African Journal of
Biochemistry and Molecular Biology Research

ISSN : 0000-0000
Index: Harvard, Boston, Sydney University, Dimensions, Lens, ResearchGet Scilit, Semantic, Google Scholar, Base etc

https://doi.org/10.58578/AJBMBR.v1i2.3819

Effect of Heavy Metals and Risk Analysis on Arable Farmlands in Selected Local Government Areas of Southern Taraba State, Nigeria

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Article Info:

Submitted:	Revised:	Accepted:	Published:
Aug 20, 2024	Sep 3, 2024	Sep 6, 2024	Sep 9, 2024

Abstract

Heavy metals are naturally occurring metallic elements that have a relatively high density compared to water. In most of the continent including Africa, the lack of food quality usually stand to be one of the major problem in which most of the food items are laden with lots of pollutants from heavy metals. Soil is said to be the reservoir of nutrients as well as pollutants. These pollutants have been implicated in causing lots of Health issues on human and Animals. Agricultural soil plays major role in food safety, food scarcity and food security, consumption of contaminated foods has serious implication on Human and Animals health. Heavy metals are potential environmental pollutants which are toxic to the human health. When present in an Arable land, they have the ability to bio-accumulate in the soil then to crops and eventually get to humans through food consumption. This study is able to evaluate the effect of heavy metals and risk analysis of arable farmlands in some selected local government areas of southern Taraba state (Donga, Wukari and Takum). All samples were processed, and heavy metals (Pb, Cd, Cr, Hg, and As) concentration were assayed using Atomic Absorption Spectrophotometry (AAS). The results showed that Chromium had a high concentration across all the studied areas with values ranging from 1.40 mg/kg to 2.25 mg/kg. However, Cadmium followed with values ranging from 0.04 mg/kg to 0.07 mg/kg and Arsenic with values ranging from 0.03 mg/kg to 0.06 mg/kg while Lead and Mercury had the lowest concentration of less than 0.03 mg/kg across the three LGAs. Ecological Risk Assessments parameters; Target Cancer Risk, Hazard Index (HI) and Estimated Daily Intake (EDI) were determined to assess the non-carcinogenic health risk. Takum recorded the highest levels of HM having the highest health risk followed by Wukari, whereas Donga had the lowest. Consistent use of crops harvested from the sampled location may pose a serious health challenge; bio-accumulation of toxicants in the soil across the studied areas may pose a health risk due to high concentration of heavy metals which are known to generate free radicals that may lead to oxidative stress and other cellular damages in humans.

Keywords: Bioaccumulation; Heavy Metals; Risk; Cancer Estimation; Toxicity; Carcinogenesis

INTRODUCTION

The basis of agricultural production and the most important production factor for farmers is land. Arable farm land is a very strategic socio-economic asset, particularly in poor societies where wealth and survival are measured by access to land (Titilola and Jeje, 2008). Arable land is from the Latin: arabilis, "able to be ploughed" is any land capable of being ploughed and used to grow crops alternatively for the purposes of agricultural statistics (WBAL, 2015). It is a land that was not abandoned resulting from shifting cultivation, but land which is regularly under a system of crop rotation (Eurostat. Glossary: arable land, 2015) Arable land is the most important economic resources most particularly for developing countries with largely rural populations and most people earn a living through agriculture. It has remained an important factor of production since the creation of man and a fundamental factor of production in the agricultural sector all over the world and provides a basis for crop production in Nigeria and sub-Saharan Africa. Securing access to productive arable farm land is critical to millions of poor people living in rural areas and depending on agriculture, livestock or forests for their livelihood. It reduces their vulnerability to hunger and poverty; influences their capacity to invest in their productive activities and in the sustainable management of their resources, (Marie *et al.,* 2014).

Heavy metals are naturally occurring metallic elements that have a relatively high density compared to water (Fergusson, 1990). In most continent including Africa, the lack of food safety is a major problem. Most of the food items are laden with lots of pollutants from heavy metals. The consumption of contaminated foods has serious effect on health and economic status of the populace (Otitoju *et al.*, 2014). With the assumption that heaviness and toxicity are inter-related, heavy metals also include metalloids, such as arsenic, that are able to induce toxicity at low level of exposure (Duffus, 2002).

Environmental pollution by heavy metals has become a major concern worldwide (Tatah *et al.,* 2017) because of their widespread use, distribution and particularly their toxicity to human beings and the ecosystem. They are the continuous environmental contaminants since they cannot be easily degraded (Ambika *et al.,* 2016). This has resulted in the release of pollutants (hydrocarbons and heavy metals) capable of contaminating soil and water bodies (Otitoju *et al.*, 2013).

The accumulation of heavy metals and metalloids in soil, especially cadmium, chromium, copper, lead, nickel, and zinc poses many risks to human health and ecosystem (Otitoju *et al.,* 2022). While many researchers have attempted to develop relationship between concentrations of contaminants in soils or plants and the effects on plants or organisms (including humans), in recent years, extensive research has been conducted on estimation of bioavailability and toxicity of metals in soils (Fergusson *et al.*, 1990).

Enrichment of heavy metals in the environment is of major concern because of their toxicity and threat to human life and the environment. Heavy metals are introduced into the environment and most especially into the soil from different sources such as industrial, agricultural and municipal waste (Parry *et al.,* 1981; Olajire and Ayodele; 1998; Olajire *et al.*, 2003), automobile emissions (Olajire and Ayodele, 1997) mining activities and agricultural practices (Olajire and Ayodele, 1997)

Common sources of heavy metal pollution include discharge from industries: such as electroplating, plastic manufacturing, fertilizer producing plants and wastes left after mining and metallurgical processes (Zouboulis *et al.,* 2014). Findings reveal that farmers use a wide range of pesticides at different levels to reduce losses from pests and diseases. However, despite the contribution of pesticides to agricultural production, pesticides are of major environmental concern (Oko *et al.*, 2024). Many pesticides and chemicals are not biodegradable, they bioaccumulate in food chain and become detrimental to human and the ecosystem (Banjo 2010; Adeola 2012). The repeated applications of these agrochemicals potentially contribute to the accumulation of heavy metals in agricultural soils as some of these fertilizers and pesticides contain heavy metals such as Cd, Pb and Cr. (Huang *et al.*, 2007). The accumulation of heavy metals in soil of the study area could either directly endanger the natural soil functions or indirectly endanger the biosphere by bioaccumulation in the food chain, and ultimately endanger human health (Liu *et al.*, 2006). It is commonly acknowledged that total soil heavy-metal concentration alone is not a good measure of bioavailability and is not a very helpful tool to determine the potential risk associated with soil contamination (Habibu *et al.*, 2024). Therefore, chemical speciation, which plays a vital role in determining the bioavailability of toxic metal in a soil solution, is often used as a predictor of metal bioavailability to soil organisms and plants (Cui, 2011). The chemical forms of the metal control its bioavailability or mobility. The exchangeable and acid extractable fractions are mobile fractions that are easily bioavailable. This bioavailable metals in the soil provides rough estimate of metal uptake by plants (especially edible plants) and their risk assessment. Mining or old mine sites are common areas with heavy metals and pollution which are increasing with increase in the proximity to the mining site (Murthy *et al.,* 2011).

