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ASSESSMENT OF LEACHATE CONTAMINATION OF GROUNDWATER AROUND THE IGBENRE EKOTEDO DUMPSITE, OTA, SOUTHWEST NIGERIA

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Abstract

The study was initiated at the instance of the Local Authority, to evaluate the physico-chemical parameters (quality) of groundwater used by residence living around the Igbenre Ekotedo dumpsite. Nine (9) groundwater samples were collected randomly from boreholes around the dumpsite and were analysed for heavy metals including Fe, Pb, Mn, Cu, Cr, and Zn, using Atomic Absorption Spectroscopy. Other elements analysed for include Mg^{2+}, Na^{+}, K^{+}, Ca^{2+}, and anions such as PO_4^{3-}, SO_4^{2-}, NO_3^{-}, and Cl^{-}.The physical properties tested for are their total dissolved solid (TDS), pH values, temperatures, hardness and electrical conductivity (EC). The results showed that the TDS, NO_3^{-}, hardness and EC concentrations of the water samples fell below the permissible limits set by the WHO standards for drinking water quality for the area except at location BH 3, BH 4 and BH 5. The concentrations of Ca^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}, Zn and Cr are found to be below the WHO standard for all locations, but with relatively higher concentration values of Ca^{2+}, and, Cl^{-} at locations BH 3, BH 4 and BH 5. Also, the concentrations of PO_4^{3-}, Mg^{2+}, K^{+} and Fe are significantly higher than the prescribed WHO standard but with relatively higher values of Mg^{2+} and Fe associated with locations BH 3, BH 4 and BH 5. The spatial distribution maps of the examined parameters show a general increase in concentration towards the Southwest and Southern directions of the study area. This implies the likely direction of groundwater flow around the area since contaminants are usually mobilised and moved in the direction of groundwater flow. At the moment, the contamination is localised and limited to the South-western part of the study area and boreholes can safely be located at the North-Western and South-Eastern parts of the surveyed area.

Keywords: *Contamination; groundwater; metal; dumpsite; concentration.*

1. Introduction

The Igbenre Ekotedo dumpsite in Ota, Ogun State is an open dumpsite and currently receives industrial, institutional and domestic wastes from communities, industries and institutions located around the area. The landfill is improperly designed and therefore not protected by either impermeable soil or polyethylene geomembrane liner, thus allowing for environmental pollution around the vicinity where the site is located. Public concerns regarding the contamination of soil and ground water by leachates emanating from the dumpsite has recently increased in the area and this drew the attention of the Local Authorities. To address the issue, there is therefore the need for constant information on the status of groundwater quality around the dumpsite. In dumpsites that are not constructed according to international standard (without liners), leachates that are formed within the waste materials eventually find their way into the subsurface environment, where they contaminate groundwater bodies Municipal landfill leachates are highly concentrated complex effluents which contain dissolved organic matters; inorganic compounds, such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, nickel, zinc among others [1-3]. The greatest contamination threat to groundwater comes from the leachate generated from the materials which most often contain toxic substances especially when wastes of industrial origins are land filled [4]. However, it has been widely reported that leachates from landfills for non-hazardous waste could as well contain complex organic compound, chlorinated hydrocarbons and metals at concentrations which pose a threat to both surface and groundwater. The produced leachate is normally composed of organic and inorganic compositions. In addition, with increase in time, the produced leachate permeates into ground systems leading to change of physical and chemical properties of groundwater. Lee *et al.* [5], stated that heavy metals such as cadmium, arsenic, chromium have been reported at excessive level in groundwater due to landfills operation. With respect to Longe *et al.* [4], the volume of leachate depends principally on the area of the landfill, the meteorological and hydrogeological factors and effectiveness of capping. According to Kostova [6], concentration (mg/L) of leachate constituent are in phases namely transition (0-5years), acid-formation (5-10years), methane fermentation (10-20years) and final maturity (>20years). The age of a landfill also significantly affects the quantity of leachate formed. The ageing of a landfill is accompanied by increased quantity of leachate. Leachates generated in the initial period of waste deposition (up to 5 years) in landfills have pH-value range of 3.7 to 6.5 indicating the presence of carboxylic acids and bicarbonate ions. With time, pH of leachate becomes neutral or weakly alkaline ranging between 7.0 and 7.6. Landfills exploited for long period of time give rise to alkaline leachate with pH range of 8.0 to 8.55 [7-8]. Excessive content of these chemical compounds may be associated with contaminants around the Igbenre Eotedo dumpsite and so, this study was initiated at the instance of the Local Authorities to determine the physico-chemical parameters (quality) of groundwater used by residence living around the dumpsite. They intend to rely on the results from this study and other geophysical investigation around the area to determine appropriate locations to provide boreholes as a way of intervention. []

1.1. Study area

The Igbenre Oke-tedo Landfill is located in Ota along the Sango-Idiroko road (Figs. 1 and 2). It is about 800 m away from the major express road by the High Court, opposite Nestle Company. The landfill is bounded by residential buildings and a very deep gulley. Currently, waste is indiscriminately being dumped on the ground surface without any compaction effort in the site, and most often the waste materials are constantly being burnt by fire. Geologically, the study area falls within the sedimentary basin of southwestern Nigeria popularly called the Dahomey Basin. The Dahomey Basin constitutes part of the system of West African precratonic (marginal sag) basin developed during the commencement of rifting, associated with the opening of the Gulf of Guinea in the early Cretaceous to late Jurassic. The Basin is very extensive and consists of Cretaceous Tertiary sedimentary sequence that thin out on the east and are partially cut off from the sediment of the Niger Delta Basin by the Okitipupa ridge. In general, rocky outcrops are poor due to the thick vegetation and soil cover. The knowledge of the geology of this basin had been improved through the availability of boreholes and recent road cuts. Major lithological sequences associated with the Basin are Abeokuta Formations (Ise, Afowo and Araromi Formations), and Ewekoro, Akinbo, Oshoshun, Ilaro and Benin Formations. The lithology is composed of loose sediment ranging from silt, clay and fine to coarse grained sand, called coastal plain sand. The exposed surface consists of poorly sorted sands with lenses of clays. The sands are in part cross-bedded and show transitional to continental characteristics [9-13].

