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Elemental Levels, Multivariate Statistic and Toxicological Hazards of Ground and Surface Water Surrounding an Open Dumpsite

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ABSTRACT

Water is an essential component of life with a wide range of uses, the mismanagement and the lack of monitoring as posed a lot of reduction on the water quality. The study aims to evaluate the level of elements and the possible health risk in water around an open dumpsite. Water samples were collected from wells, streams and boreholes surrounding the site in Abeokuta, Ogun State, Nigeria. Acid Digestions was done using 20 ml conc. HNO_3 acid solution. Elemental estimation was carried out using Atomic Absorption Spectrometer. Result showed that the level of element in the water sources were lower than the WHO standards except for Fe (0.85 mg/L) which is higher (0.30 mg/L). Pearson correlation revealed that Ca, Na and Mn had a significant positive relationship while and factor analysis reviewed four components with the component 1, having 36% variance and strong loading with Ca, Na and Mn. Hazard Index (HI) values show a downward pattern of P b> Cr > Cd.>Ni > Mn > Ag > Zn and Cr > Cd> Ag > Ni > Mn > Pb > Zn for adults and children respectively which were less than 1. This indicated no significant hazard effect on the population making use of the water. The carcinogenic risk of Pb and Cr for the population was less than the described limit of 1×10^{-6} which indicates a negligible

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carcinogenic risk to the human population. The study shows that the water sources around the open dumpsite posed no hazardous effect on the residents utilizing the water sources for domestic purposes.

***Keywords*:** Element, Toxicological Risk, Ground Water, Surface Water, Dumpsite, Abeokuta

1. INTRODUCTION

Water is an essential component for survival of life on earth, containing minerals, important for humans as well as for aquatic life (Akinbola *et al.,* 2025). It is a major constituent of all living matter, comprising up to two-thirds of the human body (Lawson, 2011). Water quality is the physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more human need or purpose (Umoren *et al.,* 2024a) and is determined by reference to a set of international regulatory standards against which compliance can be assessed. The most common standards used to assess water quality relate to the safety of human contact and consumption (Mary *et al,* 2011).

The quality of water sources is largely affected by natural processes (weathering and soil erosion) as well as anthropogenic inputs (municipal and industrial wastewater discharge). Anthropogenic discharges represent a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climatic conditions (Umoren *et al.,* 2024b). These effects can have a negative impact on the surface water making it unsuitable for established or potential uses (Umoren *et al.,* 2024c). Drinking and domestic water used comes from groundwater and surface water including rivers, lakes and reservoirs and the quality may be impaired as a result of municipal effluents (Chitmanat and Tricichaiyaporn, 2010; Len, *et al.*, 2002; Singh, *et al.,* 2024; Saha, 2018; Gordalla. *et al.,* 2013).

Water quality monitoring and risk assessment has a high priority for the abundance of organic compounds, radionuclides, toxic chemicals, nitrites and nitrates in water due to their possible unfavorable effects on the human health (Famuyiwa *et al.*, 2023; Aluko *et al*., 2024). Contamination of water sources with elements results in the reduction of water quality which in turns poses a human health risk (Varol and Sen, 2018). Chromium, Pb, Cd, As and Hg are known to be highly toxic to humans and aquatic life, causing liver and kidney problems including cancer (Nguyen *et al.*, 2018). Copper, Fe, Zn and Mn are essential elements which play important roles in biological metabolism at very low concentrations (Adesiyan *et al.*, 2018), while a high concentration leads to a hazardous health effect. Lead contamination is known as the major threat to children causing a lifetime effect on exposure, effect which includes distortion in child's growth, nervous destruction, and leading to learning impairments in children (Aluko *et al*., 2024), additionally, high exposure levels may lead to damaged lung, cadmium pneumonitis, bone defects, increased blood pressure and myocardic damage (Famuyiwa *et al.,* 2023; Aluko *et al*., 2024). Cadmium in high concentration is said to be carcinogenic and persistently a cumulative poison (Famuyiwa *et al.*, 2025). Prolong exposure to Cd in humans (adult and children) may lead to kidney problem.

