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Assessment of Some Heavy Metals and Their Health Risk on Some Vegetables Cultivated in Kwadon Farmlands, Gombe, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors UAA, ABM and BM designed, supervised and reviewed all the drafts of the manuscript. Author FY carried out the research and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The present study was aimed to determine the concentration of heavy metals (Pb, Cr, Mn, Cu and Cd) in waterleaf (*Talinum triangulare*), lettuce (*Lectuca sativa*) and spinach (*Amaranthus hybridus)* from three farmlands.
Study Design and Place of Study: The research was carried out at Kwadon in Yamaltu Deba local Government of Gombe State, Kwadon is located between latitude 10.270ºN and longitude 11.28ºE.
Methodology: The heavy metal concentration in the vegetables was determined by atomic absorption spectrophotometry.
Results: The result showed that the heavy metals concentration in the vegetables across the farms ranges from 2.0–34.4 mg/kg for Mn, 0.025 mg/kg for Cd, 1.7–23.7 mg/kg for Cr, 0.2–1.0% for Cu. The concentration of Mn and Cr are higher than the permissible limit of FAO/WHO in vegetables. To assess the health risk associated with the heavy metals concentration from these vegetables, daily intake of metal (DIM), health risk index (HRI), and target hazard quotient (THQ) were calculated. The daily intake of metals in vegetable species for Mn (0.17–2.81), Cd (2.1), Cu (0.02–0.08), Cr

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(0.1–2.0) are significantly higher than the recommended daily intake of metals and the upper tolerable daily levels.

Conclusion: This result reflects the risk associated with exposure for the period of life expectancy considered and the inhabitant, are highly exposed to the health risk associated with these metals.

Keywords: Amaranthus hybridus; heavy metals; Lectuca sativa; Talinum triangulare.

1. INTRODUCTION

Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms [1]. They, without doubt, are important constituents for plants and humans, when present only in small amount. Some micronutrient elements may also be toxic to both animals and plants at high concentrations. For instance, copper (Cu), chromium (Cr), fluorine (F), molybdenum (Mo), nickel (Ni), selenium (Se) or zinc (Zn). Other trace elements such as arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb) are toxic even at small concentrations [2]. Heavy metals, being persistent and non-biodegradable, can neither be removed by normal cropping nor easily leached by rainwater. They might be transported from soil to groundwaters or may be taken up by plants, including crops. For this reason, the knowledge of metal plant interactions is also important for the safety of the environment [2].

There has been increasing interest in determining heavy metal levels in public food supplied. However, their concentration in bio-available form is not necessarily proportional to the total concentration of the metal [3,4].

The quality of ecosystem becomes altered, when heavy metals find their way, somehow, into it through human and natural activities. These activities are one of the most pressing concerns of urbanization in developing countries like Nigeria, which result in the problem of solid, liquid and toxic waste management. Such waste may be toxic or radioactive [5]. Such waste management problems include heaps of uncontrolled garbage, roadsides littered with refuse, streams blocked with rubbish, prevalence of automobile workshops and service stations, inappropriately disposed toxic waste and disposal sites that constitute a health hazard to residential areas [6,7].

Occurrence of uncontrolled urban sewage farming is a common site in African cities which exposes consumers of such produce to poisoning from heavy metals [7]. Open dumps are a source of various environmental and health hazards. The decomposition of organic materials produces methane, which may cause explosions and produce leachates, which pollute surface and ground water. It ruins the aesthetic quality of the land. Automobile wastes include solvents, paints, hydraulic fluids, lubricants and stripped oil sludge; all results of activities such as battery charging, welding and soldering, automobile body works engine servicing and combustion processes [6].

The soil is the most important component of the environment, but it is the most undervalued, misused and abused one of the earth's resources [8]. Soil contamination has become a serious problem in all industrialized areas of the country. Soil is equally regarded as the ultimate sink for the pollutants discharged into the environment. Most plants and animals depend on the soil as a growth substrate for their sustained growth and development. In many instances, the sustenance of life in the soil matrix is adversely affected by the presence of deleterious substances or contaminants. The entry of the organic and inorganic form of contaminants results from the disposal of industrial effluents [9]. The source of the organic and inorganic elements of the soil of the contaminated area was mainly from the unmindful release of untreated effluent on the ground. The contamination of soils with heavy metals or micronutrients in phytotoxic concentrations generates adverse effects not only on plants but also poses risks to human health.

