AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 13, No 4, pp 323-332, 2021
Published by Faculty of Agriculture, Trakia University, Bulgaria
ISSN 1313-8820 (print)
ISSN 1314-412X (online)
http://www.agriscitech.eu
DOI: 10.15547/ast.2021.04.053

Review

Heavy metal uptake and stress in food crops: A Review

N. Abdullahi[1]*, E.C. Igwe[2], M.A. Dandago[1]

[1]Department of Food Science and Technology, Kano University of Science and Technology, Wudil, PMB 3244, Kano State, Nigeria
[2]Department of Food Science and Technology, Nnamdi Azikiwe University, PMB 5025, Awka, Anambra State, Nigeria

(Manuscript received 11 January 2021; accepted for publication 4 October 2021)

Abstract. *Heavy metal (HM) food contamination is detrimental to food safety and human health. Water scarcity, food shortage, illiteracy, failure to enforce environmental protection laws, and food quality regulations account for human HM contamination. Understanding their uptake pattern in food crops and how the crops behave under excessive concentration of these hazardous chemicals will guide farmers, researchers, and policymakers in devising appropriate control measures that will ensure the production and consumption of safer food crops. Relevant texts published by Science Direct, Springer Nature, and Wiley between January 2018 and December 2020 were cited in this article. The article discussed major factors affecting HM accumulation and the effects of HM stress on yield, physiology, and chemical properties of food crops. Wastewater irrigation, production in contaminated soil, and atmospheric deposit contributed to the contamination. Factors that influence HM uptake are those related to soil and irrigation water qualities and plant properties. The presence of other HMs and chemicals, growing season, crop age, planting method, and food crop type also affect HM uptake in food crops. HM stress affects anatomy, physiology including antioxidant defense mechanisms, nutrient availability and uptake, germination, seedlings development, growth, yield, leaf geometry, root and shoot length, plant genetics, pollination, and chemical composition including moisture content, soluble protein, and pigment content and characteristics.*

Keywords: accumulation, contamination, food chain, irrigation water, soil, quality

Itroduction

The menace of HM contamination is becoming a universal problem (Luo et al., 2021; Rizwan et al., 2021). HMs are found naturally in the environment, natural processes and human activities aid their movement in the ecosystem and account for soil, water, and food contamination (Rehman et al., 2020). Soil quality is fundamental to food safety and human health (Qin et al., 2021). Intense use of agrochemicals and wastewater irrigation have changed soil conditions and exposed consumers to many precarious chemicals (Kalkhajeh et al., 2021). There is a rising concern for human health and environmental safety due to the continuous release of these dangerous elements by many forms of anthropogenic activities (Samiee et al., 2019) in quantities much higher than those released by natural processes (Hu et al., 2018; Vareda et al., 2019; Yuan et al., 2019).

The jeopardy of HMs is detrimental to the environment, foods, and human life and the danger of HM contamination is becoming unbearable as it is affecting all categories of foods including organic foods (Anae et al., 2020). Ugulu et al. (2021) reported dangerous levels of Cd and Pb in organic pepper fertilized with farmyard manure and poultry waste. Vegetables produced in a greenhouse under controlled conditions were also reported to be contaminated by HMs (Kalkhajeh et al., 2021), higher levels of Hg and Cd were established by Fan et al. (2021) in vegetables produced in plastic greenhouse. When they have their way into the living tissue, HMs interfere with many physiological and biochemical processes in both plants and animals and at higher concentrations can lead to death (Rehman et al., 2020). The major route for food crops HM contamination is production in contaminated soil and irrigation with raw wastewater. Rapid population growth, hasty urbanization, and industrialization resulted in the production of a large volume of wastes and account for hiking-up soil HM content (Rai et al., 2019; Hanfi et al., 2020; Chia et al., 2020). These created ecosystem imbalances that are negatively affecting the environment (Hernandez-Ramirez et al., 2019) and the menace is intensifying soil and food HM contamination at a geometrical rate (Joseph et al., 2019; Magwaza et al., 2020; Sharma et al., 2020).

Understanding their uptake patterns in different food crops under different soil and farming conditions and factors determining their bioavailability, mobility and reactivity will assist researchers in devising means for controlling their activities in soil and water. When their mechanisms of action

*e-mail: nurafst@gmail.com

are understood, production conditions can be manipulated to ensure the production of food crops with safer levels of these metals. Humans and animal lives will be protected and food crops will be able to thrive without any stress.

The arguments presented motivated the writing of this review to clarify the factors and mechanisms leading to the accumulation of heavy metals in the crop plants and the consequences of this accumulation - stress, anatomical and morphological changes, reduced yields, changes in chemical composition, etc.

HM uptake in food crops

Soil temperature, pH, organic matter, texture, microorganisms, cation exchange capacity, presence of other metals, metals mobility, plant type, and transpiration rates determine HM uptake in food crops (Gupta et al., 2019). The uptake commonly occurs through roots when the growing soil is contaminated or when the irrigation water is contaminated, uptake through leaves is very occasional (Edelstein and Ben-Hur, 2018). Contamination of a crop simply means contamination of the entire food chain (Rai et al., 2019) and when the food chain is contaminated it will be very difficult to clean because the HMs will be rotating between the foods, humans, and environment (Kumar et al., 2019). HM contamination reaches all corners of the food chain to the level of breastmilk (Samiee et al., 2019; Zhou et al., 2019a) and food extracts such as oil (Zaanouni et al., 2018).

Soil HM concentrations vary globally (Afonne and Ifediba, 2020) and the concentration of HMs in food crops depends on the concentration of HMs in the growing location (Jafari et al., 2018). Variation in HM contents was reported in rice grown in different locations (Ebrahimi-Najafabadi et al., 2019). Human activities and geological setup account for the variation (Sharma et al., 2018). The following factors were reported to affect HM uptake in food crops.

Soil and irrigation water factors

HM uptake and transportation within a plant depends on the type of the plant, metal concentration in the soil, pH of the soil (Huang et al., 2020), age of the soil, texture, and organic matter content of the soil (Taghipour and Jalali, 2019; Zwolak et al., 2019), soil microorganisms, organic matter and redox potential (Hussain et al., 2021). Soil water levels affect root activities and metal bioavailability (Song et al., 2021). Soil pH affects the bioavailability of metals (Zhou et al., 2019b) and their accumulation is favored by low soil pH and higher organic matter content (Hu et al., 2017; Hou et al., 2019; Liu et al., 2020; Ouyang et al., 2020; Eid et al., 2020). Elevated pH lowers the solubility of HMs (Świątek et al., 2019), hence, alkaline soil retains HMs and prevents plants from accumulating them (Martínez-Cortijo and Ruiz-Canales, 2018; Hamid et al., 2019). Soil organic matter content dictates Cd uptake and translocation in the soil-rice system (Wu et al., 2021a). Irrigation with wastewater lowers soil pH (Li et al., 2019) and increases its electrical conductivity (Alghobar and Suresha, 2017). Effluent from the tannery industry is characterized by higher conductivity in addition to elevated Cr concentration (Alemu et al., 2019). High salinity in the irrigation water increases the uptake of Ni, Cu, Pb, Cr, and Cd by plants (Taghipour and Jalali, 2019).

