Heavy Metal Levels of Soil Samples Collected From a Major Industrial Area in Abeokuta, Southwestern Nigeria

Temitope M. Osobamiro[*], Oluwafemi Awolesi[*], Oluwatobi M. Alabi[*], Abiodun Y. Oshinowo[*], Mujeebat A. Idris[*], Farouq A. Busari[**]

[*]Department of Chemical Sciences, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria.
[**]Department of Chemistry, University of Ibadan, Ibadan, Oyo State, Nigeria.

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Abstract- Industrialization has propagated the incidence of heavy metal contamination in the environment, and several life-threatening diseases which people suffer from today culminate from the impact of this group of metals. The extent of certain industrial activities on soil quality in terms of heavy metals must therefore be investigated. This study aims to examine the levels of five metals (Cd, Zn, Cu, Cr, and Pb) in soil samples collected from industrial area of Abeokuta, Southwestern Nigeria. Soil samples were obtained from five different industrial sites known for the following activities: metal oxide production, ceramics production, mattress manufacturing, galvanizing, and paint production. These industries were coded Site A, Site B, Site C, Site D, and Site E, respectively. Two control samples coded Control 1 and Control 2 were obtained from locations in the city distant from major pollution sources. The concentrations of heavy metals in the samples were determined using Atomic Absorption Spectrometer (AAS) after digestion using acid mixture. The range of mean concentrations of each metal in test samples were between (12.40 - 17.20 mg /kg) Cr, (N.D - 2.00 mg/kg) Cd, (19.80 - 285.80 mg/kg) Pb, (9.65 - 69.90 mg/kg) Cu, and (174.70 - 2500.40 mg/kg) Zn. The trend shows that Zn>Pb>Cu>Cr>Cd. Mean levels of Cr were significantly below the World Health Organization (WHO) recommended limit. Except in Site A and Site D, mean levels of Cd were below the set limit. Pb recorded mean levels far above the set limit in Site A, Site B and Site D. Cu levels were above set limit in Site A and Site D; mean levels of Zn were above the set limit. The values of all metals in test samples were significantly higher than those in control samples suggesting possible mobility of metals from industrial sites to residential areas through leaching and runoffs.

Keywords- Contamination, Heavy metals, Industrial sites, Soil.

I. Introduction

Among the most common environmental pollutants are a group of metals known as heavy metals whose detrimental effects on the health of plants, animals and humans cannot be overemphasized. Although their occurrence in soils originates from natural and anthropogenic sources, industrialization coupled with urbanization has enormously influenced their widespread.
Heavy metals, when present in soils, can inhibit the biodegradation of organic contaminants, posing a great risk and hazards to biota [9][12][13]. Since soil on its own has the capacity to immobilize introduced chemicals, these toxicants accumulate over time in it, and are released into the streams, rivers and seas [7][10]. They end up through the food chain in man- via accumulation in marine organisms and plant uptake- thereby causing various toxicological manifestations [4][7].

Literature indicates that certain industrial activities including metallurgy and paint production contribute to high concentrations of these metals in soil, and prevalent metals found at contaminated sites include lead (Pb), arsenic (As), chromium (Cr), zinc (Zn), cadmium (Cd), copper (Cu), and mercury (Hg) [4][15]. Much work has been done on heavy metal pollution problems in Nigeria but no work currently exists on examining heavy metal levels in an industrial area with an array of industries in the same geography distinctively focused on the manufacture of different chemicals or products. This study is aimed at determining the levels of five (5) trace metals namely cadmium, copper, zinc, lead, and chromium in soil samples collected from an industrial area in Abeokuta, Southwestern Nigeria. Examining the levels of these metals will serve as a reference for future studies, and ultimately inform the authorities in environmental management on the risk of exposure of the inhabitants to these toxic metals.

II. EXPERIMENTAL SECTION

A. Sampling sites and Sample collection

The study area is located within latitude 6^{o}N and 8^{o}N and longitude 2.5^{o}E and 5^{o}E. Soil samples were obtained randomly from five locations within the vicinity of each industrial site in Abeokuta, Ogun State, Nigeria. Two (2) control soil samples were taken from locations within the city distant from sources of major pollution. At each sampling point, the topsoil layer was scraped off while portions of soil were scooped within a depth of 5 - 15 cm using a plastic spoon. The collected portions were subsequently combined to give a composite of each individual sample. The soil samples were labeled accordingly and stored in a polythene bag. Table 1 shows the sampling details.