Good numbers of literatures have documented elemental contamination in water sources, including various risk assessment. Although, there are still need to ensure good water quality at every level, with a major concern in low- and medium-income countries which are known to practice a lot of indiscriminate disposal of refuses and wastes (World Bank, 2016). Major communities and individuals in developing countries like Nigeria. Therefore, it is necessary to frequently monitor water quality, used for drinking and domestic purposes. The free common practice way of indiscriminate disposal of municipal waste in developing countries like Nigeria may also cause serious increase in the elemental contamination of these water sources. This study therefore aimed at to investigate the elemental level, sources and toxicological risk of different water sources around an open dumpsite in Abeokuta, Ogun Sate Nigeria.

2. MATERIALS AND METHODS

2. 1. Study Location

The study was carried out in Abeokuta is situated between the latitudes of 70010^{r} N of 7°07'E and 7°14'N, as well as the longitudes of 3°18'E and 3°25'E. The city covers an approximate area of 40.63 km^2. Located within the Nigerian rainforest, Abeokuta lies on top of a basement complex made up of volcanic rocks, which are covered by some layers of sedimentary rock.

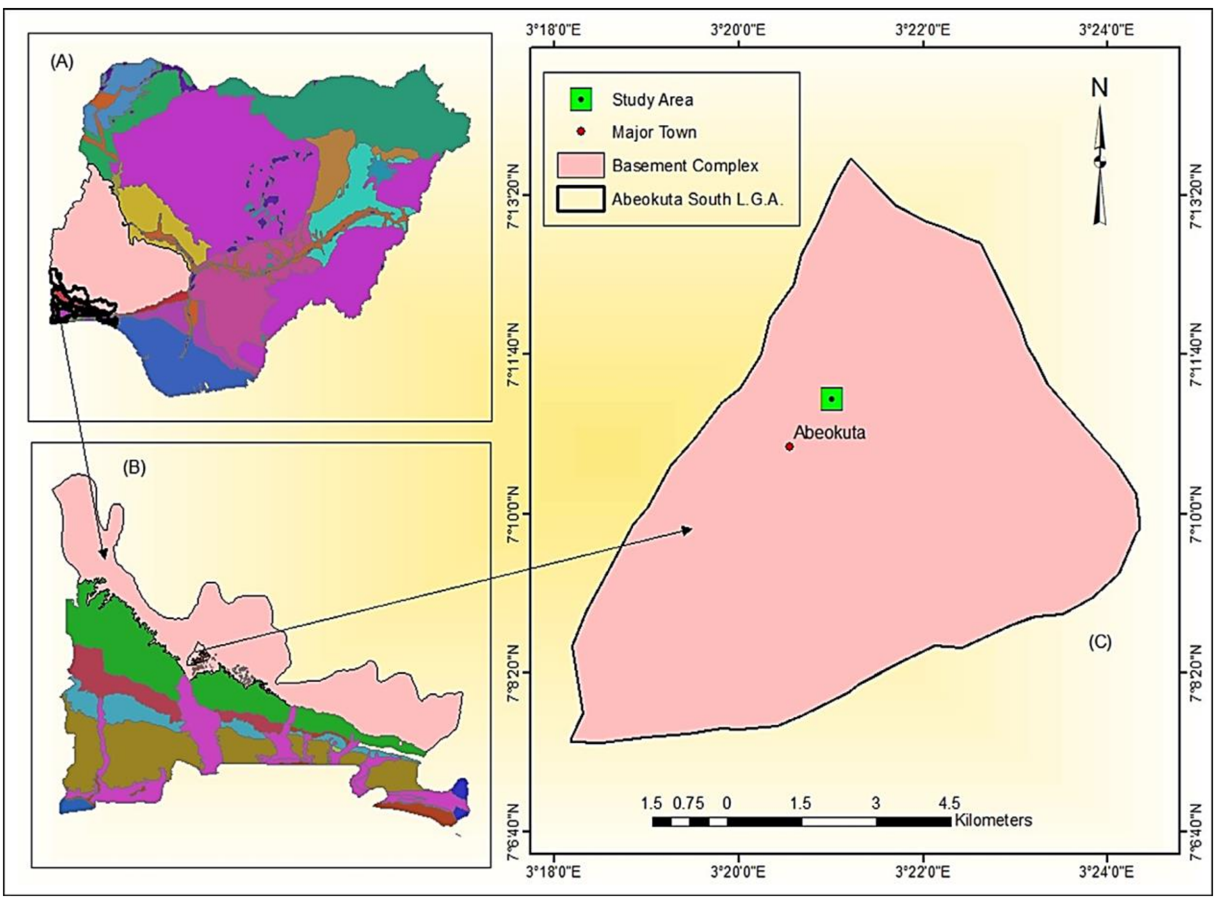


Figure 1. Map of Abeokuta showing Saje Open Dumpsite (Famuyiwa *et al.*, 2025).

