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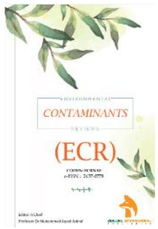

RESEARCH ARTICLE

EVALUATION OF THE IMPACTS OF METALS ON SOIL SAMPLES, SERUM CREATININE AND BLOOD UREA NITROGEN OF RESIDENTS IN SELECTED INDUSTRIAL COMMUNITIES IN A DEVELOPING COUNTRY

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ABSTRACT

Information on the major exposure biomarkers of people living around industrial areas in Africa are very limited. This study aims to analyse the level of hazardous metal (cadmium, lead, copper, and zinc) in two seasons' soil samples of four industrial and one (1) control areas of Ogun State, Nigeria. Similarly, blood samples of the volunteers (n = 200) were analysed for the impacts of the metals on serum creatinine (SCr) and blood urea (BUN). The mean metal concentrations for soils samples exhibited significant differences with strong positive correlations (r = 0.995 and 1). Compared with regulatory limits for normal individual concerning BUN and SCr, the results of volunteers were all higher, with BUN at ~200% and SCr at ~82% more. The results presented in this study revealed that both the soil environment and the body health system of the residents are being affected by the rapid industrialization, hence heavily burdened.

KEYWORDS

metalloids, toxicity, renal functions, health indicators, glomerular filtration rate, metal exposure

1. Introduction

The economic growth process of any country, be it developed or developing, have been linked to her level of industrialization (Tomaselli et al. 2019). However, there are several reports of the negative impact on human health due to environmental pollution associated with industrialization, with a reported global mortality of ~12.6 million in 2015 (Brusseau et al. 2019), and the depletion of natural resources accompanying those industrialization processes (Antoci, Galeotti, and Sordi 2018; Kaplowitz et al. 2011). The contamination of polluted areas particularly concerns soils and water for which industrial and commercial activities as well as waste disposal and treatment represent the main sources of pollution (Gorini et al. 2020).

The indiscriminate and unabated release of metals such as lead (Pb), mercury (Hg), cadmium (Cd), copper (Cu), for examples, have been linked to rapid industrialization activities including mining, smelting, refining, cement manufacturing, chemical production, e-waste recycling, amongst others in developing countries (Chanaka Udayanga et al. 2019; Laidlaw, Gordon, and Ball 2018; Liu et al. 2018; Ramesh kumar and Anbazhagan 2018). These can be found in soil and dusts, while it can also accumulate in plants, animals, water bodies, and thereafter transferred via food chain to humans (Khademi et al. 2019), with direct or indirect negative impacts on human health and the environment in general (Gil et al. 2011; K. He et al. 2017; Santos et al. 2018; Xu et al. 2014; Zhang et al. 2019). Exposure to differentiated metalloids can result in adverse health effects on various organs and systems, mostly the respiratory tract and nervous system as inhalation of mixtures of high reduction potential metals have been connected to the respiratory system response through oxidative stress (Stanislawska et al. 2020). For example, lead (Pd) and cadmium (Cd) have been associated with hearing loss in children (Liu et al. 2018), nephrotoxicity (Wongmekiat, Peerapanyasut, and Kobroob 2018), weakened bones (Huff et al. 2007), Klotho gene (DNA) methylation (Yu et al. 2020), neurological, gastrointestinal, reproductive, genetic and muscular malfunctions and nasal mucous membranes congestion (Z. L. He, Yang, and Stoffella 2005; Ramesh kumar and Anbazhagan 2018; Zhao et al. 2012), decreased grip strength (García-Esquinas et al. 2020), low gait speed and frailty (K. N. Kim et al. 2016) while copper (Cu) have been associated with testicular malfunctioning (Khushboo et al. 2018; Tsuji and Karagatzides 2001). These metals usually bind to the sulfhydryl groups of proteins, disrupting their activities especially those associated with the endocrine and reproductive systems, hence altering the expression pattern of the several genes that participate in the detoxifying processes (Pizzino et al. 2014), and ultimately causing negative effects (Chen et al. 2011; Kleckerová and Dočekalová 2014; Vega and Weng 2013). For instance, toxic metals such as lead (Pb), cadmium (Cd) and other environmental chemicals have often targeted the kidney, which is one of the most important organs for toxicity. The toxic susceptibility of the