Table 1: Sample Information

Code	Site
Site A	Metal-oxide manufacturing industry
Site B	Ceramics manufacturing industry
Site C	Mattress manufacturing industry
Site D	Galvanizing industry
Site E	Paint manufacturing industry
Control 1	Control
Control 2	Control

B. Sample Preparation

The samples were oven dried at 105^{o}C for three hours and left to cool at room temperature before crushing using mortar and pestle, then sieved with a 0.02 mm sieve mesh, and stored in polythene bag. 5g of each sample was weighed and put into pre-washed and oven dried standard flask, digested and labeled appropriately.

C. Sample Digestion

Each soil sample was transferred into 250 ml standard flask, and diluted with 50 ml of 2M HNO_3, and then heated in the sand bath for about 3 hours at a temperature of 90^{0}C to 100^{0}C. The digested solution was evaporated to near dryness, and allowed to cool at room temperature. It was then filtered into standard flask, and diluted to 100 ml with distilled water, and shaken vigorously. Subsequently, it was poured into 120 ml plastic bottle prior to aspiration into the Atomic Absorption Spectrophotometer (Perkin Elmer) to determine the metals. Settings and operational conditions were followed with respect to the manufacturer's guidelines.

D. Quality Control

Duplicate samples were analyzed to check for precision of the instrument and method used. The standard calibration curves for all five parameters were obtained using a series of varying concentrations. All calibration curves were linear with correlation coefficients close to 1.

III. RESULTS AND DISCUSSION

Average concentration of metals in soil samples collected from each site was evaluated. The results are presented in Table 2, and graphically illustrated and distinguished in Figures 1 - 5. Cr ranged from 12.20 mg/kg to 17.20 mg/kg, Cd ranged from nil to 2.00 mg/kg, Pb ranged from 19.80 mg/kg to 783.30 mg/kg, Cu ranged from 13.70 mg/kg to 69.90 mg/kg, Zn ranged from 174.70 mg/kg to 2500.40 mg/kg. For Control 1 and Control 2, mean concentrations were 14.30 mg/kg and 15.70 mg/kg for Cr, nil and 0.20 mg/kg for Cd, 36.70 mg/kg and 15.10 mg/kg for Pb, 9.65 mg/kg and 8.50 mg/kg for Cu, 181.10 mg/kg and 62.30 mg/kg for Zn, respectively. World agencies including World Health Organization (WHO), European Regulatory Standards (EURS) and United States

Environmental Protection Agency (USEPA) have set limits for heavy metals. The maximum permissible limit by WHO for soil samples are: chromium 100 mg/kg; cadmium 0.8 mg/kg; copper 36 mg/kg, zinc 50 mg/kg, and lead 85 mg/kg [14]. In an assessment of heavy metals around major industrial areas in Northwestern Nigeria, values of Pb recorded were in the range 273.10 mg/kg to 523.00 mg/kg; Cd in the range 0.10 mg/kg to 0.70 mg/kg; and Cr in the range 21.10 mg/kg to 92.70 mg/kg. A similar research carried out by Adesuyi et al. (2015) recorded mean levels of: Zn as 141.06 mg/kg which is below the levels recorded from test samples in this study; Cu as 131.70 mg/kg which is higher than values obtained from test samples in this study; Pb as 59.80 mg/kg which is significantly lower than mean levels obtained from Site A, Site B and Site D; and Cd as 0.27 mg/kg which is only lower than the value obtained for Site A (2.00 mg/kg). Another study by Iyaka and Kakulu (2012) observed mean level of Cu in soils of an industrial area in Bida, Niger State to be 467 mg/kg while 181 mg/kg was recorded for both Zn and Pb.

Table 2: Mean Concentrations of Heavy Metals in Soil Samples Collected

Parameters (mg/kg)	Cr	Cd	Pb	Cu	Zn
Site A	12.4	2	285.8	39.4	2500.4
Site B	12.2	N.D	115.2	13.7	271.7
Site C	15	0.2	51.4	15.3	293.4
Site D	15.5	1	783.3	69.9	2375.5
Site E	17.2	N.D	19.8	17.8	174.7
Control 1	14.3	N.D	36.7	9.65	181.1
Control 2	15.7	0.2	15.1	8.5	62.3

N.D: Not detected

Table 3: WHO Maximum Permissible Limits of Heavy Metals in Soil

Heavy metals	Cr	Cd	Pb	Cu	Zn
mg/kg	100	0.8	85	36	50

Source: WHO (1996)

A. Chromium

The mean levels of chromium were significantly below the maximum permissible limit set by WHO (Figure 1). Chromium has varying oxidation state of +2 to +6; the trivalent state is the most stable. Although, this stable chromium has been reported to be an essential nutrient, when inhaled, ingested or interacted with at a high level, it poses deleterious effects on human health [17]. These effects include skin irritation, headache, dizziness, nausea, kidney damage, blood disorder and stunned mental faculty. In all the collected soil samples, concentration of chromium was recorded below the maximum permissible limit set by WHO. Chronic exposure to cadmium engenders dysfunction of the body systems [11].

