Open Access **Baghdad Science Journal** **P-ISSN: 2078-8665**
Published Online First: February 2021 **2021,18(3):471-479** **E-ISSN: 2411-7986**

DOI: http://dx.doi.org/10.21123/bsj.2021.18.3.0471

The Accumulation Risk of Heavy Metals in Vegetables which Grown in Contaminated Soil

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Received 10/10/2020, Accepted 13/12/2020, Published Online First 21/2/2021, Published 1/9/2021

Abstract:

The present study has been carried out to estimate heavy metals mobility, bioconcentration and transfer from polluted soil to roots tissues and from roots tissues to aerial parts using bioconcentration factor and translocation factor. Soil samples and the biomass of the eight vegetable species have been collected during summer season, 2019 from four different sites in Wadi Al-Arg, Taif Governorate, KSA. In general, heavy metals content of soil samples in site III and IV have recorded elevated values compared with those of site I and II. The soil from site IV has shown the highest concentration of Mn, Ni, Cr, Pb, Cu, and Cd amounted 31.63, 14.05, 13.56, 22.79, 31.02 and 2.98 mg/kg dry soil respectively, while the soil from site III has shown the highest concentration of Zn. The data referred to the fact that *Mentha longifolia*, *Cucumis sativus*, *Capsicum annuum*, *Lactuca sativa Cucurbita pepo*, and *Anethum graveolens* that grown in sites of investigation could be recognized as suitable for human consumption. These six vegetables could accumulate the measured heavy metals in their tissues with acceptable quantities, less than the permissible levels of Food and Agriculture Organization of the United Nations (FAO). Otherwise, heavy metal concentrations in *Solanum lycopersicum* and *Solanum melongena* have been found to be higher than permissible limits of FAO. Both plants also have shown elevated bioconcentration factors values for most of measured heavy metals. For *S. lycopersicum* the bioconcentration factor values of Fe, Cd, Cu, Pb, Cr, Mn, Ni, and Zn have been found to be 42.150, 27.250, 1.023, ND, 5.926, 4.649, 29.409, and 0.459 respectively. While for *S. melongena*, they have been 2.360, 21.333, ND, 0.170, ND, 3.113, 50.318, and 0.623, respectively. To avoid the harmful effects of the heavy metals accumulation on human health, consideration should be given to the constant examination to the edible parts of the vegetables grown in heavy metals contaminated soil.

Key words: Bioconcentration Factor, Heavy metals, Translocation Factor, Vegetable.

Introduction:

In urban lands, the presence of heavy metals (HMs) mainly originated from industrial emissions and traffic, whereas in rural lands the HMs pollution came from warfare activities, sewage sludge, mining, drilling, electroplating, tannery, fertilizers and pesticides (1,2). The use of HMs polluted lands for crops cultivation primarily causes reduction in the total yield and results in edible parts contamination, which harmfully disturb human health (3). There are important health risks associated to wastewater use for agriculture (4), which is a probable source of HMs such as Fe, Cu, Mn, Zn, Cd, Ni, Cr, and Pb (5). Some of these HMs such as nickel, copper and zinc are essential micronutrients and required in trace quantities as these metals act as cofactors for various enzymes, however these metals are toxic in higher concentration. Other metals such as lead and cadmium existing in pesticides do not have any valuable role and come to be toxic if their concentrations go beyond certain limit (6).

In living cells and genetic macromolecules, HMs oxidative stress is primarily due to metals binding to the nuclear proteins DNA (7). Heavy metals (such as Pb, Cd and Cr) bind to protein binding locates through dislocating original metals from the natural binding sites and cause distortion of cells (8). Metals such as arsenic, mercury, and cadmium are very toxic once they arrive the biotic system (9). However, several plant species have the capability to develop in metalliferous lands such as adjacent to mining sites (10,11), and could be exploited to clean up HMs from contaminated sites (bioremediation) (12).

Uptake and accumulation of HMs vary from species to species within a genus (13,14). Vegetables are public diet by various residents over the world, as they are rich in fibers, vitamins, antioxidants and minerals; also they are a source of crucial nutrients and include functional food components by saving essential element and, protein (15). Vegetables uptake HMs from polluted soil through their roots and translocate them to the eatable parts of the plant (16,17). Several vegetables are able to bioconcentrate substantial quantities of HMs in their roots; however few have the capability to translocate appropriate quantities to their aerial parts. Plants with high translocation of HMs from roots to their shoots raise the number of plant portions that are polluted by metals and; therefore, they cause the risk of pollution to human through the food chain (18). The accumulation of HMs in agricultural soil and their effect on the vegetables grown in it has not been studied so far in the Taif region. So, the main objective of this study is to investigate HMs accumulation in vegetables species grown in four selected fields in Wadi Al-Arg, Taif Governorate, KSA.

