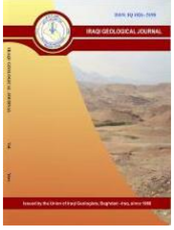
Iraqi Geological Journal

Journal homepage: https://www.igj-iraq.org



Accumulation, Bioavailability, and Health Risk of Heavy Metals in Some Plants Obtained from Abu-Ghraib Land, Baghdad, Iraq

Noor A. Ali [1]* and Enaam J. Abdullah [1]

[1] Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq
* **Correspondence**: na6023763@gmail.com

Received:
16 September 2023

Accepted:
27 November 2023

Published:
31 March 2024

Abstract

The study of the distribution of major oxides and heavy metals in some plants collecting and analyzing eighteen plant samples of vegetables including carrot, onion, eggplant, cucumber, and okra obtained from Abu Ghraib land located about 20 km west of Baghdad, Iraq. Eighteen plant samples of vegetables,.Heavy metals can have a severe impact if released into the environment, even in trace quantities. These can enter the food chain from aquatic and agricultural ecosystems and indirectly threaten human health.. Trace elements and oxides of As, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Se, Th, U, V, and Zn were measured in plant samples using an X-Ray Fluorescence Instrument (XRF). TEs analyses of vegetables were performed in the Iraqi German Laboratory in the Department of Geology, University of Baghdad. The results of XRF indicated that the highest Mean ± SD concentrations of As, Cr, Mo, Cu, Ni, Pb, Se, V and Zn were 5.24 ± 1.846, 229.436 ± 53.598, 12.97 ± 3.95, 69.128 ± 60.577, 87.14 ± 56.711, 18.826 ± 7.572, 0.5 ± 0, 88.506 ± 5.902 and 236.25 ± 227.55 ppm in carrot. Eggplant exhibited the highest concentration of Mn and U, which was 56.923 ± 39.584 and 1.76 ± 1.81 ppm, respectively. However, the total hazard quotient (THQ) of the investigated elements indicated that their levels have no potential to cause a risk to consumers' health, except Cr (THQ >1), which was higher in all plant samples. This study suggests the safety of vegetables (carrot, onion, eggplant, cucumber, and okra) harvested from farms in Abu-Ghraib, Baghdad, and their low risk of inducing serious health events and raises a concern of the elevated levels of Cr, which necessitate innovative methods to decrease its risk.

Keywords: Geochemistry; Heavy metals; Environmental; Agricultural ecosystems; The total hazard quotient ; Vegetables ; Baghdad

1. Introduction

In agriculture, the concentration of trace elements (TEs) such as Manganese (Mn), Chromium (Cr), Nickel (Ni), Vanadium (V), Zinc (Zn), Copper (Cu), Lead (Pb), Cobalt (Co), Molybdenum (Mo), Arsenic (As), Cadmium (Cd), Uranium (U), Selenium (Se), and Thorium (Th) often reflect the availability of those elements in the air and the various media (such as water, nutrient solution, and soil) used for plant cultivation (Khathi et al., 2016). The presence of these elements in plants can affect diverse fundamental biological processes, such as ionic competition and interaction, deficiency and toxicity, metabolic processes, transport within plants, speciation and concentration, and uptake (absorption) (Matejkovič et al., 2014). Some TEs, particularly heavy metals of Cu, Fe, Mn, Mo, and Zn, play a key role in plant metabolisms and are constituents of several enzymes (Arif et al., 2016). The elevated levels of heavy metals are attributed to serious diseases (such as lung and kidney cancers).

DOI: 10.46717/igj.57.1C.13ms-2024-3-25

These can enter the food chain from aquatic and agricultural ecosystems and indirectly threaten human health (Bradney et al., 2019).

Many studies have indicated the accumulation of different TEs in various plant species. In a study conducted by Hassoun (2018), the average concentrations of heavy metals in imported vegetables were as follows: Fe > Zn > Cu > Ni > Co > Cd > Pb, while the concentrations of Cr, Fe, Cu, Zn, Cd, and lead in vegetables were locally produced, including tomatoes, lettuce, onions, potatoes, and carrots, rose to 1.2075, 165.995, 37.2275, 43.775, 6.0375, and 1.48 mg/kg, respectively.

