Kadhim and Aburahma *Iraqi Journal of Science, 2023, Vol. 64, No. 2, pp: 620-629*
DOI: 10.24996/ijs.2023.64.2.11

ISSN: 0067-2904

Levels of Some Metal Contents in the Soil and Leafy Vegetables Collected From Al-Qanat Highway/ Baghdad City

Nada A. Kadhim*, Nuha Nihad A. Aburahma
Department of Chemistry, College of Science, University of Baghdad, Baghdad, Iraq

Received: 8/9/2022 Accepted: 23/10/2022 Published: 28/2/2023

Abstract

The aim of the present study is to estimate the levels of some essential and non-essential metals content of soil and seven leafy vegetable species, in the field 30m away from the Al-Qanat highway in Baghdad using X-ray fluorescence analysis. The results showed that soil and leafy vegetables had higher levels of macro elements, and that Ca in rocket and purslane was the highest. The average content of trace elements in soil and leafy vegetables has been close to the minimum than the range of permissible limits recommended by WHO and FAO/WHO except Fe, Cr and Ni in soil have exceeded the concentration of the threshold limit (13728.8 mg/kg Dw for Fe, 183.361mg/kg Dw for Cr, and 124.01mg/kg Dw for Ni) value as well for leafy vegetables, the concentration of Fe (573.29 mg/kg Dw in spinach and 540.41 mg/kg Dw in rocket) and zinc (183.52 mg/kg Dw in mallow, and 181.19 mg/kg Dw in purslane) exceeded the permissible limits.

The values of As, Cd, Pb and Hg concentrations in soil have been within the range of permissible limits recommended by WHO while in leafy vegetables higher levels of Pb (2.58 mg/kg Dw), and Cd (2.2 mg/kg Dw), were found in the rocket, and fenugreek, respectively. Also, higher levels of Sr were found in the rocket (592.42 mg/kg Dw) and purslane (560.34 mg/kg Dw) as well as Al in spinach (186.55 mg/kg Dw). In addition, P, K, Mg (purslane), Zn (rocket, purslane, mallow), Cd (grapevine, fenugreek), and Sr (rocket, purslane) accumulated the most with the transfer factor (TF) (> 1.0), followed by Ca, Mg, Fe, Co, Cu, Se, Mn, Zn, Ni, As, Cd, Pb, Hg and Sr (0.01–1.0), while Cr, and Al had the lowest accumulation (< 0.01).

Keywords: X-Ray fluorescence Spectrometer, Metals, Transfer factor, Soil, Leafy vegetable

مستويات بعض المحتويات المعدنية في التربة والخضروات الورقية المجمعة من طريق القناة السريع / مدينة بغداد

ندى عبد الكريم كاظم* ، نهى نهاد
قسم الكيمياء، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

تهدف الدراسة الحالية الى تقدير مستويات بعض المعادن الأساسية وغير الأساسية للتربة و سبعة أنواع من الخضروات الورقية في حقل على بعد 30 مترا من طريق القناة السريع في بغداد بإستخدام فلورية الأشعة السينية. أظهرت النتائج أن التربة والخضروات الورقية احتوت على مستويات عالية من العناصرالمعدنية الكبرى

*Email: nada.a@sc.uobaghdad.edu.iq

(الرئيسية)، وان مستوى الكالسيوم في الجرجير و البربين كان الأعلى. كان محتوى العناصر الصغرى في التربة والخضروات الورقية قريبًا من الحد الأدنى من نطاق الحدود المسموح بها الذي أوصت به منظمة الصحة العالمية ومنظمة الأغذية والزراعة / منظمة الصحة العالمية باستثناء تراكيز الحديد والكروم والنيكل في التربة كانت أعلى من حد العتبة (13728.8 ملجم / كجم وزن جاف للحديد ، 183.361 ملجم / كجم وزن جاف للكروم ، و 124.01 ملجم / كجم وزن جاف للنيكل)

وكذلك للخضروات الورقية تجاوزت الحدود المسموح لها ، تركيز الحديد (573.29 ملجم / كجم وزن جاف في السبانخ و 540.41 ملجم / كجم وزن جاف) في الجرجير) والزنك (183.52 ملجم / كجم من الوزن الجاف في الخباز، و 181.19 ملجم / كجم من الوزن الجاف في البربين). في التربة كانت قيم تراكيزالرصاص ،الكادميوم ،الزرنيخ و الزئبق ضمن نطاق الحدود المسموح بها التي أوصت بها منظمة الصحة العالمية بينما الخضراوات الورقية ، احتوت على مستويات عالية من الرصاص (2.58 مجم / كجم من الوزن الجاف) ، و الكادميوم (2.2 مجم / كجم من الوزن الجاف) في الجرجير ، والحلبة على التوالي. كذلك سجل مستويات عالية من السترونتيوم في الجرجير (592.42 مجم / كجم من الوزن الجاف) و البربين (560.34 مجم / كجم من الوزن الجاف) والألمنيوم في السبانخ (186.55 مجم / كجم من الوزن الجاف). بالنسبة لمعامل انتقال العناصر من التربة الى أوراق الخضروات كانت كالاتي حيث كان التراكم لكل من الفسفور ،البوتاسوم ،والمغنسيوم (البربين) ،الخارصين (الجرجير ، البربين ، الخباز) ،الكادميوم (العنب ، الحلبة) والسترونتيوم(الجرجير ، البربين) الأعلى من بقية العناصر حيث كان معامل الانتقال أكبر من واحد، ثم يليه Ca و MgوFe و Co و Cu و Se و Mn و Zn و Ni و As و Cd و Pb و Hg و Sr بينما الأقل تراكم كان لل Cr ، و Al.