2. Materials and methods

Groundwater samples were collected at about 50 to 600 m radius (Figure 1) from the landfill under study during the month of August, 2014. Nine (9) groundwater samples were collected randomly around the study area. Some of the sampling points were located far away from the sites to possibly determine the lateral extent of the spread and also to serve as control. The water samples were analysed to determine their heavy metal contents such as iron, lead, manganese, copper, chromium, cadmium, and zinc, according to international standards for the examination of water and wastewater quality [14].

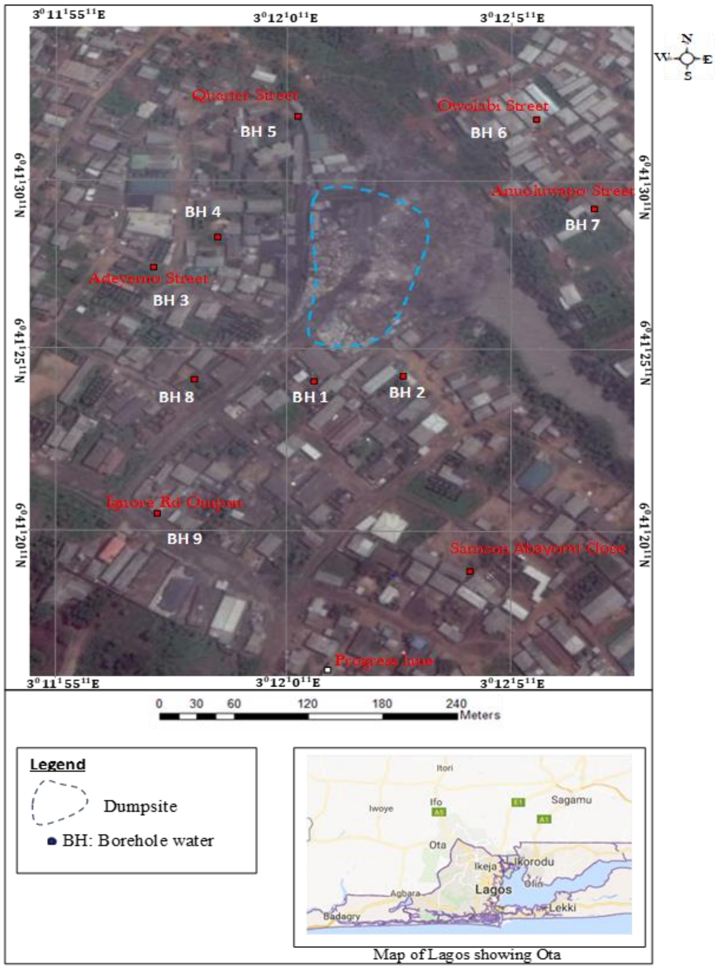

Figure 1. Data acquisition map showing location of dumpsite

Figure 2. Pictorial view of Igbere Eko-tedo dumpsite, Ota

Other elements analysed for include Mg^{2+}, Na^{+}, K^{+}, Ca^{2+}, hardness, and anions such as PO_4^{3-}, SO_4^{2-}, NO_3^{-}, Cl^{-}. The physical properties obtained in-situ were their TDS, pH values, temperatures, and EC. Samples were collected in a 7.5 litre polyethylene bottles after rinsing with the water being sampled and were properly sealed. Samples were labelled and stored until they were eventually transferred to the Chemistry Department, University of Lagos, Akoka for laboratory analysis. Global Positioning System (Garmin GPS Channel 76 model) was used to measure the coordinates of the sampling points. The field data were later interpolated using Kriging technique to produce the elemental distribution maps of the area using ArcGIS software.

3. Results and discussion

Tables 1, 2 and 3 present the results and descriptive statistics of the physico-chemical properties of water samples collected from the boreholes around the dumpsite.

Table 1. Hydrophysical analysis of water samples from boreholes around Igbenre Ekotedo landfill

Sample	Location	Coordinate	pH	Temp (°C)	EC (µS/cm)	TDS (ppm/mg/L)	Hardness (mg/L)
BH 1	Progress Lane	06^0 41′ 17.14″N 003^0 12′ 01.15″E	5.47	25.2	60	29	85.0
BH 2	Samsom Abayomi Close	06^0 41′ 20.91″N 003^0 12′ 04.56″E	5.18	25.2	23	11	75.0
BH 3	Adeyemo Street	06^0 41′ 26.48″N 003^0 11′ 56.22″E	4.52	26.1	1385	692	212.0
BH 4	Adeyemo Street (by sch.)	06^0 41′ 28.96″N 003^0 11′ 55.25″E	6.01	25.6	1053	575	175.0
BH 5	Quarter Street	06^0 41′ 31.48″N 003^0 11′ 58.90″E	5.79	25.0	1272	836	155.0
BH 6	Owolabi Street (Hill top)	06^0 41′ 34.31″N 003^0 12′ 04.36″E	5.53	26.1	30	15	90.0
BH 7	Anuoluwapo Street	06^0 41′ 32.24″N 003^0 12′ 07.58″E	5.27	24.4	15	8	10.0
BH 8	Igbenre Rd Oni-pan	06^0 41′ 23.38″N 003^0 11′ 55.87″E	5.65	24.8	50	25	40.0
BH 9	Igbenre Rd Oni-pan	06^0 41′ 24.00″N 003^0 11′ 54.60″E	5.95	24.0	83	42	40.0
Mean			5.48		474.55	248.11	99.67
Range			4.52-6.01		15-1572	8-836	10-212
SD			0.46		441.36	220.51	56.72
CV			8.39		174.91	175.16	73.24
WHO/SON standard			6.5-8.5	-	1000	500	150

SD- standard deviation; CV-coefficient of variation, %

Table 2. Macro elements and anions content of water samples obtained from boreholes around Igbenre Ekotedo dumpsite

