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RESEARCH ARTICLE

Heavy metal Accumulation and Contamination of Edible plants irrigated by wastewater in Erbil- Kurdistan Region of Iraq

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ABSTRACT

Heavy metals are important factor for metabolic reaction in edible plants, and also needed by different organs of human body, but their relatively excessive accumulation is hazardous and health risk. Therefore, their concentration in edible plants must be ranged in line, otherwise considered as contaminants. In this study, three edible plants (*E. sativa* Mill., *A. graveolens* L. and *L. Sativum* L.) were harvested and separated to root and shoot parts, then followed by determining some essential and non-essential metals (Pb, Zn, Cd, Cu, Mn and Ni), using ICP-MS. As a result, the maximum mean values for those metals were (46.58 mgPb/kg $_{root}$, 49.85 mgZn/kg $_{root}$, 71 mgMn/kg $_{shoot}$, 5.06 mgCd/kg $_{shoot}$ of *A. graveolens*. And 42 mgCu/kg $_{root}$ and 14.85 mgNi/kg $_{root}$ of *L. sativum*. As a conclusion, these plants in the studied area are not suitable for consumption, due to unacceptable amount of metal contaminants that created from wastewater as the only source of water for irrigation.

Keywords: heavy metals, edible plants, accumulation, wastewater.

1. INTRODUCTION

Heavy metals are metallic chemicals with a relatively high density that are toxic, persistent and hazardous to human health at low concentrations (Sall et al., 2020 and Subha et al., 2007). Heavy metal pollutants cause many threatened disorders, and persistently their presence in food products and edible plants increased due to the urbanization, industrialization, and misuse of lands (UN habitat, 2004). High toxicity of heavy metals, their accumulation in farmland could lead to contamination of agriculture soil Consequently, the contaminated soil adversely affects plant growth and their yield, it also threatened human health as an important base of food chain (Salazar et al. 2012; Zhao et al. 2014).

In general, many of the heavy metals are used by plants to accelerate their metabolic reactions, but the level of metals is toxic in high quantities and the plant is classified as hyper accumulator (Castaňares and Lojka, 2020). Some of the vegetables, cereals, fruits, spices, and aromatic plants and medicinal plants are the edible plants that are as essential part of the human diet and provide essential nutrients, antioxidants, dietary fiber, metabolites, and medicine. Recently, the cultivation of edible plants in urban cities and around the industries, and irrigation by wastewaters on contaminated soil is commercial, then plant reached more contaminants (heavy metal) and their consumption adversely affects different organs of the human body (Kumar et al., 2020).

Despite of heavy metal absorption via inhalation and soil consumption, the edible plants irrigated with untreated wastewater and soil contaminated by fertilizer, or any other chemical pollutants is the most potent source of human exposure by heavy metals (Rai et al., 2019). Consumption of unsafe concentrations of heavy metals in food may lead to the disruption of biological and biochemical processes in the human body (Prabu, 2009). These disorders are characterized by gastrointestinal disorders, stomatitis, tremors, diarrhea, hemoglobinuria, paralysis, vomiting, convulsions, and depression (Jaishankar et al., 2014). Similarly, heavy metals can disrupt metabolic activity and genetic makeup, or to affect embryonic or fetal development (Ali et al., 2013).

Now a day, contaminated soil with hazardous heavy metals concerned as a global issue, due to the potential impact on the environment and human health. Vast portions of farmlands have been contaminated by metals because of the activities of mining, smelting, fossil fuel burning, phosphate fertilizers and sewage sludge (Navarro et al., 2008). On the other hand, most of the countries are depending on wastewater resources for irrigation purposes, and the useful water sources are neither treated nor explored for suitability of such type of water sources (Keraita et al., 2012).

Soil-to-crop transfer of heavy metals is the major pathway of human exposure to heavy metals. An increase in human population has placed a demand for increased food supply. This has resulted in increased use of pesticides, fertilizers, manures, composts, and wastewater for irrigation. Food crops grown in metal-contaminated soil can uptake and accumulate metals in quantities high enough to affect food quality and safety (Muchuweti et al. 2006).

This study was aimed to demonstrate three of the most edible plants among society, and their ability to accumulate excess amount of heavy metal contaminants is threatened to human health. For this purpose, plant harvests were prepared and analyzed to find out the toxicity of those edible plants on human body.

