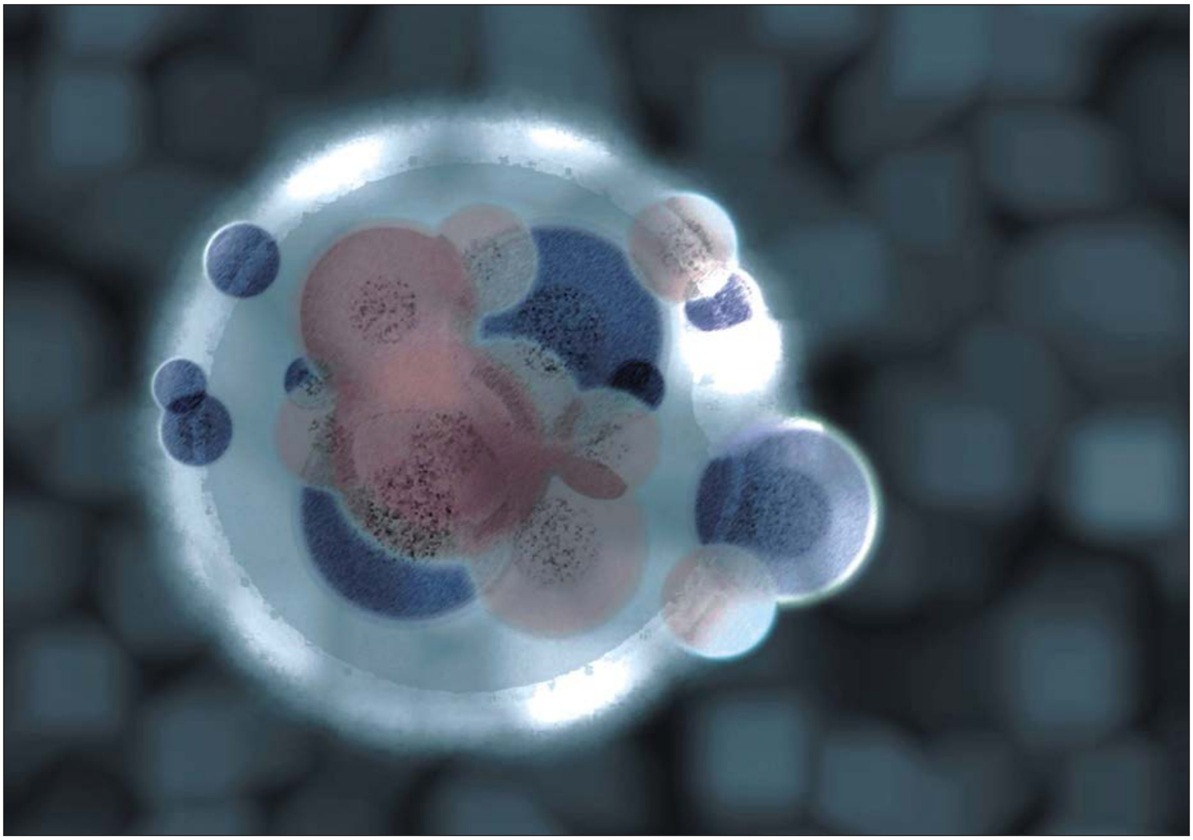

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Research Article
Estimated Heavy Metal Residues in Egyptian Vegetables in Comparison with Previous Studies and Recommended Tolerable Limits

