PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 27 (10) 2205-2211 October 2023

Levels of Heavy Metals and Potential Human Health Risks via Consumption of Leafy Vegetables Purchased in Popular Local Market in Lagos, Nigeria

[1, 6*]AGBOOLA, OO; [2]OYEDEJI, S; [3]OLAWOYIN, TA; [4]UNAZI, IE; [5]BOLARINWA, KA; [1]EZE, SC; [6,7]OLOWOYO, JO

*[1]Department of Biological Sciences, Federal University of Health Sciences Otukpo, Benue State, Nigeria
[2]Department of Plant Biology, University of Ilorin, Ilorin, Kwara State, Nigeria
[3]Department of Botany, University of Lagos, Akoka, Yaba, Lagos State, Nigeria
[4]Department of Science Education, Federal University Lokoja, Lokoja, Kogi State, Nigeria
[5]Department of Biology, Distance Learning Institute, University of Lagos, Yaba, Lagos State, Nigeria
[6]Department of Biology and Environmental Sciences, Sefako Makgatho Health Sciences University, Pretoria, South Africa.
[7]Department of Health Sciences, Florida Gulf Coast University, Fort Myers, USA

*Corresponding Author Email: dare.agboola@fuhso.edu.ng; +234 8062095034
Co-authors Email: oyedeji.s@unilorin.edu.ng; taolawoyin@gmail.com; Irene.unazi@fulokoja.edu.ng; bolarinwakehinde85@gmail.com; Sabina.eze@fuhso.edu.ng; woleolowoyo@yahoo.com

ABSTRACT: The increase in consumption of leafy vegetables and their inclusion in daily diet have necessitated vegetable farming throughout the year on very busy road-side farms and gardens and conventional and non-conventional farming areas without consideration for potential risk to health of the consumers. Therefore, the objective of this study is to determine the levels of copper, zinc, chromium and nickel and evaluate the potential health risks to human exposure via the consumption of *Celosia argentea*, *Talinum triangulare* and *Vernonia amygdalina* leafy vegetables purchased in a popular local market in Lagos, Nigeria using ICP-MS after complete dissolution by mixed-acid digestion , The results indicated the presence of Cu, Cr, Zn and Ni with ranges of 6.50 ±0.37 - 18.98±0.31 mg/g, 1.33±0.03 - 7.30±0.19 mg/g, 1.00±0.06 - 3.90±0.60 mg/g and 0.49±0.02 - 2.01±0.06 mg/g respectively. Cu had the highest significant concentrations in *V. amygdalina* among the vegetables and with the highest concentrations at Site A. The concentrations of all trace metals in the leafy vegetables exceeded the stipulated WHO/FAO permissible standards. Overall, the hazard quotients for trace metals were low, indicating that they may not pose a health risk to the populace through consumption of the leafy vegetables, however, the continuous consumption may pose a serious health risk owing to values recorded that were above the acceptable limit set by WHO.

DOI: https://dx.doi.org/10.4314/jasem.v27i10.10

Cite this paper as: AGBOOLA, O. O; OYEDEJI, S; OLAWOYIN, T. A; UNAZI, I. E; BOLARINWA, K. A; EZE, SC; OLOWOYO, J. O. (2023). Levels of Heavy Metals and Potential Human Health Risks via Consumption of Leafy Vegetables Purchased in Popular Local Market in Lagos, Nigeria. *J. Appl. Sci. Environ. Manage.* 27 (10) 2205-2211

Dates: Received: 03 August 2023; Revised: 25 September 2023; Accepted: 04 October 2023 Published: 30 October 2023

Keywords: Toxic trace metals; *V. amygdalina;* hazard quotient; Leafy vegetables

Leafy vegetables are very common daily dietary intake throughout the world due to the fact that they are rich sources of vitamins, minerals, fibres and with some possessing anti-oxidative effects (Murthy *et al*., 2015). Oulai *et al*. (2014) asserted that leafy vegetables provide health promoting and protecting attributes which is directly linked with their inherent nutritional and non-nutrient bioactive properties. Indeed, they have long been, and continue to be reported to significantly contribute to the dietary vitamin and mineral intakes of local populations (Nordeide *et al*., 1996). These micronutrients are essential food nutrients useful for the body as protective agent against diseases; thus, necessary for health and growth