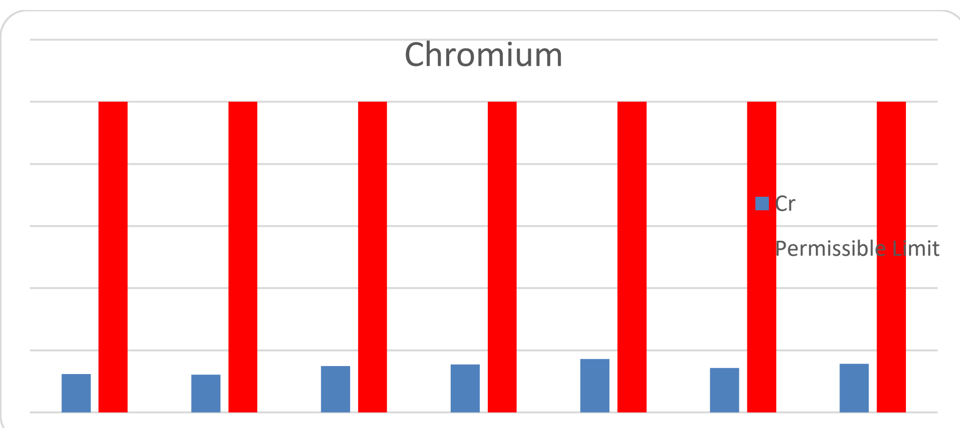

Figure 1: Mean levels of Cr in Soils Samples Collected in Comparison with WHO Maximum Permissible Limit

B. Cadmium

Cadmium exists and persists in environment as result of anthropogenic activities not limited to metal ore combustion and incineration [3][6]. Except in Site A and Site D, concentration of cadmium was recorded below the maximum permissible limit set by WHO in each soil sample collected (Figure 2). Metallurgical operations are carried out in Sites A and D, hence the result. Cadmium was not detected in Site B, Site E, and Control 1.

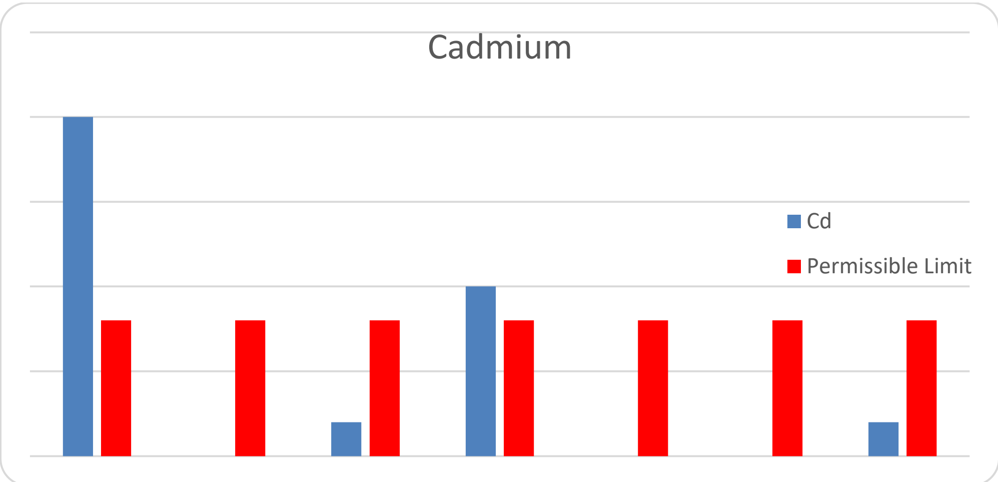

Figure 2: Mean levels of Cd in Soil Samples Collected in Comparison with WHO Maximum Permissible Limit

C. Lead

Although the brain is the main target of Lead (Pb), it affects multiple organs of the body and accumulates over time, and children are the major victims [16]. In 2010 and repeatedly 2015, lead poisoning resulting from lead-contaminated soil and dust from mining claimed the lives of many young children in Zamfara, Northern Nigeria. Inhalation and ingestion of Pb instigates long term harm in adults and pregnant women with increased risk of high blood pressure and birth deformities respectively [16]. Owing to its relevance and usefulness in the metallurgical industry, Pb recorded the highest mean concentration far above the maximum permissible limit set by WHO in Site A. Next in the spectrum are Site D and Site B. Other soil samples collected were below the WHO set standard (Figure 3).