Materials and Methods:

Study area

Soil samples and biomass of 8-10 weeks-old vegetable species; *Lactuca sativa* (Lettuce), *Mentha longifolia* (wild mint), *Solanum melongena* (eggplant), *Cucumis sativus* (cucumber), *Solanum lycopersicum* (tomato), *Capsicum annuum* (bell pepper), *Cucurbita pepo* (squash), and *Anethum graveolens* (Dill) have been collected during summer season, 2019 from four sites at Wadi Al-Arg, Taif Province, KSA. The four sites are located at different distance from the effluent of a wastewater treatment plant (Table 1). *Lactuca sativa* have been collected from site I and III, *Mentha longifolia* have been collected from site II and III, *Anethum graveolens* have been collected from site III and IV, *Solanum melongena, Cucumis sativus, Solanum lycopersicum, Capsicum annuum,* and *Cucurbita pepo,* have been collected from site III. At each site, triplicate of soil sample and their grown vegetables have been collected over an area of about 4500 m^2. The vegetables have been taxonomically identified based on morphological and taxonomical characteristics by local taxonomist from Biology department, Taif University, KSA.

Heavy metals analysis in samples of soils and plants

Soil samples have been collected from the top 30 cm at the four sites, air dried at room temperature for one week, pulverized then passed through 2mm nylon sieve (KimLab PL20 Test Sieve). For non-residual HMs extraction, (1 g) of sieved soil samples have been digested with 1:2:2 (v:v:v) HNO_3: $HClO_4$:HCl mixture using temperature control microwave heating (19). Plant samples have been firstly washed with tap water then twice with deionized water to eradicate extraneous and salts. The plants have been divided into roots and shoots, each part has then been dried in an oven at 70°C for 72 hrs, crushed, and sieved through 0.5 mm sieve. Part of each plant sample (0.3 g) has been digested with a solution of 4:1 (v:v) HNO_3: $HClO_4$ Concentrations of Fe, Zn, Cd, Ni, Cr, Pb, Cu and Mn in soil and plant prepared samples have been determined according to suitable wave length using inductively coupled plasma-atomic emission spectroscopy (ICP-Ultima (Z) VERSION 5 SOFTWARE, IRIS Intrepid II, Thermo Electron Corporation, USA) at Soils, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt (20). Calibration standards and QC solutions have been prepared using 1000 mg L^{-1} standard solutions (Fisher Chemicals, Loughborough, UK). Soil mechanical analysis (soil type) has been carried out regarding to the procedures described by (21).

Bioconcentration and Translocation Factors

Bioconcentration factor (BCF) has been calculated as the ratio of the metal concentrations in plant roots to that in the soil according to the following equation, $BCF = C_{harvested\ tissue} / C_{soil}$

Where $C_{harvested\ tissue}$ is the metal concentration in the plant roots and C_{soil} is the metal concentration in the soil (22).

Translocation factor (TF) has been calculated as the ratio of the metal concentration in the shoots to that in the roots. $TF = C_{shoot} / C_{root}$

Where C_{shoot} is the metal concentration in the plant shoots (stems or leaves) and C_{root} is the metal concentration in the plant roots (22).

Table 1. Location of the study area at Google earth on 10 March 2019

	Location
Site I	21°19ˈ36.8"N and 40°28ˈ03.4"E
Site II	21°20ˈ02.8"N and 40°28ˈ31.4"E
Site III	21°12ˈ47.5"N and 40°30ˈ18.0"E
Site IV	21°19ˈ25.3"N and 40°27ˈ35.3"E

Results and Discussion:

Heavy metal concentrations and physical parameters of soil

Mean HMs concentrations in the soil (mg/kg dry wt.) and soil texture are summarized in Table 2. The surface soil at site I, site II, and site IV has been sandy loam, having sand percent 65.47, 70.36 and 62.96, respectively; silt percent 18.05, 13.88 and 19.43, respectively and clay percent 16.48, 15.76 and 17.61, respectively. The soil from site III has shown sandy clay loam texture with 54.38% sand, 25.01% silt, and 20.6%1clay. The porosity ranged from 62.84% in surface soil of site II to 71.86% in surface soil of site III.