Exploitation and mining of heavy metals contribute significantly to national income, but adversely to environmental pollution (Obasi et al., 2017). In developing countries like Nigeria where artisan mining predominates, large quantities of tailings and waste water produced during the process are discharged into arable farmlands without regard to the environmental impact of such practice. Soils contaminated with heavy metals can pose serious threat to the ecosystem and human health, through different exposure routes (Habibu *et al.*, 2022). Heavy metals have been reported to cause varying degrees of toxicity in humans ranging from non-carcinogenic to carcinogenic risks (Obasi et al., 2017; Liang et al., 2010). Heavy metals are non-biodegradable and as such persist in the environment. Depending on the physicochemical properties of the soil-plant root environment, heavy metals accumulate in edible portions of plants and may get ingested by humans that consume them (Obasi et al., 2017). So also, heavy metals may be ingested directly from the soil when they get access to the body, it may be inhaled or taken up through dermal contact. The uptake of heavy metals by plants from soil depends largely on the different chemical forms/species of the metals in the soil and not the total heavy metals. Hence, plants uptake varies according to the chemical species which determines the mobility and bioavailability of the metals to the plants which also varies with plants species (Ogunbanjo et al., 2016).

METHODS

Research area

In this study, three Villages from Local Government areas (Donga, Wukari and Takum) where agricultural and commercial activity coexist were selected for the studies of heavy metal on the farmlands as well as their bindings to the major fractions in soil. Five heavy metals (As, Cd, Hg, Cr, and Pb) were chosen for their agricultural significance and toxicity.

Sampling Site

In Taraba state Majority of the population who are predominantly found in the southern and other parts of the state, are Fulani, Jukun, Chamba, Kuteb, and Ichen. Over 2 million people live in Taraba State, which includes about 40 unique tribes and dialects (according to the 2006 census). With the state capital as Jalingo, The state is bordered on the west by the states of Nasarawa and Benue, on the northwest by the state of Plateau, on the north by the states of Bauchi and Gombe, on the northeast by the state of Adamawa, and on the south by a province of Cameroon. The state is majorly in the tropical zone, while its southern and northern regions are covered in low woods, respectively. The main occupation for people in Taraba State is agriculture. Among the cash crops farmed in the state are cotton, coffee, tea, groundnuts, and others. Additionally produced in commercial numbers are yams, cassava, millet, sorghum, and maiz

Figure 1 Arable farmland from the sampling areas. Source: Snap shot

Sample Collection

Three sampling sites were identified for the samples from the three local government areas of Taraba State (Donga, Takum, Wukari) and soil was collected using sterile glass sample collection bottles measured at 5cm depth and then kept in a polythene sealed bags, labeled and placed in an air dried place prior to analysis of Heavy metals (As, Cd, Pb, Hg, and Cr) in the Laboratory.

Table 1: Research experimental design

Local Government Areas	S/N	Sampling sites/Villages
Donga	1	Bibino
	2	Kumbo
	3	Tudun-Wada
Takum	4	Chancangi
	5	Abuja Area
	6	Unguwan-Rogo
Wukari	7	FUW farm
	8	Kasuwan Shanu
	9	Byepyi

Sample preparation for the analysis

The collected soil samples were freed from unwanted materials and air-dried to remove excess moisture, large soil clouds were also crushed to facilitate the drying. The dried soil samples were crushed in a porcelain mortar and pestle, the crushed soil-sample was sieved through a 2 mm sieve made of stainless steel and pulverized to a fine powder ready for the analysis of heavy metals content as modified by Otitoju (2015)

Determination of heavy metals concentration

A measured volume of well prepare sample appropriate for the expected metal concentration was transferred into a conical flask in fume cupboard, 3 mL of conc. HNO_3 was added and covered with a ribbed watch glass and then placed on a heating mantle and cautiously evaporate to less than 5 ml, making sure that sample does not boil. The mixture was allowed to cool and the flask wall was rinsed and washed with a distilled water. There after 5 ml of conc. HNO_3 was added and the flask was covered with a ribbed watch glass and returned to the heating mantle. Heating continued until digestion is completed. It was cooled, and flask was washed down with water. The solution was filtered and the filtrate was then transferred to a 100 mL volumetric flask built up to the required concentration with distilled water before being used for analysis (Radojovenic and Bashkin, 2006).

Health Risk Calculation

The specific model and pollution indices used in this study is Hazard quotients model (HQ), to assess the risk of heavy metals in soil**.** Hazard quotient is the ratio of the potential exposure concentration to a substance and the level at which no adverse effects are expected. If HQ < 1, adverse health effects would be unlikely experienced, whereas potential non-carcinogenic effects would occur when HQ ≥1 (Al-Saleh *et al.*, 1999).

$$\textbf{Hazard Quotient (HQ)} = \frac{(EDI)}{(ADI)}$$

Hazard index (HI)

HI = the summation of an individual HQs.

$$HI = \sum HQ_i$$

HI = THQ = THQ (Pb) + THQ (Cr) + THQ (Cd) + THQ (As) + THQ (Hg).

if HI > 1, it means an unacceptable risk of non-carcinogenic effects on health, while HI < 1 means an acceptable level of risk (Lim *et al.*, 2008).

$$\textbf{Accepted Daily Intake (ADI)} = \frac{\textbf{10 (mg/kg) BW/D}}{\textbf{100}}$$

Estimated Daily Intake (EDI)

Estimated Daily Intake (EDI) was calculated by the following equation (Juan *et al.*, 2010).

$$EDI = \frac{(\text{CHM as mg/ kg}) \times (\text{DIF in kg/person})}{\text{ABW (60 kg)}}$$

Target Cancer Risk

$$\text{Target cancer risk (TR)} = \frac{\text{EFr x EDtot x SI x MCS x CPSo}}{\text{BWa x ATc}} \times 10^{-3}$$

Where Efr = Exposure frequency (350 days/years)

EDtot = Exposure duration, total (30 years)

SI = Soil ingestion, gram per day (1 gram) x 1000mg/kg

MCS = Metal concentration

CPSo = Carcinogenic potency slope, oral (1 mg/kg/day)

BWa = Body weight adult (60 kg)

ATc = Average time carcinogenic (25,550 days)

If multiple carcinogenic elements are present, the cancer risks from all carcinogen are summed (assuming additive effects). Risks in the range of 1.0×10^{-6} to 1.0×10^{-4} are acceptable (Cao *et al.*, 2015).

$$CRt = \sum CR$$

Cr, Cd, Pb, Hg and As were treated as potential carcinogenic contaminants elements, based on the order of classification group defined by the International agency for Research on Cancer (IARC, 2011).