Plant factors

Higher metal content in agricultural soil does not always correlate with plant metal content as many factors control the bioavailability and metal uptake by the plants (Weber et al., 2019). The distribution and concentrations of the HMs within the plant are also affected by the pH of the plant as reported by Ouyang et al. (2020) in rice. Huang et al. (2020) reported that plant Cd bioconcentration is negatively correlated with soil cation exchange capacity (CEC) and soil pH and positively correlates with soil Cd concentration and electrical conductivity (EC)/soil salinity. The findings of Bi et al. (2018) revealed that HM metal uptake by vegetables is affected by species and there is no correlation between soil HM concentration and that of the edible portion of vegetables. A similar finding was also reported by Elmi et al. (2020) in tomatoes grown in sewage sludge amended soil. Contrary findings were reported by Muhammad et al. (2019) in crop and fruit vegetables produced in Zhob valley, Baluchistan province, Pakistan, and Ai et al. (2018) in eggplants produced in Baiyin, China, linear positive correlation between soil and plant HM content was reported in both researches. Also, the results of a physiologically-based extraction test conducted by Liu et al. (2018) showed a significant correlation between total soil Cd, Cu, Ni, and Zn, and the fractions that are bio-accessible.

The concentration of HMs can vary within a crop, different organs can possess different concentrations as reported by Peng et al. (2020) in maize. Atamaleki et al. (2019) and Elmi et al. (2020) also reported higher concentrations in roots and stem than in the fruit of tomato. Similar results were also reported by Sagbara et al. (2020) in maize, Martínez-Cortijo and Ruiz-Canales (2018) and Ouyang et al. (2020) in rice, Huang et al. (2019) and Rezapour et al. (2019) in wheat and Li et al. (2019) in maize and wheat; with the grains having lower concentration than other parts in all the cases. Cell-wall carbohydrates such as pectin, hemicellulose, cellulose, and lignin determine the uptake of HMs in the plant cell wall, regulating the synthesis of these carbohydrates can alter the HM accumulation pattern in the plant (Jia et al., 2021).

Presence of other HMs and chemicals

The bioavailability and uptake of HMs are affected by the presence of other HMs and other chemicals (Lizarazo et al., 2020). It is difficult to understand the actual behaviour of trace elements in their combined form because of the complexity involved in their inter-relationship which can easily be affected by natural and environmental factors (Gupta et al., 2019). Wang et al. (2019a) reported that increase in atmospheric nitrogen deposit facilitated Cd and Cu uptake in rice. Li et al. (2019) observed a positive correlation between soil fluoride and Cd, Cr, Cu, Mn, Ni, Pb, and Zn contents, and presence of water-soluble fluoride in the soil activated HMs and facilitated their uptake by the plant roots. Wang et al. (2020a) also reported that the Ni concentration and its bioavailability in the soil was related to iron oxide content of the soil. Long-term optimal application of phosphorus fertilizer (50 kg ha^{-1}) reduces the uptake of Zn, Cu, Pb, and Ni in grain of wheat as well as decreased total non-cancer and cancer risks by 15% and 21%, respectively, for both children and adults (Chen et al., 2020). The presence of cerium oxide lowers uptake and translocation of Cu, Mn, Zn, and Fe in sugar pea (Skiba and Wolf, 2019). The presence of Pb, As and Cd affects mobility and bioavailability of Cu, Cr, Zn, and Ni (Khan et al., 2019). The presence of H_2S reduces Cd uptake in *Brassica rapa* (Li et al., 2021a). Li et al. (2021b) reported that the presence of calcium hinders Cd uptake in ginseng. The uptake of As by leafy vegetables depends on the ratio of phosphorus to arsenic in the soil (Qin et al., 2021a). Uptake of HMs in rice increases with an increase in phosphorus fertilizer application (Song et al., 2021). Application of 1% silicon and fused calcium magnesium phosphate fertilizers lowers Cd uptake by more than 40% in *Artemisia selengensis* grown in Cd-rich soil (Wang et al., 2021). Presence of $Ca(OH)_2$ (lime) lowers Pb, Cd, Ni, Cu, and Zn extractability (Kaninga et al., 2020). A combined presence of diethyl phthalate and Cd^{2+} in the soil alters the sorption properties of biochar-treated soil (Chen et al., 2021). Nanomaterials demonstrate excellent absorption ability for Cd in contaminated soil (Zhang et al., 2021). Rezaeian et al. (2020) observed a positive correlation between soil As, Pb, and Cr contents and nitrogen-free extract in alfalfa.

Growing season, crop age, and planting method

The growing season significantly affects metal uptake by food plants, Weber et al. (2019) reported that onion accumulates more HMs and has a higher concentration factor for Pb and Cr during springtime than autumn. Likewise, higher concentrations of Mn, Pb, and Cd were found in tea leaves produced during summer than those produced during spring (Peng et al., 2018). This may be associated with the seasonal variation in the concentration of HMs in water (Utete and Fregene, 2020) and the effects of seasonal changes on the physicochemical properties of the irrigation water (Kayembe et al., 2018). Wang et al. (2019a) linked Cd seasonal variation in rice with seasonal change in the atmospheric nitrogen content. The age of the crop also affects bioaccumulation and translocation of HMs as reported by Adejumo et al. (2018) in maize and Peng et al. (2018) in tea leaves. Souri et al. (2019) associated higher concentrations of HMs in older crops with long-time exposure to atmospheric deposit.

Another factor that affects HM uptake and accumulation is the planting method as reported by Deng et al. (2020) in rice, the results of their findings revealed that planting by direct seeding facilitates Cd and Pb uptake than planting by manual transplanting and seedling throwing due to variations in the root features and properties. Intercropping significantly affects the HM accumulation pattern in food crops, Wang et al. (2020b) reported that intercropping wheat with blackberry increases the concentration of Cd in wheat tissue. Similarly, intercropping cauliflower with *Sedum alfredii* increases Cd content in the edible portion of the cauliflower (Ma et al., 2021). A modified rice-fish farming system devised by Luo et al. (2021) was reported to be an excellent way of remediating Cd contaminated paddy field, the system allows rice stubbles to absorb excess Cd after harvesting the grains.

Food crop type

Crop type determines the type of HMs and their uptake capability by the food crop (Margenat et al., 2019). Different crops have different affinity to HMs (Sharma et al., 2018). Vegetables, cereals, and legumes are the common food crops prone to HM contamination. Leafy vegetables were reported most among vegetables, wheat was reported more than any other cereals, and onion more than any crops with underground storage. Wang et al. (2019b) reported that wheat accumulates more HMs than corn. Arsenic contaminates rice more than any other cereal (Mawia et al., 2020). Leafy vegetables accumulate more HMs than other food crops (Qureshi et al., 2016; Hu et al., 2017; Gupta et al., 2019; Mahmood et al., 2020) due to their fleshy tissues (Sharma and Nagpal, 2020). The larger surface area in leafy vegetables provides abundant space for HM uptake from the atmospheric deposit (Kalkhajeh et al., 2021). Growing leafy vegetables in contaminated soil can be very dangerous due to their higher HM transfer factor and accumulation capacity (Hu et al., 2017; Kumar et al., 2019a), and they tend to accumulate more HMs in the leaf than in the shoot and root (Nzediegwu et al., 2020). The health hazard quotient index is higher in leafy vegetables than root and fruit vegetables because of their higher HM affinity (Hu et al., 2017). Higher concentrations of Pb, Zn, Cr, Cd (Obiora et al., 2019) Ca, Fe, K, Mg, and Na (Mahmood et al., 2020) were found in leafy vegetables than other vegetables with edible underground storage organs. Gupta et al. (2021) also reported higher concentrations of Zn, Pb, Mn, Ni, Cu, Co, and Cd in spinach than in eggplant and chilli. Fan et al. (2017) also reported higher transfer factors for As, Cr, Ni, and Pb in leafy and fruit vegetables than in tuber vegetables grown in a greenhouse. Gebeyehu and Bayissa (2020) observed higher concentrations of Cr, Cd, Zn, Fe, Pb, As, Mn, Cu, Hg, Ni, and Co in cabbage than in tomatoes. Nzediegwu et al. (2020) established that spinach leaves accumulated more heavy metals (Cd, Cu, Cr, Fe and Pb) than the roots and stems.

