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HEAVY METALS IN FOOD CROPS: IDEAL SOURCES AND ROLES OF URBAN AGRICULTURE IN FACILITATING THEIR CONSUMPTION- A REVIEW

[*1]Abdullahi. N., [2]Igwe, E. C., [1]Dandago, M. A. and [3]Umar, N. B.

[1]Department of Food Science and Technology, Kano University of Science and Technology, Wudil, P.M.B 3244, Kano State, Nigeria.
[2]Department of Food Science and Technology, Nnamdi Azikiwe University, PMB 5025, Awka, Anambra State, Nigeria.
[3]Department of Food Science and Technology, Federal Unversity, Dutsin-Ma, PMB 5001, Dutsin-Ma, Katsina State, Nigeria.

[*]Corresponding author's email: nurafst@gmail.com

ABSTRACT
The qualities of agricultural soil and water are diminishing continuously due to the rigorous anthropogenic activities currently stocking the soil with a lot of toxic chemicals including heavy metals. Heavy metals are highly persistent and non-biodegradable, control of their contamination is very tricky to handle. Their presence in soil and water is detrimental to food crops and humans. Various sources of heavy metals contaminants and the role of urban food production on human heavy metal contamination were discussed.Heavy metals have their way into the soil and food crops through wastewater irrigation and production in contaminated soil. The habitual heavy metals contamination sources for food crops are wastewater irrigation, abuse of agrochemicals, production in the contaminated field, atmospheric deposit when foods are exposed to contaminated air, and unethical mining activities. Agricultural soil in urban and peri-urban areas are heavily contaminated with heavy metal due to various anthropogenic activities. Wastewater irrigation intensify the contamination by supplying the soil with more heavy metals. The heavy metals are passed to food during production and subsequently to humans after consumption.

Keywords: chemical contaminant, food safety, food contamination, soil contamination, urban agriculture

INTRODUCTION

Heavy metals (HMs) have their way into the soil and water either through the natural process of rock weathering or through anthropogenic activities such as mining and discharge of industrial waste (Bhagwat, 2019; Edelstein and Ben-Hur, 2018; Islam *et al*., 2019; Xia *et al*., 2021). Climate changes resulted from anthropogenic activities trigger many environmental problems that affect the quantity and quality of water and make a significant impact on food production and human health (Ruszkiewicz *et al*., 2019). The presence of HMs in water and soil increases the risk of food-chain contamination (Saadati *et al*., 2020; Taghipour and Jalali, 2019). HMs are hurtful substances that are highly perseverance and non-biodegradable (Garrigues *et al*., 2019; Liao *et al*., 2016), their presence in food is a threat to human health (Massoud *et al*., 2019) and when consumed can accumulate in different body organs and affect their functions (Ngure and Kinuthia, 2020). HMs have their way into the food during production in metal-contaminated soil (Thakali and Macrae, 2021). The intense presence of HMs in the sewage sludge raised public health and environmental concerns and the insensitive disposal of sewage sludge is gradually becoming a global challenge (Elmi *et al*., 2020; Luo *et al*., 2021; Rizwan *et al*., 2021). Higher concentrations of HMs in agricultural soil account for many structural and physiological disorders that can affect the performance of many agricultural plants (Waheed *et al*., 2021). When consumed by humans, HMs exposed human cell to oxidative stress that lead to cardiovascular disease, developmental and neurological disorders, infertility, diabetes, and renal failure (Paithankar *et al*., 2021).

The two most important resources; soil and water, which human's lives depend on are now the major carrier of HM contaminants. The main causes of food crops HMs contamination are unplanned urbanization, excessive use of natural resources, mining, warfare, climate change debauch industrialization (Pereira *et al*., 2020; Vardhan *et al*., 2019), illicit discharge of sewage andeffluent, abuse of agrochemicals, atmospheric deposit, vehicular release, and fuel combustion (Qin *et al*., 2021). Almost all water bodies are now at risk of HMs contamination including all inland water bodies, oceans, and gulfs (Amira *et al*., 2018). Irrigation water mostly used in developing countries is loaded with HMs (Deng *et al*., 2020). Wastewater irrigation commonly practiced in urban and periurban areas rise the HM levels in agricultural soil and subsequently contaminates food crops and humans (Anjum *et al*., 2021). The incessant use of wastewater for irrigation (Chaoua *et al*., 2019) and excessive use of agrochemical allied are among the major reasons for food crops HM-contamination (Margenat *et al*., 2018).

