high nitrogen content and mass flux of transported contaminants which had impacted plants heavily by entering the food chain through vegetation around the dumpsite (Weng *et al*., 2011).The only focus was on the advantages of the cheap maximum yields derived from growing these crops within the dumpsite without any extra expenses on fertilizer application compared to other free lands and the cheaper drilling cost at shallow watertables in addition to the conveniences of fetching water right within their own compounds regardless of its quality. The dumpsite had rapidly developed with high tenements for its residents with the majority of houses having locally very shallow hand dug wells used for domestic consumptions. Consequently, communities' dependence on these agricultural crops and shallow hand dug wells in the affected areas exposed them to serious health hazards. Therefore, location and viability studies on such permeable unclean soils that are capable of yielding harmful and quantitative contaminated groundwater to our domestic wells, streams/rivers and agricultural crops became very important, most especially considering its very crucial life dependence role in relation to both human and plant health. Geophysical methods such as electrical resistivity, induced polarization, Ground Penetration Rader e.t.c. have been used to investigate these challenges.

Agriculture remains a vital tool for any buoyant economy and attainment of food security and sound health. Therefore, various methods to boost crop production and enhance soil and groundwater qualities must be enforced. Thus the increasing global demand for land/soil and water use in terms of quality and quantity calls for sustainable management of water catchment areas and better understanding of water and solute movements within the subsoil, since the quality of soil and water greatly affect agro-ecosystem, environment and human health. All these apprehension led to this work, so as to determine the quality of both soil and groundwater in the study location.

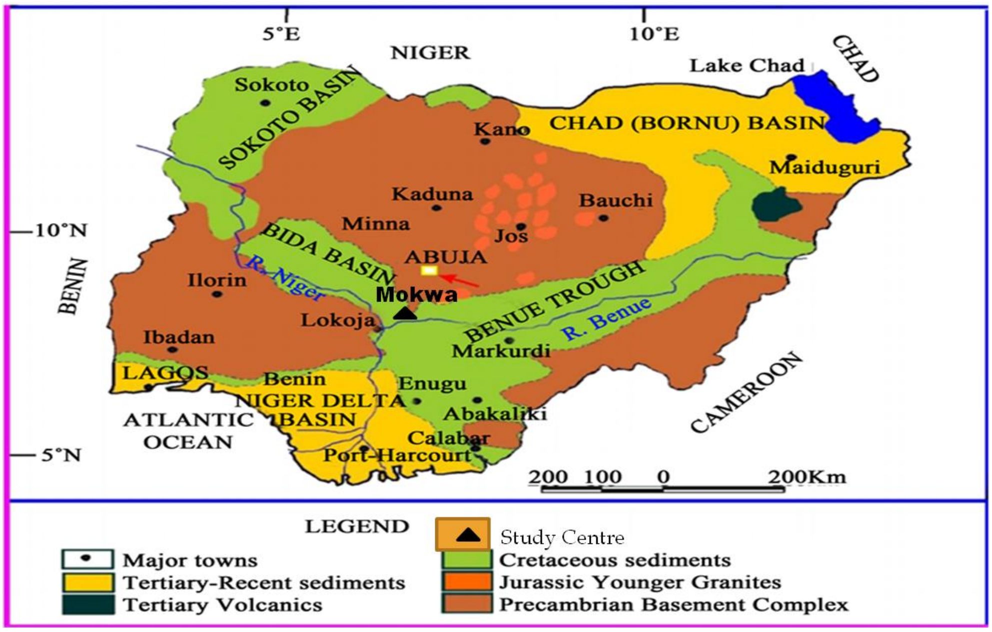


Figure 1.0: Study Locations and Geology map of Niger State (Geology Department, Federal University of Technology, Minna).

MATERIALS AND METHODS

Site Description

The study location is a dumpsite located between the College of Agric road and the Masallachi Idi prayer ground behind the Central market in Mokwa, Niger State, Nigeria (latitudes 9^{o}18' N and longitudes 5^{o}04' E). It covers an area of 300 m^2. Mokwa lies within the Mid-Niger Basin otherwise known as the Bida Basin or the Nupe 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 consist mainly of fine to coarse grained sandstone, conglomerates, siltstone and claystone. 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 (Olusola, *et al*., 2012).

Geophysical Survey

ABEM Terrameter SAS 4000 was used for Vertical Electrical Soundings (VES). The study location comprised six profiles within the dumpsite and two other profiles outside the dumpsite. Forty VES points were established, thirty points within the dumpsite and another ten points in another location outside the dumpsite to serve as control. The Schlumberger electrode configuration was adopted for the survey. The resistance values displayed by the terrameter were recorded on recording sheets and later used to compute apparent resistivity using equation (1):

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

where $\rho$is 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.

Groundwater and Soil Samples Collection and Analysis

Three Groundwater samples were collected from the untreated wells around the dumpsite which were located without obeying the recommended setback distances (500 m) as well as a samples from the control site at a distance not less than 500 m from the dumpsite. The groundwater samples were obtained using a fetch bucket which had been previously cleansed with distilled water. The groundwater samples from the fetch bucket were transferred into two plastic bottles (100 cl and 75 cl) that had also been cleansed with distilled water which were also tightly capped and clearly labeled. The temperature (^{O}C) and electrical conductivity (µS/cm) of all the groundwater samples were also measured and recorded using a Jenway 4010 Conductivity meter. An Oyster Series pH meter calibrated using a buffer 7 solution was also used to measure the pH of all the samples. The alkalinity of all groundwater samples was determined using the volumetric analysis of the samples. This was calculated using equation (2):

$$Total\ Alkalinity = \left(\frac{Volume\ of H2SO4\ x\ Molarity\ x\ 100{,}000}{Volume\ of\ Sample}\right) \qquad \ldots.(2)$$

Six soil samples within the waste dumpsite were also 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. This pit size was necessary for easier and clear observation of all the soil horizons from the bottom to the top of the pit (Plate I). The samples were collected randomly at the depth interval of (0.30 – 1.80) m. The individual representative (composite) soil samples from each of the six profile pits were collected by randomly fetching several samples from various points within the profile pit into the already prepared 75 Cl plastic bottles which were tightly capped and were properly labeled. The soil samples were air dried for four days and later oven dried for a day to ensured constant weight, gently crushed and sieved with 2 mm mesh sieve. 1.5 g of the soils samples were placed in 100 cm^3 Kjeldahl flasks and treated with a mixture of 60% $HClO_4$, Conc. HNO_3 and Conc. $H2SO_4$ in the ratio 5: 1: 0.5. The mixture was swirled gently and digested for fifteen minutes as reported in Radojeviv and Bashkin (1999), Aliyu and Bello (2004) and Inuwa (2004). The mixture was allowed to cool and diluted to 50 cm^3, heated gently and filtered. The filtrate was then diluted to 100 cm^3 and used for analysis using Atomic Absorption Spectrophotometry. 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 (Zaura *et al.,* 2013).The samples' temperatures, (^{O}C), electrical conductivity (µS/cm) and pH were determined at time of sampling on the field.