Due to the continuous increase in the human population, the amount of solid waste in Abeokuta is rising. Approximately 50% of the daily solid waste produced in the city is collected by the Ogun State Environmental Protection Agency, concerned citizens, and private waste management contractors. Waste is discarded along the streets of the city, with an average waste generation rate of 0.60 kg per person per day. The other 50% is either buried, incinerated, or disposed of in any available land area as well as in lagoons, streams, and drainage systems (Ojo *et al.*, 2022; Famuyiwa *et al.*, 2025).

The Saje dumpsite is located between latitudes 07011.201^{r} N and 07011.480^{r} Ni, and longitudes 003021.001^{r} E and 003022.250^{r}. Covering an area of approximately 119,000 m^2, this dumpsite is the largest solid waste disposal location in Abeokuta. The vegetation and stream flow of the research area are influenced by the climate, which features the wet and dry seasons characteristic of Nigeria's sub-humid and humid regions (Ganiyu *et al.*, 2015; Famuyiwa *et al.*, 2025). The average maximum temperature throughout the year is 32 °C, while the average annual rainfall is 1237 mm. During the dry season, some streams may completely dry up, and the aquifer level is perpetually low. The map of the open dumpsite is shown in Figure 1.

2. 2. Water Sampling, Digestion and Metal Estimation

Water samples were collected from three (3) sources of waters (well, streams and borehole) surrounding Saje dumpsite in Abeokuta. Collected samples were accurately labelled in a universal sample bottle and transported to the laboratory for further analysis. 10 ml of the water sample was measured with a graduated measuring cylinder. The water sample was pour into a 250 ml of sterilized Erlenmeyer flask and treated with 20 ml concentrated Nitric acid (HNO_3). The mixture was allowed to stay on a hot plate at 90 °C for 10 minutes in a fume cupboard until a clear solution was obtained.

The digested water sample was then filtered by Whatman No. 42 filter paper and the filtrate was diluted up to 50 mls with distilled water in a volumetric flask, and then corked for estimation of metal concentration using atomic absorption spectroscopy. Estimation of elements was carried out at the laboratory of the Lagos State Environmental Protection Agency (LASEPA). The elements selected for estimation were using iCE 3000 Model of Atomic Absorption Spectrometer (AAS) Analyzer.

2. 3. Toxicological Risk of Elements

The human health risks assessment of element in water sources surrounding Saje open Dumpsite were evaluated using the ingestion and dermal contact based on the United States Environmental Protection Agency (USEPA) risk assessment method (RAGS, 2018). Exposure based on the average daily dose (ADD) for the elements level in the samples from wells, streams and boreholes were calculated using Equations 1 and 2, slightly modified from the USEPA protocol (RAGS, 2018)

$$ADD_{ing} = {(Cx \times Ir \times Ef \times Ed)}\big/{(Bwt \times At)} \qquad \text{Equation 1}$$

where: ADD_{ing} is the average daily dose through ingestion per kilogram of body weight (Hadzi *et al.*, 2018) Cx is the concentration of toxic elements in the water (mg/L), Ir is the ingestion rate per unit time (L/day), Ed is the exposure duration (years), which is equal to the life expectancy, Ef is the exposure frequency (days/ year), Bwt is body weight (kg), and At is the averaging time (Ed × Ef). For the conversion factor from years to days, 365 days was used.

The water sources (wells, streams and boreholes) assessed in this study are sources of drinking and domestic water for the population surrounding the dumpsite, therefore water ingestion and dermal contact is assumed to be the main pathways for risk assessment (Hadzi *et al.*, 2018). Average daily dose for dermal contact was therefore estimated using the Eqn. 2.

$$ADD_{derm} = {(Cx \times Sa \times Pc \times Et \times Ef \times Cf)}/{(Bwt \times At)} \quad \text{Equation 2}$$

where: ADD_{derm} is the average daily dose through dermal exposure, Sa is the total skin surface area (cm^3), Cf is the volumetric conversion factor for water (1L/1000 cm^3), Et is the exposure duration (h/day), Pc is the chemical-specific dermal permeability constant (cm/h), Ef is the exposure frequency (days/years), Ed is the exposure duration (years), and Bwt is body weight.