1. Introduction

Wild world consumers began to change their eating patterns with the growing interest in the effect of foods on maintaining health. High consumption of vegetables is one of the most features of a healthy diet due to their contents of bioactive nutrient molecules which are important in human nutrition. Green Leaf vegetables are groups include spinach, purslane, chicory, etc. which contain essential metals, vitamins, and fibre sources [1-3]. Nowadays there is increasing concern about food quality in different regions of the world. The detection of hazardous components in various foods has led scientists to investigate the toxicological effects of these contaminants. Both essential and non-essential metal ions can cause toxicity. The essential metal ions for humans are the bulk metals sodium, potassium, calcium, and magnesium and the trace metals manganese, iron, cobalt, copper, zinc, and molybdenum [4-5]. Heavy metals are thought to be the main causes of the pollution of food and soil [6]. Soil-to-plant transfer of heavy metals is the major pathway of human exposure to metal contamination [7]. If heavy metal-polluted soil is used for crop cultivation, then the heavy metals deposited in the soil enter the food chain and at higher concentrations create severe human health problems. On the contrary, at the permissible limit, metals are important for enzymatic activity and genetic material integrity in the biological system [8]. Therefore, there is a need to examine the content of metals levels in soils and planted vegetables which are widely eaten in all regions of Iraq. So, for these reasons, one of Baghdad's regions was chosen to conduct this study to estimate levels of some essential metals (macro- and trace-elements) and non-essential metals content in the soil and leafy vegetables collected from Al-Qanat highway/Baghdad city as well as determine of transfer factor of these metals to evaluate the potential health effect of the people who consume those leafy vegetables.

2. Materials and Methods

Study area

The present study was carried out in Baghdad city, which is the capital of Iraq, in February 2020. The study included soil and leafy vegetable samples collected from farmers' fields on the Al-Qanat highway, as shown in Figure 1 (from Google Maps).

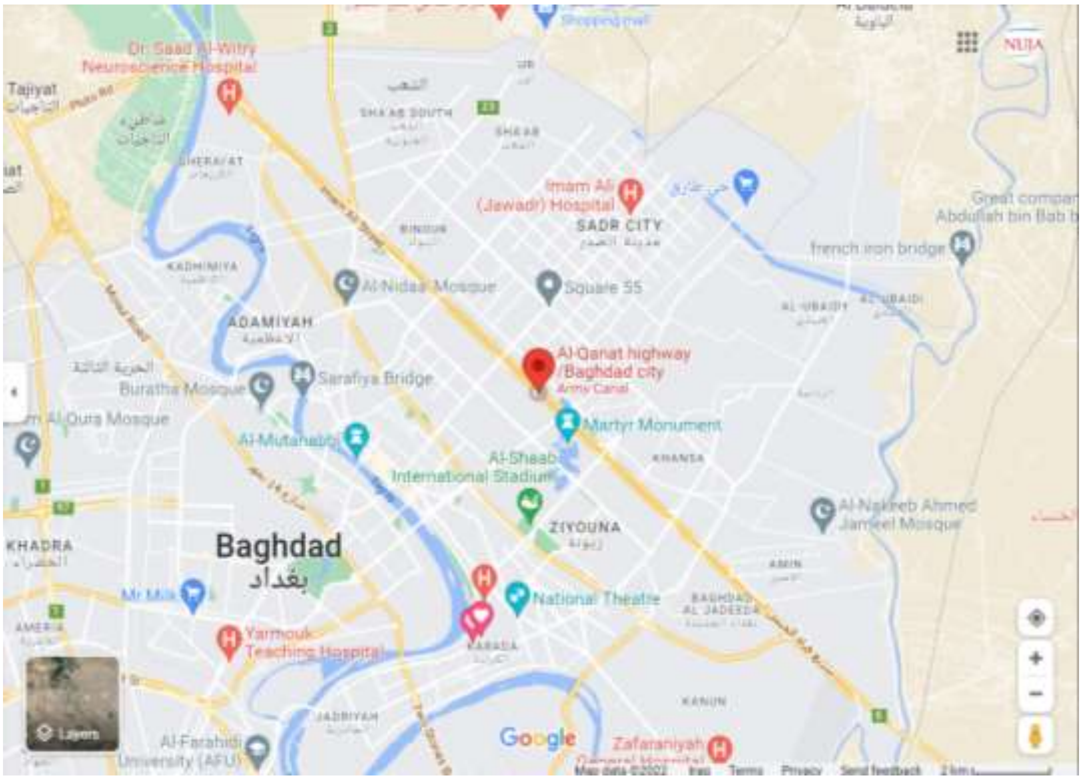

Figure 1: A map of Baghdad city showing the Al-Qanat highway.