Statistical Analysis

Statistical analysis was carried out using ANOVA and further with Duncan's multiple comparison test and results were expressed as mean ± standard error. The statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 23 and significance was at $P < 0.05$.

RESULTS

Heavy metals concentration of soil samples

The results of heavy metals concentrations are presented in table 2. Heavy metals were detected in all the soil samples from the 9 sampling points of 3 LGAs of southern Taraba State. The results showed that Chromium had a very high concentration across all the studied areas with values ranging from 1.40 mg/kg to 2.25 mg/kg. Cadmium had values ranging from 0.04 mg/kg to 0.07 mg/kg and Arsenic followed moderately with values ranging from 0.03 mg/kg to 0.06 mg/kg while Lead and Mercury had lowest concentration of less than 0.03 mg/kg across the 3 LGAs. As shown below.

Table 2: **Heavy metal concentration of Soil samples from selected LGAs in southern Taraba State**

Study areas	Pb (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	As (mg/kg)	Hg (mg/kg)
Donga	0.01 ± 0.00[a]	0.04 ± 0.01[a]	1.40 ± 0.30[a]	0.03 ± 0.01[a]	0.01 ±0.00[a]
Takum	0.02 ± 0.01[ab]	0.07 ± 0.02[ab]	2.25 ± 0.52[ab]	0.06 ± 0.01[ab]	0.02 ± 0.01[ab]
Wukari	0.02 ± 0.01[ab]	0.07 ± 0.02[ab]	2.01 ± 0.61[ab]	0.06 ± 0.02[ab]	0.02 ± 0.01[ab]

Results are expressed in mean ± standard deviation of triplicate determination. Values with the same superscript have no significant difference between groups, while Values with different superscripts significantly differs between groups within the same column at P< 0.05. WHO permissible limits: Cr; 0.001 mg/kg, Cd; 0.003 mg/kg. As; 0.0 mg/kg, Pb; 2.00 mg/kg, Hg; 0.03 mg/kg

Lead Concentration, Calculated risk and Hazard index in Soil samples from selected LGAs in southern Taraba State

The result of lead concentration in soil from some LGAs sampled in southern Taraba State is presented below. The result indicate that Donga LGA has the lowest concentration of Pb (0.01 ± 0.00 mg/kg) while both Takum and Wukari had (0.02 ± 0.01 mg/kg). However, there is no significant difference across all the sampling point (P < 0.05). Similarly, the calculated risk in Donga has the lowest value (0.07) while little higher in Takum and Wukari with (0.13).

Table 3: **Calculated risk and Hazard index of Lead in Soil samples from selected LGAs in southern Taraba State**

Study areas	Pb Concentration(mg/kg)	EDI	Calculated risk	HI
Donga	0.01 ± 0.00[a]	0.000015	0.07	9.94
Takum	0.02 ± 0.01[ab]	0.000030	0.13	15.94
Wukari	0.02 ± 0.01[ab]	0.000030	0.13	14.36

Results are expressed as mean ± standard deviation of triplicate determination. WHO permissible value of Pb is 2.00 mg/kg. Source: WHO (1999). HI > 1 is unacceptable risk level of non-carcinogenic, while HI < 1 is acceptable risk level. HI = hazard index (Lim *et al*., 2008).

Cadmium Concentration, Calculated risk and Hazard index in Soil samples from Selected LGAs in southern Taraba State

The results of Cadmium concentration in soil from some LGAs in southern Taraba State is presented below. The result showed that Donga LGA have lower concentration of (0.04 ± 0.01 mg/kg), while Takum and Wukari had (0.07 ± 0.02 mg/kg) However, Cd level in Wukari and Takum is higher across the studied areas at ($P < 0.05$). Similarly, the calculated risk shows that Donga has the lowest risk value 0.32 while Takum and Wukari has the highest calculated risk value of 0.46.

Table 4**: Calculated risk and Hazard index of Cadmium in Soil samples from Selected LGAs in southern Taraba State**

Study areas	Cd Concentration (mg/kg)	EDI	Calculated risk	HI
Donga	0.04 ± 0.01[a]	0.000076	0.32	9.94
Takum	0.07 ± 0.02[ab]	0.000107	0.46	15.94
Wukari	0.07 ± 0.02[ab]	0.000107	0.46	14.36

Results are expressed as mean ± standard deviation of triplicate determination. WHO permissible value of Cd is 0.003 mg/kg. Source: WHO (1999). HI > 1 is unacceptable risk level of non-carcinogenic while HI < 1 is acceptable risk level.

Chromium Concentration, calculated risk and hazard index of Cr in Soil samples from selected LGAs in southern Taraba State

Result of Chromium concentration in soil samples from some LGAs in southern Taraba state is presented below. The result showed that Donga LGA had low concentration (1.40 ± 0.30 mg/kg), while Wukari had (2.01 ± 0.61mg/kg) and Takum LGAs have higher concentrations of (2.25 ± 0.52mg/kg) respectively. Therefore, the level of Cr in all the studied areas implies that there is a significant difference in all the studied areas at ($P < 0.05$). However, the calculated risk showed that Donga has lower risk value of 9.23 compared to Wukari with 13.25 and Takum higher with 14.83 respectively.

Table 5: **Calculated risk and Hazard index of Chromium in Soil samples from Selected LGAs in southern Taraba State**

Study areas	Cr Concentration (mg/kg)	EDI	Calculated risk	HI
Donga	1.40 ± 0.30[a]	0.00215	9.23	9.94
Takum	2.25 ± 0.52[ab]	0.00346	14.83	15.94
Wukari	2.01 ± 0.61[ab]	0.00309	13.25	14.36

Results are expressed as mean ± standard deviation of triplicate determination. WHO permissible value of Cr is 0.001 mg/kg. Source; WHO (1999). $HI > 1$ is unacceptable risk level of non-carcinogenic while $HI < 1$ is acceptable risk level.

