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Heavy Metals Speciation and Health Risk Analysis of Arable Farmlands in Ardo-Kola, Bali and Wukari Local Government Areas of Taraba State Nigeria

[1]Bilyaminu Habibu, [1]Otitoju Olawale, [1]Yakubu Ojochenemi Ejeh, [1]Moses Adondua Abah,
[2]Togunde Idris Olalekan, [3]Emmanuel Agada Eneojo and [4]Adetoyi Moses Gbadebo
[1]Department of Biochemistry, Faculty of Pure and Applied Sciences, Federal University Wukari, Taraba, Nigeria
[2]Department of Biochemistry, Faculty of Pure and Applied Sciences, Federal University of Lafia, Nasarawa, Nigeria
[3]Department of Biochemistry, College of Biological Sciences, Joseph Sarwuan Tarka University, Markudi, Benue, Nigeria
[4]Department of Biochemistry, Faculty of Life Sciences, University of Ilorin, P.M.B. 1515, Ilorin, Kwara, Nigeria

ABSTRACT

Background and Objective: Agricultural soil plays a major role in food safety and security. A major problem in most developing nations including Africa is a lack of food safety. The soil environment is a reservoir of nutrients as well as pollutants. This study evaluated heavy metals speciation and health risk analysis of arable farmlands in Bali, Ardo-Kola and Wukari, Local Government Areas of Taraba State, Nigeria. **Materials and Methods:** Three different soil samples from three Local Government Areas of Taraba State (Bali, Ardo-Kola Wukari) were collected using sterile glass sample collection bottles measured at 5 cm depth. The collected soil samples were freed from unwanted materials such as stone, leaves debris by hand picking and air-dried for one week to remove excess moisture, large soil clouds were also crushed to facilitate the drying. The dried soil samples were crushed in a porcelain mortar with a pestle, the crushed soil sample was sieved through a 2 mm sieve made of stainless steel the sieved soil sample was further pulverized to a fine powder and passed through a 0.5-mm sieve. Heavy metals (Pb, Cd, Cr, Hg and As) concentrations were assayed using Atomic Absorption Spectrophotometry (AAS). **Results:** The results showed that Chromium had a high concentration with values ranging from 1.40 mg/kg to 2.71 mg/kg. While Lead and Mercury had the lowest concentration of less than 0.03 mg/kg across the studied areas. For ecological risk assessment parameters; target cancer risk, hazard index (HI) estimated daily intake (EDI) were all determined to assess the non-carcinogenic health risk. Ardo-Kola recorded the highest levels of HM, whereas Bali had the lowest. Consumption 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. **Conclusion:** Although the studied heavy metals were significantly present in all the analyzed soil except lead, their concentration in various soil samples across the studied areas exceeded the permissible levels as recommended by WHO.

KEYWORDS

Heavy metals, risk assessment, cancer estimation, toxicity, bioaccumulation, carcinogenesis

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INTRODUCTION

In most developing nations including Africa, the lack of food safety is a major problem. Most of the food items are laden with lots of pollutants ranging from fertilizer and pesticides to heavy metals. Consuming foods contaminated with these pollutants has detrimental effects on the population's health and economic situation[1,2]. Heavy metals specifically are naturally occurring metallic elements that have a relatively high density compared to water[3]. Assuming that weight and toxicity are connected, heavy metals also include metalloids like arsenic, which can cause toxicity at low exposure levels[4]. Even though heavy metals are naturally present in the ecosystem, their levels are rarely harmful[1]. However, due to their extensive usage, dispersion particularly their toxicity to humans and the ecosystem, heavy metals have become a major global problem for environmental contamination[5,6]. They constitute continuous environmental contaminants since they cannot be easily degraded[7,8]. This has resulted in the release of pollutants (hydrocarbons and heavy metals) capable of contaminating soil and water bodies[9,10].

