International Journal of Earth Sciences Knowledge and Applications (2022) 4 (3) 365-374

International Journal of Earth Sciences Knowledge and Applications
journal homepage: http://www.ijeska.com/index.php/ijeska

Research Article

e-ISSN: 2687-5993

Impact of Heavy Metals on the Soil and Groundwater of Ariaria Waste Dumpsite, Aba, South-Eastern Nigeria

Ese Anthony Aladin[1], Daniel Imariabe Omoruyi[1]*, Joseph Odion Odia-Oseghale[1]

[1]*Department of Geology, University of Benin, Benin City, Edo State, Nigeria*

INFORMATION

Article history
Received 29 May 2022
Revised 28 September 2022
Accepted 29 September 2022

Keywords
Soil
Heavy metals
Groundwater
Physio-chemical parameters
Dumpsite

Contact
*Daniel Imariabe Omoruyi
imariabe.omoruyi@uniben.edu

ABSTRACT

Municipal waste around Ariaria, Aba, Nigeria, was investigated to ascertain the impact of heavy metals on the soil and groundwater. Eighteen (18) soil samples were collected with each of the sampling point having three (3) soil samples collected at the depth of 0-10 cm, 10-20 cm and 20-30 cm and ten (10) groundwater samples were also collected from an existing borehole. Control soil samples were collected opposite the dumpsite area. The physio-chemical and heavy metal parameters of the soil and groundwater samples were assessed using Atomic Absorption Spectrophotometry (AAS) and Titrimetric method, respectively. Heavy metals analyzed for includes zinc, lead, iron, chromium, cadmium, copper, nickel, manganese, and cobalt. The average mean concentration of the heavy metals includes lead (6.252 mg/kg), chromium (7.486 mg/kg), iron (1493.598mg/kg), manganese (89.84 mg/kg), cobalt (16.2 mg/kg), cadmium (2.754 mg/kg), copper (41.53 mg/kg), zinc (270.4 mg/kg) and nickel (15.858 mg/kg). The mean concentration of heavy metals of the soil samples are in this order: Fe>Zn>Mn>Cu>Co>Ni>Cd>Pb>Cr. The physio-chemical parameters (pH, electrical conductivity, Total hardness, total dissolved solids, total suspended solids, major anions and cations) analyzed for all groundwater samples agree with the International World Health Organization (WHO) for potable water except pH and TDS (mg/l. The heavy metal contents include manganese (0.168 mg/l), cadmium (0.28 mg/l), lead (0.046 mg/l), nickel (0.12 mg/l), cobalt (0.016 mg/l), chromium (0.087 mg/l), copper (0.5 mg/l), magnesium (1.84 mg/l), zinc (0.023 mg/l) and iron (1.42 mg/l). The sieve analysis shows that the soil samples consist of 11.95% of Silt, 83.62% of Sand and 4.42% of little gravel. The mean permeability of the study area ranges from 0.19 (cm/sec) to 0.49 (cm/sec), the mean infiltration rate ranges from 6840 mm/hr to 31320 mm/hr and the grain size of the soil samples is well graded and well to poorly sorted. A strong degree of association was found to exist between lead and chromium, copper and zinc, nickel and lead using Pearson's Correlation Coefficient.

1. Introduction

Open dumps are the oldest and most common way of disposing of solid wastes. Solid and fluid wastes generation and their poor disposal mechanism in the urban areas of most developing countries have become a threat to the environment (Amadi et al., 2010). Solid waste management is a great problem in Aba because of the large amount of waste been generated daily from the various industries and mostly waste from Ariaria International Market. Which has been observed to be one of the major challenges being tackled by state and local government environmental protection agencies in Nigeria. Environmental and public health related risks associated with indiscriminate disposal of wastes have raised concerns about the mismanagement of waste in Nigeria. Municipal Solid Waste varies in composition, which may be influenced by many factors, such as culture affluence, location etc. Municipal Solid Waste Management depends on the characteristic of the solid waste including the gross composition, moisture contents, average particle size, chemical composition and density, in which knowledge of these, usually helps in disposal plans (Sally, 2000).

2. Overview of the Study Area

This study area was conducted at Ariaria Waste Dumpsite in Ariaria Area, Aba, Aba South Local Government Area, Abia State South-East Nigeria (Figs. 1-2). It is situated between latitude 005°06'51" N to 005° 7′0″N and longitude 007°19'45" E to 007°20′0″E. Aba is located on the Aba River. It is accessible by the Port-Harcourt-Enugu Road, Aba-Owerri Road, Umuabia, Ikot Ekpene Road. Ariaria Waste Dumpsite is the major dumpsite used in Aba town. Aba south is the main city Centre and heartbeat of Abia State. Aba is made up of many villages such as; Umuopoji-Aba. Ariaria and other villages from Ohazu merged due to administrative convenience. Aba was established by the Ngwa clan of Igbo people of Nigeria as a market town. Aba Town is a commercial center that has textiles, pharmaceuticals, plastics, timbers, cosmetics, shoe manufacturing industries and the Ariaria International market (Ukpong et.al 2006). The projected population is about Two million, five hundred and thirty-four thousand, two hundred and sixty-five (2,534,265) (Nigeria Population Census, 2016).

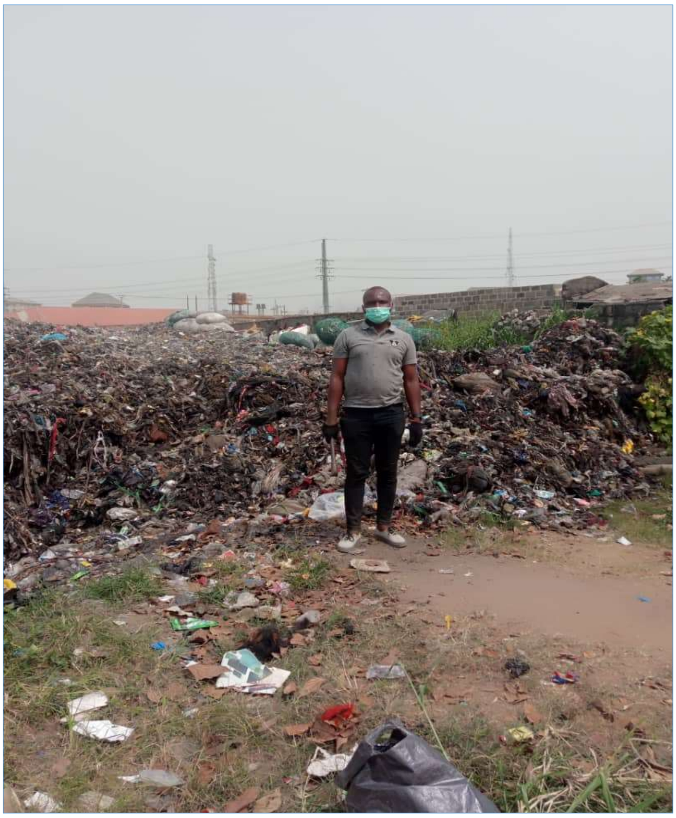

Fig. 1. View of Ariaria Aba Waste Dumpsite

The area has two distinctive climatic conditions in a year-the dry season and rainy season. The dry season starts from November to March while the rainy season is from March to September annually although it varies due to seasonal changes and September is the most wet month in Aba. Aba has a period of dusty winds cold and dry conditions known as "Harmattan" which start from December to the month of February, thought it changes depending on the season. The average mean temperature of city is between 24 °C to 34 °C with relative humidity of 70% in dry periods and 90% in rainy periods.

