Heavy metals contamination through consumption of contaminated food crops

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Contamination of food crops by heavy metals (HMs) is a public health concern that is gradually becoming a global challenge. There is rising concern about food safety and human health due to the unceasing release of HMs into the environment by various forms of anthropogenic activities and natural processes. HMs are highly persistent and when they contaminate the food chain a sustainable circle is created in the food web, the metals will be revolving between the environment, food crops and the human body. This article intended to provide an overview of the sources of HMs and their consumption through food crops. The study reviewed relevant literature published online between January 2018 and December 2020. The leading sources of food crop contamination are sewage and industrial effluents, mining, smelting, illicit dumping of solid waste, abuse of agrochemicals, atmospheric deposit and chemical processing. Leafy vegetables in general and wheat grains are the most contaminated food crops. Pb, Cr and Cd were the most reported HMs in food crops in the last three years. The rate of food crops HMs contamination in the last three years was found to be in the following order: Pb>Cd>Cr>As>Zn>Ni>Cu>Mn>Fe>Hg>Co>Al.

Introduction

Food is a basic requirement for life, its safety is a basic right to human (Fung et al., 2018) and food security cannot exist without food safety (Vipham et al., 2020; Sharma and Nagpal, 2020). Food safety, human health and environmental contamination are intimately connected (Rai et al., 2019).

The contamination of food crops by HMs possess a serious challenge to human health (Vatanpour et al., 2020; Zwolak et al., 2019). HMs are potentially harmful substances that are highly persistence and non-biodegradable (Garrigues et al., 2019; Liao et al., 2016), their presence in food can be dangerous to human health (Massoud et al., 2019) and when consumed can accumulate in different body organs (Ngure and Kinuthia, 2020).

The geochemical behaviour and health risk indices of many HMs are not well understood in agro-system (H. Wang et al., 2020). Understanding their effects on human health is even more complicated because of the diversity of their sources and some own some biological functions at minute and regulated quantities (Afonne and Ifediba, 2020). The consequences of environment and food HMs contaminations attracted public attention (L. Wang et al., 2020), meanwhile professionals and regulatory bodies have great concern on the safety of foods since many foods can mask chemicals that a dangerous to human health (Gallo et al., 2020).

Sources of heavy metals

The most common sources of HM to food crops are contaminated sewage and industrial effluents, mining, smelting, illicit solid waste dumping, misused of agrochemicals, atmospheric deposit, rock weathering, traffic pollution and chemical processing such as leather and textile processing wastes (Table 1). The sources identified in this research are very similar to those reported by Sawut et al. (2018), El-Radaideh and Al-Taani (2018) and Zwolak et al. (2019).

In addition to the aforementioned, thermal power plant, e-wastes and electroplating were also reported by Rai et al. (2019). HMs have their ways into soil and food crops through wastewater irrigation and production in contaminated soil. Soil HM concentration significantly increased in recent decades due to the hasty urbanisation and industrialisation (Rai et al., 2019; Hanfi et al., 2020). Irrigation water is contaminated with HMs from natural and anthropogenic sources (M. Deng et al., 2020).

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). Areas with a history of industrial activities possess higher levels of HMs contaminants (J. Peng et al., 2019; Liu et al., 2020) and chances of contamination for both humans and animals are higher in these areas and its environs (Bala et al., 2020). The activities of chemical and mining industries continue to intensify environmental contamination since the inception of the industrial revolution (Saadati et al., 2020). Atmospheric deposit, use of sewage sludge and industrial effluent as fertilization and irrigation with untreated industrial effluent also contributed (Rai et al., 2019). The variation in the HM concentration in different locations is an indicator of anthropogenic activities intensity (S. Sharma et al., 2018), hence, the rate of food crops HMs contamination can, to some extent, be related to the population of a location. China, Pakistan and Nigeria were the most reported nations with the highest levels of food crops metal contamination in recent years (Table 1).