*Corresponding Author Email: dare.agboola@fuhso.edu.ng; +234 8062095034

(Ertan *et al*., 2002; Falade *et al*., 2003). Inadequate intake of micronutrients known as hidden hunger contributes to the increasing rates of illness and death from infectious diseases and disability such as mental impairment (Black, 2003). Therefore, leafy vegetables may be used as basic strategy for fighting against poverty. Major contaminants such as toxic metals and organic halogenated compounds, pesticides and veterinary drugs, pollutants formed during food production and cooking which emanate from food packaging or natural toxins are reported to compromise food safety (Oskarsson, 2012; Rehman *et al*., 2018; Ullah *et al*., 2018). The prevalence of food safety has engendered research regarding the risks associated with the consumption of food stuffs containing the aforementioned environmental contaminants (Riaz *et al*., 2018). Heavy metals are those metals that possess a specific density of more than 5 g/cm^3 and elicit adverse effects on the environment and living organisms (Jaishanker *et al*., 2014). They are important environmental contaminants and their toxicity constitutes a problem of emergent implications for ecological, evolutionary, nutritional, and environmental reasons (Jaishanker *et al*., 2014; Saddique *et al*., 2018).

Exposure to high concentrations of heavy metals may not necessarily produce a state of toxicity but toxic concentrations can be attained as they accumulate in body tissues over time (Igwegbe, 2013). Absorption of heavy metals in low doses by humans over a long period of time through food has been shown to result in serious health consequences, declining economic development in terms of low productivity as well as direct costs of treating illnesses (Olowoyo *et al*., 2013; Zango *et al*., 2013). Some common health implications of heavy metals in humans include kidney disease, damage to the nervous system, diminished intellectual capacity, heart disease, gastrointestinal diseases, bone fracture, cancer and death (Zango *et al*., 2013).

However, the climate, atmospheric deposition, concentration of heavy metals in soil, nature of soil and plant maturity at time of harvest affects the level of concentration of heavy metals in plants (Qadir *et al*., 2008). Vegetables are known to naturally accumulate heavy metals from dumpsites (Arora *et al*., 2008). High concentrations of heavy metals in vegetables are responsible for the prevalence of upper gastrointestinal cancer (Sadir *et al.*, 2005). In Nigeria, most especially in Lagos State, where developmental activities have reduced the available space for farming purposes, residents and subsistence farmers are often noticed to use abandoned sites/open space for farming purposes. It is generally believed that these sites will be very rich in mineral contents which will bring about vibrant, green and good looking vegetables which are usually self-appealing to consumers. Based on persistent nature and cumulative behavior as well as the probability of potential toxicity effects of heavy metals as a result of consumption of leafy vegetables, there is need to ascertain these food items to ensure that the levels of these heavy metals meet the agreed international requirements. This is particularly important for farm products from this part of the world where only limited data on heavy metal contents of such highly consumed agricultural materials are available. This study therefore determine the levels of copper zinc chromium and nickel and evaluate the potential health risks to, human exposure via the consumption of *Celosia argentea*, *Talinum triangulare* and *Vernonia amygdalina* leafy vegetables purchased in a popular local market in Lagos, Nigeria.

MATERIALS AND METHODS

Study Area: This study was conducted in Lagos, south west Nigeria. Lagos is the commercial capital of Nigeria with high vehicular traffic on major highways and along where commercial vegetable cropping occurs. The area has a bimodal rainfall pattern with peaks in June and September. The soils in this area are formed from sedimentary rocks.

