

Contamination assessment of surface and groundwater within and around two dumpsites

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ABSTRACT: Geochemical analyses of groundwater and streams flowing around abandoned and active dumpsites in Lagos, Southwestern Nigeria were carried out. Results show that water samples have generally low total dissolved solids with average values of 163.75 and 153.4 for abandoned and active dumpsites, respectively. pH ranges from 3.96-8.34 while total hardness varies from 10-220 mg/L calcium carbonate (soft to slightly hard). Average concentrations of the dominant ions for abandoned and active dumpsites were 57.8 and 25.86 mg/L (Na) representing 40.7 and 46.3 % of the total cations respectively and Nitrate (av. 96.89 and 61.51 mg/L) representing 49.1 % and 40 %, respectively of the total anions. The pH, coliform count and concentrations of nitrate iron, manganese and sodium in most of the water samples were above the national drinking water standards proposed by the United States Environmental Protection Agency. Trace elements like silver, arsenic, beryllium, bismuth, cerium, cobalt, chromium, lithium selenium, tellurium, titanium, uranium, vanadium, tin and yttrium were below detection level for all the water samples while tungsten, thallium, molybdenum and lead were only present in surface and groundwater close to the dumpsites and also display values higher than recommended standards while copper, zinc, aluminum, barium and strontium were present in most of the samples. The pollution index among all sites varied from 0.009 to 1.26 and 0.106 to 6.25 for abandoned and active dumpsites, respectively while the water around most of the dumpsite areas exceeded the acute and chronic effect levels proposed by the United States Environmental Protection Agency in 2007.

Keywords: Anthropogenic; Environment; Pollution index; Trace elements

INTRODUCTION

The disposal of wastes generated by human activities within a municipality is generally an urban problem. The recognition of the connection between human activities and pollution and the need to protect human health, recreation and fisheries production led to the early development of water quality regulations and monitoring methods (Hem 1985; Jenkins *et al.*, 1996; USEPA, 2007). The existence of trace metals in aquatic environments has led to serious concerns about their influence on plant and animal life (Samarghandi *et al.*, 2007; Zvinowanda *et al.*, 2009). During their transport, the trace metals undergo numerous changes in their speciation due to dissolution, precipitation, sorption and complexation phenomena (Akçay *et al.*, 2003; Abdel-Ghani and Elchaghaby, 2007; Abdel-Ghani *et al.*, 2009; Mohinddin *et al.*, 2010). One of the reasons these toxins are so harmful is that they become more

concentrated in successive trophic levels of a food web, a process called biological magnification (Woodwell, 1972; Grimanis *et al.*, 1978; Adams *et al.*, 1992; Campbell, 1996; Manly, 1996; Kaonga *et al.*, 2010). The need for socio-economic advancement has led to rapid expansion of the industrial sector in developing countries like Nigeria. These waste disposal sites and landfills are neither properly designed nor constructed. After some years a dumpsite undergoes biologically, chemically, geologically and hydro geologically mediated changes resulting in a weathering process consequently, it becomes point source for pollution of the aquiferous units close to them (Arienzo *et al.*, 2001; Manjunatha *et al.*, 2001; Altindag and Yigit, 2005; Awofolu *et al.*, 2005; Wang and Zhuo, 2005; Adeniyi *et al.*, 2008). The commonly used disposal methods of the solid wastes in the study area are open dumps, non-engineering sanitary landfill and incineration. When rain falls, the rain leaches pollutants from the

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waste disposal sites. Thus introducing toxins and contaminants into the soil, surface and groundwater and eventually plants that grow within the vicinity of the dumpsite (Awofolu *et al.*, 2007; Daka *et al.*, 2007). The overall implication of this is that the hydrochemical facies of groundwater changes in response to its flow path history, that is, underground water quality is dependent on pollution status of its environment (Olabaniyi and Owoyemi, 2006).

Geological and geomorphologic features

The geology of the study area fall within coastal plain sand of Dahomey Basin and is characterized by coarse, unsorted sands and clay lenses mixed together in varying proportions at varying depth. Depth to water ranges from land surface to about 10 m for first aquifer. Generally, the lithology is composed of medium to coarse grained sandy horizon interbedded with thin band of grey black clay which occur in minor proportion (< 20 m).

The study areas which are Isolo and Ojota dumpsites are both located in Lagos, southwestern

Nigeria (Fig. 1 a and b). Ojota disposal site is located in the northeastern area of Lagos. It is very massive with a topographical height of about 45.45 m (150 ft) from the sea level it has been in operation since 1992, still very active and it is very close to so many industries. The Isolo waste disposal site is situated at the northern part of Lagos metropolis. It is sited very close to a big canal which normally overflows its banks during the rainy season and a dominant percentage of the waste deposited here are domestic wastes. Also, the site has been abandoned for the past twelve years and therefore, it is no more active. This research has been done between 2007 and 2008.