Classifying the soil layers

A brief analysis of the soil layers as observed from the dug profile pit (from top down) at the dumpsite in the various horizons (Plate II) shows that:

i. The soil structure ranged from loose – (0 – 0.5) m A1, granular – (0.5 – 0.85) m A2, blocky to platy- (1.2 – 2.0) m C1 – C3.
ii. The colors ranged from blackish (0 – 0.85) m A1 – A2, brownish- (0.85 – 1.5) m B – C1 to reddish - (1.5 – 2.0) m C2 – C3.
iii. The soil texture ranged from sandy– (0 – 1.2) m A1 – B, silt - (1.2 – 1.8) m B – C2 to clay- (1.5 – 2.0) m C2 – C3 (majorly sandstone and clay).
iv. The consistence (the firmness of the individual peds and how easily they break apart) ranged from loose - (0 – 1.2) m A1 – B, friable– (1.2 – 1.8) m C1 – C2 to firm – (1.5 – 2.0) m C2 – C3.

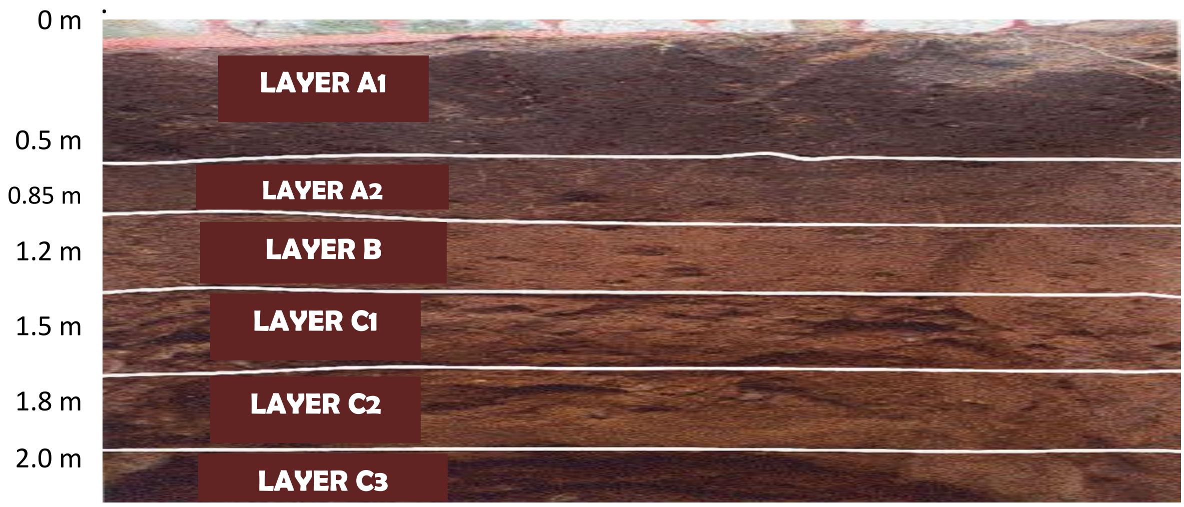


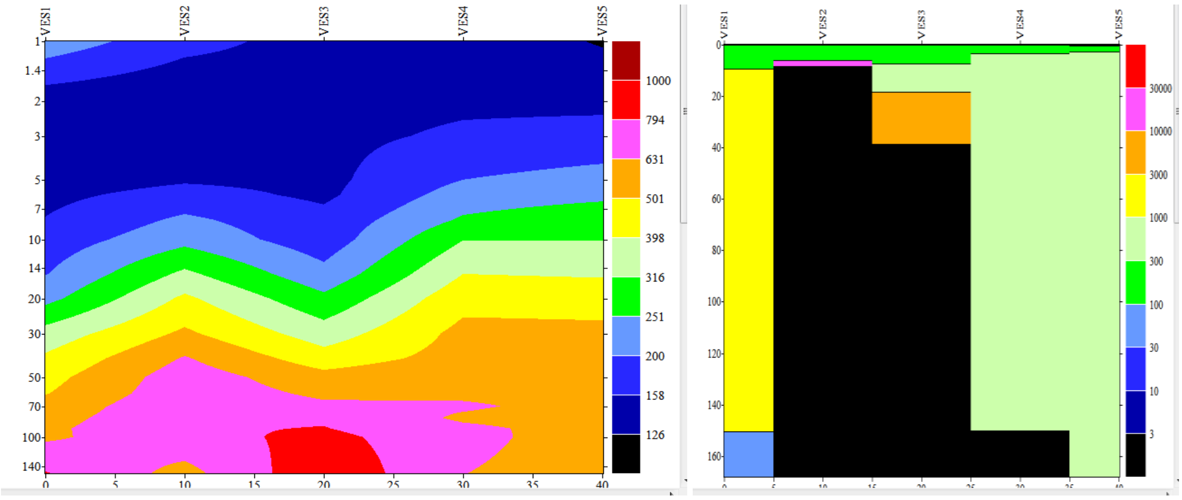
Plate I: Cross-section of the profile pit 1 dug at Masallachi Idi Dumpsite, Mokwa (N09^{0}17.874’, E005^{0}03.592’).

RESULTS AND DISCUSSION

Figures 2 to 9 show the 2-D interpretations of the Vertical Electrical Soundings at the dumpsite and the control site using IPI2WIN computer software across all the five VES points.