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Abstract

Background and Objective: Accumulation of heavy metals in vegetables might represent a major problem that could affect the food safety and human health. The objective of this study was to estimate the levels of heavy metals in potato, tomato and cucumber samples collected from some Egyptian governorates and compare the levels of recent contamination with these obtained from previous studies and the recommended tolerable limits. As well as, to evaluate the potential risk of studied heavy metals for public health. **Materials and Methods:** The experimental design was established to search for the hazards of 5 heavy metal residues in 3 common consumed vegetables collected from 3 certain locations of each of 4 governorates involved more than 25% of the Egyptian population. Thirty six samples, each of potato, tomato and cucumber were collected from Egyptian local markets of four governorates (Cairo, Alexandria, Giza and El-Faiyum). **Results:** The highest average concentrations of Pb were detected in all vegetable samples of Ibshway as 0.96, 0.25 and 0.58 mg kg^{-1} for potato, tomato and cucumber samples, respectively. Meanwhile, the highest average concentration of Cd was detected in potato samples of Al-Omraniyah as 0.16 mg kg^{-1}. Chromium was detected only in cucumber samples of Helwan and Al-Maadi. With respect to Cu and Ni, the highest average concentrations were recorded for potato samples of Dokki as 2.39 and 0.49 mg kg^{-1}, respectively. Additionally, the results revealed that values of the estimated daily intake of heavy metals, for a typical adult person, were located within the safe limits. Qualitative data showed that the highest concentration levels of Pb, Cd, Cu and Ni were obtained from potato samples comparing with those of tomato and cucumber samples. As well as all potato and tomato samples were completely Cr-free, while cucumber samples exhibited 16.6% Cr-contamination. **Conclusion:** The estimated daily intake of heavy metals in vegetable samples of the current study was less than the recommended tolerable daily intake.

Key words: Vegetables contamination, heavy metals, determination, Egyptian governorates, risk assessment

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Heavy metals are a group of the chemical hazards associated with many sources of exposure including contaminated vegetables and such inorganic contaminants are not biodegradable. So, the biological half-lives of heavy metals could be extended and accumulated in human body organs leading to undesired side effects[1]. The main sources of vegetable contamination by heavy metals are organic fertilizers, pesticides[2], contaminated soil, contaminated irrigation water[3] and atmospheric pollution from industrial or motor vehicle emission[4].

Heavy metals have tendency to be adsorbed and accumulated in the human body and cause various diseases[5]. Heavy metals have different poisoning effects on human health based on the type and nature of metal[6]. The high content of heavy metals in food is associated with number of diseases such as cardiovascular, kidney, nervous and bone diseases[7]. For example, Pb interferes with the normal function of enzymes, as well as it is toxic to the blood and the nervous, urinary, gastric and genital systems[8]. Also, Cd is a highly toxic and accumulating metal which is stored in the liver and kidney. Exposure to Cd leads to pathological effects in liver, brain, nervous system, testis, kidney, spleen and bone marrow[9]. In addition, Cr has multi-organ toxicity such as renal damage, lung and respiratory tract cancers, asthma, liver and kidney problems and allergy[10]. Although, Cu has many benefits such as its role as a constituent of metal coenzymes. However, overdose of Cu may result in acne, anemia, arthritis, hair loss, adrenal hyperactivity, cancer, diabetes, dyslexia, bone fracture, heart attacks, headaches, hypertension, kidney and liver dysfunction, strokes, vitamin C deficiency and tooth decay[11]. Exposure to Ni induces various toxic effects in lung, kidney and liver. So, accumulation of Ni in the human body through chronic exposure can lead to lung fibrosis, cardiovascular and kidney diseases[12].

Vegetables are a good source of vitamins, essential minerals, fibers and other beneficial effects on human health. Vegetables may contain some toxic metals when they cultivated in contaminated soils or when exposed to polluted air[13,14]. Previous studies determined the concentrations of heavy metals in some vegetables of Egyptian markets. The detected concentrations ranged from 0.01-0.58, 0.01-0.15, 0.83-16.5 and 7.16-20.9 mg kg^{-1} for Pb, Cd, Cu and Zn, respectively[15]. Furthermore, Mansour *et al.*[2] reported that, the concentrations of Zn, Cu, Mn, Fe, Cd, Pb, Cr, Ni and Co in Egyptian cucumber samples collected from conventional farming at July, 2006 were 1.95, 1.51, 0.33, 4.68, 0.028, 0.044, 0.364, 0.036 and 0.026 mg kg^{-1}, respectively. Also, Demirbas[16] reported that the concentrations of Pb, Cd and Cu in tomato samples ranged from 0.38-0.48, 0.61-0.71 and 12.9-18.7 mg kg^{-1}, respectively. While, Khan *et al.*[17] revealed that Pb, Cu and Ni in potato samples were 1.50, 28.96 and 2.66 mg kg^{-1}, respectively.