Collection of Samples: Leafy vegetables (*Celosia argentea, Talinum triangulare* and *Vernonia amygdalina*) cultivated at four different locations (A, B, C, D) were collected for trace metals determinations. A total of 36 samples were collected from all the four sampling points (A, B, C & D). Three samples each of plant species *Celosia argentea*, *Talinum triangulare* and *Vernonia amygdalina* were collected from the dumpsite and three of the above named samples were collected from different farmlands (B, C & D). The samples were oven dried at 60˚C for three days after which the edible parts (shoots) were homogenized by using a kitchen grinder and placed in labeled cellophane bags for analysis.

Elemental Analysis using ICP-MS: The samples were subsequently digested and investigated for heavy metal content using the microwave digestion system (Mustafa *et al.*, 2005). Briefly, 5 g were retrieved from each sample and processed with 6 ml HNO_3 (Merck supra pure), 2 ml $HClO_4$ (Merck supra pure), 3 ml of 37% HCl (Merck supra pure) and 2 ml of 48% HF (Merck supra pure) in a microwave digestion system. Samples were made up to the required volume using deionized water and then analyzed for Cu, Zn, Cr and Ni using inductively coupled plasma mass spectrometry (ICP-MS).

Fig 1: Map showing the three study sites

Hazard Quotient (Hq) Determination: The Hazard Quotient expressed as HQ was used to calculate the human health risk resulting from the consumption of vegetables. The formula below was used for the HQ calculation

$$\text{HQ} = \frac{\text{ADDM}}{\text{Rf} * \text{DM}}$$

$$\text{ADDM} = \frac{\text{DI} * MF_{veg}}{\text{WB}}$$

Where, ADDM is the average daily dose (mg kg/d) of the metal and RfDM is the reference dose (mg kg/d). RfDM is defined as the maximum tolerable daily intake of a specific metal that has no adverse effect. DI is the daily intake of leafy vegetables (kg/d), MFveg denotes the trace metal concentration in the vegetable tissues (mg/kg) and WB represents the body weight of investigated individuals (Olowoyo; Lion, 2013). The DI was calculated at 0.182 kg/person/day and 0.118 kg/person/day for adults and children respectively (Nabulo *et al*., 2012). The body weight of investigated adults and children were assumed to be 55.7 kg and 14.2 kg respectively (Nabulo *et al*., 2012). When the value of HQM calculated exceed 1 (HQM > 1), then there may be potential risk to consumer (Olowoyo; Lion, 2013).

RESULTS AND DISCUSSION

Toxic Metals in Vegetables Consumed: Concentration of copper was significantly highest in *Vernonia amygdalina* across all the sites. Mean concentration of copper was significantly highest in *V. amygdalina* (18.98±0.31 mg/g) harvested from Site A while lowest concentration of copper was found in *Talinum triangulare* (5.37±0.37 mg/g) harvested from Site D (Table 1). Zinc was observed to be significantly higher in *Celosia argentea* harvested from Site A and lowest concentration was detected in *V. amygdalina* harvested from site B. *Celosia argentea* harvested from Site D had highest concentration of chromium (3.90±0.60 mg/g) while *V. amygdalina* harvested from Site A had the least concentration of chromium (1.00±0.06 mg/g). Nickel in *C. argentea* harvested from Site A (1.794 ±0.064 mg/g) had the highest concentration while the *V. amygdalina* from Site D (0.487±0.016 mg/g) had the lowest concentration of nickel. Concentrations of heavy metals were observed to vary in the studied leafy vegetables and sites. For instance, the decreasing trend of concentration of heavy metals in *Celosia argentea*, *V. amygdalina* and *T. triangulare* was Cu>Zn>Cr>Ni for Sites A and C. In Site B and D, trace metal concentration in *C. argentea*, *V. amygdalina* and *T. triangulare* follows the decreasing trend of Cu>Cr>Zn>Ni.

Hazard quotient of vegetables from dumpsite: The health risk associated with the consumption of heavy metals through leafy vegetables was assessed by estimating the hazard quotient. The possible human health risks (HQ) calculated for adults and children for leafy vegetables (*Celosia argentea, Vernonia amygdalina* and *Talinum triangulare*) harvested from different farms (Table 2). The calculated hazard quotient (HQ) values for both adults and children were all less than 1 suggesting that there were no possible human carcinogenic risks in consumption of the studied leafy vegetables. Generally, the hazard quotient of leafy vegetables is higher in children than in adults. The highest HQ (0.1537) was for copper in *Vernonia amygdalina* in children while in adults, highest HQ for the element in *V. amygdalina* (0.0392).

