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Ecological and Human Health Implication of Heavy Metals in Soils of Urban Areas of Nigeria: A Systematic Review

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Abstract

This paper involves a systematic review of the concentration, pollution, ecological, and health hazards connected with heavy metals in Nigerian urban soil. Data were sourced from published papers in peer reviewed journals after which they were subjected to contamination, ecological and health risk analysis. Arsenic in urban soils of Nigeria is between 0.003 mg/kg and 46.66 mg/kg while that of Cadmium is between 0.001 mg/kg and 239.20 mg/kg. The amount of Cobalt in urban soils of Nigeria is between 0.42 mg/kg and 24.43 mg/kg while that of Chromium is between 0.05 mg/kg and 1915.80 mg/kg. Cobalt in Nigerian urban soils of Nigeria is between 0.42 mg/kg and 24.43 mg/kg while that of Copper is between 0.54 mg/kg and 12,830 mg/kg. Mercury in urban soils of Nigeria is between 0.02 mg/kg and 46.258 mg/kg while that of Lead is between 0.36 mg/kg and 966.90 mg/kg and that of Zinc is between 0.31 mg/kg and 8420.60 mg/kg. Urban soils of Nigeria is lowly to very highly contaminated by the metals. Some sources of heavy metals in the soils include dumping of wastes, release of industrial waste water, exhausts from vehicular movement, petroleum spill, mining activities and cement production. Risk assessment showed that soils of major towns especially those in Abuja are pose very ecological risk. Children and adult are expose to carcinogenic health issues due to oral ingestion of soil contaminated by Pb while children are exposed to non-carcinogenic health risk through ingestion and dermal contact with polluted soils.

Keywords: Ecological Risk Assessment; Health Risk Assessment; Heavy Metals; Nigeria; Soils; Urbanization

1.0 Introduction

Soil is an important natural resource because of its ability to act as a geochemical sink for a variety of foreign compounds, including potentially dangerous metals deposited by humans through urban and other activities (Pouyat *et al.*, 2020). Rapid, continuous, and uncontrolled industrialization and urbanization have weakened and polluted the environment (Xie *et al.*, 2019). One of the key natural difficulties that adds monstrously to urban ecological issues is climatic pollution (Yang *et al.*, 2021). Anthropogenic activities such as mining (Oyebamiji *et al.*, 2018), refining (Sojinu and Ejeromedoghene, 2019), petroleum ignition (Kaza *et al.*, 2011), and waste discharge (Laniyan and Adewumi, 2019) have resulted in the presence of potentially toxic metals in the soils of cities, resulting in severe environment degradation.

Cities' inhabitants are many and widely dispersed, devouring a large amount of natural resources and so releasing a large amount of foreign air pollutants (Wang *et al.*, 2018). Individuals living in urban areas are exposed to health risks from soil contaminants (Li *et al.*, 2021), water (Laniyan and Adewumi, 2019), and aerosols (Ghanavati *et al.*, 2019) via inhalation, ingestion, and dermal contact retention (Adewumi *et al.*, 2020). Because of their frequent hand-mouth action and greater retention rate than adults, children are more susceptible to the effects of soil pollution, particularly in metropolitan settings (Adewumi *et al.*, 2020). This is remarkable considering how dangerous it is and how it depletes one's well-being (Kelepertzis, 2014).

Toxic metals are harmful when concentrations exceed permitted limits because they are persistent and do not disintegrate over time (Rizo *et al.*, 2013). The presence of heavy metals in soil is owing to natural weathering of parent rock material and pedogenic processes, and their quantity is largely reliant on the geochemical composition of the parent material (Syeda and Riffat, 2011). Heavy metals are abundant in urban soils, according to studies by Dong *et al.* (2018) and Wang *et al.* (2018). Long-term exposure to metals such as Cr, Cd, Pb, and Ni can cause bioaccumulation in the liver and kidneys, leading to organ dysfunction (Yang *et al.*, 2019). Cadmium and lead, both known mutagens and/or carcinogens, are dangerous even at low levels (Mohmand *et al.*, 2015).

Assessing ecological indicators is a well-known approach for uncovering ecological data that can help policymakers and environmentalists make educated judgments regarding the well-being of the ecosystem (Radomirovic *et al.*, 2020). Ecological indicators, in combination with multivariate statistics, can help reduce additional contamination of urban soil (Nazzal *et al.*, 2014). Heavy metals in soils and road dust must be assessed for their health risks. Oral intake, inhalation, and skin contact, all of which occur on a regular basis, expose humans to heavy metals in polluted media (Adewumi *et al.*, 2020). Man bioaccumulates certain metals over time, making them difficult to eliminate (Song *et al.*, 2018). As a result, monitoring the degree of heavy metals' health dangers would dramatically minimize health problems in metropolitan areas.

The concentration, pollution, ecological, and health hazards connected with heavy metals in Nigerian urban soils are reviewed in this study. This review is designed to draw the attention of residents of Nigerian cities to the rising levels of heavy metals in the soil in their surroundings, as well as the potential health risks. The goals of this study are to (1) review the amount and sources of heavy metals in Nigerian soils, and (2) determine the extent of environmental and health concerns connected with metals in the media.

2.0 Study Area

Nigeria's elevation ranges from 600 to 700 meters along the coast to over 1,200 meters across the Jos Plateau and areas of the eastern highlands near the Cameroon border. Nigeria has a tropical climate, with rainy and dry seasons that vary depending on where you are. The southeast is hot and humid for the most of the year, whereas the southwest and deeper interior are dry. The rainy season in the south lasts from March to November, whereas in the north it lasts from mid-May to September. The southeast gets around 3,000 mm of rain every year, whereas the southwest only gets about 1,800 mm. In the south, temperature and humidity are usually stable throughout the year, but in the north, seasons fluctuate greatly; during the northern dry season, the daily temperature variation becomes even greater. Nigeria's population is expected to reach 216.7 million by 2022. According to Obaje (2009), Nigeria's geology is divided into three litho-petrological components: the Basement Complex, the Younger Granites, and Sedimentary Basins. The Migmatite-Gneiss Complex, the Schist Belts, and the Older Granites are all Precambrian in age. The younger granites, which are mostly Jurassic magmatic rings, are mostly found in Jos and parts of North-central Nigeria, whereas the Sedimentary Basins, which include the Dahomey Basin, the Sokoto Basin, the Chad Basin, the Benue Trough, the Mid-Niger (Bida/Nupe) Basin, and the Niger Delta Basin, are made up of Cretaceous to Tertiary sediments.

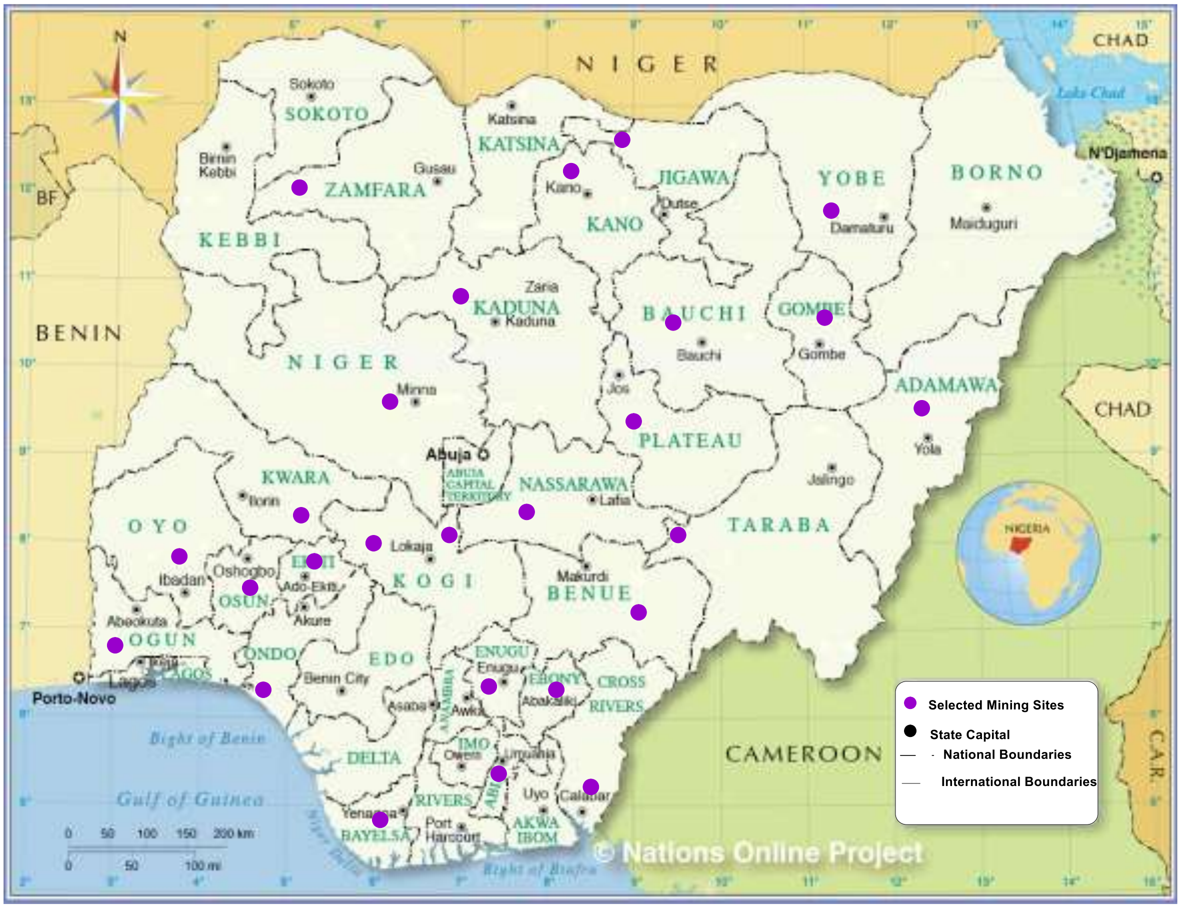

Figure 1: Map of Nigeria showing mining areas covered in this review

3.0 Review Methodology

For the purpose of this review, area of review interest was appropriately defined. The systematic review of the ecological and health risk assessment of heavy metals in urban soils in Nigeria were carried out. After this, major cities of interest were selected for inclusion. Thirty-three major cities including the Federal Capital Territory, Abuja were selected. Related researches published in peer reviewed journals in selected cities were searched online. Google search, google scholar, Africa Journal Online (AJOL) and SCOPUS archives were used in accessing related papers published in national and international peer reviewed journals. Afterwards, data extraction criteria were properly defined. For the purpose of this review, depth of sampling, heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn and Fe) and sources were major factors put into consideration. After this, data were extracted. Average value of heavy metals in soils were used. Furthermore, data were analyzed using internationally acceptable equations for calculating pollution, ecological and human health risks. For pollution assessment, contamination factor (Equation 1) were used to unravel the extent of Nigerian urban soils by heavy metals. Ecological risk assessment of heavy metals in urban soils of Nigeria was calculated using equation (2). Health risks assessment due to heavy metals in Nigeria urban soils were estimated using equation (3). Spatial maps were generated using SURFER™.

