INCIDENCE OF LEAD AND CADMIUM IN VEGETABLES AND THEIR POTENTIAL HEALTH RISKS TO CONSUMERS IN GASHUA, YOBE, NIGERIA

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INCIDENCE OF LEAD AND CADMIUM IN VEGETABLES AND THEIR POTENTIAL HEALTH RISKS TO CONSUMERS IN GASHUA, YOBE, NIGERIA

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Abstract— Ingestion of vegetables is a major route through which heavy metals enter the human body. A large population in the study area have suffered, died or are still suffering from kidney problems, however, there are no literature on the sources and causes of the disease. This study was therefore aimed at investigating the levels of two heavy metal toxins; Cadmium (Cd) and Lead (Pb) in the vegetables grown/consumed in Gashua and the potential health risks on the consumers. Concentrations of the toxins were determined using Inductively Coupled Plasma Mass Spectrometer [ICP-MS (7500 series)]. The concentrations of Pb ranged from 1.32±0.06 µg/g to 115.9±5.43µg/g and Cd ranged from 0.29±0.65 µg/g to 4.94±0.98 µg/g. The levels of the metals found in this study were compared with values reported for similar vegetables in literature and recommended limits in foods established by the NAFDAC (National Agency for Food, Drug Administration and Control) Nigeria, the European Union (EU) and the World Health Organization/ Food and Agricultural Organization (WHO/FAO). The levels of heavy metals, the target hazard quotient (THQ) and the total hazard index (THI) values suggest health risks to the consumers of the vegetables.

Index Terms—Cadmium, lead, target hazard index, total hazard index.

I. INTRODUCTION

The introduction of heavy metals in to the environment through anthropogenic sources is a serious growing problem throughout the world [1] - [2]. Anthropogenic sources of heavy metal contaminants include domestic, industrial, agricultural, bush burning and the burning of fossil fuels. Some heavy metals such as Fe, Zn, Cu and Se are essential to human beings especially when they are in small quantities. However, heavy metals are non-biodegradable and therefore readily accumulate to toxic levels and affects animals, plants and humans when they exceed certain threshold [3]. Other heavy metals such as Pb, As, Cd and Hg are toxic even at low concentrations and have been linked to a number of health problems.

Lead and Cadmium are known to accumulate in human tissues and hence they are harmful to human health [4], [5]. Apart from occupational exposure, the main pathway of exposure to Lead and Cadmium is through diet especially fruits, vegetables and grains [6]. Their toxicity depends on the total dose absorbed, the route of exposure, the severity of exposure; acute or chronic and the age of the person. Pb is known to induce renal tumors, accumulate in bones, interferes with the metabolism of calcium and high levels of Pb in blood causes learning disabilities, behavioral problems and mental retardation in children [7], [8]. Cadmium can stay in the body for a very long time long term exposure to lower levels of cadmium in air, food, or water leads to a buildup of cadmium in the kidneys and possible kidney disease. Other potential long term effects are lung damage and fragile bones, abdominal pain, liver disease, nerve or brain damage. Studies have shown that cadmium absorption after dietary exposure in humans is relatively low but Cd is highly retained in the kidney and liver in the human body, with a very long biological half-life of up to 30 years [4].

One of the important ways of determining the health risk of any metal pollutant is to identify the potential sources of the risk agents, estimate the amount of risk agents that come into contact with the human-environment boundaries that is to estimate the level of exposure through detection of the routes of exposure to the target organism and quantify the health consequence of the exposure. However, the fact that the contaminant levels exceed the permissible limits set by regulatory agencies such as WHO does not always represent a risk for human health. For this reason the target hazard quotient (THQ) method designed by USEPA for the estimation of potential health risks associated with long term exposure to heavy metals was used to assess health risk in this study [9]. THQ of equal to or greater than one (1≥) indicates a health risk to an exposed population.

Pb and Cd were chosen for risk assessment in this study because of their high toxicities. They are among the toxic heavy metals which are associated with a number of serious health risks to consumers. Therefore in our continuous effort to assess the prevalence of kidney problems in Gashua and environs, particular emphasis is placed on the health risks of ingested Pb and Cd to the consumers using the target hazard quotient (THQ) estimates. This is the first study that has assessed the potential health risks of Pb and Cd exposures via consumption of vegetables grown in the study area. The results of the investigation is expected to initiate further research in the study area in order to explore all the possible sources, routes of exposure and effects of all suspected environmental contaminants to human health.

