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### Assessment of Heavy Metal Pollution in Kubwa and its Environs, North Central Nigeria

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#### ABSTRACT

*The aim of this study was to assess the extent of heavy metals (Cu, Co, Cd, Fe, Ni, Zn, Pb and Cr) pollution in water and soil around dumpsites in Kubwa and its environs. A total of 28 samples (20 water and 8 soils) were collected within the dumpsite vicinity and away from the dumpsite and analyzed in the laboratory for some heavy metals using Atomic Absorption Spectrometry technique. Physical parameters of groundwater such as pH, Temperature and TDS were measured. The temperature of groundwater ranged from 26.1°C to 28.8°C with a mean value of 27.2°C; pH ranges from 5.42 to 7.53 with a mean value of 6.49 and TDS ranged from 3mg/l to 62mg with an mean value of 21.85mg/l. Concentration of heavy metals (Fe, Cr, Cu, Ni, Pb, Zn and Co) in groundwater ranged from Fe (0.059 to 1.852 mg/l), (Cr 0.071 to 0.973 mg/l), Cu (0.139 to 0.228mg/l), Ni (0 to 0.196 mg/l), Pb (0.009 to 0.283mg/l), Zn (0mg/l to 0.206mg/l) and Co (0 to 0.003mg/l) respectively, while Cd was not detected in groundwater samples. Heavy metal concentration in water is in the decreasing order of; Fe>Cr>Cu>Pb> Ni> Zn>Co>Cd in the study area. Results of geochemical analysis in groundwater were compared with the WHO (35) drinking water guidelines. Samples analyzed indicated some level of groundwater degradation by Pb, Cr, Ni and Fe. On the other hand, the mean concentration of heavy metals in soil of the study area ranged from; Fe (3188.75ppm to 14053ppm), Cr (104.25ppm to 183.75ppm), Cu (67.5ppm to 110.25ppm), Ni (94.75ppm to 164.25ppm), Zn (15.5 ppm to 122.75ppm), Co (25ppm to 73ppm) while Cd was also not detected in soil of study area. The level of heavy metal pollution in soil is in the decreasing order as follows; Fe>Cr>Ni>Cu>Zn>Co>Pb>Cd. Environmental pollution indices such as contamination factor and geo-accumulation index were also used to further assess soil and water pollution. Consequently, results indicate no contamination in groundwater of study area while soil of study area records low to moderate contamination with metals except Cd, Pb and Fe. Correlation coefficient revealed a strong positive correlation of most metals as follows; Co vs Fe (0.867), Cu vs Co (0.938), Zn vs Fe (0.871), Zn vs Co (0.802), Cr vs Fe (0.923), Ni vs Fe, Ni vs Co (0.970), Pb vs Fe (0.817), Pb vs Zn (0.822) except Cd indicating similar source of contamination. This infers a relationship between open dumps and pollution in the area.*

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## INTRODUCTION

For a long time, open dumps are the earliest and most typical way of disposing wastes. Many developing countries fall short of the criterion, in the practice of landfill as a method for solid waste disposal (Mull, 2005; Adewole, 2009).). The production of large quantity of wastes usually discarded indiscriminately on illegal sites, contaminate surface water and affect the quality of the environment. This stems from; rising population, proliferating urban growth, poorly organized industrial setup and anthropogenic activities in Nigeria cities (Adedeji, et al. ,2014), These inferior disposal mechanisms of solid and fluid wastes in the urban areas particularly in developing countries have become a menace to the environment (Amadi, et al., 2010).

The existence of open dumps in developed areas inhabited by millions of people is hinged on the fact that many towns in Nigeria developed without proper forethought. On this account, these dumpsites become an origin for soil and water pollution. Awomeso, et al., (2010) defined solid wastes as materials disposed of after having served its purpose while, Industrial solid wastes are usually upshots of materials from factories and industries with macro scale productions. Solid wastes in most cities in Nigeria comprises agricultural waste, domestic waste, industrial waste, hospital waste, polythene bags, plastics, wood, broken glasses, ash, abandoned automobiles, dust, human and animal waste (Amadi, et al., 2013).

In most developing countries dumpsites are typically unlined hollow pit originating from deserted quarry-sites and burrow-pits without proper impact assessment studies (Amadi, et al., 2010). As the leachate from dumpsites percolates into the groundwater, it reacts with materials that constitute the rocks as it transports through rock fissures.