Also, Hasan and Jeber (2016) reported that the mean values of lead concentrations in different plants, including peppermint, leek, cress, and celery, obtained from farms in Abu-Gruaib were high and concerning, ranging between 0.2813 and 1.4803 mg/kg. Another study reported high average concentrations of Zn in cress (67.73 mg/kg in samples: N7, N8, N9), basil (52.53 mg/kg in samples: N4, N5, N6), and arugula and celery (38.9 and 29.3mg/kg in samples: N7, N8, N9). The values of the Transfer Factor (TF) were also high in cress (0.729>TF), followed by basil (0.612>TF), arugula (0.511>TF), and celery (0.395>TF), indicating a high risk of TEs uptake by these plants. The study also reported concerning values of the total hazard quotient (THQ) in children (THQ>1 in samples: N4, N5, N7, N8, N9, N10) and adults (THQ>1 in samples: N5, N8, N9) indicating the high exposure and consumption TEs by the study participants (Al-Jumaily and Al-Berzanje, 2020).

The geo-accumulation of heavy metals in marl collected from Kirkuk and Diyala, Iraq, was also concerning where the health risk index of Ni, Cu, and Cr, among other elements, in consuming children and adult participants was high (>1), indicating their elevated environmental hazards and potential causality of serious diseases (Ali & Naser, 2021). TEs were also found in high concentrations in tree leaves and walnuts, indicating a possible tendency of hyperaccumulation of those elements, acceding to the permissible reference value indicated by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) (Cervantes-Trejo et al., 2018). Such literature shows the extended presence of TEs in high concentration in most consumed nutrients in human daily life, which, on the other hand, necessitates further inspection of their levels in different regions of Iraq, especially after wars, immature industrial development, air pollutants, and the lack of efficient waste management.

The Abu-Ghraib agricultural land is a part of the lower Mesopotamian Plain of Holocene deposits, mainly belonging to the Euphrates River's flood plain, with only a relatively narrow strip in the east containing sediments from the Tigris River. The soil of the area has a rich history of being formed from calcareous alluvium. This region has a subtropical, hot, and dry environment. It has two distinct seasons separated by brief interludes (Mohammed et al., 2014; Muhaimeed et al., 2014; Papadakis, 1975).

Abu-Ghraib's agricultural production is challenged by several reasons, including poor soil quality, conversion of farmland to non-agricultural uses, and a lack of available water (Muhaimeed et al., 2014). However, this land is still suitable for the cultivation of different crops (Yaqub et al., 2021).

Aim of the study the presence of major oxides and heavy metals (As, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Se, Th, U, V, and Zn) in plants from Abu-Ghraib land, Baghdad, Iraq, is examined. The measurements included reporting the concentration of TEs in 18 vegetable samples of carrot, onion, eggplant, cucumber, and okra collected at different seasons. Besides, the study evaluates the daily intake of TEs and reports the total hazard quotient (THQ) among children and adult participants from the same region.

2. Location of the Study Area

The studied area is a part of the Abu-Ghraib City, covering approximately 90,000 hectares. Specifically, the study area is located at a distance of 20 km to the west of Baghdad and lies between longitudes (44º 01' and 44º 15' E) and latitudes (33º 06' and 33º 25' N), and the farms of used plants are annotated as in (Fig.1).

