Spatio-Temporal Levels of Essential Trace Metals around Municipal Solid Waste Dumpsite in Abeokuta, Nigeria.

Adedayo A. Badejo, Ph.D.[1]*; Adeyemi O. Taiwo, B.Sc.[1]; Adebola A. Adekunle, Ph.D.[1]; and Babatunde S. Bada, Ph.D.[2]

[1]Civil Engineering Department, College of Engineering, Federal University of Agriculture, Abeokuta, Nigeria.
[2]Department of Environmental Management and Toxicology, College of Environmental Resources Management, Federal University of Agriculture, Abeokuta, Nigeria.

E-mail: badejoaa@funaab.edu.ng*

ABSTRACT

This study investigates spatio-temporal levels of selected trace metals around a dumpsite in Abeokuta, South-West Nigeria. Parameters including pH, electrical conductivity and essential trace metals were determined using standard procedures. Result showed that the groundwater in the study area were generally acidic 6.36 ± 0.60 and essential trace metals concentration of Cu 4.86 mg/L, Zn 0.29 mg/L, Fe 0.87 mg/L, Pb 0.013 mg/L, and Cd 0.02 mg/L were obtained. There is evidence of essential trace metals contamination around the dumpsite.

(Keywords: dumpsite, leachate, trace metals, potable water, contamination)

INTRODUCTION

Abeokuta an ancient city in Ogun State, Nigeria, has been increasingly growing because of the population spill over from Lagos State. The city depends on only one major dumpsite on which residential buildings have started to encroach.

Dumpsites may be an organized or illegitimate means of solid wastes disposal in land depressions such as abandoned quarries, excavations, or valleys (Clark, 2006). Open dumping of solid wastes generates various environmental and health related hazards. The problem of open dumping of solid waste is not only because of the increasing quantities generated but also largely because of inadequate and inefficient management systems (Tinmaz and Demir, 2006).

The biological and chemical processes that occur in open dumps produce leachates, which pollute surface and groundwater. Since the dumpsites are not usually lined to standard recommendations (Adewole, 2009) the leachate accumulates at the bottom of the dumpsite and moves through the soil into the groundwater. The leachate usually contains inorganic components such as chlorides, sulfates, nitrogen compounds, and metals, and a wide range of organic compounds. The contamination of groundwater resource poses substantial risk to local dwellers and to the natural environment causing poisoning, cancer, heart diseases and teratogenic abnormalities (Sia Su, 2008; Alloway and Ayres, 1997).

Nigeria, with a population of over 120 million, generates an average of 0.58 kg solid waste per person per day. Abeokuta in Ogun state was found to generate 0.60 kg/person/day (Adewumi *et al*., 2005; Sridhar and Adeoye, 2003). The wastes generated are illegally disposed of onto any available space, including road sides. Nigeria is among the fastest growing cities in the world and is faced with the problem of solid waste generation. Waste generation scenario in Nigeria has been of great concern both globally and locally. Of the different categories of wastes being generated in Nigeria solid wastes had posed a serious problem beyond the scope of various solid waste management systems in the country, this has resulted in streets experiencing continual presence of waste from domestic and commercial activities without proper treatment.

Ogun State, Nigeria, was originally supposed to have six major dumpsites located in Abeokuta, Agbara, Ota, Sagamu, Ijebu-ode, and Ago-Iwoye.

In low-income communities in Abeokuta that lack adequate refuse collection systems, residents tend to either dump their garbage at the nearest vacant plot, public space, creek, river, or simply burn it in their backyards. Uncollected wastes accumulate on the streets and clogs drains when it rains, this sometimes causes flooding. Wastes are sometimes carried away by runoff water to rivers, lakes and seas, affecting those ecosystems.

The role of Geographic Information Systems (GIS) in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data. GIS plays a key role in maintaining account data to facilitate collection operations; customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to dumpsites; locating new dumpsites and monitoring the dumpsites.

In this study, the effect of leachate percolation from an open dumpsite on groundwater quality was evaluated. Selected trace metals like cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), iron (Fe), zinc (Zn), and copper (Cu) were analyzed in leachate from the dumpsite and groundwater samples around the Saje dumpsite in Abeokuta Ogun State, Nigeria.

MATERIALS AND METHODS

Study Area

The study area Saje is located in Abeokuta North Local Government of Abeokuta, the capital of Ogun State, south-west Nigeria. Abeokuta covers an approximate area of about 40.63 km^2. It lies between latitude 70^0 10' N and 70^0 15' N and longitudes 30^0 17' E and 30^0 26' E (Ufoegbune *et al*., 2008).

The Saje dumpsite established in 2006, was formerly a quarry, where mining was done over a long period of time for granites. In order to reclaim the site the state government decided to use the quarry as dumpsite. The dumpsite is the only dumpsite used in Abeokuta metropolis and is about 4 ha in area. Saje area was formally an outskirt of Abeokuta town but due to increase in population of the metropolis, houses have encroached.

The location coordinate of the dumpsite and groundwater points were obtained with a hand held Global Positioning System (GPS, Garmin MAP 76CSx model made in Taipei County, Taiwan) with position accuracy of less than 3m. The choice of the sampling points within the dumpsite were considered using the following criteria: location, accessibility, proximity to residential areas and the topography of the study area.

Sample Collection

Twenty hand dug wells were randomly selected within 2 km radius from the center of the dumpsite. Grab samples of the well water and leachates were collected during the dry and raining season using one-liter bottles. The bottles were rinsed with distilled water and the well water to be collected three times before collection. Each bottle was labeled according to sampling location and preserved at 4ºC before transporting to the laboratory.