Samples	Ca^{2+} (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl^- (mg/L)	SO_4 (mg/L)	PO_4 (mg/L)	NO_3 (mg/L)
BH 1	34.72	12.38	2.67	7.04	159.53	38.0	40.6	2.2
BH 2	30.06	10.19	2.81	5.91	106.35	26.0	39.2	5.9
BH 3	89.97	13.11	2.57	7.02	159.53	45.0	10.8	14.9
BH 4	30.06	10.92	2.71	7.08	186.58	27.0	11.10	11.8
BH 5	28.07	10.19	2.31	6.04	106.35	11.0	32.40	16.7
BH 6	36.07	13.11	2.07	7.11	70.90	278.0	10.3	3.4
BH 7	4.01	1.46	2.94	5.82	88.63	125.0	22.4	6.2
BH 8	16.03	5.83	2.82	5.89	88.63	33.0	42.3	1.3
BH 9	16.03	5.83	2.56	6.71	159.53	22.0	38.5	2.8
Mean	31.67	9.22	2.61	6.51	125.11	67.22	27.51	7.58
Range	4.01-89.97	1.46-13.11	2.1-2.94	5.82-7.1	70.9-186.58	11-278	10.3-42	1.3-16.7
St. Dev.	24.23	4.00	0.27	0.58	41.28	85.74	13.88	2.36
CV	7	43	10	9	33	128	21	57
WHO*	50	2.0	1.0-2.0	200	250	200/100	5.0	10

*SD- standard deviation; CV-coefficient of variation, %; *WHO/SON standard*

Table 3. Heavy metal contents of water sample obtained from boreholes around Igbenre Ekotedo dumpsite

Samples	Fe (mg/L)	Zn (mg/L)	Mn (mg/L)	Cu (mg/L)	Pb (mg/L)	Ni (mg/L)	Cr (mg/L)
BH 1	3.91	2.30	0.71	0.52	0.01	0.02	0.02
BH 2	3.34	2.02	0.92	0.67	ND	0.02	0.01
BH 3	4.50	2.07	0.84	0.44	ND	0.02	0.02
BH 4	3.02	2.11	0.98	0.36	ND	0.02	0.02
BH 5	2.91	2.01	0.72	0.29	0.01	0.01	0.03
BH 6	2.39	3.11	0.91	0.57	0.02	0.01	0.01
BH 7	2.56	2.91	0.77	0.32	0.01	0.02	0.01
BH 8	3.11	3.08	0.78	0.58	0.02	0.03	0.01
BH 9	3.49	2.07	0.87	0.53	0.03	0.03	0.02
Mean	3.25	2.41	0.83	0.48	0.01	0.02	0.02
Range	2.39-4.5	2.01-3.11	0.71-0.98	0.29-0.67	0-0.03	0.01-0.03	0.01-0.03
SD	0.66	0.48	0.09	0.13	0.01	0.007	0.005
CV	20	20	11	27	1.0	35	5
WHO*	0.3	5.0	0.5	0.5	0.01	0.02	0.05

*SD- standard deviation; CV-coefficient of variation, %; *WHO/SON standard; ND -Not Detected*

The results show that the water samples collected around the waste dumpsite have higher concentrations of most of the analysed parameters. From Table 1, the temperature of the groundwater samples ranged from 24^{0C} to 26.1°C. The pH values of the groundwater samples are all acidic and ranging from 4.52 to 6.01. The effects of acidic waters on human health and the environment have been widely reported. For example, acidic waters have been known to be aggressive and enhance the dissolution of iron and manganese causing unpleasant taste in water [15]. The EC is a function of the degree of dissolved matters in water. Chemically pure water has a very low EC. The EC of water around the dumpsite ranged between 15 and 1385 µS/cm, and except at BH 3, BH 4 and BH 5, all other values are found to be below the permissible standard of 1000 µS/cm, set by WHO (Fig. 3). The TDS concentration showed strong positive linear relationship with the EC (suggesting common source) and was found to be low at all the locations also and less than standard limit of 500 ppm/mg/L except at location BH 3, BH 4 and BH 5 (Fig. 3). The high concentration of TDS and EC at locations BH 3, BH 4 and BH 5 may be an indication of contamination due to high content of inorganic salts such as; calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates in the groundwater. It also implies likely westward direction of groundwater flow around the area since contaminants are usually mobilised and move in the direction of groundwater flow. This was also inferred from the geophysical study around the site (Not shown). Hardness is normally expressed as the total concentration of Ca^{2+} and Mg^{2+} in mg/L, equivalent $CaCO_3$. Hardness ranged from 10 to 212 mg/L and all values are below the standard limit of 150 mg/L except also at BH 3, BH 4 and BH 5 (Fig. 3). Strong linear relationship exists between the observed hardness of water and the TDS and EC concentration from all the locations.

Table 2 provides the major elemental compositions and anion contents of water from the boreholes. Ca^{2+} and Mg^{2+} concentrations in groundwater samples from all the sampling points have mean values of 31.67 mg/L and 9.22 mg/L respectively. The Mg^{2+} content of all the water samples have elevated values above the standard limit of 2.0 mg/L in about 88.8% of the locations except at location BH 7 (fig. 3), while Ca^{2+} concentration exceeded the standard limit at location BH 3 (Fig. 3). Ca^{2+} and Mg^{2+} do not pose potential adverse health effects in drinking water. The presence of both ions in water increases its hardness, which results in the use of more soaps than what is necessary for bathing and washing [16]. Both Ca^{2+} and Mg^{2+} are beneficial to human health. Past epidemiological studies have supported the hypothesis that extra magnesium and or calcium in drinking water can contribute to reduced cardiovascular disease and other health benefits in populations [16]. K^+ values are higher than the standard limit for all the locations. Na^+ and Cl^-concentrations in all sampled locations are all below the WHO minimum requirement of 200 mg/L and 250 mg/L (Fig. 3) respectively.