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kidney is as a result of the high flow of blood to it with respect to its mass as well as the outstanding property of renal tubular epithelium in concentrating urine and its constituents (Khan, Hard, and Alden 2013). This is in addition to it being a major pathway of excretion from the body, thereby easily damaged through oxidative stress and lipid peroxidation (Buser et al. 2016; Rana, Tangpong, and Rahman 2018). Lead (Pb), on another hand, binds to the erythrocyte proteins, which thereafter locates the kidney and causes oxidative damage on cells, tissues and cellular organelles (Gonick 2011; Rana, Tangpong, and Rahman 2018; Reyes et al. 2013), while cadmium (Cd) is freely filtered at the glomerulus and gets reabsorbed by the epithelial cells lining the proximal tubule. Coupled with its long half-life and extremely limited discharge into urine, the free cadmium accumulates in the kidney over a period of time and causes renal damage whenever the kidney detoxification system becomes overwhelmed (Johri, Jacquillet, and Unwin 2010; Wongmekiat, Peerapanyasut, and Kobroob 2018). Since the pathway of these metals is usually from blood to the kidney, exposures to these heavy metal pollution can play a critical role in the burdening of kidney disease, in addition to the nephrotoxicity effect of the high level exposures (Pollack et al. 2015). Several researchers have reported the toxicological effects of these heavy metals on human resident in industrialized environment. For example, He et al. (K. He et al. 2017) reported elevated concentration levels for Cr, Cu, Zn, Ni, As, Pb, and Cd in seventy (70) soil samples collected from e-waste recycling areas and traditional industrial zones, compared to regional soil background, while Ejidike and Onianwa (Ejidike and Onianwa 2015) reported higher concentration values for zinc, copper, and lead in tree barks samples taken from industrial, high traffic commercial areas relative to residential low traffic and control areas. Furthermore, Oladoja et al. (Oladoja, Nwaedozie, and Aliyu 2018) indicated higher concentration values for seven heavy metal (Cu, Zn, Ni, Fe, Pb, Cd and Mn) in soil samples taken from nineteen (19) sites along the shores of river Kaduna stretching an industrial area in the South of Kaduna Metropolis, Nigeria, with the mean values of analysed heavy metals being above the acceptable range when compared with WHO and EU standard limits.

Biomarkers to determine the extent of exposure to these metals with respect to renal dysfunction and blood poisoning are usually measured by their concentrations in blood or urine in the form of serum creatinine, blood urea nitrogen, calcium, glucose with cadmium in urine or blood, to indicate accumulation or kidney burden (Tchounwou et al. 2012). The creatinine is a chemical waste molecule produced in human body due to muscular metabolism. In healthy individuals, most of the creatinine in the bloodstream is filtered out by the kidneys and expelled from the body in urine, hence, creatinine is a fairly reliable indicator of the functionality of the kidney, as an impaired kidney function or the probable presence of kidney disease indicates elevated creatinine level (Pundir, Yadav, and Kumar 2013; Tseng et al. 2018). For serum creatinine, the typical reference ranges from 0.5–1.0 mgdL^{-1} (about 45–90 μmolL^{-1}) for women while it is 0.7–1.2 mgdL^{-1} (60–110 μmolL^{-1}) for men, in normal healthy individuals. However, the significance of a single creatinine value may also be interpreted considering the patient's muscle mass or old age (Cappuccio et al. 2016; Randviir and Banks 2013; Tseng et al. 2018). Blood Urea Nitrogen (BUN), on another hand, is one of the oldest prognostic biomarkers in heart failure, as diseased or damaged kidneys can cause BUN to accumulate in the blood as glomerular filtration rate (GFR) drops (Xue et al. 2014). In normal individual, BUN ranges from 7-20 mgdL^{-1} (Pollack et al. 2015). However, despite several researches done on BUN and creatinine, there are very few reports evaluating the health risks influenced by heavy metal pollution, while also elucidating the impact on residents' biochemical markers in industrial areas (Wang et al. 2012), with rare systemic study report.

In this research, we determine the level of the metals like lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) in the soil samples of the budding industrial areas of Ogun State, Nigeria and in the blood samples of some of the volunteered residents. This study also aims to further elucidate the possible impacts of these toxic metals on serum creatinine and blood urea nitrogen (which are biomarkers of renal and blood malfunctioning) of the residents, a systemic study of heavy metals routes from soil (possible point source) to blood samples and finally to affecting human biomarkers.

2. MATERIALS AND METHODS

2.1 Study Area

Ogun State, located in the Southwest axis, is one of the thirty-six (36) states of the Federal Republic Nigeria. It shares boundaries with Lagos, the former Capital and Port City to the south, Oyo and Osun States to the north, Ondo State to the east and the Federal Republic of Benin to the west (Figure 1). Located on the coordinates 7°00′N 3°35′E, the State has a total area of 16,432 km^2 with a population size of about 7,100,000 at a density of 220/km^2 (570/sq. mi) (Ogun State In Brief 2017). Due to the proximity of the State to Lagos, a port city and the largest commercial hub in the country, it has, been experiencing tremendous industrialization drive and rapid urbanization especially along its border with Lagos. Currently, the State is noted to have the largest concentration of industries (Amade 2013; Ogah, Gyamfi, and Oyebade 2016).

2.2 Description of sampling sites

Samples were collected from three different industrial communities (which are: Agbara, Ibeshe, and Ogijo) during wet and dry seasons in addition to Olorunda, located in Abeokuta North Local Government Area, which was chosen as the control and non-industrialized area (Figure 2). Ogijo is an industrial area with the highest concentration of metal manufacturing, recycling and other metal-related industries. Agbara hosts a mixture of metals and chemical-related manufacturing industries, while Ibeshe is a community with a huge deposit of limestone in commercial quantities, hence the location of the two largest cement manufacturing industries in West Africa. The geographical coordinates of the sample sites are presented in Table 1.