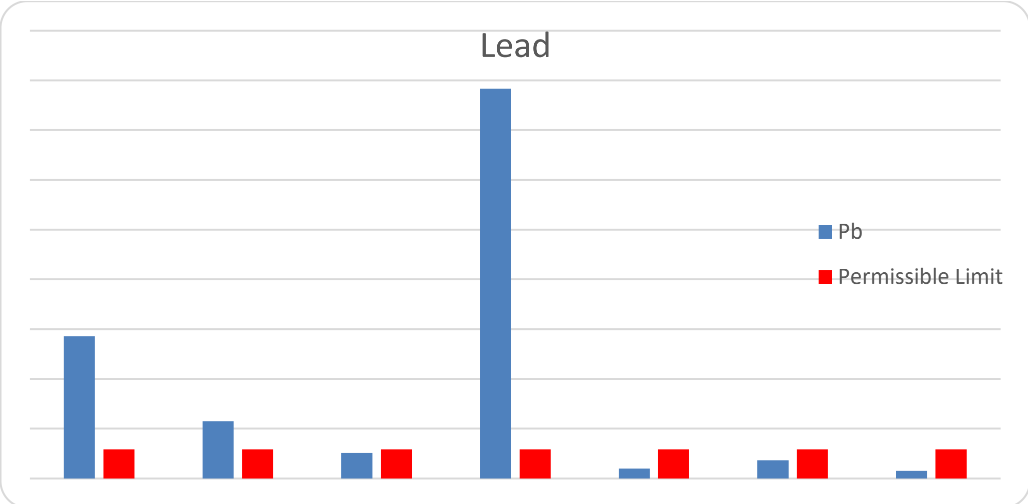

Figure 3: Mean levels of Pb in Soil Samples Collected in Comparison with WHO Maximum Permissible Limit

D. Copper

Copper is an essential trace element of the human cells but in superfluity can imperil the mitochondria and other cell membranes. Copper toxicity can lead to coma, liver damage, and even death [5]. Copper (Cu) levels recorded were below WHO maximum permissible limit in almost all the samples (Figure 4). The samples which had values above the set standard are Site A and Site D.

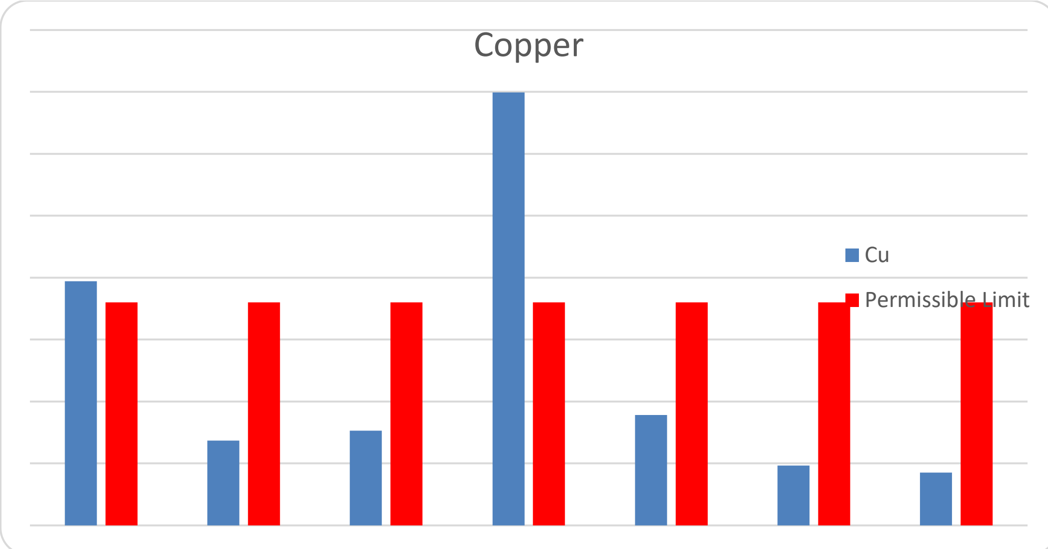

Figure 4: Mean levels of Cu in Soil Samples Collected in Comparison with WHO Maximum Permissible Limit

E. Zinc

The mean levels of zinc (Zn) were above the maximum permissible limit set by WHO. Generally, with zinc exempted, control samples had mean concentration of all examined parameters below the maximum permissible limit set by WHO (Figure 5). Toxicological manifestations of zinc include stomach pain, loss of appetite, and vomiting.