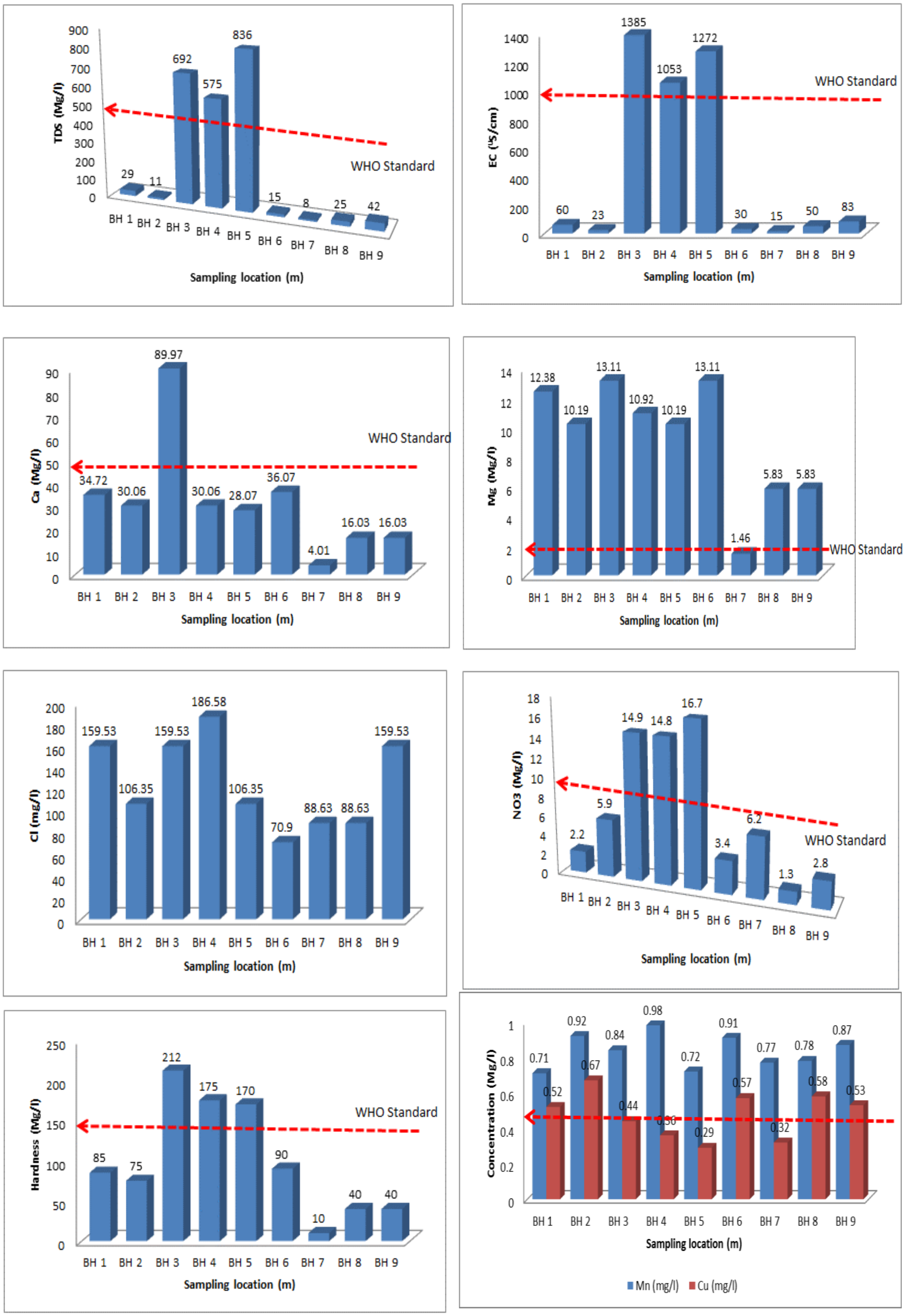

Figure 3. Concentration of other physicochemical properties of water samples versus WHO standard

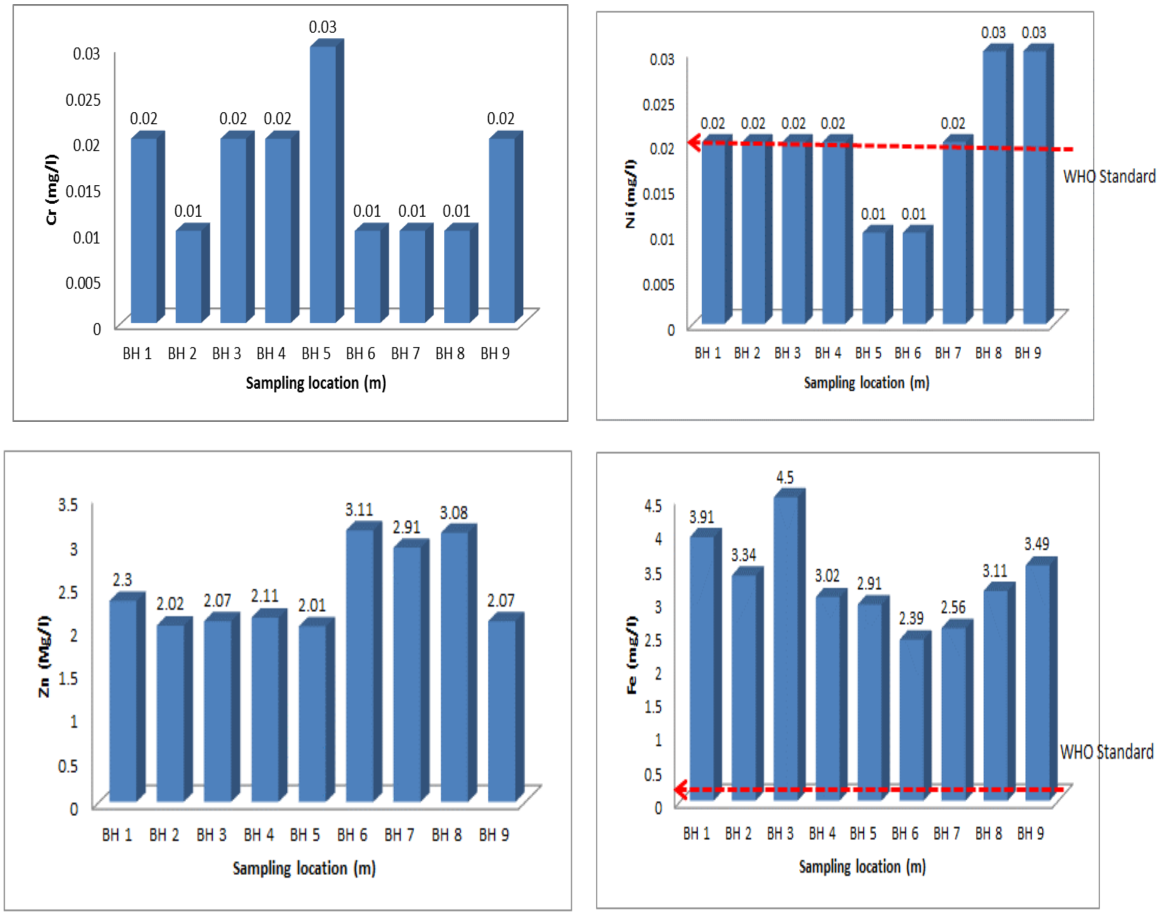

Figure 4. Concentration of EC and hardness in borehole water sample versus WHO standard