Profile 1

Figure 2 (a) and 2 (b) shows the pseudo cross sections and resistivity cross sections for VES points 1-5 along Profile 1 at the dumpsite for a maximum AB/2 spacing of (1-150) m. Among the three geologic sections delineated in this profile, the first geologic section exhibited the highest contamination level over a thickness range of (0.12 – 4.99) m indicated by the lowest apparent resistivity of 72.60 Ωm (the horizontal horizon made of up of deep blue coloration) at the depth of (1 – 7) m. This was interpreted as the contaminant plume, probably responsible for the contamination of top soil due to the accumulated leachates (Osazuwa and Abdullahi 2008). This contaminated zone further extended down to the depth range of (7.1 - 20.0) m due to the seepage of the accumulated leachates. The depths which were within the plants’ root zone can impact plants heavily and can enter the food chain through the vegetation on the dumpsite because plants rely so much on both the soil and the groundwater for their healthy growth (al Hagrey, 2007). The second layer resistivity ranged from (48.70 to 497) Ωm with thickness range of 2.02 to 15 m and the depth range of (5 – 20.02) m for VES points 1 to 5 (the horizontal horizon made up of green, grey, yellow and pink colors). This layer was interpreted as the leachates contaminated aquifer zone with the depth of water table at 20 m (Akaninyen and Magnus**,** 2011) represented by varying light blue colorations. It is overlaid by porous loosely and coarse sandstone formations, which had aided the downward infiltration of the leachate plume observed (Ehirim *et al.*, 2009, Abdullahi *et al.*, 2011, Ekeocha *et al.*, 2012, Ogungbe *et al.*, 2012). This discovery disproved the earlier findings by Olusola *et al.*, (2012) that the water in Nupe basin is very soft and portably fresh and clean for domestic, agricultural or industrial purposes. The third layer exhibited the highest resistivity zone which ranged from (420 to 1405) Ωm with thickness of (12.07 to 25) m represented by the red color delineated at the bottom around VES points 3 with resistivity value >794 Ωm. It is interpreted as a weathered basement at the deepest zone.

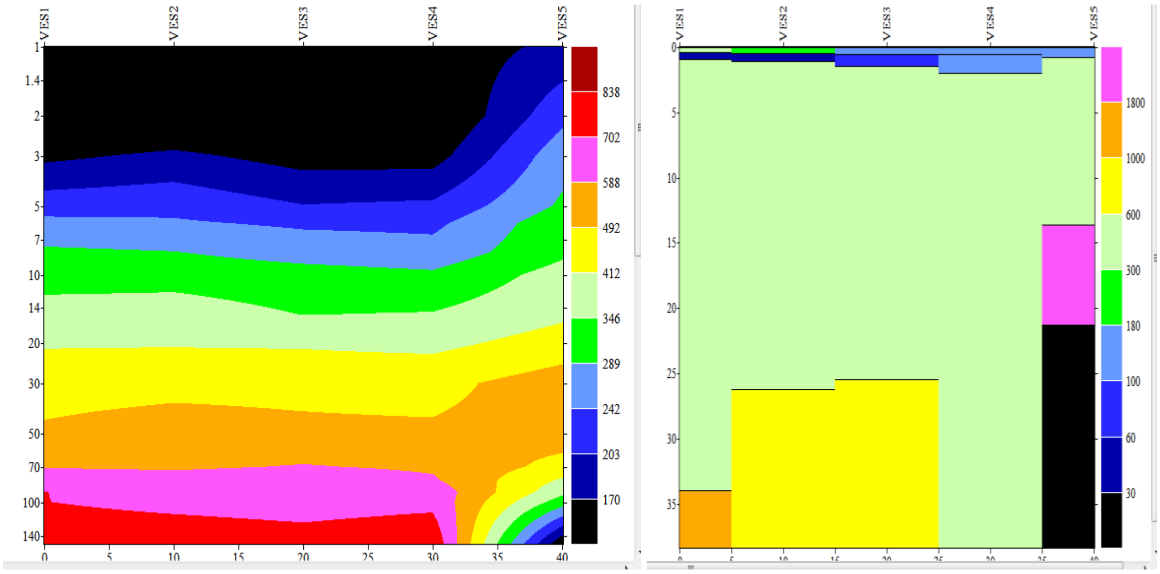


(a) Pseudo cross-section (b) Resistivity cross-section

Figure 2: Pseudo cross-section and Resistivity cross-section of VES 1-5 along profile 1 at Masallachi Idi dumpsite.

Profile 2

Profile 2 (Figure 3 a and b) also exhibited a moderately low apparent resistivity zone in the first layer with values ranging from (157 to 314) Ωm for AB/2 spacing of 1-150 m with same very narrow thickness and depth range of (0.389 to 0.778) m. This very low was attributed to heavy contamination of the top soil due to accumulated leachate plume (represented by black coloration along VES points 1 - 4) and the long age of the waste dump. The second layer is characterized by the higher resistive horizon with apparent resistivity values ranging from (177 – 334) m observed across all VES points and attributed to saturated sandstone and aquifer zone which was believed to have been contaminated by infiltrated leachates, with thickness values ranging from (0.02 – 7.02) m and depth ranged (7.03 to 19.02). This heavy topsoil contamination falls within the crop's root zone (1 to 3) m, implying greater possibility of crop intake of these human injurious contaminants which make such permeable soils unclean and non-viable for most agricultural activities. The horizontal horizon made up of green, grey, yellow and pink colors was the high potential water bearing zone which had been contaminated by leachate invasion indicated by horizontal horizon made of up varying blue colorations showing the leachates infiltration pattern towards the aquifer at a depth ranged (3 to 7) m (Abdullahi *et al*, 2010, Omolayo and Fatoba, 2014 and Fasuwon *et al.*, 2010). The third layer has apparent resistivity values that ranged from (1071 – 1770) Ωm with thickness range of (11.20 – 141) m and depth range of (21 – 150) m which depict fresh weathered basement (shown by the red coloration) observed around VES 1 to 4 with a very wide thickness.



