

Heavy Metals Contaminating Vegetables in Nigerian Markets, Sources and Health Implications: A Search Perspective View

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ABSTRACT

Vegetables are common fresh foods available in any ordinary Nigerian market both in the cities, towns and villages and are widely consumed by all. The growing human activities put the quality of these vegetables in doubt especially from Heavy Metals (HMs) contamination with potential toxicity of these HMs in humans from ingestion of vegetables. This perspective view paper looked at HMs contamination of soils and vegetables consumed by Nigerians. Literature search was carried out on HMs contamination of soils and vegetables on electronic data bases of scientific articles such as google scholar, PubMed, Science Direct, Elsevier and SciElo. Data obtained was analysed qualitatively by taking note of new information captured in each article. There was heavy contamination of soils, and vegetables sold across the Nigerian markets and the HMs found to contaminate vegetables were: arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), chromium (Cr), cobalt (Co), copper (Cu), magnesium (Mg), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn). Most of the contaminations were from anthropogenic sources and HMs accumulation and toxicity in humans could cause several diseases such as hypertension, diabetes mellitus, rheumatoid arthritis, Alzheimer's disease, and several cancers among others. There should be a regular screening of farm lands and vegetables from risk prone farm lands to detect early HMs toxicity for prompt interventions.

Keyword: Health implications, Heavy Metals, Anthropogenic sources, Soil, Contamination, Vegetables

INTRODUCTION

Vegetables are parts of plants that are eaten by both man and animals and it include plant components such as leaves, flowers, stem, roots, fruits, or seeds.

Vegetables contain several minerals that are essential for the normal functioning of the body and these include: Calcium (Ca), Magnesium (Mg), Copper (Cu),



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Phosphorus (P), Sodium (Na), Potassium (K) and Iron (Fe). They also contain dietary fibres, sugars, proteins, vitamins A, B3, B9, C, E and K. Vegetables perform vital functions in the body such as: maintenance of healthy bones and teeth; decreases risks of coronary heart diseases and spinal cord defects in fetuses; promotion of healthy blood formation, normal and stable cell functions; development of healthy bones, teeth and gums; promotion of good eyesight and prevention of infections; and promotion of quick wound healing¹⁻³.

Chronic deficiencies of vegetables could lead to various diseases such as: scurvy, night blindness, bleeding disorders, heart failure, constipation and indigestion, cancers, dyslipidaemias, diabetes mellitus, hypertension and depression. Vegetables also serve as free radical scavengers, eliminating accumulation of toxic wastes from tissues and organs hence slowing the aging process^{4,5}.

Heavy metals are generally referred to as those metals which possess specific density of more than 5g/cm³ and adversely affect the environment and living organisms. Some of their anthropogenic sources include: smelting of ores; factory chimneys; soil wastes; exhausts from automobiles; additives in gasoline and pigments; industrial wastes; fertilizers and pesticides; metal plating and finishing operations⁶.

Heavy metal contamination of vegetables has been of increasing concern and it includes metals such as: Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn) which could emanate from various sources of the environment^{7,8}. Sources of these HMs could be both anthropogenic and natural. Continuous ingestion and accumulation of heavy metals in vegetables could lead to injury to the body systems leading to various diseases⁹⁻¹¹. This review paper looks at the sources of heavy metal contamination of vegetables found in the Nigerian markets, the potential impacts on health and seeks to offer suggestions on how to reduce contamination levels.

Instrument for data collection

The study was based on a systematic review of articles on contamination of vegetables in Nigeria and the health effects in the past up to December 2021. The search was carried out on online electronic databases such as Google scholar, PubMed, SciElo, Elsevier, and Science Direct. The key words used in the search include: Heavy metals and Vegetables, Contamination with Heavy metals, Vegetables, Nigerian Markets, Contaminated Fruits with Heavy Metals in Nigerian Markets, Contaminated foods with Heavy Metals in Nigerian Markets. Metal-Analysis, Articles from cross-sectional studies written on both primary and secondary data were considered as well as review articles which provided relevant information were captured. Either the abstract or the whole article that met the selection criteria was read and relevant information extracted. Newer information in articles not captured elsewhere was given attention as well as repeated findings in others to establish the degree of strength of probability or otherwise of the findings. Data obtained was analysed qualitatively by taking notes of various elements detected in vegetables across the country as well as any associated social or perceived health hazards.