Aba is geologically underlain the Benin Formation of Miocene to Recent. The formation is made up friable fine to coarse grained sand with minor intercalation of clay. The Benin Formation composed mostly of high resistant fresh water bearing continental sand and gravel with clay and shale intercalation.

3. Geology of the Study Area

Abia state has two principal geological formations in the state namely Bende-Ameki and the Coastal Plain Sands otherwise known as Benin Formation (Fig. 3). The Bende-Ameki Formation of Eocene to Oligocene age consists of medium–coarse-grained white sand stones. The late Tetiary-Early Quaternary Benin Formation is the most predominant and completely overlies the Bende Ameki Formation with a southwestward dip. The Formation is about 200 m thick. The lithology is unconsolidated fine-medium-coarse-grained cross-bedded sands occasionally pebbly with localized clay and shale.

The two principal geological Formations have a comparative groundwater regime. They both have reliable groundwater that can sustain regional borehole production. The Bende-Ameki Formation has less groundwater when compared to the Benin Formation. The numerous lenticular sand bodies within the Bende- Ameki Formation are not extensive and constitute minor aquifer with narrow zones of sub-artesian condition. Specific capacities are in the range of 3-6 m^3/hr. On the other hand, the high permeability of Benin Formation, the overlying lateritic earth, and the weathered top of this Formation as well as the underlying clay shale member of Bende-Ameki series provide the hydrogeological condition favouring the aquifer formation in the area.

Aba is geologically underlain the Benin Formation of Miocene to Recent. The Formation is made up friable fine to coarse grained sand with minor intercalation of clay. The Benin Formation composed mostly of high resistant fresh water bearing continental sand and gravel with clay and shale intercalation.

4. Sampling and Analytical Methods

Soil samples were collected from six location point for laboratory analysis (Fig. 2). Location points 1 at side of the entrance of the dumpsite, location point 2 was 200 m away from location 1 at the edge of the Ariaria Dumpsite, location point 3 was 200 m away from location point 2 and so on. From each location point, 3 soil samples were collected, the first one was from the topsoil to 10cm depth, the second one was from 10 cm to 20 cm depth, the third one was from 20cm to 30 cm depth. The sixth one which serves as the control was collected very far away from the dumpsite. The collected samples were properly labeled and stored in polythene bags and transported to the laboratory for analysis.

Ten groundwater samples were collected from existing drilled borehole in a one-liter plastic bottle around and opposite the dumpsite area and the container was properly locked.

Seven groundwater samples were collected around the dumpsite of the study area while three groundwater samples were collected opposite the dumpsite across the Aba-Owerri express way road. Groundwater (GW) sample one was collected from South direction of the dumpsite, while GW2, GW3, was collected from the Southwest and GW4, GW5 was collected from the West direction of the dumpsite, then, GW6, GW7 was collected from the Northwest and North direction of the dumpsite and GW8, GW9 and GW10 was collected opposite the dumpsite of South-east and Northeast direction the dumpsite. The plastic bottles were first washed thoroughly using distilled water and dried. Before taking the water sample, the bottles were rinsed with the water to be taken as sample. The bottles were labeled accurately and kept in ice-box container and transported immediately to the laboratory for analysis.

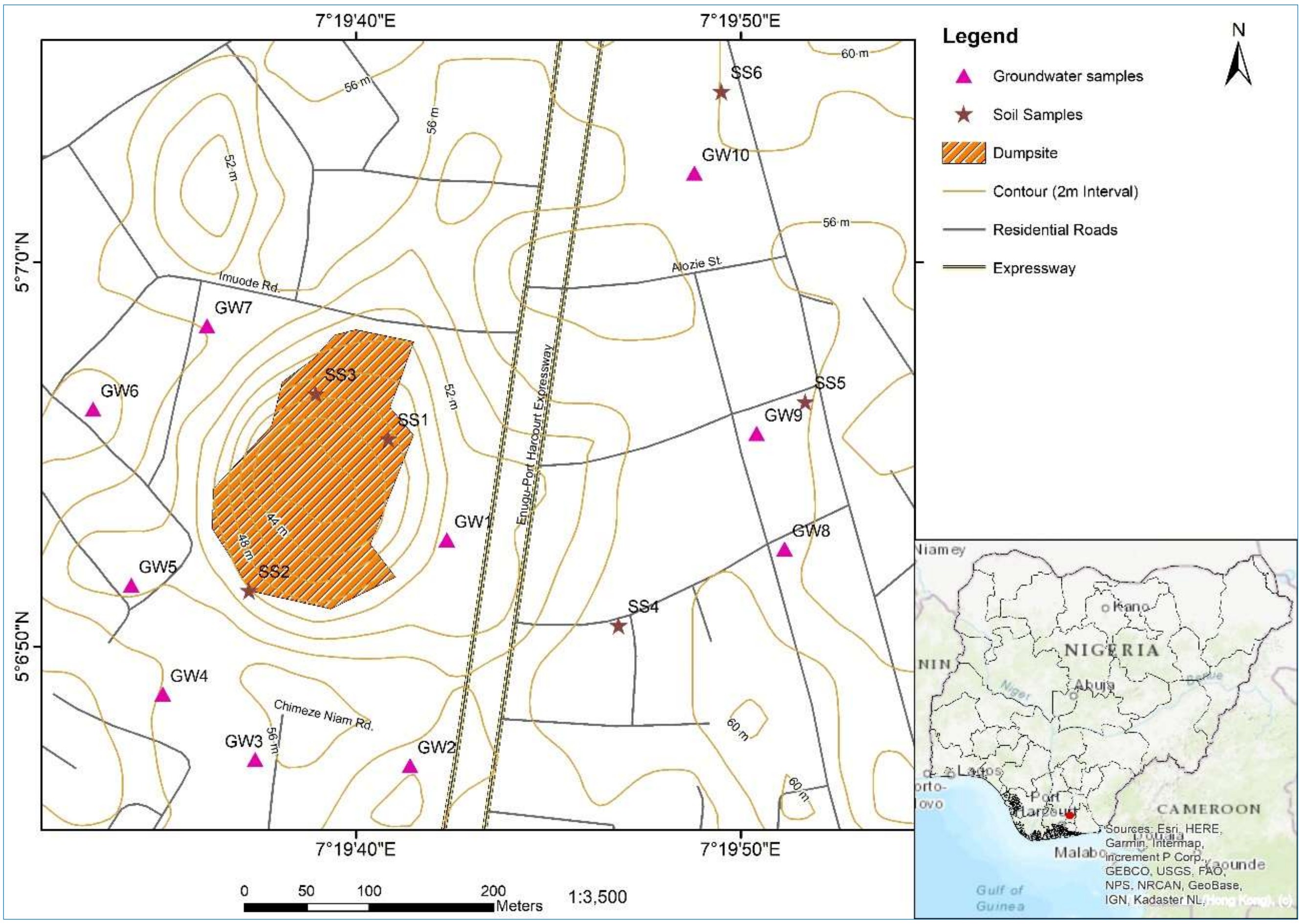

Fig. 2. Location map with sampling points

The soil samples were air-dried for 24-36 hours in the laboratory. After drying, the soils were crushed in a mortar with pestle and sieved through 2 mm mesh standard sieve to remove large debris, gravel sized materials and other unwanted materials and the sieved soils were then placed in polythene bags prior to laboratory analysis.

