Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 23 Issue 1 Version 1.0 Year 2023
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-460x & Print ISSN: 0975-587X

Cropland Bioaccumulation Risks of Potentially Toxic Elements in Soil of Some Designated Foodstuffs Cultivated in Odu'a Farm Establishment, Aawe, Oyo State, Nigeria

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Keywords: toxic heavy elements; human health risk indices; staple food crops; farm establishment; ecosystem health.

GJSFR-D Classification: DDC Code: 333.953416 LCC Code: SD399.7

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Keywords: toxic heavy elements; human health risk indices; staple food crops; farm establishment; ecosystem health.

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I. Introduction

Nigeria is an agrarian nation with about 70% of her over 195 million people involved in the farmings sector (Ogunwale et al., 2021), and it adds support for two-thirds (2/3) of Nigerians who are low-income earners (Ogunwale et al., 2021). While the Northern side can indemnity the production of cereals like sorghum, maize, millet, groundnut, melon, cowpea, and cotton, the Middle Belt and the South enjoy the potential to raise root tubers like cassava, yam, cocoyam, and the like crops plantain in addition to maize (Ogunwale et al., 2021). Besides food crops, the country is likewise included in the managing of farm animals, fisheries, forestry, and undomesticated animals.

Nigeria is enriched chiefly with ample biological resources, sundry all-season rivers and auspicious tropical weather. Rainfall is usually sufficient and correctly well-supplied throughout the country (Ogunwale et al., 2021). Of the 98.321 million ha of land found in Nigeria, about 75.30% may be assigned as arable land, of which 10% is under forest reserves and the remaining 14.70% is given to be constituted of permanent pastures, built-up areas, and useless waste (FMARD, 2012). In light of the above-mentioned, agriculture is still a key industry and continuing to be the backbone of the Nigerian economy (Ogunwale et al., 2021).

With the intention of face-lift the farm sector, quite scores of programmes and policies have been carried out by means of the Nigerian Government to boost efficiency in the farming sector consist of:- Farm Settlement Scheme (FSS), Marketing and Commodity Board, National Accelerated Food Product Programme (NAFFP), Agricultural Development Project (ADPs), National Seed Service (NSS), Agricultural Credit and Guarantee Scheme Fund (ACGSF), National Agricultural Cooperative and Rural Development Bank (NACRDB), Operation Feed the Nation (OFN), River Basin Development Authority (RBDA), Green Revolution (GR), Directorate for Food, Road and Rural Infrastructure

(DFRRI), Nigerian Agricultural Insurance Company (NAIC), National Agricultural Land Development Authority (NALDA), the National Economic Empowerment and Development Strategies (NEEDS I and NEEDS II) and the Implementation of Comprehensive African Agricultural Development Programme (CAADP), National Food Security Programme (NFSP), the National Fadama Project (Phase I, II and III), the up-to-date Agricultural Transformation Agenda (ATA), (Salisu, 2016).

With the purpose of encouraging entrepreneurship among our young people, the Odu'a Commercial Farmers' Academy has been established to serve a constructive role through empowering the young people with functional skills and appropriate knowledge needed in agribusiness. Odu'a farm settlements project is designed to let new and emerging farmers establish themselves in viable agribusiness.

The occurrence of heavy and trace elements in the soil ecosystem is gradually becoming a concern of worldwide issue at private in addition to governmental levels, specifically as soil constitutes a major feature of rural and urban ecological communities (Ogunwale et al., 2022), and can be conceived as a very significant "ecological crossroad" in the landform (Ogunwale et al., 2021). Introduction of heavy elements to cropland soils can spring up from various sources. These comprise the repeated utilization of sewage sludge, mineral fertilizers, farm animal manures, agricultural chemicals, and irrigation water, and from atmospheric fall out which, is one of the almost all serious environmental issues, in Nigeria. Some of the dreads about bioaccumulation of heavy elements in cropland soils and staple food crops come from their possible negative impacts on land fertility and in some cases, their ability to build up at the trophic level (Ogunwale et al., 2021).Amongst the substances that give anthropogenically to pollution of the ecosystem, heavy elements are the most subtle. Arsenic, Cd, Cr, Hg, and Pb are toxic elements of growing ecological concern as they enter the feeding level in considerable amounts. Though some trace elements are necessary in plant nutrition, crops cultivated in the adjoining areas of industrial sites demonstrate increased content of heavy elements, serving in many cases as biomonitors of pollution loads (Ogunwale et al., 2021). Staple food crops raised in soils polluted with toxic heavy elements intake that elements and concentrate them in their consumable and non-consumable portions in degrees high enough to cause health problems both to animals and human beings consuming these element-rich food crops as there is no suitable mechanism for their elimination from the body system (Ogunwale et al., 2021). Toxic elements are known to preclinical concerns, including carcinogenesis-induced tumor growth. Hence, the growing consciousness about the health risks related to ecological chemicals has brought a significant shift in, global interest towards avoidance of heavy element bioaccumulation in air, soil, water, and staple foodstuff crops (Ogunwale et al., 2021).

The term 'potentially toxic elements' (PTEs) are also used frequently in research articles to denote elements that are identified to be extremely toxic at elevated contents. Lead, Zn, Cu, Fe, Cd, As, and Ni are among elements that are often referred to as PTEs (Ogunwale et al., 2021). Because of the diversity of vocabularies found in research papers, the term 'heavy elements' are occurred to be the most charming to be used in this work.

There is a growing risk of public contact with heavy elements as a result of the consumption of food crops produced in contaminated soil (Ogunwale et al., 2022). There are several reports in the published articles corroborate this statement (Njagi, 2013; Balk hair and Ashraf, 2016; Ogunwale et al., 2021;Ogunwale et al., 2022). The problem of heavy elements invading the feeding level-entails systematic assessments to create timely decisions to prevent serious health effects as a result of the invisible mode of heavy element toxicity (Ogunwale et al., 2021). Risk analyses have been conducted employing various risk assessment techniques, like the hazard quotient (HQ)(Balkhair and Ashraf, 2016; Zhou et al., 2016; Ogunwale et al., 2021), (the health risk index (HRI) (Ogunwale et al., 2021), the morbidity level (ML) (Srinivasan and Reddy, 2009), the enrichment factor (EF), the degree of contamination (C_{deg}) and the uptake/transfer factor (UF) (Ogunwale et al., 2021), enumeration, mathematics, and geospatial (Hani et al., 2010).

Heavy element exposure takes place considerably by occupational contact. The biotoxin impacts of heavy elements, when consumed beyond the bio-recommended levels, are too numerous to be given little attention to. In most periods, the cultivators who help in sustaining the lives of the citizens through the cultivation of staple crops stand insecure of immediate contact with these toxic elements, via ignorance of these substances. Also, no reported data have been estimated on the Aawe farm establishment. This farm establishment supplies food to adjoining towns and villages in Oyo State and Osun State. It is this relevant to provide baseline information about the levels of toxic elements in this settlement along with equipping the citizenry about the hazards in the use of these substances and the menaces that they pose to the entire ecological community. Farm inputs like fertilizers and agrichemicals are likewise used in the farming of staple food crops, and all these might contain As, Cd, Cu, Mn, Pb, and Zn elements, for staple crops intake on the farm. There is, therefore the need for studies to assay the level of these elements in the staple foodstuffs and soil on this farm establishment. This work estimates the content of some heavy elements: As, Cd, Cu, Mn, Pb, and Zn in some designated commonly consumed staple foodstuffs: sweet cassava (*Manihot esculenta L.*), maize (*Zea mays L.*), plantain (*Musa paradisiaca L.*), and white yam (*Dioscorearotundata L.*) cultivated in Aawe communities in the Odu'a farm establishment Oyo State, Southwestern Region of Nigeria. The staple food crops were planted on a farmland soil settlement of Aawe for the period of wet and dry seasons of 2018.