Sample collection

All samples were collected in the dry season, in the case of soil samples; a spade was used to collect randomly soil samples in triplicate and on the surface at a 0–25 cm depth of the field. A typical sample of 500 g was taken after mixing the collected soil samples and then stored in pre-labelled zippered polyethylene bags to prevent them from further contamination. At the same time, leafy vegetable samples were collected from the same field based on availability in all farmers' fields and were taken into labelled zippered polyethylene bags and stored at 4°C until assayed the next day at the laboratory. Details of leafy vegetable samples are given in Table 1.

Table 1: Details of leafy vegetable samples

Sample No.	Common name	Botanical name	Family
1	Grapevine leaves	Vitis vinifera	Vitaceae
2	Rocket leaves	Eruca sativa	Brassicaceae
3	Purslane leaves	portulaca oleracea	Portulacaceae
4	Mallow leaves	Malva neglecta Wallr	Malvaceae
5	Spinach leaves	Spinacia oleracea	*Amaranthaceae*
6	Fenugreek leaves	Trigonella foenum-graecum	Fabaceae
7	Coriander leaves	Coriandrum sativum	Apiaceae

Specimen preparation for x-ray fluorescence (XRF) spectrometer

Both essential metals and nonessential metals concentrations were analyzed by x-ray fluorescent technique (at the Department of Geology, College of Science, the University of Baghdad) by X-Ray fluorescence Spectrometer device model (SPECTRO XEPOS) which represents a quantum leap in energy dispersive X-ray fluorescence technology. Usually, 10–20 elements can be determined quantitatively in a matter of minutes. Preparing soil samples by weighing five grams of soil sample then grounded in a tungsten carbide rotary swing mill together with 1 g of a boric acid binder and 100 mg of sodium stearate to obtain the soil sample as a powder. The particle size of the soil sample powder must be reduced to 50 µm by grinding the soil sample for 6 minutes. While leaves of vegetables (approximately 5 g), were dried at 85◦C, pulverized, and pressed into a pellet without any contamination [9].

Preparation of soil samples

Soil samples were cleaned by removing roots and rock particles, then soil samples were dried at 50°C and ground to a fine powder in an agate mortar. The powder of soil samples was sieved using a 0.5 mm mesh size sieve to have uniform particle size. To obtain a constant weight the pulverized samples were newly dried at 60°C for 48 hours then a weight of 3-5 grams was taken of it, and analyzed by (XRF) spectrometer.

Preparation of leafy vegetable samples

The leaves of vegetable samples were separated from the whole plant with the aid of a stainless-steel knife. The air pollutants must be removed by washing the leaves of vegetable samples several times with tap water followed by distilled water and de-ionized water, followed by drying in an oven at 85°C for 48 hours to obtain a constant weight. Agate pestle and mortar were used to pulverize the dried samples, followed by sieving through a 0.5 mm mesh size sieve to obtain a uniform particle size. Each sample (soil and leafy vegetable) was labelled and stored in a dry airtight plastic bag in a desiccator until analysis that had been pre-cleaned with concentrated nitric acid to prevent contamination with heavy metals before analysis with an (XRF) spectrometer.

Data analysis

Transfer factors (TF) of the metals from soils to the edible plant leaves

Transfer factor (TF) is an index used to calculate the transmission of metal concentrations in the soils to the leaves of vegetables based on dry weight (Dw), which was calculated as follows [10-13]:

$$\mathbf{TF} = \frac{C\ plant\ (Dw)}{C\ soil\ (Dw)}$$

Where C_{plant} = the metal concentration in edible leaves of vegetables (mg/kg Dw), C_{soil} = the metal concentration in soil (mg/kg Dw).

TF > 1 indicates that plants are enriched in elements (accumulator).

TF = 1 indicates that plants are not influenced by elements (indicator).

TF < 1 shows that plants exclude the elements from uptake (excluder).

3. Results and Discussion

The concentration of essential and non-essential metals in soil and leafy vegetables samples

Studied metals concentrations (mg/kg Dw) in soil and leafy vegetable samples collected from the Al-Qanat highway in Baghdad were presented in Tables 2, 3, 4 and Figure 2. The concentrations of most metals identified and quantified by XRF varied in all the studied samples of the studied area.