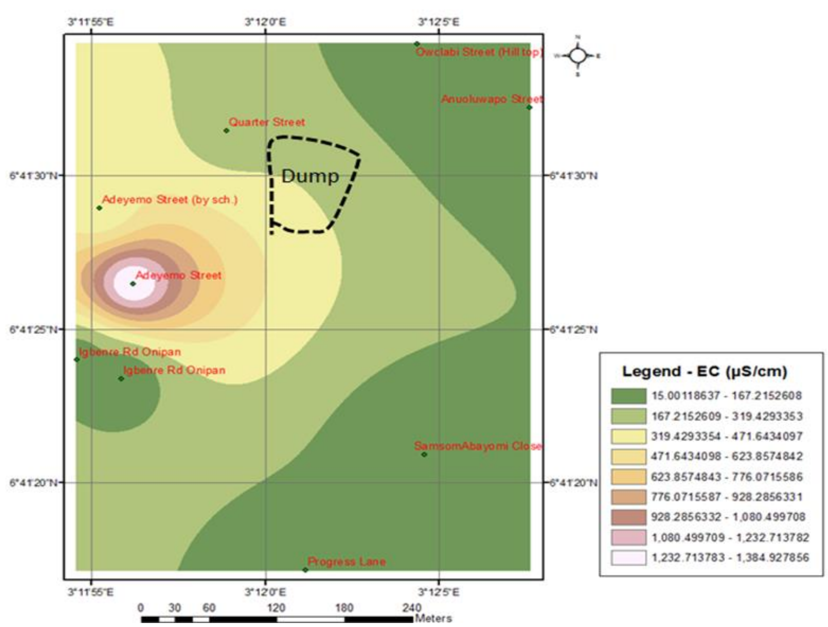

Figure 5. EC concentration distribution map around the Igbenre Ekotedo dumpsite

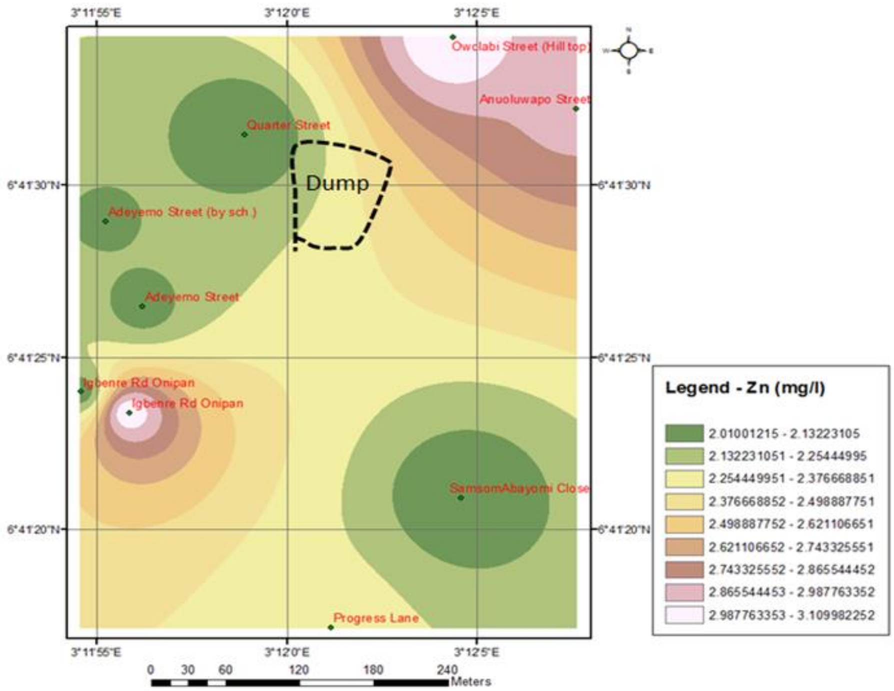

Figure 6. Zn concentration distribution map around the Igbenre Ekotedo dumpsite

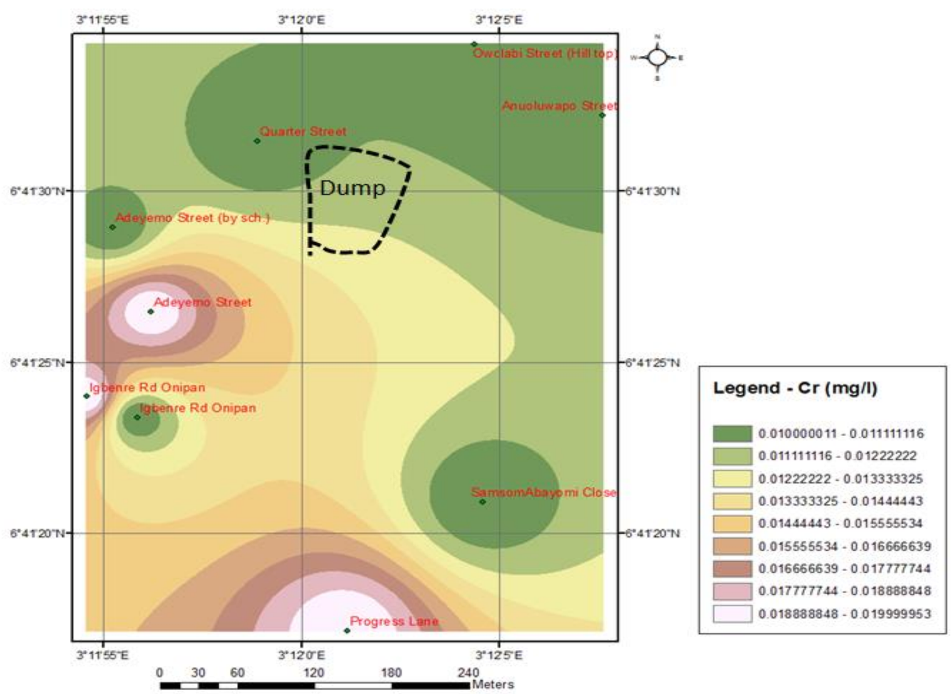

Figure 7. Cr concentration distribution map around the Igbenre Ekotedo dumpsite

Excess NO_3^- concentration in water samples are key indicators of contamination. Their values in all the locations are below the WHO limit but are elevated at locations BH 3, BH 4 and BH 5 (i.e. about 33.3% of the locations) beyond the standard limit (Fig. 3). The measured SO_4^{2-} ion exceeded the prescribed standard limits of (100-200 mg/L) set by WHO (2007) in about 11.11 % (BH 6) from the investigation.