3.1 Contamination Factor (CF)

In the examination of soil contamination, the contamination factor (CF) in equation 1 was also employed. All four classes are recognized by the CF, which is a single-element index (Hakanson, 1980). The different contamination factor classes and levels are depicted in Table 1 below.

$$Contamination\ Factor = \frac{Metal\ Concentration}{Concentration\ of\ Element\ in\ Background\ Soils} \quad (1)$$

Table 1: Classification of Contamination Factor (Hakanson, 1980)

S/N	CF Value	Contamination Factor Level
1.	CF < 1	Low contamination factor indicating low contamination
2.	1 ≤ CF < 3	Moderate contamination factor
3.	3 ≤ CF < 6	Considerable contamination factor
4.	6 ≥ CF	Very high contamination factor

3.2 Contamination Degree (CD)

The CF of the environment is the total of contamination factors for all substances studied (Hakanson, 1980). The CD's purpose is to provide a measure of overall contamination in surface layers at a given sample location. The CD is divided into four categories. Equation 2 shows the formula for calculating CD. The CD classification is presented in Table 2.

$$C_d = \sum_{i=1}^{n} C_f^i \qquad (2)$$

The Contamination Degree is Cd, and the Contamination Factor is Cf.

Table 2: Classification of Contamination Degree (Hakanson, 1980)

S/N	CF Value	Contamination Factor Level
1.	CD < 8	Low degree of contamination
2.	8 ≤ CD < 16	Moderate degree of contamination
3.	16 ≤ CD < 32	Considerable degree of contamination
4.	CD ≥ 32	Very high degree of contamination

3.3 Assessment of Potential Ecological Risk

To relate ecological and environmental implications to toxicity, the ecological risk index is used to measure heavy metal pollution in soil, and the toxic-response factors (Tri) for Cu, Zn, Cd, Cr, Ni, and Pb are 5, 1, 30, 2, 5, and 5 (g/g) respectively (Hakanson, 1980). ERI is calculated using Equation 3.

$$E_R^i = T_R^i \times C_f^i \qquad (3)$$

The toxic-response factor is Tr, while the single-element pollution factor is CF.

3.4 Potential Ecological Risk Index (PERI)

A semi-quantitative evaluation of regional pollution levels is calculated using PERI. It may be expressed using Equation 4 (Wang *et al.*, 2015):

$$RI = \sum_{i=1}^{m} E_R^i \qquad (4)$$

Where ERi is the potential ecological risk of a single element. (TR for Zn = 1, Cr = 2, Cu = 5, Pb = 5, Cd = 30).

3.5 Heavy Metals in Soils: A Health Risk Assessment

The pathways of heavy metal exposure in contaminated soils are calculated following guidelines from many American publications. The following exposure equations 5 to 11 were used to calculate ADI (mg/kg/day) for the various routes, as recommended by (USEPA, 1989).

3.5.1 Heavy Metal Ingestion through Soil

The following equation may be used to estimate average daily heavy metal consumption from soil ingestion:

$$ADI_{ing} = \frac{C \times IR \times EF \times ED \times CF}{BW \times AT} \quad (5)$$

The average daily intake of heavy metals from soil is measured in mg/kg-day, while the heavy metal concentration in mg/kg for soil is measured in mg/kg. The average dosage is measured in days, the ingestion rate is measured in milligrams per day, the exposure frequency is measured in days per year, the exposure length is measured in years, the exposed individual's body weight is measured in kilograms, and the ingestion rate is measured in milligrams per day. CF is the kg/mg conversion factor.

3.5.2 Soil Particulate Inhalation of Heavy Metal

Equation 6 is used for predicting average daily heavy metal ingestion through soil breathing:

$$ADI_{inh} = \frac{C_s \times IR_{air} \times EF \times ED}{BW \times AT \times PEF} \quad (6)$$

where ADIinh represents the average daily intake of heavy metals inhaled from soil in mg/kg/day, CS represents the heavy metal concentration in soil in mg/kg, IRair represents the inhalation rate in m^3/day, and PEF represents the particle emission factor in m^3/kg. The terms EF, ED, BW, and AT are specified in Equation 5.

Equation 7 shows the dermal contact with soil equation for estimating average daily heavy metal intake by dermal contact with soil:

$$ADI_{dems} = \frac{C_s \times SA \times FE \times AF \times ABS \times EF \times ED \times CF}{BW \times AT} \quad (7)$$

where ADIdems is the exposure dosage in mg/kg/day via dermal contact. CS represents the heavy metal concentration in soil in mg/kg, SA represents the exposed skin area in cm^2, FE represents the proportion of the dermal exposure ratio to soil, AF represents the soil adherence factor in mg/cm^2, and ABS is the fraction of the applied dosage absorbed across the skin. EF, ED, BW, CF, and AT are defined in Equation 6 before. The exposure parameters utilized for the health risk assessment for a conventional home exposure scenario along various exposure paths are shown in Table 3.

Table 3: Health risk parameters used in this review

S/N	Parameters	Unit	Child	Adult	References
1.	Body Weight (*BW*)	Kg	15	70	DEA, 2010
2.	Exposure Factor (*EF*)	days/year	350	350	DEA, 2010
3.	Exposure Duration (*ED*)	Year	6	30	DEA, 2010
4.	Ingestion Rate (*IR*)	mg/day	200	100	DEA, 2010
5.	Inhalation Rate (*IRair*)	m^3/day	10	20	DEA, 2010
6.	Skin Surface Area (*SA*)	cm^2	2100	5800	DEA, 2010
7.	Soil Adherence Factor (*AF*)	mg/cm^2	0.2	0.07	DEA,2010
8.	Dermal Absorption Factor (*ABS*)	None	0.1	0.1	DEA, 2010
9.	Dermal Exposure Ratio (*FE*)	None	0.61	0.61	DEA, 2010
10.	Particulate Emission Factor (*PEF*)	m^3/kg	1.3×10^9	1.3×10^9	DEA, 2010
11.	Conversion Factor (*CF*)	kg/mg	10^{-6}	10^{-6}	DEA, 2010
12.	Average Time (*AT*)				
	For-Carcinogens	days	365×70	365×70	DEA, 2010

For Non-Carcinogens	365×ED	365×ED	DEA, 2010

3.5.3 Risk Assessment of Non-Carcinogenic Substances

The hazard quotient is a term used to indicate non-cancerous risks (HQ). The probability of a person experiencing a negative effect is expressed as HQ, which is a unit less number. As shown in Equation 8 (USEPA, 1989), the chronic reference dose (RfD) in mg/kg/day of a given heavy metal is defined as the quotient of ADI or dosage divided by the toxicity threshold value, which is referred to as the chronic reference dose (RfD) in mg/kg-day:

$$HQ = \frac{ADI}{RfD} \qquad (8)$$

The total of all the HQs owing to individual heavy metals is the non-carcinogenic effect on the population for n number of heavy metals. This is referred to as the Hazard Index (HI) in a study issued by the USEPA (USEPA, 1989). Equation 9 shows the mathematical description of this parameter:

$$HI = \sum_{k=1}^{n} HQ_k = \sum_{k=1}^{n} \frac{ADI_k}{RfD_k} \qquad (9)$$

Heavy metal k values are HQk, ADIk, and RfDk. If the HI value is less than one, the exposed population is unlikely to incur unfavorable health consequences. If the HI value is more than one, non-carcinogenic implications may be a concern (USEPA, 1989).

3.5.4 Assessment of Carcinogenic Risk

The incremental risk of a person developing cancer over their lifetime as a result of exposure to a suspected carcinogen is used to quantify the dangers of carcinogens. The calculation for calculating the increased lifetime cancer risk is as follows:

$$Risk_{pathway} = \sum_{k=1}^{n} ADI_k CSF_k \qquad (10)$$

where A lifetime risk is the probability of an individual acquiring cancer during their lifetime. ADIk (mg/kg/day) and CSFk (mg/kg/day) are the average daily intake and cancer slope factor for the kth heavy metal, respectively, for n number of heavy metals. The slope factor directly relates an individual's projected daily intake of heavy metal over the course of a lifetime of exposure to their incremental risk of developing cancer (USEPA, 1989).

The overall increased lifetime cancer risk for a person is calculated using the following calculation, which takes into account the average effect of individual heavy metals across all pathways:

$$Risk_{(total)} = Risk_{(ing)} + Risk_{(inh)} + Risk_{dermal} \qquad (11)$$

Risk(ing), Risk(inh), and Risk(dermal) are three types of risk contributions: ingestion, inhalation, and dermal. As indicated in Table 4, RfD and CSF values acquired mostly from the South African Department of Environmental Affairs and the USEPA are used to construct both non-carcinogenic and carcinogenic risk assessments of heavy metals.

Table 4: Reference doses (RfD) in (mg/kg-day) and Cancer Slope Factors (CSF) for the different heavy metals

S/N	**Heavy Metal**	**Oral RfD**	**Dermal RfD**	**Inhalation RfD**	**Oral CSF**	**Dermal CSF**	**Inhalation CSF**	**References**
1.	As	3E-4	3E-4	3E-4	1.50E+00	1.50E+00	1.50E+01	DEA, 2010
2.	Pb	3.6E-3	-	-	8.50E-03	-	4.20E-02	DEA, 2010;

3.	Hg	3E-4	3E-4	8.6E-5	-	-	-	DEA, 2010
4.	Cd	5E-4	5E-4	5.7E-5	-	-	6.30E+00	DEA, 2010
5.	Cr(VI)	3E-3	-	3E-5	5.00E-01	-	4.10E+01	DEA, 2010
6.	Co	2E-2	5.7E-6	5.7E-6	-	-	9.80E+00	DEA, 2010
7.	Ni	2E-2	5.6E-3	-	-	-	-	DEA, 2010
8.	Cu	3.7E-2	2.4E-2	-	-	-	-	DEA, 2010
9.	Zn	3E-1	7.5E-2	-	-	-	-	DEA, 2010
10.	Fe	7E-3						

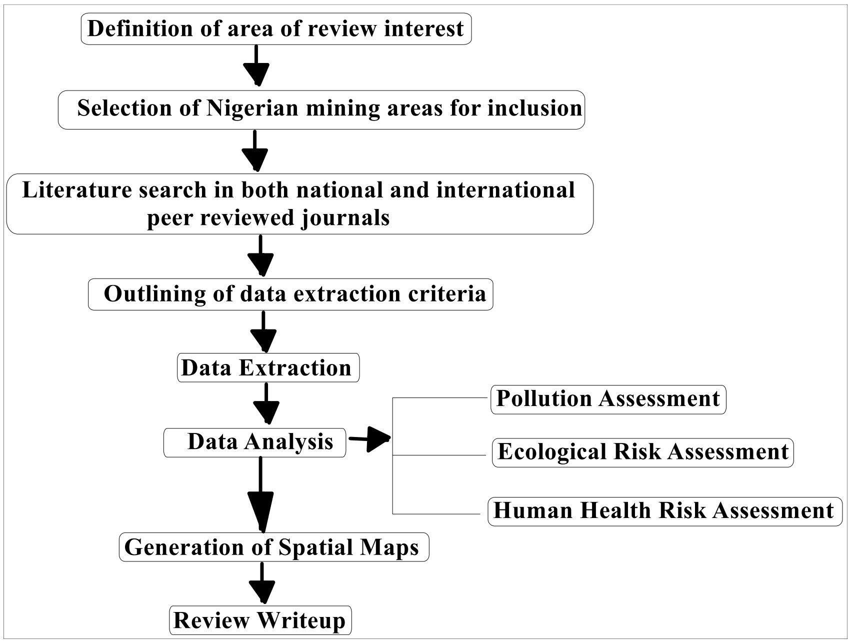

Figure 2: Steps in writing the review paper

4.0 Urbanization and Population Growth in Nigeria

Urbanization has continually increase over time. According to World Bank (2022) population of people living in cities across Nigeria increased from 6,955,837 in the year 1960 to 107,106,007 in the year 2020 (Figure 3). This represents an increase from 15.41% in 1960 to 51.96% in 2020 (Figure 3) with annual percentage change of 3.47% in 1960 to 4.10% in 2020. This showed that as at year 2020, more than half of Nigeria population is living in urban areas.