Water is a valuable resource to all forms of life. Groundwater is defined as the water that occurs underneath the Earth's surface in the pore spaces of soil and in the fractures of rocks. It is an

important part of the water cycle which derives its major source from precipitates (rain, snow, hail etc.) and surface water (rivers, streams etc.) Groundwater quality in Nigeria has for a long time been under threat due to an upsurge in urbanization rate which is marked by high population concentration, environmental degradation and indiscriminate waste disposal, as well as increased agricultural and industrial activities (Ocheri et al., 2014). Kubwa, one of the district areas in the Federal Capital Territory in particular, have been faced with indiscriminate disposals of solid waste over an extended period of time, these practices modifies the natural groundwater chemistry and jeopardizes groundwater quality.

A source of life on planet Earth, soil is a valuable natural resource to man. Without soil, the earth would be as barren as the moon, hence without life (Misra and Mani 2009). Extensively used as environmental indicators, soils are valuable natural resources and their chemical analysis provides critical information on the assessment of anthropogenic activities of an area. They are important sinks for heavy metals and also play a significant role in the remobilization of contaminants under advantageous conditions and interaction between soil and as well as sediments and water (Grosheva et al., 2000; Amadi and Nwankwoala 2013). Lately, there have been rising interests concerning heavy metal contaminations in soils, evidently due to their toxicity and perceived persistency within the aquatic systems and analysis of soil is a useful method of studying environmental pollution with heavy metals. Factors such as the climate, parent rock, and anthropogenic activities can influence the concentration of heavy metals in soil and their impact on ecosystems (Jia, et al., 2010).

Heavy metals are described as those metals with specific gravity higher or more than 5g/cm. some common heavy metals include; Nickel (Ni), Iron (Fe), Chromium (Cr), Lead (Pb), Copper (Cu), and Cadmium (Cd) Heavy metals are natural components of the Earth's crust. Occurring naturally in the ecosystem in various

concentrations, they can neither be degraded nor destroyed. Recently, anthropogenic sources, i.e. pollution from the activities of humans, have introduced some of these heavy metals into the ecosystem (Oluyemi et al., 2008). Metals and their compound are indispensable to the industrial, agricultural and technological development of any country (Amadi et al., 2016). Increase in industrial activities such as mining, tanneries, electronics, electroplating and petrochemical have resulted to heavy metal pollution of the environment. The presence of heavy metals in the environment is of great ecological significance due to their toxicity at certain concentrations, translocation through food chains and non-biodegradability which is responsible for their accumulation in the biosphere (Awofolu, 2005).

Heavy metals concentration in the environment may be attributed to geological factors however, human activities greatly contribute to the mineral composition of soils, crops and water. The recent population and industrial growth has led to the rapid production of domestic, industrial and municipal wastes which are indiscriminately dumped in landfill and water bodies without treatment (Olayiwola, 2017). Heavy metals such as cadmium zinc, copper, lead, and nickel among others have been established to be present in municipal waste, when they are leached out from the dumps; they end up in the soil as sinks.

Heavy metals such as Iron and Nickel are necessary for the survival of all forms of life albeit, in low concentrations (Leah and Johnny 2014). However heavy metals like Lead, Cadmium and Mercury are lethal to living organisms even in low concentrations, which results in anomalies in metabolic functions of the organism especially in greater quantities (Manahan, 2001). The environmental problem with heavy metals is that

they are unchanged during breakdown of organic wastes and have lethal effects on living organisms when they surpass a certain concentration (Olayiwola et al., 2017). Indiscriminate disposal of wastes has been found to be the greatest threat to water and soil quality, it is therefore crucial to examine the environmental impact of improperly disposed wastes and what potential impacts it has on the people living within its vicinity.

### 1.1 Study Area Description

Kubwa (Fig.1.1) is a residential district in Bwari, one of the area councils in the Federal Capital Territory of Nigeria. It lies between latitude 8° 25' N and 9°20' N and longitude 6°45' E and 7°39' E, part of Abuja Sheet 186S.E. It is a major suburb within the metropolitan area of the Capital Territory and is densely populated. The study area is located at the extreme NE of the Federal Capital Territory. It is characterized by hills and valleys. Hills occur either as clusters or form long ranges. It is predominantly high land with many peaks over 760m above sea level.