Moreover, foliage density affects metal accumulation in vegetables, hence, some leafy vegetables accumulate more HMs than others. Sayo et al. (2020) reported higher concentrations of HMs in spinach than in kale grown under the same soil conditions. Water spinach and sweet potato leaves possessed higher bioaccumulation factors for As than lettuce and amaranth (Qin et al., 2021b). Likewise, Lizarazo et al. (2020) reported higher concentrations of HMs in parsley than in artichoke. Rehman et al. (2019) also reported higher concentrations in amaranth and mustard leaves than in cabbage and cauliflower. On the other hand, florescence vegetables tend to accumulate more HMs in the root than in the leaf and flower as reported by Kumar et al. (2019b) in cauliflower.

Mwesigye et al. (2019) associated the high concentrations of HMs in leafy vegetables with atmospheric deposits from contaminated soil dust which cannot be removed even after thorough washing. This was supported by the findings of Pariyar and Noga (2018) which revealed that successive rainfall over a long time does not affect the ionic mass accumulation from an aerosol deposit on barley leaves. Contrary to these, Noh et al. (2019) found that thorough washing of leafy vegetables with clean tap water reduces Pb content from the atmospheric deposit. Liao et al. (2016) and Dala-Paula et al. (2018) also associated leafy vegetables Pb contamination with atmospheric deposit. Leaf uptake of HMs can occur through aqueous pores, cuticular cracks, stomata, or ectodesmata (Edelstein and Ben-Hur, 2018). The uptake through atmospheric deposit is affected by the leaf stomata size as reported by Gao et al. (2020) in Chinese cabbage. HM uptake from the atmospheric deposit is quite very insignificant as reported by Ercilla-Montserrat et al. (2018) in hydroponic lettuce produce around Barcelona busy roads. It could be deduced from the above discussion that the concentration of HMs in leafy crops depends on both soil contamination and air pollution.

Tuber crops absorb HMs more easily than leafy and fruit crops due to their proximity to the soil (Byers et al., 2020). Unlike in leafy vegetables where the absorbed HMs are evenly distributed, in tubers HMs concentrate more in the peel than in the tuber flesh as reported by Nzediegwu et al. (2019) and Dhiman et al. (2020) in potato tubers. Unlike other crops with underground storage, onion accumulates more HMs in the bulb than in the leaves (Atamaleki et al., 2019).

HM stress in food crops

The nutritional qualities and safety of food depend on the availability of good quality water, clean soil, optimum temperature, availability of sunlight, and CO_2 (Ruszkiewicz et al., 2019). Most food crops are subtle to HM contamination and at higher concentrations, their physiology is affected (Poustie et al., 2020). Ahsan et al. (2018) reported that the effects of HM stress can affect the anatomy of the plant as well. Food crops that are capable of withstanding HM stress are characterized by low metal uptake (Rai et al., 2019). HM stress can interfere with the antioxidant production within the cell (AbdElgawad et al., 2020). An excessive amount of HMs in the soil can cause oxidative stress that can lead to growth retardation, can reduce the activities of antioxidant defense mechanisms, and can trigger H_2O_2 accumulation through lipid peroxidation (Colak et al., 2019). The antioxidant activities of enzymes such as catalases, superoxide dismutases, ascorbate, and glutathione can be modified in rice under Cd stress (Hussain et al., 2021). Excess Cu in the soil causes protein oxidation and lipid peroxidation in plants (Kumar et al., 2021).

Growth and yield could be affected by HM stress as reported by Ai et al. (2018) in eggplant grown in wastewater contaminated soil. Higher concentrations of HMs in the soil can affect the bioavailability of essential nutrients and subsequently affects plant growth (Khan et al., 2019; Świątek et al., 2019). Waheed et al. (2021) reported that Cd stress in spinach can lower total biomass, leaf length and area, and root and shoot length. Reduction in mineral uptake, leaf relative moisture content, growth rate, soluble protein content, photosynthetic pigments, and antioxidant activities were observed in *Brassica rapa* exposed to artificially induced Cd stress (Li et al., 2021a). Cu is highly toxic for tomato, wheat, and pea seeds and can affect their germination and seedling growth (Baruah et al., 2019). It also interferes with the activities of soil microorganisms and affects their population, diversity, and evolution (Wang et al., 2019c). Certain species of fungus withstand higher HM concentrations due to their metal stress adaptation ability in natural and contaminated soil (Torres-Cruz et al., 2018).

Sabeen et al. (2020) reported that HM stress can affect the genetic setup of a plant by causing serious chromosomal abnormalities that can influence their normal growth, and these effects can be passed to the plant offspring and to the human after consumption, and this may cause genetic complications in humans. On the other hand, genetic modification of food crops may not affect their HM uptake pattern, a comparable accumulation pattern of As, Cd, Cr, Ni, and Pb was reported by Wei et al. (2020) in *polyphosphate kinase* (*ppk*)-expressing transgenic rice and in wild-type species. Higher concentrations of HMs in maize male inflorescence can impede pollen grain development and subsequently affects yield (Li et al., 2019). Soil amendment can change the metal chemical form and enhance translocation pattern within plant tissue (Wu et al., 2021b)

Conclusion

Understanding HM uptake patterns in food crops and how the crops behave under excessive concentration will guide farmers, researchers, and policymakers in devising appropriate control measures that will ensure the production and consumption of safer food crops. The main causes of HM food crops contamination are wastewater irrigation, production in contaminated soil, and atmospheric deposit in areas with contaminated air. Factors that influence HM uptake are those related to soil and irrigation water qualities and plant properties. The presence of other HMs and chemicals, growing season, crop age, planting method, and food crop type also affect HM uptake in food crops. HM stress affects anatomy, physiology including antioxidant defense mechanisms, nutrients availability and uptake, germination and seedlings growth, growth and yield, leaf geometry, root and shoot length, plant genetics, pollination, and chemical composition including moisture contents, soluble protein, and pigment content and characteristics. Leafy vegetables are reported to have higher metal accumulation capacity than any other food crop, therefore their production in contaminated fields or fields under remediation is seriously discouraged. Food with underground storage organs that are consumed without their outer parts and grains were reported to accumulate fewer metals in their edible parts, hence, can be produced in contaminated soil.

Soil amendment using immobilization techniques is recommended in a contaminated active agricultural field, this will prevent HM uptake by the plant and subsequently passing them to humans. The crops will also not be exposed to metals, therefore, germination, soil microorganism, essential nutrient uptake, growth, and yield will not be affected. More importantly, the chemical composition of the food crops, their safety, and their food value will be protected. Food crops that are known to accumulate fewer HMs in their edible portions and those that are not used as staples should be used for phytoremediation; when the method is the only alternative, this will minimize HM consumption through food crops.

There are serious debates regarding the actual source of HMs in leafy vegetables, some researchers opined that their contamination is largely by uptake from contaminated soil with a very insignificant amount taken through atmospheric deposit, while others opined that larger amounts of the metal contaminants are coming from the atmospheric deposit. More researches are needed in this area to eliminate the existing confusion.