Heavy metals accumulation in vegetables across Nigeria

In Ilorin, the Kwara state capital, a study on the Heavy Metals (HMs) concentration in farm soils growing vegetables was carried out using Atomic Absorption Spectrophotometry method. The study found that HMs in the soil were in the range of: Cd (0.00-4.67), Cu (1.71-30.08) and Pb (1.29-82.00) mg/kg with pH range of 6.62-9.33 and pollution index range of Cd (0.00-2.90), Cu (0.86- 11.72) and Pb (0.70-14.30). The soil was found to be most polluted with Cd and Pb¹². In another similar study in the same locality, it was found that HMs were generally found to be elevated in vegetables however, the estimated daily intakes (EDI) of Cu and Pb through consumption of these vegetables

were found to be far below the recommended tolerable daily intakes (TDI) and the hazard quotient (HQ) values were also within the safe zone for the adult population. The study found Cd to contribute to high hazard index (HHI) as the EDI for the vegetables was found to be several folds higher than the TDI¹³. Another similar study in same Ilorin found a strong correlation between high levels of HMs in vegetables and: season in which vegetables were harvested as HMs were higher in dry season; low water quality; prolonged period of rainless period; and nearness of the vegetable gardens to very busy highways and roads with heavy traffic flows. It was also found that *Amaranthus hybridus* appeared to have higher propensity for HMs accumulations compared to *Corchorus olitorius mannii*¹⁴. In a similar study on phytoavailability and fractionation of HMs in vegetable farm soils also in Ilorin found that: the altered pH of the farm soils (range 6.62±0.04 to 7.18±0.03) had the potential of causing oxidation of Cd and Pb which were found to be very high into other more toxic forms¹⁵. Other studies carried out in Ilorin and its environs also documented similar HMs contamination of soils and vegetables with a suggestion that farming activities should not take place at 10 metres close to the roads to reduce soil and crops contamination with HMs¹⁶⁻²⁰.

In a study along Makera drain in Kaduna state, it was found that different sites of soil samples collection had varying proportions of HMs soil pollution but the most heavily polluted HMs among the vegetables was with mean concentrations respectively: Cd (0.013-2.12), Cr (0.058-2.80) and Fe (331.6-1252)²¹. Also, vegetable samples collected from Kasuwan Mata market showed elevated levels of Pb, Cu, Zn, Ni, Mn, Cr and Cd though within tolerable limits but with higher levels in November compared to the months of August to October. There were however strong concerns about accumulation of these HMs to toxic levels upon prolonged consumption of these vegetables²². In another state-wide study involving 20 different sites on