Many farmers understand the dangers of using contaminated water in food production (Maleksaeidi *et al*., 2018) but have no concern about the consequences of their activities on the soil and water safety and humans health (Shaharoona *et al*., 2019). Water scarcity, poverty, and the pressing need for sufficient food production necessitate the use of contaminated water in food production (Inyinbor *et al*., 2019; Turan *et al*., 2018). Many farmers opt to use contaminated water because is the only available source they can afford (Maleksaeidi *et al*., 2018). The reluctance of food and environmental safety enforcement agencies to impose regulatory measures worsens the situation in many developing countries (Ha *et al*., 2020).

Sources of HMs in Food Crops

Various sources of food crops HMs contamination were reported by researchers, the most common dangerous and hefty sources are associated with humans activities. The contribution of natural sources is quite insignificant. Irrigation with raw industrial and domestic wastewater, excessive use of agrochemicals, contaminated solid waste from municipalities and processing industries, atmospheric deposit from contaminated air, mining, and smelting activities are the main sources of food crop HM contaminants. Microorganisms are among the rare sources of HMs contaminants, water from cyano-bloom lakes can transfer HMs to crops when used for irrigation because bloom-forming cyanobacteria have a high affinity to HMs and can mediate their distribution in lakes (Jia *et al*., 2018).

Waste water irrigation

The global water supply is decreasing due to population growth and climate change, thus, wastewater becomes the cheapest source of water for irrigation worldwide (Christou *et al*., 2016; Mkhinini *et al*., 2020). The practice of wastewater irrigation is more common in developing countries where water scarcity is more severe (Nzediegwu *et al*., 2019). In Europe, policies demanding proper treatment of wastewater before use for agricultural purposes are in place (Deviller *et al*., 2020). Wastewater irrigation exposed agricultural soil to many forms of contaminants including dangerous HMs (Chaoua *et al*., 2019; Inyinbor *et al*., 2019), pathogens, and soil salinization (Ofori *et al*., 2021). Wastewater contains more HMs than water from the canal and tube-well (Anjum *et al*., 2021). Large volumes of wastewater generated through industrial and domestic activities are used for irrigation in urban and suburban areas (Mehmood *et al*., 2019). Excessive use of wastewater over a long time can cause deleterious effects on the ecosystem and subsequently on food safety and human health (Mehmood *et al*., 2019). More damage can occur when the wastewater contains antibiotic residues in addition to HMs (Christou *et al*., 2017).

Wastewater irrigation is the major route for vegetable HMs contamination (Rehman *et al*., 2019). Irrigation using wastewater reduces the metal pressure in the water by transferring metal contaminants to agricultural soil (Cao *et al*., 2018). Continuous utilization of wastewater for irrigation causes gradual accumulation of the HMs in the soil and increases the uptake capacity of the growing vegetables (Sayo *et al*., 2020).

Treatment of mineral-contaminated wastewater is tricky due to the non-biodegradable nature of the minerals and cannot be successfully done using conventional wastewater treatment that removes organic contaminants (Garrigues *et al*., 2019). Economic viability in a large-scale treatment and compliance with the strict requirement are also other challenges (Vareda *et al*., 2019). Therefore, industrial wastewater can contaminate soil and food crops even after treatment (Cao *et al*., 2018). Higher concentrations of HMs were found in recycled industrial effluents (Martínez-Cortijo and Ruiz-Canales, 2018). Deviller *et al*. (2020) raised concern on the efficiency of the treatment methods on the removal of various contaminants and the behavior and fate of the products generated during the process of wastewater treatment that will be recycled for food production. Vegetables irrigated with wastewater treatment plants discard possessed HM concentrations at health risk levels (Chaoua *et al*., 2019). Higher concentrations of Fe, Cu, Cr, and Zn were reported by Qureshi *et al*. (2016) in lettuce, carrot, and radish irrigated with treated municipal wastewater. Trace of Cr was found in vegetables irrigated with treated water from the tannery effluent treatment plant claimed to meet international discharge standards (Alemu *et al*., 2019). Christou *et al*. (2016) also reported traces of Zn, Ni, Cu, and Co in strawberry fruits irrigated with treated wastewater.