Table 1: Geographical location of the Sampling sites

LOCATION	SOIL SAMPLING SITES				
AGBARA	N06^{0}30.26^{1} E003^{0}05.73^{1}	N06^{0}30.44^{1} E003^{0}05.54^{1}	N06^{0}30.900^{1} E003^{0}05.77^{1}	N06^{0}31.11^{1} E003^{0}05.78^{1}	N06^{0}31.23^{1} E003^{0}05.99^{1}
IBESHE	N06^{0}53.67^{1} E003^{0}12.25^{1}	N06^{0}53.83^{1} E003^{0}12.49^{1}	N06^{0}54.01^{1} E003^{0}12.15^{1}	N06^{0}54.28^{1} E003^{0}11.67^{1}	N06^{0}54.31^{1} E003^{0}12.35^{1}
OGIJO	N06^{0}45.38^{1} E003^{0}40.21^{1}	N06^{0}45.56^{1} E003^{0}40.36^{1}	N06^{0}45.68^{1} E003^{0}40.44^{1}	N06^{0}45.87^{1} E003^{0}40.68^{1}	N07^{0}15.34^{1} E003^{0}35.39^{1}
OLORUNDA	N07^{0}06.75^{1} E003^{0}17.84^{1}	N07^{0}06.74^{1} E003^{0}17.82^{1}	N07^{0}06.71^{1} E003^{0}17.83^{1}	N07^{0}06.73^{1} E003^{0}17.84^{1}	N07^{0}06.80^{1} E003^{0}17.97^{1}

2.3 Chemical Reagents Used

Perchloric acid ($HClO_4$, AR, ≥ 60%) was purchased from Rechem Products Ltd., Suffice, England, while hydrochloric acid (HCl, AR, 37%) and nitric acid (HNO_3, AR, 70%) were both procured from BDH Chemicals Ltd., Poole, England. Distilled deionized water (DDI) was used throughout the experiment. Except otherwise stated, all reagents are of analytical grades and used without purification.

2.4 Soil samples collection and metals analysis

Soil samples were collected from four industrial communities (Agbara, Ogijo, Ibeshe and Olorunda during the two seasons (wet and dry). The wet season is usually from April-October, while the dry season is usually from November-March, every year. Using a 65-mm-diameter tube, 10 (the total amount of short cores (depth < 15 cm) of soils were collected randomly at spatial distances of 100-200 m from each of the sampling points considered in/around the community area, in April and November 2016, respectively. The soil samples acquired were then sealed, tagged and returned to the laboratory intact. In the laboratory, about 5.0 g of (oven dried at 60 °C) soil samples were weighed into 125 ml of previously washed (with acid and distilled water) Erlenmeyer flask. A 4 ml of perchloric acid ($HClO_4$), 25 ml of concentrated nitric acid (HNO_3) and 2M of concentrated sulphuric acid (H_2SO_4) were added respectively to the samples in a fume cupboard. The content was mixed and warmed gently on a digestion block inside the cupboard until the materials were completely digested with the formation of white fumes at the bottom of the flask. This was done to ensure the removal of organic impurities from the samples and to prevent any form of interference in analysis. The flask was then allowed to cool and 2 ml of concentrated HNO_3 was added and re-digested again. The mixture was heated thoroughly for 30 s and allowed to cool, after which 50 ml of DDI water was added. The solution was then boiled for 30 s and the solution filtered into a 100 ml volumetric flask, after which the filtrate made up to the mark with distilled water. One blank and one certified reference (Spex Multielement Standard, Spex Industries Inc., Edison, New Jersey, USA) as well as samples spiked with known concentrations of the reference material were included in each batch of the digestion

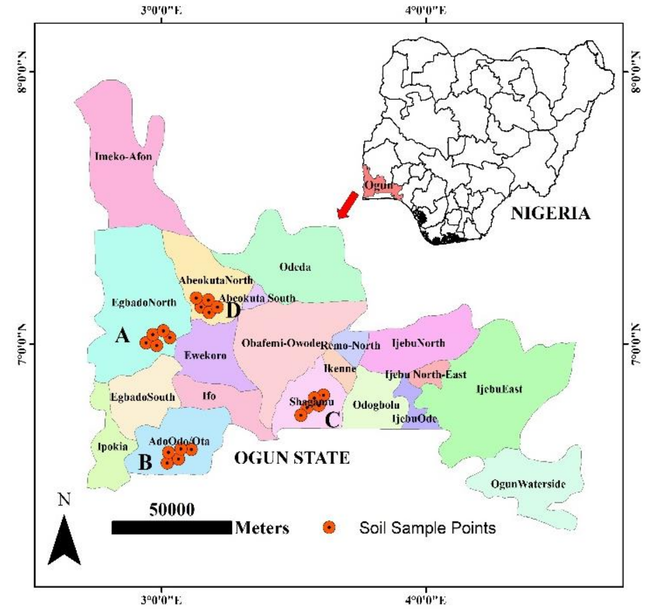

Figure 1: Map of Ogun State, Southwest Nigeria showing the Study Areas, with soil sampling locations (Inset: Map of the Federal Republic of Nigeria showing the location of Ogun State among the 36 States and the Federal Capital Territory). A – Ibeshe, Egbado North; B – Agbara, Ado-Odo/Ota; C– Ogijo, Sagamu and D – Olorunda, Abeokuta North.