Sample Analysis

The physical parameters analyzed *in situ* include temperature, electrical conductivity (EC), and pH, the chemical parameters analyzed include cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), iron (Fe), zinc (Zn), and copper (Cu). Electrical conductivity/pH meter (Jenway model) was used to determine the pH and EC while Cd, Cu, Fe, Pb and Zn were determined with the aid of the Atomic Absorption Spectrophotometer (AAS).

All the samples were analyzed according to internationally accepted procedures and standard methods (APHA, 1994). Results of laboratory analyses were subjected to data evaluation by use of standard statistical methods (Norusis and SPSS Inc. 1997). The Google Earth 6.0 imagery (2006) of the study area was sourced and processed using the Erdas Imagine software and presentations were made with ArcView 3.2a.

RESULTS AND DISCUSSION

Results of pH, temperature, electrical conductivity and distances from the dumpsite are shown in Table 1.

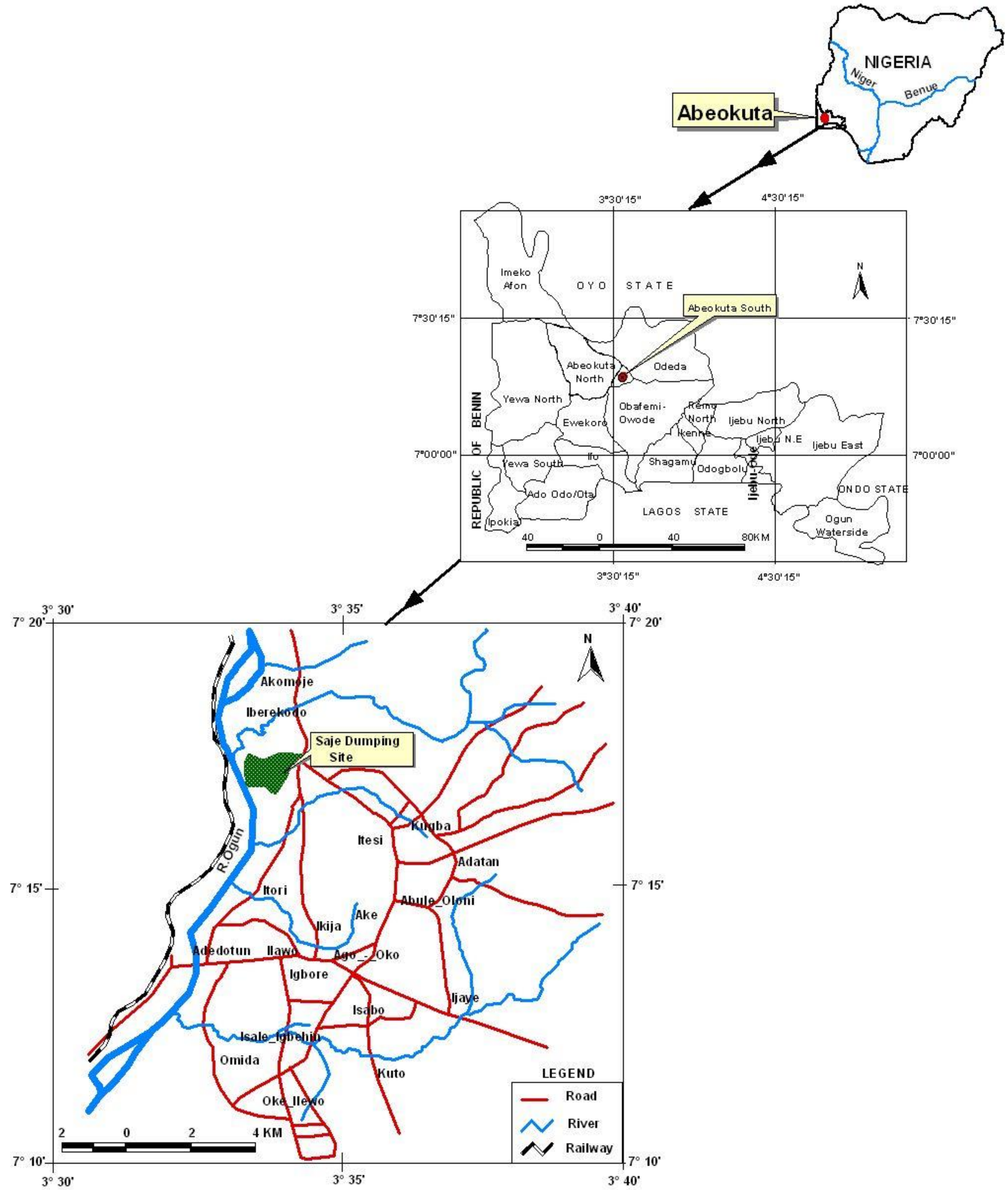

Figure 1: Saje Dumpsite Location within Abeokuta City, Ogun State, Nigeria.

Table 2 shows the trace metal parameters of hand dug wells within 2 km radius of the dumpsite and Table 3 the mean concentration and standard deviation in comparison to World Health Organisation (WHO) standards and Nigerian Standard for Drinking Water Quality (NSDWQ) standards.

Table 1: Results of Physico-Chemical Parameters within 2 km Radius of the Dumpsite.