MATERIAL AND METHODS

Water samples from boreholes, wells and streams were collected at several locations within and around the two dumpsites. Several sensitive parameters of water such as total dissolved solids (TDS), electrical conductivity and pH were determined during the on the spot sampling using the appropriate digital meters (e.g. water treatment works (WTW)-conductivity meter

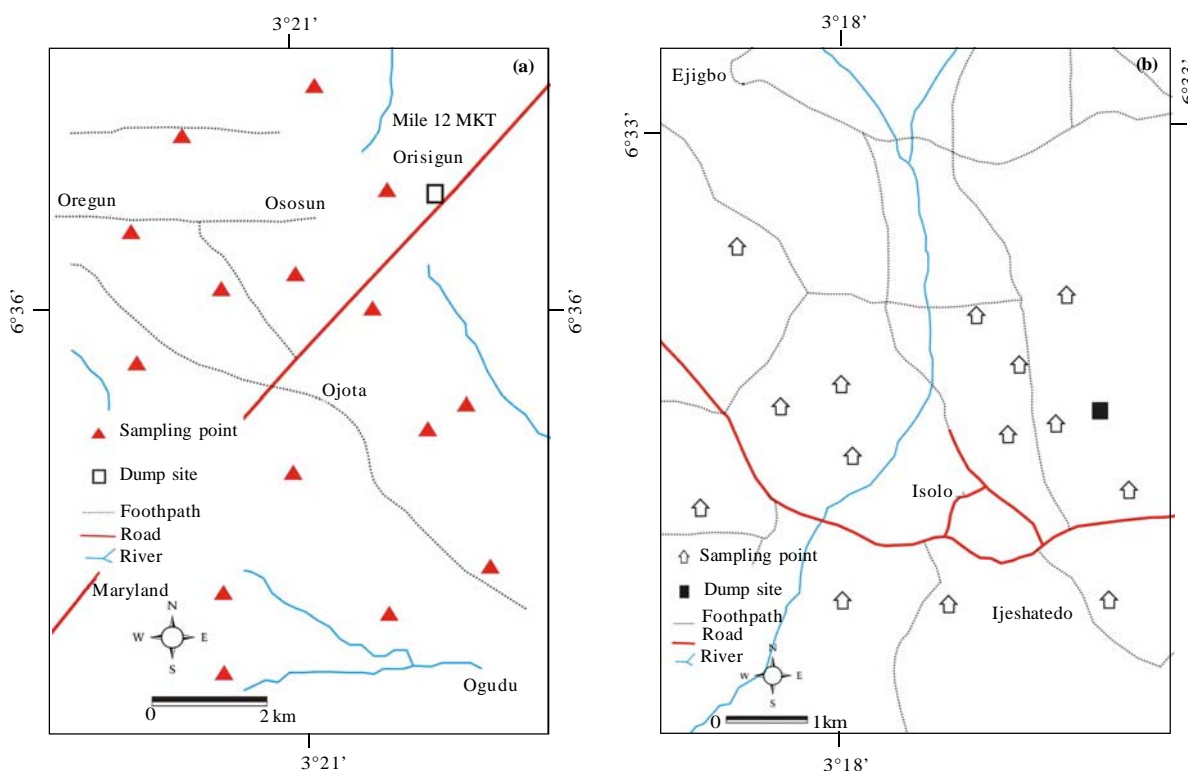


Fig. 1: Sample locations for a) Active dumpsite; b) Abandoned dumpsite

model L/92 and WTW- pH meter model pH/91). Water samples of approximately 125 mL were collected for multielement analysis; pressure filtered through 0.2 mm Nuclepore membranes and 3 mL analytical grade HNO_3 was added to bring the water acid solution to a pH ~ 2. The analysis of trace elements and cations in water were carried out using inductively coupled plasma-optical emission spectrometry (ICP-OES) while unacidified water samples were analyzed for anions concentrations using the DIONEX DX-120 ion chromatography techniques. All the analyses were carried out at the Actlabs laboratory, Ontario Canada. To check the accuracy, activation laboratories (Ontario, Canada) employed two internal standards (each run twice) and found that the errors were consistently minimal. Bacteriological analysis of the water samples was also carried out. Results were further compared with recommended standards and pollution index was calculated to determine the impacts of the two dumpsites on water quality.