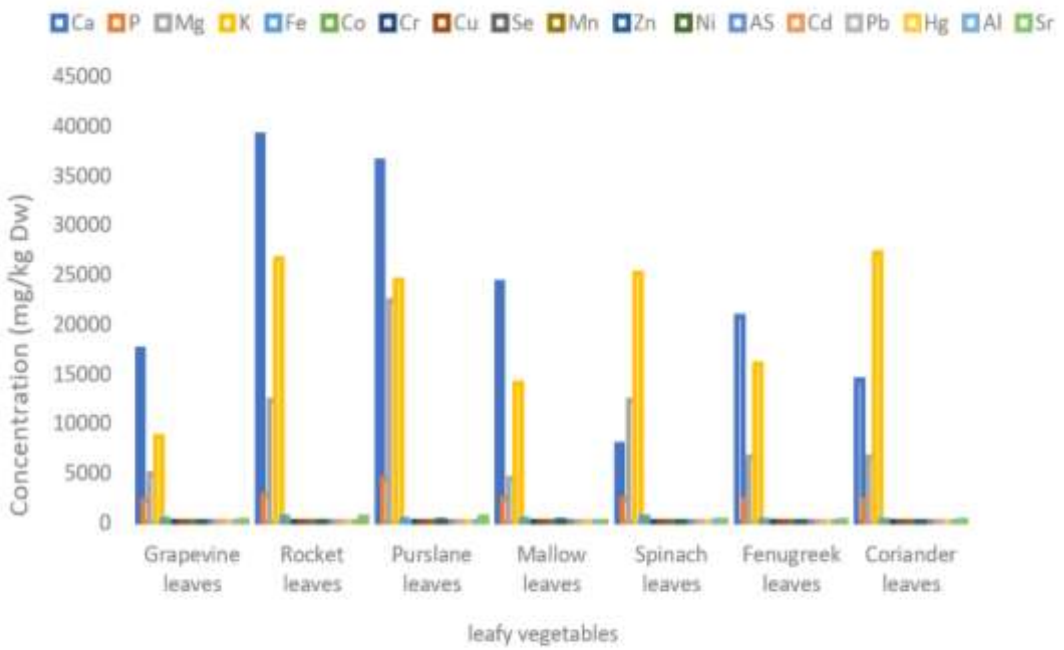

Figure 2: Concentration of essential and non-essential metals in leafy vegetables (mg/kg).

Table 2: Concentration of macro elements in studied samples (mg/kg Dw).

Common name	Macro elements (mg/kg Dw)			
	Calcium Ca	Phosphorous P	Magnesium Mg	Potassium K
Grapevine leaves	17500.11	2199.36	4891.36	8608.65
Rocket leaves	39077.84	2729.57	12261.58	26610.41
Purslane leaves	36454.54	4435.81	22388.1	24381.46
Mallow leaves	24174.36	2341.19	4432.99	14037.81
Spinach leaves	7794.38	2343.37	12321.89	25099.54
Fenugreek leaves	20779.09	2199.36	6598.21	15963.75
Coriander leaves	14331.63	2306.28	6640.43	27187.36
Soil	145460.78	1158.59	17273.56	4096.78

Table 3: Concentration of trace elements in studied samples (mg/kg Dw).

Common name	Non-essential metals (mg/kg Dw)					
	Heavy metals (Toxic elements)					
	Arsenic As	Cadmium Cd	Lead Pb	Mercury Hg	Aluminum Al	Strontium Sr
Grapevine leaves	<0.265	2.1	1.25	<1	31.2	147.47
Rocket leaves	<0.265	0.7	2.58	<1	<10	592.42
Purslane leaves	<0.265	0.7	1.07	<1	<10	560.34
Mallow leaves	<0.265	1.5	1.96	<1	<10	88.28
Spinach leaves	<0.265	<2	1.42	<1	186.55	155.78
Fenugreek leaves	<0.265	2.2	1.33	<1	<10	212.92
Coriander leaves	<0.265	<2	0.79	<1	<10	151.95
FAO/WHO Permissible levels in leafy vegetables [14]	N. A	0.1-0.2	0.3	0.1	2	N. A
Soil	2.92	<2	18.84	<1	14961.25	328.01
WHO Permissible levels in soil [15-16]	8-20	3-4	84-100	7	N. A	N. A

N.A means not available

Table 4: Concentration of non-essential metals in studied samples (mg/kg Dw).