Arsenic Concentration, Calculated risk and hazard index in Soil samples from selected LGAs in southern Taraba State

The results of Arsenic content in soil sample from some LGAs sampled in southern Taraba state is presented below. The result showed that Donga LGA had the lowest concentration (0.03 ± 0.01 mg/kg), followed by Takum with (0.06 ± 0.01 mg/kg), Wukari had (0.06 ± 0.02 mg/kg) high, However, the As level in all the studied areas showed no statistically significant difference exist among all the sampling points at ($P < 0.05$). The calculated risk shows that Donga has the lowest risk value of 0.26, while both Wukari and Takum had the highest calculated risk value of 0.39 each.

Table 6: **Calculated risk and Hazard index of Arsenic in Soil samples from Selected LGAs in southern Taraba State**

Study areas	As Concentration (mg/kg)	EDI	Calculated risk	HI
Donga	0.03 ± 0.01[a]	0.0000615	0.26	9.94
Takum	0.06 ± 0.01[ab]	0.0000923	0.39	15.94
Wukari	0.06 ± 0.02[ab]	0.0000923	0.39	14.36

Results are expressed as mean ± standard deviation of triplicate determination. WHO permissible value of As is 0.200 mg/kg. Source: WHO (1999). HI > 1 is unacceptable risk level of non-carcinogenic, while HI < 1 is acceptable risk level.

Mercury Concentration, Calculated risk and hazard index in Soil samples from selected LGAs in southern Taraba State

The result of Mercury content in soil sample from some LGAs sampled in southern Taraba state is presented below. The result showed that Donga LGA had the lowest concentration of Hg (0.01 ± 0.00 mg/kg) and both Takum, and wukari had (0.02 ± 0.01 mg/kg). Similarly, the Hg level across all the LGAs showed that there is no statistical significant difference across all the sampling points at ($P < 0.05$). However, the calculated risk showed that Donga had the lowest risk value of 0.06, while Takum and Wukari are moderately high at 0.13 values.

Table 7**: Calculated risk and Hazard index of mercury in Soil samples from Selected LGAs in southern Taraba State**

Study areas	Hg Concentration (mg/kg)	EDI	Calculated risk	HI
Donga	0.01 ± 0.00[a]	0.000015	0.06	9.94
Takum	0.02 ± 0.01[ab]	0.000030	0.13	15.94
Wukari	0.02 ± 0.01[ab]	0.000030	0.13	14.36

Results are expressed as mean ± standard deviation of triplicate determination. WHO permissible value of Hg is 0.05 mg/kg. Source: WHO (1999). HI > 1 is unacceptable risk level of non-carcinogenic while HI < 1 is acceptable risk leve

DISCUSSION

Taraba state is the host of the largest base of solid minerals, (including gold, diamond, limestone, zinc and lots more) in Nigeria. The state sits of over lots of abundant solid minerals deposits waiting for exploitation (Habibu *et al*., 2022) .

The major activity of the populace in the studied areas is farming due to its fertile nature and abundant arable farmlands in production of cash crops such as coffee, tea and cotton. Crops such as maize, rice, sorghum, millet and root crops such as cassava and yam. Other important economic activities including rearing of verities of animal such as cattle, sheep, goats and donkey in large quantity take place in the studied areas. (C-GIDD, 2008). lack of resent findings about the concentration of heavy metals in the studied areas becomes an issue of concern among the populace living the areas which geared on focusing this research to determine the concentration of heavy metals on nine sampling points from the three LGAs of southern Taraba State Nigeria.

The Heavy metals analysis was carried out in the study to ascertain the levels of metals concentrations as a result of artisanal activities in arable farmlands. Heavy metals are among the most dangerous environmental pollutants which can bio-accumulate in living tissues (Habibu *et al*., 2024). The consumption of food which is the source of energy and other nutrient for human and animal existence that is mostly cultivated by the people in the studied areas is of great concern. However, safety of populace living in the studied areas gives a reason to worry. The heavy metals available for plant uptake are those present as soluble components in the soil solution or those solubilized by root exudates (Blaylock, M.J., and Huang, J.W., 200). Plants require certain heavy metals for their growth and upkeep, excessive amounts of these metals can become toxic to plants and ability of plants to accumulate essential metals equally enables them to acquire other nonessential metals (Dingova, R., and Kuleff, I., 200). As metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly and some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress

(Assche and Clijster., 1990). Indirect toxic effect is the replacement of essential nutrients at cation exchange sites of plants (Taiz and Zeiger., 2002).

The results obtained from this study indicates that the heavy metals (Pb, As, Hg, Cd, and Cr) were present in the soil samples collected from Donga, Takum, and Wukari LGAs of southern Taraba State, Nigeria. All the metals occur in concentrations above their WHO stipulated permissible limits except for Lead and Mercury as shown in table 2 where Cd: 0.04 mg/kg to 0.09 mg/kg, As: 0.03 mg/kg to 0.07 mg/kg, Hg: 0.01 mg/kg to 0.03 mg/kg, Pb: 0.01 mg/kg to 0.03 mg/kg, and Cr: having the values greater than 1.40 mg/kg in this study.

Cr seems to be the most mobile element, followed by Cd and As, while Pb and Hg were the less mobile elements in the studied environment (table: 2). Which indicates that Cr is the most mobilized element as it is mostly distributed among arable farmlands in its higher amount with high risk value compared to Cd, As, Pb and Hg. This high amount of Cr in the arable lands shows that it may be easily transferred into the food chain through uptake by plant growing in the soil. For this reason, there is need for a high level concern regarding the level of Cr present in the soil, since it can be poisonous to mammals. Cr mostly find its way to the soil (in the arable farmlands) through application of organic manure and fertilizers, since fertilizer and organic manure remains the primary source of nutrient to the soil in an arable farmlands (Chasapis *et al.,* 2012) Chromium is known to be a toxic metal that can cause severe damage to plants and animals. Chromium induced oxidative stress involves induction of lipid peroxidation in plants that causes severe damage to cell membranes (Peralta *et al*., 2001). Chromium stress can also induce some possible metabolic modification in plants: (alteration in the production of pigments, which are involved in the life sustenance of plants (e.g., chlorophyll, anthocyanin) (Boonyapookana *et al*., 2002), Increased production of metabolites (e.g., glutathione, ascorbic acid) as a direct response to Cr stress, which may cause damage to the plants (Shanker *et al*., 2003). And its also bring about an alterations in the metabolic pool to channelise the production of new biochemically related metabolites, which may confer resistance or tolerance to Cr stress (e.g., phytochelatins, histidine). (Schnifger 2001). In tomato (*Lycopersicon esculentum*) chromium toxicity resultant decrease in plant nutrient acquisition (Moral *et al*., 1995; Moral *et al*., 1996) In onion (*Allium cepa*) shows the inhibition of germination process and reduction of plant biomass (Nematshahi *et al*., 2012). In wheat (*Triticum sp*) Reduction of shoot and root growth were noticed (Sharma *et al*., 2012; Panda *et al*., 2000).