RESULTS AND DISCUSSION

The summary of the concentrations of dissolved elements in streams and groundwater around both active and abandoned dumpsites in Lagos, Southwestern Nigeria were given together with national drinking water standards proposed by the US Environmental Protection Agency (USEPA) in may 2009 (Tables 1 and 2). pH values range from 3.96-8.34 with most of the samples slightly acidic and out of the USEPA (2009) standards as a result of dilution by leachates. Total dissolved solid is low generally with mean values of 163.62 and 153.38 while electrical conductivity (EC) showed mean of 301.63 and 311.21 for abandoned and active dumpsites, respectively. On this basis, the water can be classified as fresh (Todd, 1980). Major ions such as Fe, Mg, Mn, Na, Br and NO_3 in the water samples were higher than the limits of the above standards for samples close to the dumpsites, (Fig. 2). Concentrations for Au, Be, Hg, In, Ir, Nb, Os, Pd, Pt, Re, Rh, Ru, Sb, Se, Ta and Te were all below the detection limit for ICP-OES and therefore were not listed in Tables 1 and 2. The metals showed the following trends $\text{Zn} > \text{Al} > \text{Sr} > \text{Ba} > \text{Cu} > \text{Ni}$ and $\text{Zn} > \text{Al} > \text{Ni} > \text{Sr} > \text{Ba} > \text{Cu}$ for abandoned and active dumpsites respectively. The mean concentrations for samples taken around abandoned and active dumpsites were 551.5 and 398.76 for Zn, 4.71 and 72.06 for Ni, 52.35 and 43.76 for Ba, 32.59 and 15.29 for Cu,

182.4 and 264.7 for Al and 0.18 and 137.6 and 57.65 for Sr, respectively (Tables 1 and 2). W, Mo and Pb were found only in the two samples and both were above USEPA, 2009 standards. NO_3 ranges between 0.3 -250.3 mg/L and 3.2 mg/L – 200 mg/L while coliform ranges between 0cfu/100 mL – 600 cfu/100 mL and 10 cfu/100 mL 600 cfu/ 100 mL for abandoned and active dumpsites, respectively. The large relative standard deviation values indicate that there is significant variability among the individual sampling sites around the two dumpsites. The wide range of concentrations most likely represents different point-source inputs from different materials in the dumpsites since chemical weathering of sedimentary rocks which is Coastal Plain Sands in the case of the study area are unlikely to provide such large spatial fluctuations in trace elements content. The variability of concentrations of these elements, as well as total coliform within the water suggests local anthropogenic input sources through domestic, municipal and industrial wastes within the dumpsites. The total concentrations of the elements were compared at several sampling sites and there was a slight overall trend of increase in the concentration of trace and major elements in the water samples within and very close to the dumpsites (Figs. 3 and 4). The large increase at these sites suggests a high elemental input into the water which is probably from the dumpsites. Leachate within the two dumpsites showed the highest values for most of the elements while the control samples taken far away from the sites showed the least (Figs. 3 and 4).

Pollution index

The pollution index was used in this study to evaluate the degree of trace metal contamination (Nishida *et al.*, 1982; Chon, *et al.*, 1991; Kim *et al.*, 1998; Emoyan *et al.*, 2005; Nier 2007). The tolerable level is the element concentration in the water considered safe for human consumption (Kloke 1979; Lee *et al.*, 1998). The USEPA national drinking water standards (2009) were used as tolerable level for water and the pollution index can be calculated by the formulae below

$$\text{PI} = \frac{\frac{\text{Heavy metal concentration in water}}{\text{Tolerable level}}}{\text{Number of heavy metals}}$$

The PI among all sites varied from 0.009 to 1.26 and 0.106 to 6.25 for abandoned and active dumpsites,

Quality of water around dumpsites:

Table 1: Summary of results of water samples within and around abandoned dumpsite

