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Assessment of heavy metal pollution in soils and wells around municipal dumpsites in Osogbo metropolis

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ABSTRACT

This study assessed the contributions of dumpsites to heavy metal pollution in soils at 10m and 20m and well water at 50m, 100m and 200m away from two dumpsites; Islae-Osun and Ofatedo. The pH of soils from dumpsites, 10m and 20m away from Ofatedo dumpsite were alkaline while pH of soils from 10m and 20m away from Isale-Osun dumpsite were acidic. pH of water from all locations were alkaline except for control which was acidic. The trend of heavy metal pollution in soils at the centre, 10m away from Isale-Osun and 20m away from Ofatedo dumpsites is Pb >Cu >Ni>Cr >Cd while at 20m away from Isale-osun dumpsite, centre and 10m away from Ofatedo dumpsite is Cu>Pb>Ni>Cr>Cd. The general trend of heavy metal pollution in well water at various distances from both dumpsites is Cu>Pb>Cr>Ni>Cd except at 200m away from Isale-osun dumpsite which is Cu>Pb>Cr>Cd>Ni. Heavy metal pollution index evaluated were higher than 100; the threshold warning suggesting that all wells were critically polluted with heavy metals. Factor analysis revealed that the main source of pollution was from dumpsites.

KEYWORDS

Dumpsite;
Heavy metals;
Factor analysis;
Heavy metal pollution index;
Osogbo metropolis.

INTRODUCTION

Indiscriminate disposal of municipal, hospital and electronic wastes on open fields which have become mountains of refuse have been reported to greatly contribute to air, water and soil pollution[1]. When it rains, toxins and contaminants from the open dumpsites are leached into the soil, eventually get into ground water and make it unfit for drinking. Studies have revealed that waste dumpsites can transfer significant levels of toxic and persistent metals into the soil environment[2, 3]. In developing countries like Nigeria where there are infrastructural deficits and unavailability of pipe-borne water for all, citizens depend majorly on ground and stream waters for drinking and other domestic activities. Drinking water with significant heavy metals contamination could result into various health effects because they bioaccumulate in human tissues[4,5]. Studies have shown that ingestion of heavy metal polluted water could lead to nausea, vomiting and gastrointestinal abnormalities. Environmental exposure to heavy metals has been attributed to adverse effects on the health due to their toxicity and bioaccumulative tendencies within the environment[6,7]. Epidemiological studies have linked effects of heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni) and copper (Cu) to mortality, morbidity, haematological disorders and pulmonary edema arising from their toxicity[8]. Cadmium has been reported to cause kidney damage and bone degradation because it affects calcium metabolism. Lead has been reported to cause alterations in pregnancy, lactation, delivery of low birth weight and menopause. Zinc toxicity has been linked with diarrhea while nickel has been reported to cause lung and nasal cancer[9, 10]. Arising from these possibilities of the contribution of dumpsites to heavy metal pollution of ground water and dependence of people on well water in these areas for drinking and other domestic purposes, this study aimed to determine the levels of heavy metals in two dumpsites and their contribution to soil and ground water pollution in their vicinity in Osogbo metropolis and discuss possible effects from ingestion of heavy metal contaminated water.

MATERIALS AND METHODS

Chemicals

Analar grade trioxinitrate (v) acid (HNO_3) and perchloric acid ($HClO_4$) were bought from BDH Poole, England. Deionized-distilled water was used throughout.

Sampling

Study sites

The dumpsites located at Isale-Osun (lat 07.44°N and long 04. 47°E) and Ofatedo (lat 07.53°N and long 04.35°E). These dumpsites were characterized by wastes such as syringes, paint waste containers, spoilt food, kitchen waste, glass, broken bottles, cans, metals, plastics, fertilizers and pesticides containers, batteries, shoe polish container, television tubes, e.t.c as

Figure 1 : Isale-Osun (A) and Ofa-tedo (B) Dumpsites in Osogbo.