Heavy metals (Fe, Mg, Ni, Zn, Cu, Mn, Cr, Cd, Co and Pb) were determined using Atomic Absorption Spectrophotometer (AAS, Perkin-Elmer Analyst 300) according to the standard methods of APHA (2005) and Ekpo et al. (1999).

5. Results and Discussion

5.1. Physio-chemical characteristics of groundwater samples

The characterization of wastes component from dumpsite is essential owing to the potential hazards it poses to both the soil and groundwater.

The pH values of the groundwater samples investigated range from 4.89 to 6.72 which reveals that the ground water is acidic to slight acidic (Table 1). GW1, GW2, GW3, GW5 conform to the WHO standard while GW4, GW6, GW7, GW8, GW9, GW10 do not conform with WHO standard, because they are slightly acidic. The GW with pH value ranges from 6.55 to 6.72 falls within the WHO and NSDWQ (2007) permissible range of 6.5-8.5 for water usage in drinking. The pH value of 5.1 from the groundwater sample collected outside the dumpsite is acidic According to (Giadom et al., 2014) which conforms with the findings of this research.

EC (Electrical Conductivity) is a valuable indicator of the amount of substance dissolved in water.

Conductivity values range from 72.6 μS/cm to 1399 μS/cm, the TDS (Total Dissolved Solid) values range from 50.8 to

979 (mg/l) and salinity values ranges from 34.1 to 673 (mg/l). GW1, GW2, GW3 of EC, TDS and Salinity values do not conform with the NSDWQ and WHO standard but others conform with the WHO standard. From the results it reveals that the groundwater is contaminated with foreign materials from the dumpsite.

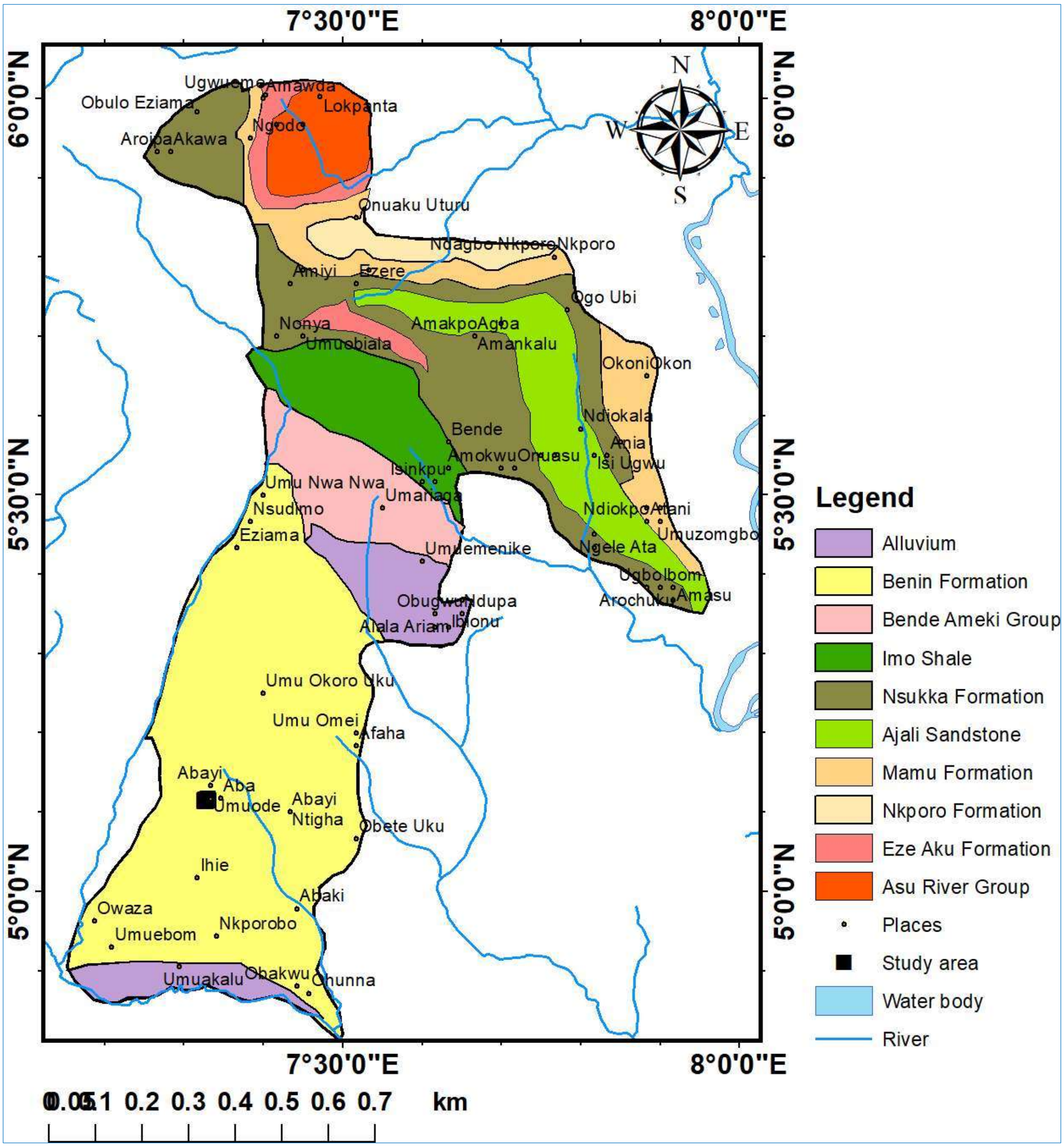

Fig. 3. Geological map of Abia State, Nigeria

TSS (Total Suspended Solids) is 0 mg/l and turbidity range from 1 to 2 which conform to the WHO (2007) and NSDWQ (2007).

