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Geoelectrical and Geochemical Investigations of Selected Dumpsites for Potential Groundwater Contamination in Gusau, Zamfara State, Nigeria

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ABSTRACT

Groundwater contamination has been a worldwide phenomenon. In this research, geoelectric and geochemical surveys were carried out on three active dumpsites in Gusau metropolis for detection of groundwater contamination. Vertical electrical Soundings (VES) were conducted on the dumpsites using Schlumberger array with maximum current electrode separations of 180 m. Five VES were conducted on each dumpsite making a total of fifteen VES along three profiles. Thirty five (35) points were assessed from three wastes dumpsites using portable XRF equipment for the in-situ testing while fifteen (15) representative groundwater samples collected were taken to the laboratory for hydro-geochemical analysis. The field data obtained from VES was analyzed using WinGlink software. The VES results revealed three subsurface layers. The topsoil has resistivity ranging from 1.5Ωm to 48.2 Ωm while the thicknesses vary from 0.47 m to 3.37 m across the profiles. The second layer's resistivity varies from 5.4 Ωm to 144.35 Ωm and their thicknesses' ranges from 1.36 m to 16.93 m. The third geoelectric layer has resistivity from 70.0 Ωm to 6003.0 Ωm. The geoelectric results revealed that the top soils in all the dumpsites were characterized by very low resistivity depicting possible pollution and contamination. Environmental pollution models applied to the geochemical dataset revealed Zn, Pb and Cu as moderately contaminants which generally indicated severe potential contamination in the investigated area. While other analytic parameters such as Mn, Cr, Ni and Fe showed low contamination factors. Hydro chemical analysis showed that pH values recorded from the water samples ranged between 7.26 to 8.12 with mean value of 7.50, whereas, recorded Total dissolve solid (TDS) ranged between 377 to 1393mg/L with average concentration of 751.27mg/L. Findings from the study indicated that there may be possible contamination of shallow groundwater system in the nearest future if proper mitigation measures are not taken into consideration at the dumpsites.

Keywords: Geoelectric, geochemical, groundwater, dumpsites, hydro-chemical

1.0. Introduction

The menace of solid waste has been a major challenge in Nigeria as well as other developing nations. Solid waste management are characterized in Nigeria by inadequate collection method, coverage of collection system and arbitrary disposal of solid waste. Solid wastes are produced on daily basis as a result of direct consequence of inevitable human activities. Refuse contents consist of various kinds of materials like metallic, organic and non-biodegradable materials (Sunmonu *et al.*, 2012). The intensity of the human's activities has led to increasing volume of solid waste worldwide despite the level of global technological advancement and industrialization (Ganiyu *et al.*, 2015; Abdullahi *et al.*, 2011; Akankpo and Igboekwe, 2011; Murana *et al.*, 2019a). Poor management of solid waste has resulted to a lot of disastrous effects such as aesthetics, environmental hazard and pollution. This has attracted insects, rodents and various disease vectors (Olayinka and Olayiwola, 2001; Adeyemi *et al.*, 2007). Arbitrary refuse dumping pose a serious pollution threat to soil, groundwater and downstream surface water. Pollution of groundwater occurs due to percolation of fluvial water and infiltration of contaminants from water percolating through a solid waste disposal sites (leachate) (Ganiyu *et al.*, 2015).

Gusau, being the state capital has witnessed an upsurge in population over the years which have led to increment in wastes littering many places in the capital. The waste disposal sites are in most cases uncontrolled open dumps, thus creating serious threats to local environmental quality and public health. Consequently, Gusau metropolis may face critical problem pertaining to its groundwater resources if this problem of waste disposal sites which litters the city is not adequately addressed.

2.0. Methodology

In this study, geo-electric and geochemical surveys were carried out at three dumpsites in Gusau to investigate effects of leachate on groundwater quality and contamination. Fifteen points were sounded using Schlumberger array. Equally, thirty five (35) points were assessed from three wastes dumpsites using portable XRF equipment for the in-situ testing while fifteen (15) representative groundwater samples were collected from hand-dug well taping shallow aquifers in different locations within the study area. The Physio-chemical analysis of water samples were carried out to see if there is elevation in the concentration of the measured parameters which may be indications of groundwater contamination as a result of solid waste leachate accumulation.

2.1. Description of the Study Area

The study areas lies within latitude 12° 15'N, 12^0 03'N and longitude 6° 30'E, 6° 45'E. The three waste dumpsites studied were located at Hira Dekodi (12° 09' 57.8"N, 06° 41' 10.6"E), Gangere Yerima (12° 10' 51.9" N, 06°41'01.1" E) and around Bebeji area (12°10'11.5" N, 06°39'52.9"E), all in Gusau metropolis (Figure 1).

The study areas are characterized by two distinct seasons, the dry and rainy seasons. The mean annual rainfall in the areas is 800 mm while the minimum and maximum temperatures are 24^0C and 40^0C respectively. The dry season range between the month of October and May of the year while rainy season normally commence from June to September and sometimes reaches October. In addition, the temperature condition of the study areas falls within temperature region (Sahelian Savanah) with temperature rising up to 40^0C and above (ZSG, 2001).

The vegetation of the study areas is that of the Sahelian Savanah with a variety of short grasses, shrubs and scattered trees which can resist long dry season. The study areas are underlain by different lithological units which are crystalline in nature and belong to the Basement complex rock suites, mostly the oldest being Pre-cambrian in age. From the field mapping exercise Migmatite, Banded gneiss, Quartzite, Mica Schists, Phyllites, Granites and minor intrusion of pegmatites were the types of rocks found underlain the study areas as shown in Figure 1.

