Journal of Mining and Geology Vol. 57(1) 2021. pp. 55 - 66 0022-2763

2D Electrical Resistivity Survey and Heavy Metal Investigations of Soils and Water at Waste Dumpsites in Gombe Metropolis, North-Eastern Nigeria

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Abstract

2D electrical resistivity survey and heavy metal investigations were carried out to delineate soils, surface, and groundwater contaminated with leachate at three waste dumpsites in Gombe metropolis. Wenner-Schlumberger configuration was adopted in the 2D resistivity survey and two profiles were occupied at each of the three waste dumpsites. Twelve soil samples collected at depth of 30 cm along six profiles and one control soil sample were subjected to X-Ray fluorescence (XRF) analysis. Two water samples collected from nearby streams to Gombe Mega Park waste dumpsite and two water samples collected from two hand-dug wells at Yelenguruza waste dumpsite were subjected to Atomic Absorption Spectrometric (AAS) analysis. All 2D resistivity models showed resistivity varying from 0.16 Ωm to 11,434.5 Ωm and represents either uncontaminated or contaminated subsurface material to a maximum depth of about 6.37 m. Regions with resistivity values < 20 Ωm suggest regions contaminated with leachate. The models also showed regions contaminated with leachate beneath the waste pile and in the subsurface beneath the resistivity profiles, indicating that leachate migration was not limited to the area of dumping but infiltrated into the subsurface beneath the waste dumpsites. The values of Rb, Zr, Cu, Zn, Fe, Mn, Pb, Sr, Ni and As in the soil samples were higher than their values in control soil sample and could be attributed to the availability of metal containing industrial and domestic wastes at the dumpsites which have eventually leached into the underlying soils suggesting anthropogenic sources. The Zr values of 66.7% of the dumpsites soils exceeded its the background value of 267.00 mg/kg, Zn value (354 mg/kg) of Ashaka road dumpsite (FCWDPL2-D) exceeded its background value of 70 mg/kg, Pb value (30 mg/kg) of Ashaka road dumpsite (FCWDPL1-B) exceeded its background value of 27 mg/kg and Cu values of 84 mg/kg of Bajoga dumpsite (MGPWDPL2-C) and 44mg/kg of Ashaka road dumpsite (FCWDPL1-BA) exceeded its background reference value of 38.90 mg/kg respectively. The values of Zr, Zn, Pb and Cu in these soil samples are indicative of leaching and dissolution in the area suggesting contributions from geogenic and/or anthropogenic sources. The concentrations of heavy metals in well and stream water samples when compared with permissible limits from WHO and NSDWQ revealed that the water samples were not contaminated with metals such as Mn, Cu, Cd, Cr, Ni and Pb but Mg concentration in all the water samples exceeded the permissible limit of NSDWQ.

Keywords: *Resistivity, Models, heavy metals, Water, Soil and Contamination.*

Introduction

The indiscrimate disposal of waste has been a source of concern in many developing countries. Unlined waste disposal sites are filled with household refuse and different kinds of potentially dangerous industrial waste. They are poorly constructed or maintained, open to the air, and are unregulated. As air and surface water mix with the decomposed waste materials, contaminants from the solid wastes are extracted into the liquid phase to form leachate. The characteristics and volume of leachate produced in a dumpsite depend on the composition of the waste materials, availability of moisture and local temperature conditions (Raji and Adeoye, 2017). Dumpsite leachate is the worst known source of shallow groundwater aquifer contamination (MacDonald et al., 2012). Depending on the topography, hydrology condition, and the rock type within the locality, leachates can travel several metres of vertical and horizontal distances, thereby polluting soils, rocks, surface water and groundwater (Bernstone et al., 2000). Studies on the effects of unlined waste dumps on the host soil and underlying shallow aquifers have shown that soil and groundwater system can be polluted due to poorly designed waste disposal facilities (Amadi et al., 2012).

Electrical resistivity method provides an economic and non-destructive means to identify and delineate leachate contaminant plumes from dumpsite because leachate diminishes the electrical resistivity of the formation containing them (Reynolds, 1997; Martinho and Almeida, 2006). Rocks and soils infiltrated by leachate or contaminated water may contain significant amount of dissolved ions that can raise their conductivities from poor or moderate to anomalously high (Karlik and Kaya, 2001). Electrical resistivity survey and geochemical investigation in soil and ground water pollution studies at waste dumpsites and landfills have been documented in several studies. These include Bernstone et al. (2000); Karlik and Kaya (2001); Yoon and Park (2001); Ugwu and Nwosu (2009); Adeoti et al. (2011); MacDonald et al. (2012); Akanbi and Eze (2014); Hamzah et al. (2014); Selvam (2016); Raji and

Adeoye (2017); Olagunju et al. (2017); and Panday and Shukla (2019).

Refuse dumpsites are found within and outskirts of cities/towns in Nigeria. In Gombe metropolis, the collection of waste is irregular and ineffectively managed and as a result most waste disposal sites are uncontrolled and open, thus creating serious threats to local environmental quality and human health. There are limited reports on the extent of contaminations of soils and groundwater around waste dumpsites within Gombe and their possible effects on the environments. The aim of this study was to delineate soil, surface and groundwater contaminated with leachate at waste dumpsites in Gombe metropolis using 2D electrical resistivity survey and heavy metal investigations.

Study Location

The study area is located within Gombe metropolis, Gombe State, Northeastern Nigeria (Figure 1) on longitudes 11º 07' to 11º 15' E and latitudes 10º 15' to 10º 19' N. Gombe metropolis is a low-lying, undulating landscape sloping from Akko escarpments in the west to Liji hill in the east which is the highest point of about 500 m. The present study was carried out at three waste dumpsites within Gombe metropolis (Figure 1) located at: (i). Bajoga road after Gombe Mega Park (latitudes 10.32073° to 10.32389° N and longitudes 11.14589° to 11.14756° E); (ii). Ashaka road after Christian cemetery (latitudes 10.34287° to 10.34430° N and longitudes 11.14597° to 11.14672°E) and (iii). Yelanguruza Quarters (latitudes 10.27347° to 10.27441°N and longitudes 11.19338° to 11.19382° E).