soils and vegetable levels of HMs, it was found that the soil levels of these HMs were: Pb; 134+94 (18.2 441), Cd; 3.2+1.6 (1.8 9.1), Ni; 36+40 (13.5 195) and Cr; 58+39 (31.8 212), respectively, and that of vegetable samples were Pb; 19.2+4.9 (1.6 67.2), Cd; 3.2+1.0 (1.0 12.5), Ni; 9.6+2.5 (1.6 23.1) and Cr; 14.1+2.3 (2.8 32.4,) respectively for the three vegetables analysed: spinach (*Amaranthus hybridus*), jute mallow (*Corchorus olitorius*) and tomato (*Lycopersicon esculentum*). Pollution load index was generally found to be moderate and rate of soil uptake of HMs by vegetables was found to be: Cd > Ni > Cr > Pb with the levels of all the HMs in the soils being higher than the FAO/WHO recommended maximum²³. Also, another study on health risk assessment of vegetables on Bashama, Danmani and Danbushiya farms within Kaduna metropolis showed that all the HMs studied were within hazard quotient limit of less than 1 except for Cd, and for the hazard index, all the metals surpassed the limit of 1, an evidence of their potential toxicity²⁴. Further, an analysis of HMs in 7 pumpkin leaves (*Telferia occidentalis*), 6 bitter leaves (*Vernonia amygdalina*) showed all the other heavy metals to be within tolerable range except Pb which was above upper limit. The mean concentration of HMs in Pumpkin leaves was in decreasing order as: Pb > Zn > Cr > Cu > Cd respectively, and for bitter leaf, it was in this order of decreasing concentration: Zn, Pb, Cr, Cu and Cd respectively²⁵. In a related study on cereals to assess the load of HMs concentrations, it was found that the levels of all the HMs analysed were however far below the maximum recommended by FAO/WHO and hence safe for human consumption as well as veritable sources of trace elements²⁶. In the Tudun Wada area of Kaduna state, levels of HMs contamination in selected vegetables such as: Spinach (*Amarantus spp*), Lettuce (*Lactuca sativa L.*); Tomato (*Lycopersicum esculentum*), Ball (Red) pepper (*Capsicum annum Linn*) and Onion (*Allium cep L.*) was carried out. Findings showed that Cd and Cr were undetected however, there was contamination of other HMs in the

order of $Fe > Zn > Cu > Pb$ but the concentration levels were below the maximum threshold approved by FAO/WHO²⁷.

Findings from other related studies across Kaduna and surroundings showed varied levels of HMs contamination from levels above the FAO/WHO maximum threshold to levels below the threshold as well as some HMs undetected in other instances. Contamination of vegetables, soils and water was however a common finding²⁸⁻³³.

In Rivers state, a study on the level of HMs contamination of edible tomatoes (*Lycopersicon esculentum*) in selected markets across Port Harcourt city showed absence of Cd and Pb with no carcinogenic potential while estimated daily intake of other HMs was far below the maximum threshold recommended. It was also found that ingestion of tomatoes containing chromium in the study area was within permissible predicted lifetime risks of carcinogens (10^{-6} – 10^{-4}); the authors recommended regular assay of these HMs so as to catch any spike in toxicity³⁴. In Egbelu-Minita community, East-West Road of Port Harcourt, an analysis of HMs concentration in a reclaimed dump site (Borrow-pit) showed HMs contaminations levels to be in the order of: $Zn > Cu > Pb$; 9.8 ± 1.25 , 0.23 ± 0.50 , 0.04 ± 0.07 mg/kg, respectively; also, the maize grown in the same reclaimed dump site showed high levels of these HMs though within tolerable human consumption levels³⁵. At Rumuolumeni dump site in the same city, HMs contamination of the soil along with vegetables grown there was equally observed³⁶. Also, an analysis of the levels of HMs pollution at solid wastes dump sites in Port Harcourt and environs showed high levels of HMs in the order of $Zn > Cu > Pb$ establishing the contribution of solid wastes in soil and vegetation contamination with HMs³⁷. An analysis of HMs content of Bitter leaf (*Vernonia amygdalina*) grown along busy traffic routes in Port Harcourt compared to those grown far away also showed HMs concentration in the leaves of those grown close to the roads with potential for accumulated heavy metal

toxicity³⁸. Furthermore, an analysis of HMs concentrations in the soils and pawpaw (*Carica papaya* Linn) grown on automobile workshops in Port Harcourt metropolis showed high levels of HMs in the order of $Pb > Cu > Hg > Zn > Cd$ in both the soil and the plant. And the C. papaya fruit had the highest concentrations of Pb (51.4 ± 14.1 mg/kg) and Zn (26.4 ± 1.9 mg/kg), levels far above tolerable limits of human consumption by the WHO/FAO³⁹.