Risk assessment of consuming heavy metals contaminated vegetables is mainly related to the accumulation pattern of heavy metals in vegetables which are influenced by many factors i.e., cultivar type, methods of cultivation, the geographical characteristics of the production region and soil acidity[18]. Translocation of heavy metals from soils to vegetables was affected by soil characteristics such as soil organic matter and soil pH, soil salinity and cation exchange capacity[19]. In addition, the irrigation by wastewater can cause contamination for soil and groundwater by heavy metals, so those metals can be transferred to the vegetables[20]. The objective of present study was to provide data on the levels of Pb, Cd, Cu, Ni and Cr in 3 types of Egyptian vegetables (potato, tomato and cucumber) as highly consumed vegetables and to compare the results with those of the previous studies and the international standard levels. Also, to evaluate the potential risk for public health due to the daily exposure to these metals through the consumption of the studied vegetables.

MATERIALS AND METHODS

Sampling: A total of 108 samples of potato, tomato and cucumber (36 samples for each) collected from different local markets representing four Egyptian Governorates (Cairo, Giza, Alexandria and El-Faiyum, involved 25% of the Egyptian population) during May, 2017. Samples were collected from 3 different cities in each governorate. Helwan, Al-Maadi and Al-Shuruq samples from Cairo governorate, Al-Ajami, Al-Manshieh and Abu-Qir samples from Alexandria governorate, Al-Omraniyah, Dokki and Atfih samples from Giza governorate as well as Sinnures, Ibshway and Etsa samples from El-Faiyum governorate. Zones of sampling are shown in Fig. 1. The edible portions were only analyzed, whereas the bruised or rotten parts were removed. A total of 1 kg of each sample were thoroughly homogenized and prepared to analysis.

Sample preparation: Five grams of the homogenized sample were accurately weighed into a crucible and were dried in an oven set at 105°C. Dry-ashing process was carried out in a muffle furnace by stepwise increase of the temperature up to 550°C and then left 5 h until the sample was completely combusted (gray or slightly colored). The obtained ash was dissolved using 1 mL concentrated HCl at crucible walls.

Fig. 1: Zones of sampling: Alexandria governorate (black sign), Cairo governorate (blue sign), Giza governorate (red sign) and El-Faiyum governorate (green sign)

Dissolved samples were transferred by de-ionized water to complete volume of 25 mL[4,21]. The ash suspension was filtered through ashless Whatman filter paper No. 42 and stored in a refrigerator until determination by atomic absorption spectrophotometer.

Standards: Standard solutions of heavy metals: Pb, Cd, Cr, Cu and Ni were provided by Merck (Darmstadt, Germany). The standards were prepared from the individual 1000 mg kg^{-1} standards (Merck), in 0.1 N HNO_3. Working standards were prepared from the previous stock solutions by dilution using 0.1 N HNO_3 till the needed concentrations for atomic absorption spectrophotometer determination[22].

Heavy metals analysis: Analysis for investigated heavy metals was performed using atomic absorption spectrophotometer (Agilent Technologies 200 Series AA) at the Central Laboratory, National Research Centre. The maximal absorbance was obtained by adjusting the specific hollow cathode lamps for each element at specific wave length for the element as 217.0, 228.8, 324.7, 232.0 and 357.9 nm for Pb, Cd, Cu, Ni and Cr, respectively. Slit width was 0.5 nm for Cd and Cu, 0.2 nm for Ni and Cr and 1.0 nm for Pb. Detection limits of heavy metals were 0.1, 0.02, 0.03, 0.1 and 0.06 mg kg^{-1} for Pb, Cd, Cu, Ni and Cr, respectively. Concentration (K) of a metal in sample was calculated according to AOAC[21]:

$$K = \frac{\left[(a\text{-}b)\times V\right]}{m}$$

Where:

K = Concentration of metal in sample (mg kg^{-1})
a = Concentration of sample solutions (mg L^{-1})
b = Average concentration in blank solutions (mg L^{-1})
V = Volume of sample solution (mL)
m = Weight of sample (g)

Daily intake and potential risk assessment: The estimated daily intake (EDI) of heavy metals depends on the corresponding concentrations in food and the daily consumption of food. The highest concentrations of the studied heavy metals were used for the calculation of EDI, assuming that human would expose to those highest levels. Averages of the daily consumption of vegetables in the middle East region were 59, 81.5 and 4.8 (g) for potato, tomato and cucumber, respectively as reported by WHO[23].