Gombe metropolis is drained by some ephemeral streams and rivers, which take their sources from the Akko escarpment and flow eastwards (Figure 2). Gombe has a tropical continental type of climate, classified as Koppen's Aw and is characterized by strong rainfall variation with distinct wet and dry seasons (Oladipo, 1995). The rainfall is concentrated between the months of May and September with a single maximum in August and the average annual rainfall is about 863.2 mm. The vegetation is of the Sudan savannah type, characterized by shrubs, scattered trees and grasses (Amos et al., 2015).

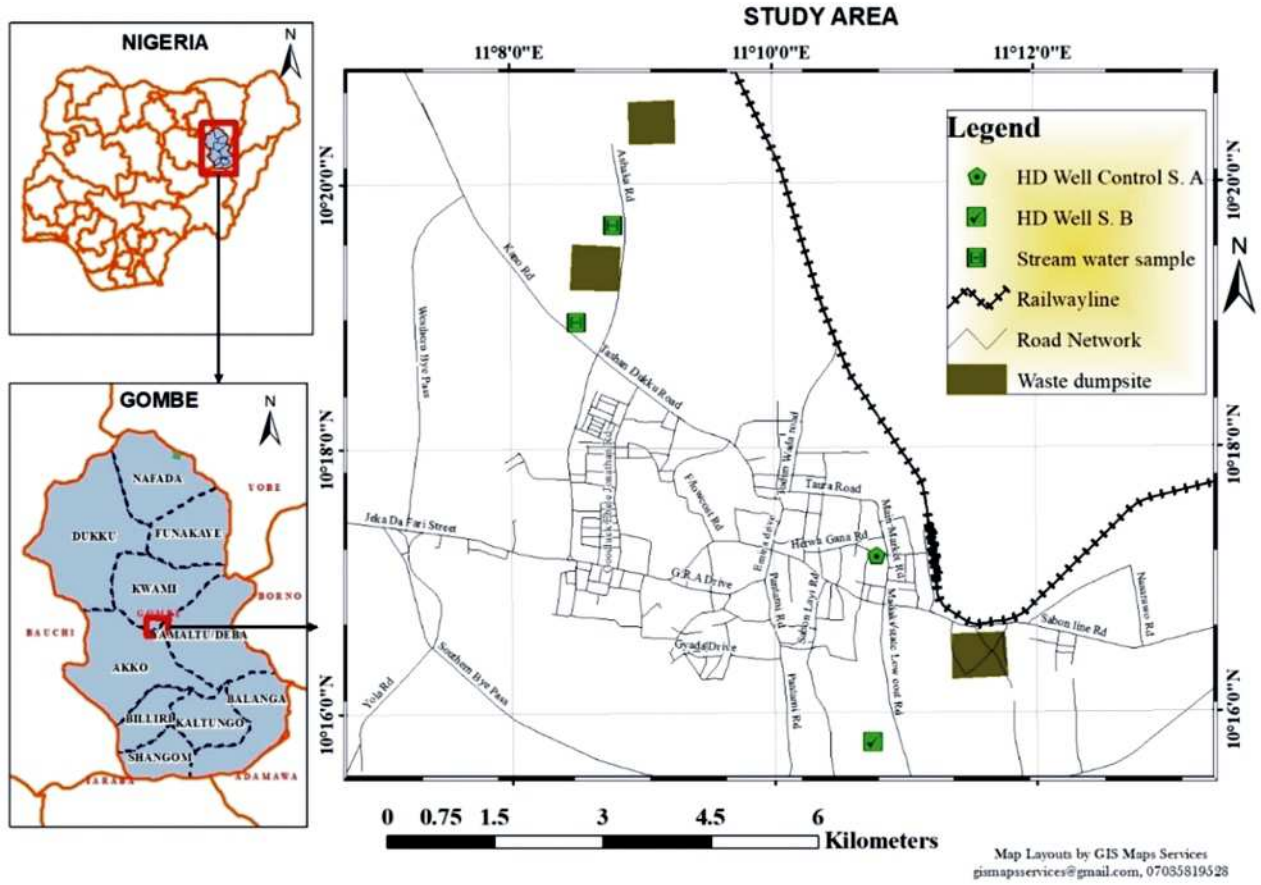

Fig. 1: Location map of Gombe, Metropolis showing the study area (Extracted from Topographical map of Gombe, sheet 152, Federal Surveys of Nigeria, 1962).

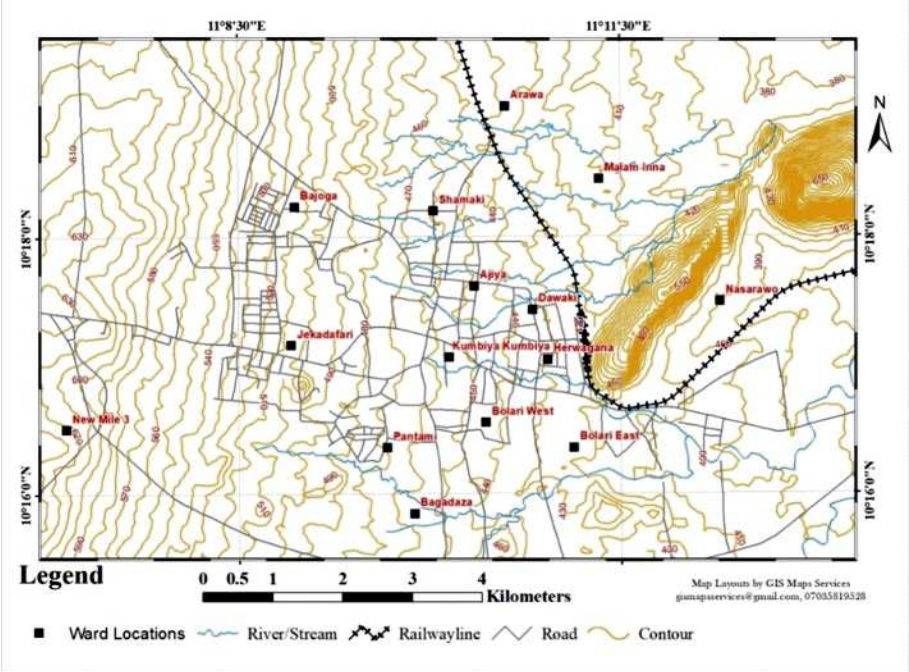

Fig. 2: Topographical map of the study area (Extracted from topography map of Gombe, sheet 152, Federal Surveys of Nigeria, 1962). Elevation contours in metres.