Cd concentration in the soil has been within the range of ND– 2.98 mg/kg dry wt. for site II and site IV respectively, while the concentration of Pb has been within the range of 0.36-22.79 mg/kg for site II and site IV, respectively. The recorded Zn concentration in the soil has been within the range of 1.38-33.92 mg/kg for site I and site III, respectively. On the other hand, the highest Cu concentration (31.02 mg/kg) has been recorded in the soil from site IV. The concentration of Cr in the soil has been within the range of 1.22-13.56 mg/kg for site III and site IV, respectively. The soil from site IV has shown the highest concentration of Mn and Ni, amounted 31.63 and 14.05 mg/kg, respectively. On the other hand, the highest concentration of Fe (2.19 mg/kg) has been recorded in site II. These values of Cd, Pb, Zn, Cu, Cr, Mn, Ni, and Fe concentrations in all soil types have been within the range of permissible level (3, 300, 300, 140, 150, 80, 50, and 5000 mg/kg dry wt. soil, respectively) recommended by European Union and Food and Agriculture Organization of the United Nations (FAO) (23,24).

Generally, HMs content of soil samples in site III and site IV have recorded elevated values compared with those of site I and site II samples. These results have been in accordance with the results obtained by Farrag *et al*. (19); as the two mentioned sites are located near the water drain from the water treatment plant, which is sometimes, used to irrigate nearby agricultural lands. Although the HMs have been present in the different soil types in concentrations lower than internationally permitted values, this is not sufficient to assess the suitability of these lands for growing edible crops. Nunes *et al.* (25) revealed that HMs concentrations in soil are not suitable for estimating its solubility, mobility and the toxicity. HMs mobility in the soil is closely related to the soil texture and chemical properties (26). Consequently, HMs toxicity must be confirmed with the results of its accumulations in different plant parts

Table 2. Mean ± standard deviation (±SD) of heavy metal contents (mg/kg dry wt.) and physical parameters of the studied soil

	Site I	Site II	Site III	Site IV
Cd	0.02±0.00	ND	0.12±0.02	2.98±0.74
Cu	0.83±0.18	0.88±0.19	0.2±0.05	31.02±4.99
Fe	1.46±0.28	2.19±0.39	0.86±0.15	1.73±0.33
Pb	0.55±0.08	0.36±0.10	16.38±2.58	22.79±5.03
Mn	4.62±1.23	3.04±0.52	13.75±2.88	31.63±8.36
Zn	1.38±0.35	3.74±1.10	33.92±7.29	9.07±1.89
Cr	2.05±0.41	1.63±0.32	1.22±0.21	13.56±2.85
Ni	0.74±0.18	0.54±0.08	0.66±0.05	14.05±2.89
Soil mechanical analysis				
Sand (%)	65.47±8.09	70.36±11.36	54.38±4.20	62.96±7.22
Silt (%)	18.05±2.25	13.88±2.20	25.01±5.69	19.43±2.55
Clay (%)	16.48±2.03	15.76±1.56	20.61±2.39	17.61±2.40
Porosity (%)	67.35±12.48	62.84±13.15	71.86±10.89	67.94±8.99
Soil texture	Sandy loam	Sandy loam	Sandy clay loam	Sandy loam

Heavy metal concentrations in plant tissues

Accumulations of HMs in organs of the studied species are summarized in Table 3. HMs concentrations in the roots and aerial parts of the eight vegetable species collected from the study areas have been investigated, and clear differences have been found in the concentrations of the HMs in investigated plants.

Lactuca sativa has been collected from site I and site III. The analysis of HMs for the soil at the two sites shows a clear difference in the concentration of the most measured elements (Table 2). However, the absorption and accumulation of HMs by lettuce plant follows almost the same pattern in both locations although the different metals concentrations in soil. Cd, Mn, Zn, Cr, and Ni have not been detected in roots or aerial parts of lettuce plants collected from both sites, while Cu, Fe, and Pb have been detected in trace amounts far less than permissible limits according to European Union and FAO (23-24). For example, Cu concentrations in lettuce collected from site I and site III have been 0.03 and 0.04 mg/kg dry wt., respectively for Lettuce roots and 0.03 and 0.03 mg/kg dry wt., respectively for aerial parts.