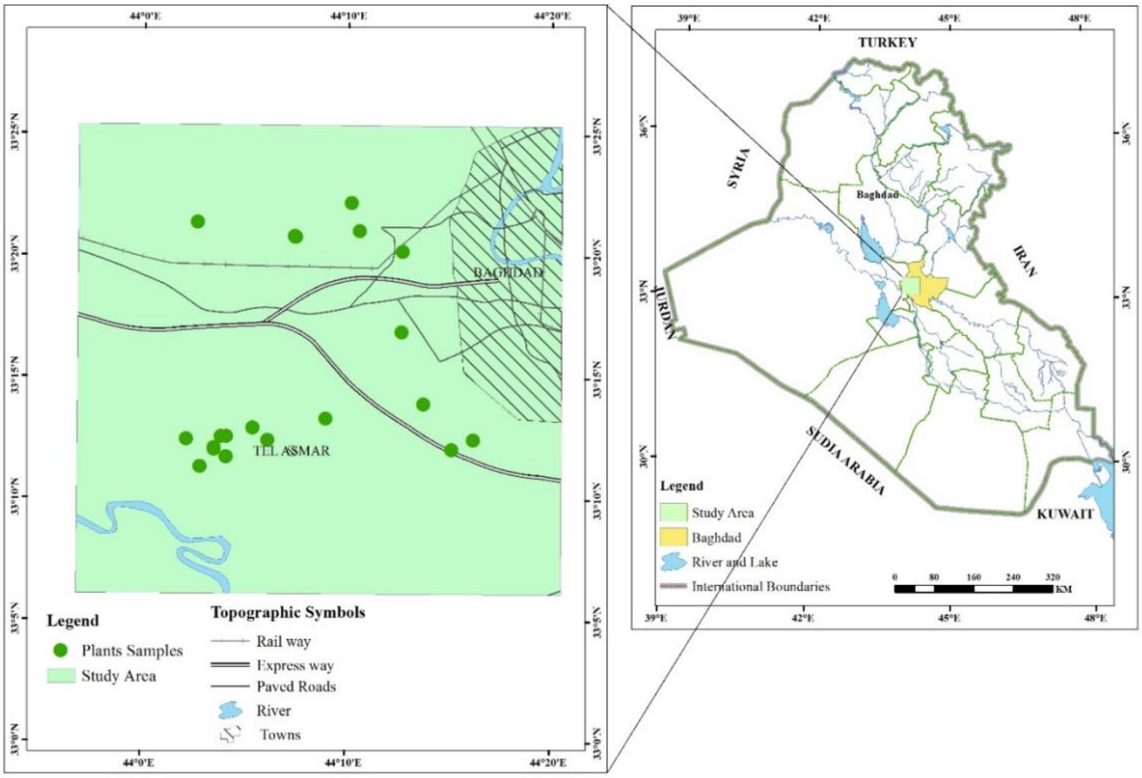


Fig. 1. site Location map of plant samples (ARC GIS map).

3. Geology of the Study Area

The soil of the study area has a rich background of calcareous alluvium. The soil is permeable, and a system of irrigation and drainage has been built to support its long-term development. The area is nearly flat, with some meso-relief generated by an old irrigation system (Mohammed et al., 2014). The issue of soil salinity, however, persists. Water from the Euphrates and Tigris is used extensively for irrigation in the study area. However, the Euphrates River provides irrigation for a much larger acreage of study area than the Tigris River (Mohammed et al., 2014).

4. Materials and Methods

4.1. Collection of Samples

Eighteen plant samples of vegetables were collected in plastic bags. These samples were collected in three periods, including December 2021 and January 2022 for the harvest of carrots (N=3), July 2022 for the harvest of eggplant (N=4), cucumber (N=3), and okra (N=4), and February 2023 for the harvest of onions (N=4). Samples were tested using an X-Ray Fluorescence Instrument (XRF).at the Iraqi-German Laboratory, Department of Geology, University of Baghdad. The distribution of plant samples is annotated in Figs. 2 and 3. The exact coordinates of the vegetable plant sampling sites are presented in Table 1.