The result from Table 1 reveals that the values of Nitrate, Phosphate and Sulphate ranges from 1.7 to 12.6 (mg/l), 0.23 to 1.46 (mg/l) and 1 to 2 (mg/l) all conform with WHO (2007) and NSDWQ (2007) limit

5.2. Heavy metal characteristics of groundwater samples

Heavy metal analyses revealed that five (5) out of 10 heavy metals analyzed conform with the WHO (2007) and NSDWQ (2007) Standard. Mn concentration ranges from 0.01 to 0.56 (mg/l), GW1, GW2, GW3 values as shown in (Table 2 and Fig. 8) do not conform with WHO (2007) and NSDWQ (2007) limit of 0.05 (mg/l) and the others conform with the WHO (2007) and NSDWQ (2007) limits. The use of the water will cause aesthetic damage and imparts brownish stains on laundry.

Manganese is a transition metal with a multifaceted array of industrial alloy uses, particularly in stainless steels.

Manganese (IV) oxide is used as a catalyst, a rubber additive and to decolorize glass that is colored green by iron impurities. Copper ion varies from 0.04 to 0.07 mg/l this is below the permissible limit of 1mg/l. Zinc concentration varies from 0.02 to 0.02 mg/l below the permissible limit of 3 mg/l.

Cobalt ion varies from 0.01 to 0.04 mg/l, the rest GW samples conform with permissible limit expected GW1 which value is above the permissible limit of 0.02 mg/l. GW1 is the borehole sited inside dumpsite and it is contaminated due to infiltration of the leachate into subsurface from the industrial dumps.

Table 1. Physio-chemical parameters of groundwater samples

Physio-chemical Parameters	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	NSDWQ (2007)	WHO (2007)
pH	6.55	6.72	6.66	6.26	6.65	6.42	6.19	6.09	5.49	4.89	6.5-8.5	6.5-8.5
E.C µS/cm	1355	1399	1078	395	272	172.3	72.6	836	695.5	555	1000	900
Turbidity	2	2	1	2	1	0	0	2	1	1	5	5
Salinity	673	695	405	174	129	81.5	34.1	406	336	266	500	500
TDS mg/l	948	979	668	205	190	120	50.8	585	486	388	500	1000
S. S mg/l	0	0	0	0	0	0	0	0	0	0	3	3
TS mg/l	948	979	668	205	190	120	50.8	585	486	388	-	-
Nitrate mg/l	11.4	12.6	1.9	1.7	2.2	2.0	1.8	4.8	5	5.2	50	5
Phosphate mg/l	1.21	1.46	0.65	0.23	0.68	0.45	0.23	0.56	0.49	0.43	-	-
Sulphate mg/l	1	1	2	1	2	1	2	1	2	2	100	400

Mg ion varies from 0.97 to 2.63 mg/l below the permissible limit of 30 mg/l. Nickel ion ranges from 0.06 to 0.16 mg/l is above the permissible limit of 0.02 mg/l. The intake of water will lead to damages to the heart and liver of humans after a long period of time.

Cadmium ion varies from 0.02 to 0.03 mg/l is above the permissible limit of 0.01 mg/l. The sources of cadmium in the environment include mining and smelting of metal ores, fossil fuel combustion and also phosphate fertilizers (Challa and Kumar, 2009). Cadmium is used in the production of Ni-Cd rechargeable batteries when this is deposited in sewage sludge; it raises the levels of Cd in the environment (Challa and Kumar, 2009). Lead concentration varies from 0.04 to 0.08 mg/l. All the GW samples do not conform with the WHO (2007) and NSDWQ (2007) permissible limit of 0.01 mg/l. The contamination is due to industrial nature of dumps disposed there. The intake of this water may affect the red blood cell chemistry, delays normal physical and mental development in babies and young children. It can also cause increase in blood pressure in adult. The common sources of lead are car batteries, tyre materials, coals, plastics and insecticides. The high level of Pb in soil could be attributed to Pb from car exhaust fumes, derived from lead petrol (Alloway, 1996).

Chromium ion concentration varies from 0.06 to 0.13 mg/l is above the permissible limit of 0.05 mg/l, all the GW samples do not conform with WHO (2007) and NSDWQ (2007) limit, the intake this may lead to liver and kidney damage, respiratory damage and ulcer on skin at high concentration after a long time.

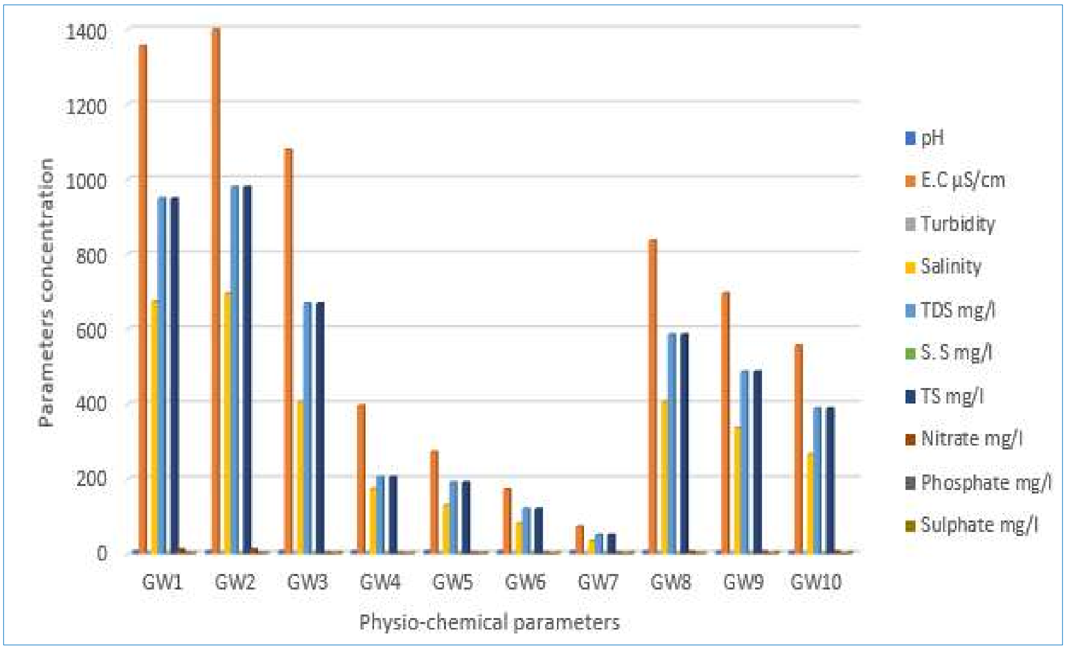

Fig. 4. Parameter concentration (in mg/l) against physio-chemical parameters of groundwater samples