*Mentha longifolia (*collected from site II and site III*), Anethum graveolens (*collected from site III and site IV*), Cucumis sativus* (collected from site III), and *Cucurbita pepo* (collected from site III) follow the same pattern of *L. sativa* plant in absorbing and accumulation of HMs in their parts. For this group of vegetables, the concentration of HMs within their roots and aerial parts does not correlate with the concentration of these metals in the soil. Investigation of HMs in roots and aerial parts of these plants has shown two categories of measured HMs; the first category has not been detected at all in roots or aerial parts of the mentioned species; it includes Cd, Mn, Zn, Cr, and Ni metals, the second category includes Cu, Fe, and Pb metals that has been detected in trace amounts far less than permissible limits according to European Union and FAO (23,24). Analysis of HMs in roots and aerial parts of *Capsicum anuum* (collected from site III) shows the presence of Zn, Cu, and Fe in trace amount while other elements have not been detected in roots and aerial parts of the plant. Therefore, no systematic pattern has been observed for the distribution of the studied metals in the investigated species and their organ tissues. These results have been almost in compliance with the report of (27), they demonstrated that the HMs accumulation differs significantly between plants, and an element uptake by a species is dependent mainly on the soil quality, the plant species, and its inherent controls. However, trace metals sequestration of Cu, Fe, and Pb from the soil to these plants characterized them as trace metals pollution indicators (28).

Solanum lycopersicum L. species has been characterized by high level concentration of Cd, Cu, Mn and Cr in its roots and aerial parts, while the *Solanum melongena* L. has been characterized by high level concentration of Fe, Pb, Zn and Ni in its roots and aerial parts (Table 3). Cd concentration is 3.27 and 2.62 mg/kg dry wt. in roots and aerial parts of *S. lycopersicum,* respectively and 2.56 and 0.67 mg/kg dry wt. in roots and aerial parts of *S. melongena,* respectively. Cd values in both plants exceed the permissible levels of European Union and FAO (0.2 mg/kg dry wt.). The results referred that tomato and eggplant could accumulate toxic concentrations of HMs, exceed the permissible levels of European Union and FAO, while having ordinary morphological appearance. So, both plants must be checked for their HMs load before using in edible purposes. This suggestion is in consistent with Shah *et al*. (29), in their study they reported that economic crops must be checked for HMs load before processing them for human consumption.

As shown in the results, the highest uptakes for all studied metals in tomato and eggplant species have been recorded in the root systems as compared to the aerial parts. The results in accordance with Badr *et al*. (30), they tested the ability of several native plants for HMs phytoextraction and found that all tested species accumulated higher HMs concentrations within their root tissues. This finding could be due to physiological damage of elevated HMs concentration in the roots, which consequently reduced its ability to translocate the HMs to aerial parts (22).

Table 3. Concentrations of heavy metals (mg/kg dry wt.) in roots and aerial parts of the plant species growing in sites under investigation. Values are means ±SD.

		Cd	Cu	Fe	Pb	Mn	Zn	Cr	Ni
Site I									
Lactuca sativa	Root	ND	0.03±0.00	0.10±0.01	0.12±0.02	ND	ND	ND	ND
	aerial part	ND	0.03±0.01	0.07±0.00	0.11±0.01	ND	ND	ND	ND
Site II									
Mentha longifolia	Root	ND	0.06±00.0	0.04±0.01	0.14±0.01	ND	ND	ND	ND
	aerial part	ND	0.02±0.00	ND	0.09±0.00	ND	ND	ND	ND
Site III									
Anethum graveolens	Root	ND	0.06±0.01	ND	0.08±0.00	ND	ND	ND	ND
	aerial part	ND	0.02±0.00	ND	0.08±0.01	ND	ND	ND	ND
Mentha longifolia	Root	ND	0.04±0.01	ND	0.08±0.02	ND	ND	ND	ND
	aerial part	ND	0.03±0.00	ND	0.04±0.00	ND	ND	ND	ND
Lactuca sativa	Root	ND	0.04±0.00	0.01±0.00	0.08±0.01	ND	ND	ND	ND
	aerial part	ND	0.03±0.00	0.01±0.00	0.07±0.02	ND	ND	ND	ND
Solanum lycopersicum	Root	3.27±0.98	8.43±1.03	0.88±0.05	0.00±0.00	63.92±9.38	15.56±2.89	7.23±1.09	19.41±2.88
	aerial part	2.62±0.55	4.31±1.22	0.79±0.11	0.00±0.00	8.06±1.29	1.35±0.36	0.69±0.17	4.18±0.88
Solanum melongena	Root	2.56±0.50	0.00±0.00	2.03±0.41	2.78±0.58	42.81±11.85	21.12±5.23	0.00±0.00	33.21±9.23
	aerial part	0.67±0.08	0.00±0.00	1.14±0.18	0.44±0.06	6.62±1.89	3.26±0.04	0.00±0.00	9.82±1.85
Cucumis sativus	Root	ND	0.03±0.00	0.03±0.01	0.01±0.00	ND	ND	ND	ND
	aerial part	ND	0.03±0.00	0.01±0.00	0.01±0.00	ND	ND	ND	ND
Cucurbita pepo	Root	ND	0.02±0.00	0.14±0.02	1.93±0.31	ND	ND	ND	ND
	aerial part	ND	0.02±0.00	0.09±0.02	1.71±0.29	ND	ND	ND	ND
Capsicum annuum	Root	ND	0.23±0.05	0.14±0.03	ND	ND	1.92±0.41	ND	ND
	aerial part	ND	0.76±0.12	0.16±0.02	ND	ND	2.10±0.6	ND	ND
Site IV									
Anethum graveolens	Root	ND	0.04±0.00	0.03±0.01	0.11±0.01	ND	ND	ND	ND
	aerial part	ND	0.03±0.00	0.03±0.00	0.10±0.02	ND	ND	ND	ND