Point	Easting	Northing	Dist. from Dumpsite (m)	pH	EC (μs/cm)	Temp (°C)
Dumpsite	540366	794470	0.00	7.53	819.00	30.00
WE	540923	794454	490.83	6.61	203.67	29.50
EE	540834	794731	546.95	6.70	195.67	29.60
EA	540818	793917	578.33	6.32	137.67	29.80
SB	539866	794179	604.58	5.80	163.00	29.50
NB	540983	794649	607.46	6.27	166.67	29.70
EB	541013	794652	643.56	6.69	504.67	29.40
EC	541053	794553	647.50	6.19	204.67	29.30
ED	540631	793631	745.39	7.10	406.67	28.30
SA	539593	794387	852.72	5.60	222.00	29.20
NC	540274	793460	905.33	5.27	477.00	29.10
SD	539710	793813	917.50	5.42	199.00	29.60
WC	539615	793847	983.93	6.48	366.67	31.20
NA	540672	793281	1097.56	6.66	1017.00	29.70
SC	539945	793350	1143.00	6.10	317.67	30.20
WA	539718	793405	1191.37	6.49	260.00	30.30
SE	540836	793137	1271.52	6.18	903.67	30.10
WB	539836	793128	1379.97	6.27	228.33	29.50
WD	539495	793181	1508.42	6.09	398.00	30.30
ND	538706	794400	1746.35	6.72	306.33	29.30
NE	539811	795990	1761.34	7.08	400.33	28.40

Table 2: Essential Trace Metal Concentration within 2 km Radius of the Dumpsite.

Point	Cd (mg/L)	Zn (mg/L)	Cu (mg/L)	Pb (mg/L)	Cr (mg/L)	Ni (mg/L)	Fe (mg/L)
Dumpsite	0.01	0.10	2.01	0.01	0.02	0.10	0.72
WE	ND	0.17	5.60	0.01	ND	0.03	0.53
EE	ND	0.54	5.04	ND	0.01	0.03	0.61
EA	ND	0.41	4.80	0.03	ND	0.07	1.16
SB	ND	0.21	6.04	ND	0.01	0.05	0.81
NB	ND	0.43	4.93	0.00	ND	0.04	0.64
EB	ND	0.22	3.94	ND	ND	0.07	0.70
EC	0.01	0.17	5.55	ND	ND	0.02	0.58
ED	ND	0.40	4.98	0.01	0.02	0.10	0.93
SA	ND	0.18	4.84	ND	ND	0.04	0.61
NC	ND	0.29	6.09	ND	ND	0.05	0.93
SD	ND	0.40	3.80	ND	0.03	0.02	0.95
WC	ND	0.22	3.71	0.00	ND	0.06	0.71
NA	ND	0.32	5.01	0.03	ND	0.06	0.69
SC	ND	0.34	3.97	ND	ND	0.02	1.51
WA	ND	0.22	6.17	ND	ND	0.04	1.01
SE	ND	0.43	6.41	ND	ND	0.03	0.58
WB	ND	0.29	5.16	ND	0.03	0.11	1.81
WD	ND	0.36	5.23	ND	ND	0.03	1.60
ND	ND	0.17	3.89	ND	ND	0.04	0.67
NE	ND	0.12	4.98	ND	ND	0.03	0.53

ND-Not Detected

Table 3: Mean Concentration and Standard Deviation of Trace Metals in Comparison to Known Standards.

Parameters	Mean ± SD	Normally found in ground water	Nigerian Standard (2007) Max. level permitted	Samples within Nigerian (MLP)	Samples beyond Nigerian (MLP)	Health based guideline by the WHO	Samples within/ below WHO Standard	Samples beyond WHO standard
pH	6.36 ± 0.6		6.5-8.5	38%	62%	6.5-8.5	38%	62%
EC (µs)	376.08 ± 250		1000 µs/cm	95%	5%	250 µs/cm	43%	57%
Temp (°C)	29.62 ± 0.64							
Cd (mg/L)	0.01 ± 0.006	< 1 µg/l	0.003 mg/L	Nil	9.50%	0.003 mg/L	Nil	9.5%
Zn (mg/L)	0.29 ± 0.12		3 mg/L	100%	Nil	3 mg/L	100%	nil
Cu (mg/L)	4.86 ± 1.04		1 mg/L	Nil	100%	2 mg/L	nil	100%
Pb (mg/L)	0.013 ± 0.01		0.01 mg/L	19%	14%	0.01 mg/L	19%	14%
Cr (mg/L)	0.022 ± 0.01	< 2 µg/l	0.05 mg/L	100%	Nil	0.05 mg/L	100%	nil
Ni (mg/L)	0.05 ± 0.02		0.02 mg/L	14%	86%	0.07 mg/L	86%	14%
Fe (mg/L)	0.871 ± 0.30	0.5-50 mg/L	0.3 mg/L	Nil	100%	No guideline	nil	100%

Results indicated that the water samples were acidic 6.36 ± 0.60 and contain most of the selected trace metals at amount above the maximum permitted level recommended (WHO, 2011; NSDWQ, 2007) except Fe, Cu and Ni. Cadmium was only found in one of the hand dug wells sampled and from leachate collected. The result showed that about 38 % of the samples are below the desirable limits set by NSDWQ standards while about 62 % were within the standards. The pH had an average value of 6.36 ± 0.6, for effective disinfection with chlorine, the pH should preferably be less than 8; however, acidic waters have been known to be aggressive and enhance the dissolution of iron and manganese causes unpleasant taste in water (Edwards *et al*., 1983).