	Surface water	Groundwater	Leachate	Control	NDWS
pH	4.5-8.34(4.72)	3.96-8.05(5.54)	6.57	7.8	6.5-8.5
Conductivity	170-250(226.25)	40-730(255.2)	665	50	1400
TDS	116-186(164.75)	26-453(168.9)	408	30	1000
Hardness	10-48(29.25)	20-220(69.4)	70	67	
Total coliform	10-420(161.5)	0-600(98.8)	205	10	0
Ca	9.2-128(44.9)	1.2-45(14.85)	43.6	81.1	200
Fe	0.05-0.23(0.13)	0.03-0.34(0.095)	0.47	0.01	0.3
K	7.4-194(56.85)	0.3-12.4(4.025)	6.7	1.9	
Mg	3-63.1(18.25)	0.5-43.2(6.98)	2.2	6	50
Mn	0.09-0.16(0.12)	0.02-0.14(0.07)	0.06	0.01	0.05
Na	27.7-243(97.8)	4.2-84(29.7)	34.8	4.9	200
P	0.82-3.76(2.3)	0.22-2.24(0.84)	1.22	0.04	
Si	2.4-10.3(5.6)	2.5-8.4(5.05)	8.5	7.6	
S	5-24(14.5)	1-22(4.03)	9	5	
Cl	28.6-406(128.7)	12.8-29.8(21.54)	91.8	34	230
Br	0-0.61(0.18)	ND-0.61(0.177)	0.19	0.04	0.01
NO ₃	0.03-250.3(135.96)	0.02-120.3(39.8)	110.1	0.01	10
SO ₄	3.07-187(51.46)	1.13-76.4(29.69)	31.1	2.81	400
HCO ₃	0-38(12)	0-25(6.3)	78	45	
Al	200-1100(400)	ND-300(90)	300	100	87
Ba	40-100(65)	40-100(49)	80	40	1
Cu	4-46(21.5)	8-232(43.6)	16	4	1
Ni	0-20(7.5)	ND-15(3.5)	10	nd	0.02
Zn	525-1060(791.25)	30-960(384.6)	2330	30	5
Sr	50-670(227.5)	20-520(105)	120	250	0.01

*NDWS: National drinking water standards, *ND: Not detected, *Major elements in mg/L, *Trace elements in µg/L

Table 2: Summary of results of water samples within and around active dumpsite

	Surface water	Groundwater	Leachate	Control	NDWS
pH	4.28-6.75(5.1)	4.23-8.04(5.64)	4.89	7.92	6.5-8.5
Conductivity	122-603(302.6)	122-703(340.9)	50	30	1400
TDS	24-185(128.4)	86-424(197.3)	25	25	1000
Hardness	10-65(37)	22-102(51.2)	210	75	
Total coliform	12-308(111)	10-308(90.3)	208	5	0
Ca	2.3-23.1(12.16)	2.4-17.9(6.83)	8.5	81.1	200
Fe	0.04-2.36(0.52)	0.02-1.32(0.18)	0.06	0.01	0.3
K	1.2-21.7(9.1)	1-20.6(6.17)	5.5	1.9	
Mg	0.5-3.9(2.32)	0.6-3.5(1.43)	1.6	6	50
Mn	0.02-0.21(0.1)	0.03-0.14(0.06)	0.06	0.01	0.05
Na	13.2-75.6(38.62)	13.4-56.7(26.08)	33.6	4.9	200
P	0.34-3.64(1.99)	0.02-2.32(0.86)	2.8	0.04	
Si	4.4-9.6(6.56)	1.7-8.7(4.7)	4.7	7.6	
S	5-19(10.8)	2-17(6.8)	11	5	
Cl	12.5-54(44.95)	5.06-78.2(38.2)	87.2	34	230
Br	ND	ND	ND	ND	0.01
NO ₃	3.2-117.9(79.13)	2.41-200.01(51.62)	217.5	0.01	10
SO ₄	1.29-7.09(4.13)	1.19-9.86(4.3)	7.09	2.81	400
HCO ₃	0-103(20.5)	0-213(24.45)	0	45	
Al	200-600(300)	200-400(290)	200	100	87
Ba	40-100(72)	ND-80(56)	35	40	1
Cu	10-24(14.4)	8-26(17.1)	28	4	1
Ni	nd-19(6)	Nd-540(65.5)	600	Nd	0.02
Zn	240-645(405)	260-895(402)	1100	30	5
Sr	20-80(58)	20-100(44.4)	30	250	0.01

*NDWS: National drinking water standards, *ND: Not detected, *Major elements in mg/L, *Trace elements in µg/L