II. Material and Method

a) Area under Study

i. Place and Suitability of Research Site

The research was conducted in Aawe, which is under the Afijio Local Government Area of Oyo State, Nigeria. It situates in the Southwestern Zone of the State, which is approximately encircled by latitudes 7.80 and 4.40 north of the equator. Aawe Farm Centre: Old Rural Community Development Centre (RCDC) Km 12, Aawe-Iwo Road, Aawe, Oyo State. Odu'a farm settlement is specifically designated for this work on account of its influence toAgri-business Industry in Nigeria and happens to be a fast developing farm settlement within the area. The farm settlement scheme conducts training and workshop for all categories of farmers, and young school leavers. Also, the clime of this area has been deemed to be the most appropriate for agricultural productivity in the southwestern Geo–political zone of Nigeria(Ogunwale et al., 2021).The landform is, by and large, undulating with highest being around 213.50 m above the mean water table. There is a good network of rivers and streams and prominent among them are Odooba and Dogiyan rivers. These rivers aid as sources of water for irrigation uses explicitly for staple crop farmers in the dry season. The area falls within two climatic regions in Nigeria (Ogunwale et al., 2021). The Semi Deciduous Forest is available in the northern part whereas the Tropical Rain forest, which is among the wettest region of the country, is available in the southern part. The mean annual rainfallfalls off from 127.77 mm in the south to 111.00 mm in the north. There are two main rainfall characteristics, present between mid-March to early-August and September to early November, with a short dry season present between December-February. Temperatures are moderately high, varying from 23.80-27.90°C. Maximum temperatures occur in February-March, and slightest low-temperature month is August.

Geologically, the research area makes up a portion of the Basement Complex of Southwestern Nigeria and it is naturally covered by hard crystalline igneous and metamorphic rocks (Ogunwale et al., 2021). The soil types of the study zone are primarily connected with Iwo and Egbeda categorizations. They have been figured out as montmorillonite soils which are by far the most extensive and almost all essential soils within the Tropical biomes for both food and tree cash crop cultivation. Such grounds, under natural conditions comprise rich nutrients that are tied-up with the organic layers in their surface soil and, thus sustain healthy crop growth (Ogunwale et al., 2021). Best food crops cultivated are cassava, cocoyam, maize, plantain, pineapple, banana, yam, and vegetables, while chief cash crops include cocoa, rubber, oil palm, cashew, mango, avocado, and citrus.

b) Plant and Soil Sampling

At farm establishment, samples were picked up from diverse plots within the farm since the agronomical practices tolerate great local variation of soil characteristics. Cassava, maize, plantain, yam, and soil samples were taken from the farm that surrounded the farm settlement and one fallow plot in which farming was not taking place, respectively within the research area. Selections from the non-farming plot were collected and assayed to provide reference data as an underlying condition of comparison to the cropland areas. Five pieces of cassava, maize, plantain, and yam with their corresponding soil samples (i.e., varying from 0-20 cm depth from the top of the ridge)were gathered in each plot. The cassava, maize, plantain, and yam samples were harvested from four farms within each parcel, dependent upon the availability of the crops. This was done after the ridges were created and the cassava andyam, and holes were dug while plantain was harvested with a clean machete and maize was plucked with glove hand and samples were taken. Pieces of each crop gathered were wrapped in foil paper and marked with cellulose masking tape to avoid wrong identity. All the pieces were stored in dried polyethylene bags and conveyed to the research laboratory for additional analysis. The pieces were well labeled depending on the location, and also geospatial coordinates were taken in addition.

The cassava, plantain, and yam samples were pared. At the same time, maize grain, each seed was extracted off the cob before drying, and the edible portions were washed with tap water, after that, deionized distilled water, broken into smaller slices with a stainless knife, and naturally dried in a spacious room on a concrete ground for seven 2-7 days. The pieces were then put in a hot air oven with a temperature of 105°C to dry till constant scale was attained. When fully dry, the samples were crushed, and both soil and plants were sieved utilizing a 2 mm plastic sieve before being assessed.

c) Soil Analysis of pH, Electrical Conductivity, Organic Carbon and Organic Matter

Following air-drying for seven days and sieved, 10 g per soil sample was quantified via a Metlar Electronic balance (Model MT 2000) scale and put in glass beakers. To measure the pH 50 mL of distilled water was introduced to the samples which were shaken in durations for one hour. The pH was then measured with a HANNA instrument, pHep®, pocket-sized pH meter (Ogunwale et al., 2021).

Electrical conductivity was carried out employing a 10 g dry basis per sample placed in glass beakers with 50 mL of distilled water. The samples were agitated for one hour, and the measurements were done with a HACHUltra meter II 6 Psi serial 6207639. Organic carbon was conducted by means of a potassium dichromate back-titration technique (Ogunwale et al., 2021). The organic matter content was estimated by a factor of 1.72 multiplied by organic carbon modified by Ogunwale et al. (2021).

d) Digestion of Samples (both Staple Food Crops and Soil) for FAAS Analysis

i. *Preparation of Wet Digestion Acid*

$HN0_3$, $HClO_4$, and H_2S0_4 were combined in the proportion of 30:4:1 with a view to composing the wet digestion acid mixture.

ii. *Digestion and Extraction Technique of Heavy Element Analysis for Food Crops and Soil*

For extraction, 1.0 g per dried and crushed sample was determined with the Metlar Electronic balance (Model MT 2000) scale and placed in a glass beaker. A volume of 5 mL aqua regia was introduced (1:3 HNO_3: HCl), and the samples were placed in a hot air oven for 30-60 minutes till finally digested. The stove did not possess a thermometer and the temperature was attuned by turning the on and off the stove, endeavoring to keep the temperature at about 100-120°C. To make sure that the samples did not get burned they were regularly examined. The end of the digestion was noticed by the emission of a dense white fume of perchloric acid ($HCl0_4$) and the decrease of volume to about 5 mL, and then the digestion system was discontinued. The digest was left to cool and conveyed measurably in 50 cm^3 volumetric flasks, then was filled into the grade with laboratory water. The digest per sample was moved into a diverse well-stopper rubber vessel, which was made ready for Flame Atomic Absorption Spectroscopic Analysis.

e) Data Assays

i. *Translocation Factor Estimation*

Heavy elements can potentially translocate from the soil to the consumable portions of the staple food crop and can be done by the bioaccumulation factor (BF) (Balkhair and Ashraf, 2016; Ogunwale et al., 2021). The BF contents for the designated heavy elements were estimated employing the following Equation:

$$BF = \frac{Heavy\ element\ content\ in\ the\ staple\ food\ crops\ consumable\ portions}{Heavy\ element\ content\ in\ the\ soil} \quad \text{.................................eqn(i)}$$

ii. *Heavy Element Pollution Load Index (HEPLI)*

The content of soil pollution perelement was estimated utilizing the heavy element pollution load index (HEPLI) technique dependent upon soil element contents. The resulting reviewed equation was employed to calculate the HEPLI content in soils.

$$HEPLI = \frac{C_{soil}\ (Samples)}{C_{benchmark}\ (Benchmark)} \quad \text{(Ogunwaleet al., 2021)................................ eqn (ii)}$$

C_{soil} (samples) and $C_{benchmark}$ suggest the heavy element contents in extracts of soil and recommended value for the element. The geochemical recommended values in continental crust mean shale of the heavy features under analysis described by Turekian and Wedepohl (1961) were applied as recommended guidelines of the component element.

iii. *Risk Analysis for Daily Allowance of Heavy Elements*

The amount of staple food that can securely be eaten on an everyday basis is estimated from uniting equations for the daily allowance of elements (DAE), human health risk index (HHRI), and target hazard quotient (THQ) (Balkhair and Ashraf, 2016; Ogunwale et al., 2021). The DAE is in line with Balkhair and Ashraf (2016) and Ogunwale et al. (2021)calculated from the daily degree of food consumed ($D_{food\ allowance}$), the content of elements in the food ($C_{element}$), and the mean weight of the body of the consumers ($B_{mean\ weight}$) concerning the equation below. The C_{rate} (0.085) is applied to convert fresh green staple food matter to dry matter (Balkhair and Ashraf, 2016; Ogunwale et al., 2021).

$$DAE = \frac{C_{element} \times A_{factor} \times D_{food\ allowance}}{B_{mean\ weight}} \quad \text{.............................. ....eqn (iii)}$$

where $C_{element}$, A_{factor}, $D_{food\ allowance}$ and, $B_{mean\ weight}$ depict the heavy elementvalues in staple food crops (mg/kg), adjustment factor, a daily allowance of foodstuff crops, and mean weight of the body of the consumers, respectively. The adjustment factor (AF) of 0.085 was meant for the transformation of fresh green staple foodstuff matter to dry matter, as revealed by Ogunwale et al. (2021). The mean weight of the body for the adult population was 60 kg, as applied in previous research (Balkhair and Ashraf, 2016; Ogunwale et al., 2021). These contents were also employed for the estimation of HHRI. The daily maximum allowance of 800 g for sweet cassava, plantain, white yam, and maize (Balkhair and Ashraf, 2016) was adopted for this analysis.

iv. *Human Health Risk Index (HHRI)*

The human health risk index is the proportion of DAE and an oral recommended allowance(ORA) employing the subsequent equation:

$$HHRI = \frac{DAE}{ORA}$$ (USEPA-IRIS, 2002; Ogunwale et al., 2021) ………………………eqn (iv)

Where DAE is the daily allowance of elements and ORA is the oral recommended allowances. The ORA is the highest amount of acomponent, in milligrams per day, that the body can be vulnerable to the outside of yielding a hazardous outcome during a lifespan. Oral recommended allowances were 3.00E-04, 1.00E-03, 4.00E-02, 3.00E-01, 4.00E-03, and 3.00E-01 mg/kg/day for As, Cd, Cu, Mn, Pb, and Zn, respectively (USEPA-IRIS, 2002). An HHRI<1 implies that the vulnerable consumers are said to be in safety (Ogunwale et al., 2021).