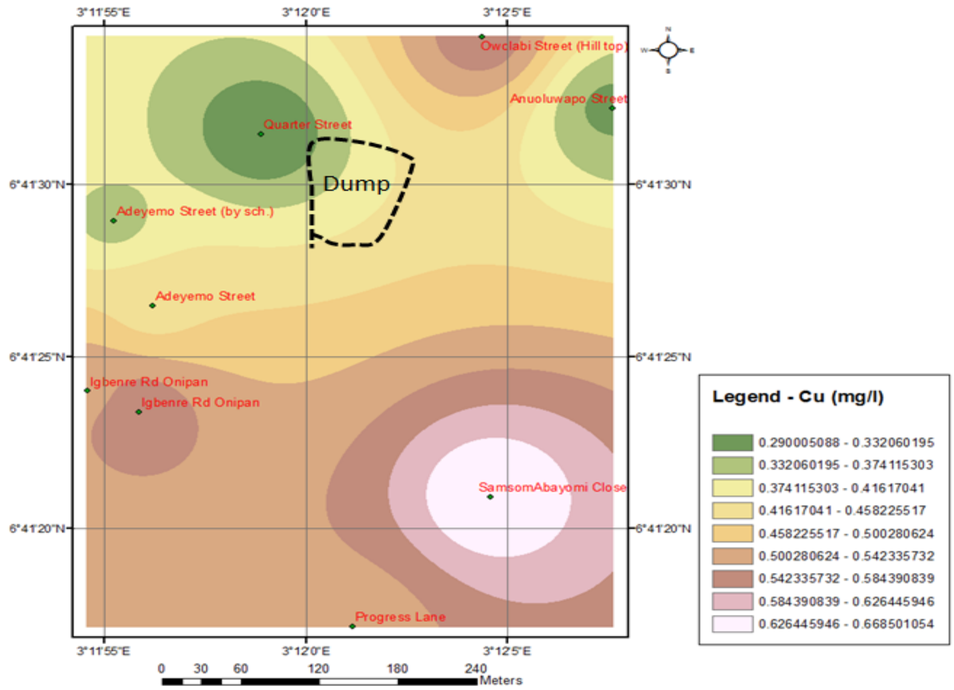

Figure 8. Cu concentration distribution map around the Igbenre Ekotedo dumpsite

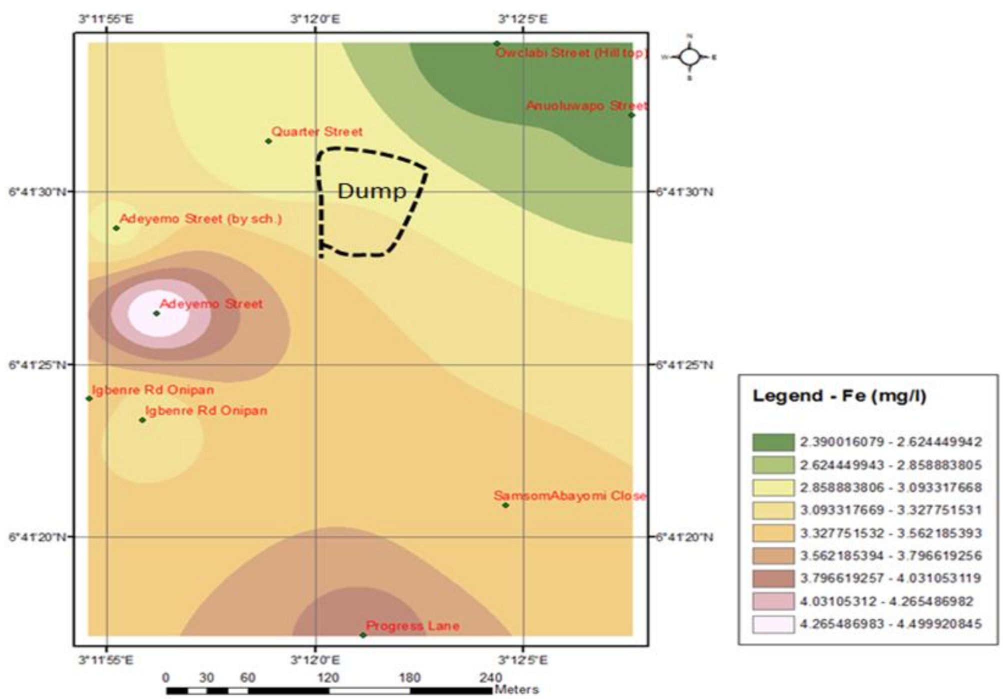

Figure 9. Fe concentration distribution map around the Igbenre Ekotedo dumpsite

Table 3 presents the descriptive statistics and standard values of heavy metals in groundwater around the site. Among the examined variables, Fe has the highest mean (3.25 mg L^{-1}), followed by Zn (2.41 mg L^{-1}) while Pb and Cr remained the least (0.01 mg L^{-1}). Also, Fe recorded the highest standard deviation (0.66 mg L^{-1}) followed by Zn (0.48 mg L^{-1}). Cr and Ni recorded the least values of standard deviation (0.005 mg L^{-1} and 0.007 mg L^{-1} respectively).