The study area is underlain by Precambrian Basement rock that is overlain by sedimentary rocks mainly consisting of sandstones of Cretaceous age and covered by Tertiary and Quaternary deposits. The stratigraphy of the study area consists of Alluvium, Kerri Kerri Formation, Gombe Formation, Pindiga Formation, Yolde Formation, Bima Formation and the Basement rocks (Figure 3). Alluvium includes most soils and comprises those deposits formed in-situ by the chemical and physical decomposition of the bedrocks. The soils are highly ferruginous (Carter et al., 1963).

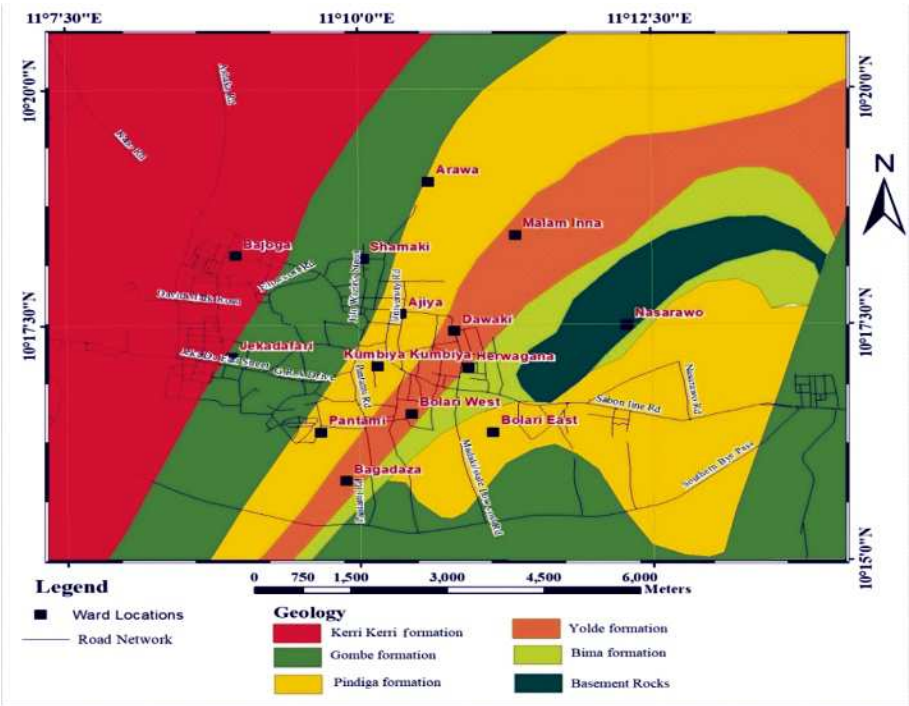

Fig. 3: Geology map of study area (Extracted from Geology map of Gombe, sheet 152, Nigerian Geological Survey Agency, 1963)

Materials and Methods

2D Resistivity Survey

2D electrical resistivity survey was carried out using Syscal Kid-IRIS 175 terrameter to measure resistance along two profiles at each of the three (3) waste dumpsites within the study area. Six (6) profile lines were occupied using Wenner-Schlumberger configuration and the arrangement of the electrodes in the field is shown in Figure 4. The profile lengths varied from 100 to 120 m depending on the available space and the electrode spacing "a" used was 2 m. The n factor (the ratio of the distance between the C1-P1 or P2-C2 electrodes to the spacing between the P1-P2, potential pair) varied from 1 to 5 and 1 to 6 depending on the length of the profile.

After the fieldwork, the measured resistance data was converted to apparent resistivity (ρ_a) data using Equation 1 (after Loke, 2004).

$$\rho_a = \frac{\Delta\Phi}{I} k \quad \text{.....(1)}$$

Where $\frac{\Delta\Phi}{I}$ is the measured resistance and k is the geometric factor for Wenner - Schlumberger configuration given by

$$k = \pi n(n+1)a \quad \text{.....(2)}$$

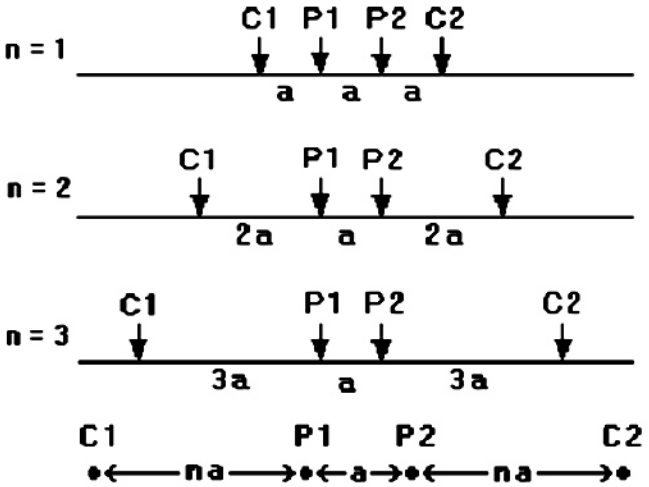

Fig. 4: Electrode arrangement for Wenner-Schlumberger Array (After, Loke, 2004)

The apparent resistivity (observed data) was then iteratively subjected to inversion using RES2DINVX64 software (after Loke and Barker, 1996) to generate the 2-D resistivity sections. The data was inverted with the standard least squares smoothness-constraint. The forward resistivity calculation was executed by applying an iterative algorithm based on finite difference method. The inversion program divided the subsurface into a number of small rectangular prisms and attempted to determine the resistivity values of the model prisms directed towards minimizing the percentage difference between the logarithms of calculated and the observed apparent resistivity values. The quality of the fit was expressed in terms of the Root Mean Square (RMS) error.

Soil and Water Samples Collection

Soil samples were collected at depth of 30 cm using hand trowel along the profile where the 2D electrical resistivity survey was conducted. Two (2) soil samples were collected along each profile and two (2) profile stations were occupied in each of the three waste dumpsites located at: (i). Bajoga road after Gombe Mega Park, (ii) Ashaka road after Christian cemetery and (iii) Yelanguruza Quarters. A control soil sample was collected at a distance of about 500 m from the waste dumpsites. A total of thirteen soil samples were collected and properly labelled in the field. The coordinates of each sampling point was taken with a Garmin-Entrex 10 Global Positioning System.