When uniting Equation (iii), and (iv) along with HHRI=1, the maximum limit for the amount of food that can securely be eaten on an everyday basis is expressed as:

$$D_{food\ allowance} = \frac{B_{mean\ weight} \times ORA}{A_{factor} \times C_{element}}$$ ………………………………………..eqn (v)

v. *Target Hazard Quotient (THQ) Technique*

The potential health risks of heavy element allowance through staple foodstuffs were analyzed-depending on the target hazard quotient (THQ) method, which was indicated thoroughly using the United States Environmental Protection Agency (USEPA-IRIS, 2002). The THQ is considering through the subsequent equation:

$$THQ = \frac{EF_r \times ET \times F_I \times EC}{ORA \times BS \times MD} \times 0.001$$ ……….eqn (vi)

Where EF_r is the exposure frequency (350 days/year); ET is the exposure time (55.12 years, corresponding to the mean lifespan of the Nigerian population); F_I is the food ingestion rate (staple foodstuff (sweet cassava, maize, plantain, and white yam) allowance analyzes for adults is 800.0 g/person/day) was adopted for this work (Balkhair and Ashraf, 2016); EC is the element content in the consumable portions of staple foods (mg/kg); ORA is the oral recommended allowance (As, Cd, Cu, Mn, Pb, and Znvalues were 3.00E-04, 1.00E-03, 4.00E-02, 3.00E-01, 3.50E-03, and 3.00E-01 mg/kg/day, respectively) (USEPA-IRIS, 2002); BS is the mean weight of the body size (60 kg for adults) (USEPA-IRIS, 2002); and MD is the mean exposure duration for non-carcinogens (365 days $year-^{1} \times$ number of exposure years, supposing 55.12 years in this work). If the THQ value is above 1, the condition is likely to cause significant harmful effects.

The total diet THQ (TDTHQ) of heavy elements for staple foods is stated explicitly using the following equation (Storelli, 2008;Zhou et al., 2016).

$$TDTHQ = \sum_{i=1}^{n} (THQ)i$$ ……………..eqn (vii)

f) *Quality Control Adopted Utilized*

With the intention of determining the effectiveness of the $HNO_3 - HClO_4$ method of sample digestion, a recovery test was done by spiking 1 g of twenty (20) and ten (10) different soil, cassava, maize, plantain, and yam samples each with 1 cm^3 of standard solutions of the elements As, Cd, Cu, Mn, Pb, and Zn. Recovery test presented % recoveries > 80%. Element contents in functioning standards and digested samples were performed with FAAS (Alpha Star Model 4, Chem-Tech Analytical) at the Centre for Energy Research and Development (CERD) of the Obafemi Awolowo University, Ile-Ife, Nigeria. Instrumental conditions are as stated earlier (Ogunwale et al., 2021). Blanks were also prepared to estimate the input of reagents to element contents.

III. Results

a) *Physicochemical and Heavy Elements Attributes of the Farmland Soils*

The soil attributes (Table2) were assessed in relation to the Ogunwale et al. (2021) guidelines. The investigated variables comprised pH, electrical conductivity (EC), total organic carbon (TOC), and total organic matter (TOM). Supposing the mean value of carbon in soil organic matter (˜58% w/w), an adjustment factor of 1.72 was applied to determine the percentage of organic matter (OM) from the value of organic carbon (Ogunwale et al., 2021).

Table 3 demonstrates the levels of As, Cd, Cu, Mn, Pb, and Zn (mg/kg) in soils present from farmed and non-farmed (control) sites in the research area for both seasons. The mean values of all heavy elements for wet and dry seasons varied from ND-743. 44 mg/kg and ND-806.73 mg/kg, respectively. Arsenic in both seasons varied from 3.27-7.38 mg/kg and Mn ranged from 236.10-806.73 mg/kg in farmed soils while their values were 0.04 and 0.07 mg/kg and 5.12 and 8.95 mg/kg in non-farmed soils, respectively. The levels of most heavy elements in wet and dry seasonswere0.06-0.46, 9.08-23.27, 3.85-13.16, and 16.66-36.12mg/kg for Cd, Cu, Pb, and Zn, respectively while the values for unfarmed soil were ND, 0.06 and 0.18, 0.03 and 0.07 and 1.64 and 1.96, 6.765, 5.635, and 0.875mg/kg for Cd, Cu, Pb and Zn, respectively.

Table 4presents the heavy elementcontents in the assigned food crops (cassava, maize, plantain, and yam) in the area under study. The mean values in cassava for both seasons varied from 0.03-12.24 mg/kg; maize ranged from 0.04-17.38 mg/kg; plantain varied from 0.05-26.14 mg/kg and yam varied from 0.02-15.43 mg/kg, respectively with an overall mean of 2.00 and 3.08 mg/kg; 0.04 and 0.05 mg/kg; 0.14 and 0.24 mg/kg; 14.89 and 17.80 mg/kg; 0.07 and 0.15 mg/kg and 7.35 and 8.60 mg/kg, respectively for As, Cd, Cu, Mn, Pb, and Zn.

The element BF in staple crops is used to express the quantity of bioaccumulation of a compound in a signified biotic complex. Table 5 reveals the BF values of heavy elements in food crops farmed in the research site while Table 6 presents the heavy element pollution load index of features across the sampling points for both seasons. To determine the human health risk per pollutant, it is significant to estimate the level of exposure by finding the routes of contact with target living things. There are numerous likely pathways of contact with humans, but among them, the trophic status is the mostcritical pathway. In our analysis, the mereal lowance path available for As, Cd, Cu, Mn, Pb, and Zn was adopted to staple food allowance.

The DAE values were estimated counted on the mean staple food allowance for adults (Table 7) and related to the recommended daily allowances (USEPA-IRIS, 2002). The results for estimating the mean DAE, HHRI, DFA, THQ,TDTHQ, and TTHQ from the heavy element-polluted staple foodstuff crop are presented in Tables 7-10. The results indicated that the DAE and HHRI values were low in the staple food crops while DFA, THQ, and TDTHQ values were high in the staple foodstuff crops. The mean DAE of the staple food crop for both seasons varied from 2.074E-03 to 4.43E-03, 2.267E-05 to 6.800E-05, 6.800E-05 to 4.873E-04,1.167E-02 to 2.963E-02, 4.533E-05 to 2.607E-04, and 3.094E-03 to 1.365E-02 mg kg^{-1} $person^{-1}$ d^{-1} for As, Cd, Cu, Mn, Pb, and Zn, respectively (Table 7).

Likewise, in staple food crops, the mean HHRI values in wet and dry seasons for As, Cd, Cu, Mn, Pb, and Zn ranged from 6.91E-01 to 1.48E+00, 2.27E-02 to 6.80E-02, 1.70E-03 to 1.22E-02, 3.89E-02 to 9.88E-02, 1.30E-02 to 7.45E-02, and 1.03E-02 to 4.55E-02mg kg^{-1} $person^{-1}$ d^{-1}, respectively (Table 8). Equally, the mean DFA of the staple food crops that can be securely eaten on an everyday basis for both seasons varied from 0.542 to 1.157, 11.765 to 35.294, 65.663 to 470.588, 8.101 to 20.560, 10.742 to 61.765, and 17.588 to 77.569, correspondingly (Table 9). Furthermore, in staple food crops, the mean THQ values in wet and dry seasons for As, Cd, Cu, Mn, Pb, and Zn ranged from 7.799 to 16.664, 0.256 to 0.767, 0.019 to 0.137, 0.439 to 1.114, 0.015 to 0.084, and 0.116 to 0.513, respectively (Table 10) while the mean TDTHQ values of the staple food crops for both seasons varied from 34.093 and 52.420, 1.790 and 2.301, 0.173 and 0.311, 2.539 and 3.035, 0.095 and 0.215 and 1.252 and 1.466, respectively for As, Cd, Cu, Mn, Pb, and Zn (Table 10).