Food Crops HMs Contamination

HMs contamination of food crops is more common in developing nations with limited access to foods and clean water (Shakoor et al., 2017). Most of these countries don’t have established guidelines for regulations of HM concentrations in foods and environments (Edogbo et al., 2020). Nevertheless, the menace is also affecting developed nations (El-Hassanin et al., 2020; Y. Sun et al., 2019). Weber et al. (2019) reported that the Pb, Zn, Cu, As, and Cr contents of the soil in some private vegetable gardens in Sheffield exceed England permissible limits, also the concentration of Mo, Ni, Pb, and As in the soil of gardens around Barcelona exceed Spanish permissible limit (Margenat et al., 2018). Amazingly, illicit waste dumping and burning in agricultural land is still a habit in Giugliano, Italy (Melai et al., 2018). Deviller et al. (2020) also identified shortfalls (that can lead to health and environmental problems) that were not properly addressed by the existing EU regulations on the use of the recycle wastewater for agricultural purposes. Also, many European countries lack definite regulations for wastewater reuse (Chojnacka et al., 2020).

Food crops normally absorb HMs through their roots and in rare cases through the leaves (Edelstein and Ben-Hur, 2018). Transpiration rate, plant species and soil conditions such as pH, organic matter content, temperature, texture, cation exchange capacity, presence of microorganisms and other metals affect bioavailability and mobility of trace elements in the soil (Gupta et al., 2019). HMs can accumulate in food crops and subsequently have their way into the food chain (Rai et al., 2019). Once a food chain is contaminated it will become very difficult to be safe, a sustainable circle is created in the food web where the metals will be revolving between the environment, food crops and the human body (S. Kumar et al., 2019). The contamination can be severe and can rich all the nooks and crannies in the food chain, down to the level of milk production and oil extraction as reported by Samiee et al. (2019) in human breastmilk, X. Zhou et al. (2019) in cow milk and Zaanouni et al. (2018) in olive oil. Even the organic foods which are now considered the safest foods can be contaminated with HMs when off-farm manure is used in their production (Zhen et al., 2020). Nevertheless, Tibu et al. (2019) recommended the use of compost from municipal solid waste in the production of organic vegetables. Likewise, the concentrations Cd and Pb in local and imported organic cereal-based products sold in Thessaloniki, Greece exceed recommended thresholds (Skendi et al., 2020). Abdallah et al. (2020) discovered nanoscale HMs fragments in plants naturally grown in HMs-contaminated soil, similarly, Singh et al. (2018) recommend bio-extraction of HM nanoparticles from the plant.

There is variation in the global distribution of HM (Afonne and Ifediba, 2020). HMs contamination levels varies with location and depend greatly on the HMs properties of the growing locations (Jafari et al., 2018). Ebrahimi-Najafabadi et al. (2019) reported variation in the HM contents between local and imported rice in Iran. Rapid urbanisation and vigorous industrial activities make China the global epicentre for food crops HMs contamination. China reported dangerous levels of HMs in food crops than any other nation in the last three years (Table 1).

HMs Consumption Through Food Crops

Consumption of foods contaminated with HMs presents critical challenges to global food security and human health (Afonne and Ifediba, 2020), it causes complicated health problems including cancers (Yu et al., 2019). Some HMs have no known biological role and can disrupt biological processes even at minute concentrations, and their rate of accumulation in biological tissues is always higher than the rate of excretion (Ngure and Kinuthia, 2020). Other species of HMs such as Co, Cu, Fe, Mn, Ni, Mo, Se and Zn are essential micronutrients and at required concentrations, they play important roles in many biological processes (Giri et al., 2020). HMs with great health worries are As, Cd, Cr, Pb and Hg (Bhagwat, 2019), they can cause severe health problems even in a small quantity (Vardhan et al., 2019). Pb contamination is now a global challenge, it was the most reported HM in food crops, other toxic HMs reported by researchers in recent years were Cr and Cd (Table 1). The data in Table 1 shows that the rate of food crops HMs contamination in the last three years was found to be in the following order: Pb>Cd>Cr>As>Zn>Ni>Cu>Mn>Fe>Hg>Co>Al. Pb, Cd, As and Hg contaminated foods and beverages more than any other HM (Massoud et al., 2019). Cd, As, Cr and Ni are the most consumed HMs with high cancer risks (V. Kumar et al., 2019). Arsenic is the most ingested HM by both children and adults (V. Kumar et al., 2019), while Cd and Pb are the most soluble and mobile HMs (Elmi et al., 2020). Cd and Hg are the potential dangerous HMs due to their bioavailability caused by their high solubility and exchange capability (L. Sun et al., 2019). Cd and Pb are dangerous and cause serious health problems to both humans and livestock even at minute levels (Sharifan et al., 2020). Hg, Pb and Cd are associated with kidney and neural damages (Fung et al., 2018). Arsenic is a chronic carcinogen, and its toxicity can also cause respiratory disorder, skin lesion, diabetes and heart-related diseases (Nachman et al., 2017). Direct consumption of As either through foods or drinking water is considered a life-threatening issue (Shakoor et al., 2017). Mercury in the form of methylmercury can cause severe health problems that can lead to loss of consciousness and death (Reis and Mizusawa, 2019). Food contaminated with Pb, Mn and Cd can lower immunity and affect the functions of vital organs (Obiora et al., 2019) Increase blood Pb level in children damage kidney and lead to the formation of cancer cells (Obiora et al., 2019).