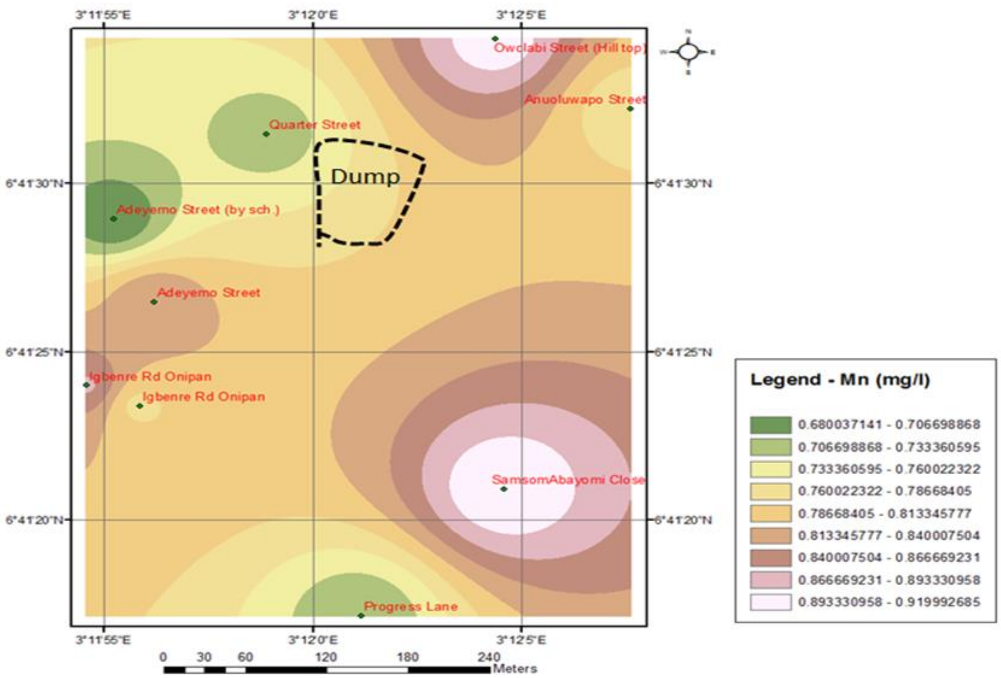

Figure 10. Mn concentration distribution map around the Igbenre Ekotedo dumpsite

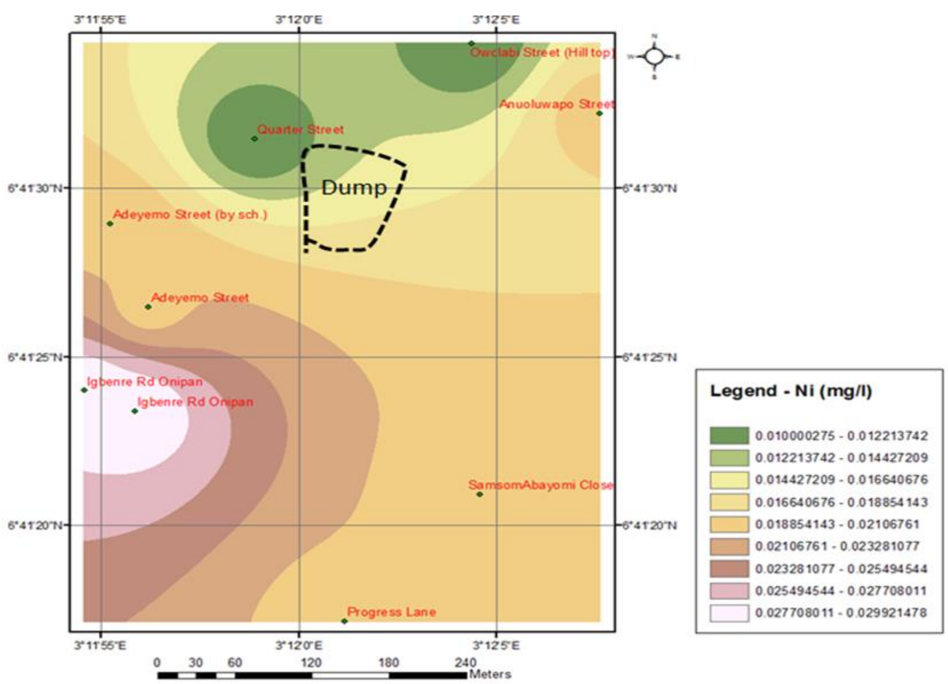

Figure 11. Ni concentration distribution map around the Igbenre Ekotedo dumpsite

Furthermore, on the pattern of relative variation, the result of the coefficient of variation shows that all the examined variables are heterogeneous. Ni and Cu for example top the list with values of 35 % and 27 % respectively. The WHO permissible level of Chromium (0.05 mg L^{-1}) is not exceeded in all the sampled boreholes in the study area, while that of Ni was below the standard limit for all locations except at BH 8 and BH 9 (Fig. 4). The spatial distribution map of Cr is presented in figure 7 with a general increase towards the Southern and Southwest parts of the study area while that of Ni indicates more concentration towards the

Southwest (Fig. 11). The concentration of Pb exceeded the WHO permissible limit (0.01 mg L^{-1}) at locations BH 6, BH 8 and BH 9, but within limit at about 33.33 % of the locations (BH 1, BH 5 and BH 7), and not detectable in the remaining locations (Table 3). Toxic concentration of Pb (≥ 0.01mg/L) in human beings has been implicated for causing anaemia, kidney damage and cerebral oedema [17-18]. The mean concentration of Cu exceeded the WHO permissible level of 0.5 mg L^{-1} for all samples at the site except at BH 3, BH 4, BH 5 and BH 7 (Fig. 3). The spatial distribution map of Cu indicates an increase towards the South-eastern part of the study area (Fig. 8). The WHO permissible level of Fe (0.3 mg L^{-1}) was exceeded in all the sampled borehole water around the study area with values ranging from 2.39-4.5 (Fig. 4).