Table 1: Heavy metal concentration for vegetables (mg/g)

Plant species	Cu mg/g	Zn mg/g	Cr mg/g	Ni mg/g
Site A				
Celosia argentea	16.52±0.21[a]	7.30±0.19[a]	2.23±0.11[b]	2.01 ±0.06[a]
Vernonia amygdalina	18.98±0.31[b]	6.26±0.15[b]	1.00±0.06[c]	0.61±0.01[c]
Talinum triangulare	9.57±0.27[c]	3.20±0.09[c]	2.58±0.05[a]	1.49±0.01[b]
Site B				
Celosia argentea	11.08±0.50[b]	1.94±0.19[b]	2.13±0.01[b]	1.32±0.07[a]
Vernonia amygdalina	11.68±0.83[c]	1.47±0.12[c]	3.55±0.73[a]	0.55±0.02[c]
Talinum triangulare	8.43±0.53[a]	1.33±0.03	2.03±0.05[c]	1.07±0.01[b]
Site C				
Celosia argentea	13.13±0.35[a]	3.33±0.512[a]	1.71±0.06[a]	1.03±0.09[b]
Vernonia amygdalina	11.06±0.51[b]	2.07±0.24[a]	1.76±0.12[b]	0.72±0.02[b]
Talinum triangulare	6.50±0.37[b]	2.56±0.07[b]	1.58±0.31[b]	1.08±0.01[a]
Site D				
Celosia argentea	10.25±0.21[a]	1.52±0.06[b]	3.90±0.60[a]	1.29±0.09[a]
Vernonia amygdalina	9.59±0.62[b]	1.71±0.11[b]	3.26±0.48[b]	0.49±0.02[b]
Talinum triangulare	5.37±0.37[b]	1.83±0.27[c]	2.35±0.06[a]	1.01±0.01[b]

Table 2: Hazard Quotient for adults and children consuming vegetables

Plant species		Cu	Zn	Cr	Ni
Site A					
Celosia argentea	Adult	0.0180	0.0016	0.0297	0.0042
Celosia argentea	Children	0.0458	0.0040	0.0756	0.0106
Vernonia amygdalina	Adult	0.0392	0.0014	0.0133	0.0014
Vernonia amygdalina	Children	0.1537	0.0035	0.0339	0.0036
Talinum triangulare	Adult	0.0198	0.0007	0.0344	0.0035
Talinum triangulare	Children	0.0775	0.0018	0.0875	0.0088
Site B					
Celosia argentea	Adult	0.0121	0.0004	0.0284	0.0031
Celosia argentea	Children	0.0307	0.0011	0.0722	0.0078
Vernonia amygdalina	Adult	0.0127	0.0003	0.0473	0.0013
Vernonia amygdalina	Children	0.0323	0.0008	0.1203	0.0032
Talinum triangulare	Adult	0.0092	0.0003	0.0270	0.0025
Talinum triangulare	Children	0.0233	0.0008	0.0687	0.0063
Site C					
Celosia argentea	Adult	0.0143	0.0007	0.0228	0.0024
Celosia argentea	Children	0.0364	0.0018	0.0579	0.0061
Vernonia amygdalina	Adult	0.0120	0.0005	0.0234	0.0017
Vernonia amygdalina	Children	0.0306	0.0011	0.0596	0.0042
Talinum triangulare	Adult	0.0071	0.0006	0.0211	0.0025
Talinum triangulare	Children	0.0180	0.0014	0.0537	0.0064
Site D					
Celosia argentea	Adult	0.0112	0.0003	0.0520	0.0030
Celosia argentea	Children	0.0284	0.0008	0.1322	0.0077
Vernonia amygdalina	Adult	0.0104	0.0004	0.0435	0.0011
Vernonia amygdalina	Children	0.0266	0.0009	0.1106	0.0029
Talinum triangulare	Adult	0.0059	0.0004	0.0313	0.0023
Talinum triangulare	Children	0.0149	0.0010	0.0796	0.0060