(Oluyemi and Olabanji, 2011) The WHO stipulated value for Cr is 0.001 mg/kg. While the Cr concentrations in this study range from 1.40 mg/kg – 2.71 mg/kg across all the study areas, with the concentration of Cr being above the WHO stipulated value 0.001 mg/kg and having the highest value of risk calculated. This implies that the populace in all the studied areas are predisposed to Cr-induced health conditions such as asbestosis, lung cancer, chromosomal aberration, DNA damage which lead to the formation of DNA adducts, alteration in replication and transcription of DNA and sometimes led to cell death due to DNA strand breaks (Monisha, *et al*., 2014).

Cd followed with high concentration after Cr across the sampled areas, showed that its availability is susceptible to ionic composition change in the environment. Cd being one of the cumulative poison for mammals find its way into the soil primarily through the application of fertilizer, pesticides and herbicides to the arable farmlands as the source of nutrient to the soil, which then can bio-accumulate in plants and get in to humans via food, Plants grown in soil containing high levels of Cd show visible symptoms of injury reflected in terms of chlorosis, growth inhibition, browning of root tips and finally death (Sanita *et al*., 1999). In wheat (*Triticum sp*.) excess of cadmium reduces the seed germination, decrease plant nutrient content, reduced shoot and root length (Ahmad *et al* 2012). In garlic (*Allium sativum*) Cd accumulation reduces shoot growth (Jiang *et al*., 2001). Lastly in Maize (*Zea mays*) it reduces shoot growth and course inhibition of root growth (Wang *et al*., 2007). Cd concentrations in this study ranges from (0.04 mg/kg-0.09 mg/kg) which are higher than the WHO stipulated permissible limit value of (0.003 mg/kg). Therefore, people living in these study areas could be in danger of Cd related health problems (WHO, 2011). High exposure to Cd can lead Health condition such as obstructive lung disease, cadmium pneumonitis, anemia, renal damage, bone disorder and cancer of the lungs (Monisha, *et al*., 2014).

Arsenic (As) as one of the metals of concern was confirmed to be present in the sampled areas in high value above the permissible limit at (0.03-0.07 mg/kg). While the WHO stipulated value is (0.02 mg/kg). High concentration of arsenic in tomato (*Lycopersicon esculentum*) reduces fruit yield the leaf fresh (Barrachina *et al*., 1995). Whereas, in canola (*Brassica napus*) arsenic causes stunted growth, chlorosis and wilting (Cox *et al*., 1996) In rice (*Oryza sativa*) reduces seed germination, decrease in seedling height, reduces leaf area and dry matter production (Marin *et al.,* 1993). So, Based on the result of this study, the populace in this studied areas could be predispose to As-induced health problems such as arsenicosis (Monisha *et al*., 2014). Most of the reports of chronic arsenic toxicity in man focus on skin manifestations because of its specificity in diagnosis. Pigmentation and keratosis are the specific skin lesions that indicate chronic arsenic toxicity (Monisha *et al*., 2014).

Lead (Pb) is one of the ubiquitously distributed most abundant toxic elements in the soil. It exerts adverse effect on morphology, growth and photosynthetic processes of plants. In maize (*Zea mays*) reduction in germination percentage; suppressed growth; reduced plant biomass, decrease in plant protein content has been noticed (Hussain *et al*., 2013). Whereas, in Portia tree (*Thespesia populnea*) lead courses reduction in number of leaves and leaf area, reduced plant height (Kabir et al., 2009). Decrease in plant biomass and in Oat (*Avena sativa*) Inhibition of enzyme activity which affected CO_2 fixation (Demirevska-Kepova *et al*., 2004).

The concentration of Pb and Hg, were low across all the soil samples studied. They are detected in low amount in this study which may be a minor pollution indicator since their present in the soil to some extent may cause a serious concern to the populace living in the area. Pb may have originated from traffic, since most of the soil samples were collected from near highways. Pb mainly enters into the soil by means of atmospheric dry and wet depositions and disposal of sewage sludge (Habibu *et al*., 2024). Lead is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults (Oluyemi and Olabanji, 2011). The WHO stipulated maximum level of Pb in soil is 2.00 mg/kg and from the result of this study, Pb concentration is very low at 0.01 mg/kg – 0.03 mg/kg in all the soil samples. Thus, Pb may not pose serious health consequence to the populace in those areas at short term exposure, but may do so in the long run (WHO, 2011).

Mercury is a dangerous heavy metal whose poisoning (or excessive intake) can result to numerous health conditions. Mercury is known to be a latent neurotoxin compared to other metals. Contamination of Hg to the soil is often due to the addition of this heavy metal as part of fertilizers, lime, sludge and manures. The large input of mercury (Hg) into the arable lands has resulted in the widespread occurrence of mercury contamination in the entire food chain. In rice (*Oryza sativa*) excess of mercury decreases plant height, reduces tiller and panicle formation and yield reduction (Kibra, 2008). In tomato (*Lycopersiconesculentum*) Hg courses reduction in germination and plant height, reduce in flowering and fruit weight and finally resultant chlorosis appears on the whole plant (Shekar *et al.*, 2011).

A high dietary intake of mercury (organic) above the stipulated limit of consumption has been hypothesized to increase the risk of coronary heart disease (Oluyemi and Olabanjo, 2011). In this study, the concentrations of Hg in all the soil samples range from (0.01-0.03 mg/kg). These concentrations are higher than the WHO stipulate permissible limit at 0.03 mg/kg. This implies that the persistent consumption of food cultivated on the study areas could lead to health problems related to Hg if the uptake by plants is directly proportional to the available concentration in the soil (Habibu *et al.*, 2024)

CONCLUSION

Although the studied HM were significantly present in all the analysed soil with the exception of lead and Mercury, their concentration in various soil samples across the studied areas exceeded the permissible levels as recommended by WHO with exception of Lead and Mercury, therefore, efforts should be put in place to address the bioaccumulation of these metals to the arable land from anthropogenic sources. The anthropogenic input of Cr was found mainly in Takum and Wukari in high concentrations which may be due to the geographical location of the study areas as they shared boundaries to each other, including Cd and As which are moderate in concentrations were significantly high in these study areas above the permissible values. Hg and Pb appeared to be in low concentration, but all other heavy metals (Cr, Cd and As) analyzed were present in concentration above the permissible limit of utilization by WHO. These heavy metals may be transferred to human on consumption of crops cultivated in the areas which may be hazardous to human health due to their cumulative effect in the human body, hence, the results possibly indicate that anthropogenic heavy metals are easily mobile and potentially more phyto available than lithogenic and pethogenic heavy metals in arable farmlands.