Common name	Essential trace elements (mg/kg Dw)							
	Iron Fe	Cobalt Co	Chromium Cr	Copper Cu	Selenium Se	Manganese Mn	Zinc Zn	Nickel Ni
Grapevine leaves	279.23	3.07	0.52	22.45	<0.5	70.717	38.8	9.59
Rocket leaves	540.41	3.1	0.923	7.27	<0.5	62.51	101.64	12.89
Purslane leaves	282.97	3.5	0.57	19.82	<0.5	58.402	181.19	8.96
Mallow leaves	328.62	3.3	0.637	23.25	<0.5	69.401	183.52	11.081
Spinach leaves	573.29	3.1	1.572	12.55	<0.5	74.59	32.54	5.65
Fenugreek leaves	186.47	3	0.55	6.631	<0.5	52.98	44.03	7.94
Coriander leaves	214.38	3.9	0.513	10.23	<0.5	50.099	34.79	9.35
FAO/WHO Permissible levels in leafy vegetables [14]	425.5	50	2.3	73.3	2	500	99.4 -100	67.9
Soil	13728.8	8.26	183.361	27.54	<0.5	566.591	94.73	124.01
WHO Permissible levels in soil [15-16]	5000	50	100	100	6-10	2000	300	50-107

In general, at the permissible limit plants usually require both macro-nutrients and micro-nutrients (trace elements) for their growth and to remain healthy [8]. There are no Iraqi guidelines standardize the concentration of metals in soil and leafy vegetables so the concentrations of metals in soils and leafy vegetables obtained from our study were compared with soil and leafy vegetables quality standards listed by the World Health Organization (WHO) and Food and Agriculture Organization of the United Nations (FAO) [17].

For soil, the descending order of macro elements concentrations was Ca > Mg > K > P. The highest level of concentration was present at Ca while the lowest level of concentration was present at P. In trace elements the descending order of concentrations in soil was as the following Fe > Mn > Cr > Ni > Zn > Cu > Co > Se, whereas the descending order of concentration of non-essential metals was Al > Sr > Pb > As > Cd > Hg. In soil Fe, Cr and Ni concentrations were exceeded the threshold limit (13728.8 mg/kg Dw for Fe, 183.361mg/kg Dw for Cr, and 124.01mg/kg Dw for Ni) value recommended by WHO. On the other hand, the values of As, Cd, Pb and Hg (heavy metals) concentrations in soil have been within the range of permissible levels (2.92, 2, 18.84, and 1 mg/kg Dw. soil, respectively) recommended by WHO.

Regarding leafy vegetable samples, the concentration of studied metals showed variations among different leafy vegetables planted in the same studied soil. Macro elements (Ca, P, Mg and K) were abundant in all types of leafy vegetables and the highest amount of these metals were present in leaves of rocket and purslane, while in trace elements iron was found in a high concentration in all leafy vegetable samples and the highest amount of this metal was present at leaves of rocket and spinach followed by zinc which was found in high amount in leaves of purslane and mallow. In all types of leafy samples, Se and Cr were present in small quantities compared to other trace elements. The concentration of these metals in all leafy vegetable samples was less than the permissible standards recommended by the FAO/WHO except for the concentration of Fe (in rocket and spinach) and Zn (in purslane and mallow) that exceeded the permissible limits recommended by the FAO/WHO. The Fe content was found highest in spinach leaves (573.29 mg/kg Dw) followed by rocket leaves (540.41 mg/kg Dw) while the Zn content was found highest in mallow leaves (183.52 mg/kg Dw) followed by purslane leaves (181.19 mg/kg Dw).

The results revealed that toxic elements like As, Cd, Pb, Hg, Al, and Sr is present in almost all varieties of leafy vegetable samples and the metal contents in leafy vegetables exceeded the permissible limits recommended by FAO/WHO (Table 4). Cadmium in fenugreek leaves (2.2 mg/kg Dw) followed by grapevine leaves (2.1 mg/kg Dw) found to have the highest content while Pb was found highest in rocket leaves (2.58 mg/kg Dw) followed by mallow leaves (1.96 mg/kg Dw). Also, the Al content was found highest in spinach leaves (186.55 mg/kg Dw) followed by grapevine leaves (31.2 mg/kg Dw) while the Sr content was found highest in leaves of rocket and purslane (592.42 mg/kg Dw and (560.34) mg/kg Dw) respectively.

Transfer factor (TF) from soil to vegetables

The plant's ability to take up metal from the soil is evaluated by a ratio of metal concentration in plants to metal concentration in soils and is called Transfer Factors (TF) Biological Absorption Coefficient (BAC), or Index of Bioaccumulation (IBA) [17], that when TF > 1, there is higher absorption of metal from the soil by the plant. The TF of studied essential and non-essential metals of leafy vegetables in the soil was represented in Figures 3, 4, and 5.