II. METHODOLOGY

A. Sampling and Sample Preparation

The edible portions of vegetable samples (Lactuca sativa (Lettuce), Hibiscus Sabdariffa Linn (Roselle), Spinacia oleracia (Spinach), Alliumcepa Linn (Onion) and Daucus Carote Linn (Carrot) were collected from Gashua along the banks of River Yobe in North-Eastern Nigeria in March-May 2014. All samples were identified at the Herbarium of the Department of Botany, University of Maiduguri, Nigeria.

Each sample was separately washed with distilled water and dried in an oven at 800C for 48 hours until constant weight was obtained. Dried samples were ground, sieved through 20-mesh sieve to a fine powder and transferred into airtight containers, labeled and stored for further analysis.

B. Sample Decomposition and Digestion

Three replicates (100mg) of each of the dried powdered samples were weighed into a 50ml Teflon vessel and 1ml of concentrated HNO3 was added to each vessel and allowed to stand overnight. H2O2 (2ml) was then added to each vessel and closed to prevent loses. After digestion the vessel holders were removed from the digester, cooled and caps were then removed.

C. Instrumental Analysis

The digested samples were diluted with deionized water and analyzed for Pb and Cd using inductively coupled plasma mass spectrometer [ICP-MS (7500 series)] equipped with G3160A integrated auto sampler. The instrument was calibrated and optimized based on the manufacturer's manual. The operating conditions of the ICP-MS used are shown in Table 1.

D. Daily Vegetable Consumption

Daily vegetable consumption was obtained through a formal survey conducted in the study area. Nine hundred and fifty (950) persons (573 males of 60-70 years age group and 377 females of 55-65 years age group) of approximately 60 kg body weight resident in Gashua were interviewed. The interview questionnaire included detailed questions about various vegetable consumption, how they were consumed (raw or cooked), the amount consumed, frequency of consumption as well as vegetable preparation methods and exposure duration.

Table 1: Operating conditions of the 7500 series ICP-MS used for multi-elements determination

Parameter	Condition
Forward RF power	1380 W
Plasma gas Flow rate	15 l/min
Carrier gas	1.27 l/min
Hydrogen gas flow	1.91/min
Sampler and skimmer cones	Nickel
Integration time	0.100 s
Sampling period	0.620 s
Sprayer temperature	2^0 C
Number & replicates	10

E. Daily Intake of Metals (DIM)

The daily intake of metals depends on both the metal concentration in food and the daily food. The DIM was calculated as follows (equation 1):

DIM = CHM x CDAC ……………………... (1)

Where; CHM is the concentration of the heavy metals in contaminated vegetable and CDAC stands for the daily average consumption of vegetable in the study area (estimated from interview).

F. Estimation of Target Hazard Quotient (THQ)

The methodology for estimation of THQ was based on the following formula (equation 2) [9].

THQ = EF x ED x DIM x 10-3
RfD x Bwt x TA …………....(2)

Where EF is the exposure frequency (365 days/year), ED is the exposure duration (the number of months a person is potentially exposed is used in this calculation as the ED). DIM is the daily intake of metal (mg/day/person), RfD is the oral reference dose for the metal (mg/kg/day) and TA is the average exposure time, it is the product of ED and 365 days/year.
The THQ calculations were made based on the USEPA assumption that that the ingested dose is equal to the absorbed metal contaminant dose and that cooking has no effect on the contaminants.

G. Data Analysis

The data were statistically analyzed using Analyse-it version 3.0 statistical software for Microsoft Excel. Summary results are presented as mean ± standard deviation. Statistical significance was computed using pair samples t-test with a significance level of $p< 0.05$.

III. RESULTS AND DISCUSSION

A. Heavy Metal Concentrations in the Vegetables

The concentrations of Pb and Cd in the tested vegetables are shown in Table 2.

Table 2: Mean (±SD) concentrations (μg/g) of Pb and Cd in the tested vegetables

Vegetable	Heavy Metal concentrations	
	Pb	Cd
Lactuca sativa	115.9±5.43	4.94±0.98
Spinacia oleracia	1.78±0.59	1.95±0.68
Hibiscus S. Linn	1.32±0.06	4.28±0.99
Daucus C. Linn	1.49±0.86	0.29±0.65
Alliumcepa Linn	3.70±0.76	0.86±0.76

Pb and Cd were detected in all the tested vegetable samples but the highest mean concentrations of the heavy metals were detected in Lactuca sativa. The levels of Pb in all the vegetables were higher than the maximum permissible limits of 0.30 μg/g stipulated by the EU [10], but only lettuce exceeded the WHO/FAO limits for Pb (5.0 μg/g) [11]. However, the concentrations of Cd in all the tested vegetables were higher than the safe limits (0.2 μg/g) for human consumption set by the EU, WHO/FAO and NAFDAC [12]. Variations in levels of the tested heavy metals may be due to the differences in the absorption capacities of the vegetables for the heavy metals. Though high levels of heavy metals in vegetables were reported [13], but the level of some metals such as Pb in lettuce obtained in this study was much higher than levels reported in wastewater irrigated vegetables [14].