Water sample was collected using a plastic bottle from a 6 m deep hand dug well located about 30 m to the east of Yelenguruza waste dumpsite. A control water sample was collected in a plastic bottle from a 9 m deep hand dug well located about 500 m to Yelenguruza waste dumpsite. Two water samples were also collected using plastic bottles from a stream located about 8 m to the south and 11 m to the east of Gombe Mega Park waste dumpsite. A total of four water samples were collected and labelled with appropriate sample numbers. The locations for 2D electrical resistivity survey profiles and the sampling points for soils and water samples collected are shown in Figure 5. The soil and water samples collected in the field were taken to the Laboratory for sample preparations and geochemical analysis

Heavy Metal Analysis

Twelve soil samples and one control soil sample were air-dried in the Laboratory for about two weeks to remove the moisture content, and subjected to X-Ray fluorescence (XRF) analysis for the determination of the concentrations of heavy metals at Department of Science Laboratory Technology, University of Jos, Nigeria. XRF-Analyzer (XL3-98293) works on wavelength-dispersive spectroscopic principles and

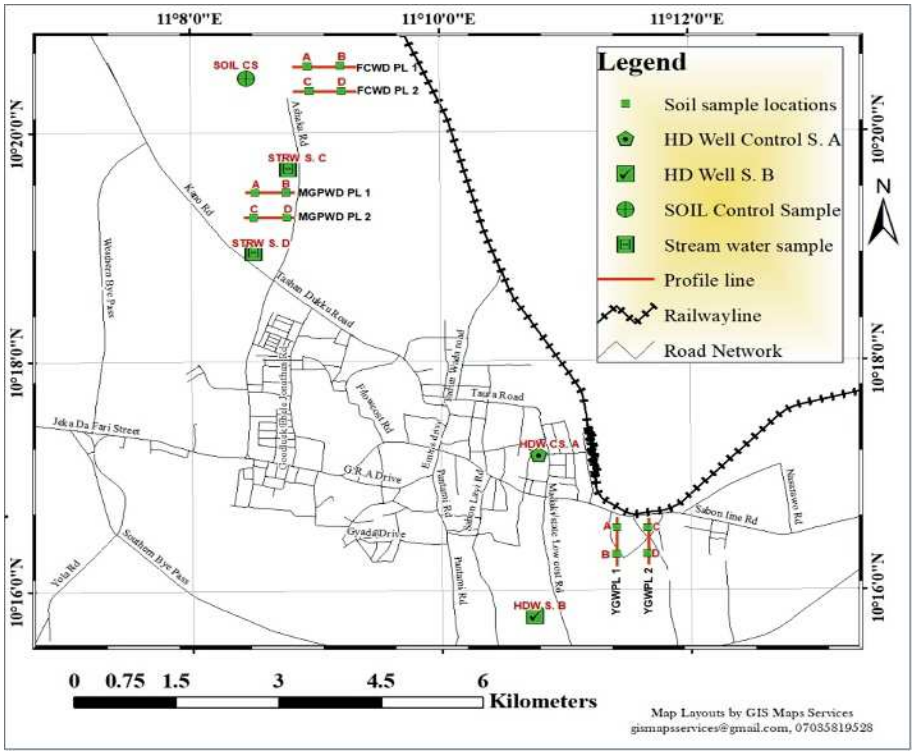

Fig. 5: Location map of Gombe Metropolis showing the 2D electrical resistivity survey profiles and sampling points of soil and water samples (Extracted from topographical map of Gombe, Sheet 152 by Federal Surveys of Nigeria, 1962) HD= Hand Dug.

was typically used for bulk analyses of soil samples Four water samples were subjected to Atomic Absorption Spectrometric (AAS) analysis for the determination of concentrations of heavy metals such as Mg, Mn, Cu, Cd, Cr, Co, Ni and Pb at Department of Biochemistry, Gombe state University, Nigeria.

Results

The inverse model resistivity sections for profiles 1 to 6 are shown in Figures 6 to 11. These are the interpretation models showing resistivity values varying laterally along the profile and vertically with depth to the maximum investigation depth. The colour scale bar in each figure shows true resistivity variation within the subsurface along each profile.

Heavy metal concentration in soil samples collected along the 2D electrical resistivity profiles and the control soil sample are presented in Table 1. The concentration of heavy metals in water samples collected from wells and streams are presented in Table 2. The heavy metal concentrations in soils obtained from this study were compared background reference levels for uncontaminated soils values (world soil average) obtained from Kabata-Pendias (2011), threshold and permissible limits from international regulatory standards (Toth, 2016; UNEP, 2013; Pendias and Pendias, 2000; and Sudhakaran et al. 2018) as presented in Table 3.

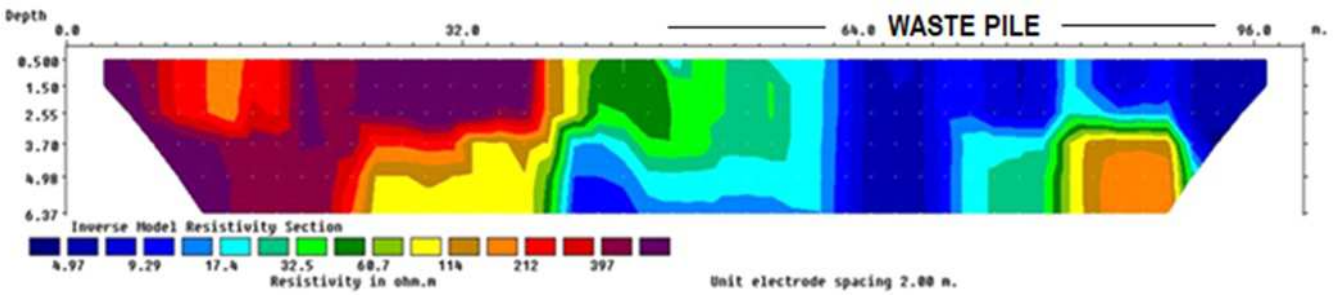

Fig. 6: 2D Resistivity model for profile 1 along FCE after Christian Cemetery dumpsite (depth in metres).