The drainage pattern generally varies from trellis to dendritic. The area is drained by many rivers in and around Abuja such as River Gwigwo and River Usman while other smaller seasonal streams form the tributaries and drain the study area. These rivers depend on rainfall for their recharge. The study locations have two main seasons; rainy (April to October) and dry (November to March). The high altitude and undulating terrain of the territory acts to provide a regulating influence on its weather. During the dry season, the typical month being March, the temperature varies between 30°C to 37°C. During the rainy season, temperatures drop considerably due to dense cloud cover. Study area is located within the Guinea Savannah, with vegetation characterized by thorn bushes, trees, herbs and shrubs.

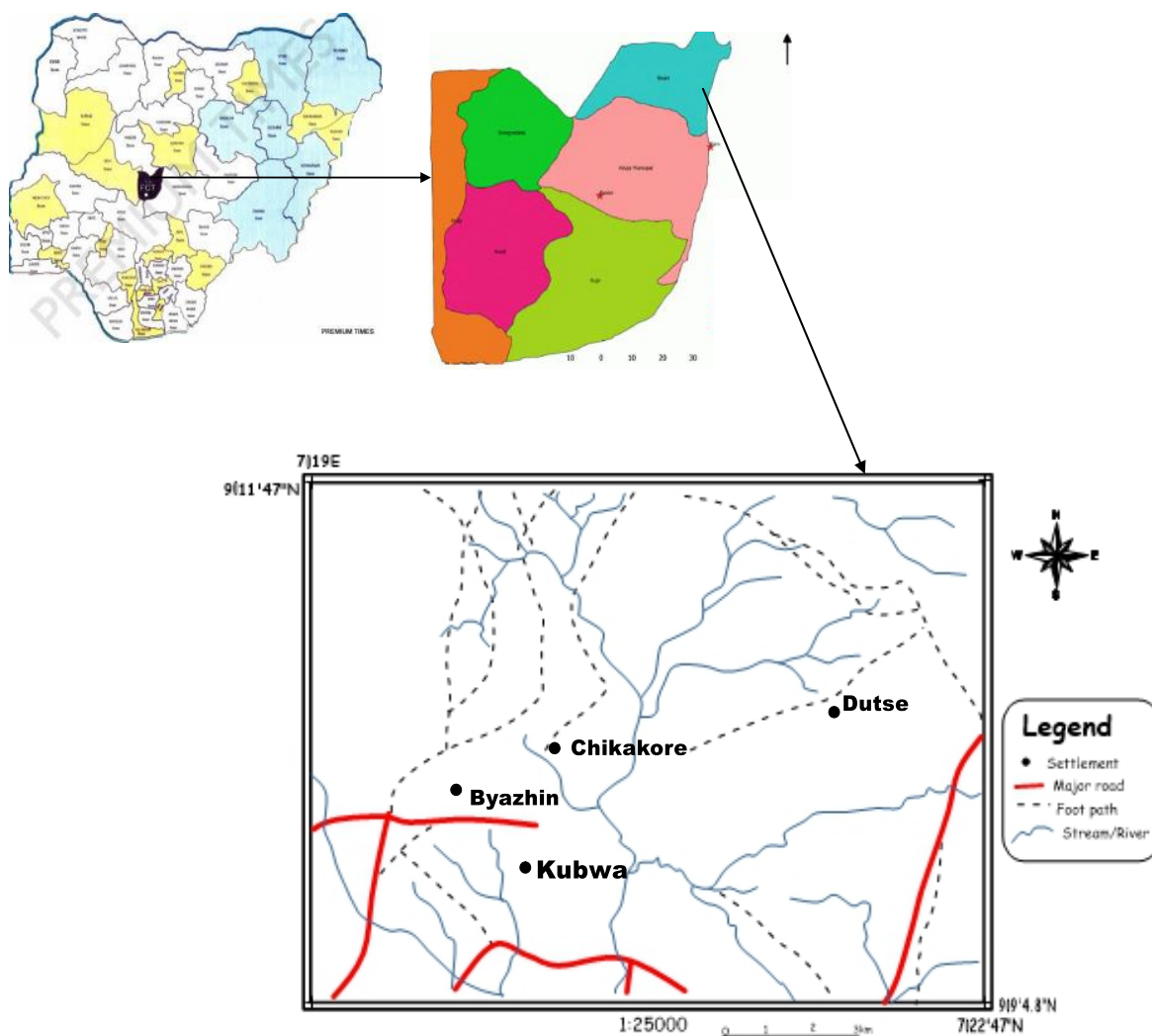


Figure 1.1 Location map of study area

## 2. METHODOLOGY

### 2.1 Mapping and sample collection

The study area was mapped and samples of soil and water were collected. A total of 28 samples (8 soil and 20 water samples) were collected around the dumpsites for this study while two samples were collected far away from the dumpsites which served as control samples. The samples collected were stored in sterile bottles and plastic bags respectively, after which they were transported to the laboratory for analyses. Both the water and soil samples were analyzed for heavy metal concentration by Atomic Absorption Spectrophotometer (AA500 PG

instrument England) at NIGERIA Geological Survey Agency (NGSA) laboratory, Kaduna Nigeria.

### 2.2 Environmental Pollution Indices Used

Pollution indices are widely considered a useful tool for the comprehensive evaluation of the degree of contamination. Moreover, they can have great significance in the assessment of soil and quality and prediction of ecosystem. When assessing water quality, priority is first given to parameters known to be of concern to human health and potability, when present in significant concentrations in the water source

(Ponsadailakshmi et al., 2018). The heavy metal concentration in water was compared with the WHO guideline values for drinking water (WHO, 2011). However, pollution indices such as contamination factor, geo-accumulation index were also used to evaluate heavy metal concentration in soil. These indices help in assessing the presence and extent of anthropogenic contaminants in soil. Results of soil analysis were further compared with Wedepohl, (1995) as well as Taylor and McLennan, (1995) recommended elemental average crustal abundance and background values.