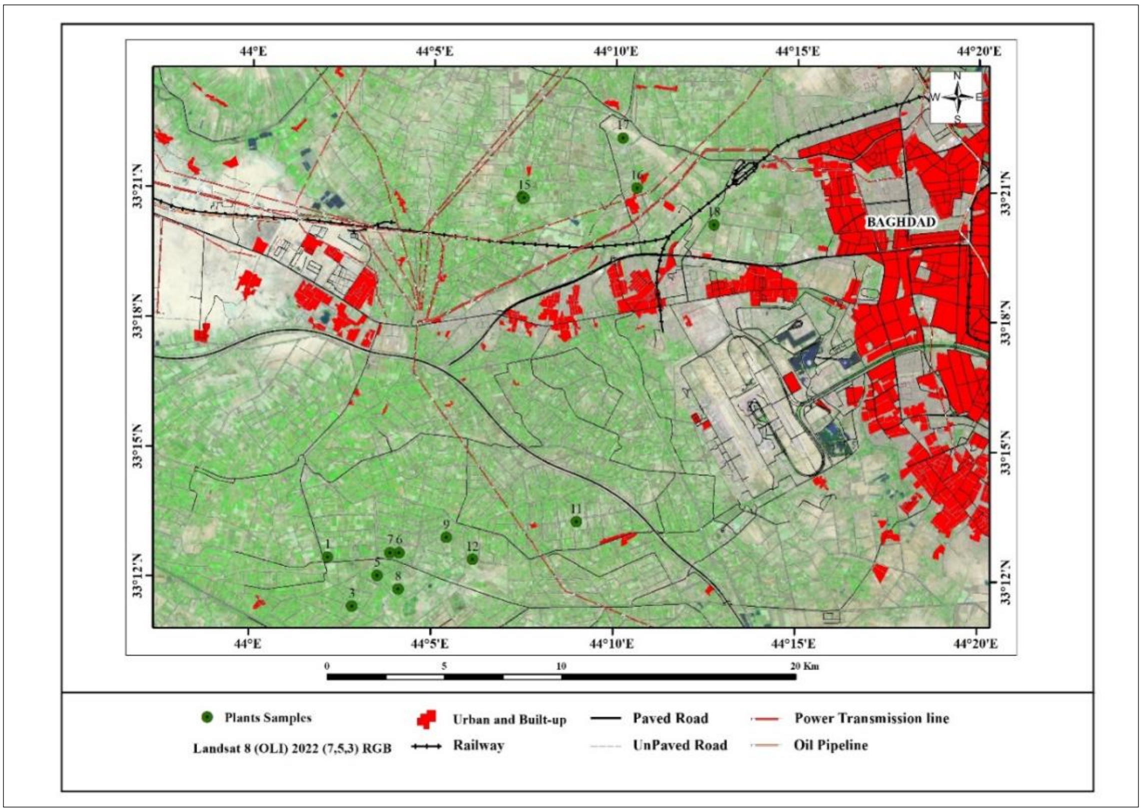


Fig. 2. Landsat 8 (OLI) 2022 (7, 3, 5) RGB Abu-Ghraib

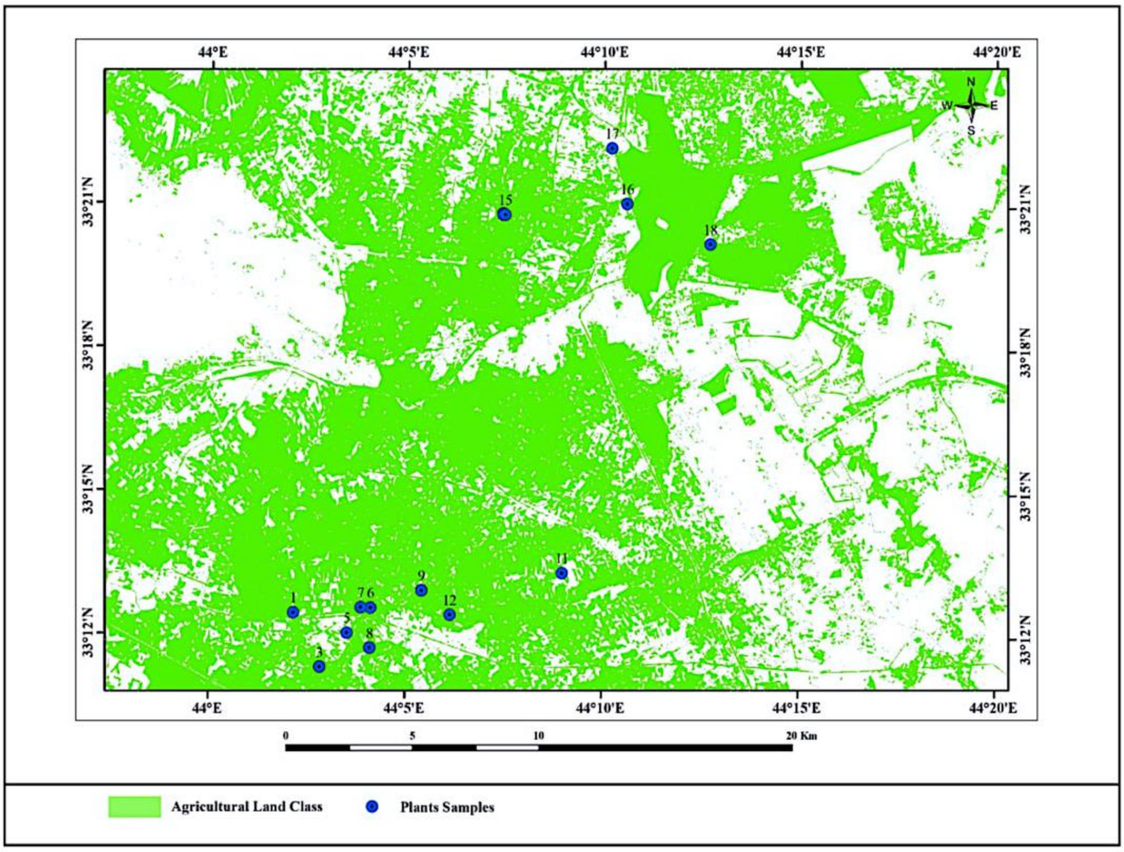


Fig. 3. Agriculture Land Class of plant samples

Table 1. Coordinates of the vegetable plant sampling sites

Sample	Longitude (E)	Latitude (N)
Cucumber 1	44.0475	33.1887
Cucumber 2	44.0361	33.2076
Cucumber 3	44.1025	33.2072
Eggplant 1	44.0589	33.2007
Eggplant 2	44.0689	33.2095
Eggplant 3	44.0647	33.2095
Eggplant 4	44.0686	33.1955
Okra 1	44.0589	33.2017
Okra 2	44.0904	33.2156
Okra 3	44.7499	33.2220
Okra 4	44.0475	33.1887
Onion 1	44.1242	33.3470
Onion 2	44.1240	33.3465
Onion 3	44.1248	33.3466
Onion 4	44.1239	33.3471
Carrot 1	44.1700	33.3700
Carrot 2	44.2120	33.3368
Carrot 3	44.1766	33.3507

4.2. Preparation of Samples

Five duplicates of each sample and blanks were digested for the preparation phase. Dry ashing and wet digestion were the two methods used for the digestion. In a muffle furnace, samples were burned in a silicon capsule for 5 hours at 480°C. Remnants were then placed in a Teflon capsule with 5ml of hydrofluoric acid (HF) to solubilize the elements. The residue was filtered into a 100-ml volumetric flask and dried on a hot plate. The pH was then corrected using purified water, following a published protocol (Hussein, 2018). X-Ray Fluorescence Instrument (XRF) was then used to identify the presence and concentration of TEs (As, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Se, Th, U, V, and Zn).

4.3. Health Risk Assessment of Heavy Metals

Because of their ability to accumulate in soil and plants, heavy metals from natural and human sources seriously threaten environmental quality. However, this is one of the most critical ecological concerns due to food safety concerns and associated health hazards (Cui et al., 2004). The constants that were used to calculate the total hazard quotient (THQ) of metals in plants are listed in Table (2).

Table 2. The constants that were used to calculate the THQ.

Constants	**Children**	**adults**	**Unit**
Exposure Frequency (EF)	180	180	Days/year
Exposure Duration (ED)	6	24	Years
Body weight average ($BW_{average}$)	15	70	Kg
Time Average ($T_{average}$)	2190	8760	
Conversion Factor (CF)	0.001	0.001	

The reference dose (R_fD) values are used to calculate the THQs of the TEs in Plants (Table 3). Daily intake of metal (DIM) in mg/kg per day of metals was calculated using Eq. (1).

$$DIM = \frac{C_{metal} \times D_{food\ intake}}{BW_{average}} \tag{1}$$

Table 3. The reference dose (R_fD) values are used to calculate the THQs.