Failure to minimize corrosion can result in the contamination of drinking-water and in adverse effects on its taste and appearance. Electrical Conductivity had average value of 376.08 ± 250 µs/cm. This shows that about 95 % were within NSDWQ standard values while 5 % were above the standard. Also 43 % were within the desirable limits set by WHO standards of 250 µs/cm while 57 % were above the standard. EC was high at the dumpsite and decreased with distance away from the dumpsite till about 607 m when it started to fluctuate. Also high values of EC was noticed at the south of the dumpsite (904 and 1017 µs/cm) which could be due to runoff down the south.

The results indicated that total iron values ranged between 0.526 and 1.818 mg/L and the average value was 0.87 ± 0.37 mg/L. This revealed that all the values were above the desirable limits of 0.3 mg/L set by NSDWQ standards, even greater than 1 mg/L at the southwest of the dumpsite (Figure 6). Iron is an essential element in human nutrition, particularly in the iron (II) oxidation state. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from 10 to 50 mg/day. The taste and appearance of drinking water will usually be affected below 0.3 mg/L, iron stains laundry and plumbing fixtures (WHO, 2011). There is usually no noticeable taste at iron concentrations below 0.3 mg/L, although turbidity and color may develop.

From Table 2, the percentage of sampled point that had the presence of Pb below the WHO and NSDWQ standard of 0.01 mg/L was about 19 %, 14 % were above the standard while Lead was not detected in the remaining 67 % of the sampled well (Figure 8). The average value was 0.0128 ± 0.0125 mg/L which ranged between 0.002 and 0.029 mg/L. Lead is used principally in the production of lead-acid batteries, solder and alloys.

Table 3 revealed that 9.5 % of the sampled hand dug wells had Cadmium at values above the WHO and NSDWQ standard of 0.003 mg/L while the rest 90.5 % do not have cadmium. From Figure 4, it was identified that cadmium was high around the dumpsite and at the east side of the dumpsite. Cadmium could cause erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints and could cause Kidney damage. Chromium is introduced into ground water source by erosion of natural deposits and discharge from steel and pulp mills. Chromium was below the WHO and NSDWQ standard of 0.05 mg/L in all of the sampled groundwater sources. Chromium is widely found on Earth's crust.

Also, Copper had values above both WHO and NSDWQ standards of 1 mg/L and 2 mg/L respectively in all of the sampled wells, an average value of 4.8643 ± 1.038 mg/L was observed. Figure 5 shows the spatial variations of Cu in groundwater in the dumpsite. Copper is both an essential nutrient and a drinking-water contaminant. Recent studies have delineated the threshold for the effects of copper in drinking water on the gastrointestinal tract, but there are still some uncertainty regarding the long-term effects of copper on sensitive populations, such as carriers of the gene for Wilson disease and other metabolic disorders of copper homeostasis.

For adults with normal copper homeostasis, the guideline value should permit consumption of 2 or 3 liters of water per day, use of a nutritional supplement and copper from foods without exceeding the tolerable upper intake level of 10 mg/day or eliciting an adverse gastrointestinal response. Staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/L. At levels above 2.5 mg/L, copper imparts an undesirable bitter taste to water; at higher levels, the color of water is also impacted.

It was discovered that none of the sampled point including leachate from the dumpsite had high value of Zinc, Zn concentration was between 0.097 and 0.40 mg/L. The spatial variation of Zinc from the studied dumpsite is shown in Figure 8.

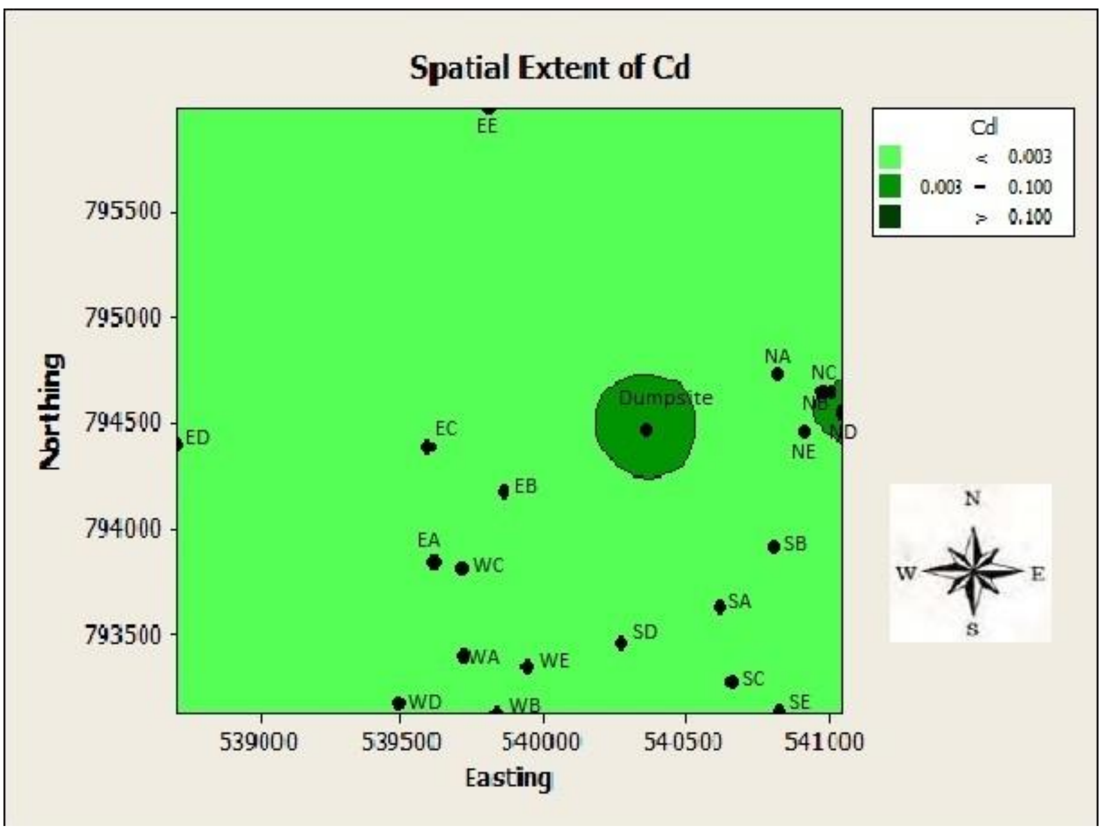

Figure 2: Spatial Variations of Cadmium (Cd) in Groundwater around the Dumpsite.