Contamination factor (CF) quantifies the degree of contamination relative to either average crustal composition of respective metal or to the measured background values from geologically similar and uncontaminated area (Tijjani et al., 2004).

It is expressed as:

$$CF = C_m/B_m \quad i$$

Where,  $C_m$  is the concentration of metal in soil and  $B_m$  is the background concentration value of metal, either taken from literature (average crustal abundance) or directly determined from a geologically similar material.

CF can be classified into four groups (Pekey et al. 2004), [13] as follows:

$CF < 1$  – Low contamination Factor

$1 < CF < 3$  – Moderate C.F

$3 < CF < 6$  – Considerable C.F

$6 < CF$  – Very high C.F

The geo-accumulation index to assess the metal pollution load (Hakanson, 1980) is expressed as:

$$I_{geo} = \log_2 \left( \frac{C_m}{1.5 \cdot B_m} \right) \quad ii$$

Where,  $C_m$  = metal concentration of study area

$B_m$  = Background concentration of metal (Taylor, 1964).

While 1.5 is a factor for possible variation in the background concentration due to lithological differences.

$I_{geo}$  is classified into five descriptive classes as follows:

$< 0$  = practically uncontaminated,

$0 - 1$  = Uncontaminated to slightly contaminated,

$2 - 3$  = moderately to highly contaminated,

$4 - 5$  = highly to very strongly contaminated,

$> 5$  = very strongly contaminated.

### 3. GEOLOGY OF THE STUDY AREA

The study area is part of the Precambrian Basement Complex. The rocks in the study area comprise mostly granite, gneisses, mica schist, hornblende, felspathic schists and migmatites. The rocks are jointed and highly fractured showing essentially two fracture patterns, NE-SW and NW-SE. These fractures control the drainage and flow patterns of rivers in the area. The gneisses outcropping as fine to medium grained granite gneiss cover a large percent of the surface area.

The rocks are occasionally overlain by superficial deposits that include laterites, soils and alluvium deposits. Gneiss covered about 50% of the western part of the study area while the other half is dominated by the porphyroblastic granite-gneiss, porphyritic granite gneiss, gneiss and schist. About 30% is occupied by the porphyritic granite gneiss and about 10% to the north east is the porphyroblastic granite-gneiss. The schist occupied the center of the area about 10% and surrounded by the gneiss and porphyritic granite gneiss (Figure 3.1).