HMs are consumed more through staple foods; cereals and vegetables are the most common carriers (Liu et al., 2019; Yu et al., 2019; Zheng et al., 2020). Lower amounts are consumed through tree-fruits and their nuts (Wu et al., 2019). Y. Huang et al. (2019) reported that vegetables and paddy farms accumulate more HMs than other upland areas. HMs intake through rice consumption is becoming a threat to human health (X. Deng et al., 2020). Contamination of rice is now a global concern and many health problems are associated with the consumption of contaminated rice due to its ability to accumulate dangerous HMs such as As, Cd, Pb, Ni, and Cr among others (Ali et al., 2020; Khanam et al., 2020). Wheat consumption also contributed greatly and account for over 60 % of human health risks (S. Wang et al., 2019). Baruah et al. (2019) reported a higher transfer rate for Pb, Cu and Cd in wheat seedling. Leafy and other vegetables are the most contaminated foods with Pb among all other foods consumed in Northern Italy (Malavolti et al., 2020). Infant foods and vegetables contain more Pb than other food categories in Brazil (Neto et al., 2019). Dangerous levels of different HMs were reported in various food crops by many researchers in different parts of the World. A summary of recent findings reported dangerous levels of HMs were presented in Table 1. Different standards, both local and international, were used by researchers in arbitrating the toxicity levels of different HMs in different food crops. The international standards commonly used as references are the Joint FAO/WHO Food Standards published by Codex Alimentarius Commission in 2001, 2007, 2010, 2011, 2013 and 2016, and European Commission regulations published in 1997 (194/97), 2006 (1881/2006) and 2008 (629/2008).

Recommendations

• Effective monitoring and enforcement of environmental protection laws and the establishment of operational food safety inspection and investigation systems can minimize the consumption of HMs and other food contaminants.

• Massive awareness through socio-environmental campaign can change the attitude of people that are careless about the soil and water safety.

• Sensitisation campaigns to the farmers and other stakeholders in the production chain on the dangers associated with food production on the contaminated field and that of using contaminated water for irrigation will contribute a lot.

• Creating awareness on the danger associated with consuming contaminated food will guide consumers to make a better decision on choosing good quality foods.

• Dangers associated with HMs contamination can be minimised by choosing crops with less metal accumulation capacity and those with low affinity to most dangerous HM species.

• Organic foods are healthier than food produced through conventional agriculture, they contain less HMs and other contaminants, and possess better nutritional qualities.

Conclusion

Vigorous industrial activities, hasty urbanization, poor environmental policy, failure to enforce environmental protection laws, illiteracy, poverty, and food scarcity are among the leading factors that caused HMs contamination in food crops. The leading sources of food crop contamination are sewage and industrial effluents, mining, smelting, illicit dumping of solid waste, abuse of agrochemicals, atmospheric deposit and chemical processing. Leafy vegetables in general and wheat grains are the most contaminated food crops. Pb, Cr and Cd were the most reported HMs in food crops in the last three years. The rate at which food crops are contaminated with HMs in recent years is observed to be in this order: Pb>Cd>Cr>As>Zn>Ni>Cu>Mn>Fe>Hg>Co>Al.

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