IV. Discussion

a) *Fertility Variables of the Soils*

The pH is one of the variables governing the bioavailability and the movement of heavy elements in the soil in line with (Ogunwale et al., 2021), heavy element mobility decreases with increasing soil pH owing to the evolution of hydroxides, carbonates, or the formation of insoluble organic molecules. In this analysis, it was revealed that the heavy element contents were rise-considerably with a decrement in the pH.

The soil EC also varied considerably with season. On the contrary, (FAO/WHO, 2011) categorized the EC of the grounds as: nonsaline < 2; moderately salty 2–8; very salty 8–16, and potentially salty > 16. From the results of the analysis, the EC is categorized as moderately salty. The EC of the soil samples indicated that all croplands caused no salinity issue (EC < 200 $\mu S\ cm^{-1}$). The degree of heavy elements mobilized in the soil ecosystem is influenced by pH, attributes of the elements, redox conditions, soil chemistry, organic matter level, and the like soil qualities (Ogunwale et al., 2021). Heavy elements are naturally more mobile at pH < 7 than at pH > 7. The pH of the soils from the farmland site in both seasons varied from 6.37 to 7.40. As a result, these pH values depict that the ecosystem is slightly acidic to neutral, which is suit able for crop land uses because crops are available to uptake and mildly concentrate heavy elements from polluted soils in their consumable portions (Ogunwale et al., 2021).

The levels of organic carbon and organic matter in the soil sample increased considerably with the season. The OC is also elevated with a rising water table (Ogunwale et al., 2021). This finding may be of great ecological interest because it was demonstrated that elevated levels of rain-supplied soil during the study periods elevated the quantities of the OC, which impacts the dissolution and readily available of heavy elements.

b) *Soils Pollution*

In all respects, the mean contents of heavy elements in farmland soils from farmed areas were higher than those obtained in soils from the unfarmed areas (Table 3).The contents of heavy elements revealed spatiotemporal differences, which may be owing to the variation in the rich element sources and the degree of heavy elements in the soil. There was an overall resemblance in the pattern of predominance element levels in grounds from both seasons diminishing in the following order Mn> Zn> Cu> Pb >As> Cd (Table 3). Data from this analysis indicated that values of all heavy elements were primarily low and within specified guidelines of FAO/WHO (2011) and National Environmental Standards and Regulations Enforcement Agency (NESREA, 2018) values for arable land. The variation of heavy elements content in the research area was also owing to inorganic fertilizer and the like agronomic practices. The low content of the rich components of the cropland may have resulted from their continuous removal by staple food crops grown in the chosen areas.

Among the different elements analyzed in soil, the content of Mn was the highest, and variation in its content was many times exceeding those described by Ogunwale et al. (2020). The most elevated deposition of Mn in cropland soil might be a result of its long-term utilization in the production of agricultural implements, paints, pigments, pesticides, insecticides, and alloying of varied farms of the investigated area that might give rise to pollution of the soil and an effect in tillage. Despite what preceded, it was found from the analysis of the data that regardless of the low element contents, there was significant burdening or bioaccumulation of heavy elements in soils from arable land areas as indicated by the evaluated heavy element pollution load index (HEPLI) in Table 6 below.

On the basis of Ogunwale et al. (2021), HEPLI is the degree of pollution per element in farmland soil relative to a recommended content (world benchmark levels of elements in shale/rock). If it is more than one, then there is significant element enrichment in the soil of interest. The overall mean indices of HEPLI for elements assessed in this analysis for both seasons were 0.54 and 0.88, 0.28 and 0.92, 0.31 and 0.37, 0.52 and 0.55, 0.28 and 0.55 and 0.24 and 0.31 for As, Cd, Cu, Mn, Pb, and Zn, respectively, with the rate of amassment being in this order for the wet season As > Mn > Cu > > Cd, Pb > Zn and for dry season Cd > As > > Mn, Pb >Cu > Zn. Cadmium and As contained the highest overall mean HEPLI (0.92 and 0.88) while Zn contained the least overall mean HEPLI (0.24 and 0.31) in the soil from the cropland site. The moderate HEPLI indices of elements in the grounds in this analysis revealed substantial loading and an indication of heavy elements buildup (pollution) in the grounds within the areas from extensive farming activities, which is in corroboration with the findings of most earlier studied (Ogunwale et al., 2021;Zango et al., 2013; Zhuang et al., 2009). In this way, comprehensive agricultural operations in the research area caused the raising of the contents of heavy elements in the soil.

c) Heavy Element Pollution in Staple Foodstuff Crops

The mean contents (in mg/kg dry matter) of heavy elements (As, Cd, Cu, Mn, Pb, and Zn) in the assigned food crops (sweet cassava, maize, plantain, and white yam) in the assessment area were all below values present in their equivalent soils (both farmed and unfarmed soils) as presented in Table 5, showing evidence of heavy element low bioaccumulation in staple food crops. The moderate element contents in the food crops may have been burdened by the noticed rise in heavy element levels as a result of farming operations, as can be inferred from the study of the HEPLI of soils from farmed areas concerning those assessed of unfarmed regions (control) in Table 6.

The HEPLIs of all the elements were below 1, signifying insignificant bioaccumulation of elements in soils in the arable land areas. Except for As, the mean contents of all the heavy features quantified in sweet cassava, maize, plantain, and white yam (Table 4) grown in the farmland areas in both seasons below the prescribed values of FAO/WHO (2011). Investigations revealed that food crops tilled on soils present in arable land sites could be polluted with a heavy element like As and so could introduce consumers of that food to severe health hazards (Ogunwale et al., 2021;Zango et al., 2013; Zhuang et al., 2009).

The findings found from this research in wet and dry seasons indicated that As in cassava, maize, plantain, and yam were above the standard tolerable limit by the Joint FAO/WHO Expert Committee on Food Additives and Food and Nutrition Board (2011) by 25.00 and 16.23%, respectively. Thereby As signify the primary causes of heavy element pollution in the selected foodstuff crops in the communities in the assessment district with Cd, Cu, Mn, Pb, and Zn and demonstrating insignificant pollutants, and this relates to the findings of Zango et al. (2013) and Zhou et al. (2016).

d) Heavy Element Transfer (AF) from Soils to Food Crops

In the general case, by sources of agrichemicals, chemicals leaking the water ecosystem, subsequently, enter into the soil. The soil absorbs the portion of the substances which, suitably, turn into part of the photosynthetic processes. It was thus estimated that the contents of elements in the sweet cassava, maize, plantain, and white yam would exhibit the contents in the soil samples. As expressed by Ogunwale et al. (2021), there is a statistical relationship between element contents in rhizosphere soils and grown crops. Nonetheless, the results of this analysis revealed inconsistency. The association between element contents assessed in soils regarding grown food crops was somewhat varied and insignificant. The contents of elements in soils for both seasons was something like Mn> Zn > Cu > Pb > As > Cd while the sequence in BF in both seasons were As > Cd > Zn > Mn > Pb > Cu and As >Zn> Cd > Mn >Cu> Cd> Pb, respectively. Nonetheless, the analysis of the HEPLI on soils in this assay indicated a statistical difference in the sequence of the HEPLI and total element contents in food crops.

The arrangement of elements for HEPLI in the wet season was As > Mn > Cu > > Cd, Pb > Zn and for dry season Cd > As > > Mn, Pb >Cu > Zn while the sequence of elements bio accumulation factor in wet and dry seasons were As > Cd > Zn > Mn > Pb > Cu and As >Zn> Cd > Mn >Cu> Cd> Pb, respectively. This is corroborated by the findings of Ogunwale et al. (2021) that contents totals of Cd, Pb, Zn, and As in soils varied substantively with the contents present in vegetables grown on the grounds in poultry farm areas. Arsenic and Cd were found to be the most bio accumulated among the foodstuff, with Cu being the minimum. This reveals that the local populations were at high risk of being vulnerable to As and Cd-related health disorders. It was told that Cd which was the second most accumulated heavy element in the food crops, was the minimum taken up in the soils. At the same time, Zn, which was the second most bio accumulated in the ground, was the third most taken up element by the four food crops. Lead (Pb) which was the moderately bioaccumulated element in the grounds, was also least taken up by the four food crops (Tables 3 and 5).