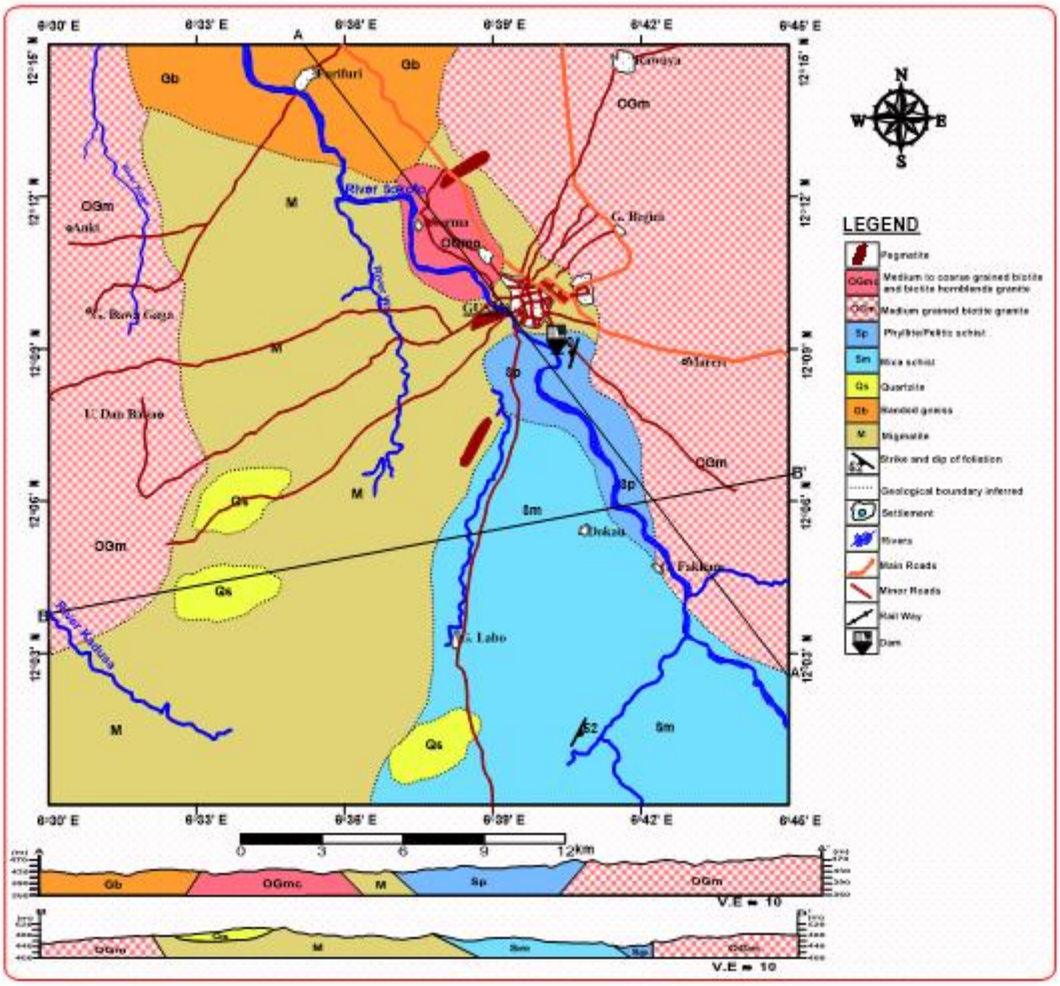

Figure 1: Geological map of the study area (Muranaet al., 2019a)

2.2. Geo-electric and geochemical survey of the dumpsites

2.2.1 Two dimensional (2D) electrical resistivity surveys

These were carried out on the dumpsites using ABEM SAS 300 and its accessories. The instrument displays directly the apparent resistivity of the subsurface under probe. It has an in-built direct current power source. A total of fifteen VES using the Schlumberger array with a maximum current electrode separation of AB/2 of 180m were carried out along three profiles. The VES involves injecting an artificially generated direct current or very low frequency alternating current into the ground through two electrodes. The resulting potential difference is measured by another pair of potential electrodes in the vicinity of the current flow. The field data acquisition was carried out by moving two or four of the electrodes used, between each measurement, following the technique outlined by (Telford *et al.,* 1990; Kunetz, 1966; Kearey *et al.,* 2002).

2.2.2. Portable X-ray fluorescence spectrometer

This was employed to determine the heavy metals of interest (such as Pb, Cu, Fe, Zn, Ni and Cr) from the three waste dumpsites where about thirty five points were sampled for the in-situ analysis. Inorganic parameters of interest were identified and quantified using a field portable energy-dispersive x-ray fluorescence spectrometer. Radiation from one or more radioisotope sources or an electrically excited x-ray tube was used to generate characteristic x-ray emissions from elements in a sample. Up to three sources were used to irradiate a sample. Each source emits a specific set of primary x-rays that excite a corresponding range of elements in a sample. For measurement, the sample was positioned in front of the probe window. This could be done in two manners using FPXRF instruments, specifically, in situ or intrusive. For this survey, it operated in the in situ mode, i.e. the probe window was placed in direct contact with the soil surface to be analyzed. Sample analysis is then initiated by exposing the sample to primary radiation from the source. Fluorescent and backscattered x-rays from the sample enter through the detector window and were converted into electric pulses in the detector.

2.2.3. Environmental pollution index

In order to quantitatively ascertain the level and extent of heavy metal contamination in the soil around the vicinity of the dumpsites, environmental pollution indices were applied which include: contamination factor, degree of contamination and potential contamination factor. The relationship among the metals was confirmed using Pearson's correlation analysis.