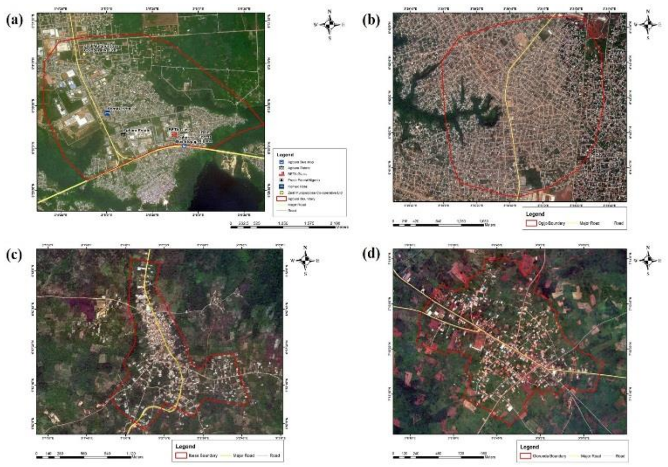

Figure 2: Aerial Mapping of the sampling locations (a) Agbara; (b) Ogijo; (c) Ibeshe and (d) Olorunda (Control), as obtained from Google Map.

2.4.1 Atomic Absorption Spectrometer (AAS) Analysis of the Digested Soil Samples

The digested samples were analysed for the metals, Cd, Pb, Ni and Cu, using the iCE 3000 Series Atomic Absorption Spectrophotometer Model (Thermo Fischer Scientific, Massachusetts, USA) with an appropriate hollow cathode lamp, air, acetylene flame and resonance wavelength of the metals according to published report (Davidson 2012). The metals, lead (Pb), cadmium (Cd), copper (Cu) and nickel (Ni) were all analysed at wavelengths of 217.0, 228.8, 324.8 and 232.0 nm, respectively. The calibration curves were obtained using six points with the certified standard. After each analytical run (usually 10 samples), the calibration curves were collected again to check for linearity and replication. Finally, a mean recovery rate of >95% was obtained for each element after two determinations.

2.5 Blood Sampling

A total of two hundred (200) male and female adult residents voluntarily participated in the study and they were all from the communities sampled for this study. These comprised of fifty (50) respondents from each of the three industrial communities namely: Ibeshe, Ogijo and Agbara, and the last fifty (50) set of voluntary participants are living and working in Olorunda, a relatively clean and non-industrialized environment, which was set as the control location. Informal consents were obtained from the respondents through their Community Heads, after which they were properly educated with the help of medical personnel about the benefits of the study. Some volunteered respondents with the history of cigarette smoking, drug addiction and those with medical history of hepatic and renal pathology were all excluded from the study.

2.5.1 Collection of blood, digestion and determination of lead, cadmium, nickel and copper, creatinine and blood urea nitrogen in blood samples

A 10 ml of venous blood was obtained from the antecubital vein of the volunteers using disposable pyrogen-free needle and syringes, after their skins have been pre-cleaned with 70% ethanol. The blood samples were then dispensed into plain vacutainer heparinised anticoagulated tubes and thereafter kept frozen at -70 °C until analysed. The blood samples were later retrieved and allowed to thaw, after which 1 ml of the blood sample was added into a conical flask, followed by the addition of 10 ml concentrated HNO_3 and thereafter heated. The solution was removed and allowed to cool after becoming almost colorless. Thereafter, DDI water was added to the solution to make up to 25 ml followed by stirring. Finally, the digested samples were then analysed for Pb, Cd, Cu, and Ni using the iCE 3000 Series Atomic Absorption Spectrophotometer Model (Thermo Fischer Scientific, Massachusetts, USA) with an appropriate hollow cathode lamp, air acetylene flame and resonance wavelength of the metals (Davidson 2012), using the same analytical procedure previously mentioned for soil heavy metals.

2.5.2 Determination of serum creatinine

The serum creatinine was determined according to the previous report of Khalil et al (Khalil et al. 2015) and Quon et al (Quon et al. 2010). The creatinine in alkaline solution is reacted with 2,4,6-trinitrophenol to form a colored complex, as the creatinine concentration is proportional to the amount of complex formed. The mixtures were mixed together and allowed to stand for 30 min. The absorbance was read at 546 nM using the Jaffer's reaction colorimetric method, with SpectrumLab 23A Spectrophotometer (RX Monza Analyzer, Randox Laboratories Limited, UK) and creatinine was calculated as:

$$\text{Creatinine (mgdL}^{-1}\text{)} = \frac{\text{Absorbance (experimental)}}{\text{Absorbance (standard)}} \times \text{concentration standard (1 mg/dL)} \quad (1)$$

2.5.3 Determination of blood urea

To determine the blood urea, Urease-Berthelot method was used (Richards, Smith, and Wilcox 1984). Urea in the blood serum is hydrolyzed to ammonia in the presence of urease. The ammonia was thereafter photometrically measured by Berthelot's reaction (Richards, Smith, and Wilcox 1984), using Spectrumlab 23A Spectrophotometer (RX Monza Analyzer, Randox Laboratories Limited, UK), with blood urea calculated as:

$$\text{Urea (mgdL}^{-1}\text{)} = \frac{\text{Absorbance (experimental)}}{\text{Absorbance (standard)}} \times \text{concentration standard (80 mg/dL)} \quad (2)$$

2.6 Statistical Analysis

One-way Analysis of Variance (ANOVA) at 95% confidence level was used to determine the statistical differences between means of the samples and this was executed in SPSS Version 21.0. The Duncan multiple range test, on the other hand, was used to separate means for soil and blood data. Furthermore, Pearson Correlation analysis was used to analysis the relationship between soil data during the wet and dry seasons, and the spatial identification of health risk exposure in the study areas.