Afterwards, the consumption of contaminated vegetables constitutes an important route of heavy metal exposure to animals and humans. Abandoned waste dumpsites have been used extensively as fertile grounds for cultivating vegetables, though research has indicated that the vegetables are capable of accumulating high levels of heavy metals from contaminated and polluted soils [10,11]. The present study aims to determine the level of some heavy metals (Pb, Cr, Mn, Cu and Cd) in three (3) vegetable samples, this include; waterleaf (*Talinum triangulare*), lettuce (*Lectuca sativa*) and spinach

(*Amaranthus hybridus)* at three farmlands in Kwadon, Gombe State.

2. MATERIALS AND METHODS

2.1 Study Area

The research was carried out at Kwadon in Yamaltu Deba local Government of Gombe State. Kwadon is located between latitude 10.270ºN and longitude 11.28ºE. The study area is characterized by moderate to high rainfall. The major sources of water supply in the area are surface water including streams and groundwater which is obtained from hand-dug wells and boreholes.

2.2 Sampling/Sample Preparation

Composite samples of fresh Spinach (*Amaranthus hybridus*), water leaf (*Talinum trangulare*) and lettuce (*Lactuca sativa*) were collected from five different farms in separate polyethene bags and labeled. Giving a total of fifteen sample of water leaf (*Talinum triangulare*), spinach (*Amaranthus hybridus*) and lettuce (*Lactuca* *sativa*).

Vegetable samples were washed with tap water in the laboratory, and thereafter with distilled water to remove the dust particle. The water was allowed to drip off and was then sliced into smaller portion. Each sample was ground and stored in a 250 cm^3 screw-capped plastic jar and appropriately labelled.

2.3 Sample Preparation for Heavy Metals Determination

2.0 g of each sample was weighed out into a 250 cm^3 beaker with 10 cm^3 mixture of concentrated sulphuric acid, concentrated nitric acid and concentrated hydrochloric acid in the ratio of 1:1:1 [12]. The flask was heated at 70ºC for 40 minutes and then, increased to 120ºC. The mixture turned black after a while. The digestion was complete when the solution became clear and white fumes appeared. The digest was diluted with 20 cm^3 of distilled water and boiled for 15 minutes. This was then allowed to cool, transferred into 100 cm^3 volumetric and dilute to the mark with distilled water. The sample solution was then filtered through a filter paper into a screw-capped polythene bottle.

The heavy metal concentrations in three vegetables namely waterleaf (*Talinum triangulare*, spinach (*Amaranthus hybridus*) and lettuce (*lactuca sativa*) were determined using atomic absorption spectrophotometer (Buck Scientific 205).

2.4 Health Risk Assessment

The potential health risks of heavy metals concentrations were assessed based on the daily intake of metal (DIM), health risk index (HRI) and the target hazard quotient (THQ). The daily intake of metals (DIM) was calculated to averagely estimate the daily metal loading in to the body system of specified body weight of a consumer. This will inform relative Phyto-availabiltity of metals. This does not take in to cognizance the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal. The estimated daily intake of metal in this study was calculated based on the formula below:

$$DIM = \frac{C_{metal} \times C_{factor} \times C_{food\ intake}}{B_{average\ weight}} \quad (1)$$

Where, C_{metal} is the heavy metal concentration in vegetables (mg/kg), C_{factor} is the conversion factor, $C_{food\ intake}$ is the daily intake of vegetables.

The conversion factor of 0.085 is to convert fresh vegetable weight to dry weight daily vegetable intake of 0.5 g/day while the average body weight used was 65 kg for this study.

The health risk index (HRI) was calculated using the formula below:

$$HRI = \frac{DIM}{RFD} \quad (2)$$

The THQ was calculated using the formula below:

$$THQ = \frac{EF \times ED \times FIR \times C}{RFD \times WAB \times TA} \times 10^{-3} \quad (3)$$

where EF is the exposure frequency (350 days (year), ED is the exposure duration (54 years, equivalent to the average lifetime of the Nigerian population), FIR is the food ingestion rate (vegetable consumption values for southwestern adult Nigeria is 65 g/person/day), C is the metal concentration in the edible parts of vegetable (mg/kg), RFD is the oral reference dose (Pb, Cd, Cu, Cr and Mn values were 0.0035, 0.001, 0.040, 0.300 and 0.020 mg/kg/day, respectively).