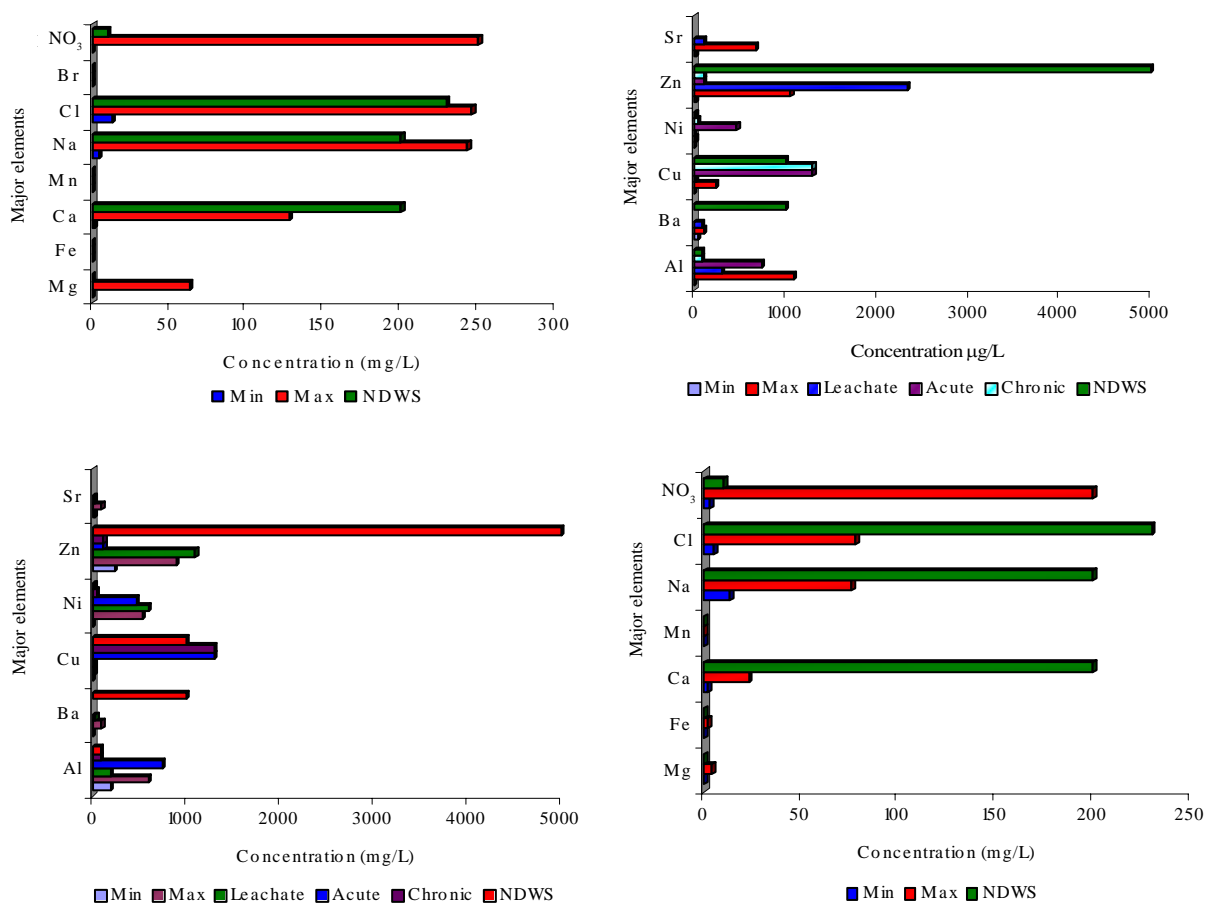


Fig. 2: Bar charts of heavy metals and some major elements concentration with acute, chronic and national drinking water standards proposed by USEPA (2009)

respectively. Concentrations of Al, Ba, Cu, Zn and Sr in most of the water samples were less than the given tolerable levels while Ni showed higher concentration in 1 and 2 samples for abandoned and active dumpsites, respectively (Figs. 5 and 6). Pi was below 0.1 at 4 and 6 samples representing (27.7 % and 37.5 %) of the total samples, between 0.1 to 0.3 at 6 and 8 samples (37.5 % and 50 %) and greater than 0.3 at 5 and 2 samples (33.3% and 12.5%) for abandoned and active dumpsites, respectively (Table 4). The pollution index for shallow well and leachate within the active dumpsite were as high as 5.42 and 6.05, respectively.

Fresh water acute and chronic criteria

The water around most of the dumpsite areas exceeded the acute and chronic effect levels proposed by the US Environmental Protection Agency (USEPA) in 2007 (Fig. 1). The tolerable acute and chronic levels

for fresh water are 470 and 52 µg/L for Ni, 750 and 87 µg/L for Al, 13 and 9 µg/L for Cu, 65 and 2.5 µg/L for Pb and 120 µg/L for both, for Zn. Among all the studied areas, 6.25 %, 84.38 %, 71.87 % and 81.25 % of water exceeded the acute and chronic limit of Ni, Al, Cu and Zn, respectively. For chloride only one sample from surface water exceeded the fresh water aquatic life acute and chronic criteria. The standard recommended for the consumption of water and organisms for human health by USEPA (2007) include 300 µg/L, 50 µg/L and 10,000 µg/L for Fe, Mn and NO₃ while 31.25 %, 46.88 % and 59.4 % of total samples exceeded these values, respectively. The source of these metals may be attributed to anthropogenic activities from the various wastes at the dumpsites and dumping of wastes/rubbish on the stream channels. The environmental implication of water contamination lies in the fact that the adsorbed portion