Land is a key factor of agricultural output and the most significant aspect of a farmer's produce. In poor communities where control over and access to land are key indicators of wealth and survival, land is a crucial socioeconomic resource[11]. Land is a valuable economic resource, especially in developing nations where the majority of the population lives in rural areas and depends on agriculture for a living. Since the dawn of humankind, it has continued to be a significant force in production and an essential component of the global agricultural industry. Furthermore, it lays forth a plan for agricultural output in Nigeria and the rest of sub-Saharan Africa[6]. Gaining access to arable land is vital for the millions of impoverished rural residents who rely on farming, raising livestock, or cutting down trees for their survival. It lessens their vulnerability to hunger and poverty and affects their capacity to engage in productive activities and manage resources sustainably[12].

Taraba State is highly endowed with purposeful diversity and arable farmlands which is an important element in development from natural to human resources. Taraba State is largely blessed. For instance, it is the host of the largest base of solid minerals, (including gold, diamond, limestone, zinc lots more) in Nigeria[6]. The state sits on over 200 solid mineral deposits waiting for exploitation. The major activity of the populace in the studied areas is farming due to its fertile nature and abundant arable farmlands, whereas report has it that in places like Ardo-Kola, a farmer needs no fertilizer application due to its natural and abundant fertile arable farmlands in production of cash crops such as coffee and tea cotton. Crops such as maize, rice, sorghum, millet root crops such as cassava and yam. Other important economic activities including fishing and rearing of variety of animals such as cattle, sheep, goats donkeys in large numbers take place in the studied areas[13]. There are several threats to human health and ecology from the buildup of heavy metals and metalloids in soil, water plants, including Cadmium, Chromium, Copper, Lead, Nickel and Zinc[14]. Heavy metals are introduced into the terrestrial environment and most especially into the soil from different sources such as industrial, agricultural municipal waste[15], automobile emissions[16], mining activities agricultural practices[17].

Based on research, it can be seen that farmers employ a variety of pesticides at various concentrations to lessen losses due to illnesses and pests. Pesticides, however, are a significant environmental concern even though they help with agricultural production. In addition to not biodegrading, many pesticides also bioaccumulate in the food chain, harming both people and the environment[18,19]. Heavy metals can enter the body through the skin, inhalation, or dermal contact and then be swallowed directly from the soil. These heavy metals enter the body system and may impede a variety of clinically aberrant forms of typical physiological and metabolic activities in cells[20]. The diverse chemical forms/species of the metals in the soil, as opposed to the total amount of heavy metals, have a significant impact on the uptake of heavy metals by plants. The mobility and bioavailability of the metals to the plants are thus determined by the chemical species these factors vary with the species of plants[21].

A health risk assessment model has been developed to evaluate the non-carcinogenic and carcinogenic risks associated with these metal contaminants' concentrations; a good assessment will consider the various exposure routes[22]. The present study evaluated heavy metals speciation and health risk analysis of arable farmlands in Bali, Ardo-Kola Wukari, Local Government Areas of Taraba State, Nigeria.

MATERIALS AND METHODS

Study area: This research was carried out from August, 2022 to March, 2023 in some selected Local Government Areas of Taraba State, North-Eastern Nigeria, popularly known for its numerous agricultural and mining activities. The research covered the following Local Government Areas (Bali, Ardo-Kola Wukari) three sampling sites in each of the Local Government Areas were chosen for the research as shown in Table 1.

Sample collection: Three different soil samples from three Local Government Areas of Taraba State (Bali, Ardo-Kola Wukari) were collected using sterile glass sample collection bottles measured at 5 cm depth. The samples were then kept in polythene sealed bags, labeled transported to Biochemistry Laboratory section of Bwacha Central Laboratory, Federal University Wukari, Taraba State in an air-dried place prior to analysis of heavy metals (As, Cd, Pb, Hg and Cr).

Sample preparation: The soil samples were carefully selected by hand to remove any undesired items including stones, leaves debris. After collecting the samples, they were air-dried for one week to remove any extra moisture. To speed up the drying process, large clouds of soil were crushed. Before being prepared for heavy metal content analysis, the dried soil samples were crushed using a pestle and porcelain mortar. The crushed soil samples were then passed through a 2 mm stainless steel sieve. To prepare for the next step, the sieved soil samples were further ground to a fine powder and passed through a 0.5 mm sieve.