Another very hazy research area is on the nature of the heavy metals contaminants in leafy foods, some findings reported that the HMs taken through atmospheric deposit are chemically bound to the leaves and cannot be removed by series of washing, while other researchers reported that the contamination is physical and just a merely surface deposit that can be removed by washing using clean water. Further researches need to be conducted to understand the effects of leaf microstructure (such as stomata size, aqueous pores), chemical composition (such as carbohydrates, pectin, hemicellulose, cellulose, and lignin), and physical cracks on the uptake of HMs through an atmospheric deposit.

Conflict of interest

The authors report no conflict of interest.

Funding

This research received no external funding.

Reference

AbdElgawad H, Zinta G, Hamed BA, Selim S, Beemster G, Hozzein WN, Wadaan MAM, Asard H and Abuelsoud W, 2020. Maize roots and shoots show distinct profiles of oxidative stress and antioxidant defense under heavy metal toxicity. Environmental Pollution, 258, 113705. doi: 10.1016/j.envpol.2019.113705

Adejumo SA, Ogundiran MB and Togun AO, 2018. Soil amendment with compost and crop growth stages influenced heavy metal uptake and distribution in maize crop grown on lead-acid battery waste contaminated soil. Journal of Environmental Chemical Engineering, 6, 4809-4819. doi: 10.1016/j.jece.2018.07.027

Afonne OJ and Ifediba EC, 2020. Heavy metals risks in plant foods – need to step up precautionary measures. Current Opinion in Toxicology, 22, 1-6. doi: 10.1016/j.cotox.2019.12.006

Ahsan M, Younis A, Jaskani MJ, Tufail A, Riaz A, Schwinghamer T, Tariq U and Nawaz F, 2018. Heavy metal accumulation imparts structural differences in fragrant Rosa species irrigated with marginal quality water. Ecotoxicology and Environmental Safety, 159, 240-248. doi: 10.1016/j.ecoenv.2018.05.003

Ai S, Liu B, Yang Y, Ding J, Yang W, Bai X, Naeem S and Zhang Y, 2018. Temporal variations and spatial distributions of heavy metals in a wastewater-irrigated soil-eggplant system and associated influencing factors. Ecotoxicology and Environmental Safety, 153, 204-214. doi: 10.1016/j.ecoenv.2018.02.026

Alemu T, Mekonnen A and Leta S, 2019. Integrated tannery wastewater treatment for effluent reuse for irrigation: Encouraging water efficiency and sustainable development in developing countries. Journal of Water Process Engineering, 30, 1-8. doi: 10.1016/j.jwpe.2017.10.014

Alghobar MA and Suresha S, 2017. Evaluation of metal accumulation in soil and tomatoes irrigated with sewage water from Mysore city, Karnataka, India. Journal of the Saudi Society of Agricultural Sciences, 16, 49-59. doi: 10.1016/j.jssas.2015.02.002

Anae J, Ahmad N, Kumar V, Thakur VK, Gutierrez T, Yang XJ, Cai C, Yang Z and Coulon F, 2020. Recent advances in biochar engineering for soil contaminated with complex chemical mixtures: Remediation strategies and future perspectives. Science of the Total Environment, In press.

Atamaleki A, Yazdanbakhsh A, Fakhri Y, Mahdipour F, Khodakarim S and Mousavi Khaneghah A, 2019. The concentration of potentially toxic elements (PTEs) in the onion and tomato irrigated by wastewater: A systematic review; meta-analysis and health risk assessment. Food Research International, 125, 1-8. doi: 10.1016/j.foodres.2019.108518

Baruah N, Mondal SC, Farooq M and Gogoi N, 2019. Influence of heavy metals on seed germination and seedling growth of wheat, pea, and tomato. Water, Air, and Soil Pollution, 230, 1-15. doi: 10.1007/s11270-019-4329-0

Bi C, Zhou Y, Chen Z, Jia J and Bao X, 2018. Heavy metals and lead isotopes in soils, road dust and leafy vegetables and health risks via vegetable consumption in the industrial areas of Shanghai, China. Science of the Total Environment, 619-620, 1349-1357. doi: 10.1016/j.scitotenv.2017.11.177

Byers HL, Mchenry LJ and Grundl TJ, 2020. Progress in achieving high-performance piezoresistive and capacitive flexible pressure sensors: A review. Journal of Materials Science and Technology, 43, 175-188. doi: 10.1016/j.jmst.2019.11.010

Chen H, Qin P, Yang X, Bhatnagar A, Shaheen SM, Rinklebe J, Wu F, Xu S, Che L and Wang H, 2021. Sorption of diethyl phthalate and cadmium by pig carcass and green waste-derived biochars under single and binary systems. Environmental Research, 193, 110594. doi: 10.1016/j.envres.2020.110594

Chen XX, Liu YM, Zhao QY, Cao WQ, Chen XP and Zou CQ, 2020. Health risk assessment associated with heavy metal accumulation in wheat after long-term phosphorus fertilizer application. Environmental Pollution, 262, 1-9. doi: 10.1016/j.envpol.2020.114348

Chia WY, Chew KW, Le CF, Lam SS, Chee CSC, Ooi MSL and Show PL, 2020. Sustainable utilization of biowaste compost for renewable energy and soil amendments. Environmental Pollution, 267, 115662. doi: 10.1016/j.envpol.2020.115662

Colak N, Torun H, Gruz J, Strnad M and Ayaz FA, 2019. Exogenous N-Acetylcysteine alleviates heavy metal stress by promoting phenolic acids to support antioxidant defence systems in wheat roots. Ecotoxicology and Environmental Safety, 181, 49-59. doi: 10.1016/j.ecoenv.2019.05.052

Dala-Paula BM, Custódio FB, Knupp EAN, Palmieri HEL, Silva JBB and Glória MBA, 2018. Cadmium, copper and lead levels in different cultivars of lettuce and soil from urban agriculture. Environmental Pollution, 242, 383-389. doi: 10.1016/j.envpol.2018.04.101

Deng X, Yang Y, Zeng H, Chen Y and Zeng Q, 2020. Variations in iron plaque, root morphology and metal bioavailability response to seedling establishment methods and their impacts on Cd and Pb accumulation and translocation in rice (*Oryza sativa* L.). Journal of Hazardous Materials, 384, 1-8. doi: 10.1016/j.jhazmat.2019.121343

Dhiman J, Prasher SO, ElSayed E, Patel RM, Nzediegwu C and Mawof A, 2020. Heavy metal uptake by wastewater irrigated potato plants grown on contaminated soil treated with hydrogel based amendments. Environmental Technology and Innovation, 19, 1-19. doi: 10.1016/j.eti.2020.100952

Ebrahimi-Najafabadi H, Pasdaran A, Rezaei Bezenjani R and Bozorgzadeh E, 2019. Determination of toxic heavy metals in rice samples using ultrasound assisted emulsification microextraction combined with inductively coupled plasma optical emission spectroscopy. Food Chemistry, 289, 26-32. doi: 10.1016/j.foodchem.2019.03.046

Edelstein M and Ben-Hur M, 2018. Heavy metals and metalloids: Sources, risks and strategies to reduce their accumulation in horticultural crops. Scientia Horticulturae, 234, 431-444. doi: 10.1016/j.scienta.2017.12.039

Eid EM, Shaltout KH, Alamri SAM, Sewelam NA and Galal TM, 2020. Uptake prediction of ten heavy metals by Corchorus olitorius L. cultivated in soil mixed with sewage sludge. Food and Energy Security, 9, 1-13. doi: 10.1002/fes3.203