2.2.3.1. Contamination factor (*Cf*)
The level of metal contamination can be expressed by contamination factor. It is the ratio between the metal content in the sediment to the background value of the metal according to Martin and Meybeck (1979). It is an effective tool for monitoring the pollution over a period of time and it is calculated as follows:

$$Cf = \frac{C_{i\ heavy\ metal}}{C_b metal\ background\ value} \tag{1}$$

2.2.3.2. Contamination degree (C_d)
In order to facilitate pollution control, Hakanson (1980) proposed a diagnostic tool referred to as degree of contamination (C_d) and is the sum of the *Cf*for each sample.

$$C_d = \sum Cf \tag{2}$$

2.2.3.3. Potential contamination index (*Cp*)
Potential contamination index Cp according to Hakanson (1980) was calculated using:

$$Cp = \frac{C_i(metal)\ Sample\ Max.}{C_b(metal)\ background\ value} \tag{3}$$

Where C_i(metal) sample Max is the maximum concentration of a metal in sediment and C_b(metal) background is the average value of the same metal in a background level.

2.3. Physio-chemical analysis of water samples

Water samples were collected from different locations within the study areas. Before sampling, the study areas were gridded using Spatial Analysis and Decision Assistance (SADA, 2005) software which requires that at least one sample be collected from each grid. Sample collection was based on EPA's document on sampling protocol. Fifteen (15) representative groundwater samples were collected from hand-dug wells taping shallow aquifers in different locations within the study areas. One litre plastic containers were used to collect the samples, these containers were washed, air dried and rinsed with the water samples before filling it to capacity and then labelled accordingly. Physical parameters were ascertained *in-situ.* The sample from the same source was divided and submitted as blind duplicate to access accuracy/precision of the laboratory. After the collection, the various samples were stored in a cool box and taking to the laboratory for investigation.

2.4. Data processing

The geoelectric data acquired were processed to remove noise arising from instrumentation. The apparent resistivity data were presented as sounding curves. The curves were obtained by plotting the apparent resistivity values against half of the current electrode separations (AB/2) on log-log graphs that have the same modulus as that of the 2-layer master curves. The curve in each VES station depends on the subsurface layer sequence (Murana *et al.,* 2014; Murana *et al.,* 2019b). The main purpose of processing the VES data displayed as curves is to determine the subsurface layers, their resistivity as well as their thicknesses. These were achieved through utilization of WinGlink software for processing the acquired data. The processed data were presented as 1-D iteration models and geoelectric sections.

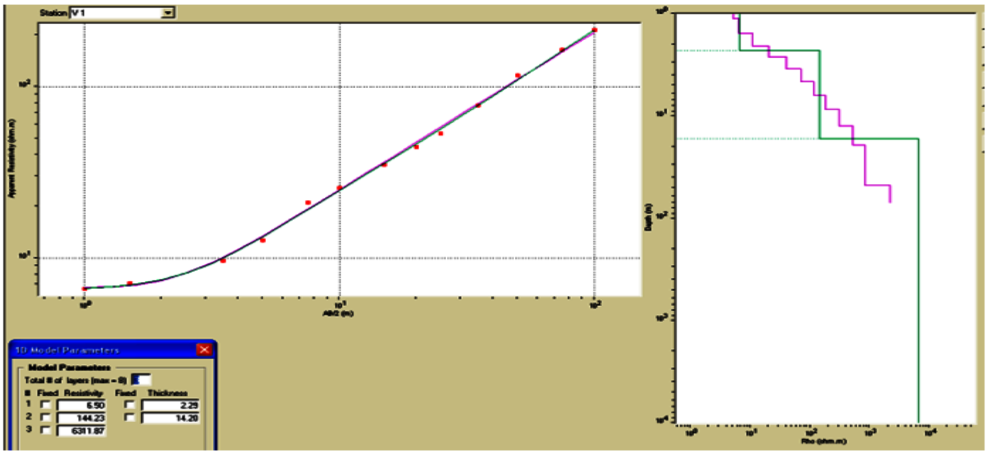

Figure 2: Typical sounding curve

3.0. Results and Discussion

3.1.Geoelectric Results

For better understanding, the interpreted layer parameters for the three dumpsites are presented in Tables 1-3. The modelling of VES measurements carried out at the fifteen stations was used to derive geoelectric and geologic sections which were plotted with the aid of Autocard (Figures 3-5). The geoelectric sections of the study area were generated to show the vertical variation of the material in relation to their resistivity values.

Three subsurface layers were delineated across the 15 VES points. The first layer is the top soil which is characterized by very low resistivity values ranging from 1.5 Ωm to72 Ωm and thickness from 0.49 m to 3.39 m. The lithology of the first layer across the study area is majorly clay. The low resistivity values at the top soil in most of the dumpsites is an indication of leachate contamination (Tables 1-3). The topsoil in most places at the three dumpsites was polluted. The second geoelectric layer across the study area has resistivity that ranges from 5.4 Ωm at Hiran Decodi dumpsite to 180 Ωm at Gangare Yerima dumpsite. The thicknesses of the second layer vary from 1.68 m at Gangare Yerima dumpsite to 16.93 m at Bebeji dumpsite. The lithology of the layer ranges from clay, sand-clay to weathered fracture.

The third geoelectric layer has resistivity variations from 70.0 Ωm to 6000 Ωm at Hiran decode dumpsite.

The study established that the dumpsites consist of topsoil, clay soil, sandy clay, weathered basement, fractured basement and fresh basement which are indications that the dumpsites are located on aquiferous zones. Results from the analysis of data revealed that the leachate from the waste has polluted and contaminated the top soil around the dumpsites as depicted by low resistivity values. At Hiran Decodi dumpsite, there is strong evidence of contamination due to low resistivity response at all the subsurface layers (Table 1 and Figure 3). On the other hand, the high resistivity responses at some VES points on the other two dumpsites is an indication that although the top soil might be polluted, the second and third subsurface layers might be free from leachate contamination. The results of XRF and water analysis give detail insight into this.