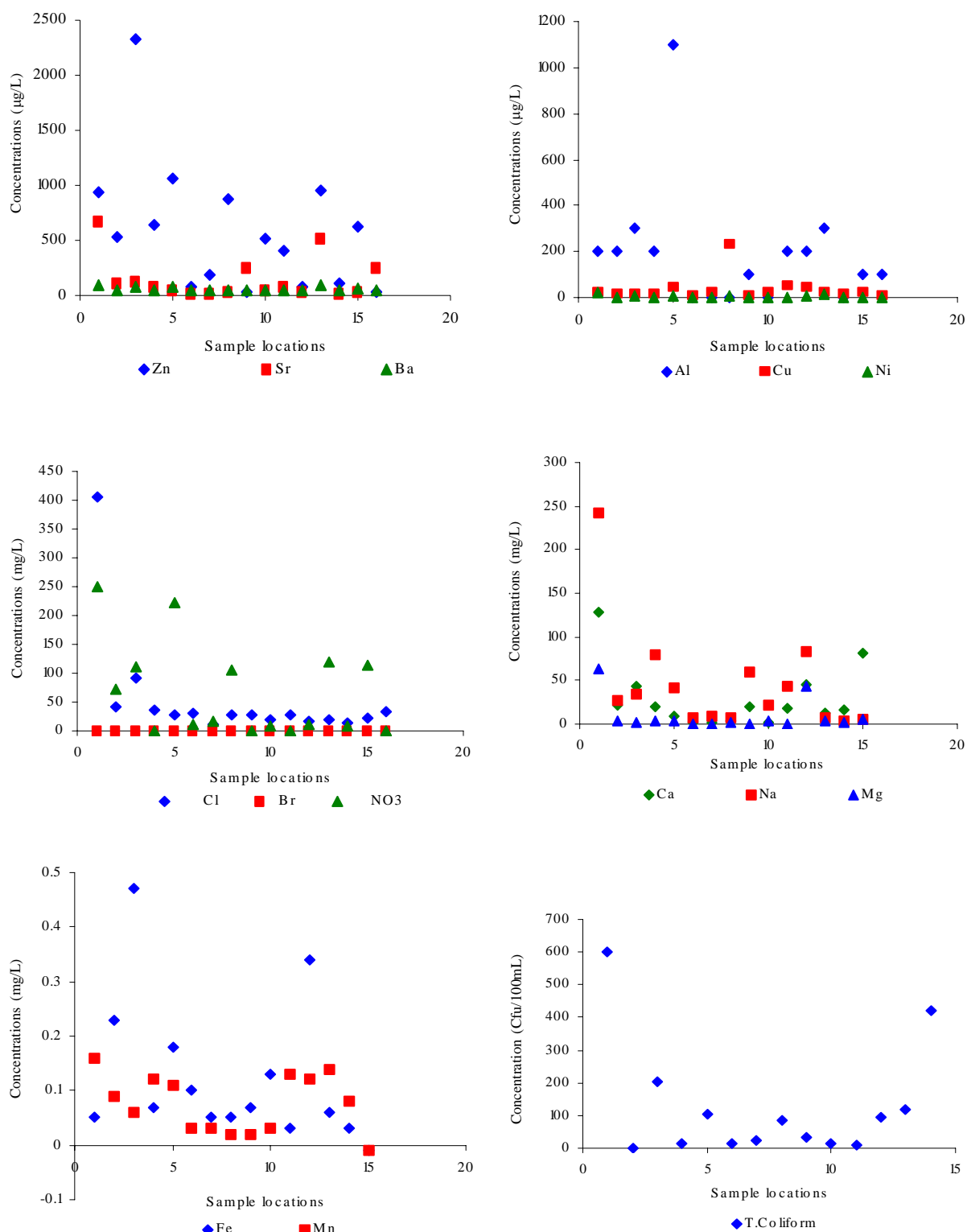


Fig. 3: Scattered plots of heavy metals against sample locations around abandoned dumpsite