Elmi A, Al-Khaldy A and AlOlayan M, 2020. Sewage sludge land application: Balancing act between agronomic benefits and environmental concerns. Journal of Cleaner Production, 250, 119512. doi: 10.1016/j.jclepro.2019.119512

Ercilla-Montserrat M, Muñoz P, Montero JI, Gabarrell X and Rieradevall J, 2018. A study on air quality and heavy metals content of urban food produced in a Mediterranean city (Barcelona). Journal of Cleaner Production, 195, 385-395. doi: 10.1016/j.jclepro.2018.05.183

Fan Y, Li H, Xue Z, Zhang Q and Cheng F, 2017. Accumulation characteristics and potential risk of heavy metals in soil-vegetable system under greenhouse cultivation condition in Northern China. Ecological Engineering, 102, 367-373. doi: 10.1016/j.ecoleng.2017.02.032

Fan Y, Zhang Y, Chen Z, Wang X and Huang B, 2021. Comprehensive assessments of soil fertility and environmental quality in plastic greenhouse production systems. Geoderma, 385, 114899. doi: 10.1016/j.geoderma.2020.114899

Gao PP, Xue PY, Dong JW, Zhang XM, Sun HX, Geng LP, Luo SX, Zhao JJ and Liu WJ, 2020. Contribution of PM2.5-Pb in atmospheric fallout to Pb accumulation in Chinese cabbage leaves via stomata. Journal of Hazardous Materials, In press. doi: 10.1016/j.jhazmat.2020.124356

Gebeyehu HR and Bayissa LD, 2020. Levels of heavy metals in soil and vegetables and associated health risks in Mojo area, Ethiopia. PLoS ONE, 15, 1-22. doi: 10.1371/journal.pone.0227883

Gupta N, Yadav KK, Kumar V, Kumar S, Chadd RP and Kumar A, 2019. Trace elements in soil-vegetables interface: Translocation, bioaccumulation, toxicity and amelioration - A review. Science of the Total Environment, 651, 2927-2942. doi: 10.1016/j.scitotenv.2018.10.047

Gupta N, Yadav KK, Kumar V, Krishnan S, Kumar S, Nejad ZD, Majeed Khan MA and Alam J, 2021. Evaluating heavy metals contamination in soil and vegetables in the region of North India: Levels, transfer and potential human health risk analysis. Environmental Toxicology and Pharmacology, 82, 103563. doi: 10.1016/j.etap.2020.103563

Hamid Y, Tang L, Sohail MI, Cao X, Hussain B, Aziz MZ, Usman M, He Z li and Yang X, 2019. An explanation of soil amendments to reduce cadmium phytoavailability and transfer to food chain. Science of the Total Environment, 660, 80-96. doi: 10.1016/j.scitotenv.2018.12.419

Hanfi MY, Mostafa MYA, and Zhukovsky M V., 2020. Heavy metal contamination in urban surface sediments: sources, distribution, contamination control, and remediation. Environmental Monitoring and Assessment, 192, 1-21. doi: 10.1007/s10661-019-7947-5

Hernandez-Ramirez AG, Martinez-Tavera E, Rodriguez-Espinosa PF, Mendoza-Pérez JA, Tabla-Hernandez J, Escobedo-Urías DC, Jonathan MP and Sujitha SB, 2019. Detection, provenance and associated environmental risks of water quality pollutants during anomaly events in River Atoyac, Central Mexico: A real-time monitoring approach. Science of the Total Environment, 669, 1019-1032. doi: 10.1016/j.scitotenv.2019.03.138

Hou S, Zheng N, Tang L, Ji X and Li Y, 2019. Effect of soil pH and organic matter content on heavy metals availability in maize (*Zea mays* L.) rhizospheric soil of non-ferrous metals smelting area. Environmental Monitoring and Assessment, 191, 1-10. doi: 10.1007/s10661-019-7793-5

Hu W, Huang B, Tian K, Holm PE and Zhang Y, 2017. Heavy metals in intensive greenhouse vegetable production systems along Yellow Sea of China: Levels, transfer and health risk. Chemosphere, 167, 82-90. doi: 10.1016/j.chemosphere.2016.09.122

Hu W, Wang H, Dong L, Huang B, Borggaard OK, Bruun Hansen HC, He Y, and Holm PE, 2018. Source identification of heavy metals in peri-urban agricultural soils of southeast China: An integrated approach. Environmental Pollution, 237, 650-661. doi: 10.1016/j.envpol.2018.02.070

Huang H, Rizwan M, Li M, Song F, Zhou S, He X, Ding R, Dai Z, Yuan Y, Cao M, Xiong S and Tu S, 2019. Comparative efficacy of organic and inorganic silicon fertilizers on antioxidant response, Cd/Pb accumulation and health risk assessment in wheat (*Triticum aestivum* L.). Environmental Pollution, 255, 1-9. doi: 10.1016/j.envpol.2019.113146

Huang L, Wang Q, Zhou Q, Ma L, Wu Y, Liu Q, Wang S and Feng Y, 2020. Cadmium uptake from soil and transport by leafy vegetables: A meta-analysis. Environmental Pollution, 264, 1-10. doi: 10.1016/j.envpol.2020.114677

Hussain B, Ashraf MN, Shafeeq-ur-Rahman, Abbas A, Li J and Farooq M, 2021. Cadmium stress in paddy fields: Effects of soil conditions and remediation strategies. Science of the Total Environment, 754, 142188. doi: 10.1016/j.scitotenv.2020.142188

Jafari A, Kamarehie B, Ghaderpoori M, Khoshnamvand N and Birjandi M, 2018. The concentration data of heavy metals in Iranian grown and imported rice and human health hazard assessment. Data in Brief, 16, 453-459. doi: 10.1016/j.dib.2017.11.057

Jia HL, Wang XH, Wei T, Wang M, Liu X, Hua L, Ren XH, Guo JK and Li J, 2021. Exogenous salicylic acid regulates cell wall polysaccharides synthesis and pectin methylation to reduce Cd accumulation of tomato. Ecotoxicology and Environmental Safety, 207, 111550. doi: 10.1016/j.ecoenv.2020.111550

Joseph L, Jun BM, Flora JRV, Park CM and Yoon Y, 2019. Removal of heavy metals from water sources in the developing world using low-cost materials: A review. Chemosphere, 229, 142-159. doi: 10.1016/j.chemosphere.2019.04.198

Kalkhajeh KY, Huang B, Hu W, Ma C, Gao H, Thompson ML and Bruun Hansen HC, 2021. Environmental soil quality and vegetable safety under current greenhouse vegetable production management in China. Agriculture, Ecosystems and Environment, 307, 107230. doi: 10.1016/j.agee.2020.107230

Kaninga B, Chishala BH, Maseka KK, Sakala GM, Young SD, Lark RM, Tye A, Hamilton EM, Gardner A and Watts MJ, 2020. Do soil amendments used to improve agricultural productivity have consequences for soils contaminated with heavy metals? Heliyon, 6, e05502. doi: 10.1016/j.heliyon.2020.e05502

Kayembe JM, Sivalingam P, Salgado CD, Maliani J, Ngelinkoto P, Otamonga JP, Mulaji CK, Mubedi JI and Poté J, 2018. Assessment of water quality and time accumulation of heavy metals in the sediments of tropical urban rivers: Case of Bumbu River and Kokolo Canal, Kinshasa City, Democratic Republic of the Congo. Journal of African Earth Sciences, 147, 536-543. doi: 10.1016/j.jafrearsci.2018.07.016