Table 1: Interpreted layer parameter for Hiran Decode dumpsite, Church Pan Area

VES Station	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)
	1	6.50	2.29	2.29
1	2	144.35	14.2	16.49
	3	6003.00		
	1	4.50	1.58	1.58
2	2	31.40	8.78	10.36
	3	309.10		
	1	2.50	1.29	1.29
3	2	14.00	4.52	5.81
	3	198.00		
	1	1.50	0.68	0.68
4	2	5.40	7.96	8.64
	3	70.0		
	1	3.70	0.74	0.74
5	2	17.50	1.36	2.10
	3	95.50		

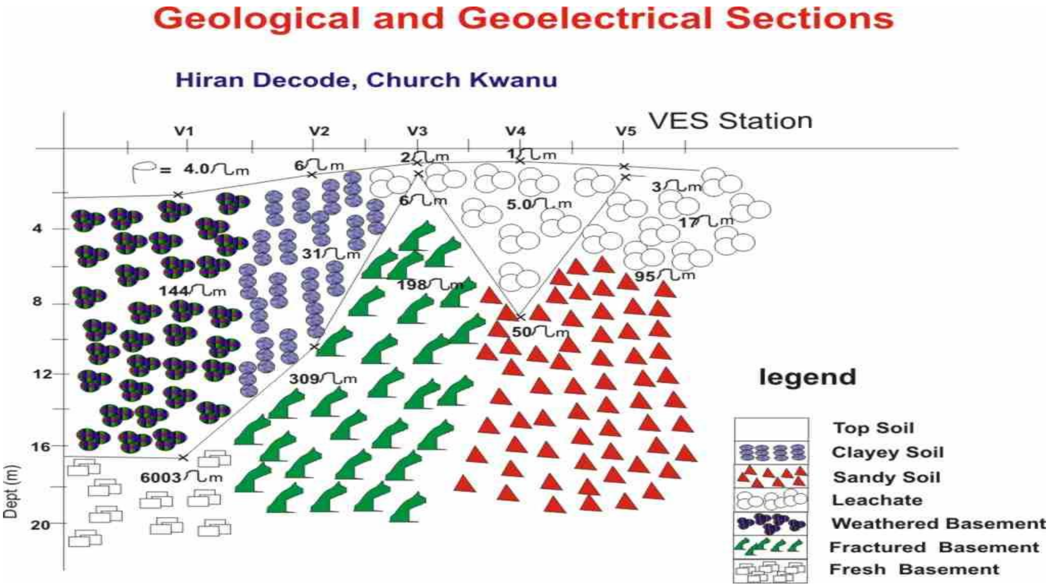

Figure 3: Geoelectricsection at HiranDeciodi

Table 2: Interpreted layer parameter for GangareYerima dumpsite

VES Station	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)
	1	5.00	0.47	0.47
1	2	120.00	2.62	3.09
	3	586.00		
	1	72.00	0.58	0.58
2	2	180.00	1.68	2.26
	3	1932.10		
	1	48.20	1.28	1.28
3	2	98.14	16.93	18.21
	3	1200.00		
	1	9.57	1.64	1.64
4	2	73.40	16.47	18.11
	3	530.0		
	1	18.40	1.25	1.25
5	2	44.50	6.14	7.39
	3	292.60		

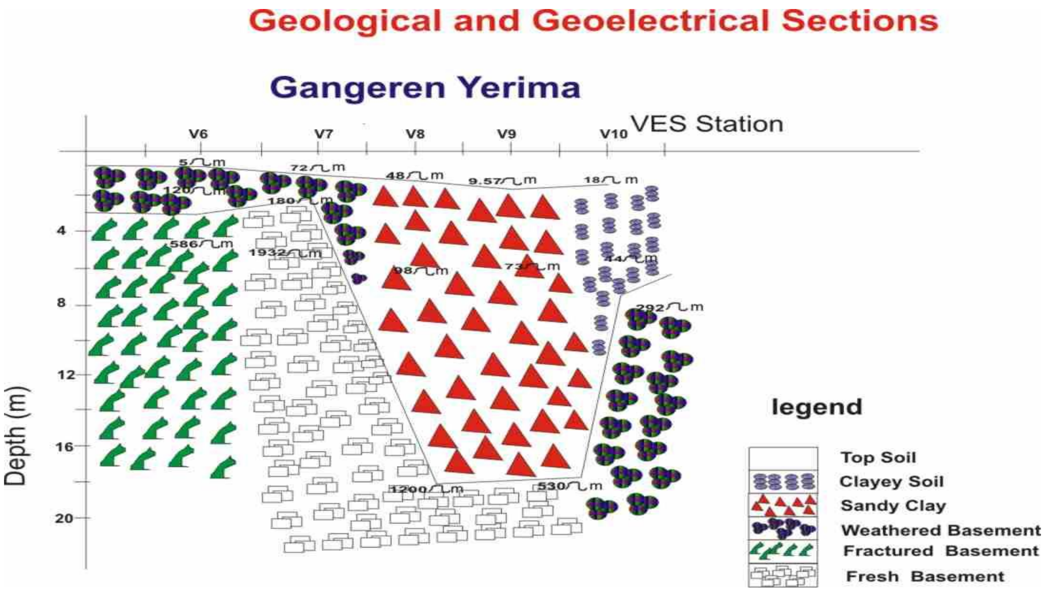

Figure 4: Geoelectricsection at GangerenYerima

Table 3: Interpreted layer parameter for Bebeji dumpsite

VES Station	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)
	1	3.40	3.38	3.38
1	2	80.00	3.80	7.18
	3	986.00		
	1	5.00	0.58	0.58
2	2	85.00	1.68	2.26
	3	572.10		
	1	4.72	1.28	1.28
3	2	132.14	16.93	18.21
	3	975.00		
	1	3.8	1.64	1.64
4	2	65.50	16.47	18.11
	3	315.50		
	1	4.15	1.25	1.25
5	2	142.50	6.14	7.39
	3	522.50		