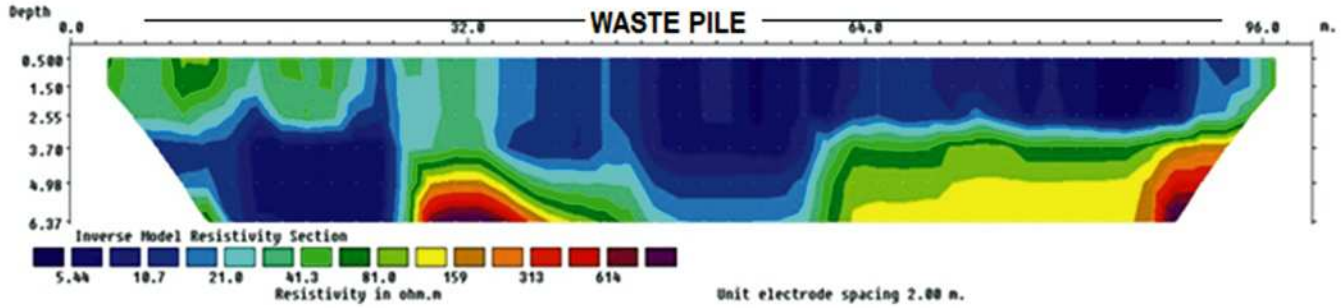

Fig. 7: 2D Resistivity model of profile 2 at FCE after Christian Cemetery dumpsite (depth in metres).

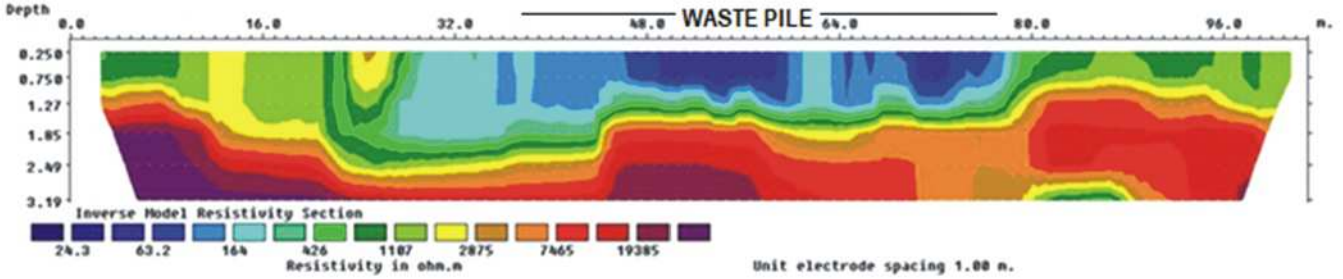

Fig. 8: 2D Resistivity model for profile 3 at Gombe Mega Park dumpsite (depth in metres).

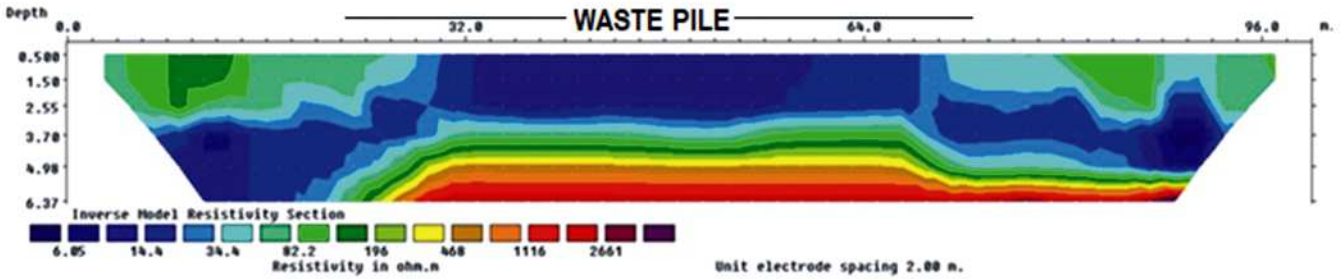

Fig. 9: 2D Resistivity model for profile 4 at Gombe Mega Park dumpsite (depth in metres).

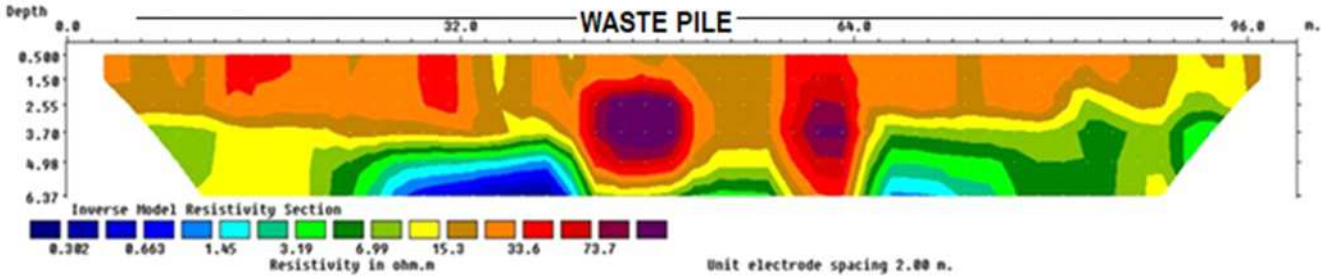

Fig. 10: 2D Resistivity model for profile 5 at Yelenguruza dumpsite (depth in metres).

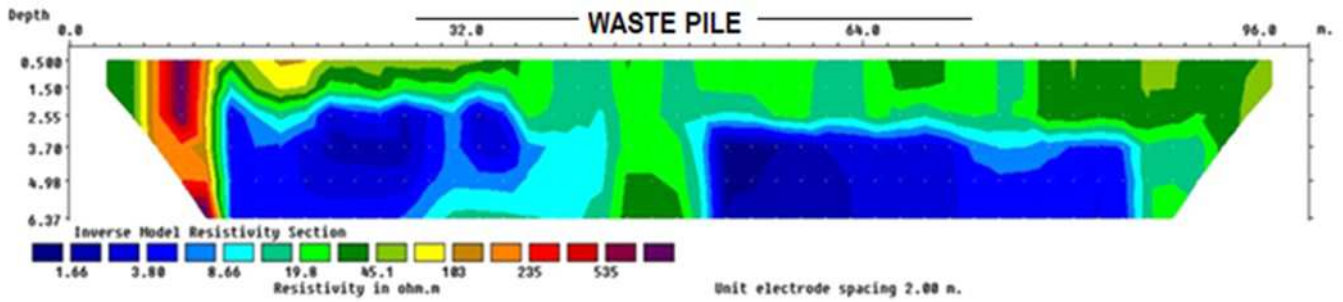

Fig. 11: 2D Resistivity model for profile 6 at Yelenguruza dumpsite (depth in metres).