Description of the study area

Erbil City the capital of KRG- in the North of Iraq was selected as the area of the study in this research and due to its hugest edible plant production in Erbil state. The latitude of Erbil, Iraq is 36.191113, and the longitude is 44.009167. Erbil, Iraq is located at Iraq country in the Cities place category with the gps coordinates of 36° 11' 28.0068" N and 44° 0' 33.0012" E, as shown in figure 1.

The farmland extended along the main Erbil wastewater channel from the Turaq is extended to Great Zab River, several villages pumped this type of water (wastewater) for irrigation purpose (Tariq, 2021).

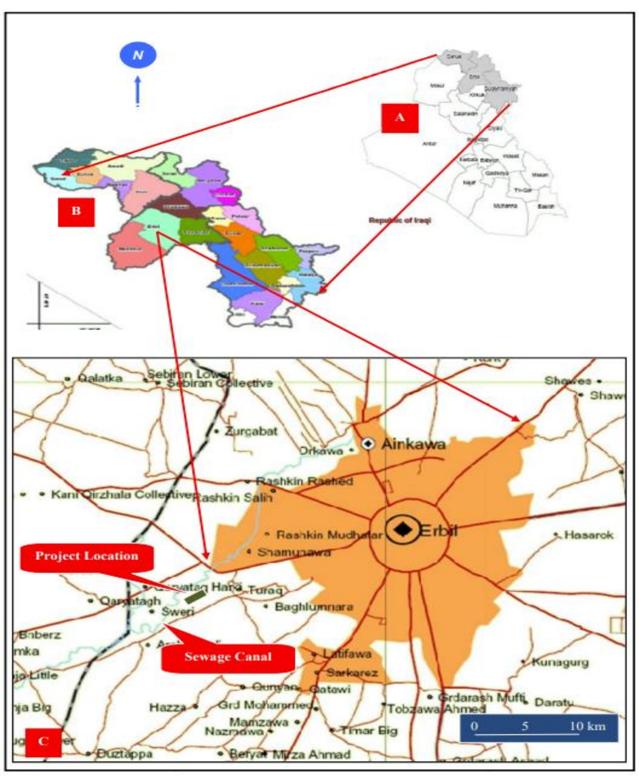

Figure 1: Description of the study area in Erbil City. A: Republic of Iraq. B: Kurdistan Region of Iraq. C: Erbil City, Tureq Village (Site of the project).

2. Materials and Methods

Plant collection and preparation

The three plants normally can be eaten as fresh vegetables during the daily meals, and sometimes cooked. ere randomly collected from a farmland during the edible state (figure 2), the whole-body plant was harvested and sealed with paper bags then directly transferred into the laboratory. Firstly, the whole plant was washed with tap water and distilled water to remove debris and soil particles. Shoot and root parts were separated and grinded, then oven dried at 60°C for about 3 days until constant weight was obtained. Finally, the dried shoot and root parts were powdered by blinding with a high pressure of blinder and kept in clean and dry containers (Azwanida, 2015).

Figure 2: Selected plants during collection. a: E. sativa Mill. b: L. sativum L. c: A. graveolens L.

ICP-MS analysis

Metals in plant parts were digested and analyzed according to Mihaylova et al. (2013) and Singh et al. (2017), respectively, using (FAAS; ICP-MS Model 4500 Elan DRC, Perkin Elmer Company, USA). Briefly, the initial and the final metal concentration in plant parts were determined at the beginning and the end of experiments. The fresh plant samples were oven-dried at 105°C for 10 min to inactivate the activity of enzymes in plants and then kept at 70°C for 4 days to get dried (dry weights were recorded). Plant material was ground in a porcelain mortar and sieved through a 2-mm mesh sieve. About 0.5 g (dw) of plant material was digested in 70% concentrated nitric acid (TraceMetal Grade), and solid impurities were removed using Whatman No. 42 filter paper.

3. Results

Heavy metal accumulation in plants

Lead (Pb)

Lead as a hazardous heavy metal in the environment is highly toxic for human health and many studies revealed the efficient amount of Pb is carcinogenic for human beings. The current study indicates that the highest concentration of Pb was 46.58 mg/kg found in root part of A. graveolens and followed by 37.32 and 7.03 mg/kg in shoot of L. sativum and E. sativa, respectively. It is worthy to note that, the obtained results regarding Pb in this study were much higher than that given by WHO as a maximum accepted value which is 0.3 mg/kg, on the other hand, the lowest value was 4.2 mg/kg in the root system of E. sativa, as shown in figure (3a).