The hazard assessment was performed by comparing the calculated contaminant dose from ingestion and dermal exposure routes with the reference dose (RfD) to develop the hazard quotient (HQ) using Equation 3 below. The purpose of the hazard assessment is to evaluate whether an agent poses a non-carcinogenic hazard to humans and under what circumstances an identified hazard may be expressed **(**(Naveedullah *et al.*, 2014).

$$Hazard\ Quotient\ (HQ) = {(ADD)}/{(RfD)} \quad \text{Equation 3}$$

where: HQ represents the hazard quotient through ingestion or dermal contact and RfD is the oral/ dermal reference dose (mg/L/day). Finally, the carcinogenic risks (CRs) of the elements were estimated using Equations 4 and 5 to assess the probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen.

The slope factor (SF) is a toxicity value that quantitatively defines the relationship between dose and response. Potential carcinogenic effect probabilities that an individual will develop cancer over a lifetime of exposure are estimated from projected intakes and slope factor. The range for carcinogenic risk acceptable or tolerable stipulated by the USEPA is 1×10^{-6} to 1×10^{-4} (RAGS, 2018).

$$CR_{ing} = ADD_{ing} \times SF_{ing} \quad \text{Equation 4}$$

$$CR_{derm} = ADD_{derm} \times SF_{derm} \quad \text{Equation 5}$$

where: CRing and CRderm represent the carcinogenic risk due to ingestion and dermal exposure routes, respectively, and SF is the slope factor (mg/kg)/ day. To demonstrate the lifetime carcinogenic risk that the local population may experience, the CR values was calculated for all elements.

2. 4. Data Analysis

Data were analyses using the Statistical Package for Social Sciences (SPSS) Version 21.0 while Microsoft Excel 2013 version were used for graphical presentation. Relationships between elements were determined with the use of Pearson correlation and Factor analysis at 95% significant confident level.

3. RESULTS AND DISCUSSION

3. 1. Elemental Concentration

Water contamination due to high toxic elements concentration is a global challenge to both the environmental expert and individual as a result of the direct impact on human health through drinking and domestic use. The average concentration of Iron presented in Table 1 and Fig. 1, shows that the highest concentration was recorded in stream (1.09 mg/L) followed by well (0.836 mg/L) while the lowest were recorded from Borehole (0.622 mg/L). The overall mean (0.850±0.34 mg/L) of the sources of water possess a Fe concentration higher than the permissible limit for Fe concentration (0.30 mg/L) in water according to World Health Organization Standard (WHO, 2011). Although not considered to be a human health challenge, an excessively high concentration of iron alters the water quality resulting it water turbidity, unpleasant taste and including the cooking utensils and food colorization.

Lead is described to be a potentially hazardous metal to various forms of life by the United State Environmental Protection Agency (USEPA, 2014). The average concentrations of Pb in the water sources for the study represented in Figure 2, shows that well (0.0043 mg/L) has the highest concentration for followed by the Borehole (0.0039 mg/L) while the lowest was recorded from the stream (0.0036 mg/L). The overall mean recorded (0.0039±0.0025 mg/L) were lower than the World Health Organization (WHO) maximum allowable concentration (0.01 mg/L) for drinking water.

This is not in agreement to the work of Aliyu *et al.* (2015) who recorded a mean concentration of 1.01 mg/L of lead in a study of surface water in Kaduna, Northern Nigeria. Nickel is well known trace elements enormously distributed in the environment, being a metal released from the combination of lithogenic sources and man-made activity, with a great input from the combination of both the stationary and the mobile sources. Nickel concentration for the study were recorded to be highest in well (0.0034 mg/L) followed by borehole (0.0021 mg/L) while the lowest were recorded in stream (0.0018 mg/L).