Continuous irrigation with treated wastewater stock up the soil with more HMs (Mkhinini *et al*., 2020; Rezapour *et al*., 2019; Sedlacko *et al*., 2020). As the concentration of these metals is growing continuously in the earth's crust (Sun *et al*., 2019), balanced composition and concentration of these metals are created within the crust regardless of depth (Zhu *et al*., 2020). This puts underground water in many areas under threat as the HMs can percolate and contaminate the groundwater (Rehman *et al*., 2019). In addition to HMs, treated wastewater can also contain xenobiotics and nanoparticles which at higher concentrations hinder the growth of many food crops (Poustie *et al*., 2020). HMs uptake by crops irrigated with wastewater depends on the properties of the soil (Ahmad *et al*., 2020), properties of the food crop, nature of the HMs, and physiochemical characteristics of the wastewater (Atamaleki *et al*., 2019).

Nutrient supply, water saving, and reduction in production cost are the major advantages of wastewater irrigation (Anjum *et al*., 2021; Ofori *et al*., 2021). Wastewater can serve as a good source of plant nutrients and organic matter (Chojnacka *et al*., 2020) and it's also the cheapest source of water for irrigation (Mehmood *et al*., 2019). Depending on its source, wastewater can supply crops with certain essential nutrients (Kumar *et al*., 2019), microorganisms, and enzymes (Ahmad *et al*., 2020). Mkhinini *et al*. (2020) claimed that the application of treated wastewater to agricultural soil increases the activities of soil microorganisms. Important nutrients such as nitrogen and phosphorous and rich organic matter can be harvested from the treatment of domestic wastewater (Wielemaker *et al*., 2018). The challenge of phosphorus depletion can be tackled by harvesting the enormous amount of phosphorous in the wastewater (Rufí-Salís *et al*., 2020). Irrigation with municipal wastewater improves soil porosity, soil water transfer rate, and earthworm density (Ababsa *et al*., 2020). Many economic and environmental benefits of using treated municipal wastewater for urban hydroponic farming were reported by Magwaza *et al*. (2020). Hussain *et al*. (2019) reported higher yield in carrot, radish, and spinach irrigated with treated wastewater.

Agricultural inputs

HMs can have their way into the food system through awful agricultural practices; excessive use of pesticides and fertilizers hasten the accumulation of HMs in agricultural soil(Massoud *et al*., 2019). The presence of HMs in vegetables depends on their concentrations in the farm inputs and the application level (Zwolak *et al*., 2019). Rigorous agricultural activities increase HMs bioavailability and favor their uptake by reducing soil pH and increasing its organic matter content (Hu *et al*., 2018). Soil organic matter content rises drastically with the application of manure(Zhen, Jia, *et al*., 2020). Animal manure can serves as a contamination source to food crops (Keeflee *et al*., 2020). Using industrial wastes as fertilizer or in soil amendment also stock soil with dangerous HMs (X. Wang *et al*., 2021).Direct application of biomass to agricultural field can as well increase the soil HMs content (Zhang *et al.*, 2020).

Ridiculous use of agrochemicals and livestock keeping are among the major anthropogenic sources of vegetables HMs contaminants (Sawut *et al*., 2018). Accumulation of HMs in Chinese agricultural soils is also associated with the application of agrochemicals in addition to industrial contaminants (Huang *et al*., 2019). Bi *et al*. (2018) associated higher Hg concentration in the soil of vegetable gardens around Shanghai, China with the application of compound fertilizer. Agricultural soil on the northern coast of the Persian Gulf is classified as "highly polluted" by HMs resulted from the misuse of agrochemicals (Arfaeinia *et al*., 2019).