Khan A, Khan S, Khan MA, Aamir M, Ullah H, Nawab J, Rehman IU and Shah J, 2019. Heavy metals effects on plant growth and dietary intake of trace metals in vegetables cultivated in contaminated soil. International Journal of Environmental Science and Technology, 16, 2295-2304. doi: 10.1007/s13762-018-1849-x

Kumar S, Prasad S, Yadav KK, Shrivastava M, Gupta N, Nagar S, Bach QV, Kamyab H, Khan SA, Yadav S and Malav LC, 2019a. Hazardous heavy metals contamination of vegetables and food chain: Role of sustainable remediation approaches - A review. Environmental Research, 179, 108792. doi: 10.1016/j.envres.2019.108792

Kumar V, Thakur RK and Kumar P, 2019b. Assessment of heavy metals uptake by cauliflower (Brassica oleracea var. botrytis) grown in integrated industrial effluent irrigated soils: A prediction modeling study. Scientia Horticulturae, 257, 1-10. doi: 10.1016/j.scienta.2019.108682

Kumar V, Pandita S, Singh Sidhu GP, Sharma A, Khanna K, Kaur P, Bali AS, and Setia R, 2021. Copper bioavailability, uptake, toxicity and tolerance in plants: A comprehensive review. Chemosphere, 262, 127810. doi: 10.1016/j.chemosphere.2020.127810

Li Y, Wang S, Nan Z, Zang F, Sun H, Zhang Q, Huang W and Bao L, 2019. Accumulation, fractionation and health risk assessment of fluoride and heavy metals in soil-crop systems in northwest China. Science of the Total Environment, 663, 307-314. doi: 10.1016/j.scitotenv.2019.01.257

Li G, Shah AA, Khan WU, Yasin NA, Ahmad A, Abbas M, Ali A, and Safdar N, 2021a. Hydrogen sulfide mitigates cadmium induced toxicity in Brassica rapa by modulating physiochemical attributes, osmolyte metabolism and antioxidative machinery. Chemosphere, 263, 127999. doi: 10.1016/j.chemosphere.2020.127999

Li Z, Mei X, Li T, Yang S, Qin L, Li B, and Zu Y, 2021b. Effects of calcium application on activities of membrane transporters in Panax notoginseng under cadmium stress. Chemosphere, 262, 127905. doi: 10.1016/j.chemosphere.2020.127905

Liao J, Wen Z, Ru X, Chen J, Wu H and Wei C, 2016. Distribution and migration of heavy metals in soil and crops affected by acid mine drainage: Public health implications in Guangdong Province, China. Ecotoxicology and Environmental Safety, 124, 460-469. doi: 10.1016/j.ecoenv.2015.11.023

Liu B, Ai S, Naeem S, Ding J, Ji W and Zhang Y, 2018. Metal bioaccessibility in a wastewater irrigated soil-wheat system and associated human health risks: Implications for regional thresholds. Ecological Indicators, 94, 305-311. doi: 10.1016/j.ecolind.2018.06.054

Liu P, Hu W, Tian K, Huang B, Zhao Y, Wang X, Zhou Y, Shi B, Kwon BO, Choi K, Ryu J, Chen Y, Wang T and Khim JS, 2020. Accumulation and ecological risk of heavy metals in soils along the coastal areas of the Bohai Sea and the Yellow Sea: A comparative study of China and South Korea. Environment International, 137, 1-12. doi: 10.1016/j.envint.2020.105519

Lizarazo MF, Herrera CD, Celis CA, Pombo LM, Teheran AA, Pineros LG, Forero SP, Velandia JR, Díaz FE, Andrade WA and Rodriguez OE, 2020. Heliyon contamination of staple crops by heavy metals in Sibat e , Colombia. Heliyon, 6, 1-10. doi: 10.1016/j.heliyon.2020.e04212

Luo W, Zhang N, Li Z, Xu Z, Wang D, Liao G, Pang G, Xu G, Wang Y, Huang X, Chen D, Zeng C and Du Z, 2021. Increasement of Cd adsorption capacity of rice stubble from being alive until death in a modified rice-fish system. Ecotoxicology and Environmental Safety, 111441. doi: 10.1016/j.ecoenv.2020.111441

Ma L, Liu Y, Wu Y, Wang Q, Sahito ZA, Zhou Q, Huang L, Li T and Feng Y, 2021. The effects and health risk assessment of cauliflower co-cropping with *Sedum alfredii* in cadmium contaminated vegetable field. Environmental Pollution, 268, 115868. doi: 10.1016/j.envpol.2020.115869

Magwaza ST, Magwaza LS, Odindo AO, and Mditshwa A, 2020. Hydroponic technology as decentralised system for domestic wastewater treatment and vegetable production in urban agriculture: A review. Science of the Total Environment, 698, 1-13. doi: 10.1016/j.scitotenv.2019.134154

Mahmood A, Mahmoud AH, El-Abedein AIZ, Ashraf A and Almunqedhi BMA, 2020. A comparative study of metals concentration in agricultural soil and vegetables irrigated by wastewater and tube well water. Journal of King Saud University - Science, 32, 1861-1864. doi: 10.1016/j.jksus.2020.01.031

Margenat A, Matamoros V, Díez S, Cañameras N, Comas J and Bayona JM, 2019. Occurrence and human health implications of chemical contaminants in vegetables grown in peri-urban agriculture. Environment International, 124, 49-57. doi: 10.1016/j.envint.2018.12.013

Martínez-Cortijo J, and Ruiz-Canales A, 2018. Effect of heavy metals on rice irrigated fields with waste water in high pH Mediterranean soils: The particular case of the Valencia area in Spain. Agricultural Water Management, 210, 108–123. doi: 10.1016/j.agwat.2018.07.037

Mawia AM, Hui S, Zhou L, Li H, Tabassum J, Lai C, Wang J, Shao G, Wei X, Tang S, Luo J, Hu S and Hu P, 2020. Inorganic arsenic toxicity and alleviation strategies in rice. Journal of Hazardous Materials, In press.

Muhammad S, Ullah R and Jadoon IAK, 2019. Heavy metals contamination in soil and food and their evaluation for risk assessment in the Zhob and Loralai valleys, Baluchistan province, Pakistan. Microchemical Journal, 149, 1-7. doi: 10.1016/j.microc.2019.103971

Mwesigye AR, Young SD, Bailey EH and Tumwebaze SB, 2019. Uptake of trace elements by food crops grown within the Kilembe copper mine catchment, Western Uganda. Journal of Geochemical Exploration, 207, 1-8. doi: 10.1016/j.gexplo.2019.106377

Noh K, Thi LT and Jeong BR, 2019. Particulate matter in the cultivation area may contaminate leafy vegetables with heavy metals above safe levels in Korea. Environmental Science and Pollution Research, 26, 25762-25774. doi: 10.1007/s11356-019-05825-4

Nzediegwu C, Prasher S, Elsayed E, Dhiman J, Mawof A and Patel R, 2019. Effect of biochar on heavy metal accumulation in potatoes from wastewater irrigation. Journal of Environmental Management, 232, 153-164. doi: 10.1016/j.jenvman.2018.11.013

Nzediegwu C, Prasher S, Elsayed E, Dhiman J, Mawof A and Patel R, 2020. Impact of soil biochar incorporation on the uptake of heavy metals present in wastewater by spinach plants. Water, Air and Soil Pollution, 231, 1-19. doi: 10.1007/s11270-020-04512-2

Obiora SC, Chukwu A, Chibuike G and Nwegbu AN, 2019. Potentially harmful elements and their health implications in cultivable soils and food crops around lead-zinc mines in Ishiagu, Southeastern Nigeria. Journal of Geochemical Exploration, 204, 289-296. doi: 10.1016/j.gexplo.2019.06.011