Table 1: Concentration of heavy metals (mg/kg) in the soil samples from Gombe metropolis

Sample Number	Coordinate	As	Ni	Sr	Pb	Mn	Fe	Zn	Cu	Zr	Rb
MGPWD PL 1- A	Lon: 11.14716° Lat: 10.32073°	ND	26	13	ND	153	1170	16	10	296	8
MGPWD PL 1- B	Lon: 11.14589° Lat: 10.32081°	1	58	33	15	184	3592	164	27	167	9
MGPWD PL 2- C	Lon: 11.14658° Lat: 10.32389°	4	ND	65	22	189	7569	188	83	125	13
MGPWD PL 2- D	Lon: 11.14756° Lat. 10.32363°	ND	29	13	13	120	4846	23	15	275	9
YGWD PL 1- A	Lon: 11.19338° Lat: 10.27441°	2	28	14	6	177	3254	18	13	283	11
YGWD PL 1- B	Lon: 11.19339° Lat: 10.27347°	2	78	11	10	142	3685	23	23	261	6
YGWD PL 2- C	Lon: 11.19382° Lat: 10.27361°	1	16	21	9	128	3152	41	18	324	9
YGWD PL 2- D	Lon: 11.19348° Lat: 10.27419°	2	51	10	11	138	2205	13	28	244	8
FCWD PL 1- A	Lon: 11.14597° Lat: 10.34291°	3	31	71	19	311	5273	96	19	449	35
FCWD PL 1- B	Lon: 11.14659° Lat: 10.34287°	3	62	87	30	358	6268	191	44	503	40
FCWD PL 2- C	Lon.11.14615° Lat. 10.34430°	3	32	25	8	173	2894	32	11	339	15
FCWD PL 2- D	Lon: 11.14672° Lat: 10.34412°	2	16	29	17	144	1310	354	24	457	18
CONTROL SAMPLE	Lon.11.14580° Lat. 10.34480°	2	22	9	5	153	3334	9	11	218	6

ND = Not Detected in soil samples

Table 2: Heavy metal concentration in water samples collected from wells and streams and their comparison with WHO (2017) and NSDWQ (2007) standards

Sample	Depth (m)	Coordinate	Concentration(mg/l)							
			Mg	Mn	Cu	Cd	Cr	Co	Ni	Pb
A (Well) Control	9.20	Lon: 11.18886° Lat: 10.27723°	4.96	0.09	ND	ND	ND	0.08	ND	ND
B (Well)	6.00	Lon: 11.18961° Lat: 10.27379°	5.15	0.11	ND	ND	ND	0.05	ND	ND
C (Stream)	1.00	Lon: 11.14710° Lat: 10.32149°	5.35	0.05	ND	ND	ND	0.08	ND	ND
D (Stream)	0.30	Lon: 11.14704° Lat: 10.32081°	6.37	0.03	ND	ND	ND	0.07	ND	ND
WHO (2017)			NGV	0.40(H)	2.00	0.003	0.05	NGV*	0.01	0.01
NSDWQ (2007)			0.20	0.20	1.00	0.003	0.05	NGV*	0.02	0.01

ND = Not detected in water sample. NGV= No health-based guideline value is proposed for hardness in drinking water because it is not of health concern at levels found in drinking water.
NGV* = No Guideline, because it is not of health concern at concentrations normally observed in drinking water. H = Health Based Value.

Table 3: Comparison of range of heavy metals obtained from the soils with Background reference levels, Threshold and permissible limits for heavy metals in soils

Heavy Metal	Background Reference Levels* (mg/kg)	Threshold limit$^{+,++}$ (mg/kg)	Permissible limit$^{+,++}$ (mg/kg)	Data from Present study (mg/kg)	
				Range	Mean
As	6.83	5.00	50.00	1.00-4.00	1.75
Ni	29.00	50.00	100.00	16.00-78.00	33.33
Sr	175.00	NM	200 (MPC)**	10.00-87.00	32.70
Pb	27.00	60.00	200.00	6.00-30.00	13.30
Mn	437.00	NA	1500 (MAC)$^{+++}$	120.00-358.00	184.75
Fe	NA	NA	NA	1170.00-7569.00	3768.17
Zn	70.00	200.00	250.00	13.00-354.00	96.60
Cu	38.90	100.00	150.00	10.00-83.00	26.30
Zr	267.00	NA	NA	125.00-503.00	310.25
Rb	68.00	NA	NA	6.00-40.00	15.00

*Kabata-Pendias (2011), ** Sudhakaran et al. (2018), +Toth et al. (2016), ++UNEP (2013), +++Pendias and Pendias (2000), MPC- Maximum Permissible Concentration, NA - Not available

Discussion

2D Electrical Resistivity Survey

The 2D resistivity models of profile lines acrosss the three waste dumpsites within Gombe metropolis have resistivities varying from 0.16 to 11,434.5 Ωm; and represent either the uncontaminated or contaminated soil, shallow aquifer and weathered rock material within the subsurface to a maximum depth of about 6.37 m. The

very low resistivities (less than 20 Ωm) obtained from the 2D electrical survey within the study area (Figures 6 to 11) have been interpreted as signatures of soil contaminated with leachate derived from the waste pile at the various waste dumpsites and that have eventually infiltrated into alluvial soils, shallow aquifers and weathered sedimentary rocks within the study area. The choice of less than 20 Ωm was determined considering several studies including the study of Hamzah et al. (2014) and Raji, and Adeoye, (2017).

The resistivity model for subsurface beneath profile 1 along FCE as shown in Figure 6 have resistivity values ranging from 1.42 to 838.9 Ωm representing resistivity of water, soils and weathered rocks. A region of very low resistivity (< 20 Ωm) was observed between 56 and 96 m along the profile down to 6.37 m.