Sample digestion: A measured volume of well-prepared sample appropriate for the expected metal concentration was transferred into a conical flask in a 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 evaporated to less than 5 mL, making sure that the sample did not boil. The mixture was allowed to cool and the flask wall was rinsed and washed with distilled water. Furthermore, 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 was completed. It was cooled 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[23].

Determination of heavy metal concentration: A conical flask in a fume cupboard was filled with a measured amount of well-mixed acid-preserved sample that was appropriate for expected metals concentration. The 3 mL of concentrated HNO_3 was added the flask was covered with a ribbed watch glass. It was then placed on a heating mantle and slowly evaporated to less than five milliliters, being careful that

Table 1: Research experimental design

Local government areas	S/N	Study areas/villages
Bali	1	Bali
	2	Maihula
	3	Kungana
Ardo-Kola	4	Sunkani
	5	Iware
	6	Sibre
Wukari	7	FUW farm
	8	Bye-pyi
	9	Kasuwan Shanu

the sample did not boil. The mixture was allowed to cool and the flask wall was rinsed and washed with distilled water. Furthermore, 5 mL of conc. HNO_3 was added and the flask was covered with a watch glass and returned to the heating mantle. Heating continued until digestion was completed. It was cooled the 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. Heavy metal concentration was determined by the use of an Atomic Absorption Spectrophotometer model 6650F using a modified standard method of Liang *et al.*[24]. The concentration of each element in the sample solutions in the sample bottles was measured. Each element has a unique cathode discharge lamp it was this lamp that was utilized to identify a certain element. Each element being tested by the discharge lamp emits light at a certain wavelength. The only way to achieve this specificity is from a pure sample of the element that has undergone electrical excitation to create an arc spectrum on that element. The following heavy metals were examined: Cadmium (Cd), Lead (Pb), Chromium (Cr), Mercury (Hg) and Arsenic (As).

Risk assessment

Hazard quotient: 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[25]:

$$\text{Hazard quotient (HQ)} = \frac{\text{Estimated daily intake (EDI)}}{\text{Acceptable daily intake (ADI)}}$$

Hazard index (HI):

$$\text{HI} = \sum \text{HQ}_i$$

Where:

HI = Summation of an individual HQs

$$\text{HI} = \text{THQ} = \text{THQ (Pb)} + \text{THQ (Cr)} + \text{THQ (Cd)} + \text{THQ (As)} + \text{THQ (Hg)}$$

if HI>1, it means an unacceptable risk of non-carcinogenic effects on health, while HI<1 means an acceptable level of risk[26].

Estimated daily intake (EDI): The EDI was calculated by the following equation[26]:

$$\text{EDI} = \frac{(\text{Concentration of heavy metal as mg / kg}) \times (\text{Daily intake of food in kg / person})}{\text{Adult body weight (60 kg)}}$$

Target cancer risk:

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

Where:

EFr = Exposure frequency (350 days/years)
EDtot = Exposure duration, total (30 years)
SI = Soil ingestion, gram per day (1 gram) x 1000 mg/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 carcinogens are summed (assuming additive effects). Risks in the range of 1.0×10^{-6} to 1.0×10^{-4} are acceptable[27]:

$$\text{CRT} = \sum \text{CR}$$

Where:

CRT = Carcinogenic risks elements
$\sum$CR = Additive carcinogenic risks

The 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[28].

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 AND DISCUSSION

Heavy metal concentration (mg/kg) of soil samples from Ardo-Kola, Bali and Wukari Local Government Areas of Taraba State: The results of heavy metal concentrations are presented in the Table below. Heavy metals were detected in all the soil samples from the 9 sampling points of 3 LGAs of Taraba State. The results showed that Chromium had a very high concentration across all the studied areas with values ranging from 2.01 to 2.62 mg/kg. Cadmium had values ranging from 0.07 to 0.09 mg/kg and Arsenic followed moderately with values ranging from 0.06 to 0.07 mg/kg while Lead and Mercury had lowest concentrations of less than 0.04 mg/kg across the 3 LGAs, as shown in Table 2.