Bioconcentration factor (BCF) and translocation factor (TF)

The results of HMs accumulation by tested plant species has been proven to use bioconcentration factors (BCF) and translocation factors (TF) to evaluate the effectiveness of these plants in HMs accumulation and translocation. BCF is used in the determination of the degree of uptake and storage of HMs in plants (31). This ratio must be greater than one for species inclusion into the hyperaccumulator category (30). Species with TF values more than 1 have been classified as high efficacy plants for HMs translocation from plant roots to aerial parts (32).

As presented in Fig. 1, the BCF values of Cu, Fe, and Pb for *L. sativa species* have been found to be 0.036, 0.068, and 0.218, respectively at site I and 0.200, 0.012, and 0.005, respectively at site III. While for *M. longifolia* (Fig. 2**)** BCF has been 0.068, 0.018, and 0.389, respectively at site II and 0.200, ND, and 0.005, respectively at site III. *A. graveolens, C. anuum, C. sativus,* and *C. pepo* follow the same pattern of *L. sativa* and *A. longifolia* plants in that BCF of all measured HMs has been lower than unity except BCF of Cu for *C. anuum* has been 1.150 at site III **(**Figs. 3 and 4**)**. On the other hand, *S. lycopersicum* and *S. melongena* showed elevated BCF values for most of measured HMs. For *S. lycopersicum* the BCF values of Cd, Cu, Fe, Pb, Mn, Zn, Cr, and Ni have been found to be 27.250, 42.150, 1.023, ND, 4.649, 0.459, 5.926, and 29.409 respectively. While for *S. melongena*, it has been 21.333, ND, 2.360, 0.170, 3.113, 0.623, ND, and 50.318, respectively.

Plant ability to translocate HMs from the roots to the aerial parts has been measured with the translocation factor (TF). The translocation of the concentrated HMs from the roots to the aerial parts proceeds after the roots lose its ability to stabilize or store the HMs (33). TF values of measured HMs by the studied vegetables species have been found to be less than or equal to unity, except for *C. anuum* (Fig 1-4). This means that the quantities of trace elements are concentrated in the roots tissues exceeded those in the aerial tissues. These results in accordance with Youssef (34), the author illustrated that HMs concentration in eggplant roots exceeds that in their aerial parts; consequently TF values have been found to be lower than unity. On the same manner, Wu *et al.* (35) confirmed this claim upon studding Cd accumulation in different tomato rootstocks. TF greater than one represents that translocation of HMs effectively has been made to the aerial tissues from roots (36). Species with both BCF and TF larger than one could be used in phytoextraction. Moreover, species with BCF larger than one and TF less than unity could be used for phytostabilization (37).