WAB is the average body weight (65 kg for adults vegetable consumer in southwestern Nigeria) [1], and TA is the average exposure time for non-carcinogens (ED x 365 days/year). If

THQ value is greater than 1, the exposure is likely to cause obvious adverse effects.

3. RESULTS AND DISCUSSION

The results obtained from the analysis of vegetable samples collected from the various farms are shown in Table 1.

The DIM results in Tables 2, 3 and 4 were compared with the recommended daily intake of metals and the upper tolerable daily intake level (UL) established by the institute of medicine for people between the ages of 19 to 70 years [13]. It is very clear from the table that daily intake of metals in vegetables for Mn (0.17–2.86 mg/kg) is significantly higher than the recommended daily intake of metals. However, DIM of Cu (0.02–0.08 mg/kg) is lower than the recommended daily intake. Similar Daily Metal Intake (DIM) was investigated from 4 popular market in Lagos metropolis using Atomic absorption spectrophotometer (AAS) on 5 heavy metals (Mn, Cd, Pb, Cu, Cr) result revealed a significantly lower value than the recommended daily metal intake.

The recommended maximum limit of cadmium, chromium, lead, copper and manganese for vegetable by FAO and WHO [13] is 0.2, 2.3, 0.3, 40 and 35 (mg/kg) respectively. The Chinese Department of Protective Medicines 1994 has a safe limit for lead in vegetable as 0.2 mg/kg [11]. The recommended limits for various heavy metals vary depending on the food being considered and the country sometimes or the organization. While we find safe limits of heavy metals documented by health sectors in some countries other countries do not have an available document to guide the heavy metal consumption of it citizens. Cd was not detected in the entire sample except in sample (LA) 0.025 mg/kg.

Cadmium is a heavy metal with high toxicity and it is a non-essential element in foods and natural water and it accumulates principally in the kidney and liver [2,14]. Higher values have been previously reported for leafy vegetable cultivated along road sides (0.27 mg/kg) [15]. According to FAO/WHO, [13], the safe limit for Cd consumption in vegetable is 0.2 mg/kg.

The most common sources of cadmium in the vegetable are sewage sludge application, deposition from fossil fuel, Combustion, phosphate fertilizers etc [14]. Cadmium accumulates especially in the kidneys leading to dysfunction of the kidney with increase secretion of e.g. proteins in urine (Proteinuri) and other effects. Pb was not detected in the analyzed sample of vegetables. Lead pollution has been shown to be commensurate with population/ vehicular density [14].

Generally, lead contaminations occur in vegetable grown on contaminated soils, through air deposition or through sewage sludge/wastewater application [15]. Lead poisoning is a global reality, and fortunately is not a very common clinical diagnosis yet in Nigeria except for few occupational exposures [14]. Lead influences the nervous system, slowing down nervous response. This influences learning abilities and behaviour [14].

Table 1. Concentration of heavy metals in the farms (mg/kg)

Sample ID	Mn	Cd	Pb	Cu	Cr
LA	22.4	0.025	ND	ND	12.4
LB	33.5	ND	ND	0.65	18.8
LC	33.6	ND	ND	1.0	23.7
LD	19.6	ND	ND	0.4	5.7
LE	34.4	ND	ND	ND	17.5
SA	17.3	ND	ND	ND	1.7
SB	2.0	ND	ND	ND	ND
SC	19.7	ND	ND	ND	9.1
SD	5.5	ND	ND	ND	1.7
SE	30.7	ND	ND	0.2	20.2
WA	30.3	ND	ND	0.3	13.0
WB	19.7	ND	ND	ND	7.9
WC	33.6	ND	ND	ND	21.7
WD	33.8	ND	ND	ND	14.0
WE	31.2	ND	ND	ND	13.9

**ND-Not detected*

Table 2. Daily Intake rate of heavy metals in lettuce (mg person^{-1} day^{-1})