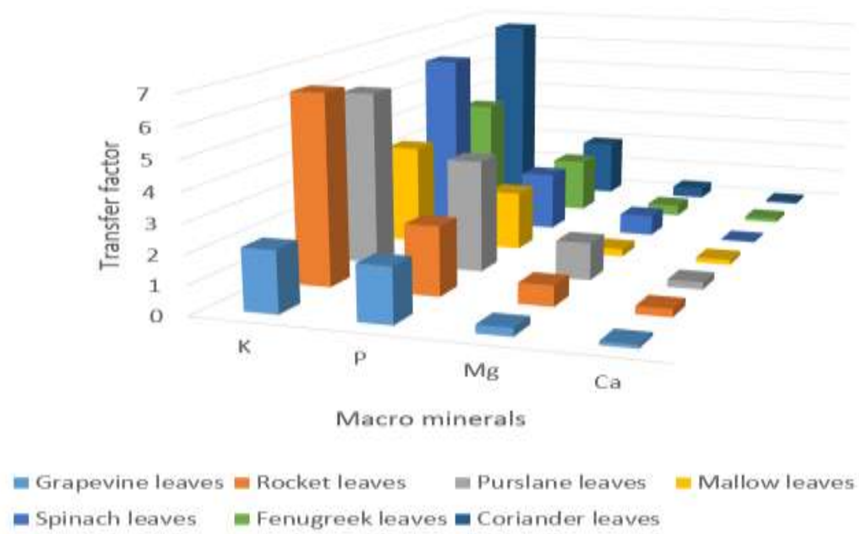

Figure 3: Transfer factor of macro elements in leafy vegetables

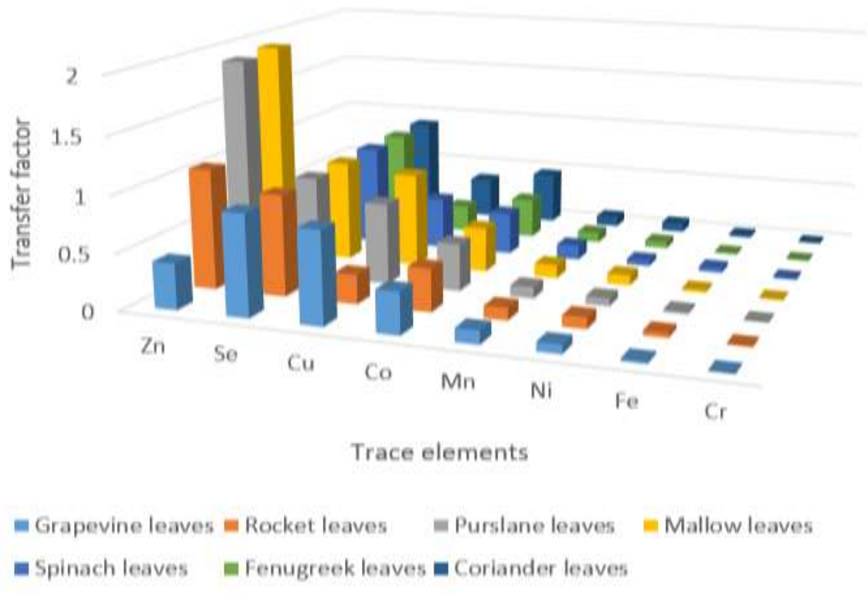

Figure 4: Transfer factor of trace elements in leafy vegetables

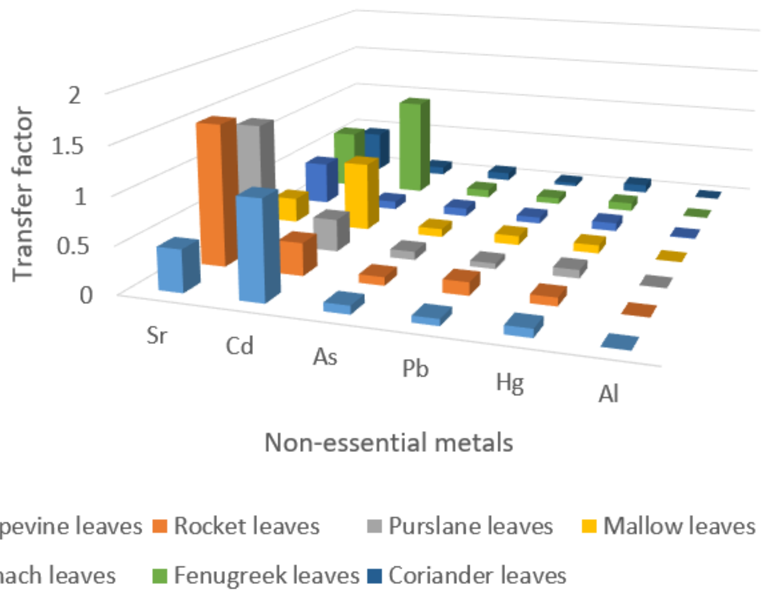

Figure 5: Transfer factor of non-essential metals in leafy vegetables

From Figures 3 and 4 (essential metals) the highest transfer factor for macro elements belonged to K in coriander (6.64), followed by P in purslane (3.83), Mg in purslane (1.29), and Ca in the rocket (0.27), while for trace elements the highest transfer factor belonged to Zn in mallow (1.94), followed by Se in all leafy vegetables (< 1), Cu in mallow (0.84), Co in coriander (0.47), Mn in spinach (0.13), Fe in rocket and spinach (0.04), and Cr in spinach (0.009). On the other hand, heavy metals (non-essential metals, Figures 5) were observed as follows: the highest transfer factor belonged to Sr in the rocket (1.81) followed by Cd in fenugreek (1.1), Hg in all leafy vegetables (< 1), Pb in the rocket (0.14), as Hg in all leafy vegetables (< 1) and Al in spinach (0.01).