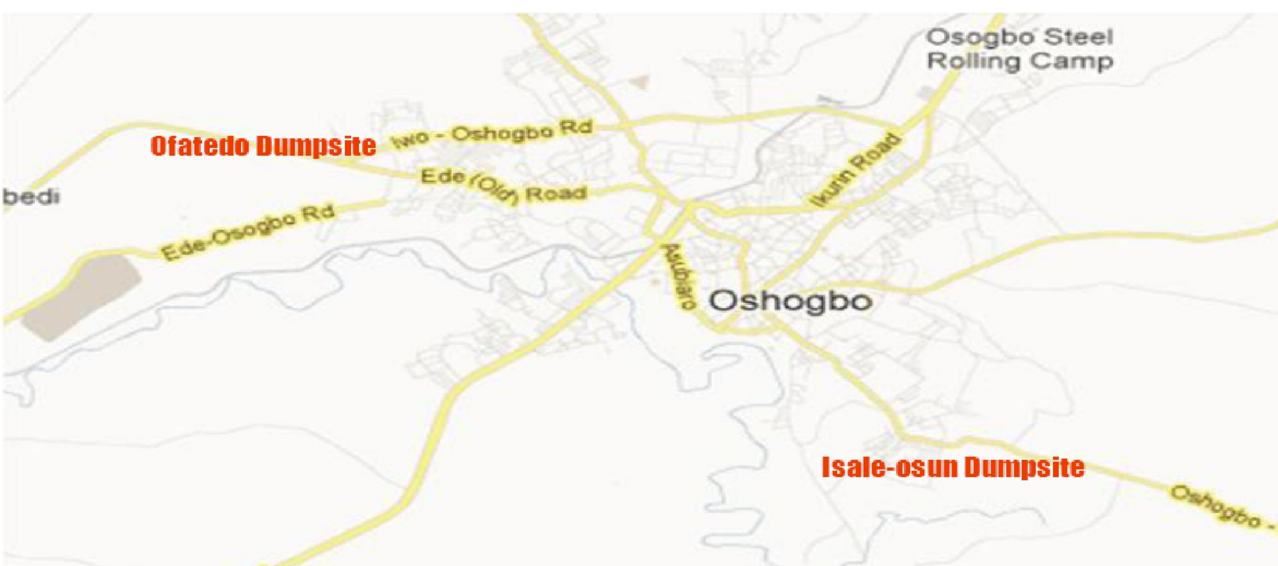

Figure 2: Map of Osogbo showing sampling locations

shown in figures 1A and B. Originally, these dumpsites were on the outskirts of the metropolis but due to rapid urban development, the sites are presently within developed locality of the metropolis being surrounded by residential, commercial and industrial neighbourhoods.

Sampling and treatment

Soil sampling and treatment

Six soil samples (from top-soil 1-15cm deep) were taken from two designated dumpsites in Isale-Osun and Ofatedo, 10m and 20m away from the dumpsites. The soil samples obtained were fine particles, dark coloration and moist. The soil samples were air-dried at 25°C, ground to break down the lumps into fine particle as much as possible for uniform particle size and were sieved using a 10mm mesh. The sieved soil samples were then stored and labeled with reference to the specific location they were obtained from.

Water sampling and treatment

Seven water samples were collected from hand-dug wells at 50m, 100m and 200m away from both dumpsites and control from Fountain University about 4km from Isale-Osun dumpsite. The samples were pretreated with 10ml of concentrated HNO_3 to minimize biological actions, hydrolysis of chemical compounds, volatility absorption and precipitation of constituents prior to analysis as outlined by Abdus-Salam *et al.*[1]. The water samples were stored and labeled in 20ml white plastic kegs.

Chemical analyses

Soil and water pH were determined according to the method of[11] using Jenway 3505 pH meter.