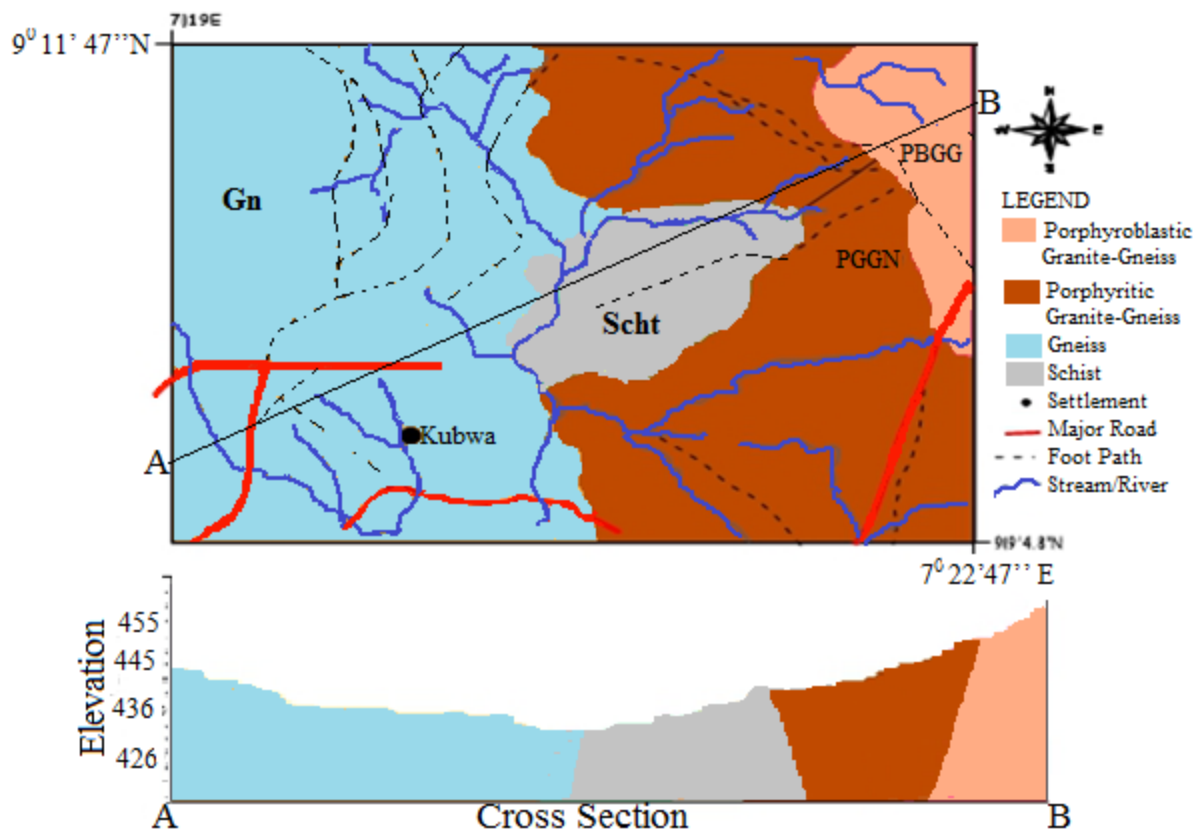


Figure 3.1 Geological map of study area

#### 4. RESULTS AND DISCUSSION

##### 4.1 Water Quality

Table 1 shows the physical parameters measured in groundwater. Generally, all the measured physicochemical parameters (i.e. temperature, and TDS) were all within the acceptable WHO guideline values for drinking water except pH. Values of pH measured at the study wells ranged from 5.42 to 7.53 (Table 1). The pH value of the analyzed samples indicates that, the groundwater under study is slightly acidic, soft

and capable of corroding or leaching metal ions such as iron, copper, lead, and zinc from the aquifer. Generally, heavy metals of various concentrations were measured in samples of study area. A comparison of the concentration of heavy metals indicates that Cu, Co, and Zn were below the WHO (2011) guidelines values for drinking water, Cr, Pb, Ni and Fe were above the guidelines while Cd was not detected in water samples.