These results indicate the studied soil contains a high concentration of the following metals Fe, Cr, and Ni (essential metals), and exceeded the permissible limits recommended by the WHO. The results of the present study agree with Jolly *et al.*, [7] who reported the concentration of most of the elements in the soil in Bangladesh is higher than the World Average value, also resemble to the results obtained by Kabata-Pendias [18] in different countries.

Also, there are some studies on soil have been conducted in other areas of Baghdad using X-ray fluorescence spectrometry such as the study that was conducted by Al Derzi and Naji in which they recorded an increase in concentrations of six metals (Cd, Cu, Ni, Pb, Zn and Cr) in top soils from urbanized in comparison to rural areas of Iraq but that increase was less than that listed by WHO and the highest metal concentrations were recorded in Baghdad urban districts due to pollution [19]. In the current study, the obtained results are in agreement with Al Derzi and Naji except for the increase in the concentrations of Ni and Cr which exceeded the permissible limits recommended by WHO. Also, the obtained results of soil in the current study agree with the range of concentration of the results of a study that was conducted by Mahmood in the Al-Dora district of Baghdad in which he found the samples of soil contained Pb in the range of 12.4 - 58.2, Ni 144.5-214.83, and Zn 83.07- 286.09, but regarding Fe, the range (16905.37-22259.56 mg/kg) which is higher from the obtained result in the current study (13728.8 mg/kg) although both of results exceeded the permissible limits recommended by WHO [20].

Similarly, a study by Ameen on heavy metal pollution in Samawa city, Al-Muthanna province, south-western of Iraq found the samples of soil contained high concentrations of Cr and Ni elements as follows; Cr (93.04-186.87 mg/kg), Ni (93.04-186.87 mg/kg), Cu (12.94-31.87 mg/kg) and Pb (5.84-13.23 mg/kg) and the levels of Cr and Ni were above the limits of the WHO while Cu and Pb were below the limits [21]. In addition, high concentrations of Ni element were shown in the samples of soil in a study by Ghazi on some heavy metals using an Atomic Absorption Spectrophotometer on Mohammed AL-Qassim Highway in Baghdad city for different distances [22].

Conclusion

In the present study, the composition of some essential and non-essential metals content of soil and seven leafy vegetable species were identified by X-ray fluorescence analysis. The trace elements in soil and vegetables have been close to the minimum range of permissible limits recommended by WHO and FAO/WHO except for Fe, Cr, and Ni in the soil were higher than the threshold limit for leafy vegetables as Fe (in spinach and rocket) and Zn (in mallow and purslane) exceeded the permissible limits.

The value of heavy metals As, Cd, Pb, and Hg in soil have been within the range of permissible limits recommended by WHO while in leafy vegetables higher levels of Pb and Cd were found especially in rocket and fenugreek respectively also higher levels of Sr were found in rocket and purslane as well as in spinach. In addition, P, K, and Mg (purslane), Zn (rocket, purslane, and mallow), Cd (grapevine, fenugreek), and Sr (rocket, purslane) accumulated with transfer factor (TF) >1.0, while the others metals have the lowest TF (TF<1.0) in the rest of leafy vegetables.

High concentrations of metals can be accumulated in different parts of the plants arriving from traffic discharge, industrial activity, organic fertilization, sewage irrigation, and dust storms may cause health risks especially some of these leafy plants were consumed by the local population as a medicinal treatment. We recommend the concerned authorities, in particular the Ministry of Agriculture, follow up on the study area and treat pollution to reduce the health risks of consuming these leafy plants, especially as they are an essential component in the diet of the Iraqi individual.

Acknowledgment

The authors are grateful to the Department of Geology, College of Science, University of Baghdad for the technical assistance.

References

[1] T. Ülger, A. Songur, O. Çırak, and F. Çakıroğlu, “Role of vegetables in human nutrition and disease prevention", Importance of Quality Vegetables to Human Health. London, United Kingdom, pp.7-9, 2018.

[2] N. Pathak, "Role of vegetables in human nutrition and disease prevention ", The Pharma Innovation Journal, vol. 11, no. 5, pp. 1745-1748, 2022.

[3] M. Asaduzzaman, T. Asao (Eds.) Vegetables - Importance of Quality Vegetables to Human Health. London, United Kingdom, IntechOpen, 2018 [Online]. Available from: https://www.intechopen.com/books/6492 doi: 10.5772/intechopen.70972.

[4] I. Rather, W. Koh, W. Paek, and J. Lim, "The sources of chemical contaminants in food and their health implications", *Frontiers in pharmacology*, vol. 8, pp. 830, 2017.