Among four of the most consumed vegetables in the southern part of the country [fluted pumpkin (*Telfairia occidentalis*), Bitter leaf (*Vernonia amygdalina*), Scent leaf (*Ocimum gratissimum*) and Water leaf (*Talinum triangulare*)]; their HMs (Cr, Mn, Ni, Co, Cu, Cd, Zn and Pb) concentrations were also analysed from a farm in Port Harcourt metropolis. Findings showed that their concentrations in mg/kg were: Cr (1.50-10.25), Mn (9.75-62.75), Ni (15.75-19.25), Co (1.75-3.00), Cu (7.75-11.00), Cd (1.25-1.50), Zn (79.75-186.95) and Pb (6.25-8.00), levels generally far above the internationally approved maximum safety levels. The carcinogenic metals Ni, Cd and Pb were high in the vegetables from this farm which was located close to a busy highway⁴⁰. HMs contamination of vegetables sold in Port Harcourt and her environs has been extensively documented with many of the authors expressing concern over a prolonged period of ingestion and potential risks of poisoning⁴¹⁻⁴⁶.

In plateau state, HMs contamination of vegetables sold at her markets is also a common occurrence. A study on HMs (As, Cd, Hg, Pb, Sn, Cr and Cu) contamination of six cruciferous vegetables: white cabbage (*Brassica oleracea* var. *capitata*); broccoli (*Brassica oleracea* var. *italica*); cauliflower (*Brassica oleracea* var. *botrytis*); red cabbage (*Brassica oleracea* var. *rubra*); curly kale (*Brassica oleracea* var. *sabellica*); and radish (*Raphanus sativus*) showed their various concentrations to be: As 0.552-3.010 mg/kg; Cd 0.009-0.064 mg/kg; Hg 0.001-0.057 mg/kg; Pb 0.331-0.451 mg/kg; Cr 0.251-0.529 mg/kg; and Cu 1.892-3.510 mg/kg. The most heavily

contaminated metals were Cr, Pb, As, and Cd while there was no evidence of Hg, Cu and Sn in these vegetables obtained from Farin Gada, Vom, Anglo-Jos and Foron irrigation fields⁴⁷. Road side soils in Jos metropolis were analysed in another study for the levels of Pb, Zn, Mn, Cu, Ni, Cd, Co and Fe in order to assess the potential environmental impacts of automobile emissions on soil. It was found that HMs accumulation was in this decreasing order Fe > Zn > Mn > Pb > Cd > Cu and were all below the approved maximum threshold while Co and Ni were undetectable⁴⁸. In another related study accumulation of Cd, Fe and Pb were found to be 10, 20, 40 times respectively the FAO/WHO recommended levels in the vegetables studied and these HMs were said to originate from atmospheric dust, irrigation water and refuse dumps⁴⁹. Also, an assessment of HMs in cabbage, lettuce, spinach, turnip, carrot, radish, beet root, tomato and spring onions grown on some vegetable gardens in Jos showed that As, Cd, Co, Cr, Ni, Pb, Cu, Zn, Sb and Se were all elevated in these greens. And that the HRI of As, Pb and Zn were >1 indicating high toxicity and hence unsafe for human consumption⁵⁰.

A comparative analysis of HMs contamination of vegetables: *Spinacia oleracea* (spinach), *Lactuca sati* (lettuce), *Cucumis sativus* (cucumber), *Daucus car* (carrot) and *Brassica oleracea* (cabbage) from four local government areas in Plateau state (Jos North, Jos South, Bassa and Barkin Ladi) showed excess concentrations of Cd, Pb, Fe, Cr and Mn. There was spectacular high Fe toxicity and lettuce and spinach were found to be good bioaccumulators of these metals⁵¹. Other related studies on soil, vegetables, fruits and cereals have similar documented reports on HMs accumulation and contaminations in varying proportions⁵²⁻⁵⁷.