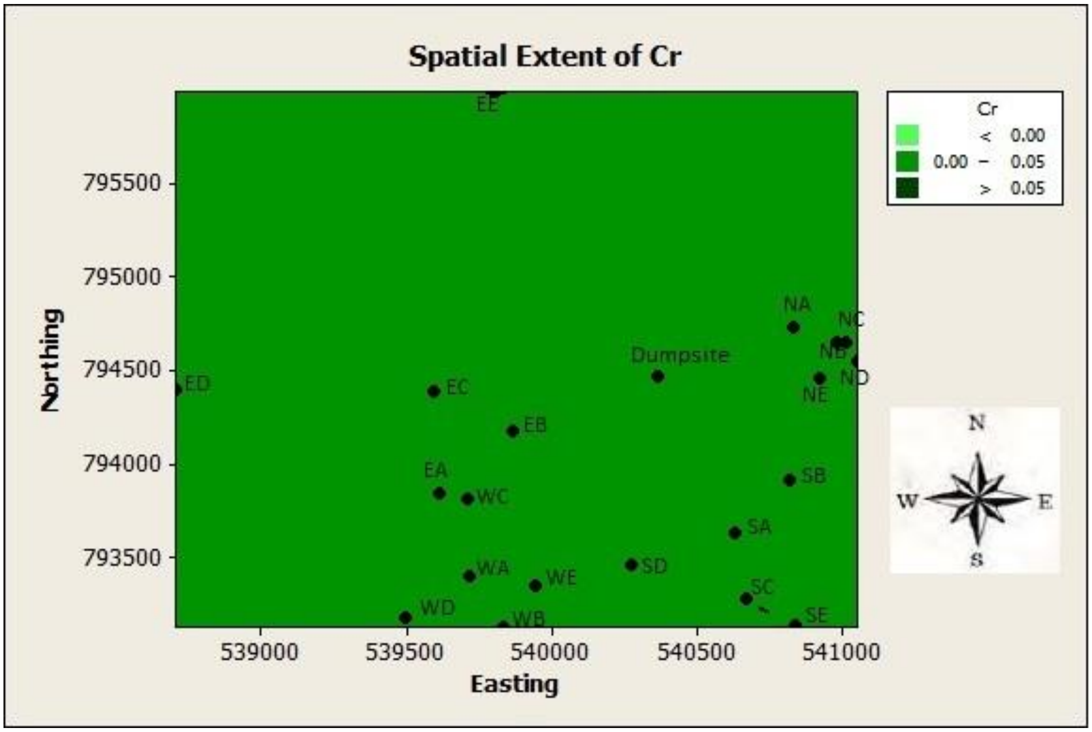

Figure 3: Spatial Variations of Chromium (Cr) in Groundwater around the Dumpsite.

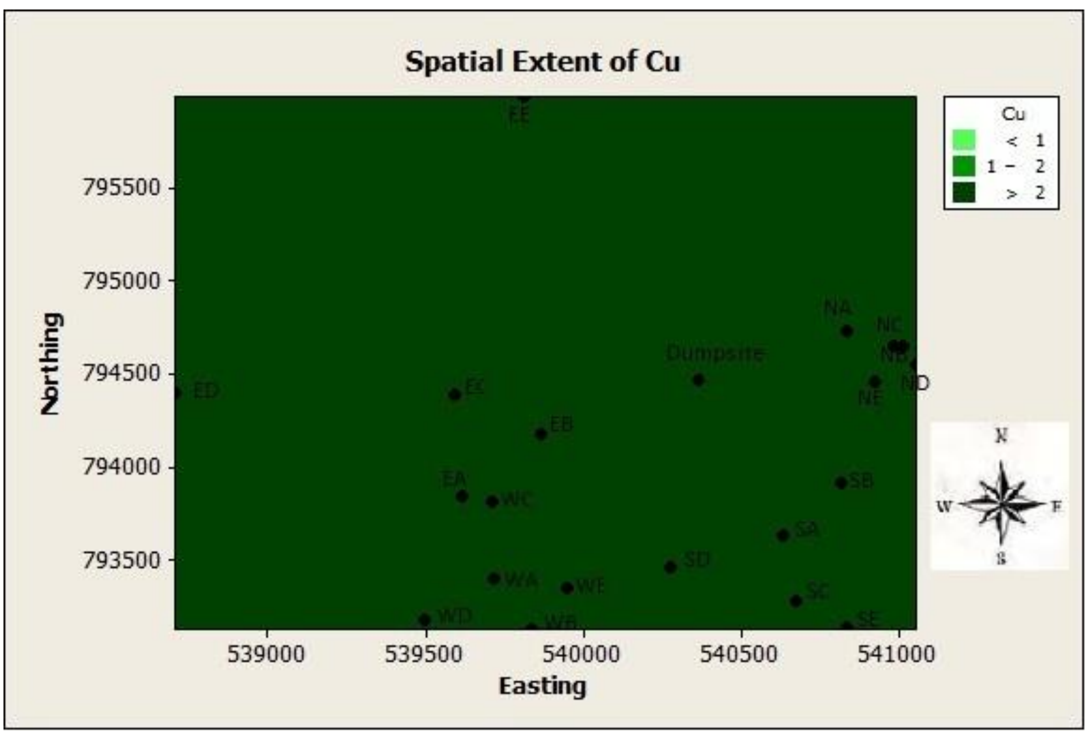

Figure 4: Spatial Variations of Copper (Cu) in Groundwater around the Dumpsite.