Presence of Fe in water can lead to change of colour of groundwater [20]. These high values of Fe also support the results of previous research that concluded that water in Nigeria generally has high Fe content. The spatial distribution map of Fe in figure 9 shows more of the concentration towards the Southern and Southwest parts of the study area. The WHO permissible level of Zn (5.0 mg L^{-1}) is not exceeded in sampled groundwater in all the locations while that of Mn (0.5 mg L^{-1}) is exceeded in all sampled borehole in the study area (Figs. 3 and 4). Concentrations of Mn in excess of 0.2 mg L^{-1} make water distasteful to drinking with no specific toxic effects [4]. The spatial distribution map of Zn is shown in figure 6 with a general increase towards the Southwest and Northeast directions of the study area while that of Mn indicates a Southeast and Northeast distributions (Fig. 10). Very low correlations exist between Cu, Zn, $Cl^-$and EC, TDS and SO_4, indicating multiple anthropogenic source, while moderate correlations exist between hardness and Mg^{2+}, Na and Cl (Fig. 12).

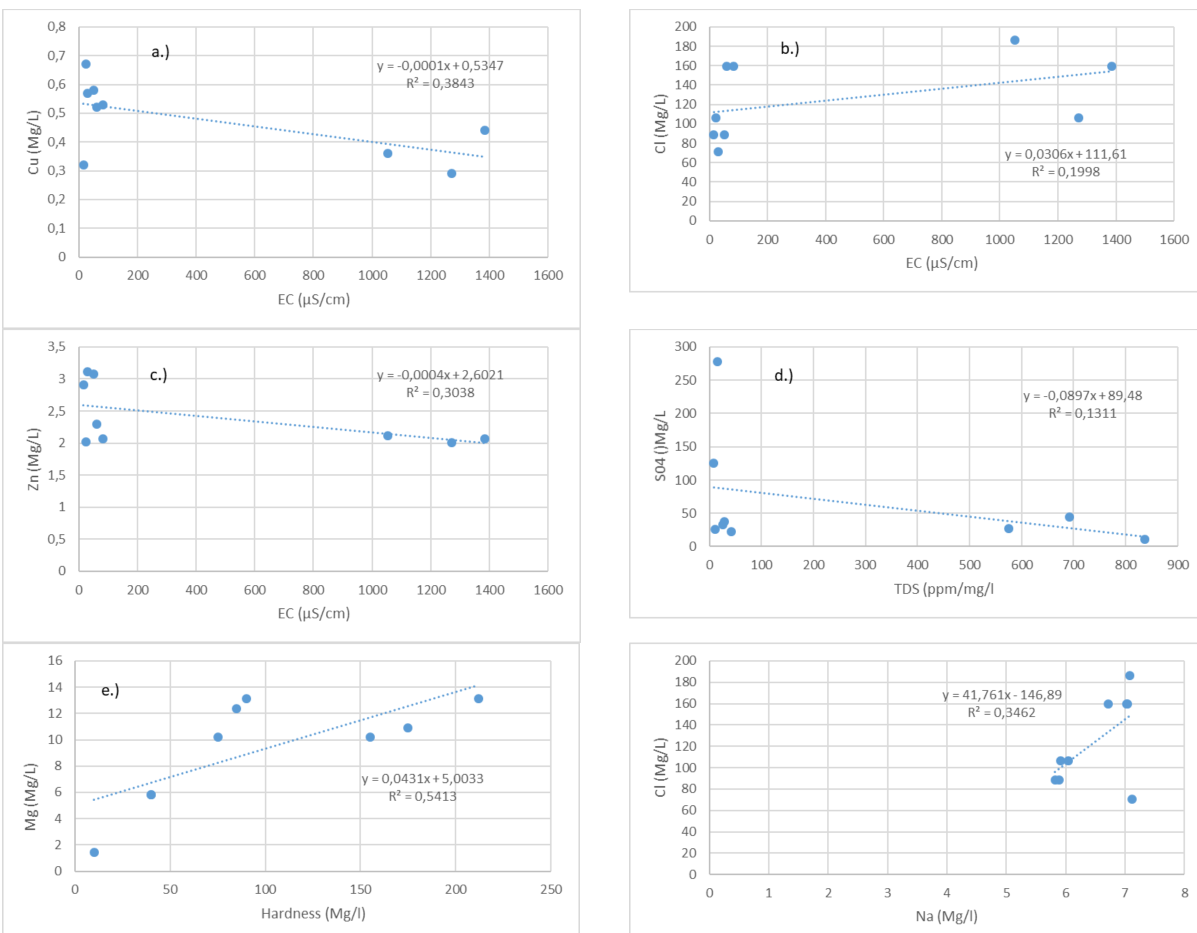

Figure 12. Scatter plot for the correlation between EC and Cu (a), Cl (b) Zn (c) and between TDS and SO4 (d), hardness and Mg (e), Cl and Na (f)

4. Conclusion

The borehole water from all the dumpsites have been analysed and the various elemental compositions determined. The physical properties of water obtained around the dumpsite showed TDS, hardness, NO_3^-, and EC values greater than the standard limit at BH 3, BH 4 and BH 5. There is a corresponding increase in value for Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} for these same locations. The high values of most of the physicochemical properties at BH 3, BH 4 and BH 5 locations is not unconnected with contamination arising from the release of leachate generated at the dumpsite. It also implies likely Southwest direction of groundwater flow around the area since contaminants are usually mobilised and move in the direction of groundwater flow. At the moment, the contamination is localised and limited to the Southwestern part of the study area and boreholes can be safely located at the North-eastern and South-eastern parts of the surveyed area. Public complaints regarding the colour and taste of water from their borehole confirms the results around this area. The pH values obtained from water samples indicates high acidic content. The heavy metals analysis and subsequent evaluation revealed that Fe and Mn concentration from all the water samples have exceeded their background levels. This further supports the report of high iron concentrations in groundwater in Nigeria according to WHO and UNICEF, 2006. The spatial distribution of all the examined parameters shows a Southwest/Southern increase around this waste site. The proximity of the dumpsite to residential areas is a potential danger and proactive measures must be put in place by the appropriate authorities to avoid epidemic outbreak that might result from the consumption of the contaminated groundwater around this area.

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