Table 4.1: Physical Water Quality Parameters Data

Sample No.	Sample ID	pH	Temp (°C )	TDS (mg/H)
1	HDW1	6.81	28.7	084
2	BH1	7.53	26.9	045
3	BH2	6.77	26.7	063
4	HDW2	6.54	28.7	095
5	BH3	6.19	26.1	054
6	BH4	7.09	26.2	069
7	HDW3	6.08	26.8	115
8	BH5	6.43	26.6	042
9	HDW4	5.72	26.8	088
10	BH6	6.30	27.0	051
11	HDW5	5.42	27.7	102
12	HDW6	6.14	26.5	097
13	BH7	6.45	27.4	038
11	BH8	6.75	27.4	052
15	BH9	6.40	26.4	070
16	BH10	6.39	28.8	067
17	BH11	6.55	27.0	080
18	BH12	6.57	28.1	069
19	HDW7	6.40	27.7	134
20	HDW8	7.27	27.3	109

Table 4.2: Statistical summary of groundwater data from Kubwa and Standards

Parameters	Minimum	Maximum	Mean	Standard
(mg/L)				WHO (2011)
Fe	0.059	1.852	0.713	0.300
Cd	0.000	0.000	0.0000	0.003
Co	0.000	0.003	0.0008	0.005
Cu	0.139	0.228	0.175	1.000
Zn	0.000	0.206	0.0706	3.000
Cr	0.071	0.973	0.366	0.050
Ni	0.000	0.196	0.0974	0.020
Pb	0.009	0.283	0.119	0.010
pH	5.42	7.53	6.49	6.5-8.5
Temp.	26.1°C	28.8°C	27.2°C	ambient
TDS	3	62	22	500



The statistical summary of laboratory analysis results of the heavy metals in soils around Kubwa dumpsites are contained in Table 4.3, while Table 4.4 shows the average crustal abundance of the

analyzed metals according to Wedepohl, (1995) as well as Taylor and McLennan, (1995). The metals (Cr, Cd, Pb, Cu, Zn, Co, Ni, and Fe) were used in this study.

**Table 4.3: Statistical Summary of Heavy Metals Concentration in ( ppm)**

Parameters	Min.	Max.	Mean
Fe	3188.750	14053.000	8079.594
Cd	ND	ND	ND
Co	25.000	73.000	46.281
Cu	67.500	110.250	91.906
Zn	15.500	122.750	66.375
Cr	104.250	183.750	139.219
Ni	94.750	164.250	122.688
Pb	3.000	6.2500	4.6562

**Table 4.4: Mean concentration of metals in soils around Kubwa dumpsites compared to their Average Crustal Abundance (Wedepohl, 1995); Taylor and McLenna, (1995)**

Parameters	Mean conc. (ppm)	Guideline for maximum allowable limit in upper continental crust			
		Wedepohl, 1995	Status	Taylor and McLenna(1995)	Status
Fe	8079.594	30890ppm	Low	70700ppm	Low
Cd	ND	0.102ppm	Low	0.098ppm	low
Co	46.281	11.6ppm	High	10ppm	High
Cu	91.906	14.3ppm	High	25ppm	High
Zn	66.375	52ppm	High	71ppm	Low
Cr	139.219	35ppm	High	35ppm	High
Ni	122.688	18.6ppm	High	20ppm	High
Pb	4.6562	17ppm	Low	20ppm	Low