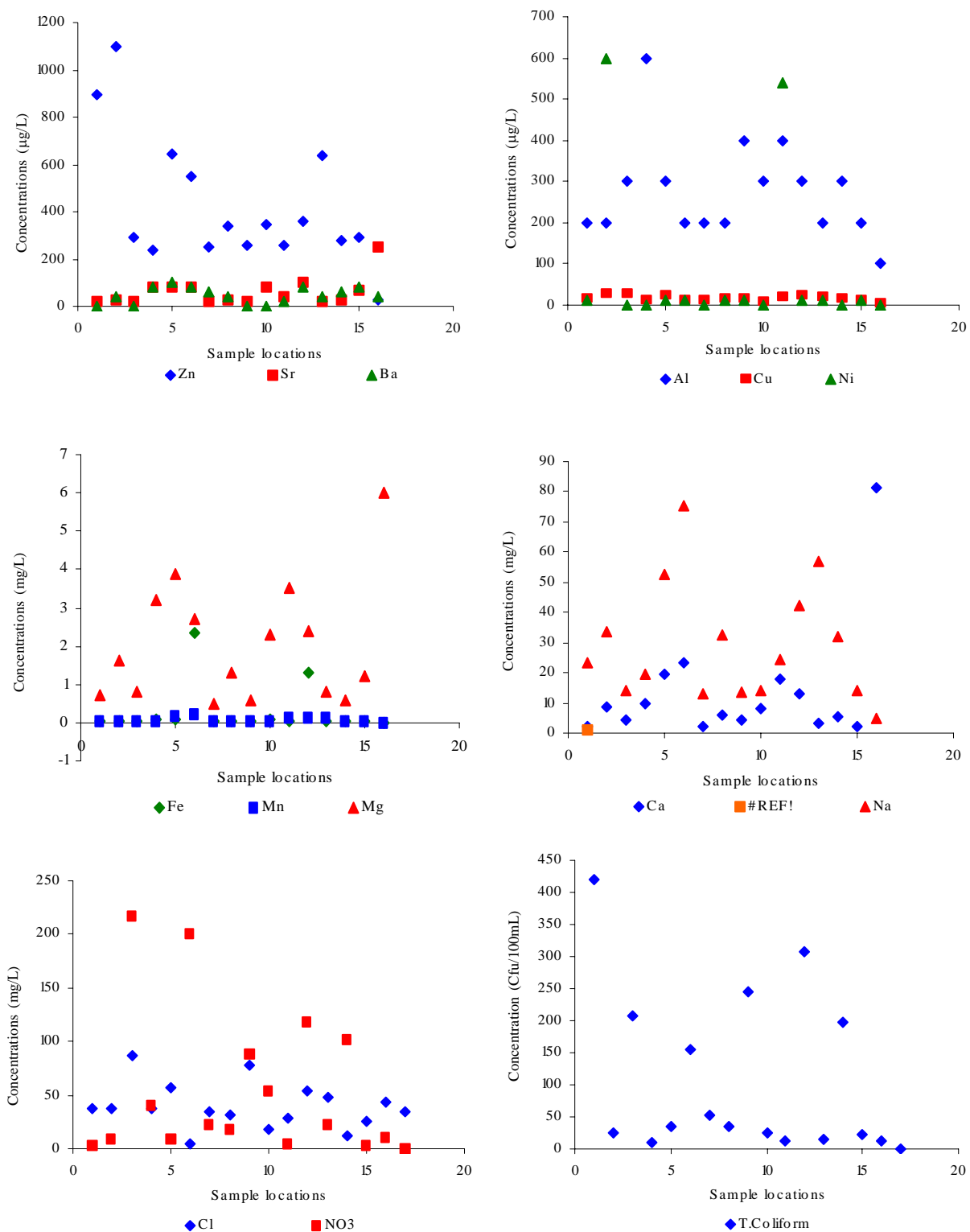


Fig. 4: Scattered plots of heavy metals against sample locations around active dumpsite