The ban on the importation and usage of leaded fuel in Nigeria and the absence of industries in the area of research indicates that industrial activities and leaded fuel are not the likely sources of Pb. Therefore, waste disposal, the use of fertilizers and pesticides in agriculture may be responsible for the contamination with Pb and Cd. Furthermore, desert storm is a characteristic feature of the area of study, therefore atmospheric deposition from such storms and agricultural depositions may also play important roles in the enrichment of the tested vegetables from Pb and/or Cd. Lead and Cadmium exposure have been shown to cause severe skeletal damage, renal tubular damage and may also give rise to kidney damage [2], [15].

Although exposure to lead causes serious health effects in adults, especially pregnant women, the toxicity of lead is greatly increased in children. Prenatal exposure to Pb can affect the fetus through the placenta and in utero exposure to Pb can lead to miscarriage, low birth weight or premature birth [8].

The International Agency for Research on Cancer (IARC) classified cadmium and lead as human carcinogen [16]. Studies have also shown that long term exposure to lower levels of Cd can lead to a buildup of cadmium in the kidneys and can cause irreversible damage to the proximal tubules of each nephron of the kidney leading to kidney failure [17], [18]. Other long term health effects include lung damage, bronchitis, fragile bones, anemia, discoloration of teeth and pulmonary edema.

B. Risk Assessment

C. Target Hazard Quotient (THQ)

THQ provides an excellent indication of the risk levels due to exposure to pollutants and it has been proven to be very reliable [9], [18]. The daily ingestion rates of the vegetables (g/person/day) by the inhabitants (males and females) were estimated based on the results of the interview which was used in calculating the daily intake of metals using equation 1. The results obtained were used to estimate the THQ using equation 2. The oral reference doses used in the calculations of the THQ were based on 0.004 μg/g for Pb and 0.001 μg/g for Cd as per USEPA regulations [9].

The THQ results showed that the THQ values for Pb and Cd in Lactuca sativa for both males and females were greater than 1 (Fig. 1). In fact the THQ for Pb in Lactuca sativa were many times higher than the recommended value of less than 1 (Fig. 1).

The high THQ values for Pb and Cd in Lactuca sativa indicates that the inhabitants of Gashua are already experiencing the adverse health effects. This fact was confirmed by University of Maiduguri Teaching Hospital Kidney center where records showed that a large number of their patients who either suffered from kidney problems or are receiving treatment came from our study area (Gashua). Similar high THQ values of 17 for As were reported from consumption of fish and 49.9 for Cu from consumption of oyster [19]. THQ values of 1.01, 1.37, and 2.58 were also recorded for Cd from consumption of Alliumcepa Linn, Spinacia oleracia and Hibiscus Sabdariffa respectively, suggesting further potential health risks for the consumers of the study area (Fig. 2).

The additive or interactive effects can be estimated by assessing the potential health risk posed by all the metals. This can be achieved by calculating the total hazard index (THI) that is the sum of individual metal THQ's for all the tested vegetables as shown in Fig. 3. The THI used in this study is a modified form of risk index derived from the total hazard quotient (THQ) [20] and the hazard index (HI) used by Zhuang [21].

The THI results show high prevalence of the tested metals especially Pb and Cd in the combined THQ for all the vegetables. The high values may be attributed to the major risk contribution from Pb and Cd due to consumption of Lactuca sativa and were highly significant. The fact that dietary intake of food may constitute a major source of long term accumulation of heavy metals in the body and the effects become apparent after several years of exposure, indicate that the investigated vegetables are contaminated. The results further confirm that the inhabitants in the study area are already experiencing adverse health problems or will likely be affected in the future from excessive buildup of metals in the food chain. The THQ values for both investigated metals were higher in female consumers of the tested vegetables compared to the males. Similarly the THI values show higher health risks in females (42% Pb; 12% Cd) than males (36% Pb; 10% Cd). Studies have shown that women have lower daily Cd and Pb intakes due to lower energy consumption than men [17]. The reverse situation observed in this study might be due to differences in dietary habits. The women tend to consume more of the tested vegetables especially raw Lettuce compared to men as confirmed from the interview conducted.