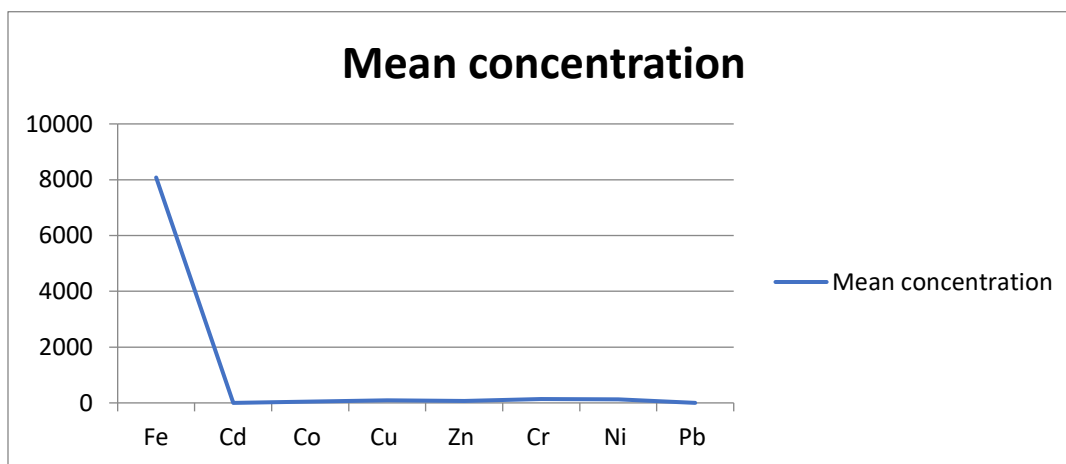


Figure 4.1: Mean concentration of heavy metals from dumpsites



**Table 4.5: Metal contamination factor and geo-accumulation index of metals in soil from the dumpsite**

Parameters	Cm	Bm	CF	Igeo	Overall summary of contamination level
Fe	8079.594	56,300	0.14	0.02	Low contamination
Cd	ND	0.2	ND	ND	Uncontaminated
Co	46.281	25	1.85	0.37	Slightly contaminated
Cu	91.906	55	1.67	0.33	Slightly contaminated
Zn	66.375	70	0.94	0.19	Low contamination
Cr	139.219	100	1.39	0.27	Slightly contaminated
Ni	122.688	75	1.63	0.32	Slightly contaminated
Pb	4.65	12.5	0.3	0.07	Low contamination

CF- contamination factor; Geol- geo-accumulation index;

Cm- mean concentration of the metal in the soil;

Bm- average crustal abundance (background value) in an uncontaminated soil (Taylor, (1964).

**Table 4.6: Correlation Matrix for both water and soil**

	Iron	Cobalt	Copper	Zinc	Cadmium	Chromium	Nickel	Lead
Iron	1.000							
Cobalt	0.867	1.000						
Copper	0.924	0.938	1.000					
Zinc	0.871	0.802	0.863	1.000				
Cadmium	0.000	0.000	0.000	0.000	1.000			
Chromium	0.923	0.943	0.987	0.845	0.000	1.000		
Nickel	0.906	0.970	0.978	0.796	0.000	0.975	1.000	
Lead	0.817	0.906	0.925	0.822	0.000	0.922	0.912	1.000

## 4.2 Heavy metals in soil

The mean concentrations of the elements analyzed were compared with maximum allowable limits in the upper continental crust. The classification by Wedepohl, (1995) as well as Taylor and McLennan (1995) indicate that the concentration of cobalt, copper, nickel and chromium were high in soils from Kubwa dump sites. However, zinc was classified high based on Wedepohl, (1995) and low based on Taylor and McLennan (1995) classification model.

The concentration of Iron ranged from 3188.75ppm to 14053ppm with an average value of 8019.594ppm. Iron concentration in the study area were far below the limits by Wedepohl (1995) and Taylor and McLennan (1995) indicating no pollution from Iron (Table 4.5). Samples 4 and 8 with the highest concentration shows that input of Iron to the study area must have been host rocks and the action of natural agents of erosion and transportation. The supply

of Iron into the study area is principally from the source rocks from which the soil was derived as well as transport mechanism and overall geochemical history (Amadi et al., 2017). This correlates with the CF and Igeo values that suggest low contamination of the study area.

The average crustal abundance of cadmium is 0.102ppm by Wedepohl (1995) and 0.098ppm by Taylor and McLennan (1995). Cadmium was not detected in all samples analyzed. This implies that the soil from the study area is uncontaminated with respect to cadmium. Uses of cadmium are as pigments, stabilizers for polyvinyl chloride (PVC), in alloys and electronic compounds. Because cadmium is extremely toxic, the use of soil high in cadmium in form of manure for the cultivation of vegetables and other food crops could engender pernicious health effect to consumers such as renal disease and cancer (Gorenc et al. 2004).

The concentration of cobalt in the analyzed samples ranged from 25ppm to 73ppm with an

average concentration of 46.28ppm. All samples analyzed were above the crustal abundance of 11.6ppm by Wedepohl (1995) and 10ppm by Taylor and McLennan (1995). Soil contamination of cobalt in the study area may be attributed to anthropogenic activities like discarding cobalt containing materials at the dumpsite. Cobalt is widely used as alloys for steels, electroplating, fertilizer, porcelain and glass making. Cobalt is carcinogenic and the health effects of cobalt include bronchitis, dermatitis and inflammation of the tissue (Aboud and Nandini 2009). Calculated CF and Igeo values indicate that these sampling stations are moderately contaminated and slightly contaminated respectively by cobalt. The concentration of copper in the analyzed soil samples varied from 67.5ppm to 110.25ppm with an average value of 91.9ppm.