The bioaccumulation factor (BF) for As, Cd, Cu, Mn, Pb, and Zn was below 1 in all of the monitored food crops indicating insignificant bioaccumulation. Those elements that contain a slight transfer factor migrate to the edible part of the plant easier than those with a low transfer factor (Ogunwale et al., 2021), this is the reason that these elements demonstrate their mild bioaccumulation values in sundry food crops to such a minor ratio. The BF values varied for heavy parts in sundry food crops and in farmland plots (Ogunwale et al., 2021). Nominal BF values were present in all of the assayed features with foodstuff crops and could be one of the probable causes for health hazards in humans via their intake. Low BF values for heavy elements were shown in the soil. This result indicated that the absorption of heavy ingredients by means of food crops did not rise directly with rising element contents in the ground. Our research isrelative to the previous conclusions of (Balkhair and Ashraf, 2016; Ogunwale et al., 2021). This occurrence is significant concerning long-lasting utilization of agrichemical; hence so the same degrees would not be part of the feeding level.

e) *Daily Allowance of Elements and Human Health Risk Analysis*

The human risk analysis determination from the route of the trophic level is of crucial significance in countries like Nigeria, where the agrichemical application continues uncontrolled. There are manifold exposure routes mainly depend on polluted sources of air, water, soil, food, and the consuming community (Ogunwale et al., 2021), but the pathway of contact via the trophic level is one of the primary means of heavy element contact with humans (Ogunwale et al., 2021; Zhou et al., 2016). The Nigerian people are chiefly vegan and count on cereal, fruits, and tuber crops such as (*Manihot esculenta L.*, *Zea mays L.*, *Musa paradisiaca L.,* and *Dioscoreaspp. L.*) as some staple foods. The food crops produced in the current analysis are consumed linearly through the localpopulation or are sold to the marketplace for isolated population intake.

To determine the health risk of occupants of these foodstuff crops in the area under study, the daily allowance rates of element (DAE), the human health risk index (HHRI), target hazard quotient (THQ),total diet target hazard quotient (TDTHQ),and TTHQ were estimated. It was revealed in this analysis (Table 7) that the daily allowance rates of all the heavy elements (As, Cd, Cu, Mn, Pb, and Zn) in the food crops (sweet cassava, maize, plantain, and white yam) are at values which were lower than prescribed by FAO/WHO (2011). Hence, the dwellers in the study region were not likely to be vulnerable to ill health from excess intake of As, Cd, Cu, Mn, Pb, and Zn in sweet cassava, maize, plantain, and white yam at present. The HHRI has been known as a very estimable indicator to assess the human health risk connected with the allowance of heavy element contaminated food crops (USEPA, 2002; Zango et al., 2013; Balkhair and Ashraf, 2016; Ogunwale et al., 2021). If the content of a particular staple food crop is below 1, it is considered to be safe for human health to eat that foodstuff. But if the concentration is above 1, it is considered to be unsafe for human health (USEPA-IRIS, 2002; Ogunwale et al., 2021).

The mean calculated HHRI in this study for sweet cassava, maize, plantain, and white yam was close to 1 in both seasons. Their values ranged from 0.0017-0.839, 0.00397-1.18, 0.00737-1.48, and 0.00227-1.15, respectively. Plant a in being a rhizome food crop, contained higher contents relative to sweet cassava, white yam, and maize, which are stem and root tubers and cereal food crops. Arsenic had the highest HHRI content, with an overall mean of 0.756 and 1.162 in staple food crops, and after that, Mn with an overall mean of 0.0564 and 0.0625 in all the foodstuffs, respectively. The sequence of the dominance of mean HHRI indicator for the element in both seasons are As > Mn > Cd > Zn > Pb > Cu and As > Mn > Cd > Pb > Zn > Cu, respectively. This obviously indicates that the local populations, are most likely to be affected by potential health hazards from the nutritional As.

The oral recommended allowance (ORA) is the daily contact of persons with toxins or pollutants that can make no considerable risk over their lifespan. The ORA values for the toxic elements As, Cd, Cu, Mn, Pb, and Zn are 3E-03, 1.0E-03, 4.0E-02, 3E-01, 3.50E-03, and 3E -01 mg $kg^{-1} d^{-1}$, respectively (USEPA-IRIS, 2002; Ogunwale et al., 2021). In this work, the heavy elements, apart from As, contained HHRI >1, indicating a possible future human health risk via the intake of food crops. Nevertheless, As was regarded to be non-essential element susceptible to health hazards, even at very low concentrations. Zhuang et al.(2009), Zhou et al.(2016), Ogunwale et al.(2021), and Ogunwale et al. (2022)have also signified anHHRI content for As that above the prescribed values in cereals, tuber, rhizome, and vegetables crops.

Chronic low-level intake of toxic elements harms human health, and the deleterious impact begins to be evident after manifold years of contact with them (USEPA-1RIS, 2002; Ogunwale et al., 2021). The THQ technique was applied to quantify the potential health risks of heavy element bioaccumulation by means of staple foodstuff crop intake in this work. A staple foodstuff intake value for adults in Nigeria is 800.0 g/person/day, respectively (Zango et al., 2013). In the allowance lifestyles of indigenous inhabitants, the plantain intake in both seasons made up 26.80 and 32.20% of the total intake of staple food. After that maize, white yam, and sweet cassava foodstuffs, each of them made up 25.03 and 24.77%, 25.99 and 24.22% and 22.17 and 18.73%, respectively. The mean THQ values of As, Cd, Cu, Mn, Pb, and Zn resulting from staple food allowance for dwellers (adults) of the study area were recorded in Table 10. The mean THQ values of As via intake of sweet cassava, maize, plantain, and white yam for inhabitants were more than for the other five elements types in this study, signifying that the potential health hazards exposure for As were greater for residents. For staple foods, the As mean THQ values of adults ranged from 7.799-9.205 and 9.461-16.664, respectively, and mean Cd THQ values varied from 0.256-6.390 and 0.384-0.767 for adults in both seasons, while mean THQ values for Cu and Zn were below 1, and Mn above 1.0 utilizing the intake of the plantain types only. These findings implied that the potential health risks of heavy elements through intake of staple foods were the highest for all foodstuff types. Furthermore, the total diet THQ of each element (TDTHQ) values of heavy elements in both seasons decreased following the order As >Mn > Cd > Zn > Cu > Pb (Table 10). This signified that for toxic heavy elements, the potential health risks of As and Mn through staple food allowance were more than for Pb.

It has been observed that contact with two or more pollutants may bring about additive and/or cause negative impacts (Zhou et al., 2016; Ogunwale et al., 2021). Thereby, it is difficult to evaluate the potential health hazards of multiple elements by means of each individual THQ value for the heavy stuff. Moreover, the total THQ (TTHQ) of heavy elements is the sum of the unique rich element (As, Cd, Cu, Mn, Pb, and Zn).Target hazard quotient (THQ) values for the four staple foodstuff types, and the values are also presented in Table 10. The TTHQ values for adults via staple food intake in both seasons were 9.986 and 14.937, respectively. This result signified that the inhabitants of the Odu'a farm establishment area might be susceptible to health risks, and the potential health risks for dry season were higher than for the wet season. The relative contributions of As, Cd, Cu, Mn, Pb, and Zn to the TTHQ in damp and dry seasons were 85.36 and 87.74%, 4.48 and 3.85%, 0.43 and 0.52%, 6.36 and 5.08%, 0.24 and 0.36% and 3.13 and 2.45%, respectively; therefore, As was the central element contributing to the potential health risks of staple foodstuff intake for occupants in the study ecozone.

V. Conclusions

The assigned food crop (sweet cassava, maize, plantain, and white yam) are the staple food for the occupants of the research suburb (Odu'a Aawe environs) and the greater part of especially southwestern parts of Nigeria. It is in thisregion that both major and minor agricultural operations are carried out in Nigeria. Albeit, the content of heavy elements in soils from the large-scale farming area where the study was conducted was relatively low and within prescribed values set by FAO/WHO and NESREA standards. The activities of large-scale farmers had led to heavy element burdening or pollution as present from the calculated HEPLIs.