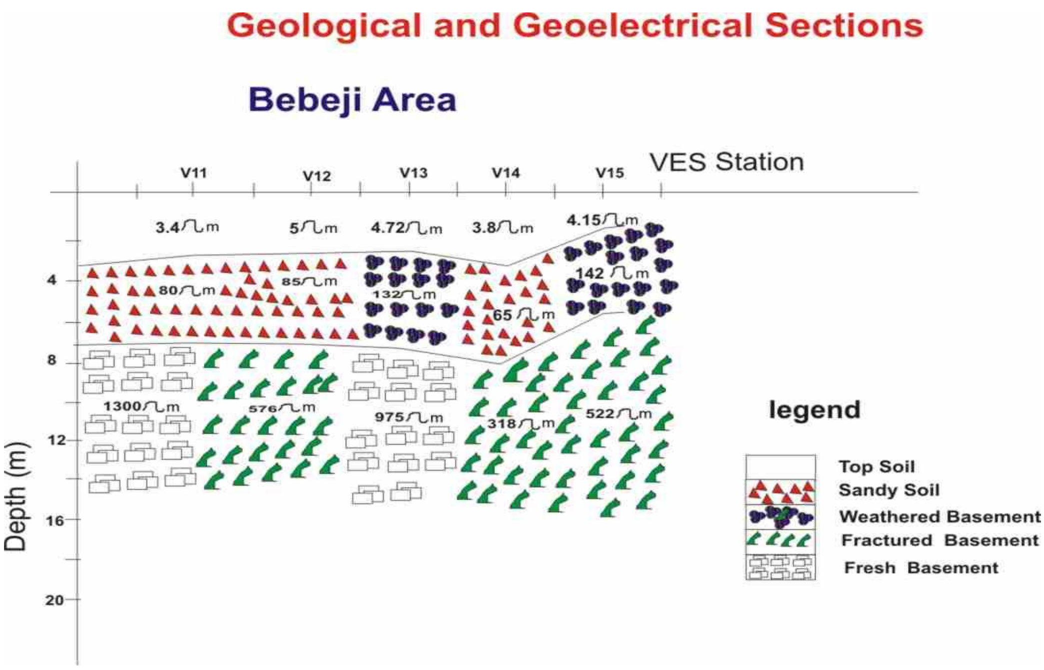

Figure 5: Geoelectricsection at Bebeji Area dumpsite, Gusau

3.2. XRF results

Table 6a-c showed comparative interpretation of three waste dumpsites investigated. It is obvious that virtually Pb, Zn and Cu concentrations were elevated above the maximum permissible limit set by WHO (2011) while the rest elements indicated low concentration. Though, the dumpsites at Hira Decodi and Bebeji areas showed significant metal enrichment with respect to that of GagereYerima.

Table 6a: Statistical summary of heavy metal from Hira Decodi dumpsites

Parameters	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Pb	24.53	121.18	48.94	37.97	1.85	3.26
Mn	255.51	427.45	359.45	66.57	-0.77	-0.67
Fe	5456.6	14016.56	8950.99	3546.97	0.535	-1.70
Cu	28.37	124.82	51.44	37.076	2.143	4.74
Zn	218	709.24	354.87	188.83	1.749	2.82
Cr	31.35	78.66	53.38	15.44	0.434	1.71
Ni	0	49.02	14.69	22.97	1.049	-1.39

Table 6b: Statistical summary of heavy metal from Gangere Yerima dumpsite

Parameters	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Pb	0	42.87	26.84	12.83	-1.042	1.46
Mn	0	397.31	251.83	112.81	-1.39	2.98
Fe	3677.18	12799.66	7560.55	2767.38	0.86	0.57
Cu	0	45.16	19.02	19.34	0.16	-2.03
Zn	0	1549.61	329.13	467.93	2.75	7.92
Cr	44.79	96.26	61.12	18.09	1.92	4.22
Ni	0	55.62	21.59	25.83	0.33	-2.39

Table 6c: Statistical summary of heavy metal from Bebeji dumpsite

Parameters	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Pb	30.8	92.98	46.79	21.49	2.11	4.84
Mn	232.56	386.64	280.83	50.67	1.82	3.98
Fe	3828.08	27939.65	10307.23	8287.24	2.01	4.52
Cu	0	93.06	44.04	35.24	0.61	-0.97
Zn	115.56	512.93	251.96	136.94	1.32	1.45
Cr	33.72	145.26	57.03	39.65	2.45	6.17
Ni	0	48.08	28.48	20.25	-0.9	-1.04

3.2.1. Correlation analysis

Correlation matrix was performed on the geochemical data set to decipher their relationship as shown in Table 7. The chemical assay reveals positive significant relationship between Cu, Pb, Mn and Fe while Cr shows positive significant relationship with Mn, Fe and Cu. However, Zn shows significant level of relationship only to Mn (Table 7). Virtually all the heavy metals show significant correlation to each other. Thus, this reveal that they are similar sources of enrichment, which might not be unconnected to the weathering/bed rock dissolution and anthropogenic sources (Boban *et al.*, 2016; Amadi *et al.*, 2017).

This is certainly due to the fact that heavy metals are persistent even for a long period of time with little or no change in concentration after introduction into the environment by anthropogenic sources as they don’t undergo biodegradation (Murana *et al.*, 2019b).

Table 7: Correlation coefficients between the heavy metals of the study areas

Parameters	Pb	Mn	Fe	Cu	Zn	Cr	Ni
Pb	1						
Mn	.481*	1					
Fe	0.421	0.422	1				
Cu	.762**	.572**	.471*	1			
Zn	0.217	.525*	0.055	0.333	1		
Cr	0.192	.510*	.817**	.561*	0.445	1	
Ni	0.179	0.125	-0.206	0.054	0.303	-0.134	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

3.2.2. Environmental Pollution Index Analysis

The results of contamination factor (*Cf*) for each measured element in the three waste dumpsites are presented in Tables 8a-c. It was depicted through-out the three waste dumpsites that Zn and Pb show moderate contaminations respectively (Tables 7a-c and Figure 6). Though copper shows moderate enrichment at Gangere Yerima dumpsite. However the remaining four elements show low enrichment factor.