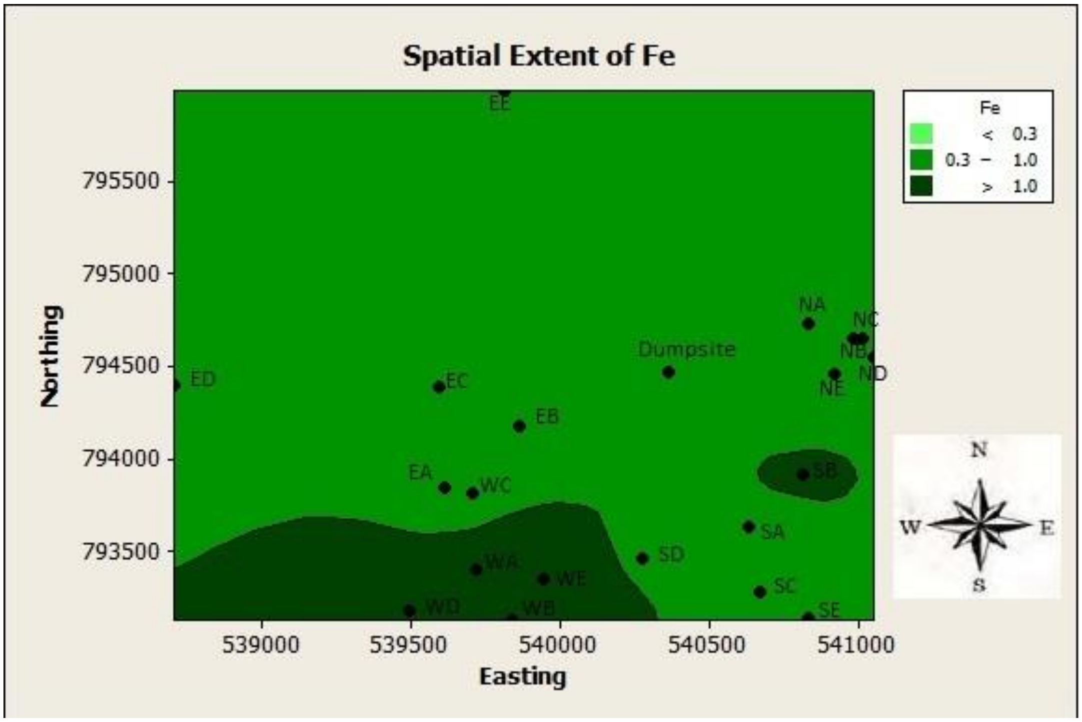

Figure 5: Spatial Variations of Iron (Fe) in Groundwater around the Dumpsite.

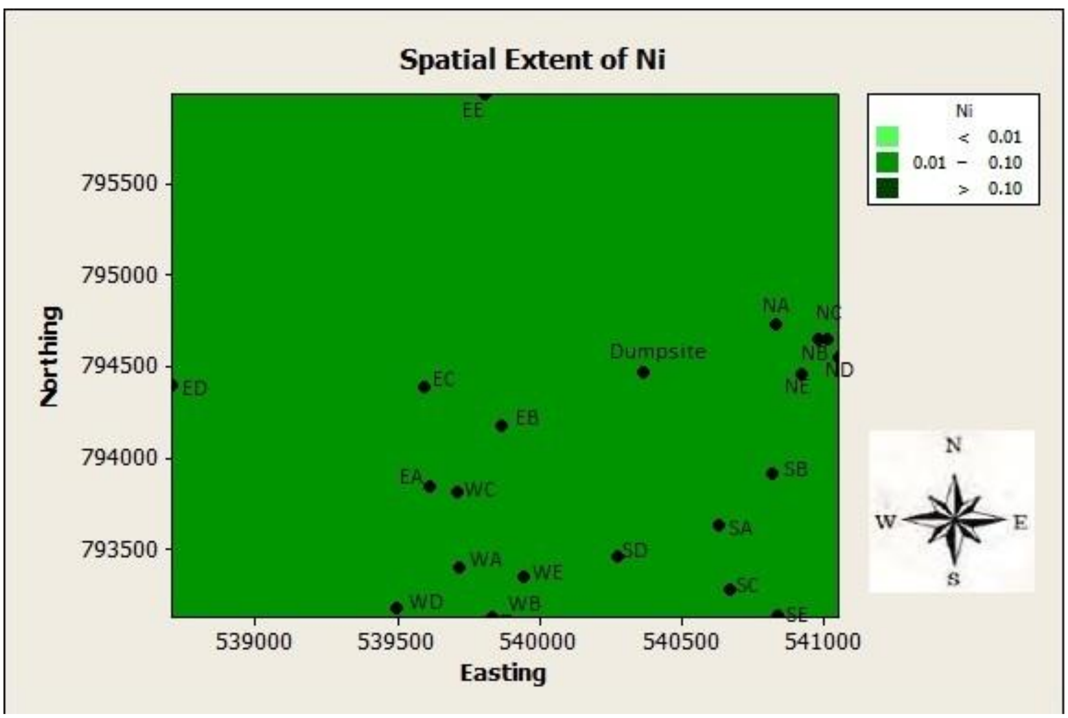

Figure 6: Spatial Variations of Nickel (Ni) in Groundwater around the Dumpsite.