Ouyang J, Liu Z, Zhang L, Wang Y and Zhou L, 2020. Analysis of influencing factors of heavy metals pollution in farmland-rice system around a uranium tailings dam. Process Safety and Environmental Protection, 139, 124-132. doi: 10.1016/j.psep.2020.04.003

Pariyar S and Noga G, 2018. Rainfall does not impair particulate matter accumulation on peri-urban field crops, but improves photosynthetic activity at UV exposure. Environmental and Experimental Botany, 156, 288-297. doi: 10.1016/j.envexpbot.2018.09.019

Peng CY, Zhu XH, Hou RY, Ge GF, Hua RM, Wan XC and Cai HM, 2018. Aluminum and Heavy Metal Accumulation in Tea Leaves: An Interplay of Environmental and Plant Factors and an Assessment of Exposure Risks to Consumers. Journal of Food Science, 83, 1165–1172. doi: 10.1111/1750-3841.14093

Peng M, Zhao C, Ma H, Yang Zhongfang, Yang K, Liu F, Li K, Yang Zheng, Tang S, Guo F, Liu X and Cheng H, 2020. Heavy metal and Pb isotopic compositions of soil and maize from a major agricultural area in Northeast China: Contamination assessment and source apportionment. Journal of Geochemical Exploration, 208, 1-10. doi: 10.1016/j.gexplo.2019.106403

Poustie A, Yang Y, Verburg P, Pagilla K and Hanigan D, 2020. Reclaimed wastewater as a viable water source for agricultural irrigation: A review of food crop growth inhibition and promotion in the context of environmental change. Science of the Total Environment, 739, 1-12. doi: 10.1016/j.scitotenv.2020.139756

Qin G, Niu Z, Yu J, Li Z, Ma J and Xiang P, 2021a. Soil heavy metal pollution and food safety in China: Effects, sources and removing technology. Chemosphere, 267, 129205. doi: 10.1016/j.chemosphere.2020.129205

Qin J, Niu A, Liu Y and Lin C, 2021b. Arsenic in leafy vegetable plants grown on mine water-contaminated soils: Uptake, human health risk and remedial effects of biochar. Journal of Hazardous Materials, 402, 123488. doi: 10.1016/j.jhazmat.2020.123488

Qureshi AS, Hussain MI, Ismail S and Khan QM, 2016. Evaluating heavy metal accumulation and potential health risks in vegetables irrigated with treated wastewater. Chemosphere, 163, 54-61. doi: 10.1016/j.chemosphere.2016.07.073

Rai PK, Lee SS, Zhang M, Tsang YF and Kim KH, 2019. Heavy metals in food crops: Health risks, fate, mechanisms, and management. Environment International, 125, 365-385. doi: 10.1016/j.envint.2019.01.067

Rehman ur K, Bukhari SM, Andleeb S, Mahmood A, Erinle KO, Naeem MM and Imran Q, 2019. Ecological risk assessment of heavy metals in vegetables irrigated with groundwater and wastewater: The particular case of Sahiwal district in Pakistan. Agricultural Water Management, 226, 1-7. doi: 10.1016/j.agwat.2019.105816

Rehman AU, Nazir S, Irshad R, Tahir K, ur Rehman K, Islam RU and Wahab Z, 2020. Toxicity of heavy metals in plants and animals and their uptake by magnetic iron oxide nanoparticles. Journal of Molecular Liquids, 321, 114455. doi: 10.1016/j.molliq.2020.114455

Rezaeian M, Tohidi Moghadam M, Kiaei MM and Mahmuod

Zadeh H, 2020. The effect of heavy metals on the nutritional value of Alfalfa: comparison of nutrients and heavy metals of Alfalfa (*Medicago sativa*) in industrial and non-industrial areas. Toxicological Research, 36, 183-193. doi: 10.1007/s43188-019-00012-6

Rezapour S, Atashpaz B, Moghaddam SS and Damalas CA, 2019. Heavy metal bioavailability and accumulation in winter wheat (*Triticum aestivum* L.) irrigated with treated wastewater in calcareous soils. Science of the Total Environment, 656, 261-269. doi: 10.1016/j.scitotenv.2018.11.288

Rizwan MS, Imtiaz M, Zhu J, Yousaf B, Hussain M, Ali L, Ditta A, Zahid Ihsan M, Huang G, Ashraf M and Hu H, 2021. Immobilization of Pb and Cu by organic and inorganic amendments in contaminated soil. Geoderma, 385, 114803. doi: 10.1016/j.geoderma.2020.114803

Ruszkiewicz JA, Tinkov AA, Skalny A V., Siokas V, Dardiotis E, Tsatsakis A, Bowman AB, da Rocha JBT and Aschner M, 2019. Brain diseases in changing climate. Environmental Research, 177, 108637. doi: 10.1016/j.envres.2019.108637

Sabeen M, Mahmood Q, Ahmad Bhatti Z, Faridullah, Irshad M, Bilal M, Hayat MT, Irshad U, Ali Akbar T, Arslan M and Shahid N, 2020. Allium cepa assay based comparative study of selected vegetables and the chromosomal aberrations due to heavy metal accumulation. Saudi Journal of Biological Sciences, 27, 1368-1374. doi: 10.1016/j.sjbs.2019.12.011

Sagbara G, Zabbey N, Sam K and Nwipie GN, 2020. Heavy metal concentration in soil and maize (*Zea mays* L.) in partially reclaimed refuse dumpsite 'borrow-pit' in Port Harcourt, Nigeria. Environmental Technology and Innovation, 18, 1-12. doi: 10.1016/j.eti.2020.100745

Samiee F, Vahidinia A, Taravati Javad M and Leili M, 2019. Exposure to heavy metals released to the environment through breastfeeding: A probabilistic risk estimation. Science of the Total Environment, 650, 3075-3083. doi: 10.1016/j.scitotenv.2018.10.059

Sayo S, Kiratu JM and Nyamato GS, 2020. Heavy metal concentrations in soil and vegetables irrigated with sewage effluent: A case study of Embu sewage treatment plant, Kenya. Scientific African, 8, 1-8. doi: 10.1016/j.sciaf.2020.e00337

Sharma S, Nagpal AK and Kaur I, 2018. Heavy metal contamination in soil, food crops and associated health risks for residents of Ropar wetland, Punjab, India and its environs. Food Chemistry, 255, 15-22. doi: 10.1016/j.foodchem.2018.02.037

Sharma A and Nagpal AK, 2020. Contamination of vegetables with heavy metals across the globe: hampering food security goal. Journal of Food Science and Technology, 57, 391-403. doi: 10.1007/s13197-019-04053-5

Sharma P, Tripathi S, Vadakedath N and Chandra R, 2020. *In-situ* toxicity assessment of pulp and paper industry wastewater on *Trigonella foenum-graecum* L: Potential source of cytotoxicity and chromosomal damage. Environmental Technology & Innovation, 101251. doi: 10.1016/j.eti.2020.101251

Skiba E and Wolf WM, 2019. Cerium Oxide Nanoparticles Affect Heavy Metals Uptake by Pea in a Divergent Way than Their Ionic and Bulk Counterparts. Water, Air, and Soil Pollution, 230, 1-13. doi: 10.1007/s11270-019-4296-5

Song T, Das D, Hu Q, Yang F and Zhang J, 2021. Alternate wetting and drying irrigation and phosphorus rates affect grain yield and quality and heavy metal accumulation in rice. Science of the Total Environment, 752, 141862. doi: 10.1016/j.scitotenv.2020.141862