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

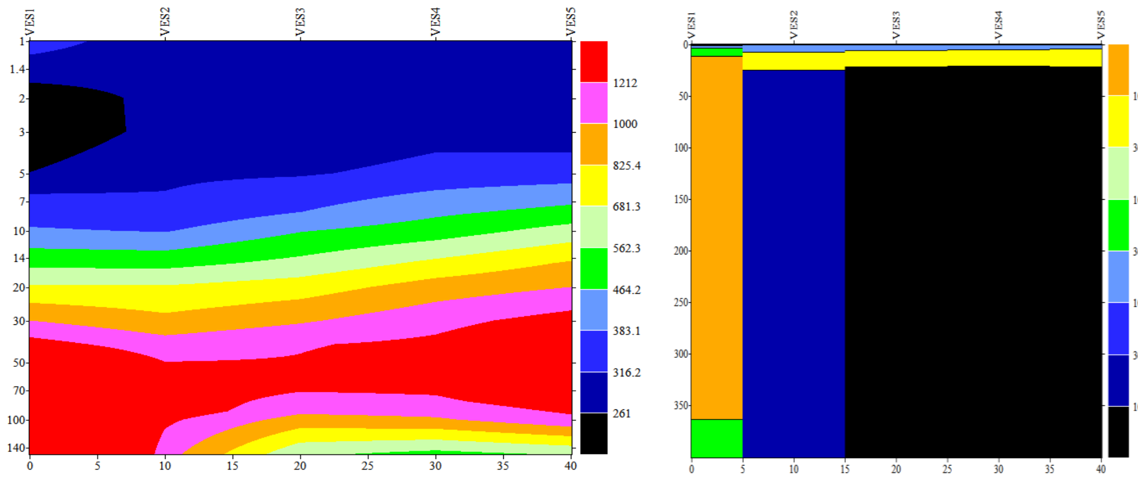
Figure 3: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 2 in Masallachi Idi Dumpsite.

Profile 3

Profile 3 (Figure 4 a and b)also exhibited a moderately low apparent resistivity zone in the first layer with values ranging from (276 to 637) Ωm for AB/2 spacing of 1-150 m with same very narrow thickness and depth range of (2.13 to 5.01) m. This lowest resistive zone was attributed to heavy contamination of the top soil due to accumulated leachate plume (represented by black coloration along VES points 1 - 4) and the long age of the waste dump. The second layer is characterized by the higher resistive horizon with apparent resistivity values ranging from (278.30 to 857) m with thickness values ranging from (3.02 to 12.33) m. This very low apparent resistivity was observed across all VES points and attributed to saturated sandstone and aquifer zone which was believed to have been contaminated by infiltrated leachates. This heavy topsoil contamination falls within the crop's root zone (1 to 3) m, implying greater possibility of crop intake of these human injurious contaminants which make such permeable soils unclean and non-viable for most agricultural activities. The horizontal horizon made up of green, grey, yellow and pink colors was the high potential water bearing zone which had been contaminated by leachate invasion indicated by horizontal horizon made of up varying blue colorations showing the leachates infiltration pattern towards the aquifer at a depth ranged (3 to 7) m (Abdullahi *et al*, 2010, Omolayo and Fatoba, 2014 and Fasuwon *et al*., 2010). The third layer has apparent resistivity values that ranged from (1060 – 1345) Ωm with thickness range of (11.01 – 147) m and depth range of (21.03 – 150) m which depict fresh weathered basement (shown by the red coloration) observed around VES 1 to 4 with a very wide thickness.

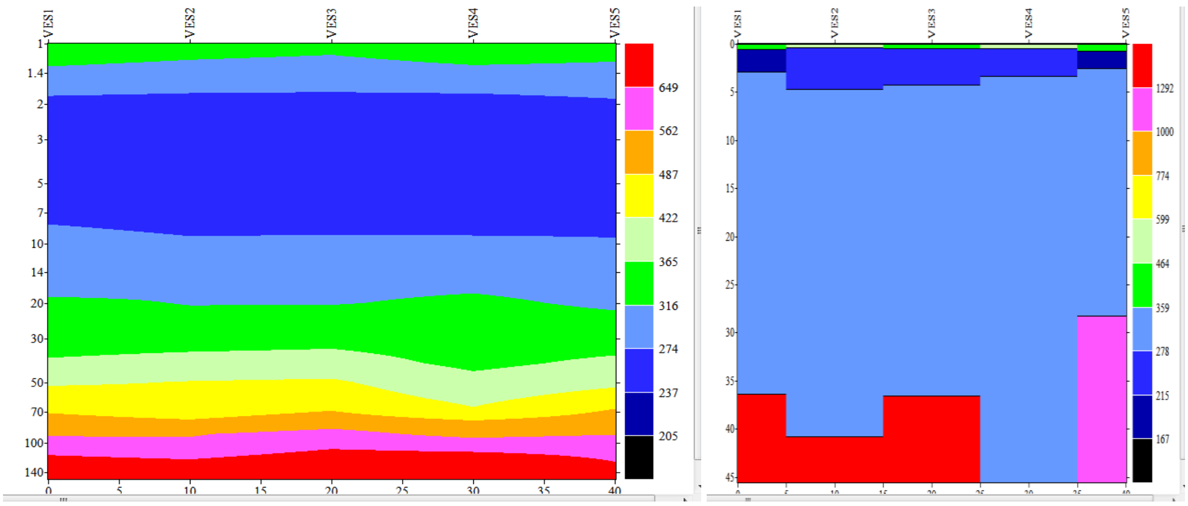
Profile 4

Profile 4 (Figure 5 a and b)also three geologic zones were delineated with apparent resistivity zones of 258.30 to 488.30 Ωm for the first layer with same thickness and depth ranged (2.01 – 4.50) m and (2 – 4.74) m respectively. Apparent resistivity values ranged from (92.60 to 192) Ωm with thickness ranged (2.35 to 14.01) m and depth ranged (8 to 15.01) m for the second layer, while the apparent resistivity values ranged (970 to 1920) Ωm with thickness ranged (7.63 to 175) m and depth ranged (21 – 178) m. This delineated moderately low apparent resistivity zone <217 Ωm varying blue colorations observed at the depth of 5.52 to 14.60 m was attributed to seeped of leachates from the topsoil down to aquifer zone with the water table at 13.00 m which implied groundwater contamination by leachates invasion (Abdullahi *et al*, 2010, Omolayo and Fatoba, 2014). This heavy topsoil contamination falls within the crop's root zone (1 to 3) m, observed across VES point 1 to midway towards VES2 believed to had infiltrated downwards and laterally thereby responsible for the pollution of VES points 2, 3, 4 and 5 as indicated by the varying blue colorations down to a depth ranged from (5.52 to 14.6) m engulfing the water table, implying greater possibility of crop intake of these human injurious contaminants which make such permeable soils unclean and non-viable for most agricultural activities. The underlay horizontal horizon made up of green, grey, yellow and pink colors observed between the depths ranged from 13 to 30 m was the leachate contaminated water bearing zone. The dominantly lower resistive zone delineated even from the topsoil implied saturated claystones and sandstones with contaminant plume and clearly indicated that the soil and the groundwater were contaminated and thus not viable for any agricultural cultivation Olorode and Alao (2013). The highly resistivity zones observed at the third layer depicted an intensively weathered basement with a varied thickness wideness and depth cutting across all the VES points.