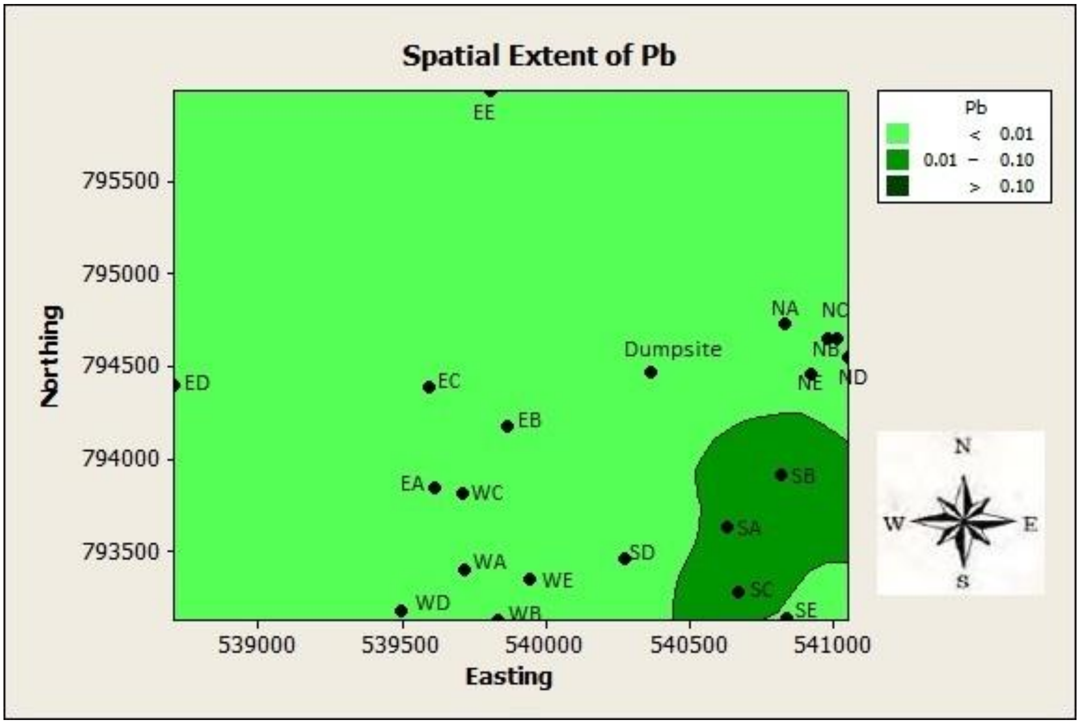

Figure 7: Spatial Variations of Lead (Pb) in Groundwater around the Dumpsite.

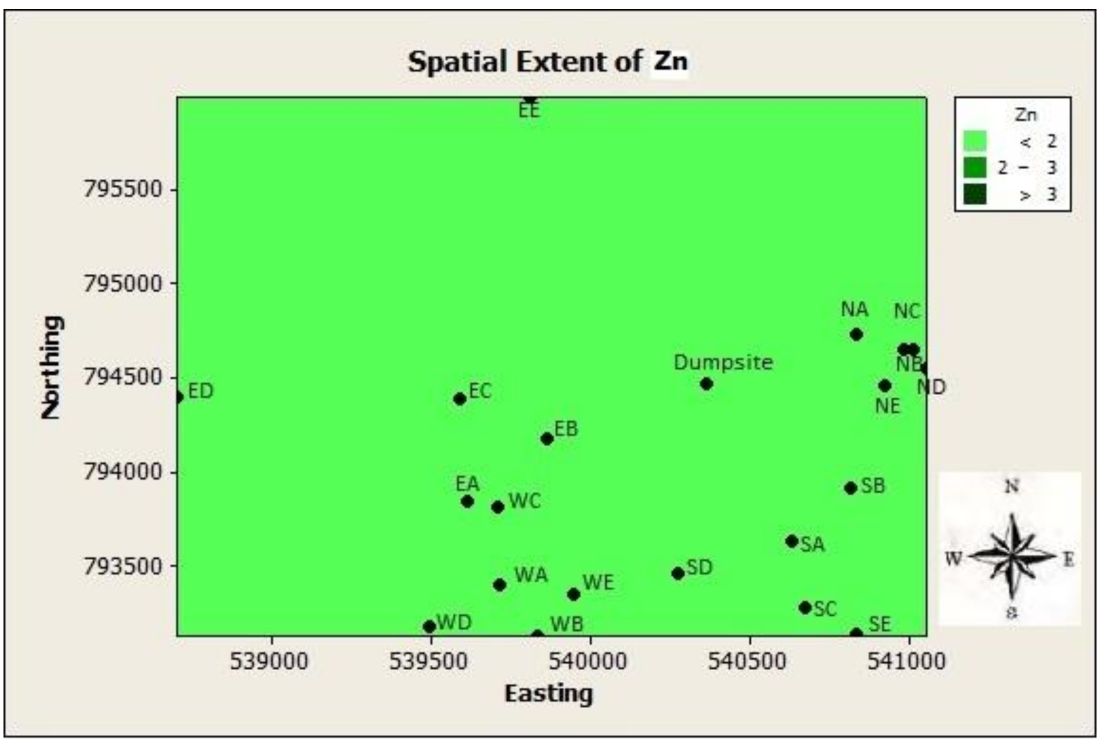

Figure 8: Spatial Variations of Zinc (Zn) in Groundwater around the Dumpsite.