The recorded concentrations exceeded the stipulated regulatory limit by WHO/FAO standard of 0.3 mg/kg. Concentration of Cu across the sites ranged from 6.50±0.37 - 18.98±0.31 mg/g. The highest concentration of copper was recorded in *Vernonia amygdalina* from the dumpsite with concentration value of 18.98 mg/g. The calculated HQs for the accumulation of Cu across the sites were lower than 1. This indicates that consumers of vegetables from all sites of collection are not exposed to the health risks associated with consumption of vegetables with high concentration of Cu. The highest concentrations of Cu were recorded in vegetables from the dumpsite. Copper binds strongly to organic and inorganic matter in the soil and this affects its availability and further uptake by plants (Femandes; Henriques, 1991). According to Chibuike and Obiora (2014), accumulation of Cu in plants could cause inhibition in photosynthetic activities by blocking the ions involved in photosynthetic electron transport, inhibit vegetative growth and induce symptoms of senescence, promotes the production of free radicals leading to chain reactions and cause a general disturbance to plant physiology. Study by Cunningham *et al*., (1975) showed that the presence of Cr reduced the uptake of Cu as the presence of copper also reduces the availability of Nickel. Study by Mamatha *et al*., (2014) showed that ingestion of leafy vegetables containing high concentrations of copper can lead to severe muscular irritation, nausea, vomiting, diarrhea, intestinal cramps, severe gastrointestinal irritation, and other dangerous health defects.

Concentration of Zinc across the sites of collection ranges from 1.331±0.03-7.295±0.192 mg/g. The highest recorded concentration of zinc was found in *Celosia argentea* across all the sites and HQ values were below 1 indicating no potential health risk to consumers though the recorded mean concentration exceeded the regulatory limits, accumulation of Zinc in leafy vegetables in this study posed no health risks to consumers. The highest concentration of Zn across the sites were recorded in vegetables collected from the Site A. According to Divrikli *et al*., (2003), Zn is useful for plant growth and also for normal growth and development in humans. Udosen (2000) also stated that excessive intake of Zn from plants could lead to vomiting, electrolyte imbalance, abdominal pain and lack of muscular coordination. Sources of zinc includes disposal of batteries and electrical materials, paints, pesticides, insecticides and fertilizer application.

Chromium across the sites ranged from 1.00±0.06-3.90±0.60 mg/g. The highest concentration was recorded in *Vernonia amygdalina* from Site D. The recorded values exceeded the WHO/FAO standards of 1 mg/kg. The HQ values of Cr indicated that the consumption will expose the consumers to the negative health effects of consuming vegetables with high concentration of Cr. According to Oleiveira (2012), high exposure to Cr in plants could lead to decreased seed germination, growth reduction, prohibition of photosynthesis and enzymatic activities and they cause nutrient imbalances. They are also generally not harmful and are considered necessary for human metabolism in humans but exposure to high concentrations usually has carcinogenic effects. According to Mamatha *et al*. (2014), Cr is a vital metal in all physiological processes in both animals and human beings; Cr has adverse impact on living organisms due to its quick and easy penetrating capacity and have noxious effect on cells causing various cancers, it causes kidney and liver damage, stomach upset and ulcers, skin rashes, lung cancer, respiratory problems, and weakens the immune system.