Lead concentration, calculated risk and hazard index in soil samples from Ardo-Kola, Bali Wukari Local Government Areas of Taraba State: The result of lead concentration in soil from some LGAs sampled in Taraba State is presented below. The result indicates that Wukari LGA had the lowest concentration of Pb (0.02±0.01 mg/kg) and Bali had (0.02±0.02 mg/kg), while Ardo-Kola LGA had the highest level of Pb (0.03±0.01 mg/kg). However, the Pb level showed a statistically significant difference across all the sampling points ($p<0.05$). Similarly, the calculated risk shows that Wukari and Bali have the lowest value of 0.13, while Ardo-Kola has the highest calculated risk of 0.19 (Table 3).

Table 2: Heavy metal concentration (mg/kg) of soil samples from Ardo-Kola, Bali and Wukari Local Government Areas of Taraba State

Study areas	Pb	Cd	Cr	As	Hg
Ardo-Kola	0.03 ± 0.01^{b}	0.09 ± 0.02^{b}	2.62 ± 0.61^{b}	0.07 ± 0.02^{b}	0.03 ± 0.01^{b}
Bali	0.02 ± 0.02^{ab}	0.07 ± 0.07^{ab}	2.29 ± 2.29^{ab}	0.06 ± 0.06^{ab}	0.02 ± 0.02^{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 differ between groups within the same column at $p<0.05$

Table 3: Calculated risk and hazard index of lead in soil samples from Ardo-Kola, Bali Wukari Local Government Areas of Taraba State

Study areas	Pb concentration (mg/kg)	EDI	Calculated risk	HI
Ardo-Kola	0.03 ± 0.01^{b}	0.000046	0.19	18.70
Bali	0.02 ± 0.02^{ab}	0.000030	0.13	16.20
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, HI>1 is an unacceptable risk level of non-carcinogenic, while HI<1 Is an acceptable risk level, HI: Hazard index and Source[29]

Cadmium concentration, calculated risk and hazard index of soil samples from Ardo-Kola, Bali and Wukari Local Government Areas of Taraba State: The results of Cadmium concentration in soil from some LGAs in Taraba State are presented below. The result showed that Wukari had a lower concentration of (0.07±0.02 mg/kg) and Bali had (0.07±0.07 mg/kg) while Ardo-Kola LGA had a higher concentration of (0.09±0.02 mg/kg). However, Cd level in Ardo-Kola LGA is higher across the studied areas at ($p<0.05$). Similarly, the calculated risk shows that both Bali and Wukari had a low risk value of 0.46, while Ardo-Kola had the highest calculated risk value of 0.59 (Table 4).

Chromium concentration, calculated risk and hazard index in soil samples from Ardo-Kola, Bali and Wukari Local Government Areas of Taraba State: Result of Chromium concentration in soil samples from some LGAs in Taraba State is presented below. The result showed that wukari LGA had low concentration of (2.01±0.61 mg/kg) and Bali had (2.29±2.29) while Ardo-Kola LGA had higher concentrations of (2.62±0.61 mg/kg). Therefore, the level of Cr in all the studied areas implies that there is a significant difference between the studied areas at ($p<0.05$). However, the calculated risk showed that Wukari has a lower risk value of 13.25 and Bali has 15.09 compared to Ardo-Kola with 17.27, respectively (Table 5).

Arsenic concentration, calculated risk and hazard index in soil samples from Ardo-Kola, Bali Wukari Local Government Areas of Taraba State: The results of Arsenic content in soil samples from some LGAs sampled in Taraba State are presented below. The result showed that Wukari LGA had the lowest concentration (0.06±0.02) and Bali had (0.06±0.06), while Ardo-Kola LGA had the highest concentration of (0.07±0.02 mg/kg). However, the As level in all the studied areas showed no statistically significant difference among all the sampling points at ($p<0.05$). The calculated risk shows that both Wukari and Bali have a low risk value of 0.39, while Ardo-Kola has the highest calculated risk value of 0.46 (Table 6).