TEs	R_fD	TEs	R_fD
Mn	5	Zn	300
Pb	24	V	5
Cu	49	U	3
Cr	0.3	Se	5
Cd	0.5	Ni	1.4
As	0.3	Mo	20
Co	3		

Where C_{metal} is the concentration of heavy metal in plants (mg/g), $D_{food\ intake}$ is the daily intake of vegetables (g/day), and $BW_{average}$ is the average body weight (kg). The total hazard quotient (*THQ*) was calculated using Eq. (2).

$$THQ = \frac{C \times EF \times ED \times DIM}{R_f D \times BW_{average} \times T_{average}} \times CF \tag{2}$$

Where *C* is the concentration of heavy metals, *EF* is the exposure frequency, *ED* is the exposure duration, $BW_{average}$ is the body weight average, $T_{average}$ is the time average, and *CF* is the conversion factor. THQ values exceeding the value of 1.0 indicate a high risk of TEs on health.

4.4. Statistical Analysis

Microsoft Excel 365 was used for descriptive statistics and data visualization. IBM SPSS Statistics 26 was used to perform advanced analyses, including regression and hypothesis testing, to extract technical insights from the collected data.

5. Results

5.1. Sample Distribution

In this study, 18 samples of plants were selected to study (Table 4 & Fig .4).

Table 4. The selected plant species in this study with scientific name and number of samples (N).

Plant	Binomial nomenclature	N
Carrot	*Daucus carota*	3
Cucumber	*Cucumis sativus*	3
Eggplant	*Solanum melongena*	4
Onion	*Allium cepa*	4
Okra	*Abelmoschus esculentus*	4

5.2. Bioacumlation of TEs

In this study, different TEs (As, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Se, U, V, and Zn) accumulated in plant samples were measured using the XRF instrument (Table 5). According to the results, the highest Mean ± SD concentrations of As, Cr, Mo, Cu, Ni, Pb, Se, V and Zn were 5.24 ± 1.846, 229.436 ± 53.598, 12.97 ± 3.95, 69.128 ± 60.577, 87.14 ± 56.711, 18.826 ± 7.572, 0.5 ± 0, 88.506 ± 5.902 and 236.25 ± 227.55 mg/kg in carrot. Eggplants exhibited the highest concentrations of Mn and U, which were 56.923 ± 39.584 and 1.76 ± 1.81 mg/kg, respectively.

Fig .4. Images of soil and plant sample collection from Abu-Gruaib farms.

Table 5. Concentration of TEs in plant samples (ppm).

Plants	Stat.	As	Cd	Co	Cr	Cu	Mn	Mo
Carrot	Mean ± SD	5.24 ± 1.846	2 ± 0	11.037 ± 5.332	229.436 ±53.598	69.128± 60.577	47.944 ± 3.472	12.97 ± 3.95
	Range	7.357 - 3.969	2 – 2	17.145 - 7.314	261.57 - 167.561	138.843 - 29.318	51.889 - 45.352	17 - 9.1
Cucumber	Mean ± SD	0.159 ± 0.183	1.53 ± 0.25	3.067 ± 0	2.874± 2.684	17.149± 9.001	43.37 ± 22.436	2.73 ± 0.98
	Range	0.37 - 0.053	1.8 - 1.3	3.067 - 3.067	5.953 - 1.026	27.401 - 10.545	58.394 - 17.58	3.3 - 1.6
Eggplant	Mean ± SD	3.514 ± 3.912	1.88 ± 1.54	12.128 ± 12.679	110.868 ±149.475	31.651 ± 18.57	56.923 ± 39.584	4.74 ± 4.93
	Range	7.939 - 0.106	4.3 - 0.5	29.414 - 3.067	295.712 - 1.026	48.092 - 9.506	99.905 - 15.876	11.6 - 1.1
Okra	Mean ± SD	1.469 ± 2.162	1.48 ± 1.1	4.267 ± 2.399	56.669± 91.543	42.34 ± 19.182	60.95 ± 24.969	5.2 ± 7.06
	Range	4.71 - 0.318	2.7 - 0.2	7.865 - 3.067	193.698 - 2.942	61.113 - 25.644	92.315 - 36.709	15.7 - 0.9
Onion	Mean ± SD	4.957 ± 4.062	2.17 ± 0.29	8.546 ± 9.49	153.763± 131.874	29.957± 14.364	47.087 ± 11.578	7.43 ± 6.47