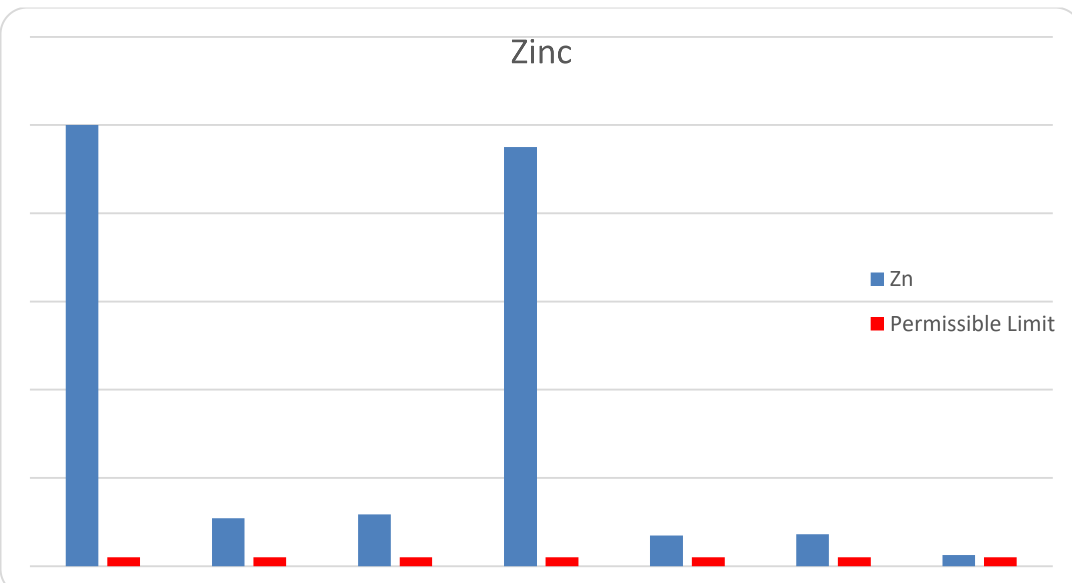

Figure 5: Mean levels of Zn in Soil Samples Collected in Comparison with WHO Maximum Permissible Limit

IV. CONCLUSION

The results show that availability and distribution pattern of the examined parameters varied with industrial activities and this is indicated by the range of concentration values observed for virtually all the heavy metals in the soils analyzed across the sample locations. Analysis also shows significant difference between the test samples and controls. With increase in vehicular movements in the industrial area as well as other small scale industrial activities such as vehicle repairs, welding, battery charging amongst others, there is bound to be an increase in environmental pollution especially heavy metal contamination since this class of metals tends to accumulate in the soil due to their non-biodegradable nature. Since these metals have toxic potential and long term chronic effect on exposure, regular assessment should be carried out to ascertain the level of heavy metal contamination in the soil to avoid accumulation of these metals in individuals through food chain. Research work should be carried out to study the effects of heavy metals on the people of Abeokuta. Sustainable management of soil should be imbibed [2]. Planting of food crops close to the industries should be avoided, and ultimately, appropriate measures should be put in place by the government to ensure that industries are in compliance with environmental guidelines.

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AUTHORS

First Author – Temitope M. Osobamiro, PhD Analytical/Environmental Chemistry, Department of Chemical Sciences, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria, topebamiro@gmail,com.
Second Author – Oluwafemi Awolesi, BSc Industrial Chemistry, Department of Chemical Sciences, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria, awolesi.oluwafemi99@gmail.com**.**
Third Author – Oluwatobi M. Alabi, MSc Inorganic Chemistry, Department of Chemical Sciences, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria, alabioluwatobi2@gmail.com**.**
Fourth Author – Abiodun Y. Oshinowo, MSc Analytical Chemistry, Department of Chemical Sciences, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria, oshinowoabiodun95@gmail,com.
Fifth Author – Mujeebat A. Idris, BSc Industrial Chemistry, Department of Chemical Sciences, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria, idrismujeebat2015@gmail.com**.**
Sixth Author – Farouq A. Busari, MSc Chemistry, Department of Chemistry, University of Ibadan, Ibadan, Oyo State, Nigeria, faruqadeola@gmail.com

Correspondence Author – Oluwafemi Awolesi, awolesi.oluwafemi99@gmail.com, +2347087401623.