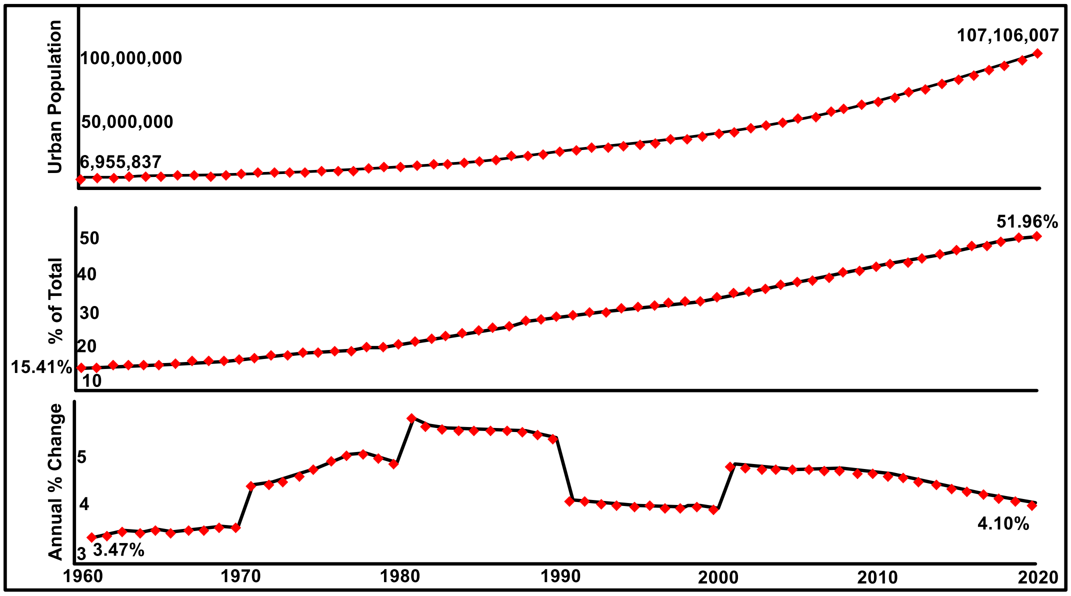

Figure 3: Urban population, percentage total and annual percentage change in cities across Nigeria

5.0 Heavy Metals in Urban Soils of Nigeria

Research have shown urban soils in Nigeria are collected at a depth of between 0 and 100 cm below the surface (Table 5). For heavy metals analysis in urban soils of the country, aqua regia, HF-HNO_3-HCl, $HClO_4$-HF, HNO_3-$HClO_4$, HNO_3-$HClO_4$-H_2SO_4 and double acid digestions were employed while atomic absorption spectrometer (AAS), flame atomic absorption spectrometer (FAAS), inductively coupled plasma – atomic emission spectrometer (ICP-AES) and microwave - atomic emission spectrometer (M-AES) (Table 5).

This review uncovered that the average concentration of As in urban soils of Nigeria is between 0.003 mg/kg and 46.66 mg/kg (Table 6). The lowest concentration of Arsenic (As) as reported by Isiguzo and Bashiru (2014) is found in the soils of Minna metropolis while its highest concentration is found in soils of the city of Markudi (Akan *et al.*, 2013). The amount of As in soils of Umahia (Ogoko *et al.*, 2021), Maiduguri (Dikwa *et al.*, 2009), Calabar (Ekwere *et al.*, 2014), Ado-Ekiti (Olayiwola and Onwadi, 2015), Lafia (Anzene, 2019), Minna (Isiguzo and Bashiru, 2014), Akure (Adewumi, 2022) and Port-Harcourt (Odigi *et al.*, 2011) were lesser than the South African standard (DEA, 2010) for heavy metals in soils. Arsenic in soils of Jos (Uriah *et al.*, 2014) and Markudi (Akan *et al.*, 2013) were higher the South African standard for heavy metals in soils (DEA, 2010).

The concentration of Cd in urban soils of Nigeria is between 0.001 mg/kg and 239.20 mg/kg. The concentration of Cd in soils of Umahia (Ogoko *et al.*, 2021), Uyo (Ukpong *et al.*, 2013), Awka (Amaechi and Onwuka, 2021), Dass (Hassan *et al.*, 2020), Yenogoa (Amos-Tautau *et al.*, 2014), Maiduguri (Dikwa *et al.*, 2009), Calabar (Ekwere *et al.*, 2014), Benin-City (Bala *et al.*, 2019), Ado-Ekiti (Adeyeye *et al.*, 2018), Enugu (Nwachukwu and Okiri, 2013), Owerri (Duru *et al.*, 2020), Kaduna (Funtua *et al.*, 2017), Lokoja (Lawal *et al.*, 2017), Ilorin (Sawyerr *et al.*, 2019), Lafia (Anzene, 2019), Minna (Isiguzo and Bashiru, 2014), Abeokuta (Olayinka and Adedeji, 2014), Akure (Adewumi,, 2022), Ibadan (Olatunde *et al.*, 2021), Jos (Uriah *et al.*, 2014), Port Harcourt (Odigi *et al.*, 2011) and Wukari (Achadu *et al.*, 2016) were below the South African standard for heavy metals in soils (DEA, 2010). However, the amount of Cd in soils of Yola (Hong *et al.*, 2014), Markudi (Akan *et al.*, 2013), Dutse (AbdulAziz *et al.*, 2019), Kano (Dawaki *et al.*, 2013), Sokoto (Warrah *et al.*, 2021) and Abuja (Ekeocha and Anunzo, 2016) were above the South African standard for heavy metals in soils (DEA 2010). The amount of Co in urban soils of Nigeria is between 0.42 mg/kg and 24.43 mg/kg (Table 6). Cobalt in soils of Calabar (Ekwere *et al.*, 2014), Ado-Ekiti (Adeyeye *et al.*, 2018), Lagos (Olorunfemi *et al.*, 2020), Abeokuta (Olayinka and Adedeji, 2014), Akure (Adewumi, 2022), Ibadan (Olatunde *et al.*, 2021) and Jos (Uriah *et al.*, 2014) are below the South African standard for heavy metals in soils (DEA, 2010). The concentration of Cr in urban soils of Nigeria is between 0.05 mg/kg and 1915.80 mg/kg. The concentration of Cr in soils of Yola (Hong *et al.*, 2014), Akwa (Amaechi and Onwuka, 2021), Maiduguri (Dikwa *et al.*, 2019), Calabar (Ekwere *et al.*, 2014), Benin-City (Bala *et al.*, 2019), Kaduna (Funtua *et al.*, 2017), Lafia (Anzene, 2019), Akure (Adewumi, 2022), Ibadan (Olatunde *et al.*, 2021), Jos (Uriah *et al.*, 2014), Port Harcourt (Odigi *et al.*, 2011) and Abuja (Ekeocha and Anunzo, 2016) were above the South African standard for heavy metals in soils (DEA, 2010). The amount of Cu in urban soils of Nigeria is between 0.54 mg/kg and 12,830 mg/kg. The concentration of Cu in Yola (Hong *et al.*, 2014), Awka (Amaechi and Onwuka, 2021), Dass (Hassan *et al.*, 2020), Markudi (Dikwa *et al.*, 2019), Enugu (Nwachukwu and Okiri, 2013), Dutse (AbdulAziz *et al.*, 2019), Ilorin (Sawyerr *et al.*, 2019), Lagos (Olorunfemi *et al.*, 2020), Minna (Isiguzo and Bashiru, 2014), Abeokuta (Olayinka and Adedeji, 2014), Akure (Adewumi, 2022), Osogbo (Olayiwola and Onwadi, 2015), Ibadan (Olatunde *et al.*, 2021), Port Harcourt (Odigi *et al.*, 2011), Sokoto (Warrah *et al.*, 2021), Gashua (Nasir and Bakoma, 2020) and Abuja (Ekeocha and Anunzo, 2016) are above the South African recommended standard for heavy metals in soils (DEA, 2010). The amount of Hg in urban soils of Nigeria is between 0.02 mg/kg and 46.258 mg/kg. Hg in soils of Ibadan (Olatunde *et al.*, 2021) and Port Harcourt (Odigi *et al.* 2011) are above the South African standard for heavy metals in soils (DEA 2010). The concentration of Ni in urban soils of Nigeria is between 0.05 mg/kg and 402.40 mg/kg. The concentration of Ni in soils of Abuja are above the South African standard for heavy metals in soils (DEA, 2010). The concentration of Pb in urban soils of Nigeria is between 0.36 mg/kg and 966.90 mg/kg. The concentration of Pb in soils of Yola (Hong *et al.*, 2014), Uyo (Ukpong *et al.*, 2013), Awka (Amaechi and Onwuka, 2021), Markudi (Dikwa *et al.*, 2019), Calabar (Ekwere *et al.*, 2014), Benin City (Bala *et al.*, 2019), Enugu (Nwachukwu and Okiri, 2013), Owerri (Duru *et al.*, 2020), Kaduna (Funtua *et al.*, 2017), Kano (Dawaki *et al.*, 2013), Ilorin (Sawyerr *et al.*, 2019), Lagos (Olorunfemi *et al.*, 2020), Lafia (Anzene, 2019), Akure (Adewumi, 2022), Osogbo (Olayiwola and Onwadi, 2015), Ibadan (Olatunde *et al.*, 2021) and Abuja (Ekeocha and Anunzo, 2016). The amount of Zn in urban soils of Nigeria is between 0.31 mg/kg and 8420.60 mg/kg. The amount of Zn in soils of Yola (Hong *et al.*, 2014) and Abuja (Ekeocha and Anunzo, 2016) are above the South African standard for heavy metals in soils (DEA, 2010). The amount of Fe in urban soils of Nigeria is between 3.24 mg/kg and 42,300 mg/kg (Table 6).