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

Figure 4: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 3 in Masallachi Idi Dumpsite.

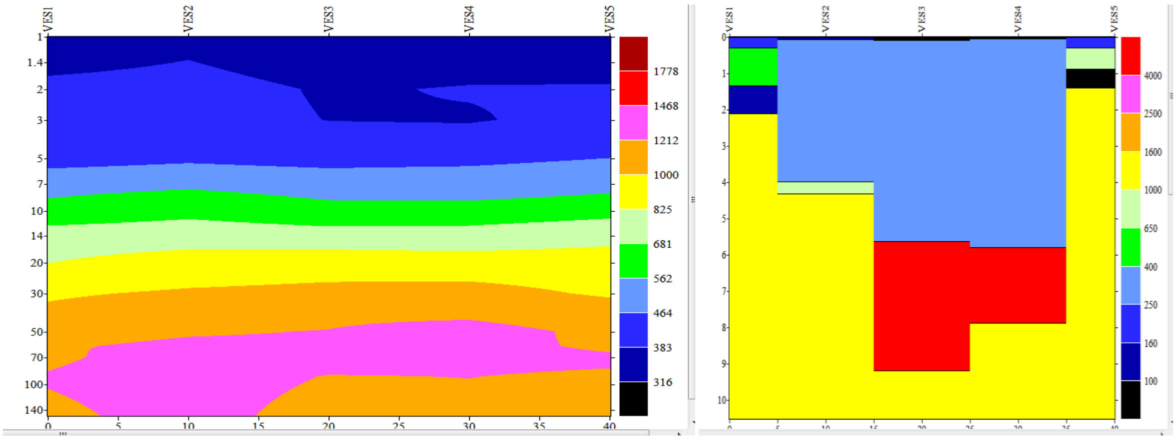


(a) Pseudo cross-section (b) Resistivity cross-section

Figure 5: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 4 in Masallachi Idi Dumpsite

Profile 5

Profile 5 (Figure 6 a and b) was also characterized by very low resistive anomaly with apparent resistivity values ranged from (72.60 to 385.6) Ωm with thickness and depth variations from (0.06 to 3.02) m and (0.09 to 3.65) m respectively for the first layer. Higher apparent resistivity zone with values ranged from (266 to 294) Ωm for a thickness ranged from (2.56 to 14.02) m and depth ranged from (8.06 to 22) m were delineated for the second layer, while resistivity zone of (1096 to 1920) Ωm was the delineated with its thickness range from (0.18 to 33) m and depth ranged from (21.02 to 41.02) m for the third layer. The dominant very low apparent resistive anomaly delineated in the first layer at the depth ranged (1 – 3) m from the top soil identified as the contaminant plume (represented by the deep blue color) accounted for the leachates infiltration observed at depth ranged from (1.5 to 8) m. This implied sandy clay soil underlain by the aquifer zone which had been trapped by the delineated fractured zone indicated by the sharp drop in apparent resistivity value from (1060 to 857) Ωm between the second and third layers. This was believed to have also aided the observed rapid leachates infiltration into the very shallow water table delineated at the depth of 8 m. This moderately lower soil physical property (apparent resistivity values <274 Ωm (represented by varying blue colorations) mapped out from shallow top soil (within the crop's root zone) across the all VES points indicated a very strong negative challenge on the continued use of dumpsite for agricultural practices in addition to the quality of the groundwater from the hand dug wells most of which were spotted below the recommended setback distances from the dumpsite. These negative effects were directly on plants grown and the groundwater which we survive on implying that soil and groundwater sources from dumpsites were not hygienically viable for plant cultivation. The third layer exhibited the highest resistivity horizon which depicted weathered basement with thickness of 33 m.

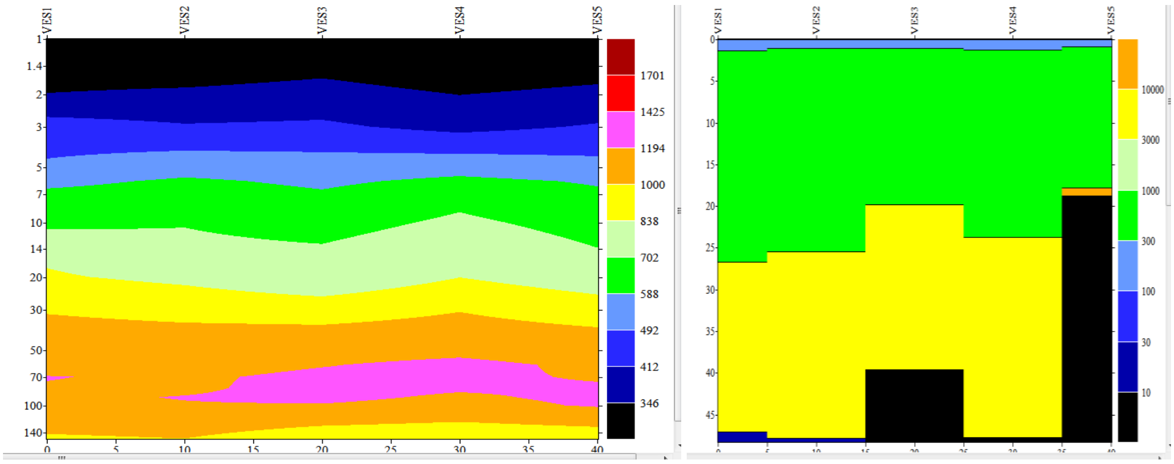


(a) Pseudo cross-section (b) Resistivity cross-section

Figure 6: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 5 in Masallachi Idi Dumpsite.