Mercury concentration, calculated risk and hazard index in soil samples from Ardo-Kola, Bali Wukari Local Government Areas in Taraba State: The result of Mercury content in soil samples from some LGAs sampled in Taraba State is presented below. The result showed that Wukari had (0.02±0.01 mg/kg) Bali had (0.02±0.02 mg/kg), while Ardo-Kola LGA had the highest concentration (0.03±0.01 mg/kg). Similarly, the Hg level across all the LGAs showed a statistically significant difference across all the sampling points at ($p<0.05$). However, the calculated risk showed that both Wukari and Bali had low risk value of 0.13, while Ardo-Kola had the highest calculated risk value of 0.19 (Table 7).

Table 4: Calculated risk and hazard index of cadmium in soil samples from Ardo-Kola, Bali Wukari Local Government Areas of Taraba State

Study areas	Cd Concentration (mg/kg)	EDI	Calculated risk	HI
Ardo-Kola	0.09 ± 0.02^{b}	0.000138	0.59	18.70
Bali	0.07 ± 0.07^{ab}	0.000107	0.46	16.20
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, HI>1 is unacceptable risk level of non-carcinogenic while HI<1 is acceptable risk level and Source[29]

Table 5: Calculated risk and hazard index of chromium in soil samples from Ardo-Kola, Bali and Wukari Local Government Areas of Taraba State

Study area	Cr Concentration (mg/kg)	EDI	Calculated risk	HI
Ardo-Kola	2.62 ± 0.61^{b}	0.00403	17.27	18.70
Bali	2.29 ± 2.29^{ab}	0.00352	15.09	16.20
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, HI>1 is an unacceptable risk level of non-carcinogenic while HI<1 is acceptable risk level and Source[29]

Table 6: Calculated risk and hazard index of arsenic in soil samples from Ardo-Kola, Bali Wukari Local Government Areas of Taraba State

Study area	As concentration (mg/kg)	EDI	Calculated risk	HI
Ardo-Kola	0.07±0.02^{b}	0.0001076	0.46	18.70
Bali	0.06±0.06^{ab}	0.0000923	0.39	16.20
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, HI>1 is an unacceptable risk level of non-carcinogenic, while HI<1 is an acceptable risk level and Source[29]

Table 7: Calculated risk and hazard index of mercury in soil samples from Ardo-Kola, Bali Wukari Local Government Areas of Taraba State

Study area	Hg concentration (mg/kg)	EDI	Calculated risk	HI
Ardo-Kola	0.03±0.01^{b}	0.000046	0.19	18.70
Bali	0.02±0.02^{ab}	0.000030	0.13	16.20
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, HI>1 is unacceptable risk level of non-carcinogenic while HI<1 is acceptable risk level, Source[29], EDI: Estimated daily intake and HI: Hazard index

Heavy metals quantification was carried out in the study to ascertain the levels of metal concentrations as a result of artisanal activities in arable farmlands[6]. Heavy metals are among the most harmful environmental pollutants that can bioaccumulate in biological tissues[29]. 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 which is the environment from which food is gotten gives a reason to worry.

The findings obtained from this study indicated that heavy metals (Pb, As, Hg, Cd and Cr) were present in the soil samples collected from Bali, Ardo-Kola Wukari LGAs of Taraba State, Nigeria. All the metals are present in concentrations that are higher than the WHO-approved safe levels. The Cd concentrations range from 0.07-0.09, as from 0.06-0.07 mg/kg, Hg from 0.02-0.03 mg/kg, Pb from 0.02-0.03 mg/kg and Cr from 2.01 mg/kg and above in this study. Extraction of heavy metal contents in soil may give indications of the origin of the metals in Arable farmlands. The distribution of trace heavy metals in soil samples allows us to predict their mobility and bioavailability toxicity[30]. In this study, Cr, Cd and As seemed to be easily mobilized since a high percentage of these metals were found in all the studied areas and most higher in Ardo-Kola LGA, (Sibre). The significant difference may be due to vast agricultural, commercial mining activities in the sampling areas and their geographical area.