Table 5: Location, depth of collection and sample processing of urban soils in Nigeria

S/N	Depth of Sampling	Location	State	Digestion Process	Chemical Analysis
1.	0-10	Umahia	Abia	Aqua Regia	AAS
2.	0-30	Yola	Adamawa	Aqua Regia	AAS
3.	0-15	Uyo	Akwa Ibom	Aqua Regia	AAS
4.	0-15	Awka	Anambra	Aqua Regia	AAS
5.	0-15	Dass	Bauchi	Aqua Regia	AAS
6.	0-20	Yenogoa	Bayelsa	Aqua Regia	AAS
7.	0-15	Markudi	Benue	Aqua Regia	AAS
8.	0-5	Maiduguri	Bornu	Aqua Regia	AAS
9.	0-15	Calabar	Cross River	HF-HNO_3-HCl	ICP-AES
10.	0-15	Asaba	Delta	$HClO_4$-HF	AAS
11.	0-30	Benin City	Edo	Aqua Regia	AAS
12.	0-30	Ado-Ekiti	Ekiti	HNO_3-$HClO_4$	AAS
13.	0-15	Enugu	Enugu	Aqua Regia	AAS
14.	0-15	Gombe	Gombe	Aqua Regia	AAS
15.	0-15	Owerri	Imo	Aqua Regia	AAS
16.	0-20	Dutse	Jigawa	Aqua Regia	AAS
17.	0-10	Kaduna	Kaduna	Aqua Regia	AAS
18.	0-20	Kano	Kano	Double acid digestion	AAS
19.	0-10	Lokoja	Kogi	HNO_3-$HClO_4$-H_2SO_4	AAS
20.	0-15	Ilorin	Kwara	HNO_3-$HClO_4$-H_2SO_4	FAAS
21.	0-20	Lagos	Lagos	Aqua Regia	AAS
22.	0-12	Lafia	Nasarrawa	Aqua Regia	AAS
23.	0-20	Minna	Niger	Aqua Regia	AAS
24.	0-50	Abeokuta	Ogun	Aqua Regia	AAS
25.	0-10	Akure	Ondo	Aqua Regia	AAS
26.	0-20	Osogbo	Osun	HNO_3-$HClO_4$	AAS
27.	0-30	Ibadan	Oyo	Aqua Regia	MP-AES
28.	0-10	Jos	Plateau	Aqua Regia	ICP-AES
29.	0-100	Port Harcourt	Rivers	Aqua Regia	AAS
30.	0-50	Sokoto	Sokoto	Aqua Regia	AAS
31.	0-20	Wukari	Taraba	Aqua Regia	AAS
32.	0-10	Gashua	Yobe	Aqua Regia	AAS
33.	0-15	FCT	Abuja	Aqua Regia	AAS

AAS – Atomic Absorption Spectrometer; **ICP-MS** – Inductively Coupled Plasma – Mass Spectrometer; **FAAS** – Flame Atomic Absorption Spectrometer; **ICP-OES** - Inductively Coupled Plasma – Optical Emission Spectrometer; **ICP-AES** - Inductively Coupled Plasma – Atomic Emission Spectrometer; **XRF** – X-Ray Fluorescence

Table 6: Average Concentration of Heavy Metals in Urban Soils of Nigeria

S/N	Location	State	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Fe	Authors
1.	Umahia	Abia	0.03	1.95	-	-	14.20	0.30	-	2.14	143.00	-	Ogoko *et al.*, 2021
2.	Yola	Adamawa	-	239.20	-	199.20	253.8	-	74.43	158.70	309.20	292.70	Hong *et al.*, 2014
3.	Uyo	A/Ibom	-	4.60	-	1.70	-	-	7.00	81.90	-	920.10	Ukpong *et al.*, 2013
4.	Awka	Anambra	-	2.04	-	129.61	84.5	-	6.37	23.94	6.02	1230.05	Amaechi and Onwuka, 2021
5.	Dass	Bauchi	-	0.43	-	0.50	66.33	-	6.27	2.04	71.47	366.33	Hassan *et al.*, 2020
6.	Yenogoa	Bayelsa	-	0.0001	-	0.05	-	-	16.14	-	-	-	Amos-Tautau *et al.*, 2014
7.	Markudi	Benue	46.66	28.64	-	-	44.21	-	28.45	155.44	90.43	48.54	Akan *et al.*, 2013
8.	Maiduguri	Bornu	2.50	0.10	-	20.40	3.5	-	78.00	18.80	39.00	1882.20	Dikwa *et al.*, 2019
9.	Calabar	C/River	4.61	1.23	7.04	16.46	14.89	-	12.01	73.78	46.00	41.14	Ekwere *et al.*, 2014
10.	Asaba	Delta	-	-	-	0.15	-	-	3.96	10.14	7.88	66.00	Bassey *et al.*, 2014
11.	Benin City	Edo	-	6.53	-	44.18	-	-	26.85	26.73	-	1829.13	Bala *et al.*, 2019
12.	Ado-Ekiti	Ekiti	0.11	0.47	0.42	0.17	1.78	-	0.76	0.36	0.31	-	Adeyeye *et al.*, 2018
13.	Enugu	Enugu	-	1.70	-	-	46.40	-	0.54	84.20	-	597.72	Nwachukwu and Okiri, 2013
14.	Gombe	Gombe	-	-	-	0.08	-	-	6.02	12.12	22.18	58.64	Magaji *et al.*, 2019
15.	Owerri	Imo	-	0.03	-	1.19	0.54	-	7.29	198.69	0.67	-	Duru *et al.*, 2020
16.	Dutse	Jigawa	-	18.00	-	5.56	-	-	-	6.09	-	84.07	AbdulAziz *et al.*, 2019
17.	Kaduna	Kaduna	-	3.02	-	48.03	770.79	-	67.91	592.63	-	-	Funtua *et al.*, 2017
18.	Kano	Kano	-	94.71	-	-	5.33	-	56.41	67.98	153.21	-	Dawaki *et al.*, 2013
19.	Lokoja	Kogi	-	0.79	-	-	6.24	-	0.63	4.74	79.34	155.50	Lawal *et al.*, 2017
20.	Ilorin	Kwara	-	1.45	-	-	27.77	-	11.87	31.95	32.41	9970.80	Sawyerr *et al.*, 2019
21.	Lagos	Lagos	-	-	5.64	1.40	44.79	-	12.00	33.74	105.28	-	Olorunfemi *et al.*, 2020
22.	Lafia	Nasarrawa	2.52	7.28	-	16.38	-	-	-	138.46	123.64	2250.91	Anzene, 2019
23.	Minna	Niger	0.003	0.016	-	0.26	21.41	0.02	0.05	15.50	27.70	-	Isiguzo and Bashiru, 2014
24.	Abeokuta	Ogun	-	0.06	0.56	1.03	23.05	-	2.11	5.11	30.08	-	Olayinka and Adedeji, 2014
25.	Akure	Ondo	1.67	1.87	27.4	27.68	36.29	-	10.07	34.34	67.76	1198.89	Adewumi, 2022
26.	Osogbo	Osun	-	-	-	3.63	110.00	-	26.30	137.00	1133	-	Olayiwola and Onwadi, 2015
27.	Ibadan	Oyo	-	0.85	2.76	17.81	17.81	3.48	-	13.00	10.91	47.08	Olatunde *et al.*, 2021
28.	Jos	Plateau	7.71	0.40	24.43	47.25	7.80	-	7.70	38.50	48.15	42300.00	Uriah *et al.*, 2014
29.	P/Harcourt	Rivers	2.00	0.02	-	-	55.00	-	-	4.63	70.00	-	Odigi *et al.*, 2011
30.	Sokoto	Sokoto	-	38.19	-	32.33	20.37	46.25	36.39	15.09	42.05	-	Warrah *et al.*, 2021
31.	Wukari	Taraba	-	0.01	-	-	2.69	-	-	1.14	7.58	3.84	Achadu *et al.*, 2016
32.	Gashua	Yobe	-	-	-	3.71	157.33	-	-	0.99	192.72	191.97	Nasir and Bakoma, 2020
33.	FCT	Abuja	-	10.6	-	1915.8	12830	-	402.40	966.90	8420.60	4229	Ekeocha and Anunzo, 2016
	Range		0.003-46.66	0.001-239.20	0.42-24.43	0.05-1915.80	0.54-12830	0.02-46.25	0.05-402.40				
	S/Afr Standard		5.80	7.50	300.00	6.50	16.00	0.93	91.00	20.00	240.00	-	DEA, 2010