In Lagos state, a study on 162 samples collected from fruits and leafy vegetables sold on the streets of Lagos were analysed for the presence of HMs showed high levels of Cd, Zn, Cu, Co, and Ni though within tolerable

limits while Cr, Ar and Hg were undetected in any of the samples. They then advised farmers, sellers and consumers of vegetables in Lagos on measures to mitigate the impact of this toxicity on human health⁵⁸. In another study, the level of HMs in *Amaranthus viridis* (Green Amaranth) grown at a distance of 5, 10, 15 and 20 metres away from roads with heavy traffic in Lagos was analysed along with the soils. The study found high levels of Pb and Cd in the soils with the levels of concentrations inversely proportional to the distance from the roads. While the high soil contents were still within acceptable levels the concentrations in the soils were exceedingly higher than the acceptable tolerable limits indicating an inherent capacity of the plant to concentrate these HMs in its tissues⁵⁹. In another study on HMs contamination of five vegetables sold on the streets of Lagos showed heavy contamination with Cu, Pb and Zn but the concentrations were within approved tolerable limits. The study found a significant difference between the levels of contaminations among the water-washed and unwashed vegetables in the urban areas which were both much higher compared to that in the remote areas; and water-washing reduced considerably the concentration of HMs in the vegetables⁶⁰. Findings of⁶¹

⁶⁷ in different parts of Lagos have all corroborated the above findings. In Kano state around the industrial area of Chillawa, HMs in both the soils and the potato, onion, tomato, lettuce and spinach were found to be high, and Cd had the highest rate of accumulation in the vegetables while Pb was lowest. The study found daily intake of HMs in the community to be in the order of Cr > Cd > Pb > Zn⁶⁸. In another study carried out on irrigation water, vegetables farm soils and vegetables showed that HMs accumulation in all the irrigation waters were far above the recommended maximum threshold of 0.5 µg/ml, 0.2 µg/ml, 0.2 µg/ml and 0.017 µg/ml for Fe, Zn, Mn and Cu respectively. Also, there was heavy contamination of HMs in all the soils and vegetables analysed⁶⁹. HMs accumulation in soils and vegetables cultivated from

industrial effluent water irrigation activity at Sharada, Kwakwachi and Jakara dams in Kano metropolis also showed HMs accumulations in spinach, okra, onions and tomatoes grown in such fields. There was a statistically significant difference in HMs concentrations compared with soils and vegetables cultivated at distant sites⁷⁰. Findings by other researchers in Kano on levels of soil and vegetables contamination with HMs were essentially similar⁷¹⁻⁷⁶. Findings on HMs contamination of soils and vegetables from Sokoto^{77,78}, Maiduguri^{79,80}, Calabar^{81,82}, Benin-city^{83,84}, Ibadan^{85,86}, and Abuja^{87,88} have differently revealed HMs contaminations of soils and vegetables in the respective cities.

DISCUSSION

Heavy metals implicated with contamination of soils and vegetables were Cd, Zn, Cu, Co, Mn, Fe, Hg As, Sn, Cr, Sb, and Ni across Nigeria and this study has presented a picture of HMs contamination of soils within and around cities as well as vegetables and crops harvested from Nigerian markets. The levels of these HMs in several cases are however still within the approved FAO/WHO approved limits while the levels are already above these limits in others. This raises concern about the toxic effects of HMs in the body as continuous ingestion of greens whose HMs accumulation is still within tolerable range raises danger of potential toxicity in events of prolonged and cumulative ingestion over time. Sources of HMs found in soils and vegetables include anthropogenic activities such as: land reclamation from refuse dump sites, using heavily polluted effluent waters from factories for irrigation purposes, emissions from vehicles to environments close to busy roads, agricultural activities involving use of HMs such as pesticides, other industrial emissions which may be influenced by direction of winds and water currents.^{89,90} Cutting down on the use of fossil fuel in vehicles and reducing the number of vehicles on roads are options to

consider to reduce HMs accumulation in farm soils close to roads with heavy vehicular loads and eventual reduction in vegetables planted there. Also, planting vegetables and food crops on soils less than 20 metres from busy roads and high ways should be discouraged as the levels of HMs in such soils is generally high. More enlightenment and awareness should be created to discourage farming close to roads as such soils often appear more fertile, with better proximity and hence more tempting compared to distant sites⁹¹.