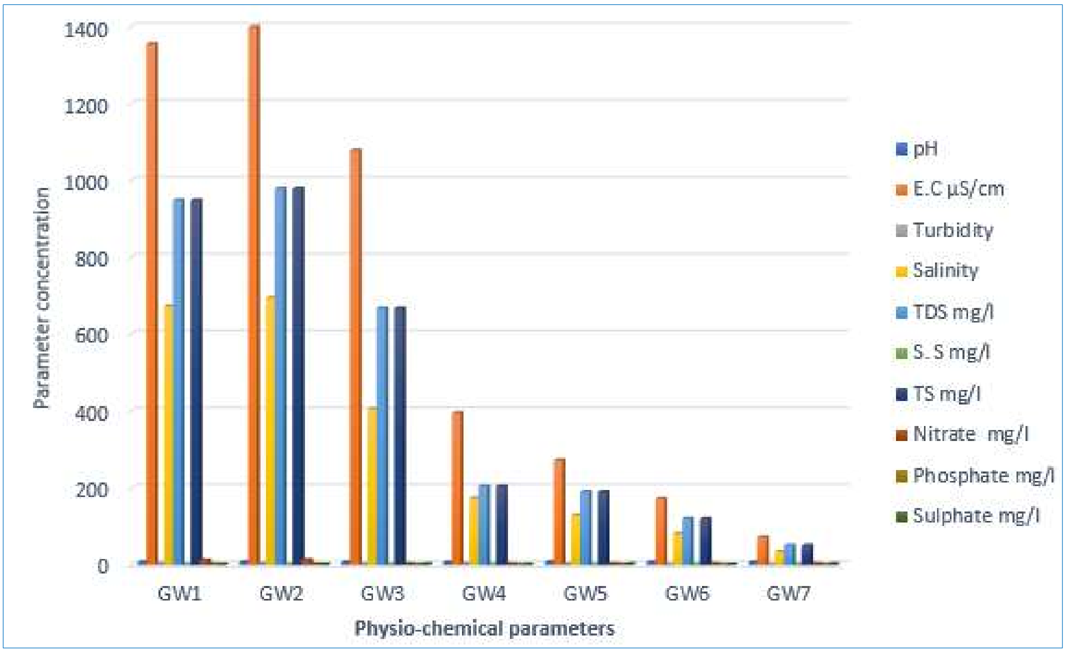

Fig. 5. Parameter concentration in (mg/l) against physio-chemical parameters of groundwater samples from SW-NW direction around the dumpsite

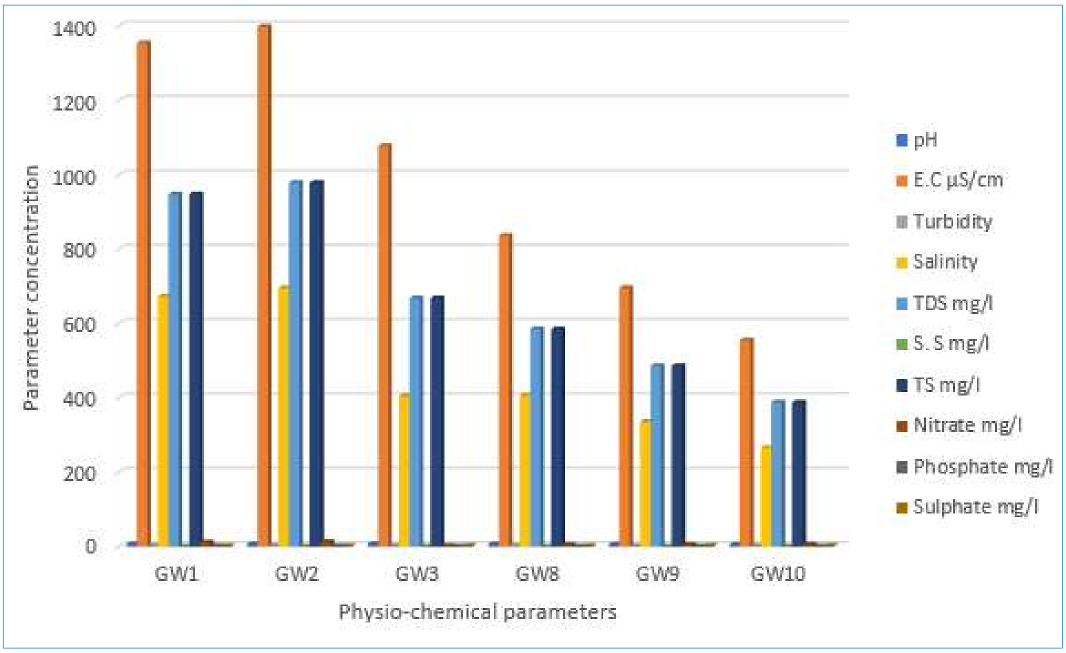

Fig. 6. Parameter concentration in (mg/l) against physio-chemical parameters of groundwater samples from SW-SE-NE direction of Ariaria Dumpsite and environ

Table 2. Heavy metal parameters of groundwater samples

Heavy metal (mg/l)	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	Mean	Std. Dev.	Min	Max	NSDWQ (2007)	WHO (2007)
Mn	0.45	0.56	0.56	0	0	0.01	0	0.05	0.02	0.03	0.168	0.25	0	0.56	0.2	0.1
Cu	0.05	0.07	0.06	0.05	0.03	0.05	0.04	0.06	0.05	0.04	0.05	0.011	0.03	0.07	1	2
Zn	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.023	0.005	0.02	0.03	3	5
Co	0.04	0.01	0	0.01	0.01	0	0	0.01	0	0	0.008	0.012	0	0.04	0.05	1
Mg	2.25	2.11	1.85	0.97	0.35	1.25	1.88	2.58	2.5	2.63	1.837	0.758	0.35	2.63	20	30
Ni	0.16	0.15	0.15	0.12	0.15	0.16	0.12	0.06	0.06	0.07	0.12	0.042	0.06	0.16	0.02	0.02
Cd	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.028	0.004	0.02	0.03	0.01	0.01
Pb	0.04	0.08	0.05	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.046	0.013	0.04	0.08	0.01	0.04
Cr	0.09	0.13	0.09	0.06	0.1	0.09	0.09	0.07	0.07	0.08	0.087	0.019	0.06	0.13	0.05	0.05
Fe	3.72	4.86	0.78	0.87	0.82	0.72	0.74	0.58	0.5	0.62	1.421	1.54	0.5	4.86	0.3	0.3

The sources of chromium in the environment include, cement, leather, plastics, dyes, textiles, paints, printing ink, cutting oils, photographic materials, detergents, wood preservatives among others (Hilgenkamp, 2006). Other sources of chromium are power plants, liquid fuels, brown and hard coal and industrial and municipal wastes. Iron ion concentration ranges from 0.5 to 4.86 mg/l, is above the permissible limit of 0.3 mg/l.

All the GW samples do not conform with the WHO (2007) and NSDWQ (2007) limit. The use of the water will impact a bitter astringent taste to water and a brownish colour to laundered clothing and plumbing fixtures. The high presence of iron can lead to change in coloration of the water (Rowe et al., 1995).

From Table 2 and Fig. 6, it reveals that iron ion concentration is very high in study area. It was revealed that nickel (0.0560 mg/l), chromium (0.0560 mg/l) and lead (0.4149 mg/l) concentration is above WHO standard (Giadom et al., 2014) which conform with the findings of this research. From the physiochemical analysis of the heavy metals from groundwater samples collected from the study area reveals that the direction movement of the heavy metal from the dumpsite is from Southwest direction to Northeast direction.