Table 8a: Calculated contamination factor (Cf) values for soil from Hira Decodidumpsites

Parameters	Pb	Mn	Fe	Cu	Zn	Cr	Ni
Cf	2.45	0.42	0.19	1.14	3.74	0.59	0.22
Contamination Factor	Moderate Contamination	Low Contamination	Low Contamination	Moderate Contamination	Considerable Contamination	Low Contamination	Low Contamination

Table 8b: Calculated contamination factor (Cf) values for soil from GangereYarimadumpsite

Parameters	Pb	Mn	Fe	Cu	Zn	Cr	Ni
Cf	1.34	0.29	0.16	0.42	3.46	0.67913	0.32
Contamination Factor	Moderate Contamination	Low Contamination	Low Contamination	Low Contamination	Considerable Contamination	Low Contamination	Low Contamination

Table 8c: Calculated contamination factor (Cf) values for soil from Bebeji

Parameters	Pb	Mn	Fe	Cu	Zn	Cr	Ni
Cf	2.34	0.33	0.22	0.97	2.65	0.63	0.42
Contamination Factor	Moderate Contamination	Low Contamination	Low Contamination	Low Contamination	Moderate Contamination	Low Contamination	Low Contamination

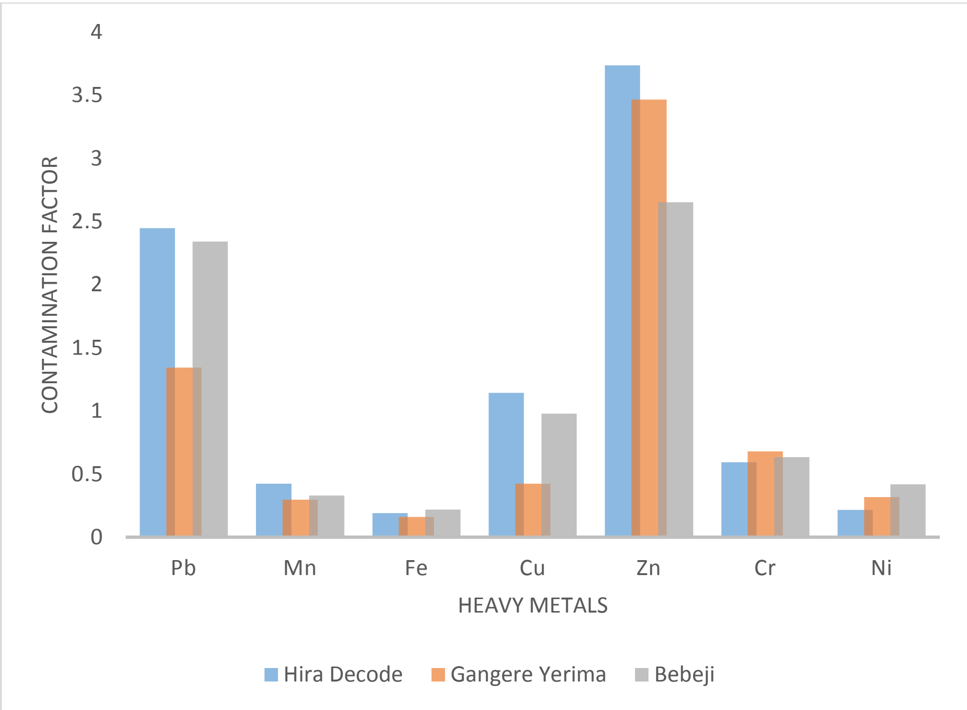

Figure 6: Comparative interpretation of contamination factor

The soil geochemical data set reveals potential contamination of seven elements analysed from the three waste dumpsites (Tables 8a-c). Zn, Pb, Cu and Cr show severe/moderate potential contamination in the soil of the Hira Decodi and Bebeji dumpsites while other elements analysed remain low in concentration. Though this seems to be slightly different at GangereYerima dumpsite where Zn reveals severe potential contamination and Pb, Cu and Cr reveal moderate potential enrichment. However the details of how the seven elements play out in terms of their potential enrichment level / distributions from the dumpsites is presented in Figure 6.

The result of contamination degree C_d is aimed at providing a measure of the degree of overall contamination in the surface layers in a particular core or sampling site. The calculated degree of contamination (Cd) for three waste dumpsites Hira Dekodi, Gangare Yerima and Bebeji areas are

8.75, 6.67 and 7.56 respectively which depict moderate degree of overall contamination in surface layers of the investigated areas using Equation 2 above.

Tables 9a-c showed the calculated C_p. C_p was interpreted using Dauvalter and Rognerud (2001) and Chandranohan *et al.*,(2016).