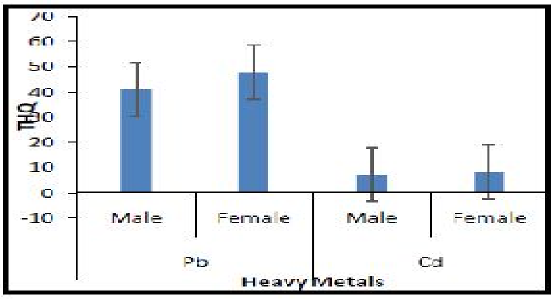

Fig. 1:Target Hazard Quotient (THQ) for Pb and Cd due to Consumption of Lactuca sativa

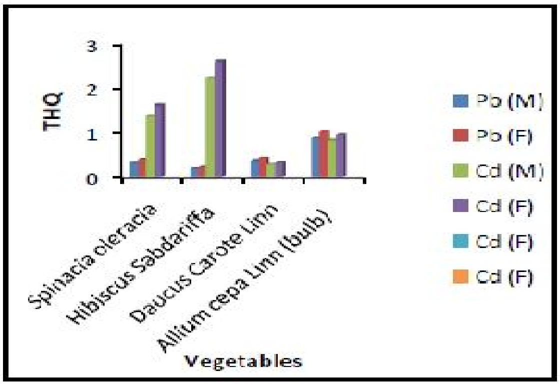

Fig. 2: Target Hazard Quotient (THQ) for Pb and Cd due to Consumption of other Investigated Vegetables (M-Male, F-Female)

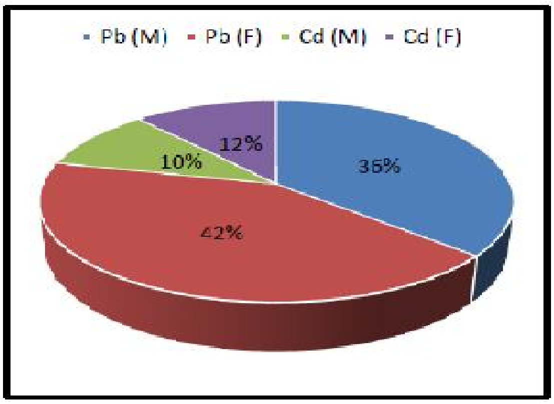

Fig. 3: Total Hazard Index (THI) due to Consumption of all Investigated Vegetables (M-Male, F-Female)

CONCLUSION

The concentrations of Pb and Cd in the common vegetables grown and consumed by the inhabitants (Lactuca sativa (Lettuce), Hibiscus Sabdariffa Linn (Roselle), Spinacia oleracia (Spinach), Alliumcepa Linn (Onion) and DaucusCarote Linn (Carrot)) were investigated. Among the tested vegetables, Lactuca sativa showed high accumulation tendency towards Pb. The levels of Pb and Cd in most of the tested vegetables were higher than the recommended limits for human consumption. The potential health risks posed by the metals to the inhabitants through consumption of the vegetables were estimated using the target hazard quotient (THQ) for risks caused by consumption of each vegetable and the total hazard index (THI) for risks caused by the consumption of all the investigated vegetables. The study showed appreciable levels of Cd and Pb in the vegetables, which gave high THQ values suggesting potential hazardous exposure over a life time for consumers. The high THQ values estimated for Pb and Cd in Lactuca sativa and high THI also signify that the inhabitants in the study area are already experiencing adverse health problems. This may be true because the people of the area have been suffering from kidney diseases for over three decades which might be due to body accumulation of toxic heavy metals such as Cd through vegetables and other sources. Reports from the Kidney Center, University of Maiduguri Teaching Hospital, Maiduguri, Borno State and the Federal Medical Center Nguru, Yobe State, also confirmed that a high percentage of the patients with kidney problems who visited their hospitals in the last two to three decades came from the area of study (Gashua), indicating a possible link to our findings.

ACKNOWLEDGEMENTS

The authors are grateful to Idris Baba of the research Laboratory, Yobe State University for his assistance. We thank the residents of Gashua and Gashua Fadama farmers for their assistance throughout the period of the research.