While many studies reported high HMs concentrations in soils and vegetables studied, they were however within tolerable limits. This should not be seen as a normal trend but a possible transition stage of these elemental accumulations and is bound to increase over time. We also agree with the views of researchers who recommended a regular screening of these soils and vegetables to detect abnormal accumulation early, and also to deploy measures to halt or slow down the process of accumulation.

HMs toxicity in human tissues is associated with several diseases and these include: Alzheimer's disease and Multiple sclerosis which have been closely linked with high levels of Pb, Sn and Hg in the blood of affected patients⁹²; Cardiovascular diseases (Hypertension, Stroke) is associated with arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg), and some of the essential trace metals such as chromium (Cr), cobalt (Co), copper (Cu), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), tungsten (W), vanadium (V), and zinc (Zn) with As causing hyperglycaemia and dyslipidaemia leading to diabetes mellitus and may also cause endocrine disruption⁹³; Neurodegenerative diseases associated with As, Pb and Hg⁹⁴. Other diseases include: chronic kidney disease believed to be associated with As, Cd, lead and Cr from prolonged ingestion in drinking water⁹⁵; Mn and Se associated with Amyotrophic Lateral Sclerosis (ALS)⁹⁶; Rheumatoid arthritis has been found to be closely linked with systemic toxicity of mercury sulphide, cadmium sulphide, arsenic

sulphide, lead, antimony, tin, cobalt, manganese, and chromium⁹⁷, and Autoimmune diseases^{98,99}.

Ar, Cd, Cr, and Ni are grouped under class 1 carcinogens by International Agency for Research on Cancer; cancers associated with heavy metals include: Hepatocellular carcinoma caused by Pb, Cd, As and Hg¹⁰⁰; Gastric cancers caused by lead, cadmium, mercury, chromium, and arsenic¹⁰¹; Thyroid cancers¹⁰²; Lung cancer^{103,104}; Breast cancer commonly associated with high levels of silver, arsenic, gold, boron, barium, beryllium, calcium, cadmium, cerium, cobalt, cesium, gadolinium, manganese, nickel, lead, antimony, scandium, selenium, and zinc¹⁰⁵; Brain cancer caused by Cd, Pb, As, Hg and Th when they cross the brain barrier and cause various neurodegenerative conditions¹⁰⁶; Oesophageal cancer caused by Cd¹⁰⁷; Kidney¹⁰⁸ and Colon cancers¹⁰⁹. One of the major challenges of HMs associated cancers is the difficulty in linking each of the cancers with a particular HM, hence, identifying the sources of pollution and hence instituting control and preventive measures at individual and community levels a difficult task^{110,111}.

CONCLUSION

Heavy metal contamination of soils and vegetables is common among vegetables sold in the Nigerian markets and the major sources of pollution are anthropogenic involving emissions from automobiles, road dusts, industrial effluent pollutants, land reclamation from solid wastes dumps, and agricultural activities with pesticides. HMs are associated with several diseases such as hypertension, stroke, diabetes mellitus, dyslipidaemia, degenerative brain disease, rheumatoid arthritis and cancers of liver, lung, breast, stomach, colon, kidney, oesophagus among others. Linking many of these diseases with the associated HMs may prove difficult and hence devising preventive measures as well.

Recommendation

A general approach towards cutting down emissions from vehicles in our environments is strongly recommended, and also cultivating vegetables in farm lands and gardens at least 20 metres away from roads and streets with heavy vehicular loads. Also, solid wastes used in land reclamation for agricultural activities should be thoroughly screened for HMs contamination to reduce soil contamination. Inappropriate disposal of wastes containing HMs should be discouraged. Environmental Monitoring and Enforcement Agencies should be strengthened to prosecute offenders of set guidelines aimed at reducing HMs contamination of soils and vegetables to serve as deterrent. Furthermore, procurement and application of agro-chemicals on farm lands should be selectively done and also balanced against the backdrop of potential HMs contamination of the soils and crops grown therein. Finally, there should be a regular screening of farm lands and vegetables from risk prone farm lands to detect early HMs toxicity for prompt interventions.

Conflict of interest

The authors declare no conflict of interest.

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