The method of Adelekan and Alawode[11] was used to digest the soil samples. 0.5g of pre-treated soil sample was weighed into a beaker. 10ml of perchloric/nitric acid mixture ratio (1:2) was added to the sample. The sample was digested at 105°C for 3hr in a fume cupboard. The digested samples was cooled after 3hr and transferred into a 25ml flask and made to the mark with deionized-distilled water. Concentrations of heavy metals such as Cu, Cr, Cd, Pb and Ni were determined in the solution using Atomic Absorption Spectrophotometer, (AAS) S series 711047v1.22 with deuterium lamp. Water samples were digested according to the method of Sallau *et al.*[12]. 50cm^3 of each sample was treated with 5cm^3 of conc. HNO_3 and heated on a hot plate with gradual addition of conc. HNO_3 as necessary until the solution boiled. It was then evaporated to about 20cm^3; 5cm^3 of conc. HNO_3 was finally added, covered and allowed to cool and then filtered. The filtrate was poured into a 50cm^3 standard volumetric flask and made up to the mark with distilled water. Portion of the solution was used for metal analysis with atomic absorption spectrophotometer (AAS) S series 711047v1.22 with deuterium lamp.

Statistical analysis

Data are expressed as mean ± standard deviation. Heavy metal concentrations in well water from different sites were subjected to factor analysis using Statistical Package for Social Sciences (SPSS) 15 version.

RESULTS AND DISCUSSION

pH and heavy metal concentrations in soil from the centre,10m and 20m away from Isale-Osun and Ofatedo dumpsites are presented in TABLE 1. The pH of soils from dumpsites, 10m and 20m away from Ofatedo dumpsite were alkaline while pH of soils from 10m and 20m away from Isale-Osun dumpsite were acidic. There was a decrease in pH levels as one moves away from both dumpsites. pH and heavy metal concentrations in water from 50m, 100m and 200m away from Isale-osun and Ofatedo dumpsites are presented in TABLE 2. pH of water from both locations were alkaline while acidic pH was recorded for control. All the pH values were within the limit of Standard Organization of Nigeria[14]. pH is one of the properties that affect the availability, retention and mobility of nutrients and heavy metals in the soil. Soils with low pH increase micronutrient solubility, mobility and favour redistribution of heavy metals[12,15]. As determined in this study, high pH in soils from both dumpsites might be responsible for retention and low dispersal of heavy metals in them compared with other soils from distances away from dumpsite. High pH in water could indicate the presence of carbonates of calcium and magnesium in water[16]. Thus, except in the control, others could be hard water due to possible presence of carbonates of calcium and magnesium because of their high pH.

Heavy metal concentrations were generally higher in soils from the centre of both dumpsites except for Cd at Ofatedo dumpsite. The concentrations of heavy metals decrease as we move away from the dumpsite except for Cd at 10m away from both dumpsites and 20m away from Ofatedo dumpsites. The trend of heavy metal pollution at the centre and 10m away from Isale-Osun and 20m away from Ofatedo dumpsites is Pb >Cu >Ni>Cr >Cd while at 20m away from Isale-osun dumpsite, centre and 10m away from Ofatedo dumpsite is Cu>Pb>Ni>Cr>Cd.

TABLE 1 : pH and heavy metal concentrations (mg/kg) in soil from and around isale-osun and ofatedo dumpsites.

	Cu	Cr	Cd	Ni	Pb	Ph
			Isale-Osun			
Centre	3363.33 ±424.21	314.87 ±12.42	87.27 ±3.41	1944.72 ±341.17	4696.78 ±512.24	757.23 ±12.15
10m	2855.19 ±415.07	262.28 ±6.08	31.06 ±7.12	1092.46 ±212.16	2954.44 ±701.67	689.03 ±5.08
20m	2274.41 ±353.13	268.03 ±28.11	58.00 ±18.3	724.53 ±63.87	1787.45 ±318.39	616.65 ±3.25
			Ofatedo			
Centre	5671.22 ±937.04	294.48 ±21.39	39.19 ±6.30	2145.01 ±281.94	3897.49 ±801.10	820.04 ±14.19
10m	4145.25 ±615.18	186.01 ±41.13	69.28 ±8.14	809.22 ±12.19	2354.23 ±510.64	796.92 ±12.02
20m	1676.07 ±582.10	260.67 ±19.00	66.06 ±11.04	782.15 ±41.45	1807.30 ±96.71	760.67 ±33.33

Heavy metal concentrations in water decrease with increase in the distance of wells from dumpsites except at 200m at Ofatedo dumpsite. Ni was not detected at 200m away from Isale-Osun dumpsite. Heavy metal concentrations in control sample were below detection limit except for Cu. The general trend of heavy metal availability in well water at various distances from both dumpsites is Cu>Pb>Cr>Ni>Cd except at 200m away from Isale-osun dumpsite which is Cu>Pb>Cr>Cd>Ni.