6.0 Pollution of Soils by Heavy Metals of Nigeria Cities

Contamination assessment of soils in major cities of Nigeria is presented in Figure. As outlined by Hakason (1980), soils of Maiduguri, Ado-Ekiti, Enugu, Dutse, Minna, Akure and Port-Harcourt are lowly contaminated by As while soils of Makurdi and Plateau are moderately contaminated by As. Also, soils of Benin-City and Ilorin are considerably and very highly contaminated by As. In Nigeria, urban soils Umahia, Yola, Awka, Markudi, Maiduguri, Calabar, Asaba, Ado-Ekiti, Enugu, Owerri, Kaduna, Kano, Ilorin, Minna, Akure, Ibadan, Jos, Port-Harcourt and Wukari are lowly contaminated by Cd while soils of Uyo and Lagos are moderately contaminated by the metal. Soils of Sokoto are considerably contaminated by Cd. Soils of Umahia, Maiduguri, Ado-Ekiti, Enugu, Lokoja, Ilorin, Lagos, Minna, Akure, Ibadan and Jos are lowly contaminated by Co while the soils of Lafia are considerably contaminated the same pollutant. In the country, soils of Umahia, Maiduguri, Calabar, Ado-Ekiti, Dutse, Osogbo and Gashua are lowly contaminated by Cr while soils in Makurdi, Asaba, Ibadan and Gombe are moderately contaminated by the same metal. Also, the soils of Ilorin, Minna and Sokoto are considerably contaminated by Cr while Awka, Yenogoa, Benin-City, Enugu, Owerri, Kano, Lokoja, Lagos, Lafia, Akure, Jos and FCT are very highly contaminated by the metal. Soils of Yola, Yenogoa, Makurdi, Calabar, Asaba, Benin-City, Ado-Ekiti, Dutse, Ilorin, Minna, Abeokuta, Jos and Wukari are lowly contaminated by Cu while soils of Gombe, Lokoja, Akure, Ibadan and Sokoto are moderately contaminated by the same metal. Also soils of Maiduguri, Lagos, Lafia and Port Harcourt are considerably contaminated by Cu while soils of Uyo, Enugu, Owerri, Osogbo, Gashua and FCT are very highly contaminated by the metal. Soils of Awka, Makurdi, Maiduguri, Calabar and Akure are lowly contaminated by Hg while soils of Ibadan and Sokoto are considerably and very highly contaminated by mercury. Soils of the selected cities are lowly contaminated by Ni except those of FCT that are considerably contaminated by the metal. Suds of Umahia, Yola, Awka, Dass, Makudi, Calabar, Asaba, Ado-Ekiti, Dutse, Lagos, Ibadan, Port-Harcourt, Sokoto, Wukari and Gashua are lowly contaminated by Pb while the soils of Yenogoa, Maiduguri, Benin-City, Enugu, Owerri, Kano, Lokoja, Lafia and Jos are moderately contaminated by the metal. The soils of Gombe are considerable contaminated by Pb while Uyo, Kaduna, Ilorin, Minna, Akure, Osogbo and FCT are very highly contaminated by the metal. Soils of Yola, Awka, Dass, Yenogoa, Makurdi, Maiduguri, Calabar, Asaba, Benin-City, Ado-Ekiti, Enugu, Gombe, Owerri, Dutse, Kano, Lokoja, Ilorin, Lagos, Minna, Abeokuta, Akure, Ibadan, Jos, Port Harcourt, Sokoto, Wukari and Gashua are lowly contaminated by Zn while soils of Uyo, and Kaduna are moderately contaminated by it. Also, soils of Osogbo are considerably contaminated by Zinc while soils of Lafia and FCT are very highly contaminated by the metal. Contamination degree (Figure 4) also affirmed that soils of Umahia, Yola, Dass, Makurdi, Maiduguri, Calabar, Asaba, Ado-Ekiti, Dutse, Abeokuta, Port Hacourt and Wukari are lowly contaminated by heavy metals while soils of Awka. Benin City, Gombe, Kaduna, Kano, Lokoja, Ibadan, Jos and Gashua are moderately contaminated by heavy metals. Soils of Uyo, Yenogoa, Enugu, Owerri, Ilorin, Lagos, Lafia, Akure and Osogbo are considerably contaminated by heavy metals while soils of Minna, Sokoto and FCT are very highly contaminated by heavy metals.

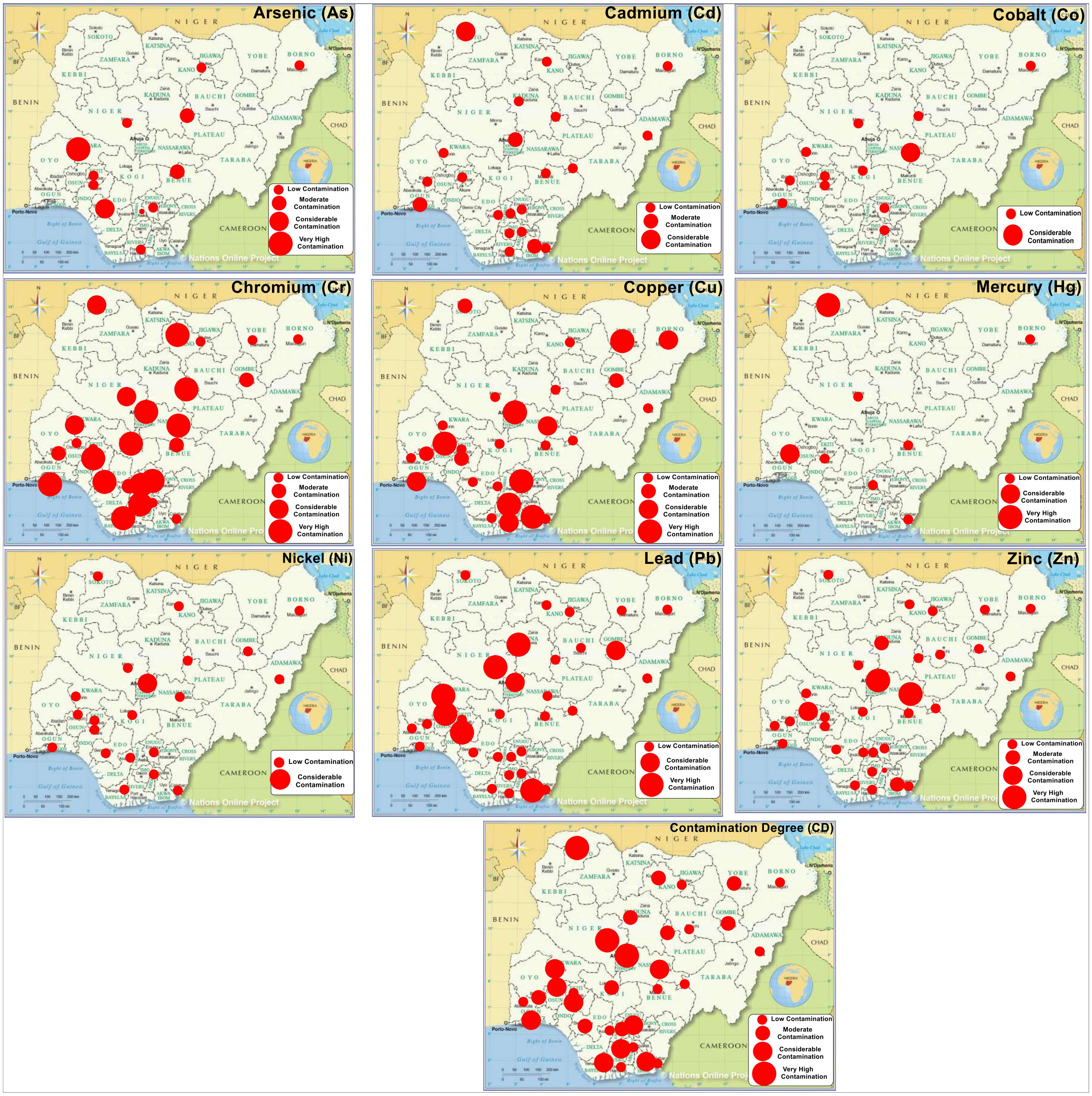

Figure 4: Contamination factor and contamination degree of heavy metals in soils of selected urban areas in Nigeria

7.0 Sources of Heavy Metals in Nigeria Cities

Industrialization through urbanization play a major role in the release of heavy metals in soils of cities across the world. Nigeria is not an exception, this review revealed that generation and dumping of solid and non-solid wastes, industrial waste water, repair of automobiles in mechanic villages, exhausts from vehicular movement, sawmilling, sales of mechanical spare parts, vulcanizing, sales and dumping of scrap metals, petroleum spill, mining activities and cement production are some mains sources of heavy metals in soils of urban areas in the country.

8.0 Ecological Risk of Heavy Metals in Soils of Nigeria Cities

Ecological risk assesment of heavy metals in soils of cities in Nigeria revealed that Cu pose slight ecological riks in soils of Maiduguri, Ado-Ekiti, Owerri, Kano, Lokoja, Jos and Wakuri representing 27% of the reviewed cities while it pose medium ecological risk in soils of Umahia and Calabar representing 8% of the cities studied. Also, Cu pose high ecological risk in soils of Ilorin, Minna, Abeokuta, Ibadan and Sokoto while it also pose higher ecological risk in soils of Makurdi, Enugu, Lagos, Akure and Port Harcourt which represent 5% each of the studied cities (Figures 5 and 6). Copper pose highest ecological risk in soils of Yola, Awka, Dass, Kaduna, Osogbo, Gashua and FCT which represent 7% of the towns studied. Cadmium pose slight ecological risk in soils of Umahia, Awka, Dass, Yenogoa, Maiduguri, Calabar, Ado-Ekiti, Owerri, Lokoja, Minna, Abeokuta, Ibadan, Jos, Port-Harcourt and Wukari representing 56% of the cities covered in this study. Also, Cd pose medium ecological risk in soils of Enugu, Ilorin and Akure representing 11% of the major cities while in the metal pose high ecological risk in soils of Uyo and Enugu which represent 7% of the cities. Cadmium in soils of Benin-City pose higher ecological risk while it pose highest ecological risk in soils of Yola, Makurdi, Dutse, Kano, Sokoto and FCT which stand for 22% of the cities studied. Chromium pose slight ecological risk in soils of Uyo, Dass, Yenogoa, Calabar, Asaba, Ado-Ekiti, Gombe, Owerri, Dutse, Lagos, Lafia, Minna, Abeokuta, Osogbo, Ibadan, Port-Harcourt and Gashua which stands for 65% of the cities covered in this review. Also, Cr pose medium ecological risk in soils of Maiduguri, Benin-City, Akure and Sokoto which represent 15% of the cities. Meanwhile, Cr pose high ecological risk in soils of Kaduna and Jos while it poses higher ecological risk in soils of Anka. Chromium pose highest ecological risk in soils of Yola and FCT which represent 8% of the studied cities. Lead pose slight ecological risk in soils of Umahia, Yenogoa, Ado-Ekiti, Dutse, Lokoja, Abeokuta, Port-Harcourt, Wukari and Gashua which represent 28% of the cities covered in this review. It pose medium ecological risk in soils of Asaba, Gombe, Minna, Ibadan and Sokoto which represent 16% of the cities (Figures 5 and 6). Lead in soils of 6% of the cities studied (Dass, Maiduguri, Benin-City, Ilorin and Jos) pose high ecologicsl risk . It also pose higher ecological risk in soils of Lagos and Akure. Lead pose highest ecological risk in soils of Yola, Makurdi, Enugu, Owerri, Kaduna, Kano, Lafia, Osogbo and FCT which represent 31% of the cities covered in this study. Zinc pose slight ecological risk in soils Awka, Maiduguri, Asaba, Ado-Ekiti, Gombe, Owerri, Ilorin, Minna, Abeokuta, Ibadan and Wukari which stand for 41% of the cities while it pose medium ecological risk in Dass, Calabar, Lokoja, Akure, Jos, Port-Hacourt and Sokoto which represent 26% of the studied cities. Zinc pose high ecological risk in soils of Umahia, Makurdi, Kano, Lagos and Lafia which stand for 19% of the cities covered in this study. Zinc pose higher ecological risk in soils of Yola and Gashua while in soils of Osogbo and FCT it pose highest ecological risk. Risk index (RI) further revealed that heavy metals pose slight risk in soils of Yenogoa, Ado-Ekiti, Wukari, Asaba and Gombe which stand for 18% of the cities () while toxic metals pose medium risk in soils of Lokoja, Abeokuta, Maiduguri, Minna, Ibadan and Umahia which represent 15% of the major cities (Figures 5 and 6). Also heavy metals pose high to higher ecological risk in soils of Port-Harcourt, Ilorin, Jos, Benin-City, Dass, Lagos, Akure, Uyo, Calabar and Dutse which stand for 30% of the reviewed towns while it pose highest risk in soils of Enugu, Awka, Gashua, Owerri, Lafia, Sokoto, Makurdi, Osogbo, Kano, Kaduna, Yola and FCT which represent 37% of the reviewed cities.