Table 9a: Calculated Potential Contamination Factor (Cp) values for soil from Hira Dekodi dumpsites

Parameters	Pb	Mn	Fe	Cu	Zn	Cr	Ni
Cp	6.05	0.50	0.29	2.77	7.46	0.87	0.72
Contamination Potential	Severe Contaminated	Low Contamination	Low Contamination	Moderately Contaminated	Severe Contaminated	Low Contamination	Low Contamination

Table 9b: Calculated Potential Contamination Factor (Cp) values for soil from GangereYarima dumpsite

Parameters	Pb	Mn	Fe	Cu	Zn	Cr	Ni
Cp	2.14	0.47	0.27	1.00	16.31	1.07	0.82
Contamination Potential	Moderately Contaminated	Low Contamination	Low Contamination	Moderately Contaminated	Severe Contaminated	Moderately Contaminated	Low Contamination

Table 9c: Calculated Potential Contamination Factor (Cp) values for soil from Bebeji dumpsite

Parameters	Pb	Mn	Fe	Cu	Zn	Cr	Ni
Cp	4.65	0.45	0.59	2.07	5.39	1.614	0.71
Contamination Potential	Severe Contamination	Low Contamination	Low Contamination	Moderately Contaminated	Severe Contamination	Moderately Contaminated	Low Contamination

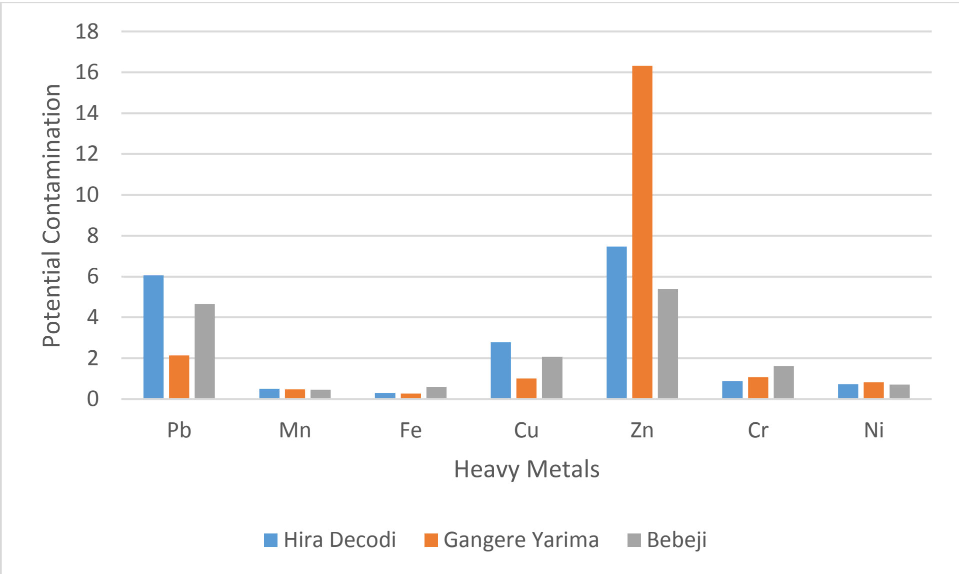

Figure 7: Comparative interpretation of potential contamination factor

3.3. Water analysis results

Table 10 summarizes the descriptive statistics of analytical results for the fifteen (15) groundwater samples obtained from the studied area.

Table 10: Statistical summary of the physical and chemical analyses of Groundwater samples from the study area

Parameters	Minimum	Maximum	Mean	Skewness	WHO Water Quality Standard (2011)
TDS	377	1393	751.27	1.044	500
TH	60.66	253.43	153.38	-0.049	200
pH	7.26	8.12	7.50	1.711	7.5
Na^+	210	900	382.67	2.064	200
K^+	3.4	86	28.3	1.113	100
Ca^{+2}	14.39	88.67	50.46	-0.075	200
Mg^{+2}	6.01	7.78	6.65	0.593	150
Cl^-	3.1	25.5	9.35	2.07	250
SO_4	56.42	95.69	69.90	0.936	100
HCO_3	4	14.6	8.67	0.513	100
NO_3	0.03	0.31	0.09	2.419	50
Cu^{+2}	0.29	0.42	0.32	2.882	1
Cr^{+2}	0.02	0.81	0.2587	1.344	0.05
Pb^{+2}	0.12	0.53	0.3427	-0.12	0.01
Fe^{+2}	0.21	0.69	0.3265	2.655	0.3

3.3.1. Physical parameters assessment

From Table 10 among the physical parameters pH values recorded range between 7.26 to 8.12 with mean value of 7.50, this indicate neutrality nature of the water conditions (WHO, 2011) suggesting moderate mineralization of the groundwater with respect to major and minor ions. However, recorded Total Dissolve Solid (TDS) range between 377 to 1393 mg/L with average concentration of 751.27 mg/L this shows high level dissolution of ionic compound due to intense weathering from the lithologic framework within the study areas. The mean value recorded is above > 500 mg/L which is limit set by W.H.O for drinking water. Though based on (Chebostarev, 1955) classification of waters, all the water samples falls under fresh category because all the TDS value recorded <1500 mg/L. Total hardness measured from the water samples studied range between 60.66 to 253.43 mg/L with mean value of 153.38 mg/L, though the average concentration is < 200 mg/L W.H.O standard, in some instances studied water samples show elevated value above the threshold of permissible limit for drinking water by WHO 2011. This justifies the relative hardness of the groundwater (resistance to foaming against any detergent) within the study areas.

3.3.2. Hydro chemical assessment of the studied water samples

From Table 10 major dissolve constituents (Ca, Mg, Na, K, Cl, SO_4, HCO_3, NO_3) were presented, among which Sodium (Na^+) concentration range between 210 to 900 mg/L with average value of 382.67 mg/L, which is higher than WHO set standard. The elevated value suggested dissolution of feldspathic minerals within the host rock. Sodium is an essential electrolyte that helps maintain the balance of water in and around the cells of our body. It's important for proper muscle and nerve function: it also helps (regulating) the blood pressure. High concentration of sodium in drinking water can result to hypernatremia, involves dehydration which can cause lot of problems including diarrhoea, kidney dysfunction, and diuretics.

From the studied water samples, potassium (K) concentration range between 3.4 to 8.6 mgL with mean value of 28.3 mg/L, this is lower than <100 mg/L set up standard by W.H.O. This suggested that the potassium present in feldspars (Orthoclase and Microcline) are however not very significant to K^+ production. Potassium is a dietary requirement for humans, and we take up to 1 – 60 g/day. Potassium intake is relatively rare, but may lead to depression, muscle weakness, heart rhythm disorder and confusion (Shuaibu, 2020).