The use of chemical fertilizers and pesticides was discouraged by Martínez-Cortijo and Ruiz-Canales (2018) due to their contribution to water and soil HMs contamination. Over fertilization in urban agriculture may affect soil quality and contaminate surface and groundwater (Wielemaker *et al*., 2019). Fertilizer applications account for more than 30 % of soil HMs contamination in south-eastern China (Hu *et al*., 2018). Long-term research conducted by Chen *et al*. (2020) in a wheat field revealed that continuous application of phosphorous fertilizer facilitates the accumulation of As, Cd, Pb, and Zn in topsoil and increases the concentrations of Cd and As in the wheat grains. Livestock manure can transfer a large amount of Cu to soil (H. Peng *et al*., 2019). Chicken and cattle manures increase soil HMs content and long-term usage of these manures in a protected vegetable field can stock the soil with more Cd, Zn, Cr, and Cu (Zhen, Jia, *et al*., 2020). Bioleaching of HMs using oxidizing bacteria can lower organic manure HM contents to a safe level (Wei *et al*., 2019). HMs can leach into the soil and surrounding water during chelate-aided phytoremediation if the plant failed to absorb all the activated HMs (Park and Sung, 2020).

Solid wastes

Another important anthropogenic source of HMs is the solid wastes from municipals and industries. These wastes are dump directly into the agricultural field or they are transported to the field by wind or by running water (Lin *et al*., 2018). The contamination of soil through landfills is also becoming rampant (Elbehiry *et al*., 2020). Varieties of solid wastes were reported to contaminate food crops through agricultural soil and water. Industrial activities in the Persian Gulf region extremely contaminated the soil around with dangerous HMs and the HMs concentrations in the region exceed ecological dangerous levels (Arfaeinia *et al*., 2019). Using iron and steel slags in agricultural soil amendment contaminates soil with many HMs including dangerous species such as Ni, Cu, Hg, Zn, Cd, Cr, As, and Pb (X. Wang *et al*., 2021). Micro and nano-scale plastic wastes are also potential carriers of HM contaminants (Rai *et al*., 2021).Ceramic processing waste can contain a high concentration of Cd which is used in the ceramic coating (Zhou *et al*., 2019). Solid waste from ceramic, stone crushing, and sugar processing factories can alter HM contents of soil and increase Cd, Cu, Pb, Ni, and Zn contents in the root, shot, and fruit of cucumber (Taghipour and Jalali, 2019).

A recent troubling source of HM contaminants is electronic waste (e-waste). E-waste is characterized by multiple HMs species, most of which are dangerous (Wu *et al*., 2021). Vegetables and crops produced in the soil around e-waste recycling areas can be contaminated with Zn, Cd, Ni, Cu, and Pb (Yu *et al*., 2019). The soil, surface water, and groundwater in the Guiyu village of Guangdong Province, China are not suitable for agricultural activities due to the HMs leachates from e-waste deposit (Weila Li and Achal, 2020).

Domestic solid wastes can also harbour HMs, Bi *et al*. (2018) reported higher concentrations of Cd, Zn, Pb, Hg, and Cu in the soil near municipal solid waste incineration plant in Shanghai, China. Similarly, dumpsite soil used for agricultural purposes in Sunyani, Ghana is contaminated with Fe, As, Cd, Pb, and Zn (Agbeshie *et al*., 2020). The acidic nature of the solid municipal waste (Sagbara *et al*., 2020) and the higher organic matter will favor HMs uptake by the plant (Liu *et al*., 2020). Leachate from food waste compost also contaminates soil with dangerous HMs either from the foods or from packaging materials (Chu *et al*., 2019).

Atmospheric deposition

The atmospheric deposit of HMs is connected to industrialization, smoke, and other airborne contaminants from vehicular release and heavy industrial machines that are directly discharged into the atmosphere, these contaminants are deposited on the water bodies and soil, or directly on the food crops. China was reported to be the hotspot for HMs atmospheric deposit due to their vigorous industrial activities (J. Wang *et al*., 2019), and this account for about 33 % of their total HMs contamination (Hu *et al*., 2018) while vehicle emission alone is account for 81 % of atmospheric Pb (M. Peng *et al*., 2020). Feng *et al*. (2020) reported that atmospheric deposition is the most common source of Cd, Cu, Pb, and Zn soil contamination in China, and it account for more than 50 % of As, Cd, Cr, Hg, Ni, and Pb contamination in the country (H. Peng *et al*., 2019).