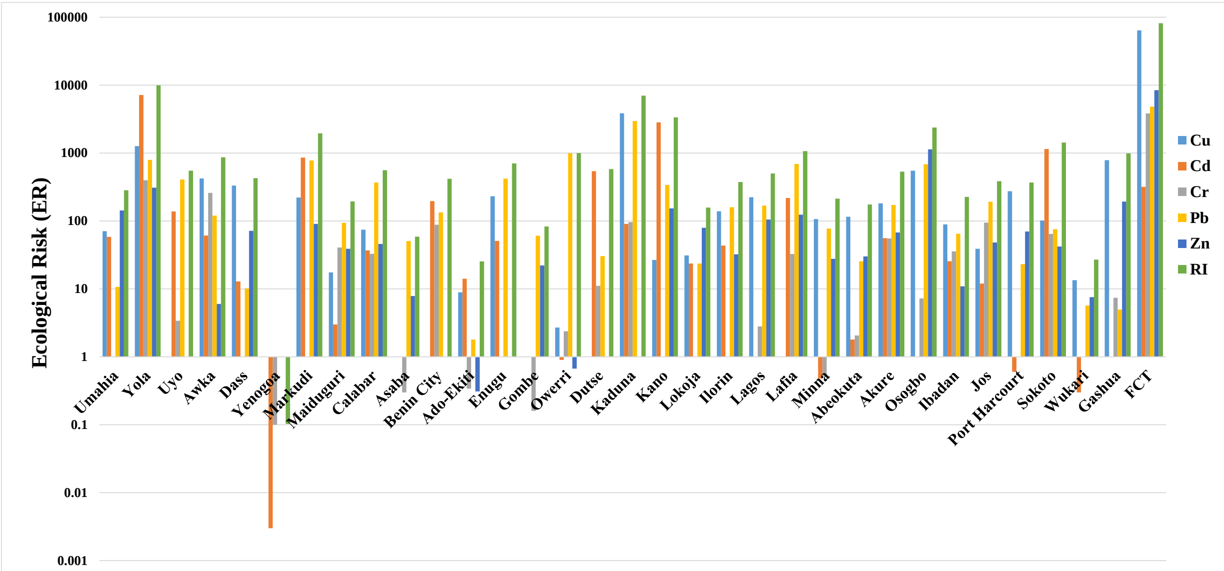

Figure 5: Ecological Risk (ER) and Risk Index (RI) of Heavy Metals in Soils of Urban Areas in Nigeria

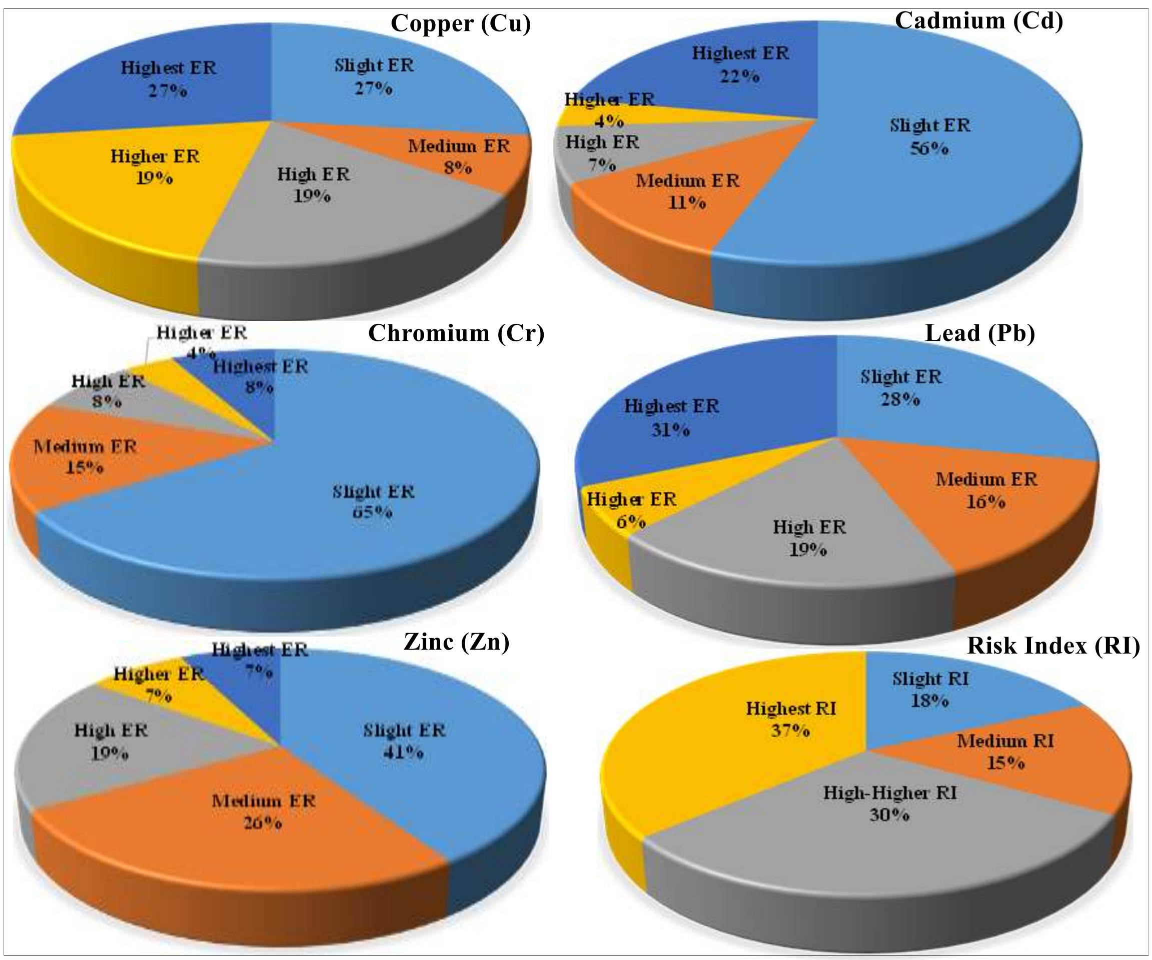

Figure 6: Percentage Ecological Risk (ER) and Risk Index (RI) of Heavy Metals in Urban Soils of Nigeria

9.0 Health Implications of Heavy Metals in Soils of Nigeria Cities

Health risk assessment research is carried out to evaluate the extent to which contact with heavy metal through ingestion, inhalation and dermal contact can affect human health (Adewumi and Laniyan, 2020). For carcinogenic health risk assessment, this study revealed that average daily intake (ADI) through oral ingestion of As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for children are 7.4E-6 mg/kg/day, 1.8E-5 mg/kg/day, 1.1E-5 mg/kg/day, 1.1E-4 mg/kg/day, 6.2E-4 mg/kg/day, 1.2E-5 mg/kg/day, 3.8E-5 mg/kg/day, 1.0E-4 mg/kg/day, 4.6E-4 mg/kg/day and 3.5E-3 mg/kg/day respectively (Table 7). These are lower than the recommended daily intake of heavy metals. The ADI through inhalation of As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for children are 2.9E-10 mg/kg/day, 6.9E-10 mg/kg/day, 4.1E-10 mg/kg/day, 2.4E-8 mg/kg/day, 5.3E-10 mg/kg/day, 1.5E-9 mg/kg/day, 1.5E-9 mg/kg/day, 3.9E-9 mg/kg/day, 1.8E-8 mg/kg/day and 1.4E-7 mg/kg/day respectively. These are lower than the recommended daily intake of heavy metals. The ADI through dermal contact with As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for children are 9.5E-7 mg/kg/day, 2.3E-6 mg/kg/day, 1.3E-6 mg/kg/day, 1.4E-5 mg/kg/day, 7.6E-5 mg/kg/day, 1.8E-6 mg/kg/day, 4.9E-6 mg/kg/day, 1.3E-5 mg/kg/day, 5.9E-5 mg/kg/day and 4.5E-4 mg/kg/day respectively. These are lower than the recommended daily intake of heavy metals. Average daily intake (ADI) through oral ingestion of As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for adults are 8.6E-5 mg/kg/day, 2.1E-4 mg/kg/day, 1.3E-4 mg/kg/day, 1.3E-3 mg/kg/day, 7.2E-3 mg/kg/day, 1.6E-4 mg/kg/day, 4.5E-4 mg/kg/day, 1.1E-3 mg/kg/day, 5.3E-3 mg/kg/day and 4.1E-2 mg/kg/day respectively. These are lower than the recommended daily intake of heavy metals. ADI through inhalation of As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for adults are 3.3E-9 mg/kg/day, 8.6E-9 mg/kg/day, 4.8E-9 mg/kg/day, 4.9E-8 mg/kg/day, 2.7E-7 mg/kg/day, 6.2E-9 mg/kg/day, 1.7E-8 mg/kg/day, 4.5E-8 mg/kg/day, 2.1E-7 mg/kg/day and 1.6E-2 mg/kg/day respectively. These are lower than the recommended daily intake of heavy metals. The ADI through dermal contact with As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for adult are 1.1E-5 mg/kg/day, 2.7E-5 mg/kg/day, 1.6E-5 mg/kg/day, 1.7E-4 mg/kg/day, 8.9E-4 mg/kg/day, 2.1E-5 mg/kg/day, 5.7E-5 mg/kg/day, 1.5E-4 mg/kg/day, 6.8E-4 mg/kg/day and 5.3E-3 mg/kg/day respectively which are lower than the recommended daily intake of heavy metals.