3. Results

3.1 Metals (Lead, Cadmium, Copper and Nickel) Contents of Soil Samples

The concentration of the metals in the soil samples collected from the sampling locations are shown in Tables 1 and 2 and Figure 3. The mean lead (Pb) concentration ranged from 182.20 $mgKg^{-1}$ to 405.05 $mgKg^{-1}$ during the wet season, while it ranged from 248.70 $mgKg^{-1}$ to 442.50 $mgKg^{-1}$ during the dry season, with Agbara having the highest value. The mean Cd concentration ranged between 6.00 mgKg^{-1} and 55.00 mgKg^{-1} and 10.07 mgKg^{-1} to 59.40 mgKg^{-1} for wet and dry season, respectively, with Ogijo possessing the highest value. Furthermore, the mean Cu concentration ranged from 120.07 mgKg^{-1} to 178.00 mgKg^{-1} and 134.04 mgKg^{-1} to 181.00 mgKg^{-1} for wet and dry season, while the mean concentration for Ni ranged from 58.05 mgKg^{-1} to184.02 mgKg^{-1} and 72.20 mgKg^{-1} to 203.50 mgKg^{-1} for wet and dry season, respectively, with Ogijo having the highest values for both the Cu and Ni analyzed.

Table 1: Metal contents of soil samples from industrial communities during wet season

Heavy metal (mgkg^{-1})	Location						
	AGBARA	IBESHE	OGIJO	OLORUNDA(C)	DSG$^{\delta}$	CDS$^{\delta}$	CNS$^{\delta}$
Pb	405.05±7.0^{c}	182.20±3.0^{a}	266.00±4.0^{b}	35.15±3.0^{a}	530	600	300
Cd	18.00±2.0^{a}	6.00±0.8^{b}	55.00±6.0^{a}	0.82±0.04^{b}	12	22	0.30
Cu	142.05±6.0 ^{a}	120.07±2.0^{a}	178.00±8.0^{a}	18.10±1.0^{b}	190	91	100
Ni	134.00±2.0^{a}	58.05±7.0^{b}	184.02±6.0^{a}	BDL	210	50	50

Means in the same row with different superscript letter are significantly different at $p < 0.05$. BDL = Below detectable limit,

DSG: Dutch Soil Guideline; CDS: Canada Soil Guideline; CNS: China Soil Guideline. $^{\delta}$Qing, et al. (Qing, Yutong, and Shenggao 2015)

Table 2: Metal contents of soil samples from industrial communities during dry season

Heavy metal (mgkg^{-1})	Location						
	AGBARA	IBESHE	OGIJO	OLORUNDA (C)	DSG$^{\delta}$	CDS$^{\delta}$	CNS$^{\delta}$
Pb	442.50±6.0^{c}	248.50±15.0^{a}	322.00±6.0^{b}	15.15±4.0^{a}	530	600	300
Cd	30.00±3.0^{b}	10.07±2.0^{a}	59.40±2.0^{c}	2.10±0.7^{a}	12	22	0.30
Cu	161.10±10.0^{a}	134.04±5.0^{a}	181.00±2.0^{a}	14.04±5.0^{b}	190	91	100
Ni	151.00±10.0^{a}	72.20±5.0^{b}	203.50±10.0^{a}	BDL	210	50	50

Means in the same row with different superscript letter are significantly different at $p < 0.05$. BDL = Below detectable limit,

DSG: Dutch Soil Guideline; CDS: Canada Soil Guideline; CNS: China Soil Guideline. $^{\delta}$Qing, et al. (Qing, Yutong, and Shenggao 2015)

Also, there were significant differences for Pb and Cd contents, with some insignificant differences in Cu and Ni at $p < 0.05$, in the soil samples obtained from the industrial communities during wet and dry seasons respectively. It could be observed that the mean metal concentrations of the metals were significantly higher in the dry season compared to wet season, possibly due to washing off, percolation or leaching of the metallic species as a result of flow of water through the soil matrix. Although, the mean values for Pb, Cu and Ni were within the Dutch Soil (DSG) and Canadian Soil Guidelines (CDS), they are much higher than that of China Soil Guidelines (CNS) for urban soil samples (Figure 3), while the mean value obtained for Cd were higher than those reported in all the guidelines (Qing, Yutong, and Shenggao 2015). This revealed that the residents within the industrial belts are exposed to toxic metals in their environment, which may be due to or immensely magnified by the noted rapid industrialization in the communities.

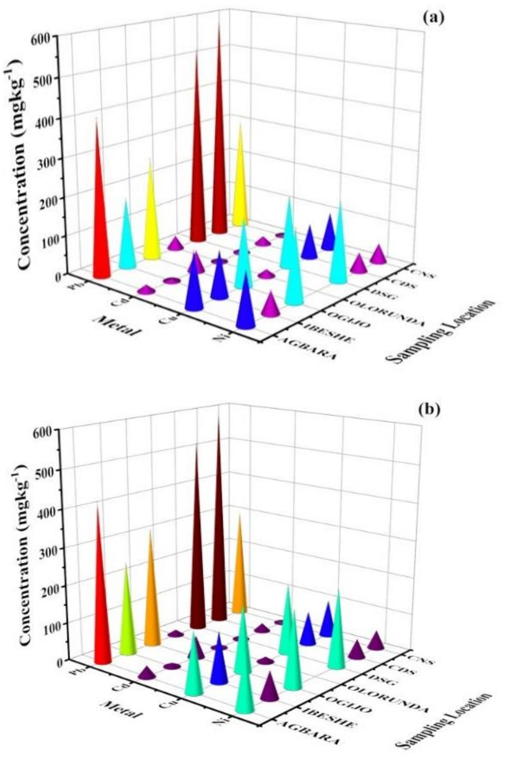

Figure 3: Metal concentration in soil samples and compared with regulatory limits. (a) during wet season, (b) during dry season.