None of the samples were beyond the 3 mg/L standard given by NSDWQ and WHO. Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. Drinking water containing zinc at levels above 3 mg/L may not be acceptable to consumers.

Nickel was found within the range of 0.0163 and 0.1137 mg/L with average value of 0.0496 ± 0.0277. The percentage of sampled wells that have Nickel value within the NSDWQ standard of 0.02 mg/L and WHO standard of 0.07 mg/L were 14 % and 86 %, respectively. Food is the dominant source of nickel exposure in the non-smoking, non-occupationally exposed population. The Spatial variation of Nickel is shown in Figure 7. Water is generally a minor contributor to the total daily oral intake. Nickel compounds are carcinogenic to humans and that metallic nickel is possibly carcinogenic.

Field observation also revealed that some of the wells were neither lined nor covered, extraction from some of the wells were also noticed to be from the ground level as no provision was made for steel cover.

CONCLUSION

Based on the findings of the study, it could be inferred that there are evidences of heavy metals contamination especially Cu, Fe and Ni at 2 km radius around the dumpsite. High concentration of heavy metals at the dumpsite was due to uncontrolled disposal of metal waste, lead acid batteries and spent petroleum products. The adverse pollution effect of the dumpsite on the groundwater was felt within 550 m radius away from the dumpsite. It is therefore recommended that wells should be properly located, lined and covered away from the flow path of potential sources of pollution and erosion. Also the dumpsite should be properly managed and residential houses should be restricted around the dumpsite including installation of wells at radius of 600 m away from the dumpsite.

REFERENCES

1. Adewole A.T. 2009. "Waste Management towards Sustainable Development in Nigeria: A Case Study of Lagos State". *Int. NGO J.* 4(4):173-179.

2. Adewumi, I., I.A. Oke, and P.A. Bamgboye. 2005. "Determination of the Deoxygenation Rates of a Residential Institution's Wastewater". *Journal of Applied Sciences*. 5(1):108-112.

3. Alloway, B.J. and D.C. Ayres. 1997. "Chemical Principles of Environmental Pollution". In: *Wastes and Their Disposal, 2nd ed.*, Blackie Acad. Professional: London, UK. 353-357.

4. APHA-AWWA-WPCF. 1994. *Standard Methods for the Examination of Water and Wastewater, 15th eds* American Public Health Association: Washington, DC.

5. Clark, J. 2006. "Rivers and their Catchments: Impact of Landfill on Water Quality". Earth Sci. Branch, Scottish Natural Heritage.

6. Edwards, K.A., G.A. Classen, and E.H. Schroten. 1983. *The Water Resource in Tropical Africa, and its Exploitation*. ILCA – Int. Livestock Centre for Africa, Res. Rep.: Addis Ababa, Nigeria. p. 28.

7. Hudak, P.F. 1998. "Groundwater Monitoring Strategies for Variable versus Constant Contaminant Loading Functions". *Environ. Monit. Assess*. 50: 271-288.

8. Longe, E.O. and. M.R. Balogun. 2010. "Groundwater Quality Assessment near a Municipal Landfill, Lagos, Nigeria". *Research Journal of Applied Science, Engineering and Technology*. 2(1):39-44.

9. Moo-Young, H., B. Johnson, A. Johnson, D. Carson, C. Lew, S. Liu, and K. Hancock. 2004. "Characterization of Infiltration Rates from Landfills: Supporting Groundwater Modeling Efforts". *Environ. Monit. Assess*. 96:283-311.

10. Nigerian Standard for Drinking Water Quality NSDQW. 2007. *Nigerian Industrial Standard NIS 554*. Standard Organization of Nigeria, pp. 30.

11. Norusis, M.J. and SPSS Inc. 1997. *SPSS for Windows Professional Statistics 7.5*. Prentice Hall: Englewood Cliffs, NJ.

12. Sia Su, G.L. 2008. "Assessing the Effect of a Dumpsite to Groundwater Quality in Payatas, Philippines". *American Journal of Environ. Sci*. 4(4):276-280.

13. Sridhar, M.K.C. and G.O. Adeoye. 2003. "Organo-Mineral Fertilizer from Urban Wastes: Development in Nigeria". *The Nigerian Field*. 68: 91-111.

14. Tinmaz, E. and I. Demir. 2006. "Research on Solid Waste Management System: To improve Existing

Situation in Çorlu Town of Turkey". *Waste Management*. 26:307-314.

15. Ufoegbune, G.C., O. Oguntoke, C.O. Adeofun, and A. Salako. 2008. "Remote Sensing Techniques applied to Time Related Changes in the Landuse of Abeokuta and its Environs". *South Western Nigeria. Asset Series A*. 8(1):98-108.

16. UNEP and WHO.1996. *Water quality Monitoring*. An imprint of Chapman and Hall: London, UK.

17. WHO. 2011. *Guidelines for Drinking Water Quality Vol. IV*. World Health Organization: Geneva, Switzerland.

SUGGESTED CITATION

Badejo, A.A., A.O. Taiwo, A.A. Adekunle, and B.S. Bada. 2013. "Spatio-Temporal Levels of Essential Trace Metals around Municipal Solid Waste Dumpsite in Abeokuta, Nigeria". *Pacific Journal of Science and Technology*. 14(2):682-692.