Nickel across the sites ranged from 0.49±0.02-2.01±0.06 mg/g with the highest mean concentration observed in *Celosia argentea* from Site A. The recorded concentration values exceeded the stipulated WHO/FAO limit of 2 mg/kg. Hazard quotient of the vegetables showed only *Celosia argentea* from Bariga had a high enough concentration of Ni to pose serious health risk. Study by Graham *et al*. (1985) showed that Ni is useful to plant in low concentration as it promotes plant growth, promotes metabolism of nitrogen in plants and enables urease to catalyze urea into ammonium ion, also could lead to reduced efficiency of N fixation and reduced nodulation in leaves, delay and decrease of leaf expansion, chlorosis in leaves and necrosis when present in high concentrations. Research by Brown (2006) also showed that normal concentration of nickel in plants could lead to increased disease resistance by plants. Sources of Ni in the environment include batteries and electrical materials, fertilizers and fuel (Oleiveira, 2012). Uptake of Ni beyond the permissible levels may cause adverse effects on human being in two stages; the immediate symptoms of headache, vertigo, nausea, vomiting, insomnia, irritability and later symptoms are tightness of the chest, non-productive cough, dyspnoea, cyanosis, tachycardia, palpitations, vertigo; sweating and visual disturbances (Mamatha *et al*., 2014).

Conclusion: The results showed that the concentration of heavy metals have negative environmental and health impacts because; it is above the regulatory limits. Therefore, certain policy should be made to discourage cultivation of plants on polluted sites or dump sites because; plants growing at polluted sites accumulates high level of heavy metals which can lead to serious problems along the food chains. Regular monitoring of heavy metals in vegetables and other food items in the markets is paramount in order to prevent Bioaccumulation in humans and other organisms.

REFERENCES

Arora, M; Kiran, B; Rani, A; Kaur, B; Mittal, N. (2008). Heavy metal accumulation in vegetables irrigated with water from different sources. *Food Chemistry*. 111: 811-815.

Black, R. (2003). Micronutrient deficiency-an underlying cause of morbidity and mortality. Bulletin of World Health Organisation, 81: 79-83. Champ, M.M. Non-nutrient bioactive substances of pulses. *British J. Nutrit.* 88: 307-319.

Brown, PH. (2006). Nickel. In *Handbook of plant nutrition*, 395-410. Boca Raton, FL:CRC Press Taylor and Francis Group.

Chibuike, GU; Obiora, SC. (2014). Heavy metal polluted soils: Effects on plants and bioremediation methods. *Applied and Environ. Soil Sci*., 2014(1): 1-12.

Cunningham, JD; Ryan, JA; Keeney, DR. (1975). Phytotoxicity in and metal uptake from soil treated with metal-Amended sewage sludge. *J. Environ. Qual*. 4(4): 455–460.

Divrikli, U; Saracoglu, S; Soylak, M; Elci, L. (2003). Determination of trace heavy metal contents of green vegetables samples from Kayseri-Turkey by flame atomic absorption spectrometry. *Fresenius Environ. Bulletin*, 12: 1123-1125.

Ertan, P; Yereli, K; Kurt, O; Balcioglu, IC; Onag, A. (2002). Serological levels of zinc, copper and iron element among Giadia lamblia injected children in Turkey. *Pediatrics Intern.* 44: 286-288.

Falade, OS; Sowunmi, OR; Oladipo, A; Tubosun, A; Adewusi, SRA. (2003). The level of organic acids in some Nigerian fruits and their effects on mineral availability in composite diets. *Pakistan J. Nutrit*., 2: 8288.

Fernandes, JC; Henriques, FS. (1991). Biochemical, physiological and structural effects of excess copper in plants. *Botanical Review*, 57 (3): 246-273.

Graham, RD; Welch, RM; Walker, CD. (1985). A role of Nickel in the resistance of plants to rust." Proc. 3rd Australian Agronomy Conference. Hobart Tasmania, Australia.

Igwegbe, AO. (2013). Effects of Location, Season, and Processing on Heavy Metal Contents in Selected Locally Harvested Fresh Fish Species from Borno State of Nigeria. A Ph.D Thesis, Department of Food Sciences and Technology, Faculty of Engineering, University of Maiduguri, Nigeria. PP xii + 160.

Jaishanker, M; Tseten, T; Krishnamurphy, NB. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxi*. 7(2): 60-72.

Jarup, L. (2003). Hazards of heavy metals contamination. *British Medical Bulletin*, 68: 167-182.