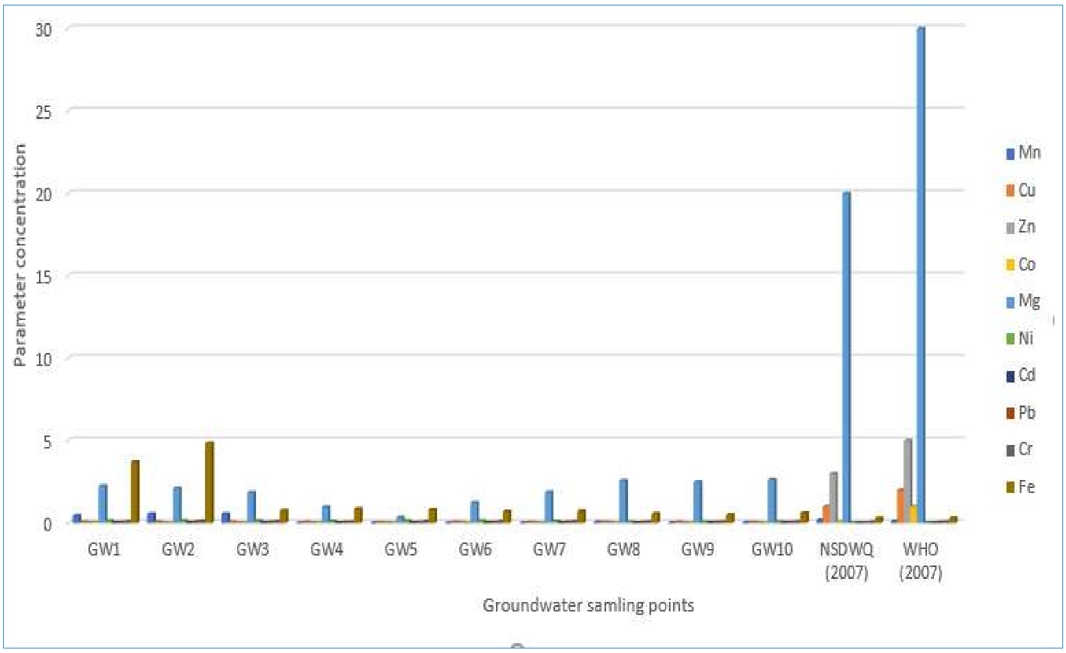

Fig. 7. Heavy metals concentration in (mg/l) against groundwater sampling points

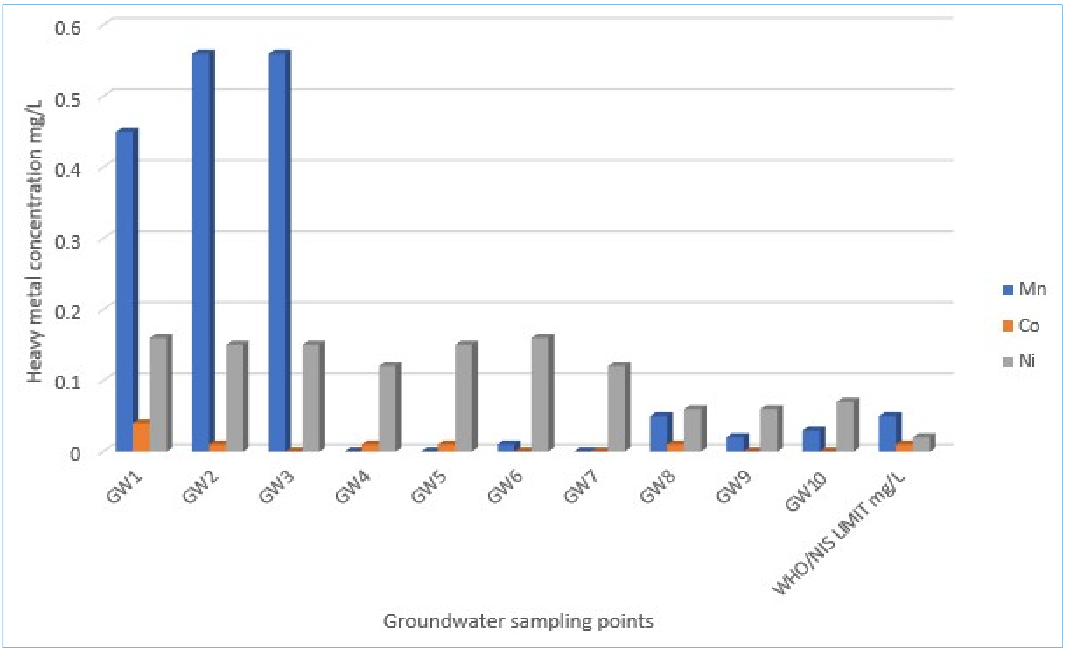

Fig. 8. Variation of Heavy metals concentration in (mg/l) against groundwater sampling points

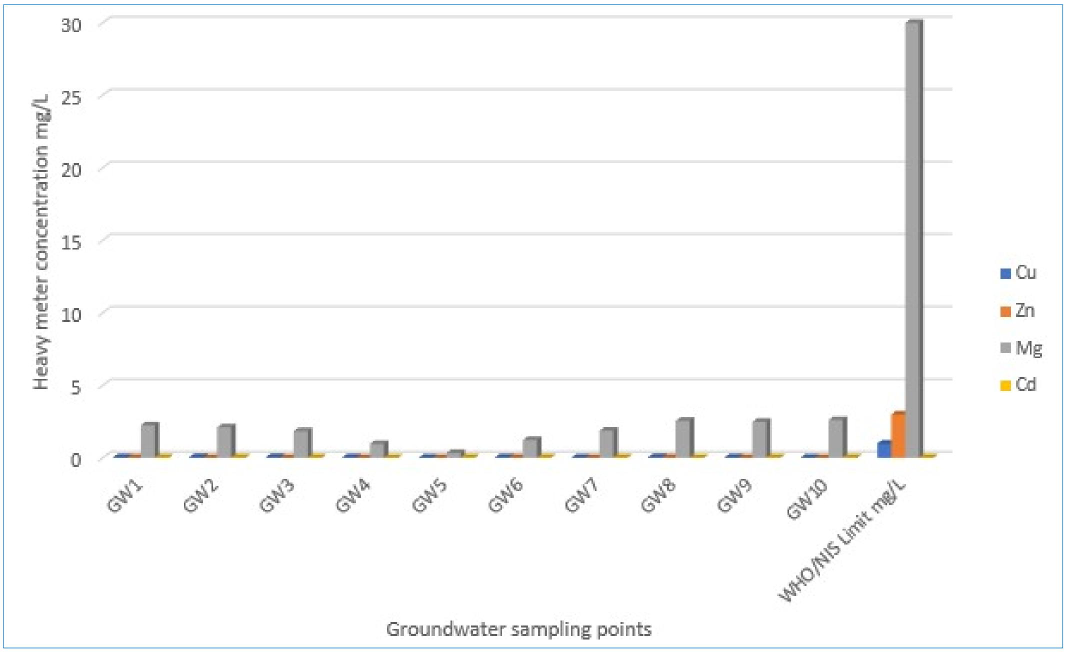

Fig. 9. Variation of heavy metals concentration in (mg/l) against groundwater sampling points