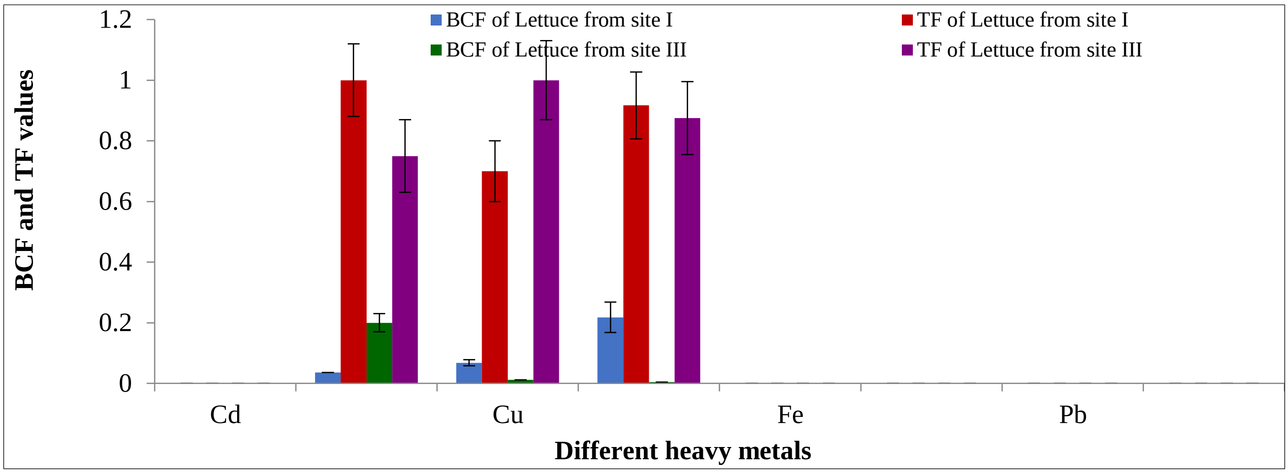

Figure 1. Bioconcentration factor (±SD) and translocation factor (±SD) of HMs in *Lactuca sativa* grown in site I and site III.

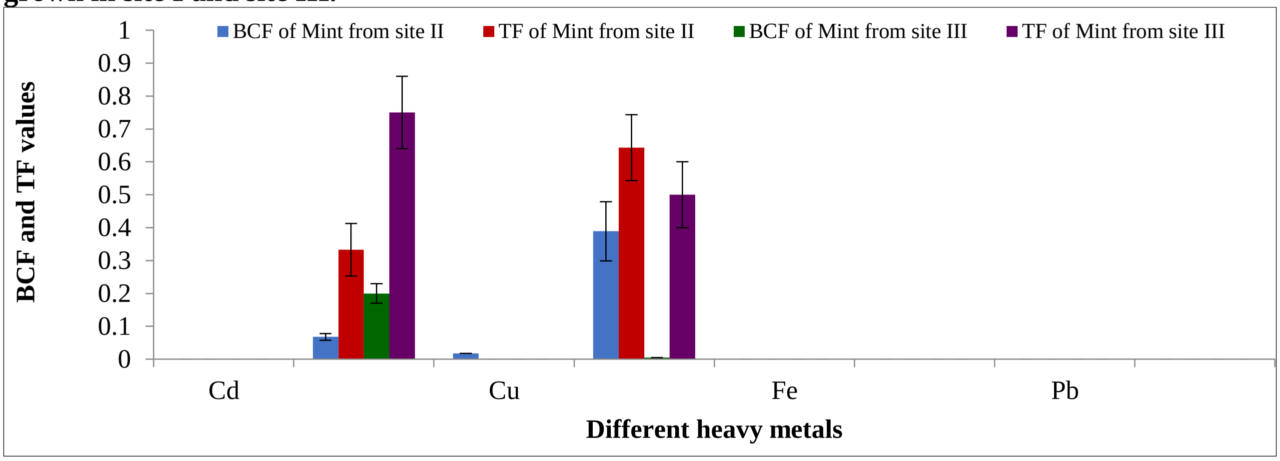

Figure 2. Bioconcentration factor (±SD) and translocation factor (±SD) of HMs in *Mentha longifolia* grown in site II and site III.