REFERENCES

Al-Saleh, I., Nester, M., Shinwari, N., Al-Shahria, S. (1999). Determinants of blood lead levels in Saudi Arabian schoolgirls. *International Journal of Environmental Health*, 5: 107114.

Ambika, A., Mohish, P. and Kumar, N. (2016) Effect of Heavy Metals on Plants. An overview, *international journal of application or Innovation in Engineering and Management (IJAIEM),* vol. 5, no. 3, pp. 2 6.

Banjo, A.D., Aina, S.A. and Rije, O.I. (2010) Farmers' Knowledge and Perception Towards Herbicides and Pesticides Usage in Fadama Area of Okun-Owa, Ogun State of Nigeria. *African Journal of Basic & Applied Sciences,* 2, 188-194.

Barrachina A.C, Carbonell F.B. and Beneyto J.M. (1995) "Arsenic uptake, distribution, and accumulation in tomato plants: effect of arsenite on plant growth and yield," *Journal of Plant Nutrition,* vol. 18, no. 6, pp. 1237–1250.

Blaylock M.J. and Huang J.W. (2000) "Phytoextraction of metals," in Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment, I. Raskin and B. D. Ensley, Wiley, New York, NY, USA, pp. 53–70

Boonyapookana, B., Upatham, E.S., Kruatrachue, M., Pokethitiyook, P., Singhakaew, S. (2002) Phytoaccumulation and phytotoxicity of cadmium and chromium in duckweed Wolffia globosa. *International Journal of Phytoremediation,* 4:87 100.

Cao, S., Duan, X., Zhao, X., Wang, B., Ma, J., Fan, D., Sun, C., He, B., Wei, F., Jiang, G. (2015). Health risk assessment of various metalloids via multiple exposure pathways on children living near a typical lead-acid battery plant, China Environmental Pollution. 200: 16–23.

Cao, Z. R., Cui, S. M., Lu, X. X., Chen, X. M., Yang, X., Cui, J. P. and Zhang, G. H. (2018). Effects of occupational cadmium exposure on workers' cardiovascular system. *Chinese Journal of Industrial Hygiene and Occupational Diseases*, 36(6): 474-477.

Centeno, J. A., Gray, M. A., Mullick, F. G., Tchounwou, P. B. and Tseng, C. (2005). Arsenic in drinking water and health issues. In: TA Moore, A Black, JA Centeno, JS Harding, DA Trumm (eds.), *Metal Contaminants in New Zealand*. Resolutionz Press, New Zealand. 195219.

Centeno, J. A., Tchounwou, P. B., Patlolla, A. K., Mullick, F. G., Murakat, L., Meza, E., Gibb, H., Longfellow, D. and Yedjou, C. G. (2005). Environmental pathology and health effects of arsenic poisoning: A critical review. In: Naidu R, Smith E, Smith J, Bhattacharya P (eds.), *Managing Arsenic In the Environment: From Soil to Human Health*. CSIRO Publishing Corp. Adelaide, Australia

Chen. P., Greenberg B., Taghavi, S., Romano, C., Van der Lelie, D. and He, C. (2008). An exceptionally selective lead (11)-regulatory protein from Ralstonia metallidurans: development of a fluorescent lead (11) probe. *Angiev chemical and International Edition. England*. 44, 2715-2719.

Clarkson, T. W., Magos, L. and Myers, G. J. (2003). the toxicology of mercury-current exposures and clinical manifestations. *The New England Journal of Medicine*, 1731–1737

Cox, M.S., Bell, P.F. and Kovar, J.L. (1996) "Differential tolerance of canola to arsenic when grown hydroponically or in soil," *Journal of Plant Nutrition*, vol. 19, no. 12, pp. 1599–1610.

Cui, Y. and Du, X. (2011) Soil Heavy-Metal Speciation and Wheat Phytotoxicity in the Vicinity of an Abandoned Lead-Zinc Mine in Shangyu City, Eastern China. Environmental Earth Sciences, 62, 257-264.

Davis, B. J., Price, H. C., O'Connor, R. W., Fernando, R. R. A. S., Rowland, A. S. and Morgan, D. L. (2001). Mercury vapor and female reproductive toxicity. *Journal of Toxicological Sciences*, 59(2): 291-296.

Demirbas, A. (2004). Combustion characteristics of different biomass fuels. *Progress in energy and combustion science*, 30(2): 219-230.

Demirevska-Kepova, K., Simova-Stoilova, L., Stoyanova, Z., Holzer, R., Feller, U. (2004) Biochemical changes in barley plants after excessive supply of copper and manganese. Environmental Exposure Bot 52:253–266.

Dopp, E., Hartmann, L. M., Florea, A. M., Rettenmeier, A. W. and Hirner, A. V. (2004). Environmental distribution, analysis, and toxicity of organometal (loid) compounds. *Critical Reviews in Toxicology*, 34(3): 301-333.

Duffus, J.H. (2002). Heavy metals-a meaningless term?. Pure Applied Chemistry, 74(5): 793807.

Effect of Salt Stress on the Germination, Water Content and Seedling Growth of Zea mays L. *International Journal of Water and Soil Resources Research*, 3, 20-25.

EPA. (2011). Risk Assessment Guidance for Superfund (Part E, Part F); EPA: Washington, DC, USA, 2011. 3:20-22.

Fergusson, J.E. (1990). Environmental Ecology: The impacts of pollution and other stresses on Ecosystem structure and function. Pp: 6-8 Academic press, San Diego. Fish in Langkawi island, Malaysia. *International Food Research Journal, 16,*105-112.

Flora, S. J., Flora, G. and Saxena, G. (2006). Environmental occurrence, health effects and management of lead poisoning. In Lead (pp. 158-228). *Elsevier Science BV*.

Guo, J., Dai, X., Xu, W., Ma, M. (2008). Over expressing GSHI and As PCSI simultaneously increases the tolerance and accumulation of cadmium and arsenic in Arabidopsis thaliana. *Chemo-sphere*, 72: 1020–1026.