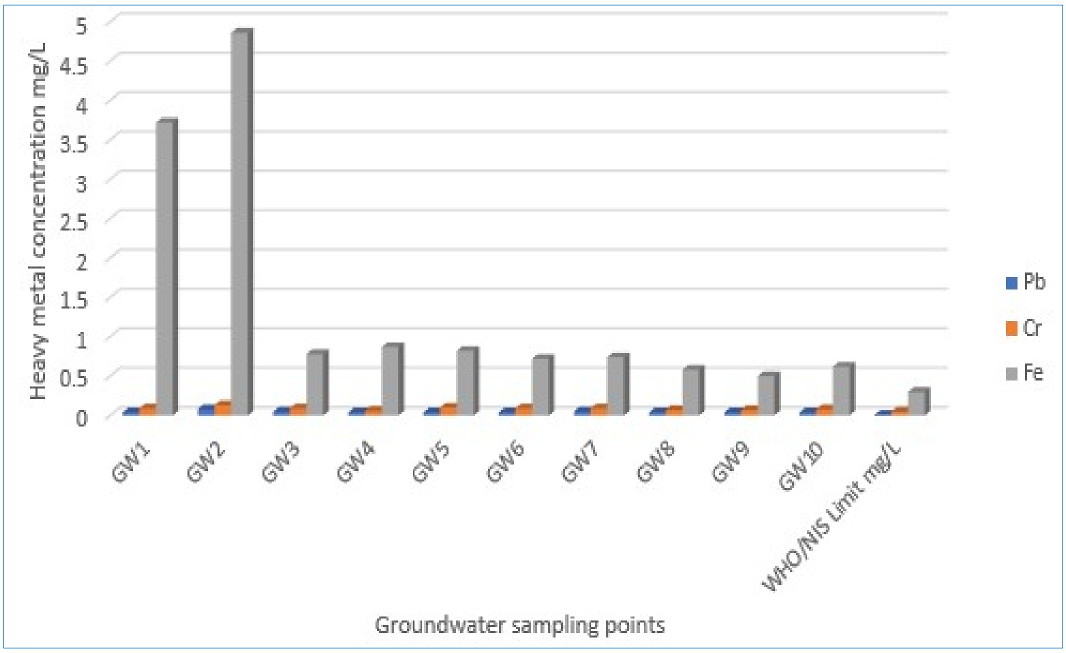

Fig. 10. Variation of heavy metals concentration in (mg/l) against groundwater sampling points

The mean concentration of the heavy metal from the groundwater samples is high at Southwest area of dumpsite and lower toward the Northeast area of the dumpsite. From the analysis of leachate and groundwater samples (150 m) south at the Ariaria Waste Dumpsite and its adjacent area likely indicates that groundwater quality is being affected by leachate percolation (Giadom et al., 2014).

From the heavy metals concentration result, the following heavy metals: Mn, Ni, Cd, Pb, Cr, and Fe have very high concentration across all the groundwater samples. It is revealing that Mn, Cd, Ni, Cd, Pb, Cr and Fe has these sources of contamination. The very high heavy metal concentration in GW1 and GW2 might be due depth to water table or the geology (lithology) of the area because of the intercalation of clay in the formation of the study area.

However, the geology and dynamics of groundwater flow in the Ariaria area of Aba, Abia State present viable conditions for the migration of leachates from the sources (waste dump) through its pathway (moderately pervious soils) to receptors (several water wells) located in the south and southeast of the dump and the groundwater flow directions deduced from the direction of flow of major Rivers in the area (Giadom et al., 2014). This conforms with the findings of this research with the trail that the heavy metals concentration which was obtain from the analyzed ten groundwater samples collected around and adjacent the dumpsite follows the flow direction pathway. The dendrogram show the relationship between the heavy metals of ten groundwater samples collected from the various sampling point.

It also divides the ten groundwater sampling into four clusters. From the dendrogram it is reveals that GW8,GW9 and GW10 has close relationship which indicates that the three sampling points has the same sources of contamination, GW4,GW5 and GW6 has close relationship which indicates that the three sampling points has the same sources of contamination, GW3 and GW7 has close relationship which indicates that the two sampling points has the same sources of contamination and GW1 and GW2 has close relationship which indicates that the two sampling points has the sources of contamination. The heavy metals majorly present in the four clusters are: Ni, Cr, Cd, Pb and Fe. This indicates that they might be from the same of contamination

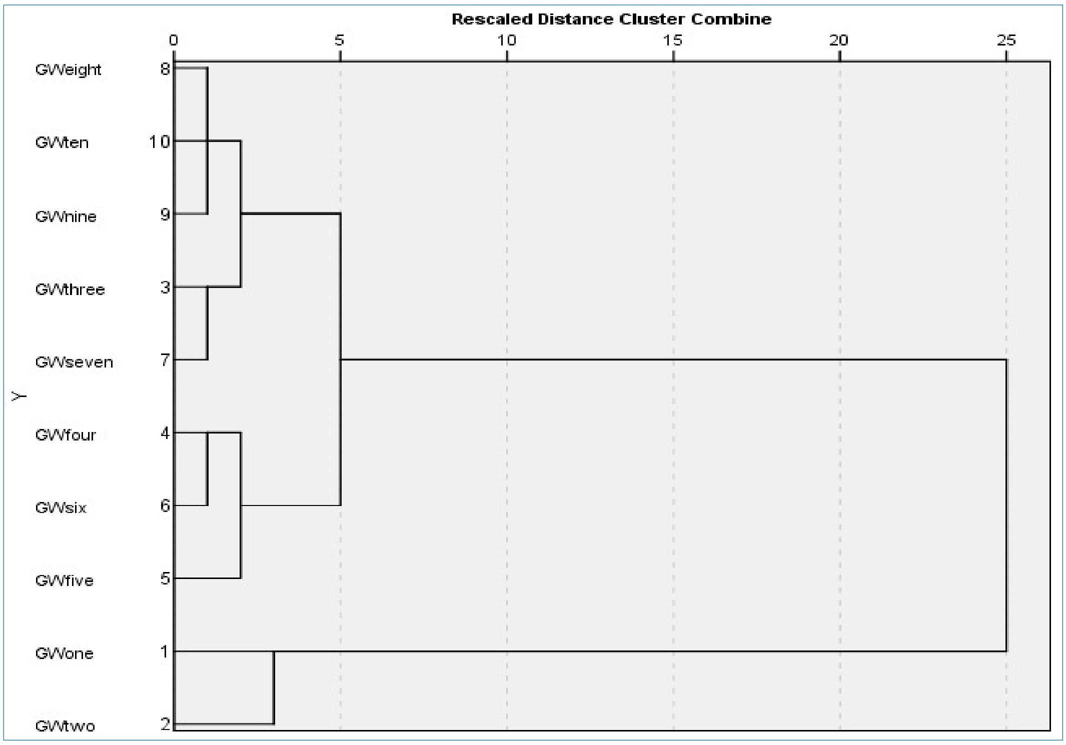

Fig. 11. Dendrogram using Average Linkage (Between Groups) to show the heavy metals relationship of various groundwater samples collected around the dumpsite

Table 3. Correlation of heavy metals concentration in the groundwater samples.