Profile 6

Profile 6 (Figure 7 a and b) also exhibited a moderately low resistivity zones of (169 to 274) Ωm with both thickness and depth ranged from (1.54 to 4.11) m and (1.64 to 4.11) m respectively for the first layer, apparent resistivity zone ranged from 431 to 885 Ωm with thickness ranged from (2.17 to 12.77) m and depth ranged from (8.03 to 15.06) m for the second layer while apparent resistivity values ranged from (1162 to 1455) Ωm with thickness ranged from 21.04 to 33 m and depth ranged (21.04 to 33.90) m for the third layer probed. The dominantly very high concentration of the contaminant plume was also observed at very shallow depth which ranged from 1 to 2 m in this profile. This again was another great challenge on the quality of both the soil and groundwater resources relevant for sustainable agricultural products and the human life within the study location. The water table here was observed at 7 m which was the shallowest water table out of profiles investigated, implying that it was the most exposed to the leachate invasion. The low apparent resistivity < 346 Ωm (black color)delineated even from the immediate top soil across all the VES also indicated the high concentration of the contaminant plume posing negative effects on soil, plants and the groundwater which the entire life depended upon. The infiltration horizon from the depth of 2 m down to the water table boundary at 7 m into the water bearing horizon with thickness ranged from (7 to 32) m were mapped out. This high aquifer thickness might also be due to the delineated fractured zone between second and third zones indicated by sharp jump in apparent resistivity from (885 to 1162) Ωm which cut across all VES points. The third layer for VES points (1-5) with highest resistivity variation depicted weathered basement delineated between VES points 2 - 5 with thickness of 11.96 m Rafiu and Mallam (2015)

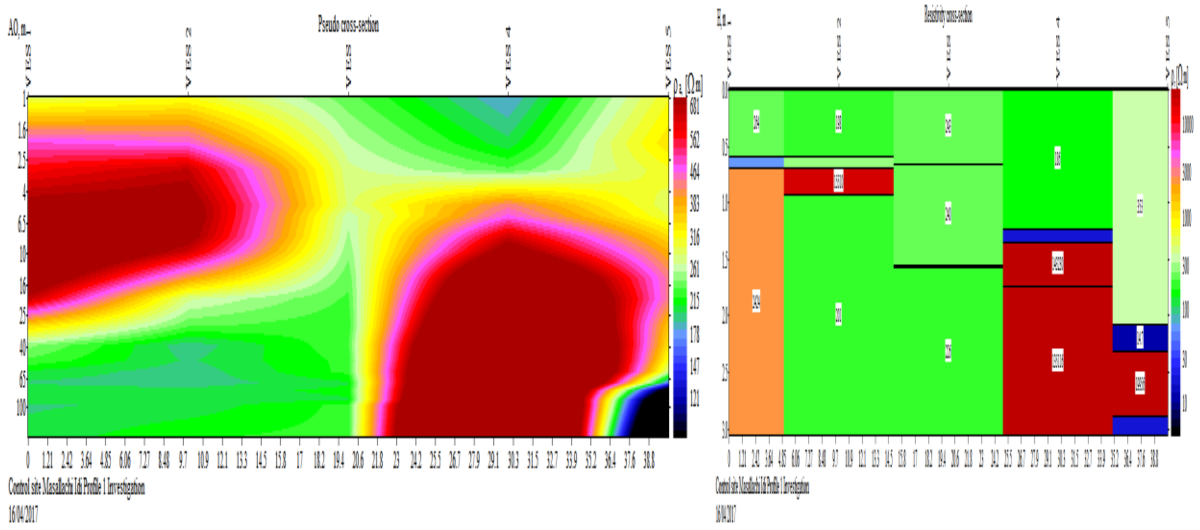


(a) Pseudo cross-section (b) Resistivity cross-section

Figure 7: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 6 in Masallachi Idi Dumpsite.