Habibu, B., O. Olawale., Y.O. Ejeh., M.A. Abah and O.T. Idris, 2024. Heavy metals speciation and health risk analysis of arable farmlands in Ardo-kola, Bali and Wukari local government areas of Taraba State, Nigeria. Asian J. Bio. Sci. 17 (4): 587-598.https://doi.org/10.3923/ajbs.2024.587.598

Habibu, B., O.O. Francis, Y.O. Ejeh and M.A. Abah, 2022. Heavy metals and health risk analysis of arable farmlands in selected local government areas of Taraba State, Nigeria. Toxicol. Adv., Vol. 5. 10.53388/202305015.

Huang, S.S., Liao, Q.L., Hua, M., Wu, X.M., Bi, K.S., Yan, C.Y. and Zhang, X.Y. (2007) Survey of Heavy Metal Pollution and Assessment of Agricultural Soil in Yangzhong District, Jiangsu Province, China. Chemosphere, 67, 2148-2155. https://doi.org/10.1016/j.chemosphere.2006.12.043.

Hussain, A., Abbas, N., Arshad, F. (2013) "Effects of diverse doses of lead (Pb) on different growth attributes of *Zea mays L.*," Agricultural Sciences, vol. 4, no. 5, pp. 262–265. b.

Juan, C., Moltó, J.C., Mañes, J., Font, G. (2010). Determination of macrolide and lincosamide antibiotics by pressurised liquid extraction and liquid chromatography-tandem mass spectrometry in meat and milk. *Food Control*, 21: 1703–1709.

Kabir, M., Iqbal, M.Z. and Shafiq, M. (2009) "Effects of lead on seedling growth of *Thespesia populnea L.*,"Advances in Environmental Biology, vol. 3, no. 2, pp. 184–190.

Kibra, M.G. (2008) "Effects of mercury on some growth parameters of rice (*Oryza sativa*)," Soil and Environment, vol. 27, no. 1, pp. 23–28.

Liu, X., Wu, J. and Xu, J. (2006) Characterizing the Risk Assessment of Heavy Metals and Sampling Uncertainty Analysis in Paddy Field by Geostatistics and GIS.

Environmental Pollution, 141, 257-264. https://doi.org/10.1016/j.envpol.2005.08.048

Liu, Y., Wang, H., Li, X., and Li, J. (2015). Heavy metal contamination of agricultural soils in Taiyan, China, Pedosphere 25(6): 901-909.

Loomis, D., Guha, N., Hall, A. L., and Straif, K. (2018). Identifying occupational carcinogens: an update from the IARC Monographs. *Occupational and Environmental Medicine*, 75(8): 593-603.

Magomya, A.M., Yebpella, G.G., Udiba, U.U., Amos, H.S. and Latayo, M.S. (2013). Potassium Bromate and Heavy Metal Content of Selected Bread Samples Produced in Zaria, Nigeria. *International Journal of Science and Technology, 2* (2), 232-237

Monisha, J., Tenzin, T., Naresh, A., Blessy, B. M. and Krishnamurthy, N. B. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology, 7*(2), 60–72. doi:10.2478/intox-2014-0009.

Moral, Navarro, Pedreno, R.J., Gomez, I. and Mataix, J. (1995) "Effects of chromium on the nutrient element content and morphology of tomato," *Journal of Plant Nutrition*, vol. 18, no. 4, pp. 815–822.

Murthy, S., Geetha, B. and Sarangi, S.K. (2011). Effect of lead on metallothionein concentration in lead-resistant bacteria Bacillus isolated from industrial effluent. *African Journal of Biotechnology* 10, 15966-15972.

Nematshahi N, Lahouti M. and Ganjeali A. (2012) "Accumulation of chromium and its effect on growth of (*Allium cepa cv. Hybrid*)," *European Journal of Experimental Biology*, vol. 2, no. 4, pp. 969 974.

Nies, D.H. (1999), Microbial heavy-metal resistance Applied Microbiology and Biotechnology 51:730-750.

Niharranjan, M. and Nabanita, D. (2017). Coal mining and local environment: a study in Talcher coalfield of India. *Air, Soil and Water Research*, 10.

NRC, (1983). Risk assessment in the Federal Government: Managing the Process. *National Academy Press, Washington.*

Obasi, N. A., Obasi, S. E., Elom, S., Elom, O., Kalu, K.M., Aloke, C., Igwenyi, I.O., Isienyi, C.C. and Justus, C.A. (2017) "Health Risk Assessment of Heavy Metals in Ameri Lead-Zinc Mining Community via Consumption of Cassava (*Manihot esculenta* Cruz) in Ikwo L.G.A., Ebonyi State, Nigeria." *American-Eurasian Journal of Sustainable Agriculture*., vol. 11, no.6, pp. 22-30, 2017.

Oko, J.O., E.A. Yerima., S. Atiku., B. Habibu and S. Yakubu, 2024. Polycyclic aromatic hydrocarbon (PAHs) levels in treated spent engine oil contaminated soil from automechanic workshop site in Wukari, Nigeria. Lafia Journal of Scientific and Industrial Research, 2(1), 70 – 77. https://doi.org/10.62050/ljsir2024.v2n1.308

Olajire, A.A., Ayodele, E.T. (1997). Contamination of roadside soil and grass with heavy metals. Environ. Int. 23(1): 91-101.

Olajire, A.A., Ayodele, E.T. (1998). Heavy metal analysis of solid municipal wastes in the western part of Nigeria. Water, Air, Soil Pollut. 103: 219-228.

Olajire, A.A., Ayodele, E.T., Oyediran, G.O., Oluyemi, E.A. (2003). Levels and speciation of heavy metals in soils of industrial southern Nigeria. Environmental Monitoring and Assesement. 85: 135-155.

Otitoju, O., Abah, M.A., Grace, O.T., Habibu, B., Okoli, E.C. and Omajali, P.U. (2022). Risk assessment of pesticide residues in water samples from river Gongola, Adamawa state, Nigeria. *World Journal of Advanced Research and Reviews,* (2022), 13 (01): 424–432.

Oluyemi, E.A. and Olabanji, I.O. (2011). Heavy Metsls Determination in Some Species of Frozen Fish Sold at Ile-Ife Main Market, South West Nigeria. *Iife Journal of Science*, 13(2): 355-362.

Otitoju, O. and Onwurah, N. E. (2007). Preliminary investigation into the possible endocrine disrupting activity of Bonny light crude oil contaminated-diet on Wistar albino rats. *Biokemistri*, 19(1):

Otitoju, O., Akpanabiatu, M.I., Otitoju, G.T.O., Ndem, J.I., Uwah, A.F., Akpanyung, E.O. and Ekanem, J.T. (2012) Heavy metal contamination of green leafy vegetable gardens in Itam Road Construction site in Uyo, Nigeria. *Journal of Environmental and Earth Sciences* 4(4): 371-375.