The EDI was calculated as follows:

$$EDI = C \times W$$

Where:

- C = Concentration of certain heavy metal in contaminated vegetable
- W = Average of the daily consumption of the studied vegetable

Also, the tolerable daily intake (TDI) of heavy metals for an adult person of 70 kg (assumed as an ideal body weight of an Egyptian adult person) was calculated by multiply the value of TDI (μg kg^{-1} b.wt./day, reported by FAO/WHO[24] and Baars *et al.*[25]) with 70 kg.

Statistical analysis: Results were subjected to one-way analysis of variance (ANOVA) of the General Linear Model (GLM) using SAS statistical package[26]. The results were the average of three replicates ($p \leq 0.05$).

RESULTS AND DISCUSSION

Heavy metals in potato: Qualitative data showed that the percentages of heavy metal contamination of potato samples were 33.3, 25, 100 and 58.3% for Pb, Cd, Cu and Ni, respectively, while all potato samples were completely Cr-free (Table 1). Quantitative data revealed that the Pb concentrations in potato samples of Ibshway (0.96 mg kg^{-1}) and Helwan (0.22 mg kg^{-1}) were higher than the maximum residue limits of FAO/WHO[27] as 0.2 mg kg^{-1}. Meanwhile, Pb content in potato samples of Al-Shuruq (0.12 mg kg^{-1}) and Abu-Qir (0.16 mg kg^{-1}) were below MRLs of FAO/WHO[27] and exceeded the limited levels of European Commission[28] as 0.1 mg kg^{-1}. Elevated levels of Pb in potato samples of Ibshway and Helwan cities could be attributed to heavily traffic and industrial activities[4]. The highest level of Cd was observed in potato samples of Al-Omraniyah as 0.16 mg kg^{-1} (above MRLs of European Commission[29], 0.05 mg kg^{-1}), which could be due to tobacco industries in this area[30]. On the contrary, the levels of Cu and Ni in all potato samples were below MRLs as 10 and 1.5 mg kg^{-1}, respectively[31,32].

The levels of Pb in potato of the current study were similar to those reported in some previous studies in Egypt[4,15,33,34] and in other countries such as Libya[35] and Poland[36], which ranged from 0.01 to 1.35 mg kg^{-1}. However, higher levels of Pb in Saudi Arabia[37,38] and Pakistan[17], were in the range of 1.50-6.19 mg kg^{-1} (Table 2). The present levels of determined Cd were corresponding to those revealed by Radwan and Salama[15], Mansour *et al.*[33], Loutfy *et al.*[34] and Elbagermi *et al.*[35], which located between 0.1 and 0.11 mg kg^{-1}. However, Cd concentrations were lower than those determined by the other studies[36-38]. With regard to Cu contents in potato samples, levels of Cu in the present study were in agreement with all compared studies in Table 2 except that of Khan *et al.*[17] as 28.96 mg kg^{-1}. While, Ni levels of the current study were in accordance with those reported by Mansour *et al.*[33] and Elbagermi *et al.*[35], which were in the range of 0.01-0.65 mg kg^{-1}, while the levels were far away those reported by Mohamed *et al.*[38] and Khan *et al.*[17].

Table 1: Concentrations of heavy metals in potato samples collected from different Egyptian governorates