All samples analyzed were exceedingly higher than the acceptable limits of 14.3ppm by Wedepohl (1995) and 25ppm by Taylor and McLennan (1995). This confirms the CF and Igeo values that suggest moderate contamination and slight contamination respectively. Contamination of copper in soils of study area could stem from weathering of copper-rich rocks introduced to the environment in the course of quarry activities. Copper is the most used metal in the world (VCI, 2011). It is broadly used in electrical wiring, roofing, cooking utensils and piping. Exposure to high concentration of copper can lead to health problems such as pulmonary oedema, lung carcinoma and transitory fever (Pascual, et al., 2004).

Zinc concentration varied from 15.5ppm to 122.75ppm with an average value of 66.37ppm. Although zinc occurs naturally in soil, the mean concentration of zinc slightly exceeds the acceptable limits of 52ppm by Wedepohl (1995). The continuous rise of zinc in soil, stems from anthropogenic additions. Zinc concentration in the soil may also be a function of the composition of parent rock as well as activities such as mining (Leah and Johnny 2014). Most zinc is introduced into the environment during industrial activities such as mining, waste combustion and steel processing. It is a trace element that is essential

for human health as shortages of zinc can cause birth defects (Wuana and Okieimen 2011). However, elevated concentration of zinc leads to phyto-toxicity in soil, nausea, vomiting, severe anemia and renal failure in man (Aboud and Nandini 2009). The CF and Igeo values records low contamination of soil by zinc

The concentration of chromium ranged from 104.25ppm to 183.75ppm with an average value of 139.219ppm. The mean concentration is beyond the acceptable limits of 35ppm by Wedepohl (1995) and Taylor and McLennan (1995). Chromium is carcinogenic by inhalation and corrosive to tissue (Grosheva et al., 2000; Aboud and Nandini 2009).

The distribution of nickel concentration in the studied samples ranged from 94.75ppm to 164.25ppm with an average concentration of 122.69ppm. Nickel is found to be above the acceptable limits of 18.6ppm and 20ppm of Wedepohl (1995) and Taylor and McLennan (1995) respectively. These high values observed signify contamination in those locations. The CF and Igeo values indicate slight contamination. The major sources of nickel contamination in the soil are metal plating industries, combustion of fossil fuels, nickel mining and electroplating (Khodadoust, et al., 2004).

The concentration of lead in the study area ranged from 3ppm to 6.25ppm. The average concentration of lead at 4.65ppm is below the acceptable limits of 17ppm by Wedepohl (1995) and 20ppm by Taylor and McLennan (1995) suggesting that soil in the study area is yet to be contaminated with Pb. Although, the values of Pb in the area is low it is known to be toxic and its effects have been more extensively reviewed than the effect of other trace metals. Lead can cause serious injury to the brain, nervous system, red blood cells and kidney (Baldwin and Marshall 1999). CF and Igeo values indicate low concentration.

## 5. CONCLUSION

This study assessed the impact of dump sites in water and soil of the study area. In ground water of the study area, the physico-chemical

parameters compete favorably with the standards except for Cr, Ni, Pb, and pH where in isolated locations was above the acceptable drinking water standard. The pH of groundwater in certain locations is slightly low, signifying marginally acidic water; this condition enhances the precipitation and bio-accumulation of heavy metals in water.

Heavy metal concentration in water is in the decreasing order of; Fe>Cr>Cu>Pb> Ni> Zn>Co>Cd in the study area. Correlation analysis applied to dataset suggests a strong positive correlation for most metals (Fe, Co, Cu, Zn, Cr, Ni and Pb) except Cd. This further suggests that metals found to be present in both water and soil probably emanates from similar source.

Furthermore, soil collected around the dumpsite, as expected is polluted with Co, Cu, Zn, Cr and Ni. The levels of heavy-metal pollution in soil is in the decreasing order as follows; Fe>Cr>Ni>Cu>Zn>Co>Pb>Cd. Results of computed contamination factor and geo-accumulation indices generally indicate low contamination in soil of the study area. This indicates a link between open dumps and pollution; hence, there is the need to regulate it to control the pollution and protect the water resources from further pollution and its associated health implications on the populace.

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