Assessment of element transfers (bioaccumulation factors) revealed that there had been a moderate buildup of heavy elements in the designated food crops, with the contents of As above the maximum limit given by FAO/WHO. Variation in the heavy element contents, in the four food crops is a mark of the differences between the absorption potentials and their translocation to the consumable parts of the plants. The assessments of HHRI and DAE have indicated that plantain is more polluted with heavy elements than white yam, maize, and sweet cassava. The research further reveals that the dwellers were unsafe and at risk of being vulnerable to long-lasting health effects from nutritional As and this is of public health issue. Furthermore, HHRI values >1 were also observed for As intake in food crops. It signified that people who are residing in this settlement and the like areas of equivalent agricultural operations in southwestern Nigeria be enlightening not to consume large quantities of these food crops, in an attempt to reduce or prevent extreme buildup of heavy elements in their bodies. The TTHQ values for wet and dry seasons by foodstuff allowance were 9.986 and 14.628, respectively, signifying that the residents of the Odu'a area may be facing health risks owing to foodstuff intake, and that consumers were subject to the harmful effects of ingestion of heavy elements. Heavy element bioaccumulation by nutritional information of food usually occurs slowly and over a long period (years) and could harm human health. Arsenic was the main contributor to potential health hazards of foods tuff in take for inhabitants in the area under study. It is therefore also recommended that a critical research is necessary to plan and execute proper ways of checking heavy element contents in food crops grown in cropland settlements to avoid their undue accumulation in the feeding level. The potential health hazards of heavy elements utilizing other exposure pathways need to be in the interest of future research. The work has provided information on the extent of heavy element pollution in the cropland establishment as a way of assessing the environmental health of the area under study as a result of heavy element pollution. The work also added to the baseline data on risk of potentially toxic elements studies in our environment.

Acknowledgements

The authors are grateful to Directors and Workers of Odu'a Farm Settlement, Oyo State for permitting the use of their arable land as sampling site for this analysis. The Centre for Energy Research and Development (CERD) of the Obafemi Awolowo University, Ile-Ife, Nigeria, is to be thanked for their assistance in physico-chemical and heavy elements analysis. The Obafemi Awolowo University, Ile-Ife is also acknowledged for providing the conducive atmosphere for the work.

Statement of Competing Interests

The authors declare that they have no competing interests.

References Références Referencias

1. Balkhair, K. S. and Ashraf, M. A. (2016). Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia, Saudi J Biol Sci., 23(1): S32–S44.
2. FAO/WHO, (2011). Joint FAO/WHO food standards programme codex committee on contaminants in foods, fifth session pp 64-89.
3. Federal Ministry of Agriculture and Rural Development, (2012). Nigeria Environmental and Social Impact Assessment, ESIA/ESMP Report, (1-155).
4. Hani A., Pazira, E., Manshouri, M., Kafaky, S. B. and Tali, M. G. (2010) Spatial distribution and mapping of risk elements pollution in agricultural soils of southern Tehran, Iran. Plant Soil Environ.,56(6): 288–296.
5. National Environmental Standards and Regulations Enforcement Agency, (2018). "National Environmental Regulation for water, food, beverages and tobacco, sector, NESREA, Nigeria" (S.I. No. 33).
6. Njagi, J. M. (2013). Assessment of Heavy Metal Concentration in the Environment and Perceived Health Risks by the Community around Kadhodeki Dumpsite, Nairobi County," pp 1-163.
7. Ogunwale, T. O., Oyekunle, J. A. O., Ogunfowokan, A. O. and Oluwalana, A. I. (2021). Seasonal Appraisal of Heavy Metal Bioaccumulation in Amaranthus, Gruty-stalked Jatropha, Scent Leaf, Bitter Leaf, and Water Leaf in Some Poultry Farms within the State of Osun, Southwest Nigeria, Applied Ecology and Environmental Sciences, 9 (5) 541-549.
8. Ogunwale, T. O., Oyekunle, J. A. O., Ogunfowokan, A. O. and Oluwalana, A. I. (2021). Evaluation of Trace Metals Contamination of some Poultry Farms Groundwater in Osun State, Southwestern Nigeria Utilizing Various Indices, International Journal of Science Academic Research, 02 (05): 1497-1508.
9. Ogunwale, T. O., Oyekunle, J. A. O., Ogunfowokan, A. O. and Oluwalana, A. I. (2021).Seasonal Speciation Study of Heavy Metals Content in Well Water of Some Chicken Farms in Osun State, Southwestern Nigeria, American Journal of Water Resources, 9 (2) 32-40.
10. Ogunwale, T. O., Oyekunle, J. A. O., Ogunfowokan, A. O. and Oluwalana, A. I. (2021).Seasonal Chemical Speciation and Potential Mobility of Heavy Metals in the Surface Soil of some Poultry Farm Establishments of Osun State, Southwestern Nigeria, International Journal of Environment and Pollution Research, 9(2) 1-24.
11. Ogunwale, T. O., Oyekunle, J. A. O., Ogunfowokan, A. O. and Oluwalana, A. I. (2021). Seasonal Assessment of some Trace Metals and Physico-Chemical Variables from Poultry Farms Surface Soils in Osun State, Southwestern Nigeria,British Journal of Environmental Sciences, 9 (4): 18-40.
12. Ogunwale, T. O., Ogar, P. A., Kayode, G. F., Salami, K. D., Oyekunle, J. A. O., Ogunfowokan, A. O., Obisanya, J. F. and Akindolani, O. A. (2021) Health Risk Assessment of Heavy Metal Toxicity Utilizing Eatable Vegetables from Poultry Farm Region of Osun State, Journal of Environment Pollution and Human Health, 9 (1) 6-15.
13. Ogunwale, T. O., Oyekunle, J. A. O., Ogunfowokan, A. O. and Ogar, P. A. (2021). Groundwater Quality Assessment of some Poultry Farms in Osun State, Southwestern Nigeria, for Irrigation and Household Uses, International Journal Water Resources Management and Irrigation Engineering Research, 3 (1):1-23.
14. Ogunwale, T. O., Oyekunle, J. A. O., Ogunfowokan, A. O., Ogar, P. A. and Akande, F. O. (2020). Assessment of Trace Metal Pollution in Surface Soils along some Main Public Roadside Areas in Ile-Ife, Nigeria, Proceedings of 7th NSCB Biodiversity Conference, UI, October 2020, pp. 70-85
15. Ogunwale, T. O., Oyekunle, J. A. O., Ogunfowokan, A. O., Oyetola, S.O. (2022). Evaluation of Bioavailable Contents of Arsenic, Copper and Zinc in Some Poultry Farms Soils in Osun State, Nigeria. Industrial and Domestic Waste Management, 2(2):84-99.

16. Ogunwale, T. O., Oyekunle, J.A. O., Ogunfowokan, A. O. and Oyetola, S.O. (2022). Evaluation of Heavy Metals Found in Vegetables of Some Poultry Farms in Osun State, Nigeria, Industrial and Domestic Waste Management, Volume 2(2): 100-112.
17. Salisu, R. (2016). Impact of Commercial Agricultural Development Project on Productivity and Food Security Status of Maize Farmers in Kaduna State, Nigeria, Department of Agricultural Economics and Rural Sociology Faculty of Agriculture Ahmadu Bello University Zaria, Kaduna State Nigeria, pp. 50.
18. Storelli, M. M. (2008). Potential human health risks from metals (mercury, cadmium and lead) and polychlorinated biphenyls (PCBs) via seafood consumption: Estimation of target hazard quotients (THQs) and toxic equivalents (TEQs). Food Chem. Toxicol., 46: 2782–2788
19. Turekian, K. K. and Wedepohl, K. H. (1961). Distribution of the Elements in some major units of the Earth's Crust. Geological Society of American Bulletin. 72: 175-192.
20. USEPA-IRIS, (2002). United States Environmental Protection Agency, Integrated Risk Information System http://www.epa.gov/iris/subst (December, 2006)
21. Zango, M. S., Anim-Gyampo, M. and Ampadu, B. (2013).Health Risks of Heavy Metals in selected Food Crops cultivated in Small-scale Gold-mining Areas in Wassa-Amenfi-West District of Ghana, Journal of Natural Sciences Research, Vol.3 (5): 96-106
22. Zhou, H., Yang, W.T., Zhou, X., Liu, L., Gu, J. F. and Wang, W. L., Zou, J. L., Tian, T., Peng, P. Q and Liao, B. H. (2016). Accumulation of Heavy Metals in Vegetable Species Planted in Contaminated Soils and the Health Risk Assessment, Int. J. Environ. Res. Public Health, 13: 1-12
23. Zhuang, P., McBride, M.B., Xia, H., Li, N. and Li, Z. (2009). Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China. Sci. Total Environ., 407: 1551-1561.