Otitoju, G.T.O., Otitoju, O. and Igwe, C.J. (2014). Quantification of heavy metal levels in imported rice (*Oryza sativa*) consumed northern parts of Nigeria. *Journal of Biodiversity and Environmental Sciences, 4*(4)*:* 2222- 3045.

Otitoju, O. and Otitoju, G. T. O. (2013). Heavy metal concentrations in water, sediment and periwinkle (*Tympanotonus fuscastus*) samples harvested from the Niger Delta region of Nigeria. *African Journal of Environmental Science and Technology*, *7* (5): 245-248

Otitoju, O.F. (2021). Heavy metals analysis in indoor dust particles in Wukari, Taraba State, Nigeria. *International Journal of Applied Biomedical Sciences*, 2(6): 6-12.

Park, J.H., Bolan, N., Meghraj, M., Naidu, R. and Clung, J.W. (2011). Bacterial-assisted immobilisation of lead in soils: implications for remediation. Pedologist 54,162-174.

Parry, G.D.R., Johnson, M.S., Bell, R.M. (1981). Trace metal surveys of soil as a component of strategic and local planning policy development. *Environmental Pollution Series B*. 2: 97-107

Peralta, J.R., Gardea, Torresdey, J.L., Tiemann, K.J., Gomez, E., Arteaga, S., Rascon, E. (2001) Uptake and effects of five heavy metals on seed germination and plant growth in alfalfa (*Medicago sativa*) L. B. *Environmental Contamination Toxicology*. 66:727–734

Reeves, R.D., Baker, A.J.M. (2000) "Metal accumulating plants. In: Raskin I, Ensley BD (eds) Phytoremediation of toxic metals: using plants to clean up the environment." Wiley, New York, pp 193–229.

Sanita, Toppi, L., Gabbrielli, R. (1999) Response to cadmium in higher plants. *Environmental Expossure and Botany*. 41:105–130.

Schmfger, M.E.V. (2001) Phytochelatins: complexation of metals and metalloids, studies on the phytochelatin synthase. PhD Thesis, Munich University of Technology (TUM), Munich.

Shanker, A.K., Djanaguiraman, M., Pathmanabhan, G., Sudhagar, R., Avudainayagam, S. (2003b) Uptake and phytoaccumulation of chromium by selected tree species. In: *Proceedings of the international conference on water and environment held in Bhopal, India.*

Sharma, D.C. and Sharma, C.P, (1993) "Chromium uptake and its effects on growth and biologica yield of wheat," Cereal Research Communications, vol. 21, no. 4, pp. 317–322.

Shekar, C.H.C., Sammaiah, D., Shasthree, T. and Reddy, K.J. (2011) "Effect of mercury on tomato growth and yield attributes," *International Journal of Pharmaceutical and Biological Sciences*, vol. 2, no. 2, pp. B358 B364.

Tatah, V.S., Otitoju, O., Ezeonu, C.S., Onwurah, INE and Ibrahim, KLC. (2017).Characterization and adsorption isotherm studies of Cd (II) and Pd (II) Ions

Bioremediation from Aqueous solution Using Unmodified sorghum Husk. *Journal of Applied Biotechnology and Bioengineering,* 3 (2): 3-4.

Taiz, L. and Zeiger, E.Z. (2002) Plant Physiology, Sinauer Associates, Sunderland, Mass, USA.

Tchounwou, P. B. and Centeno, J. A. (2008). Toxicologic pathology. *In: Handbook of PreClinical Development*. Gad SC (ed). John Wiley and Sons. New York. NY. pp 551-580

Thomas, D. J. (2010). Arsenolysis and thiol-dependent arsenate reduction. *Toxicological Sciences*, 117(2): 249-252.

Titilola, S.O. and Jeje, L.K. (2008). Environmental degradation and its implications for agricultural and rural development: the issue of land erosion. *Journal of Sustainable Development in Africa,* 10 (2): 116-146.

United States Environmental Protection Agency (USEPA), "Risk assessment Guidance for superfund, Volume 1," *Human Health evaluation Manual*, Office of Emergency and Remedial Response, Washington, DC, USA, 1989..

US EPA, 1977. Exposure Factor Handbook (EPA/600/p-95/002Fa) (Update to Expo-sure Factors Handbook EPA/600/8-89/043). Environmental Protection AgencyRegion I, Washington, DC.

US EPA IRIS (US Environmental Protection Agency)'s Intergrated Risk Informa-tion System, 2011. Environmental Protection Agency Region I, Washington DC20460.US EPA, 2012. http://www.epa.gov/iris/

Valko, M., Rhodes, C. J. B., Moncol, J., Izakovic, M. M. and Mazur, M. (2006). Free radicals, metals and antioxidants in oxidative stress-induced cancer. *Chemico-biological interactions*, 160(1): 1-40.

Wallander, H. (2014). Soil: Reflections on the Basis of our Existence. *Springer.*

Wang, Y., Kendall, J., Cavet J.S. and Giedroc, D.P. (2010). Elucidation of the functional metal blin ding profile of a cd/pb sensor C.mtR from Streptomyces coelicolor Biochemistry 49, 6617-6626.

WHO, 2008. Guideline for Drinking-water Quality (3rd ed. Incorporating 1st and 2nd Agenda),Vol. 1. Recommendations. Geneva., pp. 668p.

WHO. World Health Organization (1996). Switzerland: Geneva; 1996. Trace Elements in Human Nutrition and Health

Wilson, D.N. (1988) Cadmium - market trends and influences. In*: Cadmium Association (eds.), Cadmium 87. Proceedings of the 6th International Cadmium Conference*. London. 9-16.

Wuana, R.A. and Okuiman, F.E. (2011). Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies from remediation. ISRN Ecology Article ID 402647, pp.20.

World Bank, 2014. The World Bank Group: Average Life Expectancy in Nigeria:2009–2013. www.goggle.com.ng/#9=life+expectancy+in+Nigeria

Wu, S. (1994). Effect of manganese excess on the soybean plant cultivated under various growth conditions. *Journal of Plant Nutrition*., 17: 993–1003.

Zouboulis, A.I., Loukidou, M.X. and Matis, K.A. (2004). Biosorption of toxic metals from aqueous solutions by bacteria strains isolated from metal polluted soils. Process biochemistry 39, 909-916.