3.2 Correlation between metals (Pb and Cd) in soil during wet and dry seasons

The correlation between the widely reported hazardous metals (Pb and Cd) in the soil samples during both seasons are shown in Table 3, indicating strong positive correlations (r = 0.995 and 1) at 0.01 level of significance. It is evident here that the soil samples obtained are heavily burdened with hazardous metal pollutants.

Table 3: Correlation between metals (Pb and Cd) in soil during wet and dry seasons

	PbSW	*CdSW*	*PbSD*	*CdSD*
PbSW	1			
CdSW	-.292	1		
PbSD	.995**	-.241	1	
CdSD	-.298	1.000**	-.250	1

**. Correlation is significant at the 0.01 level (2-tailed).

PbSW =Pb correlation for soil during wet season; CdSW = Cd correlation for soil during wet season; PbSD = Pb correlation for soil during dry season; CdSD = Cd correlation for soil during dry season.

3.3 Metal Content in Blood of Residents of Industrial Communities

The mean blood Pb and Cd concentrations of residents in the study locations are shown in Table 4 and Figure 4, with Agbara having the highest mean blood Pb and Cd levels (36.06 μgL^{-1} and 11.49 μgL^{-1}), followed by Ibeshe (13.43 μgL^{-1} and 6.06 μgL^{-1}) while the control location (Olorunda) has the least (4.72 μgL^{-1} and 4.80 μgL^{-1}), respectively, with a significant difference ($p < 0.05$) between the Pb and Cd level in the Agbara and Olorunda (control) groups.

Table 4: Metal content in blood of residents of industrial communities

Heavy metal (μgL^{-1})	Agbara	Ibeshe	Ogijo	Olorunda
Pb	36.06^{c}	13.43^{b}	7.31^{ab}	4.72^{a}
Cd	11.49^{b}	6.06^{ab}	4.41^{a}	4.80^{ab}
Cu	0.15^{a}	0.13^{a}	0.03^{b}	BDL
Ni	0.67^{b}	0.41^{ab}	0.07^{a}	0.06^{a}

Means in the same row with different superscript letter are significantly different at $p < 0.05$. BDL = below detectable limit

Also, the mean blood Cu and Ni showed that residents of Agbara has the highest Cu and Ni levels (0.15 μgL^{-1} and 0.67 μgL^{-1}, respectively), followed by Ibeshe (0.13 μgL^{-1} and 0.41 μgL^{-1}, respectively), while the mean Cu level of residents in the control group (Olorunda) was below the detectable limit. Furthermore, there was a significant difference ($p < 0.05$) between the Ni level in the control (Olorunda) and Agbara groups.

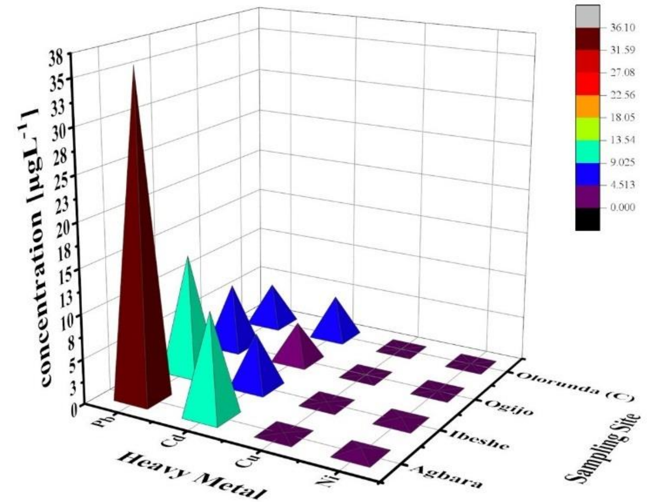

Figure 4: Mean blood heavy metal content of residents of sampled industrial communities.

3.4 Serum Creatinine (SCr) and Blood Urea Nitrogen (BUN) of Residents

The mean blood urea nitrogen and serum creatinine of sampled residents of industrial communities are shown in **Table 5**. The blood urea nitrogen (BUN) level ranged from 44.08 to 54.38 $mgdL^{-1}$ while that of the serum creatinine (SCr) level ranged from 1.80 to 2.18 $mgdL^{-1}$ with Agbara having the highest levels in both analyses. The mean BUN and SCr levels in all the three industrial locations were, however, higher than that of the control location (25.58 and 1.03 $mgdL^{-1}$).

Table 5: Mean Blood Urea and Creatinine of residence of industrial communities

$mgdL^{-1}$	Agbara	Ibeshe	Ogijo	Olorunda (C)
Blood Urea Nitrogen	54.38_a	45.11_{ab}	44.08_b	25.59_c
Serum creatinine	2.18_a	1.82_a	1.80_a	1.03_b

Means with different superscript letter are significantly different.