Table 1: Geographical Positions of the Sampling Locations

Sampling Point	Latitude(N)	Longitude(E)
Yam	07°49.519'	003° 27.520'
Cassava	07°49.486'	003° 27.459
Maize	07°49.629'	003° 27.578
Plantain	07°49.475'	003° 27.409
Control	07°49.856'	003° 27.722

Source: Field Survey, (2018)

Table 2: Mean Physico-chemical Variables of Soils Sample for Wet and Dry Seasons

Sampling Point	pH	EC (µS/cm)	%TOC	%TOM
		Wet Season		
Cassava	6.57±0.06	44.23±3.76	0.86±0.02	1.48±0.05
Maize	6.70±0.07	39.73±3.72	0.95±0.04	1.63±0.07
Plantain	6.50±0.05	51.56±3.95	0.98±0.05	1.69±0.09
Yam	6.97±0.08	75.19±4.08	0.83±0.02	1.43±0.06
Control	6.68±0.07	44.91±3.82	1.02±0.06	1.75±0.11
Min.	6.50	39.73	0.83	1.43
Max.	6.97	75.19	1.02	1.75
Overall mean	6.68	51.12	0.93	1.60
SD	0.08	3.80	0.05	0.08
CV	1.20	7.43	5.38	5.00
		Dry Season		
Cassava	6.93±0.12	81.53±5.06	0.63±0.06	1.08±0.08
Maize	6.77±0.08	87.28±6.30	0.70±0.08	1.20±0.09
Plantain	6.57±0.05	86.96±5.20	0.65±0.06	1.12±0.05

Yam	7.40±0.18	159.94±10.40	0.72±0.05	1.24±0.06
Control	6.70±0.08	92.45±7.50	0.80±0.08	1.38±0.09
Min.	6.57	81.53	0.63	1.08
Max.	7.40	159.94	0.80	1.38
Overall mean	6.87	101.63	0.70	1.20
SD	0.10	9.36	0.03	0.09
CV	1.46	9.21	4.29	7.50

Source: Field Data, (2018)

Table 3: Mean Total Elements Content of Soils Sample for Wet and Dry Seasons (mg/kg)

Sampling Point	As	Cd	Cu	Mn	Pb	Zn	Total metal load
Wet Season							
Cassava	3.27±0.28	0.09±0.02	10.14±2.08	236.10±20.26	3.85±0.71	16.66±3.42	270.11
Maize	3.76±0.30	0.06±0.01	16.01±3.06	302.64±23.08	6.03±0.83	18.81±3.50	347.31
Plantain	3.96±0.29	0.07±0.01	20.26±3.24	743.44±40.16	8.06±0.92	25.64±3.70	801.43
Yam	3.93±0.25	0.12±0.03	9.08±1.02	468.91±31.20	4.26±0.74	30.01±4.08	516.31
Control	0.04	ND	0.06±0.01	5.12±0.90	0.03±0.00	1.64±0.96	6.89
Min.	0.04	ND	0.06	5.12	0.03	1.64	6.89
Max.	3.27	0.12	20.26	743.44	8.06	30.01	801.43
Overall mean	2.99	0.09	11.11	351.24	4.45	18.55	388.43
SD	0.25	0.01	1.85	24.62	0.75	3.70	
CV	8.36	11.11	16.65	7.01	16.85	19.95	
Dry Season							
Cassava	4.91±0.80	0.25±0.02	13.30±2.26	251.10±45.26	8.89±0.99	21.39±3.48	299.84
Maize	6.77±0.88	0.16±0.01	17.26±2.60	313.89±50.20	11.63±1.02	25.86±3.70	375.57
Plantain	7.38±0.93	0.23±0.02	23.27±3.55	806.73±80.60	13.16±1.23	34.15±3.91	884.92
Yam	5.46±0.85	0.46±0.03	11.50±2.20	498.75±58.25	10.67±1.20	36.12±3.90	562.96
Control	0.07±0.01	ND	0.18±0.03	8.95±2.19	0.07±0.02	1.96±0.63	11.23
Min.	0.07	ND	0.18	8.95	0.07	1.96	11.23
Max.	7.38	0.46	23.27	806.73	13.16	36.12	884.92
Overall mean	4.92	0.28	13.10	375.88	8.88	23.9	426.96
SD	0.58	0.03	2.58	60.63	0.97	3.76	
CV	11.79	10.71	19.69	16.13	10.92	15.73	
FAO/WHO Guideline (2011)	30	3	140	2000	300	300	

Source: Field Survey, (2018)

Table 4: Mean Heavy Elements Staple Crops Sample of Odu'a Farm Establishment for Wet and Dry Seasons (mg/kg)

Foodstuff	As	Cd	Cu	Mn	Pb	Zn	Total metal load
Wet Season							
Cassava	1.83±0.06	0.03±0.00	0.06±0.01	10.30±2.21	0.08±0.01	2.73±0.10	15.03
Maize	1.98±0.07	0.04±0.01	0.14±0.01	15.26±2.36	0.05±0.00	8.95±1.08	26.42
Plantain	2.03±0.09	0.05±0.01	0.26±0.02	21.70±2.50	0.09±0.01	7.17±1.03	31.30
Yam	2.16±0.10	0.02±0.00	0.08±0.01	12.32±2.28	0.04±0.00	10.54±1.23	25.16

Min.	1.83	0.02	0.06	10.30	0.04	2.73	15.03
Max.	2.16	0.05	0.26	21.70	0.09	10.54	31.30
Overall mean	2.00	0.04	0.14	14.89	0.07	7.35	24.49
SD	0.09	0.01	0.01	1.26	0.01	0.61	
CV	4.50	2.50	7.14	8.46	14.29	8.30	
				Dry Season			
Cassava	2.22±0.12	0.06±0.01	0.18±0.03	12.24±2.06	0.16±0.02	3.34±0.18	18.20
Maize	3.12±0.18	0.04±0.00	0.23±0.06	17.38±2.68	0.11±0.01	10.24±1.20	31.12
Plantain	3.91±0.20	0.05±0.01	0.43±0.08	26.14±2.80	0.23±0.03	8.79±1.08	39.55
Yam	3.05±0.14	0.03±0.00	0.13±0.02	15.43±2.17	0.09±0.01	12.04±1.40	30.77
Min.	2.22	0.03	0.13	12.24	0.09	3.34	18.20
Max.	3.91	0.06	0.43	26.14	0.23	12.04	39.55
Overall mean	3.08	0.05	0.24	17.80	0.15	8.60	29.92
SD	0.17	0.01	0.02	1.60	0.01	0.80	
CV	5.52	20	8.33	8.99	6.67	9.30	
FAO/WHO Guideline (2011)	0.50	0.20	40	45	0.30	60	

Source: Field Data, (2018)

Table 5: Mean Bioaccumulation Factor (BF) of Heavy Elements Staple Crops of Odu'a Farm Establishment for Wet and Dry Seasons (mg/kg)

Common Name	Scientific Name	As	Cd	Cu	Mn	Pb	Zn
				Wet Season			
Sweet Cassava	*Manihot esculenta*	0.56±0.02	0.33±0.01	0.006±0.001	0.044±0.002	0.021±0.001	0.164±0.002
Maize	*Zea mays L.*	0.53±0.01	0.67±0.03	0.009±0.002	0.050±0.001	0.008±0.001	0.476±0.005
Plantain	*Musa paradisiaca*	0.51±0.01	0.71±0.05	0.013±0.003	0.029±0.001	0.011±0.002	0.280±0.003
White Yam	*Dioscorea rotundataL.*	0.55±0.02	0.17±0.01	0.010±0.002	0.026±0.001	0.009±0.001	0.350±0.004
Min.		0.51	0.17	0.006	0.026	0.008	0.476
Max.		0.56	0.71	0.013	0.05	0.021	0.164
	Overall mean	0.54	0.47	0.009	0.037	0.012	0.318
SD		0.01	0.01	0.001	0.001	0.002	0.005
CV		3.56	2.13	11.11	2.70	16.67	1.570
				Dry Season			
Sweet Cassava	*Manihot esculenta*	0.452±0.02	0.240±0.01	0.014±0.001	0.049±0.003	0.018±0.003	0.156±0.002
Maize	*Zea mays*	0.461±0.03	0.250±0.02	0.013±0.001	0.055±0.005	0.009±0.002	0.396±0.004
Plantain	*Musa paradisiaca*	0.530±0.02	0.217±0.01	0.018±0.002	0.032±0.002	0.017±0.003	0.257±0.003
White Yam	*Dioscorea rotundata L.*	0.559±0.03	0.065±0.02	0.011±0.001	0.031±0.001	0.008±0.001	0.333±0.002
Min.		0.452	0.065	0.011	0.031	0.008	0.156
Max.		0.559	0.250	0.018	0.055	0.018	0.396
	Overall mean	0.500	0.193	0.014	0.042	0.013	0.286
SD		0.010	0.020	0.001	0.002	0.003	0.007
CV		2.00	10.36	7.14	4.76	23.08	2.45

Source: Field Data, (2018)

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Table 6: Mean Heavy Element Pollution Load Index across the Sampling Points