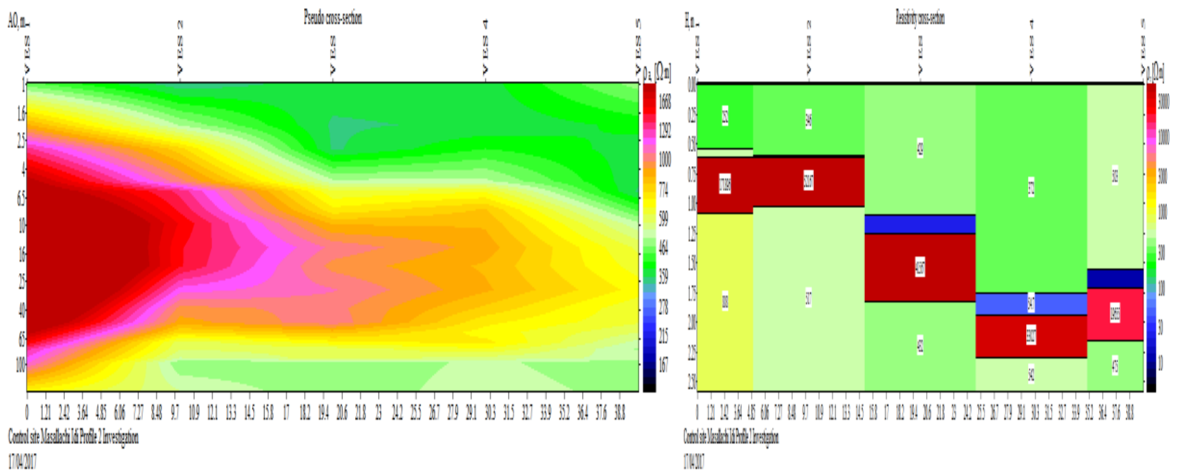
Profile 1 at Control site

Profile 1 (Figure 8 a and b) is the pseudo cross sections and resistivity cross sections for VES points 1-5 outside the refuse dumpsite 500 m away from the refuse dumpsite with three to four geologic sections delineated. The first section exhibited a low resistivity zone (219 – 428) Ωm with thickness and depth ranged from (0.12 to 4.56) m and (0.01 to 1.03) m respectively. The second geologic section is characterized by very low resistive zone where apparent resistivity values ranged from (115.28 to 613) Ωm with thickness ranged from (0.75 to 19.96) m and depth ranged from (8.02 to 20.01) m. This represents the aquifer zone which is free from contamination (Ogungbe *et al.*, 2012, Adabanija and Alabi, 2014). This higher apparent resistivity values within the plant root zone showed presence of well sorted clay/sandstone soil on the shallow subsurface and high humus and mineral contents which is also free from contamination. The third section is characterized by extremely higher resistivity values ranged from (963 to 1920) Ωm with thickness ranged from (15.09 to 99.81) m and depth ranged (21 – 100.03) m which implied weathered basement delineated along VES points 1, 2 and 4. Quantitative interpretation of this profile revealed that it has the lowest resistivity value of 115.28 Ωm which implies that the second layers in all the VES points were mainly clayey sandstone of low resistivity values indicating a rich soil (especially around VES points 3 and 4) with dissolved minerals that were free from contamination due to the relatively high resistivity values compared with the refuse disposal site. Both the soil and groundwater here were thought to be free from contamination. This is also in agreement with the results from the conducted physicochemical soil and water analysis at this site. Most parts of this profile comprise of good quality and quantity of viable soil and groundwater because the Dumpsite under investigation is dominantly free from the contaminant plume as observed at the dumpsites, thus VES points 4 and 5 have great groundwater potentials for exploration.



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

Figure 8: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 1 at the control site 500 m away from the Masallachi Idi dumpsite.



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

Figure 9: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 2 at the control site 500 m away from the Masallachi Idi dumpsite.

Profile 2 at Control site

Profile 2 (Figure 9 a and b) is the pseudo cross sections and resistivity cross sections for VES points 1-5 of profile 2 outside the refuse dumpsite 500 m away with three to four geologic sections delineated. The first section exhibit a low resistivity zone which ranged from (220 to 428) Ωm with thickness and depth ranged from (3.50 to 4.99) m and (2 to 5) m respectively. The second geologic section is characterized by higher resistive zone where apparent resistivity values ranged from (354 to 7555) Ωm with thickness ranged from 1(4.08 to 19.03) m and depth ranged from (15.08 to 20.10) m. This is the aquifer zone which is free from contamination (Ogungbe *et al.*, 2012, Adabanija and Alabi, 2014). The low apparent resistivity values exhibited show presence of well sorted clay/sandstone soil on the shallow subsurface with high humus and mineral contents which is also free from contamination. The third section is characterized by extremely higher resistivity values ranged from (963.17 to 1920) Ωm with thickness ranged from (22.01 to 37.23) m and depth ranged from (19.06 to 40.11) m which implies weathered basement delineated along VES points 1 and 2. Quantitative interpretation of this profile revealed that it had lowest resistivity value of 5.86 Ωm which implies that the second layer in all the VES points is mainly clayey sandstone of low resistivity values which is a property that indicate the higher level of richness of this soil for agricultural activity or groundwater sources (especially around VES points 2, 3, 4 and 5) with dissolved minerals that were free from contamination due to the relatively high resistivity values compared with the refuse disposal site. Both the soil and groundwater here were free from contamination as also revealed by the results from the conducted physicochemical soil and water analysis at the same site, Thus VES points 2, 3, 4 and 5 had great potential for water exploration and viable soil for agriculture, as evident from the delineated fractured zone across control profile 1 indicated by sudden drop in resistivity values from (428 to 115.28.) Ωm between the first and the second layer which accounted for the high groundwater potential inferred.

Soil Chemical Properties

Table 1 shows the results of analysed soil samples within the vicinity of Masallachi Idi Dumpsite compared with the control site and the standard set up by Canadian Soil Quality Guideline (CSQG) for the protection of the agricultural land and human health value for each metal. Descriptive Statistics using the computed mean and standard deviation were employed to interpret the measured soil parameters' (pH, Zn, Pd, Fe, Cu, Cr and Cd) concentrations. The results indicate that the measured high soil pH for both the dumpsite and the control site are within the CSQG standard signifying a slightly acidic soil type with a normal distribution which means micronutrients such as iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn) as well as other toxic metals (Pd, Cr and Cd) in this soil become less available from soil surface at such observed soil pH range, due to the facilitation of the minerals' solubility in soil by such high pH. These were gradually being dissolved and as they seeped down the soil, consequently being absorbed by the plants and partly seeped down to the groundwater (Bolland, *et al.,* 2004). The results revealed the presence of the toxic hard metals (Zn, Pd, Fe, Cu, Cr and Cd), some with very high concentrations in the soil and groundwater as well. A deviation of these toxic hard metal concentrations from the edge of the dumpsite westwards was observed which depicted the trend of the leachates movement direction. This was supported by the water analysis for wells A, B and C located very close to the dumpsite which showed elevation in concentrations of the analysed organic/inorganic parameters exceeding the permissible limits and thereby supporting the established contaminations of both the soil and the groundwater. The variations in different parameters may be attributed to the fluctuations in waste type and characteristics (Rafiu and Mallam, 2015). The concentrations as observed at the control site were within the normal allowable range and also indicated further decreases along the same pattern as observed by (Awokunmi *et al.,*(2010) and Rafiu and Mallam, (2016) which was in line with the electrical resistivity result. Chemical Properties of Soil Samples at Masallachi Idi Dumpsite at depth range of (0 – 2) m.

Table 1: Chemical Properties of Soil Samples at Depth ranged (0 - 2) m Masallachi Idi Dumpsite, Mokwa

Location	pH	Zn (mg/Kg)	Pb (mg/Kg)	Fe (mg/Kg)	Cu (mg/Kg)	Cr (mg/Kg)	Cd (mg/Kg)
MI1	6.45	7.91	27.65	7.86	56.12	136.00	10.49
MI2	6.23	5.87	25.72	8.48	44.00	116.00	7.84
MI3	6.41	5.53	22.43	6.86	38.50	84.33	5.34
MI4	6.67	4.97	18.64	6.47	27.50	64.66	4.92
MI5	6.53	4.60	19.75	4.44	19.10	43.74	3.24
MI6	6.68	4.08	15.29	2.49	13.50	22.33	1.92
CSQG	6 - 8	200	70		270	6.4	1.4
Min	6.23	4.08	15.29	2.49	13.50	22.33	1.92
Max	6.68	7.91	27.65	7.86	56.12	136.00	10.49
Mean	6.50	5.49	21.58	6.10	33.12	77.84	5.62
S.D	0.16	1.23	4.21	2.05	14.67	39.37	2.85
MIC1	6.19	0.00	1.25	0.00	0.00	8.11	1.82
MIC2	6.23	1.60	0.61	0.07	7.40	12.83	1.54
MIC3	6.26	0.10	0.15	0.00	4.00	0.00	1.37
Min	6.19	0.00	0.15	0.00	0.00	0.00	1.37
Max	6.26	1.60	1.25	0.07	7.40	12.83	1.82
Mean	6.23	0.57	0.67	0.02	3.80	6.98	1.58
S.D	0.03	0.73	0.45	0.03	3.02	5.30	0.19

MI: Masallachi Idi, MIC: Masallachi Idi Control, CSQG: Canadian Soil Quality Guideline.