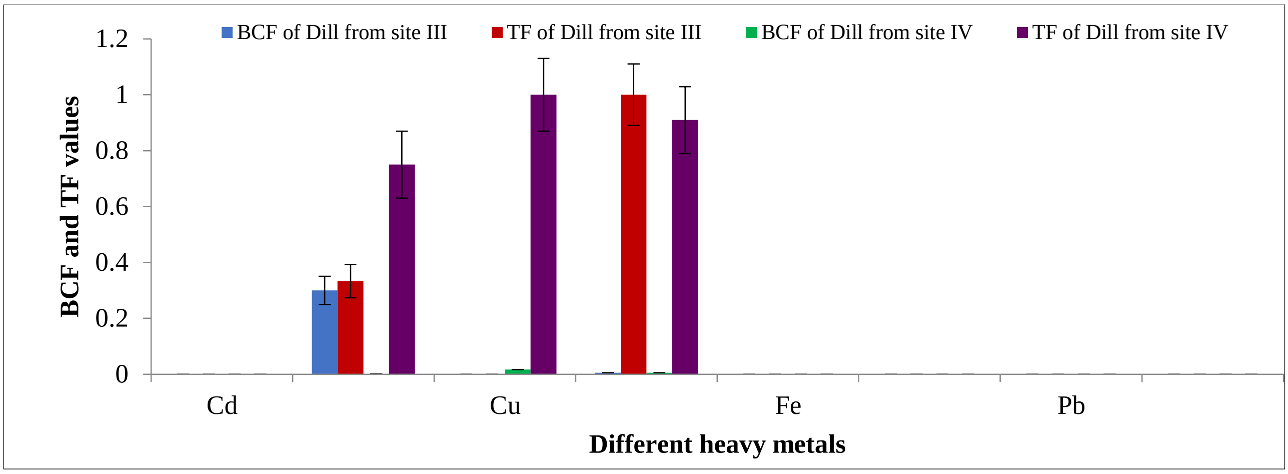

Figure 3. Bioconcentration factor (±SD) and translocation factor (±SD) of HMs in *Anethum graveolens* grown in site III and site IV.