Vegetable	Mn	Cd	Pb	Cu	Cr
LA	1.90	2.1	-	-	1.05
LB	2.85	-	-	0.05	1.6
LC	2.86	-	-	0.08	2.0
LD	1.7	-	-	0.03	0.5
LE	2.8	-	-	-	1.5

Table 3. Daily Intake rate of heavy metals in spinach (mg person^{-1} day^{-1})

Vegetable	Mn	Cd	Pb	Cu	Cr
SA	1.5	-	-	-	0.1
SB	0.17	-	-	-	-
SC	1.7	-	-	-	0.8
SD	0.5	-	-	-	0.1
SE	2.7	-	-	0.02	1.7

Table 4. Daily intake rate of heavy metals in waterleaf leaf (mg person^{-1} day $^{-1}$)

Vegetable	Mn	Cd	Pb	Cu	Cr
WA	2.6	-	-	0.02	1.1
WB	1.7	-	-	-	0.7
WC	2.6	-	-	-	1.8
WD	2.8	-	-	-	1.2
WE	2.7	-	-	-	1.2
*DI (mg day^{-1} person^{-1})	0.005	0.00	0.00	0.9	-
*UL (mg day^{-1} person^{-1})	0.06	0.064	0.240	10.00	-

**Recommended daily intake (DI) and upper tolerable daily intake (UL) level of heavy metals in vegetables [13]*

Cr ranged between 1.7-23.7 (mg/kg) from all the vegetable samples. Chromium level in the vegetable sampled are not within safe limits (2.3) of consumption. However, the chromium level obtained from this study are higher than the values (0.1 mg/kg chromium) reported by Sharma, et al. [16]. Chromium can be beneficial or harmful depending on the valent state. The hexavalent state of Chromium is harmful [17]. Chromium is known to help maintain normal blood glucose levels by enhancing the effects of insulin. The mostwide spread human effect is chromium allergy caused by exposure to chromium (especially Cr (vi) compounds), and they are assumed to cause cancer.

Cu level of vegetables from these farms ranged between 0.2 to 1.0 (mg/kg) but not detected in samples LE SA, SB, SC, SD, WB, WC, WD and WE. Copper is essential to human life as metalloproteins and function as enzymes. However, critical doses led to health risks such as anaemia, diabetics, inflammation, kidney and liver dysfunction and vitamin deficiency [17]. EU, 2006 [17] suggested safe limits of 40 mg/kg in adults which was significantly higher than the maximum copper level of vegetable in this study. Although the toxicity of copper is rare, its metabolism is enhanced by molybdenum and zinc constituents in the body [11].

The concentration of manganese ranged from 2.0 to 34.35 (mg/kg). The highest concentration of manganese was observed in sample (LE) and the lower concentration of manganese was observed in sample (SB). The values of this study are higher than the 0.005 to 0.06 mg/kg, as reported by Wong, et al. [18]. This could be due to fertilizer application, and animal Dungs. It was observed that all the studied samples were below the FAO/WHO maximum limits.

4. CONCLUSION

This work investigated five heavy metals (Pb, Mn, Cr, Cu, Cd) accumulation in lettuce, spinach ad waterleaf in Kwadon farm land. Daily intake of metal (DIM), health risk index (HRI) and target hazard quotient (THQ) were calculated. The results revealed that the lettuce, spinach and water leaf samples obtained from five farms in Kwadon, Gombe State contained Mn, Cu and Cr in varied concentrations due to the particular type of agricultural practices in the area, such as the use of polluted water for growing of vegetables and the over-application of fertilizers and animal dung. The values obtained in this study for Cr and Mn were higher than the recommended daily intake in vegetables as reported by Tsafe, et al. [19]. Calculated values of health risk index (HRI) for Cu were lower than the WHO maximum limit (ML) in vegetables. Consumption of these vegetables as food may constitute possible health hazards at the time of the study. This result may serve as a base line data for determination of heavy metals in vegetables in the area.

Based on the findings from this research work, it is recommended that:

(I) Other metals should also be investigated.
(II) Farmers should be educated on the problems associated with excessive usage of fertilizer and other chemicals, as well as irrigating the crops with waste and all sorts of polluted water and the needs to grow crop with safe level of heavy metals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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