All heavy metal concentrations measured except for Cu in control were higher than the limits of[14].

High concentrations of heavy metals measured in soils in this study could be due to indiscriminate disposal of wastes ranging from television tubes, used syringes and batteries that characterized the dumpsites, and their low dispersal. Concentrations of heavy metals measured in the study were higher than previously reported by Adelekan and Alawode[11]. This suggests that these dumpsites could be more polluted with heavy metals. Soils at various distances from the dumpsites have also been rendered unfit for agricultural and recreational purposes because of presence of heavy metals.

Presence of heavy metals in the wells could have come from dumpsites as showed by their concentrations compared to control. This was in agreement with what[3] observed that wells in the vicinity of dumpsites usually contain higher heavy metal concentrations. Large difference between the measured concentrations in water compared with the standards suggests that continuous drinking from these wells could cause hazards because heavy metals bioaccumulate[7]. Some of these heavy metals have been reported to cause vomiting, dizziness, mortality, morbidity, pulmonary disorder and hematological disorder[8]. Pb has no biological role and has been implicated in the alteration of pregnancy and lactation in women[10]. Cd is a known carcinogen[17], thus continuous ingestion of water containing Cd could lead to cancer. Concentrations of Cr in wells at 50m away from both dumpsites are close to the chronic toxic level of 5mg/l suggested by WHO[18]. Ni has been reported to be toxic and cause nasal cancer[10,12].

TABLE 2 : pH and heavy metals concentration (mg/l) in wells around dumpsites

	Cu	Cr	Cd	Ni	Pb	pH
			Isale-Osun			
50m	23.94±6.36	3.57±0.62	0.16±0.03	4.48±0.05	17.51±2.06	8.20±0.14
100m	16.82±1.41	2.38±0.48	0.28±0.01	1.60±0.11	23.13±2.17	7.40±0.06
200m	12.06±3.53	1.76±0.05	0.17±0.02	ND	11.74±1.08	7.03±0.05
			Ofatedo			
50m	18.60±1.70	4.01±0.28	0.14±0.02	3.18±1.41	11.21±1.14	7.14±0.03
100m	16.36±2.82	2.97±0.31	0.12±0.02	1.05±0.06	9.96±1.03	7.10±0.26
200m	13.22±2.12	1.19±0.70	0.09±0.01	1.04±0.02	11.63±0.72	7.20±0.08
Control	0.02	BDL	BDL	BDL	BDL	6.75±0.13
SON	1.00	0.05	0.003	0.02	0.01	6.5-8.5

SON – Standard Organization of Nigeria, 2007

Data evaluation

Pollution indices of heavy metal concentrations in water was also evaluated using heavy metal pollution index (HPI) as described by Ameh and Akpah[13].

HPI is a rating that rates the aggregate influence of individual heavy metal on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance individual quality considerations and defined as inversely proposal to the recommended standard (Si) for each parameter. Water quality and its suitability for drinking purpose can be examined by determining its quality index[16].

It is defined as Wi taken as inversely proportional to the recommended standard (Si) for each parameter. HPI model is given as

$$HPI = \sum Wi\,Qi / \sum Wi \quad (1)$$

Where Qi = subindex of the ith parameter. Wi is the unit weightage of ith parameter and n is the number of parameters considered. The subindex of the parameter is calculated by

$$Qi = \sum Mi\,(-)\,Ii/(Si - Ii) \quad (2)$$

Where is the monitored value of heavy metal of the ith parameter, is the ideal/baseline value of ith parameter; Si is the standard value of ith parameter. The sign (-) indicates the numerical difference of the two values, ignoring the algebraic sign. The critical pollution index value is 100.