Chromium seems to be the most mobile element, followed by Cd and As, while Pb and Hg were the less mobile elements in the studied arable farmlands (Table 2). The order of mobility of the extractable metals from soil samples of the studied areas as analyzed and their calculated risk values is Cr>Cd>As>Pb>Hg order. Therefore, since Cr concentration was highest among the other metals analyzed in all the soil in the studied areas. It 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 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 plants growing in the soil. For this reason, there is a need for a high level of concern regarding the level of Cr present in the soil, since it can be poisonous to mammals. The Cr mostly finds its way to the soil (in arable farmlands) through the application of organic manure and fertilizers, since fertilizer and organic manure remain the primary source of nutrients to the soil in arable farmlands[31].

Everyone knows that chromium is a poisonous element that kills or severely harms living things. Plants experience chromium-induced oxidative stress when the metal induces lipid peroxidation, which damages cell membranes to a significant degree[32]. The first of three potential metabolic changes in plants caused by chromium stress is an alteration in the synthesis of pigments essential to plant life, including chlorophyll and anthocyanin[33], (ii) In response to Cr stress, plants manufacture more metabolites, such as glutathione and ascorbic acid, which can harm them and (iii) Changes in the metabolic pool direct the production of new metabolites, such as phytochelatins and histidine, which are biochemically related and may provide resistance or tolerance to Cr stress. Chromium poisoning caused a decrease in plant nutrient uptake in tomatoes (*Lycopersicon esculentum*)[34]. The germination process of onions (*Allium cepa*) is inhibited plant biomass is decreased. Shoot and root growth were seen to be reduced in wheat (*Triticum* sp.)[35].

The value set out by the WHO for Cr is 0.001 mg/kg, while Cr concentrations in this study varied from 2.01 to 2.62 mg/kg in all study regions, the maximum risk value was computed for the Cr concentration, which was over the WHO-recommended minimum of 0.001 mg/kg. This implies that the populace in all the studied areas is 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 lead to cell death due to DNA strand breaks[36].

Cadmium followed with high concentration after Cr across the sampled areas, showed that its availability is susceptible to ionic composition change in the environment. The Cd being one of the cumulative poison for mammals find its way into the soil primarily through the application of fertilizer, pesticides herbicides to the arable farmlands as the source of nutrients to the soil, which then can bio-accumulate in plants and get into humans via food, soil with high concentrations of Cd causes chlorosis, stunted growth, browning of the root tips eventually plant death[37]. Excessive cadmium in wheat (*Triticum* sp.) inhibits seed germination, lowers nutritional content in the plant shortens the length of both the shoots and the roots[38]. The accumulation of Cd in garlic (*Allium sativum*) stunts the growth of new shoots[39]. Finally, it inhibits root growth and decreases shoot growth in maize (*Zea mays*)[40]. Cd concentrations in this study range from (0.07-0.09 mg/kg) which is 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[41]. High exposure to Cd can lead to health conditions such as obstructive lung disease, cadmium pneumonitis, anemia, renal damage and bone disorder cancer of the lungs[41].

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 (0.06-0.07 mg/kg), while the WHO stipulated value is (0.02 mg/kg). The tomato (*Lycopersicon esculentum*) has low fruit production and a fresh leaf yield due to its high arsenic content[42]. As opposed to this, arsenic in canola (*Brassica napus*) produces stunted growth, chlorosis wilting[43]. Reduces the production of dry matter, seed germination, seedling height leaf area in rice (*Oryza sativa*)[44]. So, Based on the result of this study, the populace in these studied areas could be predisposed to As-induced health problems such as arsenicosis[45]. Most of the reports of chronic arsenic toxicity in men focus on skin manifestations because of its specificity in diagnosis. Pigmentation and keratosis are the specific skin lesions that indicate chronic arsenic toxicity[46].