The overall Ni concentrations (0.0024±0.0018 mg/L) for the water sources were lower than the WHO. standard (0.02 mg/L) for metal in water. Concentration of Cadmium (0.00025 mg/l) was recorded to be equal in both Stream and borehole while a higher concentration was recorded in well (0.00033 mg/l). The overall mean (0.00028±0.0002 mg/L) for the sources of water possesses cadmium concentration lower than WHO standard of (0.003 mg/l). The result from the study is in contrast to various cadmium studies in water from Rivers (0.25 mg/L) (Edori *et al.*, 2019), and Osun stream (0.03 mg/l) (Adebanjo and Adedeji, 2019).

Chromium is considered a low moving toxic metal, most especially under moderately redox conditions and at nearly neutral pH. The principal source of Chromium is industrial steel while other sources are amalgams, chrome coating, and color production (Aluko *et al.*, 2024). The concentration of Chromium recovered in the study were highest in well (0.0050 mg/l) followed by stream (0.0020 mg/l) while the lowest is recorded from borehole (0.0017 mg/l). The overall mean concentrations (0.0029±0.0019 mg/l) of the water source were within the WHO standards (0.05 mg/l).

Calcium is an important component of a human diet which is contributing to human physiology. Calcium concentration with the highest value recorded from borehole (0.382 mg/l) followed by well (0.277 mg/l) while the lowest from stream (0.224 mg/l). The overall mean concentrations (0.294±0.127 mg/L) of water sources were extremely lower than the WHO Standard (200 mg/l) in water.

Zinc concentration has an equal value in both stream and well (0.00033 mg/l) while lower concentrations were recorded form borehole (0.00018 mg/l). The overall mean concentrations of (0.0003±0.0002 mg/l) in water sources were lower than the WHO standard of (3.0 mg/L). Sodium concentration has its highest value from borehole (0.233 mg/l) followed by the stream (0.220 mg/l) while the lowest is from the well (0.213 mg/l). The overall mean concentrations of (0.222±0.0504 mg/l) in water sources were extremely lower than the WHO standard of (200 mg/L). Argyria is a medical condition in which silver is deposed on skin and hair, and in various organs due to occupational exposure to metallic silver and its compounds, or the misuse of silver preparations. The concentration of silver in the study has an equal value for both stream and borehole (0.00058 mg/l) while the well (0.00035 mg/l) has a lower concentration.

The overall mean concentrations of (0.0005±0.0002 mg/l) in water sources were extremely lower than the WHO standard of (0.005 mg/L). Manganese concentration has its highest value from borehole (0.00498 mg/l) followed by the stream (0.00305 mg/l) while the lowest is from the well (0.00265 mg/l). The overall mean concentrations of (0.004±0.002 mg/l) in water sources were extremely lower than the WHO standard of (0.05 mg/l). Water source surrounding Saje Dumpsite shows an obvious low concentration of elements (excluding Iron) in comparison to the WHO Guideline for elements in water. The increase in the concentration of Fe might be due to the metallic waste or substances surrounding the source of water. The low concentration observed in stream might also be as a result of its lotic nature. The sources of water also reveal a down trend of well >borehole > stream for majority of the elements.

Table 1. Elemental Concentration in the Water sources with the WHO benchmark.

Elements (mg/L)	Surface	Ground		Mean±SD (mg/L)	WHO Benchmark
	Streams	Hand Dug Wells	Boreholes		
Fe	1.09	0.836	0.622	0.850±0.34	0.30
Pb	0.0036	0.0043	0.0039	0.0039±0.0025	0.01
Ni	0.0018	0.0034	0.0021	0.0024±0.0018	0.02
Cd	0.00025	0.00033	0.00025	0.00028±0.0002	0.003
Cr	0.0020	0.0050	0.0017	0.0029±0.0019	0.05
Ca	0.224	0.277	0.382	0.294±0.127	200
Zn	0.00033	0.00033	0.00018	0.0003±0.0002	3.00
Na	0.220	0.213	0.233	0.222±0.0504	200
Ag	0.00058	0.00035	0.00058	0.0005±0.0002	0.005
Mn	0.00305	0.00265	0.00498	0.004±0.002	0.05

3. 2. Correlation Between Elements

Correlation between elements can give good information about their sources and route in the environment (Rodríguez *et al*., 2008). Pearson's correlation coefficient estimated between elements (Table 2). Reveals that Ca were significantly related to Na ($r = 0.728, p < 0.01$) while Mn were significantly related to Na ($r = 0.667$, $p < 0.05$) and Ca ($r = 0.856$, $p < 0.01$). Significantly related elements indicate similarities in source of origin. The obvious positive relationship between Na, Ca and Mn, shows that these elements are of the lithogenic source.