		Heavy metals (mg kg^{-1})				
Governorates	Cities	Lead	Cadmium	Copper	Nickel	Chromium
Cairo	Helwan	0.22 ± 0.02^{b}	<d.l.	1.14 ± 0.04^{d}	0.33 ± 0.04^{bc}	<d.l.
	Al-Maadi	<d.l.	<d.l.	1.86 ± 0.06^{b}	0.29 ± 0.02^{bc}	<d.l.
	Al-Shuruq	0.12 ± 0.01^{c}	<d.l.	1.40 ± 0.04^{c}	0.24 ± 0.02^{cd}	<d.l.
Alexandria	Al-Ajami	<d.l.	<d.l.	1.22 ± 0.03^{d}	<d.l.	<d.l.
	Al-Manshieh	<d.l.	0.04 ± 0.01^{b}	0.61 ± 0.02^{f}	<d.l.	<d.l.
	Abu-Qir	0.16 ± 0.02^{bc}	<d.l.	1.19 ± 0.03^{d}	<d.l.	<d.l.
Giza	Al-Omraniyah	<d.l.	0.16 ± 0.02^{a}	0.97 ± 0.02^{e}	0.15 ± 0.01^{d}	<d.l.
	Dokki	<d.l.	<d.l.	2.39 ± 0.05^{a}	0.49 ± 0.03^{a}	<d.l.
	Atfih	<d.l.	<d.l.	1.94 ± 0.04^{b}	0.38 ± 0.04^{b}	<d.l.
El-Faiyum	Sinnures	<d.l.	<d.l.	1.44 ± 0.06^{c}	0.17 ± 0.02^{d}	<d.l.
	Ibshway	0.96 ± 0.03^{a}	0.07 ± 0.01^{b}	1.51 ± 0.04^{c}	<d.l.	<d.l.
	Etsa	<d.l.	<d.l.	1.23 ± 0.03^{d}	<d.l.	<d.l.
	LSD	0.08	0.06	0.12	0.09	---

<d.l.: Below the detection limit. Means followed by different subscript alphabets within the row are significantly different at the 5% level

Table 2: Levels of heavy metals in potato samples (mg kg^{-1}) collected from the Egyptian market compared with earlier published results from other studies of the world

Compared studies	Lead	Cadmium	Copper	Nickel	Chromium
Present study	<d.l.-0.96	<d.l.-0.16	0.61-2.39	<d.l.-0.49	<d.l.
Egypt[a]	0.01	0.02	0.83	---	---
Egypt[b]	0.04-0.62	0.01-0.07	0.11-1.83	0.01-0.65	0.01-2.17
Egypt[c]	0.55-1.35	---	---	---	---
Egypt[d]	0.06-0.21	0.03-0.11	1.0-2.0	---	0.01-0.05
Libya[e]	0.02	0.02	0.75	0.25	---
Saudi Arabia[f]	1.51-6.19	0.97-1.18	2.06-6.41	---	---
Saudi Arabia[g]	2.81	0.84	0.88	10.74	---
Poland[h]	0.34	0.34	---	---	---
Pakistan[i]	1.50	---	28.96	2.66	---

<d.l.: Below the detection limit. [a]Radwan and Salama[15], [b]Mansour *et al*.[33], [c]Abou-Arab *et al*.[4], [d]Loutfy *et al*.[34], [e]Elbagermi *et al*.[35], [f]Ali and Al-Qahtani[37], [g]Mohamed *et al*.[38], [h]Dziubanek *et al*.[36], [i]Khan *et al*.[17]

Table 3: Concentrations of heavy metals in tomato samples collected from different Egyptian governorates

		Heavy metals (mg kg^{-1})				
Governorates	Cities	Lead	Cadmium	Copper	Nickel	Chromium
Cairo	Helwan	<d.l.	<d.l.	0.68±0.02[b]	<d.l.	<d.l.
	Al-Maadi	<d.l.	0.04±0.01[a]	0.84±0.04[a]	0.28±0.02[a]	<d.l.
	Al-Shuruq	0.16±0.01[a]	<d.l.	0.46±0.03[c]	0.16±0.01[b]	<d.l.
	Al-Ajami	<d.l.	<d.l.	0.69±0.04[b]	<d.l.	<d.l.
Alexandria	Al-Manshieh	<d.l.	0.03±0.01[a]	0.43±0.03[cd]	<d.l.	<d.l.
	Abu-Qir	<d.l.	<d.l.	0.43±0.02[cd]	<d.l.	<d.l.
Giza	Al-Omraniyah	<d.l.	<d.l.	0.36±0.04[de]	<d.l.	<d.l.
	Dokki	<d.l.	<d.l.	0.27±0.02[e]	<d.l.	<d.l.
	Atfih	<d.l.	<d.l.	0.48±0.03[c]	0.14±0.01[b]	<d.l.
El-Faiyum	Sinnures	0.24±0.02[a]	<d.l.	0.62±0.03[b]	<d.l.	<d.l.
	Ibshway	0.25±0.03[a]	<d.l.	0.63±0.02[b]	<d.l.	<d.l.
	Etsa	<d.l.	<d.l.	0.33±0.03[e]	<d.l.	<d.l.
	LSD	0.09	0.06	0.09	0.06	---