Hydroponic greenhouse agriculture which is now practiced in many cities exposes vegetable crops to the atmospheric deposit of heavy metals and nanoparticles (Sharifan *et al*., 2020). Raw foods sold in an open market can be contaminated from the atmospheric deposit as reported by Nuapia *et al*. (2018) in Kinshasa (Democratic Republic of Congo) and Johannesburg (South Africa).

Mining

Vareda *et al*. (2019) reported that mining activities are among the major source of water and soil HMs contamination. Mining activities can increase the HM contents of the surrounding soil, water, and air (Kicińska and Wikar, 2021). Potential toxic HMs such as Cr and Pb are commonly found in mining areas and can have their way into the human body through the consumption of foods produced in contaminated soil (Khan *et al*., 2020). Zn, As and Ni are the major contaminants in the iron mines (Chung *et al*., 2018). Mining and smelting activities in China continue to be the major contamination sources for Cd and Hg (Huang *et al*., 2019). The concentrations of Pb, Cd, Zn, and Ni in agricultural soil and food produced around the *Migori* gold mining area in Kenya exceed maximum allowable levels (Ngure and Kinuthia, 2020). Coal mining can be a source of Hg, Cd, Zn, and Cu contamination (Sun *et al*., 2019). Limestone mining can contaminate surrounding soil with dangerous levels of Cu, Cr, Ni, Pb, and Zn (Jafari *et al*., 2019). The effect of HMs contamination in mining areas can be beyond the vicinity of the mining zone as the contaminants can be carried away by wind or running water to nearby catchment and contaminate the surrounding soil and water (Mwesigye *et al*., 2019).

The Roles of Urban Agriculture in Food Crops HM-Contamination

The contributions of urban agriculture in supplying city inhabitants with fresh produce (Benis and Ferrão, 2018) at a lower cost (Amos *et al*., 2018) and the provision of a natural-based solution to sustainable urban transformation (Sartison and Artmann, 2020) were appreciated over a long time. Urban agriculture is associated with several social and economic benefits (R. Wielemaker *et al*., 2019) including improvement of urban food security (Song *et al*., 2020). Urban agriculture is expected to provide an abundance of good quality products to the fast urbanizing cities at less or no environmental damage (Zhen, Gao, *et al*., 2020).

Urban agriculture which is considered to be a sustainable way for maintaining the ecological cycle in the cities and instant means for supplying towns with perishable foods is, unfortunately, the detrimental conduit for passing various contaminants into the food cycle (Ferreira *et al*., 2018). The soil in many cities harbour dangerous levels of toxic HMs (Cooper *et al*., 2020). Limited farmland in many cities forces city dwellers to produce foods in contaminated lands including refuse dumpsites (Sagbara *et al*., 2020). Lack of a sufficient amount of clean water for irrigation leads to the used of wastewater in many developing cities (Sayo *et al*., 2020). Vegetable gardens located in urban and peri-urban areas are at risk of been contaminated with dangerous HM from various sources (Bi *et al*., 2018; Hong *et al*., 2019) due to intense industrial activities that are taking place in many cities (Deng *et al*., 2020; Weber *et al*., 2019) which releases tonnes of contaminants (Margenat *et al*., 2018). Atmospheric deposits through fossil fuel combustion and dust from contaminated areas intensify soil contamination in urban areas (Weber *et al*., 2019). A systemic review conducted by Frank *et al*. (2019) in United states showed that the Pb content of the soil in the urban areas is three times higher than in the soil outside cities. Y. Huang *et al*. (2019)also reported low levels of HM contaminations in agricultural fields far away from cities. Vegetables produced in peri-urban areas are more prone to trace elements contaminants when compared with vegetables produce in rural areas (Margenat *et al*., 2019). Even greenhouse produce can be contaminated with HMs(Y. Fan *et al*., 2021), dangerous levels of Cr, Ni, and Pb were reported by (Yuan Fan *et al*., 2017) in the root, leaf, and fruit vegetables produced in the greenhouse. Children Pb contamination via food produced in urban soil greatly surpass contamination through drinking water and other sources (Byers *et al*., 2020).