REFERENCES

[1] C. Qu, Z. Ma, J. Yang, Y. Lie, J. Bi and L. Huang, "Human Exposure Pathways of Heavy Metal in a Lead-Zinc Mining Area", In: E Asrari (ed.), Heavy Metal Contamination of Water and Soil: Analysis, assessment, and remediation strategies, Apple Academic Press, Oakville, Ontario, pp. 129–156, 2014.

[2] P.B. Tchounwou, C.G. Yedjou and A.K. Patlolla, "Heavy metal toxicity and the environment", EXS, vol. 101, pp. 133-64, 2012.

[3] USEPA (United States Environmental Protection Agency), "Highlights of the Exposure Factors Handbook (Final Report)", U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/030, 2011.

[4] ATSDR (Agency for Toxic Substances and Diseases Registry), "Toxicological Profile for Cadmium", Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 2012.

[5] ATSDR (Agency for Toxic Substances and Diseases Registry), "Toxicological Profile for Lead", Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 2012.

[6] Q.S. Li, Y. Chen , H.B. Fu, Z.H. Cui and L. Shi L, "Health risk of heavy metals in food crops grown on reclaimed tidal flat

soil in the Pearl River Estuary, China", J Hazard Mat. 2012, vol. 227–228, pp. 148–154.

[7] WHO (World Health Organization), "Stop lead poisoning in children",

[8] http://www/who.int/mediacentre/news/notes/2013/lead 20131018/en/ viewed 10th August, 2016.

[9] C. Kennedy, R. Lordo and M.S. Sucosky, "Primary prevention of lead poisoning in children: a cross-sectional study to evaluate state specific lead-based paint risk reduction laws in preventing lead poisoning in children", Environ Health, vol. 13, pp. 93, 2014.

[10] USEPA (United States Environmental Protection Agency),"Integrated Risk Information System-database" Philadelphia PA; Washington, DC, 2007.

[11] EU (European Union), "Commission Regulation No 420/2011 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs", 2011.

[12] FAO/WHO (Food and Agricultural Organization/World Health Organization), "Codex Alimentarius Commission (FAO/WHO), Food additives and contaminants", Joint FAO/WHO Food Standards Programme, ALINORM 01/12A:1-2892001, 2001.

[13] NAFDAC (National Agency for Food, Drug Administration and Control). Abuja, 2013.

[14] M.H. Givianrad, T. Sadeghi, K. Larijani and H. SE, "Determination of cadmium and lead in Lettuce, Mint and Leek cultivated in different sites of Southern Tehran", Food Tech Nut, vol. 8, no. 2, pp. 38-44, 2011.

[15] C. Luo, C, Liu, Y. Wang, X. Liu, F. Li and G. Zhang, "Heavy metal contamination in soils and vegetables near an e-waste processing site, South China", J Hazard Mater, vol. 186, no.11, pp. 481–90, 2011.

[16] L. Barregard and C.G. Elinder, "Renal effects from exposure to metals", In: Handbook on the Toxicology of Metals, Nordberg GF, Fowler BA, Nordberg M. (Eds), Academic Press, Amsterdam, vol 1, pp.333., 2014.

[17] IARC (International Agency for Research on Cancer), "Cadmium and cadmium compounds", In: Beryllium, cadmium, mercury and exposure in the glass manufacturing industry. IARC Monographs on the evaluation of carcinogenic risks to humans, vol. 58, pp. 119-237, 1993.

[18] K. Ji, J. Kim, M. Lee, S. Park and H.J. Kwon, "Assessment of exposure to heavy metals and health risks among residents near abandoned metal mines in Goseong", Korea. Environ Pollution, vol. 178, pp. 322–328, 2013.

[19] P. Zhuang, Z.A. Li, M.B. McBride and B. Zou, "Health risk assessment for consumption of fish originating from ponds near Dabaoshan mine, South China", Environ Sci Poll, vol.20 no. 8, pp. 5844–5854, 2013.

[20] B.C. Han, W.L. Jeng, R.Y. Chen, G. T. Fang, T. C. Hung, R.J. Tseng, "Estimation of target hazard quotients and potential health risks for metals by consumption of seafood in Taiwan" Arch. Environ. Contam. Toxicol, vol. 35, pp. 711–720, 1998.

[21] P. Zhuang , H. Lu, Z. Li, B. Zou and M.B. McBride, "Multiple Exposure and Effects Assessment of Heavy Metals in the Population near Mining Area in South China", PLoS ONE, vol. 9, no. 4, pp. e94484, 2014.

[22] P, N. . Zhuang, B.M. Murray, X. Hanping Li, Z. Li, "Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China Sci", Total Environ, vol. 407, pp. 1551-1561, 2004.

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