Zinc (Zn)

It is preferred as an essential trace element in human body, and it is applicable for immune response regulation and many other duties. Sometimes the edible plants are undergone high content and surely cause to lead some risks within body. The results indicated that the highest accumulated Zn was noticed in the root system of L. sativum and A. graveolens, their values were 51.4 mg/kg and 48.85 mg/kg, respectively (figure 3b). Whereas Zn concentration in the shoot of E. sativa was 47.01 mg/kg and it was higher than that accumulated in root system (43.94 mg/kg), and the lowest Zn was 43.94 mg/kg.

Cadmium (Cd)

Generally, Cd content in shoot system was higher than that noticed in root system. The highest concentration of Cd was 5.06 mg/kg reported from root system of A. graveolens which is higher than the total concentration of heavy metals in the current study. Moreover, this value is followed by 1.5 mg/kg Cd from shoot of the same plant, and 0.78 mg/kg Cd and 0.63 mg/kg Cd in E. sativa, then 0.51 and 0.28 in L. sativum, as shown in figure (3c). The results revealed that, the three plants toxic and considered to be dangerous form of edible plant, as the Cd content was higher than 0.2 mg/kg as the maximum accepted level by WHO.

Copper (Cu)

More concentration of Cu was noticed in root system of plants, except E. sativa when the value of Cu in shoot was higher than root. The level of mean concentration in root was ordered as; L. sativum > A. graveolens > E. sativa, with the value of 42, 39 and 13 mg/kg, respectively. Whereas the shoot system was ordered as; A. graveolens > E. sativa > L. Sativum, with concentrations of 18.5, 13.5 and 9 mg/kg, respectively (figure 3d). The concentration of Cu in roots of L. sativum and A. graveolens was higher than the accepted level (20 mg/kg).