For non-carcinogenic health risk assessment, this study revealed that average daily intake (ADI) through oral ingestion of As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for children are 8.6E-5 mg/kg/day, 2.1E-4 mg/kg/day, 1.3E-4 mg/kg/day, 1.3E-3 mg/kg/day, 7.2E-3 mg/kg/day, 1.6E-4 mg/kg/day, 4.5E-4 mg/kg/day, 1.2E-3 mg/kg/day, 5.3E-3 mg/kg/day and 4.1E-2 mg/kg/day respectively (Table 8). These are lower than the recommended daily intake of heavy metals. ADI through inhalation of As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for adults are 3.3E-9 mg/kg/day, 8.6E-9 mg/kg/day, 4.8E-9 mg/kg/day, 4.9E-8 mg/kg/day, 2.7E-7 mg/kg/day, 6.2E-9 mg/kg/day, 1.7E-8 mg/kg/day, 4.5E-8 mg/kg/day, 2.1E-7 mg/kg/day and 1.6E-2 mg/kg/day respectively. These are lower than the recommended daily intake of heavy metals. The ADI through dermal contact with As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for children are 9.5E-7 mg/kg/day, 2.3E-6 mg/kg/day, 1.3E-6 mg/kg/day, 1.4E-5 mg/kg/day, 7.6E-5 mg/kg/day, 1.8E-6 mg/kg/day, 4.9E-6 mg/kg/day, 1.3E-5 mg/kg/day, 5.9E-5 mg/kg/day and 4.5E-4 mg/kg/day respectively. These are lower than the recommended daily intake of heavy metals. Average daily intake (ADI) through oral ingestion of As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for adults are 9.2E-6 mg/kg/day, 2.3E-5 mg/kg/day, 1.3E-5 mg/kg/day, 1.4E-4 mg/kg/day, 7.7E-4 mg/kg/day, 1.7E-5 mg/kg/day, 4.7E-5 mg/kg/day, 1.3E-4 mg/kg/day, 5.7E-4 mg/kg/day and 4.4E-3 mg/kg/day respectively. These are lower than the recommended daily intake of heavy metals. ADI through inhalation of As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for adults are 2.0E-11 mg/kg/day, 4.9E-11 mg/kg/day, 2.9E-11 mg/kg/day, 3.1E-10 mg/kg/day, 1.7E-9 mg/kg/day, 3.8E-11 mg/kg/day, 1.1E-10 mg/kg/day, 2.8E-10 mg/kg/day, 1.3E-9 mg/kg/day and 9.7E-9 mg/kg/day respectively. These are lower than the recommended daily intake of heavy metals. The ADI through dermal contact with As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Fe in soils of urban areas for adult are 2.3E-6 mg/kg/day, 5.6E-6 mg/kg/day, 3.3E-6 mg/kg/day, 3.4E-5 mg/kg/day, 1.9E-4 mg/kg/day, 4.3E-6 mg/kg/day, 1.2E-5 mg/kg/day, 3.1E-5 mg/kg/day, 1.4E-4 mg/kg/day and 1.1E-3 mg/kg/day respectively which are lower than the recommended daily intake of heavy metals.

This study also showed that HQ for Fe and Co are higher than 1 for children living in the cities which showed that they are more prone to non-carcinogenic health risks through oral ingestion of Fe and dermal contact with Co in soils of the area (Figures 7 and 9). For the adults, HQ for metals are less than 1 which showed that they are not exposed to non-carcinogenic health risks. Oral ingestion of Pb in soils play significant roles in the development of carcinogenic health issues in both adults and children (Figures 8 and 9). High carcinogenic and non-carcinogenic health risk is observed more in Abuja than any other cities in Nigeria. Children's low immune system may lead to this high risk (WHO, 2011), Studies have shown that Pb bioaccumulate more in the blood, nail and hairs of children than adult (Adewumi *et al.*, 2019). Some health issues associated with lead include: neurological damage, lowered IQ, learning disabilities, decreased stature and may be associated with delinquency. It may also affect speech and language processing, attention and classroom performance. Lead exposure can cause similar neurological health problems for adults. Fetuses are also at risk, because lead can be transferred from the mother. Nursing mothers can deliver lead through breast milk (Hamel *et al.*, 2010).

Table 7: Average daily intake (mg/kg/day) of heavy metals in soils of urban areas of Nigeria for children and adults carcinogenic health risk

		As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Fe
					Child						
Oral Ingestion	**Minimum**	3.2E-9	1.1E-10	4.6E-7	5.5E-8	5.9E-7	2.6E-8	5.6E-8	3.9E-07	3.4E-7	4.2E-6
	Maximum	5.1E-5	2.6E-4	3.0E-5	2.1E-3	1.4E-2	5.1E-5	4.4E-4	1.1E-3	9.2E-3	4.6E-2
	Average	**7.4E-6**	**1.8E-5**	**1.1E-5**	**1.1E-4**	**6.2E-4**	**1.2E-5**	**3.8E-5**	**1.0E-4**	**4.6E-4**	**3.5E-3**
Inhalation	**Minimum**	1.3E-13	4.2E-15	1.8E-11	2.1E-12	2.3E-11	1.0E-12	2.2E-12	1.5E-11	1.3E-11	1.6E-10
	Maximum	1.9E-9	1.0E-8	1.2E-9	8.1E-8	5.4E-7	1.9E-9	1.7E-8	4.1E-8	3.6E-7	1.8E-6
	Average	**2.9E-10**	**6.9E-10**	**4.1E-10**	**2.4E-8**	**5.3E-10**	**1.5E-10**	**1.5E-9**	**3.9E-9**	**1.8E-8**	**1.4E-7**
Dermal Contact	**Minimum**	4.2E-10	1.4E-11	5.9E-8	7.0E-9	7.6E-8	3.4E-9	7.2E-9	5.1E-8	4.4E-8	5.4E-7
	Maximum	6.5E-6	3.4E-5	3.9E-6	2.7E-4	1.8E-3	6.5E-6	5.7E-5	1.4E-4	1.2E-3	5.9E-3
	Average	**9.5E-7**	**2.3E-6**	**1.3E-6**	**1.4E-5**	**7.6E-5**	**1.8E-6**	**4.9E-6**	**1.3E-5**	**5.9E-5**	**4.5E-4**
					Adult						
Oral Ingestion	**Minimum**	3.8E-8	1.2E-9	5.4E-6	6.3E-7	6.9E-6	3.1E-7	6.5E-7	4.6E-6	3.9E-6	4.9E-5
	Maximum	5.9E-4	3.1E-3	3.5E-4	2.5E-2	1.6E-1	5.9E-4	5.1E-3	1.2E-2	1.1E-1	5.4E-1
	Average	**8.6E-5**	**2.1E-4**	**1.3E-4**	**1.3E-3**	**7.2E-3**	**1.6E-4**	**4.5E-4**	**1.1E-3**	**5.3E-3**	**4.1E-2**
Inhalation	**Minimum**	1.4E-12	4.9E-14	2.1E-10	2.5E-11	2.6E-10	1.2E-11	2.5E-11	1.8E-10	1.5E-10	1.9E-9
	Maximum	2.2E-8	1.2E-7	1.4E-8	9.4E-7	6.3E-6	2.3E-8	1.9E-7	4.8E-7	4.1E-6	2.1E-5
	Average	**3.3E-9**	**8.6E-9**	**4.8E-9**	**4.9E-8**	**2.7E-7**	**6.2E-9**	**1.7E-8**	**4.5E-8**	**2.1E-7**	**1.6E-6**
Dermal Contact	**Minimum**	4.9E-9	1.6E-10	6.9E-7	8.1E-8	8.8E-7	3.9E-8	8.4E-8	5.9E-7	5.1E-7	6.3E-6
	Maximum	7.6E-5	3.9E-4	4.5E-5	3.1E-3	2.1E-2	7.6E-5	6.6E-4	1.6E-2	1.4E-2	6.9E-2
	Average	**1.1E-5**	**2.7E-5**	**1.6E-5**	**1.7E-4**	**8.9E-4**	**2.1E-5**	**5.7E-5**	**1.5E-4**	**6.8E-4**	**5.3E-3**
		-	**-**	**2.3E-2 FSA (2015)**	**3.0E-1 EFSA (2014)**	**-**	**-**	**2.8E-3 EFSA (2015)**	**5E-4 WHO/FAO (2010)**	**4.3E-1 SCF (2003)**	**8.0E-1 EFSA FAO/WHO (2010)**

Table 8: Average daily intake (mg/kg/day) of heavy metals in soils of urban areas of Nigeria for children and adults carcinogenic health risk

		As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Fe
					Child						
Oral Ingestion	**Min**	3.8E-8	1.2E-9	5.4E-6	6.3E-7	6.9E-6	3.1E-7	6.5E-7	4.6E-6	3.9E-6	4.9E-5
	Max	5.9E-4	3.1E-3	3.5E-4	2.4E-2	1.6E-1	5.9E-4	5.2E-3	1.2E-2	1.1E-1	5.4E-1
	Avg.	**8.6E-5**	**2.1E-4**	**1.3E-4**	**1.3E-3**	**7.2E-3**	**1.6E-4**	**4.5E-4**	**1.2E-3**	**5.3E-3**	**4.1E-2**
Inhalation	**Min**	1.4E-12	4.9E-14	2.1E-10	2.5E-11	2.7E-10	1.2E-11	2.5E-11	1.8E-10	1.5E-10	1.9E-9
	Max	2.3E-8	1.2E-7	1.3E-8	9.4E-7	6.3E-6	2.3E-8	1.9E-7	4.8E-7	4.1E-6	2.1E-5
	Avg.	**3.3E-9**	**8.2E-9**	**4.7E-9**	**4.9E-8**	**2.8E-7**	**6.2E-9**	**1.7E-8**	**4.5E-8**	**2.1E-7**	**1.6E-6**
Dermal Contact	**Min**	4.9E-9	1.6E-10	6.8E-7	8.1E-8	3.9E-8	3.9E-8	8.4E-8	5.9E-7	5.1E-7	6.3E-6
	Max	7.6E-5	3.9E-4	4.4E-5	3.1E-3	7.6E-5	7.6E-5	6.6E-4	1.6E-3	1.4E-2	6.9E-2
	Avg.	**1.1E-5**	**2.7E-5**	**1.6E-5**	**1.7E-4**	**9.2E-4**	**2.1E-5**	**5.7E-5**	**1.5E-4**	**6.8E-4**	**5.3E-3**
					Adult						
Oral Ingestion	**Min**	4.1E-9	1.3E-10	5.8E-7	6.8E-8	7.4E-7	3.3E-8	6.9E-8	4.9E-7	4.3E-7	5.3E-6
	Max	6.3E-5	3.3E-4	3.8E-5	2.6E-3	1.8E-2	6.3E-5	5.5E-4	1.3E-3	1.2E-2	5.8E-2
	Avg.	**9.2E-6**	**2.3E-5**	**1.3E-5**	**1.4E-4**	**7.7E-4**	**1.7E-5**	**4.7E-5**	**1.3E-4**	**5.7E-4**	**4.4E-3**
Inhalation	**Min**	9.0E-15	3.0E-16	1.3E-12	1.5E-13	1.6E-12	7.2E-14	1.5E-13	1.1E-12	9.3E-13	1.2E-11
	Max	1.4E-10	7.2E-10	8.3E-11	5.8E-9	3.9E-8	1.4E-10	1.2E-9	2.9E-9	2.5E-8	1.3E-7
	Avg.	**2.0E-11**	**4.9E-11**	**2.9E-11**	**3.1E-10**	**1.7E-9**	**3.8E-11**	**1.1E-10**	**2.8E-10**	**1.3E-9**	**9.7E-9**
Dermal Contact	**Min**	1.0E-9	3.4E-11	1.4E-7	1.7E-8	1.8E-7	8.1E-9	1.7E-8	1.2E-7	1.1E-7	1.3E-6
	Max	1.5E-5	8.1E-5	9.3E-6	6.5E-4	4.4E-3	1.6E-5	1.4E-4	3.3E-4	2.9E-3	1.4E-2
	Avg.	**2.3E-6**	**5.6E-6**	**3.3E-6**	**3.4E-5**	**1.9E-4**	**4.3E-6**	**1.2E-5**	**3.1E-5**	**1.4E-4**	**1.1E-3**
		-	**-**	**2.3E-2 FSA (2015)**	**3.0E-1 EFSA (2014)**	**-**	**-**	**2.8E-3 EFSA (2015)**	**5E-4 WHO/FAO (2010)**	**4.3E-1 SCF (2003)**	**8.0E-1 EFSA FAO/WHO (2010)**