<d.l.: Below the detection limit. Means followed by different subscript alphabets within the row are significantly different at the 5% level

Table 4: Levels of heavy metals in tomato samples (mg kg^{-1}) collected from the Egyptian market compared with earlier published results from other studies of the world

Compared studies	Lead	Cadmium	Copper	Nickel	Chromium
Present study	<d.l.-0.25	<d.l.-0.04	0.27-0.84	<d.l.-0.28	<d.l.
Egypt[a]	0.26	0.01	1.83	---	---
Egypt[b]	0.99-2.54	---	---	---	---
India[c]	12.20	----	23.12	10.11	----
Iran[d]	<d.l.	0.28	25.98	7.18	0.97
Libya[e]	0.51	0.25	2.25	0.20	----
Saudi Arabia[f]	2.62-3.49	1.18-2.45	3.57-7.46	---	---
Saudi Arabia[g]	2.59	0.77	4.47	14.64	----
Turkey[h]	0.34-0.67	0.11-0.26	----	----	----
Turkey[i]	0.38-0.48	0.61-0.71	12.9-18.7	<d.l.-0.28	----
Spain[j]	0.04-0.35	0.04-0.31	5.4-28.6	---	0.42-1.80
China[k]	0.93	0.20	7.15	---	----

<d.l.: Below the detection limit. [a]Radwan and Salama[15], [b]Abou-Arab *et al*.[4], [c]Yadav *et al*.[41], [d]Taghipour and Mosaferi[39], [e]Elbagermi *et al*.[35], [f]Ali and Al-Qahtani[37], [g]Mohamed *et al*.[38], [h]Mor and Ceylan[42], [i] Demirbas[16], [j]Rodriguez-Iruretagoiena *et al*.[40], [k] Li *et al*.[43]

Heavy metals in tomato: Qualitative data showed that all tomato samples were completely Cr-free, while the contamination percentages of Pb, Cd, Cu and Ni were 25, 16.7, 100 and 25%, respectively (Table 3). Quantitative assay revealed that the Cd, Cu and Ni levels in the studied samples were lower than the maximum residue limits of the international legislations as 0.05, 10 and 1.5 mg kg^{-1}, respectively[29,31,32]. Meanwhile, the detected levels of Pb in tomato samples were slightly over the MRLs of European Commission[28] as 0.1 mg kg^{-1} and FAO/WHO[27] as 0.2 mg kg^{-1}.

Table 4 summarizes the comparison between the current study data and previous studies concerning heavy metals contents in tomato. The concentrations of Pb in tomato were in accordance with those detected in an Egyptian study by Radwan and Salama[15], Iranian study by Taghipour and Mosaferi[39] and Spanish study by

Table 5: Concentrations of heavy metals in cucumber samples collected from different Egyptian governorates

		Heavy metals (mg kg^{-1})				
Governorates	Cities	Lead	Cadmium	Copper	Nickel	Chromium
Cairo	Helwan	<d.l.	<d.l.	1.31 ± 0.02^{a}	0.30 ± 0.03^{a}	0.10 ± 0.01^{a}
	Al-Maadi	<d.l.	<d.l.	0.47 ± 0.05^{de}	0.28 ± 0.02^{a}	0.07 ± 0.01^{b}
	Al-Shuruq	<d.l.	0.04 ± 0.01	0.53 ± 0.03^{d}	0.14 ± 0.01^{b}	<d.l.
Alexandria	Al-Ajami	<d.l.	<d.l.	0.92 ± 0.05^{b}	<d.l.	<d.l.
	Al-Manshieh	<d.l.	<d.l.	0.93 ± 0.04^{b}	0.16 ± 0.02^{b}	<d.l.
	Abu-Qir	<d.l.	<d.l.	0.46 ± 0.02^{de}	<d.l.	<d.l.
Giza	Al-Omraniyah	<d.l.	<d.l.	0.70 ± 0.05^{c}	<d.l.	<d.l.
	Dokki	<d.l.	<d.l.	0.67 ± 0.04^{c}	<d.l.	<d.l.
	Atfih	<d.l.	<d.l.	0.64 ± 0.03^{c}	<d.l.	<d.l.
El-Faiyum	Sinnures	<d.l.	<d.l.	0.39 ± 0.02^{e}	<d.l.	<d.l.
	Ibshway	0.58 ± 0.03	<d.l.	0.89 ± 0.03^{b}	<d.l.	<d.l.
	Etsa	<d.l.	<d.l.	0.28 ± 0.02^{f}	<d.l.	<d.l.
	LSD	---	---	0.10	0.08	0.06