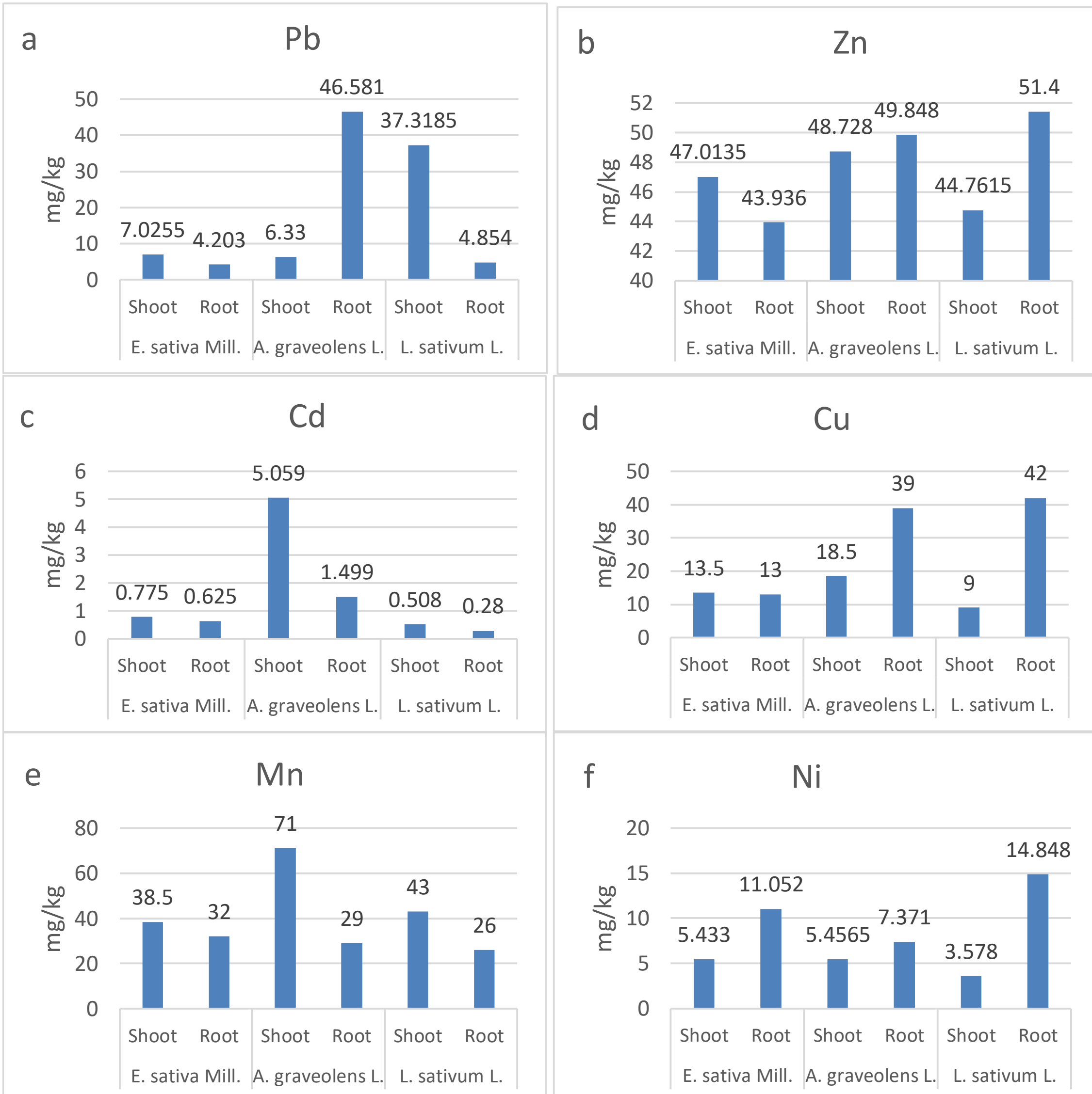

Figure 3:Concentration of heavy metals within shoot and root system of the studied plants (a: Pb, b: Zn, c: Cd, d: Cu, e: Mn, f: Ni).

Manganese (Mn)

The three studied plants were relatively accumulated high concentrations of Mn, particularly in shoot system. On the bases of plant, the level of Mn concentration in shoot was ordered as: A. graveolens > L. sativum > E. sativa, with values 71, 43 and 38.5 mg/kg, as depicted in figure (3e). Maximum value in root system was 32, 29 and 26 mg/kg, with the respects to E. sativa, A. graveolens and L. sativum. Furthermore, Mn in each part of the studied plants were taken up higher than the accepted value (20 mg/kg), which is given by Hochmuth and his colleagues (2004).

Nickel (Ni)

The results revealed that more accumulation occurred in roots, where the concentration of Ni was 14.85, 11.05 and 7.37 mg/kg, and they were ordered in plants as: L. sativum > E. sativa > L. graveolens. While in shoot part the accumulated concentration in E. sativa and L. graveolens was almost the same (5.4mg/kg), and this value was only 3.58 mg/kg for L. sativum (figure 3.f).

The level of the studied heavy metals from different plant parts were ordered as the following: Mn > Zn > Pb > Cu > Ni > Cd.

4. Discussion

Human exposure to heavy metals may occur through various pathways, and edible plants are one of the most popular routes of accumulation within body tissues and blood streams (Luo et al., 2020 and Ametepey et al., 2018). There are several factors to promote soil and water pollution and accelerating chemical pollutants (ex: heavy metals) in plants. Prolonged farming activities involving the use of fertilizers, herbicides and insecticides also contribute to soil pollution. Rapid industrialization has also brought about dangerous pollution of soil by heavy metals in many countries (Makino et al. 2010). The use of contaminated water or untreated wastewater also leads to plant exposure by excess amount of heavy metals and their accumulation within various parts of edible plants, as concluded by (Mengistu, 2021). Thus, the contamination of plants selected in the current study may result as the use of wastewaters. Transferring black wastewater from house wells is also another popular mistake in some farmlands around the current studied area. Moreover, the only water source of the studied plant cultivation is the main wastewater canal of the Erbil City, which is derived from both municipal and industrial wastewater (Shekha and Al-Abaychi, 2011). In this study, the three selected plants were contaminated by the heavy metals, and these results were agreed with the results that revealed by Tariq (2021).