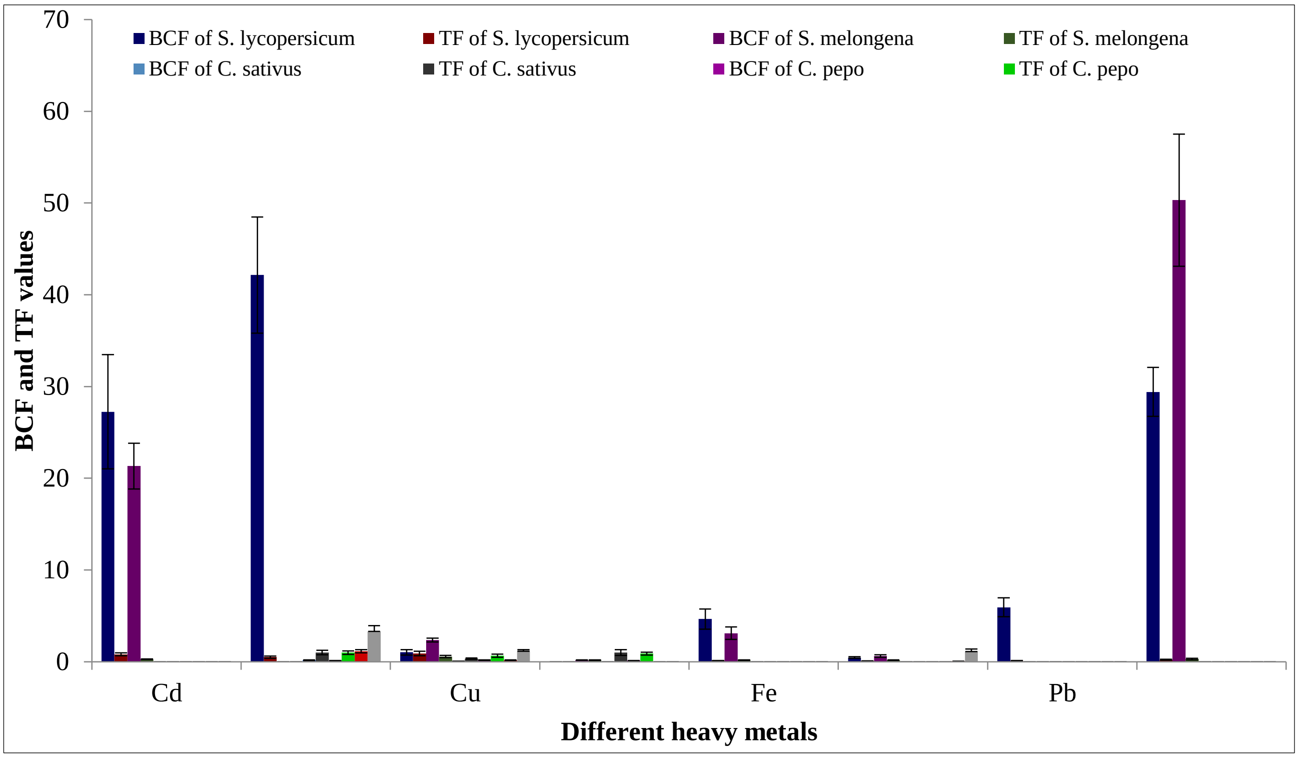

Figure 4. Bioconcentration factor (±SD) and translocation factor (±SD) of HMs in *Solanum lycopersicum, Solanum melongena, Cucumis sativus, Cucurbita pepo,* and *Capsicum annuum* grown in site III.

Conclusion:

The concentration of HMs in *L. sativa, M. longifolia, A. graveolens, C. sativus,* and *C. pepo* have been less than the permissible FAO and European Union levels. Also, BCF and TF of HMs for these plants have been found to be less than unity. The concentration of HMs in roots and aerial parts of *C. anuum* has been less than permissible levels, however higher TF is greater than unity need further investigation to evaluate the plant suitability for human consumption if it is grown in soil containing higher concentrations of HMs. The present study shows that *S. lycopersicum* and *S. melongena* grown in site III have a risk of having some HMs concentrations beyond the permissible limits of FAO and European Union. In addition to that, this study indicates that both plant species tend to absorb and accumulate some HMs in their root tissues.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in King Abdulaziz University.

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خطر تراكم المعادن الثقيلة بالخضروات المزروعة بالأراضى الملوثة

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الخلاصة

أجريت الدراسة الحالية لتقييم الحركة، التراكم الأحيائي ونقل المعادن الثقيلة (الحديد، الزنك، الكادميوم، النيكل، الكروم، المنجنيز، النحاس والرصاص) من التربة الملوثة إلى أنسجة الجذور ومن الجذور إلى الأجزاء الهوائية عن طريق حساب معامل التركيز الأحيائي وعامل الانتقال. جمعت عينات التربة والعينات النباتية لثمانية أنواع من الخضروات خلال موسم الصيف 2019 من أربعة مواقع مختلفة تقع في وادي الأرج ، محافظة الطائف ، المملكة العربية السعودية. بشكل عام ، سجلت عينات التربة المأخوذه من الموقع الثالث والرابع قيمًا مرتفعة من المعادن الثقيلة مقارنةً بالموقعين الأول والثاني. أظهرت التربة من الموقع الرابع أعلى تركيز من Mn و Ni و Cr و Pb و Cu و Cd بلغ 31.63 و 14.05 و 13.56 و 22.79 و 31.02 و 2.98 ملجم / كجم تربة جافة على التوالي ، بينما أظهرت التربة من الموقع الثالث أعلى تركيز للزنك. أشارت البيانات من الدراسة إلى أنه يمكن التعرف على نباتات الخس، النعناع، الشبث، الخيار، الفلفل والقرع التي نمت في مواقع الدراسة على أنها مناسبة للاستهلاك البشري، فهذه الخضروات الستة تراكم المعادن الثقيلة في أعضائها بكميات مقبولة بأقل من المستويات المسموح بها لمنظمة الأغذية والزراعة للأمم المتحدة. بخلاف ذلك، وجد أن تركيزات المعادن الثقيلة في نبات الطماطم ونبات الباذنجان أعلى من الحدود المسموح بها لمنظمة الأغذية والزراعة. الطماطم والباذنجان أيضاً أظهرت قيم عامل التركيز الأحيائي مرتفعة لمعظم المعادن الثقيلة المقاسة. بالنسبة للطماطم كان معامل التركيز الأحيائي لكل من الكادميوم، النحاس، الحديد، الرصاص، المنجنيز، الزنك، الكروم والنيكل 27.250، 42.150، 1.023، ND، 4.649، 0.459، 5.926 و 29.409 على التوالي. بينما كان في الباذنجان 21.333، ND، 2.360، 0.170، 3.113، 0.623، ND و 50.318 على التوالي.لتجنب الآثار الضارة لتراكم المعادن الثقيلة على صحة الإنسان ، يجب مراعاة الفحص المستمر للمحاصيل المزروعة في الترب الملوثة بالمعادن الثقيلة.

الكلمات المفتاحية: معامل التركيز الأحيائي، المعادن الثقيلة، معامل الانتقال، الخضروات.