Blood urea nitrogen (BUN), serum creatinine (SCr) and glomerular filtration rate (GFR) are few of the biomarker tests usually conducted in diagnostic laboratories for monitoring renal function (Khan, Hard, and Alden 2013) Compared with regulatory optimum limit set for normal individual concerning BUN and SCr (Pollack et al. 2015; Tseng et al. 2018), the mean results in Table 5, Figures 5 and 6 are higher, with BUN level indicating 200% and SCr almost 82% increase more than regulatory limits. A high blood urea level indicated reduced glomerular filtration rate, while a low blood urea level indicates liver problem. Since creatinine is also related to kidney and liver function, a high blood creatinine is an indication of a possible kidney impairment.

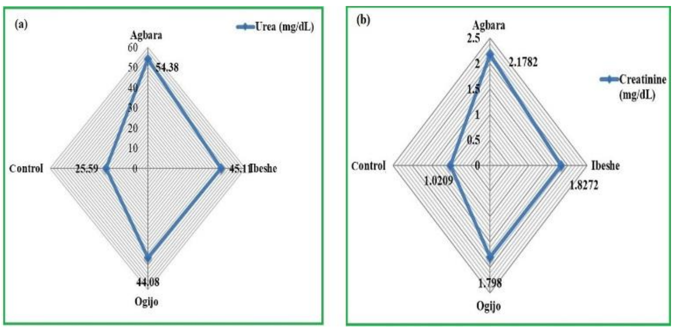

Figure 5: (a) Blood urea level; (b) Blood creatinine level, of residents at different locations

The results presented here suggest that residents in the industrial communities are possibly having some health issues regarding renal functionality, due to the increased BUN and SCr. Moreover, the mean BUN in all the industrial locations is statistical significantly higher than Olorunda (control location) at $p < 0.05$. The justification for this observed difference is a possible due to the fact that Olorunda, our control location, is yet to be industrialized like other locations with significant industrial presence.

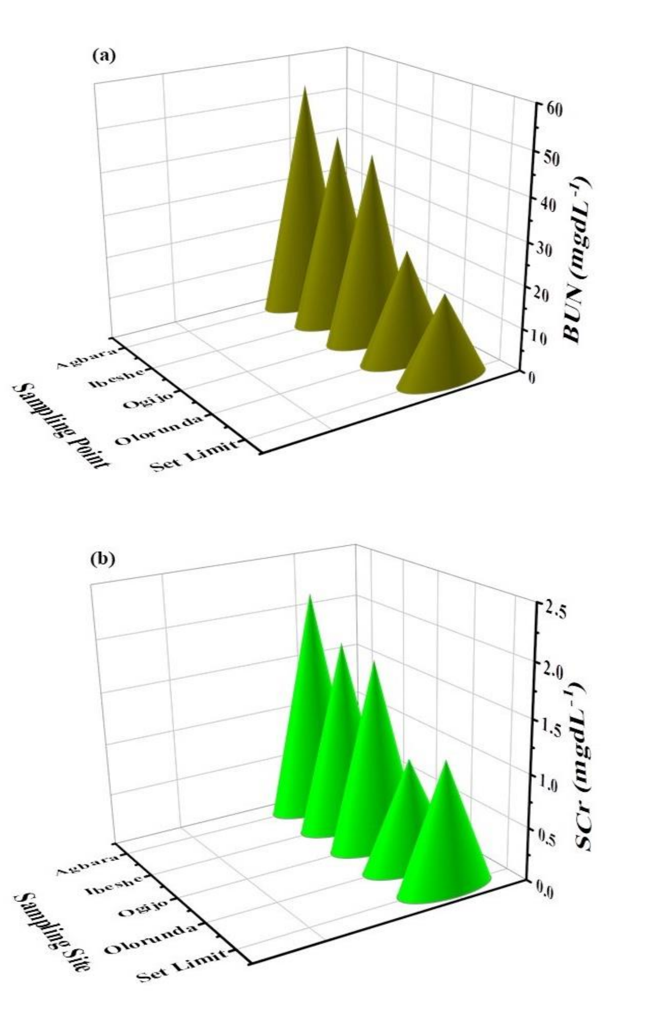

Figure 6: Mean (a) blood urea nitrogen (BUN); (b) serum creatinine (SCr), of residents of sampling locations and regulatory limits, according to Pollack et al. (Pollack et al. 2015) and Tseng et al (Tseng et al. 2018).

4. Discussions

Industrial activities including steel manufacturing, metal smelting and processing, cement manufacturing and refinery industries, amongst others, have contaminated soils with toxic elements (metals inclusive) (Keshavarzi et al. 2019; Lee et al. 2006), with several reports of health implications due to high concentrations of Pb, Cd an Cu, especially, to general human health (Z. L. He, Yang, and Stoffella 2005; Khushboo et al. 2018; Ramesh kumar and Anbazhagan 2018; Tsuji and Karagatzides 2001; Wongmekiat, Peerapanyasut, and Kobroob 2018; Zhao et al. 2012). It is noteworthy to say that the residents along these industrial belts of Agbara, Ogijo and Ibeshe are toxic metals-burdened due to the higher than set limits concentrations found in their soil samples. Furthermore, due to the inability of these toxic metals to biodegrade, coupled with their long half-lives for total elimination, they will bioaccumulate in the fatty tissues of the human body through ingestion, thereby causing long term significant effects on human health including affecting the central nervous and circulatory systems (Alloway 2012; Lee et al. 2006; Waisberg et al. 2003). Other health complications include birth defects, low intelligent quotient (IQ), mutagenesis, increased oxidative DNA damage, mental retardation hyperactivity, brain and kidney damage (H. S. Kim, Kim, and Seo 2015; Martin and Griswold 2009), with possible increased hospital attendance. For example, several hundreds of deaths especially children, have also been reported due to unsafe and illegal mining of lead in Zamfara State, Northwest Nigeria, in addition to thousands of people being hospitalized (Dooyema et al. 2012; Gayton and Mwatia 2010).