Pollution index of heavy metal contamination in all well water samples are presented in TABLE 3. All HPI were higher than 100; the threshold warning. HPI was highest at 100m away from Isale-Osun dumpsite and lowest in the control. This shows that all wells were critically polluted with heavy metals and highest contamination of heavy metal was at 100m away from Isale-Osun dumpsite.

Factor analysis was employed to reveal the contribution and source apportionment of heavy metal pollution in the well water analyzed. It has emerged as a useful tool for better understanding of the relationships among the variables (heavy metal concentrations in this study) and for revealing groups that are mutually correlated within a data body. This procedure reduces the overall dimensionality of the linearly correlated data by using a smaller number of new independent variables each of which is a linear combination of correlated variable[2].

TABLE 3 : Heavy metal pollution indices of different well water analyzed

Location	HPI
Isale-Osun	
50m	127.41
100m	136.39
200m	114.86
Ofatedo	
50m	124.09
100m	121.77
200m	112.26
Control	0.45

The factor analysis results for well water around Isale-Osun and Ofatedo dumpsites are presented in TABLE 4 and 5 respectively. For Isale-Osun, three factors extracted by PCA accounted for 97.23% of total variance (eigenvalue e” 1). F1 with variance 42.25% has high loading of Cd, Cu and pH. This indicates that the release of Cd and Cu are pH dependent. These metals are used in making various electronic components and pigments in plastics and their decay can result in their release into dumpsite soils which afterwards leach into the ground water[2,7]. F2 with variance 32.27% has loading of Cr and Pb. This could result from rusting and decomposition of television and battery scraps in the dumpsite[2,7]. F3 with variance 18.78% has high loading of Ni. This could be as a result of disintegration of tubes containing Ni[2,7].

TABLE 4 : Factor analysis of parameters measured in well water at various distances from Isale-Osun dumpsites

Heavy metal	Component		
	F1	F2	F3
Ni	-0.05	0.08	0.99
Cd	0.81	0.07	0.43
Cu	0.99	0.10	0.05
Cr	-0.01	0.99	-0.09
Pb	0.35	0.97	0.69
pH	0.96	0.04	0.15
% variance	42.25	32.27	18.78
Cummulative %	42.25	78.52	97.23

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization and significant are in bold. Only factors with eigenvalue e”1 shown

For Ofatedo, three factors extracted accounted for 94.84% of total variance (eigenvalue e” 1). F1 with variance 49.51% correlated with Cd, Pb and pH. These metals are pH dependent and their source could have resulted from decomposition of electric and electronic materials in the dumpsites[2,7,19]. F2 with variance 32.27% correlated with Cu and pH. F3 with variance 17.92% has high loading of Cu. This could be from anthropogenic input and decomposition of electric materials in dumpsite soil leaching into the wells[2,7,19].

TABLE 5 : Factor analysis of parameters measured in well water at various distances from Ofatedo dumpsites

Heavy metal	Component		
	F1	**F2**	**F3**
Ni	-0.26	0.44	0.15
Cd	0.92	-0.56	-0.89
Cu	-0.71	0.82	0.94
Cr	-0.58	0.67	0.22
Pb	0.84	0.08	0.16
pH	0.72	0.87	0.46
% variance	49.51	26.41	17.92
Cummulative %	49.51	76.92	94.84

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization and significant are in bold. Only factors with eigenvalue e"1 shown

CONCLUSION AND RECOMMENDATIO

Our study revealed the levels of contamination of heavy metals on the quality of well water and soils at different distances from dumpsites. The concentrations of Cu, Cr, Cd, Ni and Pb determined in water samples analyzed were found to be higher than allowable standards of Standard Organization of Nigeria (SON). Heavy metal indices showed that these wells were critically contaminated by heavy metals. Factor analysis revealed that the major contributors to heavy metal pollution in wells were the dumpsites containing battery and metal scraps. This might not be unconnected to indiscriminate disposal of wastes as access to other waste disposal methods is not available. Since these metals have been found to possess carcinogenic character and no nutritional value, we thus, recommend that children should not be allowed to play on soil in the vicinity of the dumpsite to prevent ingestion, that the well water should not be used for drinking, treated before being used for other domestic purposes and possibly, the wells in the vicinity should be locked up and alternatives provided.

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