Lead (Pb) is a harmful heavy metal that considered as an environmental pollutant which causes to many threatened problems for human body, particularly; toxicity of the Central Nerve System (CNS) which causes injury and reduction of neuron transportation within adjusted nerve cells, and adversely affect immune function (Boskababy et al., 2018 and Wang et al., 2013). In the current study, Pb content was over the permissible level (0.3 mg/kg). Moreover, indicated that all studied plants were toxic and not suitable for eating by human and other animals. The same finding was revealed by Khalid and Ganjo, (2021), when the N. officinale was able to accumulate more than the accepted level and considered as contaminated edible plant too.

Zinc is evaluated as one of the most important micronutrients, efficiently promoting protein synthesis, energy production and enzyme regulation, and maintains the cell membrane (Randjelovic et al., 2014). It also triggers a vital role in the metabolic and physiological processes of many organisms and important for growth and bone development (Haftu, 2020). However, in this study the highest reported concentration of Zn was lower than the accepted level (99.4 mg/kg), but the plants can be considered as a good source of Zn as an essential metal.

The results of the current study found that cadmium (Cd) availability in the selected plants is considered toxic, the detected concentrations were distinctly higher than the level of acceptance (0.2 mg/km) (FAO/WHO). Accumulation of Cd in body tissues, particularly in kidneys is more popular and causes damage kidneys (Godt et al., 2006).

On the other hand, it can be used for phytoremediation purposes as a good accumulator for surface soil and water contaminated by heavy metals, including cadmium.

Copper (Cu) is an essential metal for human body, at the same time can adversely affect bone, immunity, cardiovascular risk and alters cholesterol metabolism. The availability of Cu in human blood is related to iron toxicity and deficiency (Araya et al., 2007). The current results indicated that, the root system of L. sativum and A. graveolens contained 42 and 39 mg/kg Cu, which were duplicated in comparison to accepted level (20 mg/kg), respectively. However, in E. sativa the mean concentration of Cu was lower than the accepted level, but more translocate in shoot than that accumulated in root system.

Manganese (Mn) is considered as an important micronutrient for growth and development of plants, its availability as a source leads sustainability of metabolic reactions within plant tissues. It is an important regulator for photosynthesis process (Alejandro et al., 2020). The results revealed that, the concentrated Mn in root and shoot in all plants was higher than the accepted level (20 mg/kg). And the Mn in the selected plants was more accumulated in shoot in compared to root system. And the same finding was observed by Hochmuth et al., (2004). This phenomenon might be due to the high potential of the plants to proceed translocation factor, heavy metals and other nutrients transfer from root to upper part (shoot). It is also possible to estimate environmental factors as precipitate Mn on leave and other upper parts of shoot system, which may result from industries around the studied farmland. Several studies revealed that, Mn poisoning may be encountered more frequently upon overexposure to this metal causing hepatic cirrhosis, polycythemia, dystonia, and Parkinson-like symptoms (Alejandro et al., 2020 and Li and Yang, 2018).

Nickel (Ni) is now recognized by plant scientists as an essential element for plants. It is involved in the enzyme urease and is a part of several other enzymes involved in plant metabolism (Hochmuth et al., 2014). The obtained results indicate that the root part of L. sativum and E. sativa highly contained higher amount of Ni as compared to accepted level (10 mg/kg). However, this level of permission is differ from plant to plant but no more than 10 mg/kg is acceptable (Hockmuth et al., 2014). Thus, the total estimated concentration of collected Ni as a whole plant is higher than the permissible level and considered as hazardous to human body.

Mostly, the edible plants in the current study were contaminated by heavy metals with the concentrations higher than their permissible levels that would be estimated as health risk for consumers. Therefore, the main source of water must be strictly monitored and avoid of using municipal and industrial wastewaters for irrigation purposes.

5. Conclusion

The results ensured that the selected edible plants irrigated by main wastewater of Erbil City have been indicated as good accumulator for essential and non-essential heavy metals. The level of accumulation was ordered as: Mn > Zn > Pb > Cu > Ni > Cd. Lead is highly accumulated within shoot and root parts of the selected plants, the results revealed that the concentrated Pb in plants much higher than the accepted level and known as contaminated edible plant. However, most studies have found that more metal accumulation occur within root, while in this study all selected plants were accumulated higher Cd and Mn in shoot system, and this is also true for other metals occasionally. As conclusion, the selected plants are not recommended to be consumed as they were contaminated by higher levels of acceptance by FAO/WHO.

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