Soil Lead (Pb) is among the most plentiful and widely dispersed hazardous elements. Hormones have a negative impact on plant development, growth photosynthetic activities. Reduced plant biomass, decreased plant protein content, delayed growth decreased germination percentage have all been seen in the maize (*Zea mays*) plant[47]. Lead courses in Portia trees (*Thespesia populnea*) result in fewer leaves, smaller foliage shorter plants[48]. Reduced plant biomass and inhibition of CO_2 fixation-related enzyme activity in oat (*Avena sativa*)[49]. The concentration of Pb and Hg was low across all the soil samples studied. They are detected in low amounts in this study which may be a minor pollution indicator since their presence in the soil to some extent may cause a serious concern to the populace living in the area. Since the majority of the soil samples were taken from areas near highways, Pb might have come from traffic.

The Pb mainly enters into the soil by means of atmospheric dry and wet depositions and disposal of sewage sludge. Lead is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults[50]. The WHO has set a maximum threshold of Pb in soil at 2.00 mg/kg, but according to the findings of this study, Pb concentrations in all of the soil samples are extremely low, ranging from 0.02-0.03 mg/kg. The Pb exposure may not have a severe negative impact on the population's health in certain locations in the short term, but it may in the long term[51].

Mercury is a harmful heavy metal whose poisoning (or excessive consumption) can cause a variety of health issues. When compared to other metals like lead, cadmium, chromium, arsenic and mercury is recognized to be a latent neurotoxic. Contamination of Hg to the soil is often due to the addition of this heavy metal as part of fertilizers, lime, sludge 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 mercury decreases plant height, reduces tiller and panicle formation yields reduction[52]. In tomatoes (*Lycopersicon esculentum*) Hg causes a reduction in germination and plant height, reduce in flowering and fruit weight finally, resultant chlorosis appears on the whole plant[53]. It has been suggested that a high dietary intake of organic mercury above the recommended limit of consumption raises the risk of coronary heart disease[54]. The Hg levels in all of the soil samples used in this investigation range from (0.02-0.03 mg/kg). These amounts exceed the permissible limit set by the WHO. This suggests that if the uptake by plants is directly proportionate to the available concentration in the soil, then prolonged intake of food grown in the research areas could result in health issues associated with Hg.

CONCLUSION

Although the studied HM were significantly present in all the analyzed soil with the exception of lead, their concentration in various soil samples across the studied areas exceeded the permissible levels as recommended by WHO, therefore, efforts should be put in place to address the bioaccumulation of these metals from anthropogenic sources. The anthropogenic input of Cr was found mainly in Bali and Ardo-Kola in high concentrations which may be due to the geographical location of the study areas as they shared boundaries, including Cd and As which are moderate in concentrations were significantly high in these study areas above the permissible values. The Hg and Pb appeared to be in low concentration, but all other heavy metals (Cr, Cd, As and Hg) analyzed were present in concentration above the permissible limit of utilization by WHO. These heavy metals may be transferred to a human on the consumption of crops cultivated in the studied areas which may be hazardous to human health due to their cumulative effect on the human body, hence, It appears that anthropogenic heavy metals, as opposed to lithogenic and pathogenic heavy metals, are more easily transported and, possibly, more phytoavailable on arable farmlands. Anthropogenic pollution sources may be useful in determining which metals have recently reached the soil since a high mobile level of any metal could be an indication of which metals have entered the soil. Lastly, in order to decrease or improve the current levels of these harmful heavy metals in the area, it is necessary to properly regulate the use of agricultural pesticides.

SIGNIFICANCE STATEMENT

In most developing nations including Africa, the lack of food safety is a major problem. Most of the food items are laden with lots of pollutants ranging from fertilizer and pesticides to heavy metals. These heavy metals could be taken up by plants and even terrestrial and aquatic organisms which are eventually consumed by humans, hence, posing a threat to their well-being. The present study evaluated heavy metals speciation and health risk analysis of arable farmlands in Bali, Ardo-Kola Wukari, Local Government Areas of Taraba State, Nigeria. Therefore, efforts should be put in place to address the bioaccumulation of these metals from anthropogenic sources.

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