The resistivity model for subsurface beneath profile 2 along FCE as shown in Figure 7 is characterised by resistivity values ranging from 3.7 to 337.4 Ωm. The subsurface beneath the profile is largely dominated by very low resistivity (< 20 Ωm) particulary close to the ground surface where the waste pile was located. The very low resistivity was observed from 3 to 22 m along profile 2; depth of 2.5 to 6.37 m and 24 to 26 m along the profile down to the maximum depth of investigation (Figure 7). The very low resistivity region was also observed from 34 to 44 m down to the maximun depth of investigation; and 60 to 96 m along the profile down to an average depth of 3.70 m.

The resistivity model for subsurface beneath profile 3 from Gombe Mega Park as shown in Figure 8 has resitivity values ranging from 19.8 to 11434.5 Ωm, with regions of relatively high resistivity dominating the subsurface beneath the profile. Region of very low resistivity (< 20 Ωm) was observed close to the ground surface, from about 49 to 56 m; and 72 to 76 m along the profile down to an average depth of 1m.

The resistivity model for subsurface beneath profile 4 from Gombe Mega Park as shown in Figure 9 shows resistivity values ranging from 10.4 to 970.7 Ωm, largely dominated by very low resistivity (< 20 Ωm) particularly below the waste pile. The resistivity model for subsurface beneath profile 5 from Yelenguruza (Figure 10) have resistivity values of 1.8 to 1043.5 Ωm while the resistivity model for subsurface beneath profile 6 from Yelenguruza (Figure 11) have resistivities of 0.16 to 467.7 Ωm. Figures 10 and 11 show that resitivity largely decreases with depth beneath profiles 5 and 6. The subsurface of profiles 5 and 6 is largely dominated by very low resistivity (< 20 Ωm).

All 2D electrical resistivity models (Figures 6 to 11) revealed regions of very low resistivity (< 20 Ωm), suggesting regions within the subsurface contaminated with leachate. In addition, leachate migration into the soil within the study area was not strictly limited to the area of dumping; it migrated from the waste dump pile vertically into the subsurface and then changed direction. This change of direction could depend on soil type, topography, arrangement of voids, degree of water saturation, resistivity of fluid and temperature. As a result, soil contaminated with leachate was observed beneath the waste pile and within the subsurface beneath resistivity profiles (Figures 6 to 11).

The 2D resistivity models (Figures 6, 7, 9, 10 and 11) apart from the model for profile 3 (Figure 8), revealed leachate migration to a depth of 6.37 m, which is the maximum depth of investigation in this study. Apart from nature of earth materials and other factors that might cause a decrease in resistivity, heavy metals in the soil samples and infiltration of leachates contribute to the very low resistivity values obtained beneath the waste pile and within the subsurface beneath the resistivity profile lines.

In this study, very low resistivity signature was not interpreted in terms of contaminated ground water because according to Bala (2009), areas where Gombe Sandstone cropped out, water shortage is experienced soon after the rainy season because the shallow aquifer of the Gombe Sandstone is a poor aquifer. Carter et al (1963) noted that Bima and Yolde Formations were the potential sources of water supply in Gombe Township. The provisions of groundwater to rural communities have focused on drilling of deep boreholes, with the aim of tapping water from the Bima or Yolde. Depths of boreholes within Gombe Township vary from about 180 - 250m and occasionally up to 300 m in other locations such as Kumo and environs (Bala, 1981). In this study, the maximum depth of the 2D resistivity models was 6.37 m, so the likelihood of the very low resistivity being that of contaminated ground water is low.

Heavy Metal Investigations

Leachate from waste dumpsites can travel several metres of vertical and horizontal distances thereby polluting soils, rocks, surface water and groundwater (Bernstone et al., 2000). The heavy metal concentration in soil samples shown in Table 1 was compared with standards in Table 3. The concentration of Arsenic in the soil samples range from 1.00 to 4.00 mg/kg and was less than the background reference value for uncontaminated soil, threshold, and permissible limits.

The concentration of Nickel in the soil samples range from 16.00 to 78.00 mg/kg while Ni concentration in samples collected at Mega Park Profiles 1-B and 2-D, Yelenguruza Profiles 1-B and 2-D, and FCE Profiles 1-A, 1-B and 2-C exceeded background reference values for uncontaminated soils. Two samples collected at Yelenguruza Profiles 1-B and 2-D have higher Nickel concentration than the threshold value and all samples collected for this study have concentration of Nickel below permissive limits.

The concentration of Strontium in the soil samples range from 10.00 to 87.00mg/kg and was below the background reference value for uncontaminated soil and Maximum Permissible Concentration (MPC). The concentration of Lead in the soil samples range from 6.00 to 30.00 mg/kg and the concentration of Lead in sample collected at FCE Profile 1-B exceeded the background reference values for uncontaminated soils while other samples were below the threshold and permissible limits for Lead.

The concentration of Manganese in the soil samples range from 120.00 to 358.00mg/kg and was below the background reference value for uncontaminated soil, threshold, and permissible limits. The concentration of Iron in the soil samples range from 1170.00 to 7569.00 mg/kg. Zinc values in the soil samples range from 13.00 to 354.00 mg/kg and the concentration of Zinc in samples collected at Mega Park Profiles 1-B and 2-C, and FCE Profiles 1-A, 1-B and 2-D exceeded the background reference values for uncontaminated soils.

The concentration of Copper in the soil samples range from 10.00 to 83.00 mg/kg and Copper in samples collected at Mega Park Profile 2-C and FCE Profile 1-B exceeded the background reference values for uncontaminated soils while other samples were below the threshold, and permissible limits for Copper. Concentration of Zirconium in the soil samples range from 125.00 to 503.00 mg/kg and the concentration of Zirconium in samples collected at Mega Park Profiles 1-A and 2-D, Yelenguruza Profiles 1-A and 2-C, and FCE Profiles 1-A, 1-B, 2-C and 2-D exceeded the background reference values for uncontaminated soils. Concentration of Rubidium in the soil samples range from 6.00 to 40.00 mg/kg and was less than the background reference values for uncontaminated soils.