Urban agriculture is gradually declining in many cities due to water scarcity (Ng *et al*., 2018) and rapid urbanization (Ulm *et al*., 2019) which was projected to rise from 55 % to 68 % by 2050 (Kookana *et al*., 2020). This boost will continue to consume agricultural land, intensify environmental pollution (Tian *et al*., 2019), and pose challenges to food and water security (Kookana *et al*., 2020). Many backyard gardens in cities also fail due to inadequate rainfall and poor irrigation resulted from water scarcity (Amos *et al*., 2018). Depletion in soil nutrient contents and rapid population growth in many urban areas worsen the situation (Magwaza *et al*., 2020). Internal conversion and occupation of lands lead to a decrease in the supply of non-staple foods from urban production (Wenbo Li *et al*., 2019). Inter-agency policies and innovative agriculture are required to maintain food production in the cities (Diehl *et al*., 2020)

Commercial farms which are increasing exponentially in many cities of the developed world (Benis and Ferrão, 2018), innovative urban agriculture which is safer and more productive (Armanda *et al*., 2019), and intelligent irrigation system that can minimize water use by up to 59 % in a sub-humid climate without affecting the crop yield (Mason *et al*., 2019) may replace the traditional urban farming in the future. The practice of rooftop farming in densely populated cities is also another alternative (Safayet *et al*., 2017).

Recommendations and Further Research

- Curtailing the spread of HMs by preventing their movement from contaminated areas to untainted areas by wind or running water. For example, canals carrying contaminated water should be cemented or lined to prevent leaching of HMs into the surrounding soil.
- All anthropogenic activities that are responsible for contaminating the ecosystem with HMs should be tackled and rectified.
- The benefits of using wastewater for irrigation are pretty meagre when compared with the danger which has lasting effects on the soil, food web, and humans health. Wastewater irrigation should be abolished to protect food crops and human health and to prevent contamination of groundwater which occurs in areas with incessant wastewater irrigation.
- Underground water from boreholes, reported to contain low levels of HMs in many places, can be used as a substitute for wastewater in developing countries that cannot afford an expansive treatment system.
- More attention should be given to food safety and environmental contamination, government at different levels and donor organizations are budgeting huge amounts on improving food production efficiency through the provision of improved varieties, interest-free loan, and distribution of farm inputs freely or at a subsidized price. It is hard to sight any bequest on food safety or environmental protection.
- Some findings associated higher HMs in soil and food crops with fertilizer application, hence, farmers should be educated on the proper use of fertilizer.
- Soilless farming prevents uptake from contaminated soil, modern farming should be encouraged in densely populated cities with contaminated soil.
- If possible, farms should be located far away from cities, industrial estate, mining and smelting areas.
- Organic wastes and compost should be neutralized before use as manure since HMs bioavailability and mobility are favoured by low pH and high organic matter.
- The present wastewater treatment technologies are inefficient in removing HMs from wastewater, HMs were reported in different crops irrigated with treated wastewater. There is an urgent need for the development of a wastewater treatment system that can effectively remove HMs from contaminated wastewater at a low cost.
- Researches should be conducted to find the effect and the fates of various wastewater treatment by-products on soil, food crops, and humans health.
- Researches are needed to find out how application of chemical fertilizer increases soil and food HM contents. Preferably, fertilizer and other agrochemicals should not be a source of soil or food crop contamination.
- There is a need for the development of a dust-barrier screen or membrane that will prevent HMs uptake from contaminated air. Using this kind of shield in a greenhouse operated in urban and peri-urban areas will prevent food crops from taken HMs from contaminated air.

CONCLUSION

The contamination is habitually occurring through anthropogenic activities such as discharge of contaminated solid and liquid wastes, mining, abuse of agricultural chemicals, air pollution, and industrial processes such as tanning, dying, and energy and chemical plant operations. Soil and water are the primary victims for the contamination, food crops are in most cases secondary victims, except for the atmospheric deposit. Food crops become contaminated when grown in contaminated soil or irrigated with contaminated water. Food production using HM-contaminated wastewater is a terrible feat due to its negative consequences on the food crops, soil, and groundwater. Vegetables that are produced through irrigation in urban and periurban areas are contaminated with HMs more than any other food crop. Generally, foods produced in the cities and environs are more disposed to HMs contamination than that produced far away from the cities.

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