<d.l.: Below the detection limit. Means followed by different subscript alphabets within the row are significantly different at the 5% level

Table 6: Levels of heavy metals in cucumber samples (mg kg^{-1}) collected from the Egyptian market compared with earlier published results from other studies of the world

Compared studies	Lead	Cadmium	Copper	Nickel	Chromium
Present study	<d.l.-0.58	<d.l.-0.04	0.28-1.31	<d.l.-0.30	<d.l.-0.14
Egypt[a]	0.19	0.15	5.69	---	---
Egypt[b]	1.22-1.25	---	---	---	---
Libya[c]	0.10	0.20	5.75	0.22	---
Saudi Arabia[d]	3.67-6.98	1.13-1.28	3.21-7.18	---	---
Saudi Arabia[e]	4.26	0.59	2.48	10.88	---
China[f]	1.00	0.08	10.9	---	---

<d.l.: Below the detection limit. [a]Radwan and Salama[15], [b]Abou-Arab *et al.*[4], [c]Elbagermi *et al.*[35], [d]Ali and Al-Qahtani[37], [e]Mohamed *et al.*[38], [f]Li *et al.*[43]

Rodriguez-Iruretagoiena *et al.*[40]. Meanwhile, the Pb levels of present study were lower than those found in other Egyptian study[4], Indian[41], Libyan[35], Saudi Arabian[37,38], Turkish[16,42] and Chinese[43]. The Cd levels in the current tomato samples were only in accordance with those recorded in Egypt by Radwan and Salama[15]. On the other hand, the concentrations of Cu in tomato of the current study were lower than those recorded by all previous selected studies. Nickel concentrations of the current study were corresponding to those reported by Elbagermi *et al.*[35] and Rodriguez-Iruretagoiena *et al.*[40]. Meanwhile, the average of Ni levels were comparatively lower than those found by Mohamed *et al.*[38], Taghipour and Mosaferi[39] and Yadav *et al.*[41].

Heavy metals in cucumber: The contamination percentages of Pb, Cd, Cu, Ni and Cr in cucumber samples were 8.3, 8.3, 100, 33.3 and 16.7%, respectively (Table 5). The results revealed that, Pb was only detected in cucumber samples collected from Ibshway (0.58 mg kg^{-1}) as attributed to heavily traffic in this city as previously mentioned. This level is higher than the maximum residue limits according to FAO/WHO[27] and European Commission[28] as 0.2 and 0.1 mg kg^{-1}, respectively. Positive Cd-contamination was only observed with the cucumber samples collected from Al-Shuruq city, which are still less than the acceptable levels of European Commission[29] as 0.05 mg kg^{-1}.

Vegetables are naturally containing a necessary amount of Cu for the normal growth of plants. Besides it, copper based fertilizers may increase the levels of Cu in vegetables[15]. In the present study, contamination level of Cu in cucumber samples, which ranged from 0.28-1.31 mg kg^{-1}, were lower than the permissible limit as 10 mg kg^{-1} [31]. Concerning the detected levels of Ni, they were below the safe limit recommended by FAO/WHO[32] as 1.5 mg kg^{-1}. Meanwhile, Cr was only detected in cucumber samples of Helwan and Al-Maadi as 0.14 and 0.07 mg kg^{-1}, respectively (there is no recommended tolerable limit of Cr available, so far). Helwan samples contained the highest average of Ni and Cr in cucumber. Generally, heavy metals concentrations, especially Pb and Cu in tomato, were lower than those in potato and cucumber. This variation between heavy metal levels in the studied three vegetables reflected different efficiencies of vegetables in adsorbing heavy metals[44].