However, in the study area the calcium concentration for all the sample measured range between 14.39 to 88.67 mg/L with average value of 50.46 mg/L (Table 9) this is lower than WHO standard for drinking water. Low concentration in the body could cause malfunction of neuromuscular excitability, and function of myocardial system, heart and muscle contractibility, including blood coagulation.

Magnesium is usually less abundant in water than calcium. The recommended magnesium daily intake for an adult is about 300 to 400 mg/L (SCF, 1993). The values of magnesium recorded in the studied groundwater range from 6.01 to 7.78 mg/L with mean value of 6.65 mg/L. All samples

studied had magnesium values less than 400 mgpd intake for adult as suggested by (SCF, 1993). It is worthy to note that magnesium deficiency increase risk to humans of developing various pathological conditions, such as hypertensions, atherosclerotic vascular disease, and acute myocardial infection.
The recorded Sulphate value in the studied water samples ranged between 56.42 to 95.69 mg/L with mean concentration of 69.90 mg/L, this suggesting that all the groundwater samples studied had Sulphate content below the WHO standard. The amount present cannot cause any taste impairment (WHO, 2011).

The chloride concentration recorded in the studied water samples range between 3.1 to 25.5 mg/L with mean value of 9.35 mg/L, this suggested low concentration as it is <259 mg/L permissible limit for chloride by WHO. Similarly, biocarbonate revealed low concentration against the set standard (Tables 10 and 11).

The result of heavy metals such as Cu^{+2}, Cr^{+2}, Pb^{+2} and Fe^{+2} as presented in table 9 show that average concentration of Pb^{+2} and Cr^{+2} are elevated above the threshold of the set up standard by WHO (2011) for domestic water use. However, Fe^{+2} show moderate concentration while Cu^{+2} reveals lower average enrichment as presented in Table 9.

The hydrochemical data set obtained from studied sampled water were subjected to multivariate statistical analysis, the result of the correlation matrix as presented in Table 11 shows that virtually all the major and minor ions are significantly correlated with high level positivity, suggesting similar source of their enrichment, which is not far from the mineral dissolution from the lithological framework due to chemical weathering. Similarly, they equally show significant relationship with total dissolve solids (TDS) and pH indicating their control efficiency of the groundwater within the study areas. However, $Fe^{+2}$and Pb^{+2} are significantly correlated; this may not be unconnected with anthropogenic inputs, particularly from the waste dumpsites.

Table 11: Correlation matrix for the studied sampled water hydrochemistry

Parameters	TDS	TH	pH	Na	K	Ca	Mg	Cl	SO_4	HCO_3	NO_3	Cu	Cr	Pb	Fe
TDS	1														
TH	.745**	1													
pH	-0.512	-.593*	1												
Na	.960**	.625*	-0.332	1											
K	-0.087	-0.099	-0.15	-0.106	1										
Ca	.731**	1.000**	-.591*	.611*	-0.096	1									
Mg	.935**	.719**	-0.466	.873**	-0.176	.703**	1								
Cl	.949**	.760**	-0.435	.951**	-0.159	.750**	.850**	1							
SO4	.730**	.543*	-0.353	.703**	0.419	.534*	.648**	.698**	1						
HCO3	0.212	-0.184	0.068	0.335	-0.436	-0.193	0.141	0.212	-0.323	1					
NO3	.879**	.656**	-0.24	.923**	-0.061	.645**	.820**	.893**	.808**	0.039	1				
Cu	0.276	0.279	-0.351	0.276	-0.244	0.275	0.315	0.207	-0.089	0.293	0.263	1			
Cr	-0.284	-0.193	0.405	-0.26	0.169	-0.185	-0.398	-0.267	-0.276	-0.015	-0.338	-0.286	1		
Pb	0.243	0.206	0.126	0.348	-0.359	0.204	0.191	0.362	-0.208	.570*	0.153	0.258	0.365	1	
Fe	0.045	0.06	-0.106	0.08	-0.127	0.056	0.166	-0.043	-0.104	0.093	0.189	.870**	-0.42	-0.015	1

** Correlation is significant at the 0.01 level (2-tailed)

4.0. Conclusions

The geoelectric survey reveals that the study areas are underlain by three subsurface layers. The results showed that the topsoil in all the dumpsites are polluted and contaminated as depicted by low resistivity values. The infiltration of contaminated plumes was due to the high porosity and permeability that characterizes the soil of the study areas. The layer parameters together with geoelectric and geologic sections confirmed that the Hiran Decodi dumpsite display strong evidence of contamination as revealed by very low resistivity at almost all the VES points. At both Gegeri Yerima and Bebeji dumpsites, although the topsoil might be polluted but the high resistivity values at some points in second and third subsurface layers are an indication of leachate free zone.

The XRF in-situ investigation confirms that domestic waste dumpsites constitute a major source of soil contamination. Mean concentration of analyzed parameters in comparison with their average crustal abundance revealed that Pb, Cu, Zn and Ni are already high in the surface of the soil within the dumpsites. The results indicated that the soil are unpolluted Pb, moderately polluted Cr, Ni and Cu and heavily polluted by Zn. Environmental pollution models applied to the sets of geochemical data revealed that Zn, Pb and Cu show moderate contamination while Mn, Cr, Ni and Fe show low contamination.

The statistical analysis of water samples reveals that among the parameters of interest, only pH has mean value that corresponds with WHO 2011 standard, which is an indication of neutral nature of the sample studied. Other physical and chemical parameters are either elevated or lower than the WHO 2011 standard. This may have significant health implications on the people consuming such water. It is therefore concluded that refuse dumping has affected groundwater quality around the area as indicated by measured dumpsites resistivity and hydro chemical parameters of the water samples.

Conflict of Interest

There is no conflict of interest associated with this research.

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