Souri MK, Hatamian M and Tesfamariam T, 2019. Plant growth stage influences heavy metal accumulation in leafy vegetables of garden cress and sweet basil. Chemical and Biological Technologies in Agriculture, 6, 1-7. doi: 10.1186/s40538-019-0170-3

Świątek B, Woś B, Gruba P and Pietrzykowski M, 2019. Bioaccumulation of heavy metals (Pb, Cd, Cr, Cu) in fine roots under three species of alders (*Alnus* spp.) plantation at different soil substrates addition on the reclaimed combustion wastes landfill. Water, Air and Soil Pollution, 230, 1-10. doi: 10.1007/s11270-019-4350-3

Taghipour M and Jalali M, 2019. Impact of some industrial solid wastes on the growth and heavy metal uptake of cucumber (*Cucumis sativus* L.) under salinity stress. Ecotoxicology and Environmental Safety, 182, 1-11. doi: 10.1016/j.ecoenv.2019.06.030

Torres-Cruz TJ, Hesse C, Kuske CR and Porras-Alfaro A, 2018. Presence and distribution of heavy metal tolerant fungi in surface soils of a temperate pine forest. Applied Soil Ecology, 131, 66-74. doi: 10.1016/j.apsoil.2018.08.001

Ugulu I, Akhter P, Iqbal Z, Akhtar M and Ahmad K, 2021. Trace metal accumulation in pepper (*Capsicum annuum* L .) grown using organic fertilizers and health risk assessment from consumption. Food Research International, 140, 109992. doi: 10.1016/j.foodres.2020.109992

Utete B and Fregene BT, 2020. Assessing the spatial and temporal variability and related environmental risks of toxic metals in Lake Asejire, south-western Nigeria. Scientific African, 7, 1-15. doi: 10.1016/j.sciaf.2019.e00259

Vareda JP, Valente AJM and Durães L, 2019. Assessment of heavy metal pollution from anthropogenic activities and remediation strategies: A review. Journal of Environmental Management, 246, 101-118. doi: 10.1016/j.jenvman.2019.05.126

Waheed S, Ahmad R, Irshad M, Khan SA, Mahmood Q and Shahzad M, 2021. Ca2SiO4 chemigation reduces cadmium localization in the subcellular leaf fractions of spinach (*Spinacia oleracea* L.) under cadmium stress. Ecotoxicology and Environmental Safety, 207, 111230. doi: 10.1016/j.ecoenv.2020.111230

Wang J, Yi X, Cui J, Chang Y, Yao D, Zhou D, Yang J, Zhou J, Chan A, Wang W and Yin X, 2019a. Nonlinear effects of increasing nitrogen deposition on rice growth and heavy metal uptake in a red soil ecosystem of southeastern China. Science of the Total Environment, 670, 1060-1067. doi: 10.1016/j.scitotenv.2019.03.245

Wang S, Wu W and Liu F, 2019b. Assessment of the human health risks of heavy metals in nine typical areas. Environmental Science and Pollution Research, 26, 12311-12323. doi: 10.1007/s11356-018-04076-z

Wang X, Gao P, Li D, Liu J, Yang N, Gu W, He X and Tang

W, 2019c. Risk assessment for and microbial community changes in Farmland soil contaminated with heavy metals and metalloids. Ecotoxicology and Environmental Safety, 185, 1-12. doi: 10.1016/j.ecoenv.2019.109685

Wang H, Li X, Chen Y, Li Z, Hedding DW, Nel W, Ji J and Chen J, 2020a. Geochemical behavior and potential health risk of heavy metals in basalt-derived agricultural soil and crops: A case study from Xuyi County, eastern China. The Science of the Total Environment, 729, 139058. doi: 10.1016/j.scitotenv.2020.139058

Wang L, Zou R, Li YC, Tong Z, You M, Huo W, Chi K and Fan H, 2020b. Effect of Wheat-Solanum nigrum L. intercropping on Cd accumulation by plants and soil bacterial community under Cd contaminated soil. Ecotoxicology and Environmental Safety, 206, 111383. doi: 10.1016/j.ecoenv.2020.111383

Wang G, Zhang Q, Du W, Lin R, Li J, Ai F, Yin Y, Ji R, Wang X and Guo H, 2021. *In-situ* immobilization of cadmium-polluted upland soil: A ten-year field study. Ecotoxicology and Environmental Safety, 207, 111275. doi: 10.1016/j.ecoenv.2020.111275

Weber AM, Mawodza T, Sarkar B, and Menon M, 2019. Assessment of potentially toxic trace element contamination in urban allotment soils and their uptake by onions: A preliminary case study from Sheffield, England. Ecotoxicology and Environmental Safety, 170, 156-165. doi: 10.1016/j.ecoenv.2018.11.090

Wei R, Wang X, Tang W, Yang Y, Gao Y, Zhong H and Yang L, 2020. Bioaccumulations and potential human health risks assessment of heavy metals in ppk-expressing transgenic rice. Science of the Total Environment, 710, 136496. doi: 10.1016/j.scitotenv.2020.136496

Wu Jiahui, Song Q, Zhou J, Wu Y, Liu X, Liu J, Zhou L, Wu Z, and Wu W, 2021a. Cadmium threshold for acidic and multi-metal contaminated soil according to *Oryza sativa* L. Cadmium accumulation: Influential factors and prediction model. Ecotoxicology and Environmental Safety, 208, 111420. doi: 10.1016/j.ecoenv.2020.111420

Wu J, Zhou Q, Huang R, Wu K and Li Z, 2021b. Contrasting impacts of mobilisation and immobilisation amendments on soil health and heavy metal transfer to food chain. Ecotoxicology and Environmental Safety, 209, 111836. doi: 10.1016/j.ecoenv.2020.111836

Yuan Z, Luo T, Liu X, Hua H, Zhuang Y, Zhang X, Zhang L, Zhang Y, Xu W and Ren J, 2019. Tracing anthropogenic cadmium emissions: From sources to pollution. Science of the Total Environment, 676, 87-96. doi: 10.1016/j.scitotenv.2019.04.250

Zaanouni N, Gharssallaoui M, Eloussaief M and Gabsi S, 2018. Heavy metals transfer in the olive tree and assessment of food contamination risk. Environmental Science and Pollution Research, 25, 18320-18331. doi: 10.1007/s11356-018-1474-8

Zhang Yuenan, Zhang Yujie, Akakuru OU, Xu X and Wu A, 2021. Research progress and mechanism of nanomaterials-mediated in-situ remediation of cadmium-contaminated soil : A critical review. Journal of Environmental Science, 104, 351–364. doi: 10.1016/j.jes.2020.12.021

Zhou X, Zheng N, Su C, Wang J and Soyeurt H, 2019a. Relationships between Pb, As, Cr, and Cd in individual cows' milk and milk composition and heavy metal contents in water, silage, and soil. Environmental Pollution, 255, 1-7. doi: 10.1016/j.envpol.2019.113322

Zhou Y, Jia Z, Wang J, Chen L, Zou M, Li Y and Zhou S, 2019b. Heavy metal distribution, relationship and prediction in a wheat-rice rotation system. Geoderma, 354, 1-11. doi: 10.1016/j.geoderma.2019.113886

Zwolak A, Sarzyńska M, Szpyrka E and Stawarczyk K, 2019. Sources of soil pollution by heavy metals and their accumulation in vegetables: a Review. Water, Air, and Soil Pollution, 230, 1-9. doi: 10.1007/s11270-019-4221-y