Table 2. Relationship between elements in different sources of water.

	Fe	**Cr**	**Na**	**Ni**	**Cd**	**Zn**	**Ag**	**Ca**	**Mn**	**Pb**
Fe	1									
Cr	-0.143	1								
Na	0.080	-0.214	1							
Ni	0.112	0.209	0.145	1						
Cd	-0.157	0.243	-0.313	0.300	1					
Zn	0.266	0.241	-0.379	0.534	0.149	1				
Ag	-0.170	-0.207	0.156	-0.234	0.405	-0.414	1			
Ca	0.018	-0.256	**0.728****	0.362	-0.102	-0.239	0.271	1		
Mn	-0.096	-0.431	**0.667***	0.101	-0.091	-0.355	0.370	**0.856****	1	
Pb	-0.167	0.322	-0.565	-0.283	-0.257	0.395	-0.508	-0.532	-0.569	1

** and * Correlation values in bold are significant at $p<0.01$ and $p<0.05$ respectively.

3. 3. Factor analysis

The factor analysis of water parameters is shown in Table 3; the factor was plotted in 3-dimensional rotated space to show their associations (Figure 2).

Table 3. Rotated Component Matrix.

Elements	**Components**			
	PC1	**PC2**	**PC3**	**PC4**
Ca	**0.934**	0.101		
Mn	**0.887**	-0.159	0.129	

Na	**0.878**		-0.129	
Pb	-0.645		-0.566	-0.296
Ni	0.307	**0.896**	0.127	
Zn	-0.360	**0.777**	-0.140	0.169
Cd	-0.204	0.316	**0.858**	-0.178
Ag	0.233	-0.418	**0.768**	
Fe		0.228	-0.101	0.879
Cr	-0.309	0.452		-0.562
Eigenvalue	3.604	1.865	1.662	1.085
Variance %	36.0	18.7	16.6	10.9
Cumulative %	36.0	54.7	71.3	82.2