Table 2: Physiochemical Properties of Groundwater from Hand Dug Wells near Masallachi Idi Dumpsite, Mokwa.

Parameter	**Unit**	**Well A**	**Well B**	**Well C**	**Control Well**	**WHO**	**NSDWQ**
Distance from Dumpsite (m)		46	152	256	512	500	500
Temp	^{O}C	23.6	23.3	23.1	35.7	35-40	NS*
pH		7.42	7.35	7.22	8.9	6.5-9.2	6.5-9.2
Conductivity	µS/cm	637	815	872	99.6	100	100
Alkalinity	mg/l	210	513	150	198	200	200
Acidity	mg/l	24	23	25	35	NS*	NS*
TDS	mg/l	1560	1200	1300	520	500-550	500
Total Hardness	mg/l	67	63	65	56	500	500
Zinc	mg/l	0.09	0.06	0.07	0.0001	3.0	3.0
Lead	mg/l	0.19	0.77	0.00	0.00	0.001	0.001
Iron	mg/l	0.07	0.0378	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	0.84	0.32	2.03	0.002	0.05	0.05
Cadmium	mg/l	0.02	0.05	0.06	0.0001	0.003	0.005

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

Groundwater Samples Interpretation

The results revealed that groundwater temperature for this study location ranged between 23.1 ^{O}C and 23.6 ^{O}C which is below WHO and SON limits (35 – 40) ^{O}C and the control well had temperature of 35.7 ^{O}C which is within the range of the WHO and SON. The pH value for the Groundwater from the sampled wells averaged 7.33, while pH value for control well was 8.9. The pH values for both three wells as well as control well met the WHO and SON standards. The value of alkalinity for wells A and B were above WHO and SON limits, while that of Well C was within the allowable limits. Groundwater from all the wells sampled around the dumpsite were found to be contaminated by Lead, Chromium and Cadmium with level of their contaminations exceeded WHO and SON regulated guidelines, this was similar to work of Jegede e*t al*,(2011) and Osazuwa and Abdullahi (2008).This also agreed with the interpretations from the electrical resistivity pseudo-sections for the same dumpsite (Figures 2 – 7). In the light of WHO and SON standards, it was inferred from the results of the physiochemical analysis (Table 1 and 2) that the values of the different analyzed parameters showed pollution of both the soil and groundwater. Particularly the contaminants (lead and cadmium) which are very toxic to living organisms even at low concentrations they had been found to have caused anomalies in metabolic functions of the organisms Manahan, (2001) and so it became a great danger for both plant and human health standards, so long as plants are being cultivated on the dumpsites and leachates contaminated wells remains the sole sources of the domestic groundwater sources for human consumptions.

Conclusion

This research has shown the soil and water quality of hand dug wells and the impacted polluted points in the research location (Mokwa). The research was developed as a Spatial Decision Support System and an aid to support decision making. Geo-electrical imaging was very useful in mapping resistivity variations at Masallachi Idi dumpsite. Leachate was inferred from the inverse model sections as well as the VES data. The results revealed leachate migration into the subsurface as well as its ingress into the surrounding soils and groundwater up to the depth of 20 m. This result was supported by physicochemical analysis of both soil and groundwater samples from the dumpsite investigated. The study location was mostly characterized by three (3) layered geologic sections which included the Topsoil, Weathered basement and Fresh basement. The 2-D Inversion delineated contaminant plumes as lowest resistivity zones which were mostly from the ground surface to varying depths of 0-3 m (plant root zones) across all profiles, believed to be leachates derived from decomposed wastes of higher concentrations. The inversion also revealed weak zones which were interpreted as fractured zones, which aided the migration of the leachate as shown in profile 1, 2, 3 and 6. The VES data revealed that the location has the shallowest water table of about 7 m in profiles 2 and 6, indicating that the groundwater at these profiles was already contaminated by leachate invasion. The conductivity level of the subsurface materials was believed to have facilitated the movement of the leachates near and below the surface. The movement of leachates constituted a threat to the soil and groundwater system and especially groundwater around the dumpsite since it had a shallow aquifer and therefore, water from all the spotted wells around the dumpsite was dangerous for consumption.

The results of Physicochemical analysis of soil and groundwater samples (Tables 1 and 2) around the dumpsite showed elevations in the parameters analyzed which implied pollution of the soil and groundwater by Copper, Iron, Lead, Chromium and Cadmium with levels of their concentrations exceeded WHO and SON regulated limits, while samples analyzed from the control sites were within the tolerable limit, implying that the elevation observed around the dumpsite was caused by the effect of dumpsite and so soils and groundwater invaded by leachates from dumpsites were not viable for agricultural activities or domestic consumption on health ground. This identified nature and quality status of both the groundwater and the soil viability in relation to sustainable agricultural practices were a testimony that Agricultural geophysical researches remains the most simplest and rapid method in as much as the soil humus content remained the key control on plant growth and health. A continuous and precise spatially and temporal follow-up of soil physical and chemical properties is mandatory in order to have maximum crop yield with a guaranteed quality. Sustainable treatment methods on these delineated leachates should also be adopted to make it viable for agricultural activities. Government should as a matter of national priority discourage the practice of spotting open dumps around residential areas, enforce the recommended soak-away setback distance (30 m), dumpsite to hand dug wells (500 m), seal up all the contaminated wells, ban the agricultural practices on dumpsite soils, provide borehole and promptly commence populace sensitization campaign on the danger of cultivating crops on leachate contaminated soils and drinking leachate contaminated groundwater**.**

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