Level of heavy metals in cucumber for the present study was compared with some previous studies that are given in Table 6. The levels of Pb in cucumber samples were nearly to

Table 7: Estimated daily intake of heavy metals compared to the tolerable daily intake

Heavy metals	TDI (µg kg^{-1} b.wt./day)	References	TDI* (µg/70 kg adult person/day)	EDI** (µg) Potato	Tomato	Cucumber
Lead	3.6	FAO/WHO[24]	252	56.64	20.38	2.78
Cadmium	0.5	FAO/WHO[24]	35	9.44	3.26	0.19
Copper	500.0	Baars *et al.*[25]	35000	141.01	68.46	6.29
Nickel	50.0	Baars *et al.*[25]	3500	28.91	22.82	1.44
Chromium	1500.0	Baars *et al.*[25]	105000	ND***	ND	0.67

*TDI: Tolerable daily intake for assumed ideal Egyptian body weight (70 kg). **EDI: Estimated daily intake (calculated by multiply the highest detected value of certain metal with the daily consumed amount (g) of vegetable according to WHO[23]. ***ND: Not detected

those detected by Radwan and Salama[15] and Elbagermi *et al.*[35]. Meanwhile, Abou-Arab *et al.*[4], Ali and Al-Qahtani[37], Mohamed *et al.*[38] and Li *et al.*[43] detected higher Pb levels than those of the present study. Regarding Cd and Cu levels in cucumber samples of the current study, current recorded concentrations were lower than those reported by all selected previous studies. Additionally, the results of Ni in cucumber samples of the present study were in accordance with those reported by Elbagermi *et al.*[35] (0.22 mg kg^{-1}), while Mohamed *et al.*[38] recorded higher value of Ni as 1.88 mg kg^{-1}. Finally, Cr was detected in cucumber samples of the present study but not determined by selected previous studies. The variation between levels of heavy metal residues in the studied vegetables obtained from different studies are influenced by many factors including seasonal variation, soil characteristics (organic matter, pH, salinity and cation exchange capacity), cultivar type and irrigation by wastewater[18-20].

Potential risk assessment: As safety assessment is an essential complementary section in the survey studies dealing with food contaminants; the obtained data of the levels of heavy metal residues in the 3 studied vegetables were employed to determine EDI. Considering the Egyptian nutritional habits, an adult person (70 kg) consumes 59, 81.5 and 4.8 g of potato, tomato and cucumber, respectively in a daily manner. In this regards, calculated data in Table 7 revealed that values of the estimated daily intake (EDI) of the studied heavy metals, for a 70 kg adult person, were markedly lower than those of the tolerable daily intake (TDI). Where, EDI values posed percentages ranged from 0.01% (Ni in cucumber) to 26.9% (Cd in potato) of the TDI which means that detected amounts of heavy metals in the studied vegetables were located within the safe limits of TDI, taking into consideration the other sources of exposure to heavy metals. Therefore, no potential risk could be expected with the consumption of the studied vegetables.

CONCLUSION

Results of the present study concluded that the detected heavy metals in vegetables of Egyptian markets were arranged descendingly as Cu>Ni>Pb>Cd>Cr. Moreover, potato plant showed high ability to accumulate Pb, Cd, Cu and Ni than tomato and cucumber plants. Meanwhile, Cr element was not detected in potato samples. This variation in metals concentrations between vegetables may be due to differences in plants structure, metals selectivity and adsorption rate of metals from the soil. Additionally, the study also recommends moving the industrial factories far from the agricultural farms. Besides, further studies are needed to limiting the food contamination by heavy metals starting with the remediation of contaminated soil and ending by the possible treatments for food. For the safety assessment, it was found that the daily intake of heavy metals was lower than the tolerable daily intake for atypical adult person, with assumption of consuming the samples of the highest detected concentrations which means no potential risk for human health would be expected.

SIGNIFICANCE STATEMENT

The study did a comparative analysis of metals in vegetables with previous studies and discovered that the heavy metals contamination in vegetables is lower than the tolerable limit and found safe for the consumption. Moreover, it was also noticed that, potato plant showed high ability to accumulate Pb, Cd, Cu and Ni than tomato and cucumber plants. This would help the researchers in evaluating the reason behind the potato accumulation of metals then other plants in future and help the farmers in growing the safe food for the people of Egypt.

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