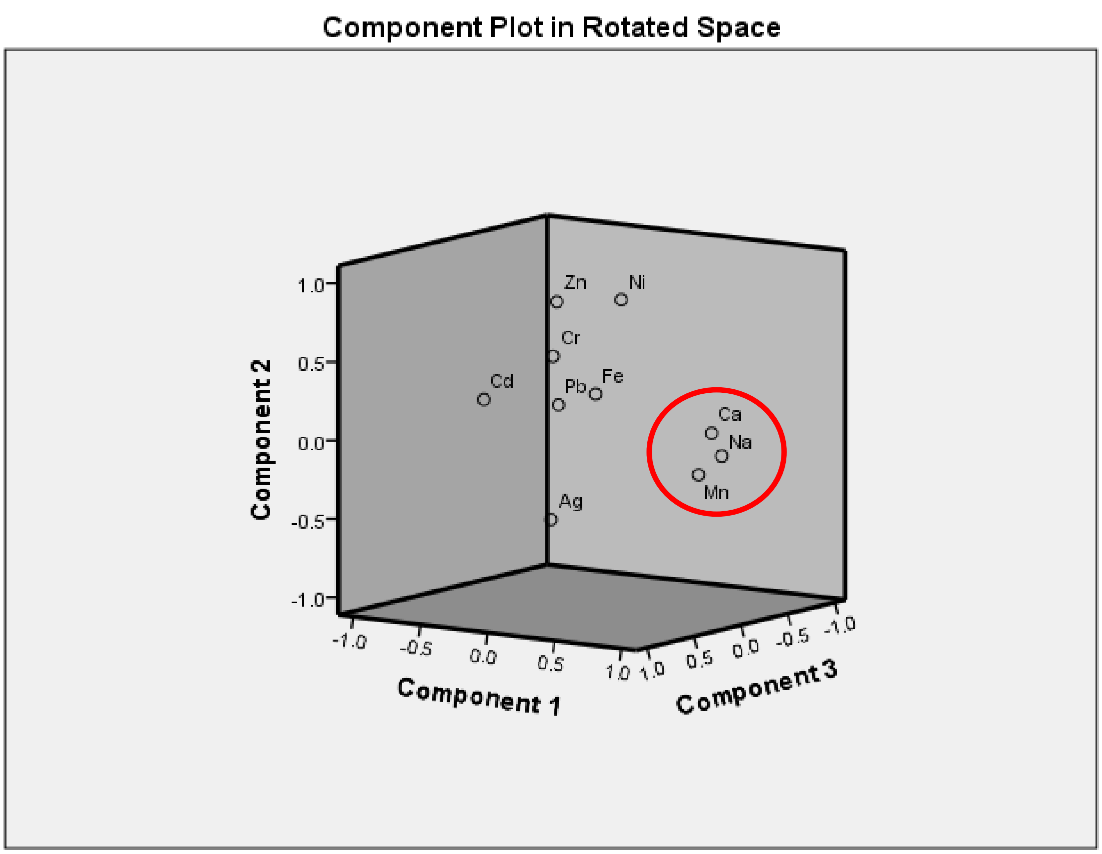


Figure 2. Factor Analysis of water parameters.

Four components make up 82.2% of the overall variance. The first component accounted for 36.0 % of the total variance and a strong loading (Ca, Mn and Na), The second component accounted for 18.7% and a strong loading (Ni and Zn), weak loading (Cd, Fe and Cu) respectively, the third component accounted for 16.6% and a strong loading (Cd and Ag) while the fourth component accounted for 14.8 % and a strong loading with Fe.

3. 4. Toxicological Risk Assessment

The average daily dose (ADD) of elements in water source around the open dumpsite presented in Table 4 shows that ingestion is the major route of elemental exposure to the human population around the dumpsite. The non-carcinogenic and carcinogenic human health risks of the elements (Iron, Lead, Nickel, Cadmium, Chromium, Calcium, Zinc, Sodium, Silver and Manganese) were estimated for both adult (18-70 years) and children (1-17 years) population through the two different routes of potential exposure for water presented in Tables 5. The value of the hazard index (HI) greater than 1 indicates a high probability of adverse human health effects upon exposure (US EPA, 2014).

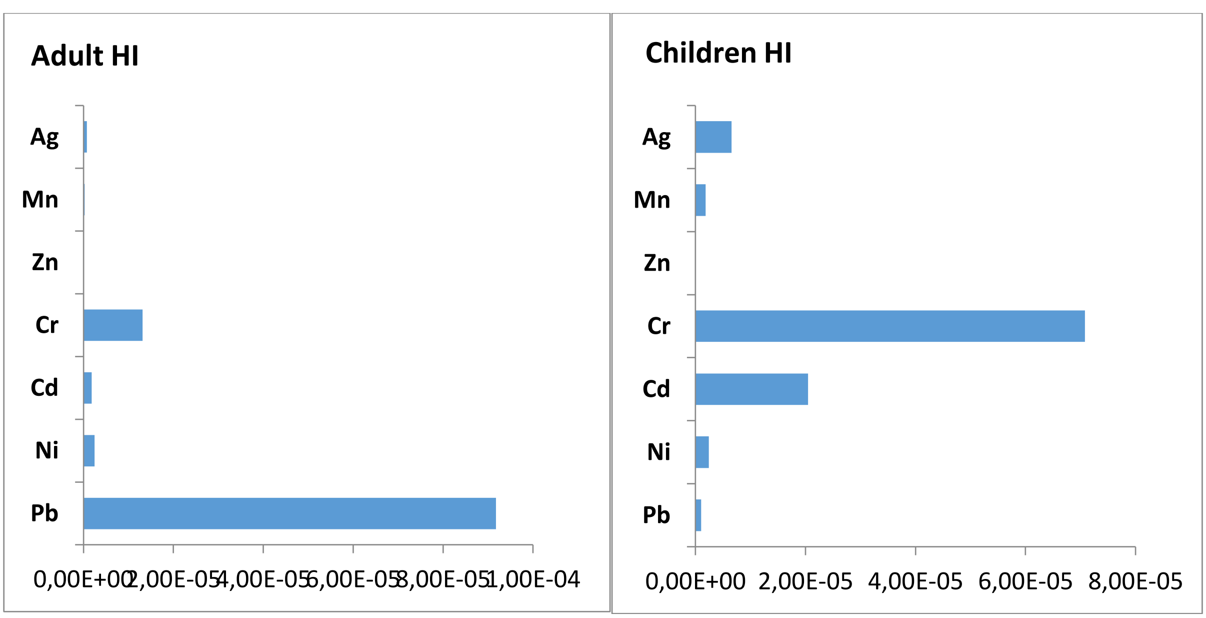
Table 4. Average Daily Dose of Elements.