Site	As	Cd	Cu	Mn	Pb	Zn
			Wet Season			
Cassava	0.47	0.30	0.23	0.28	0.19	0.18
Maize	0.54	0.20	0.36	0.36	0.30	0.20
Plantain	0.57	0.23	0.45	0.87	0.40	0.27
Yam	0.56	0.40	0.20	0.55	0.21	0.32
Min.	0.47	0.20	0.20	0.28	0.19	0.18
Max.	0.57	0.40	0.43	0.87	0.40	0.32
Overall mean	0.54	0.28	0.31	0.52	0.28	0.24
			Dry Season			
Cassava	0.70	0.83	0.30	0.30	0.44	0.23
Maize	0.97	0.53	0.38	0.37	0.58	0.27
Plantain	1.05	0.77	0.52	0.95	0.66	0.36
Yam	0.78	1.53	0.26	0.59	0.53	0.38
Min.	0.70	0.53	0.26	0.30	0.44	0.23
Max.	1.05	1.53	0.52	0.95	0.66	0.38
Overall mean	0.88	0.92	0.37	0.55	0.55	0.31

Source: Field Data, (2018)

Table 7: Mean Daily Element Allowances Estimate (DEA) for Wet and Dry Seasons

Foodstuff	As	Cd	Cu	Mn	Pb	Zn
			Wet Season			
Cassava	2.07E-03	3.40E-05	6.80E-05	1.17E-02	9.07E-05	3.09E-03
Maize	2.24E-03	4.53E-05	1.59E-04	1.74E-02	5.67E-05	1.01E-02
Plantain	2.30E-03	5.67E-05	2.95E-04	2.46E-02	1.02E-04	8.13E-03
Yam	2.45E-03	2.27E-05	9.07E-05	1.40E-02	4.53E-05	1.20E-02
Min.	2.07E-03	2.27E-05	6.80E-05	1.17E-02	4.53E-05	3.09E-03
Max.	2.45E-03	5.67E-05	2.95E-04	2.46E-02	1.02E-04	1.20E-02
Overall mean	2.27E-03	3.97E-05	1.53E-04	1.69E-02	7.37E-05	8.33E-03
			Dry Season			
Cassava	2.52E-03	6.80E-05	2.04E-04	1.39E-02	1.81E-04	3.79E-03
Maize	3.54E-03	4.53E-05	2.61E-04	1.40E-02	1.25E-04	1.16E-02
Plantain	4.43E-03	5.67E-05	4.87E-04	2.96E-02	2.61E-04	9.96E-03
Yam	3.46E-03	3.40E-05	1.47E-04	1.75E-02	1.02E-04	1.37E-02
Min.	2.52E-03	3.40E-05	1.47E-04	1.39E-02	1.02E-04	3.79E-03
Max.	4.43E-03	6.80E-05	4.87E-04	2.96E-02	2.61E-04	1.37E-02
Overall mean	3.49E-03	5.10E-05	2.75E-04	1.88E-02	1.67E-04	9.76E-03

Source: Field Data, (2018)

Table 8: Mean Human Health Risk Index for Specific Heavy Elements Owing to the Intake of varied Staple Crops Raised in the Vicinity of Odu'a Farm Establishment for Wet and Dry Seasons

Foodstuff	As	Cd	Cu	Mn	Pb	Zn
			Wet Season			
Cassava	6.91E-01	3.40E-02	1.70E-03	3.89E-02	2.59E-02	1.03E-02
Maize	7.48E-01	4.53E-02	3.97E-03	5.80E-02	1.62E-02	3.38E-02
Plantain	7.67E-01	5.67E-02	7.37E-03	8.20E-02	2.91E-02	2.71E-02
Yam	8.16E-01	2.27E-02	2.27E-03	4.65E-02	1.30E-02	3.98E-02
Min.	6.91E-01	2.27E-02	1.70E-03	3.89E-02	1.30E-02	1.03E-02
Max.	8.16E-01	5.67E-02	7.37E-03	8.20E-02	2.91E-02	3.98E-02
Overall mean	7.56E-01	3.97E-02	3.83E-03	5.60E-02	2.11E-02	2.78E-02
			Dry Season			
Cassava	8.39E-01	6.80E-02	5.10E-03	4.62E-02	5.18E-02	1.26E-02
Maize	1.18E+00	4.53E-02	6.52E-03	4.62E-02	3.56E-02	3.87E-02
Plantain	1.48E+00	5.67E-02	1.22E-02	9.88E-02	7.45E-02	3.32E-02
Yam	1.15E+00	3.40E-02	3.68E-03	5.83E-02	2.91E-02	4.55E-02
Min.	8.39E-01	3.40E-02	3.68E-03	4.62E-02	2.91E-02	1.26E-02
Max.	1.48E+00	6.80E-02	1.22E-02	9.88E-02	7.45E-02	4.55E-02
Overall mean	1.16E+00	5.10E-02	6.88E-03	6.25E-02	4.73E-02	3.25E-02

Source: Field Data, (2018)

Table 9: Mean Maximum Limit for the Amount of Food Crop that can in Safety be consumed on an Everyday Basis in Area under Study (Wet and Dry Seasons)

Foodstuff	As	Cd	Cu	Mn	Pb	Zn
			Wet Season			
Cassava	1.16E+00	2.35E+01	4.71E+02	2.06E+01	3.09E+01	7.76E+01
Maize	1.07E+00	1.77E+01	2.02E+02	1.39E+01	4.94E+01	2.37E+01
Plantain	1.04E+00	1.41E+01	1.09E+02	9.76E+00	2.75E+01	2.95E+01
Yam	9.80E-01	3.53E+01	3.53E+02	1.72E+01	6.18E+01	2.01E+01
Min.	9.80E-01	1.41E+01	1.09E+02	9.76E+00	2.75E+01	2.01E+01
Max.	1.16E+00	3.53E+01	4.71E+02	2.06E+01	6.18E+01	7.76E+01
Overall mean	1.06E+00	2.27E+01	2.84E+02	1.54E+01	4.24E+01	3.77E+01
			Dry Season			
Cassava	9.54E-01	1.18E+01	1.57E+02	1.73E+01	1.54E+01	6.34E+01
Maize	6.79E-01	1.76E+01	1.23E+02	1.28E+01	2.25E+01	2.07E+01
Plantain	5.42E-01	1.41E+01	6.57E+01	8.10E+00	1.07E+01	2.41E+01
Yam	6.94E-01	2.35E+01	2.17E+02	1.37E+01	2.75E+01	1.76E+01
Min.	5.42E-01	1.18E+01	1.23E+02	8.10E+00	1.07E+01	1.76E+01
Max.	9.54E-01	2.35E+01	6.57E+01	1.73E+01	2.75E+01	6.34E+01
Overall mean	7.17E-01	1.68E+01	1.41E+02	1.30E+01	1.90E+01	3.15E+01

Source: Field Data, (2018)

Table 10: Mean Element Target Hazard Quotient (THQ) Values Springing up from Intake of Four Staple Food Types (Adults) for Wet and Dry Seasons

Foodstuff	As	Cd	Cu	Mn	Pb	Zn	TTHQ
Wet Season							
Cassava	7.80E+00	3.84E-01	1.90E-02	4.39E-01	2.90E-02	1.16E-01	8.79E+00
Maize	8.44E+00	5.11E-01	4.50E-02	6.50E-01	1.80E-02	3.81E-01	1.00E+01
Plantain	8.65E+00	6.39E-01	8.30E-02	9.25E-01	3.30E-02	3.06E-01	1.06E+01
Yam	9.21E+00	2.56E-01	2.60E-02	5.25E-01	1.50E-02	4.49E-01	1.05E+01
TDHQ	3.41E+01	1.79E+00	1.73E-01	2.54E+00	9.50E-02	1.25E+00	9.99E+00
Dry Season							
Cassava	9.46E+00	7.67E-01	5.80E-02	5.22E-01	5.80E-02	1.42E-01	1.10E+01
Maize	1.33E+01	5.11E-01	7.40E-02	7.41E-01	4.00E-02	4.36E-01	1.51E+01
Plantain	1.67E+01	6.39E-01	1.37E-01	1.11E+00	8.40E-02	3.75E-01	1.90E+01
Yam	1.30E+01	3.84E-01	4.20E-02	6.58E-01	3.30E-02	5.13E-01	1.46E+01
TDTHQ	5.24E+01	2.30E+00	3.11E-01	3.04E+00	2.15E-01	1.47E+00	1.49E+01

Source: Field Data, (2018)

The total diet THQ of each element (total diet i.e., the sum of sweet cassava, maize, plantain, and white yam)