Since the targets of these toxic metals in the body are often the blood, liver and kidney, the mean concentration of the metals in the blood samples of volunteers revealed that Agbara residents have the highest, while Olorunda (control) recorded the least of all the metals analyzed. Looking at the mean blood Pb concentration, it could be observed that even though the results were still within the recommended limit set for Pb (31–39 μgL^{-1}), the obtained mean blood Cd was however slightly higher (~59.6% more) for Agbara than the recommended Cd limit (5.4–7.2 μgL^{-1})

(Wennberg et al. 2006), even as the European Food Safety Authority (EFSA) recommended that blood lead of 12 μgL^{-1} in children should be a reference point as higher value could be associated with neuro-psychological development (Wennberg et al. 2017). However, since the toxicological effects of copper and nickel are yet widely reported compared to that of lead and cadmium, excessive copper exposure have been linked to testicular malfunctioning, which can directly affect sperm quality and possible genetic change (Khushboo et al. 2018). Biomonitoring of the toxic metals exposure have been employed to identify high-risk groups, while tracking exposure over a period of time, with serum creatinine and blood urea nitrogen being often employed as biomarkers of the functionality of the kidney, especially in the nephrotoxicity assessment of environmental exposures to these metals (Calisi et al. 2011; Li, Zhang, Li, et al. 2013; Li, Zhang, Yang, et al. 2013). From the results obtained for mean serum creatinine (SCr) and blood urea nitrogen (BUN), it could be observed that the mean BUN for all the industrial communities was 2 to 2.5 times more than recommended limit (Pollack et al. 2015), a situation that could be attributed to the possible triggering effects of toxic metals exposure in their environment. This observation is also noticed for the mean serum creatinine with Agbara having the highest of ~82% and Ogijo recording the lowest of ~49.8% more than the recommended limit (Cappuccio et al. 2016; Randviir and Banks 2013; Tseng et al. 2018). Elevated urea and serum creatinine in heavy metal exposure have been reported to be indicative of histopathology-related biochemical alterations and induced cell death through oxidative stress, which could possibly lead to acute or chronic hepatic and renal dysfunction (Jayawardena et al. 2017; Wilson-Frank 2019). Also, excessive exposure to cadmium have also been linked with increasing serum creatinine with time in humans with renal tubular dysfunction (β_2-microglobulinura), suggesting a progressive glomerulopathy (Goyer and Clarkson 2001), while García-Esquinas et al. reported higher cadmium exposure being cross-sectionally associated with decreased grip strength, a strong predictor of all-cause mortality among US adults (García-Esquinas et al. 2020) and Yu et al have established an association of liver and kidney functions with Klotho (an ageing-related) gene methylation in a population environment exposed to cadmium in China (Yu et al. 2020). Tchounwou and coworkers (Tchounwou et al. 2012) and Arora et al. (Arora et al. 2009) also reported an estimation of about 2.3% population of the United States of America having elevated levels of urine cadmium (> 2μg/g creatinine), which could serve as a marker of chronic exposure and burden to health. Moreover, according to the data obtained from the Office of the Nigeria's National Population Commission, the 2016 estimated population figures of the sampled areas were 20,625 (Agbara), 35,725 (Ogijo), 10,525 (Ibeshe) and 7,905 (Olorunda, control). With the number of respondents (50) from each area and compared with the mean results obtained for blood urea and serum creatinine levels, it could be noted that these respondents' numbers were substantial enough to draw our report that the residents of the industrial communities are all-round burdened from their surrounding soil samples to blood health due to the effect of the toxic metals in the hepatic and renal functionalities, although long-term toxicological implications and attendant hospitalization due to these are yet reported.

5. Conclusions

This research was conducted to ascertain the possible damaging health risks involved in living around industrial areas, despite the gains associated with rapid industrialization. From the findings, it was revealed that the metals in the analysed soil samples were higher than regulatory limits, with a strong, positive correlation (r = 0.995 and 1) at 0.01 level of significance in lead (Pb) and cadmium (Cd), while the metals concentration in the blood also showed a significance difference of $p < 0.05$ for Pb and Cd in the industrial areas to the control. Furthermore, the BUN and SCr at maximum of 54.38mgdL^{-1} and 2.18 mgdL^{-1}, respectively, found in some areas were more than the reported regulatory limits, indicating possible reduced glomerular filtration rate, a pointer to liver problems and kidney impairment. In overall, these results indicated that, not only that the residents along the industrial zones do not only have soils burdened with toxic metals, but also that the functionality of their general well-being, based on the analysed toxic metals, blood urea and serum creatinine in their blood samples which could possibly affect their kidney functionality. Moreover, it is advisable that triggering health effects from the heavy metals' constant exposure should be a concern not only to these residents, but also to the regulatory agency of the government.

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Conflicts of Interest

The authors declare no conflicting interest.

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