Quality of water around dumpsites 1

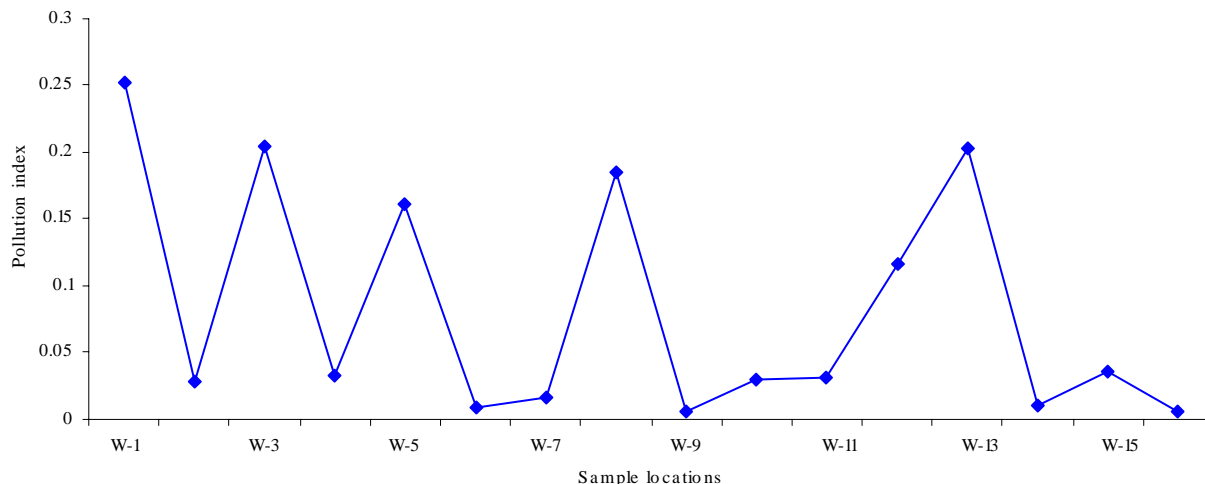


Fig. 5: Pollution index for abandoned dumpsite

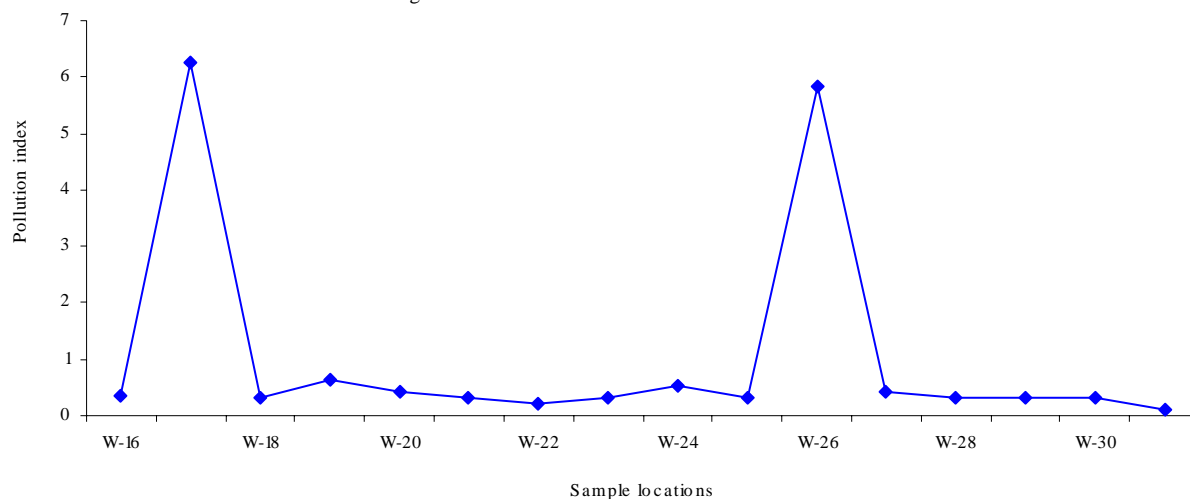


Fig. 6: Pollution index for active dumpsite

of these metals will pollute the water which serves as source of drinking water for some people while the possible trophic transfers especially at the downstream outside the urban areas where local inhabitants use the water in vegetable nurseries/ farming call for concerns.

CONCLUSION

Quality evaluation of surface and groundwater from Lagos Southwestern Nigeria, were discussed as a case study of anthropogenic influence of dumpsites in a typical urban environment of a developing country. From this study, it is clearly evident that lack of well constructed environmental friendly landfills and indiscriminate dumping of wastes to stream channels

have considerable influences on the heavy metal contaminations of surface and groundwater in the study area. The study revealed slight degree contamination of Al, Zn, Ba, Cu, B, Pb, Mo, W and Ni in the some water samples around the two dumpsites compared to the [USEPA \(2009\)](#) standards. Among the major elements, NO_3 and Fe are the most critical in the water system. Also, total coliform counts were very high in all the samples. The pollution index among all sites varied from 0.009 to 1.26 and 0.106 to 6.25 for abandoned and active dumpsites, respectively while the water around most of the dumpsite areas exceeded the acute and chronic effect levels proposed by the US Environmental Protection Agency ([USEPA, 2007](#)).

Generally, the water contamination is related to anthropogenic sources mostly from different wastes within the dumpsites which are domestic/municipal and slightly industrial in origin.

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