Mamatha, H; Srinivasa, RNK; Hunashikatti, L; Shivashankara, KS. (2014). Impact of elevated CO2 on growth, physiology, yield and quality of tomato (*Lycopersicon esculrntum mill)* cv Arka Ashish. *Photosynthetica*, 52: 519-528.

Murthy, R; Bearman, G; Brown, S; Bryant, K.; Chinn, R; Hewlett, A; George, GB; Goldstein, EJC; Holzmann-Pazgal, G; Rupp, EM. (2015). Animals in healthcare facilities: recommendations to minimize potential risks. *Infect. Control Hosp. Epidemiol*. 36(5): 495-516.

Mustafa, S; Narin, I; Tuzen, M; Sari, H. (2005). Heavy Metal Content of Potato and Corn Chips from Turkey. Bull. *Environ. Contam. Toxicol.* 74: 1072–1077. Springer Science Business Media, Inc.

Nabulo, G; Black, CR; Craigon, J; Young, SD. (2012). Does consumption of leafy vegetables grown in peri-urban agriculture pose a risk to human health? *Environ. Pollut*. 162: 389-398.

Nordeide, MB; Hatloy, A; Folling, M; Lied, E; Oshaug, A. (1996). Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district, Koutiala, in Southern Mali. *Intern. J. Food Sci. and Nutrit.* 45: 455-468.

Oleiveira, H. (2012). Chromium as an environmental pollutant: Insights on Induced Plant Toxicity. *J. Botany*, 1-8.

Olowoyo, JO; Van Heerden, E; Fischer, J. (2013). Trace metals concentrations in soil from different sites in Pretoria, South Africa. *Sustain. Environ. Res.* 23(1): 93.

Olowoyo; Lion (2013). Population health risk due to dietary intake of toxic heavy metals from *Spinacia oleracea* harvested from soils collected in and around Tshwane, South Africa. *South Afr. J. Botany*, 88: 178-182.

Oskarsson, A. (2012). Environmental contaminants and food safety. *Acta Vet. Scand.*, 54(1):S5.

Oulai, PD; Zoué, LT; Megnanou, R; Doué, R; Niamké, SL. (2014). Proximate composition and nutritive value of leafy vegetables consumed in northern Côte d'ivoire. *Eur. Sci. J.*, 10: 1857–7881.

Qadir, MA; Mahmood, A; Igbal, M. (2015). Synthetic, characterization and antibacterial activities of Novel Sulfonamides derived through condensation of amino group containing drugs, Amino acids and their analogs. *BioMed. Res. Interna*. 1-7.

Rehman, K; Fiza, F; Waheed, I; Akash, MSH. (2018). Prevalence of exposure of heavy metals and their impact on health consequences. *J. Cellular Biochem.* 119(1).

Riaz, U; Murtaza, G; Farooq, MS. (2018). Influence of different sewage sludges and composts on growth, yield and trace elements accumulation in rice and wheat. *Land Degrad. Develop.* 29(5): 1343-1352.

Saddique, MAB; Ali, Z; Khan, AS. (2018). Inoculation with the endophyte *Piriformospora indica* significantly affects mechanisms involved in osmotic stress in rice. *Rice.* 11(34).

Sadir, N; Shojaei, M; Moadab, K; Abbasi, R; Bahrampour, A; Nakhaee, N. (2013). Outcome Evaluation of Therapeutic Community Model in Iran. *Intern. J. Health Policy and Manage.* 1(2): 131–135.

Udosen, ED. (2000). Levels of toxic metal in Achatina achatina from parts of Akwa Ibom State, Nigeria. *J. Environ. Sci.* 12(1): 68-74.

Ullah, A; Bangash, SS; Ali, Y. (2018). Community perception towards the socio-economic impact of CPEC on Northern Pakistan. *Greener J. Soc. Sci*. 8(2): 012-017.

Zango, A; Dube, K.; Kelbert, S; Meque, I; Cumbe, F; Chen, PL; Janneke, VDW. (2013). Determinants of prevalent HIV diagnosis among young women with two or more sexual partners in Beira, Mozambique. *PLoS ONE* 8(5): e63427. Doi: 10.1371/journal.pone.0063427