The Zr content of Bajoga dumpsite (125 - 296 mg/kg), Ashaka road dumpsite (339 - 503 mg/kg) and Yelanguruza Quarters dumpsite (344 - 324 mg/kg) exceeded the soil Zr background value of 267.00 mg/kg (Kabata-Pendias, 2011). The Zn concentration of soil sample FCWD PL 2- D (354 mg/kg) from Ashaka road dumpsite exceeded the soil Zn background reference value of 70 mg/kg (Kabata-Pendias, 2011). The Cu concentration of soil samples (MGPWD PL 2- C) from Bajoga dumpsite (84 mg/kg) and (FCWD PL 1- B A) from Ashaka road dumpsite (44mg/kg) exceeded the Cu background reference value of 38.90 mg/kg (Kabata-Pendias, 2011)

The Pb value of soil sample FCWD PL 1- B (30 mg/kg) from Ashaka road dumpsite exceeded the soil Pb background values of 27 mg/kg (Kabata-Pendias, 2011). Higher values of Zr, Zn, Cu and Pb obtained from these soil samples (Table 1) underlying the waste dumpsites than the soil background reference value of Kabata-Pendias (2011) are indicative of leaching, weathering and dissolution in the area suggesting the contribution of geogenic and/or anthropogenic sources of heavy metals.

The Zn value of soil sample FCWD PL 2-D (354 mg/kg) from Ashaka road dumpsite exceeded the Permissible limit of 250 mg/kg and this indicates contamination in the area. According to Alloway (1995), heavy metals are mobile in acid conditions, where dissolution and leaching are more likely to occur. The values of As, Sr, Mn and Rb obtained from the three waste dumpsites were below the background reference levels for uncontaminated soil (Kabata-Pendias, 2011), Threshold and permissible limits (Toth et al., 2016; UNEP, 2013; Sudhakaran et al., 2018), indicating that the soils were not contaminated with heavy metals such As, Sr, Mn and Rb.

It was also observed from Table 1 that the concentration of heavy metals in some waste dump soil samples exceeded the concentration of these heavy metals in the control soil sample. The concentration of Rb from the dumpsite soils (6.00 - 40.00 mg/kg) exceeded the Rb value of control soil sample (6 mg/kg); Zr values from the dumpsite soils (125 - 503 mg/kg) exceeded Zr value of control soil sample (218 mg/kg) and Cu values from the dumpsite soils (10.00 - 83.00 mg/kg) exceeded Cu value of control soil sample (11 mg/kg). The Zn content from the dumpsite soils (13 - 354 mg/kg) exceeded the Zn value of control soil sample (9 mg/kg); Fe values from the dumpsite soils (1170-7569 mg/kg) exceeded Fe value of control soil sample (3334 mg/kg) and the Mn content from the dumpsite soils (120.00 - 358.00 mg/kg) exceeded Mn value (153 mg/kg) of control soil sample.

The Pb values from the dumpsite soils (6.00 - 30.00 mg/kg) exceeded Pb value of control soil sample (5 mg/kg); Sr contents from the dumpsite soils (10.00 -

87.00 mg/kg) exceeded Sr value of control soil sample (9 mg/kg); Ni values from the dumpsite soils (16.00 - 78.00 mg/kg) exceeded Ni value of control soil sample (22 mg/kg) and Arsenic content from the dumpsites soils (1.00 - 4.00 mg/kg) exceeded As value of control soil sample (2 mg/kg). Higher values of Rb, Zr, Cu, Zn, Fe, Mn, Pb, Sr, Ni and As in about 80% of the soils underlying the three waste dumpsites than the control soil sample (Table 1) could be attributed to the availability of metal containing industrial and domestic wastes at the dumpsites which have eventually leached into the underlying soils suggesting anthropogenic sources.

The heavy metal concentration obtained from water samples collected from wells and streams in the study area were compared with permissible limits of World Health Organisation (WHO) (2017) and Nigerian Standard for Drinking Water Quality (NSDWQ) (2007) as presented in Table 2. Heavy metal concentration for well and stream water samples revealed that Magnesium, Manganese and Cobalt were detected in the water samples while Copper, Chromium, Cadmium, Nickel and Lead were not detected in the water samples. The Magnesium concentration in all the water samples exceeded the guideline value (Table 2) proposed by the Nigerian Standard for Drinking Water Quality (NSDWQ). Concentration of Manganese in all water samples collected for this study falls below guideline values proposed by WHO (2017) and NSDWQ (2007). The water samples contained cobalt but WHO (2017) and NSDWQ (2007) proposed no guideline value for the metal. It can thus be said that the water samples collected for this studies are safe from Manganese, Copper, Cadmium, Chromium, Nickel and Lead.

The Comparison of the concentration of the heavy metals investigated in soils (Rb, Zr, Cu, Zn, Fe, Mn, Pb, Sr, Ni and As) with that of water samples collected for this study (Mg, Mn, Cu, Cd, Cr, Co, Ni and Pb) indicates that the soil and water samples are not contaminated with Ni, Pb, Mn and Cu. Continuous dumping of waste however, will increase the susceptibility of soil and water within the study area to heavy metal contamination.

Conclusion

The 2D electrical resistivity models revealed regions with resistivity less than 20 Ωm, suggesting regions within the subsurface of Bajoga road after Gombe Mega Park, Ashaka road after Christian cemetery and Yelanguruza Quarters, to be contaminated with leachate. It was also observed from the models that leachate migration into the soil within the study area was not strictly limited to the area of dumping; it migrated from the waste dump pile vertically into the subsurface and then changed direction.

The Zn value of Ashaka road waste dumpsite (FCWD PL 2-D) exceeded the Permissible limit and this indicates contamination in the area. The values of Rb, Zr, Cu, Zn, Fe, Mn, Pb, Sr, Ni and As in 80% of the soil samples were higher than the control soil sample and could be attributed to the availability of metal containing industrial and domestic wastes at the dumpsites which have eventually leached into the underlying soils suggesting anthropogenic sources.

The Zr values of the three waste dumpsites, Zn (FCWDPL2-D) and Pb (FCWDPL1-B) values of Ashaka road dumpsite, Cu values of Bajoga (MGPWDPL2-C) and Ashaka road (FCWDPL1-BA) dumpsites exceeded the background reference values and are indicative of leaching and dissolution in the area suggesting contributions from geogenic and/or anthropogenic sources of heavy metals

The concentrations of heavy metals in well and stream water samples when compared with permissible limits from WHO and NSDWQ revealed that the water samples were not contaminated with Mn, Cu, Cd, Cr, Ni and Pb but Mg concentration in all the water samples exceeded the permissible limit of NSDWQ.

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