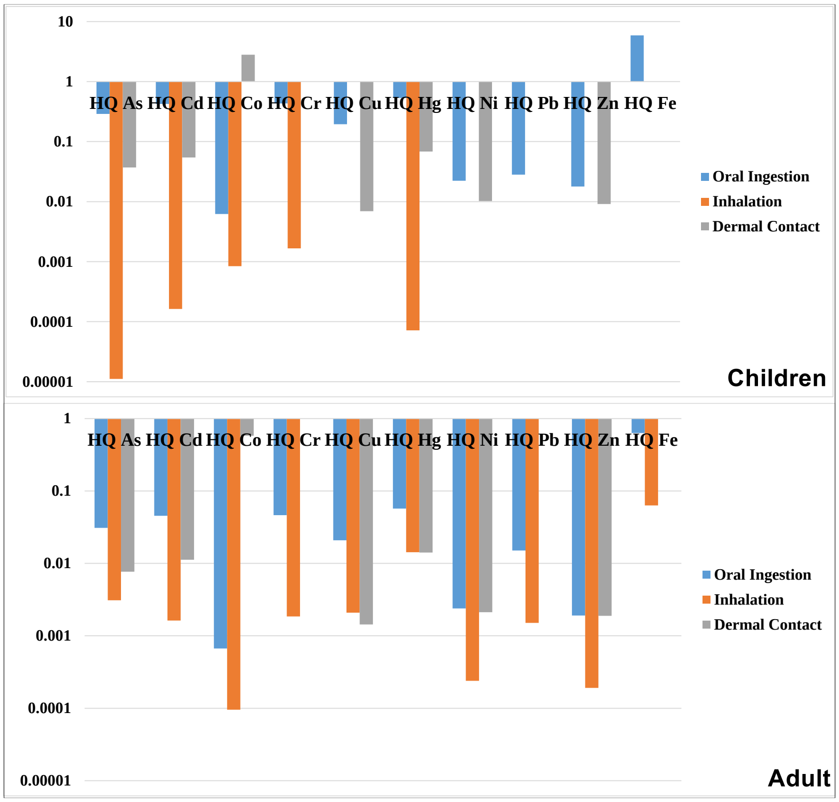

Figure 7: Non-Carcinogenic hazard quotient (HQ) of Heavy Metals in Urban Soils of Nigeria

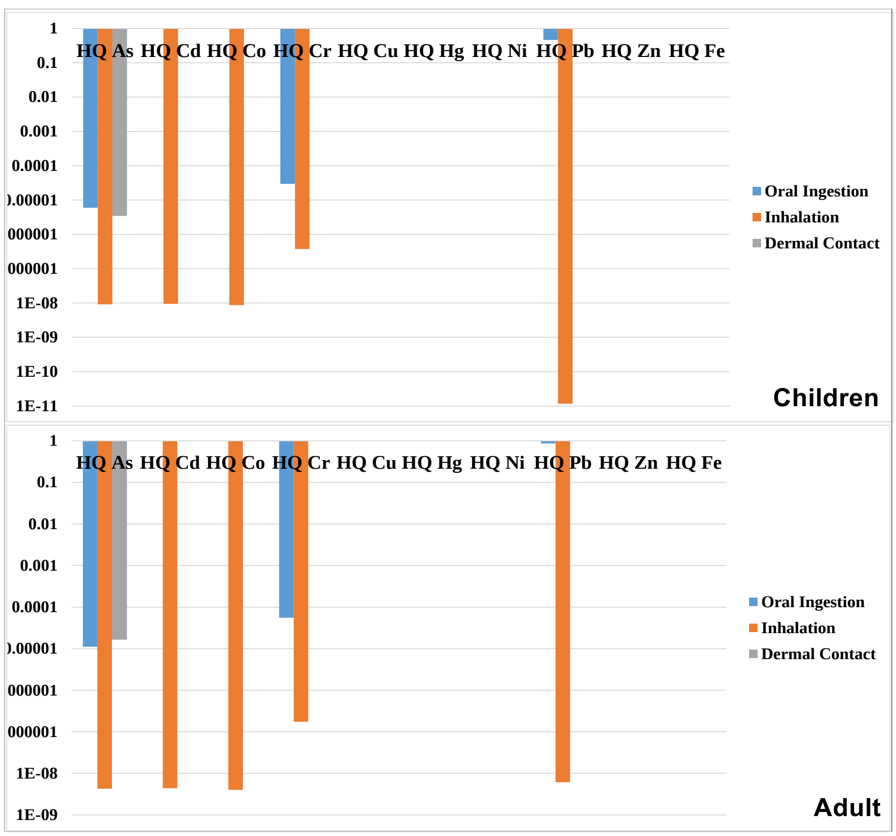

Figure 8: Carcinogenic hazard quotient (HQ) of Heavy Metals in Urban Soils of Nigeria

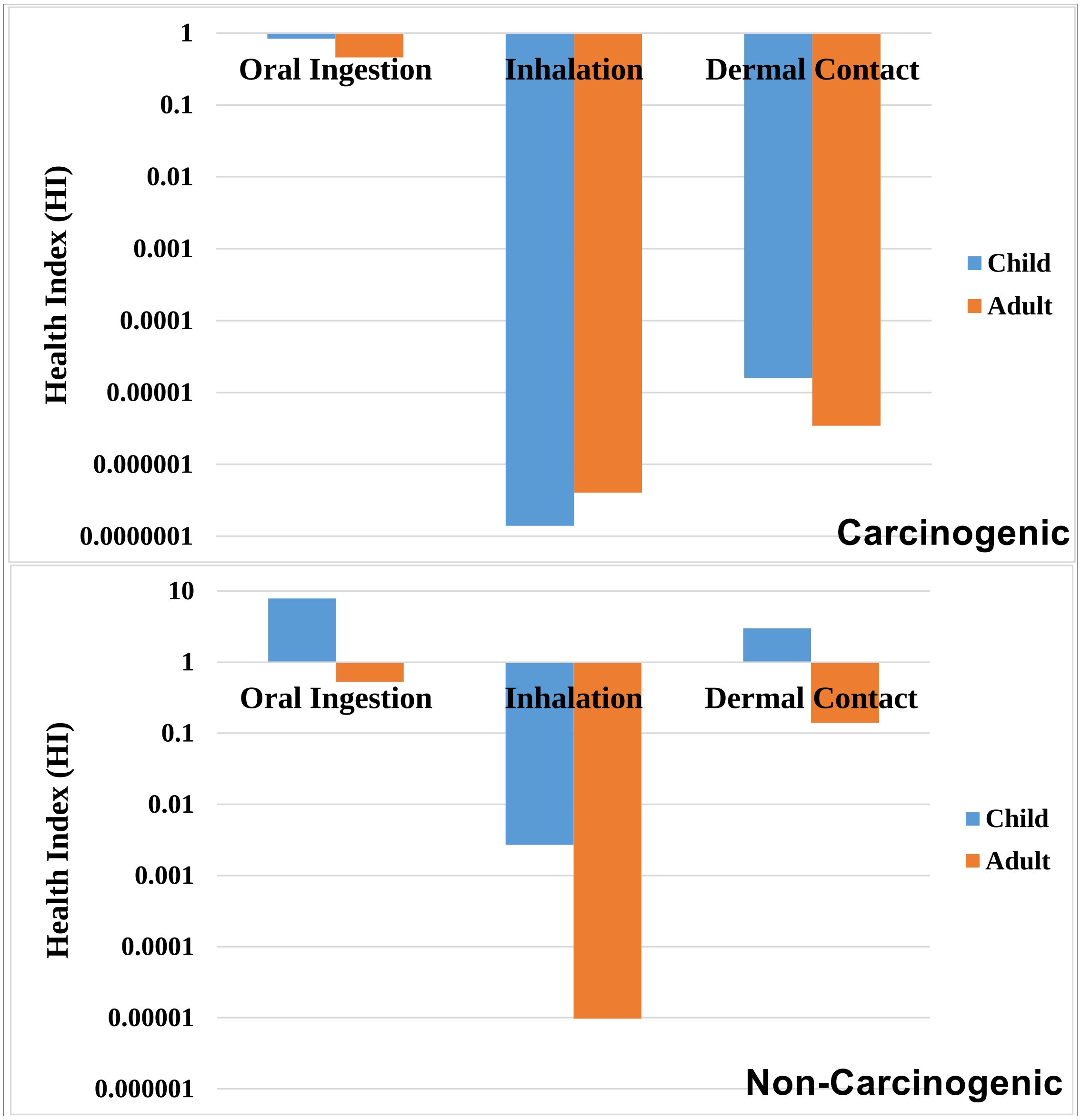

Figure 9: Carcinogenic and non-carcinogenic health index (HI) of heavy metals in urban soils of Nigeria

10.0 Conclusions and Further Studies

This systematic review was carried out to decipher the extent of soil contamination and the potential ecological and health risks associated with heavy metals in urban soils of Nigeria. From this review it was observed that urban soils of Nigeria are lowly to moderately polluted by heavy metals. It revealed that soils of the Federal Capital Territory, Abuja were the most contaminated. Sources of heavy metals in urban soils in Nigeria include: generation and dumping of wastes, industrial waste water, repair of automobiles in mechanic villages, exhausts from vehicular movement, sawmilling, sales of mechanical spare parts, vulcanizing, sales and dumping of scrap metals, petroleum spill, mining activities and cement production. Release of heavy metals from these sources pose low to very high ecological risk. Also, oral ingestion and dermal contact with heavy metals especially Pb and Fe in soils of towns may pose high non-carcinogenic health risk especially for children. Oral ingestion of Pb in soils may contribute significantly to cancer-related diseases in the country. From this review, we suggest that there is a necessity to continually monitor the presence of heavy metals in in urban environment to prevent outbreak of diseases. Where possible, rural to urban migration should be reduced in the country. Environmental sanitation rules should be strictly adhere to. This will go a very long way in promoting a healthier urban environment. Inhabitants should be sensitized on the impact of heavy metals in the environment and the roles that they can play. Researches that focus more on the impact of urbanization on soil degradation should also be promoted.

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