	Cu	Zn	Cd	Mn	Co	Ni	Pb	Cr	Fe	Mg
Cu	1									
Zn	0.232	1								
Cd	-0.246	-0.218	1							
Mn	0.641*	0.006	0.305	1						
Co	0.126	0.487	-0.086	0.389	1					
Ni	0.145	0.11	0.38	0.499	0.347	1				
Pb	0.587	-0.327	0.25	0.636*	-0.057	0.316	1			
Cr	0.253	-0.13	0.596	0.594	0.111	0.603	0.803**	1		
Fe	0.498	0.113	0.238	0.732*	0.625	0.478	0.709*	0.709*	1	
Mg	0.301	0.173	0.043	0.245	0.037	-0.588	0.133	-0.105	0.168	1

** Correlation is significant at the 0.05 level (2-tailed)*
*** Correlation is significant at the 0.01 level (2-tailed)*

5.3. Test of significance of observed correlation coefficients (Heavy metals in groundwater samples correlation)

The significance of the observed correlation coefficient results presented is in Table 3. Out of the 44 correlation values found between two parameters, one (1) was found to have very strong positive correlation at 1% level (P < 0.01) and ten (10) strong positive correlation at 5% level (P < 0.05). The eight (8) negative correlations were found to be between Cu and Cd (-0.228), Zn and Cd (-0.218), Zn and Pb (-0.327), Zn and Cr (-0.129), Co and Cd (-0.0857), Co and Pb (-0.0571), Mg and Ni (-0.587) and Mg and Cr (-0.105). This means that these heavy metals displayed a weak association with one another. The very strong positive correlation exists between Pb and Cr (0.803) and strong correlation exists between Mn and Cu (0.641), Pb and Cu (0.587), Pb and Mn (0.636), Cr and Cd (0.596), Cr and Cd (0.596), Cr and Ni (0.603) Fe and Mn (0.732), Fe and Co (0.625), Fe and Pb (0.709), Cr and Fe (0.709). The very high degree of positive correlations between lead and chromium, reflect their simultaneous release, identical source from the dumpsite, transport and accumulation in soil. The significance correlations indicate that they may have originated from common source of contamination.

5. Conclusion

Soil around the dump site is impacted and evident by the high level of heavy metals recorded in groundwater samples within the vicinity of the dumpsite. Strong correlation exists between the heavy metals especially lead and chromium which had a very strong correlation indicating a common source, in this case, heavy metal and waste dumps found within the dumpsite. Groundwater is generally acidic indicating an acidic soil environment which encourages the movement of heavy metal leachates.

References

Alloway, B.J., 1996. Heavy metals in soils. Halsted Press, John Wiley and Sons Inc. London, UK. p. 240.

Amadi, A.N., 2010. Effects of urbanization on groundwater quality: A case study of Port-Harcourt, Southern Nigeria. Natural and Applied Sciences Journal 11 (2), 143-152.

Challa, S., Kumar, R., 2009. Nanostructure oxides. Weinheim, Germany, Wiley. Pp. 29.

Eddy, N.O, Odoemelem, S.A., Mbaba, A., 2006. Elemental Composition of soil in some dumpsites located within Ikot-Ekpene. Electronic Journal of Environmental, Agricultural and Food Chemistry 5 (3), 1349-1365.

Elaigwu, S.E., Ajibola, V.O., Folaranmi F.M., 2007. Studies on the Impact of Municipal Waste Dumps on Surrounding Soil and Air Quality of Two cities in Northern Nigeria. Journal of Applied Sciences 7 (3), 421-425.

ESMP, 2017. Environmental and Social Management Plan Final Report of Abia State. SFG1692 V6 Pp 20-52.

Ezeoha, U.M., 2012. The Effect of the Solid Waste on the Quality of Soil in Ugwuaji Dumpsite. Unpublished M.Sc. Thesis. University of Nigeria, Nsukka, Nigeria.

FEPA, 1991. Guidelines and Standard for Environmental Pollution Control in Nigeria. Federal Republic of Nigeria, Nigeria. Pp. 61-63.

Giadom, F.D., Akpokodje, E.G., Abam, T.K.S., 2014. The contaminant status of Ariaria waste dumpsite in Aba, Abia State, Nigeria. Journal of Nigerian Environmental Society (JNES) 1 (2), 1-8.

Hilgenkamp, K., 2006. Environmental health: ecological perspective. Jones and Bartlett Publishers, Toronto, Canada, p. 83.

Iwuoha, G.N., Osuji, L.C., Onwuachu, U.I., 2013. Impact of waste dump on the sediment and surface water quality of otamiri river, Nigeria. Journal Applied Scientific Environmental Management 17 (4), 573-575.

Majolagbe, A.O., Kasali, A.A., Ganiyu, L.O., 2011. Quality assessment of groundwater in the vicinity of dumpsites in Ifo and Lagos, Southwestern Nigeria. Advances in Applied Science Research 2 (1), 289-298.

National Population Census, 2016. PHC priority Table. c2016. Available from: http://population.gov.ng/core-activities/surveys/dataset/2016-phc-priority-tables

NSDWQ, 2007. Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard NIS 554, Standard Organization of Nigeria, p30.

Nwankwoala, H.O., Nwowo, K.N., Udom, G.J., 2016. Assessment of Heavy Metal status of Groundwater in parts of Aba, Southeastern, Nigeria. International Journal of Emerging Engineering Research and Technology 4 (11), 27-36.

Nwankwoala, H.O., Amadi, A.N., 2013. Hydro Geochemical Attributes and Quality Status of groundwater in Port Harcourt Eastern Niger Delta. World journal of Science and Technology Research 1 (7), 151-167.

Sally, W., 2000. Control of Municipal Solid Wastes. Oxford Universe. Press, Oxford 6th eds. p. 642.

Tijani, M.N., Onodera, S., 2009. Hydrogeochemical assessment of metals contamination in an urban drainage system: a case study of Oshogbo township, SW Nigeria. Journal of Water Resource and Protection 3, 164-173.

Ukpong, E.C., Antigha, R.E., Moses, E.O., 2013. Assessment of heavy metals content in soils and plants around waste dumpsites in Uyo Metropolis, Akwa Ibom State. International Journal of Engineering and Science 7 (2), 2319-1805.

WHO, (2007. World Health Organization. Guidelines for Drinking Water, 4th Edition, Geneva.

Wizor, C.H., 2019. Impact of Ogbor Hill waste dumpsite on socio-economic activities of urban dwellers in Aba metropolis, Abia State, Nigeria. International Journal of Science and Research 8 (7), 1206-1213.