Elements	**Human Receptors**			
	Adult		Children	
	ADD_{ing}	ADD_{dermal}	ADD_{ing}	ADD_{dermal}
Fe	5.99E-06	1.38E-07	5.59E-05	1.56E-07
Pb	2.75E-08	6.35E-10	2.56E-07	7.18E-10
Ni	1.69E-08	3.91E-10	1.58E-07	4.42E-10
Cd	1.97E-09	4.56E-11	1.84E-08	5.16E-11
Cr	2.04E-08	4.72E-10	1.91E-07	5.34E-10
Ca	2.07E-06	4.78E-08	1.93E-05	5.41E-08
Zn	2.11E-09	4.88E-11	1.97E-08	5.52E-11
Na	1.56E-06	3.61E-08	1.46E-05	4.09E-08
Ag	3.52E-09	8.14E-11	3.29E-08	9.21E-11
Mn	2.82E-08	6.51E-10	2.63E-07	7.36E-10

The Hazard Index (HI) value in the study for the water sources in adult population shows a down trend of Pb > Cr > Cd. >Ni > Mn > Ag > Zn. All investigated metals show a HI value lower than 1 which indicates no significant hazard effect on the adult population making use of the surrounding sources of water. The value also shows that Pb and Cr are the major contributors to exposures through ingestion and dermal contact. Children population shows a down trend of Cr > Cd > Ag > Ni> Mn> Pb > Zn.

Table 5. Non-Carcinogenic and Carcinogenic Risk.

Elements	**Human Receptor**					
	Adult			Children		
	HQ_{ing}	HQ_{dermal}	HI	HQ_{ing}	HQ_{dermal}	HI
Pb	9.17E-05	1.81E-07	9.18E-05	8.53E-07	2.05E-07	1.06E-06
Ni	1.54E-06	8.89E-07	2.43E-06	1.44E-06	1.00E-06	2.44E-06
Cd	1.07E-10	1.82E-06	1.82E-06	1.84E-05	2.06E-06	2.05E-05
Cr	6.80E-06	6.29E-06	1.31E-05	6.37E-05	7.12E-06	7.08E-05
Zn	7.03E-09	1.63E-10	7.20E-09	6.57E-08	1.84E-10	6.59E-08
Mn	2.01E-07	4.65E-09	2.06E-07	1.88E-06	5.26E-09	1.88E-06
Ag	7.04E-07	-	7.04E-07	6.58E-06	-	6.58E-06
Elements	Adult			Children		
	CR_{ing}	CR_{dermal}	CR (Total)	CR_{ing}	CR_{dermal}	CR (Total)
Pb	8.01E-11	-	8.01E-11	1.87E-10	-	1.87E-10
Cr	3.50E-09	-	3.50E-09	8.15E-09	-	8.15E-09



(a) **(b)**

Figures 3(a,b). Adult and Children population hazard index of elements.

Similar to adult population all studied elements shows a HI value < 1, indicating also no significant hazard effect on the children population making use of the water. It also indicates that Cr and Cd are major contributors to exposures through ingestion and dermal contact to the children population (Figures 3a and 3b).

Carcinogenic risk value represented in Table 5, shows Lead (Pb) for the adult population (8.01E-11) and the children population (1.87E-10) respectively while Chromium (Cr) for adults (3.05E-09) were less than 1×10^{-6} which indicates a negligible carcinogenic risk to the local population (Wu *et al*., 2015).

4. CONCLUSIONS

Elemental level, possible source and toxicological risk in water sources (well, stream and borehole) around Saje open dumpsite in Abeokuta, Ogun state, Nigeria was investigated. The result documented the concentration of elements within the WHO standards except for Fe. Pearson and factor analysis reveals a significantly strong positive relationship between Ca, Na and Mn which suggest an emergence from lithogenic origin. Toxicological risk showed suggest a negligible no non cancer and cancer effect on the human population making use of the water. Therefore, the water sources around the open dumpsite posed no hazardous effect on the users.

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