[5] R. Crichton, R. Ward, and R. Hider, “Chapter 1: Metal Toxicity – An Introduction”, in *Metal Chelation in Medicine*, Royal Society of Chemistry, pp. 1-23, 2016.

[6] P. Rai, S. Lee, M. Zhang, Y. Tsang, K. Kim. "Heavy metals in food crops: Health risks, fate, mechanisms, and management", *Environment international*, vol. 125, pp. 365-85, 2019, doi: 10.1016/j.envint.2019.01.067.

[7] Y. Jolly, A. Islam, and S. Akbar, "Transfer of metals from soil to vegetables and possible health risk assessment", *SpringerPlus* Vol. 2, no. 385, pp. 1-8, 2013, doi: 10.1186/2193-1801-2-385

[8] M. Oves, M. Saghir Khan, A. Huda Qari, M. Nadeen Felemban, and T. Almeelbi, "Heavy metals: biological importance and detoxification strategies", *Journal of Bioremediation and Biodegradation*, vol. 7, no. 2, pp. 1-5, 2016.

[9] B. Beckhoff, B. Kanngießer, N. Langhoff, R. Wedell, and H. Wolff, Handbook of practical X-ray fluorescence analysis. Springer Science & Business Media, pp.426, 2007.

[10] A Rosa, E Melo, A Junior, J Gondim, A de Sousa, C Cardoso, L Viana, A Carvalho, D, "Transfer of Metal(loid)s from Soil to Leaves and Trunk Xylem Sap of Medicinal Plants and Possible Health Risk Assessment", *International Journal of Environmental Research and Public Health*, vol. 19, No. 2, pp. 660, 2022, doi: 10.3390/ijerph19020660.

[11] M. Miclean, O. Cadar, E. Levei, R. Roman, A. Ozunu, and L. Levei, "Metal (Pb, Cu, Cd, and Zn) transfer along food chain and health risk assessment through raw milk consumption -from free-range cows." *International journal of environmental research and public health*, vol. 16, No. 21, pp. 4064, 2019, doi: 10.3390/ijerph16214064.

[12] V. Garg, P. Yadav, S. Mor, B. Singh and V. Pulhani, "Heavy Metals Bioconcentration from Soil to Vegetables and Assessment of Health Risk Caused by Their Ingestion", *Biological Trace Element Research*, vol. 157, no. 3, pp. 256-265, 2014. doi: 10.1007/s12011-014-9892-z.

[13] J. Olowoyo, E. van Heerden, J. Fischer and C. Baker, "Trace metals in soil and leaves of Jacaranda mimosifolia in Tshwane area, South Africa", *Atmospheric Environment*, vol. 44, no. 14, pp. 1826-1830, 2010. doi: 10.1016/j.atmosenv.2010.01.048.

[14] Fao.org, 2019. "General standard for contaminants and toxins in food and feed". *Codex and science*, pp.193,1995. [Online]. Available: Home | CODEXALIMENTARIUS FAO-WHO, [website]. Rome; WHO and FAO.

[15] Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume 1. Policy and regulatory aspects. World Health Organization, Geneva, Switzerland pp. 40, 2006.

[16] TM. Chiroma , RO. Ebewele, and FK. Hymore. "Comparative assessment of heavy metal levels in soil, vegetables and urban grey waste water used for irrigation in Yola and Kano", *International refereed journal of engineering and science*, vol. 3, no. 2, pp. 1-9, 2014.

[17] E. Mensah, N. Kyei-Baffour, E. Ofori and G. Obeng, "Influence of human activities and land use on heavy metal concentrations in irrigated vegetables in Ghana and their health implications ", *In Appropriate Technologies for Environmental Protection in the Developing World*, Springer, Dordrecht, pp. 9-14, 2009.

[18] A. Kabata-Pendias. *Trace elements in soils and plants*, 4th ed, USA, CRC press, Taylor and Francis Group, 2011.

[19] N. Al Derzi , A. Naji, "Mineralogical and Heavy Metal Assessment of Iraqi Soils from Urban and Rural Areas", *Al-Nahrain Journal of Science*, vol. 17, no. 2, pp. 55-63, 2014.

[20] M. Mahmood, "Estimation the levels of some heavy metals in the soil and vegetables irrigated with wells water in some agriculture fields at Al-Dora district–Baghdad", *Iraqi Journal of Science*, vol. 57, no. 3B, pp. 1918–1925, 2016.

[21] N. Ameen. "Topsoil Magnetic Susceptibility and Heavy Metal Contamination: A Case Study in Al-Muthanna Province, Iraq", *Iraqi Journal of Science*, vol. 61, no. 2, pp. 371-381, 2020.

[22] F. Ghazi. "Modeling the Contamination of Soil Adjacent to Mohammed AL-Qassim Highway in Baghdad", *Iraqi Journal of Science*. vol. 61, no. 10, pp. 2663-2670, 2020.