	Range	8.098 - 0.37	2.5 – 2	19.505 - 3.067	234.271 - 1.574	43.219 - 14.699	58.084 - 35.005	14.9 - 3.6

Plants	**Stat.**	**Ni**	**Pb**	**Se**	**U**	**V**	**Zn**
Carrot	Mean ± SD	87.14 ± 56.711	18.826 ± 7.572	0.5 ± 0	1 ± 0	88.506 ± 5.902	236.25 ± 227.55
	Range	120.391 - 21.658	27.33 - 12.811	0.5 - 0.5	1 - 1	94.668 - 82.905	498.83 - 96.65
Cucumber	Mean ± SD	14.983 ± 3.564	0.743 ± 0.246	0.5 ± 0	0.63 ± 0.32	7.095 ± 0.647	47.16 ± 28.45
	Range	19.017 - 12.259	1.021 - 0.557	0.5 - 0.5	1 - 0.4	7.842 - 6.722	79.38 - 25.47
Eggplant	Mean ± SD	17.779 ± 7.658	9.617± 8.26	0.5 ± 0	1.76 ± 1.81	64.083± 74.251	82.46 ± 33.62
	Range	26.64 - 10.452	18.102 - 0.371	0.5 - 0.5	5 - 0.8	147.324 - 6.162	109.5 - 29.48
Okra	Mean ± SD	27.025 ± 14.213	14.505 ± 26.042	0.5 ± 0	0.8±0.44	34.73± 52.307	111.63± 110.68
	Range	41.257 - 13.014	53.564 - 1.021	0.5 - 0.5	1.3 - 0.3	113.154 - 6.722	274.12 - 36.8
Onion	Mean ± SD	14.57 ± 5.584	8.726 ± 7.475	0.5 ± 0	0.7 ± 0.26	80.29 ± 66.427	64.99 ± 18.39
	Range	20.841 - 10.137	14.482 - 0.279	0.5 - 0.5	1 - 0.5	132.759 - 5.602	- 50.94

5.3. Health Risk Assessment of TEs

Heavy metals from natural and anthropogenic sources accumulate in soil and plants and therefore represent important environmental contamination problems. To assess the potential health hazards associated with a given pollutant, it is crucial to accurately determine the extent of exposure by identifying the pathways by which the target organisms encounter the pollutant. There exist multiple avenues by which humans may be exposed to various substances, with the food chain being identified as the primary conduit of significance. The estimation of daily metal intake was conducted based on the average intake of vegetables among adults and children. However, food safety issues and adverse health risks make this one of the most serious environmental issues (Yu-Jing, et al., 2004).

Among the studied vegetables, the highest Daily Intake of Metals (DIM) and target hazard quotients (THQ) values for both adults and children were observed in Cr in carrots, with DIM values of 4,093.70 and 5,226.20 mg/kg per day, and THQ values of 5.93145 and 18.61387, respectively. Mn exhibited the highest DIM and THQ values in cucumbers for adults and children. In eggplants, DIM values were highest for Mn (2,314.53 and 2,954.84 mg/kg per day), while Cr had the highest THQ values at 0.89823 and 2.81878 for adults and children, respectively. Similarly, in okra, Cr displayed the highest DIM (859.78 and 1,097.63 mg/kg per day) and THQ values of 1.24575 and 3.90937 for adults and children, respectively. Onions exhibited the highest DIM values in Mn (915.67 and 1,168.99 mg/kg per day), and the highest THQ values for adults were associated with Cr (0.45912) (Table 6; Fig. 5).

Table 6. DMIs, DMIs, and HQs of Carrot in this study.

TE	DIM (adults)	DIM (children)	THQ (adults)	THQ (children)
		Carrot		
As	29.30	37.40	0.04245	0.13321
Cd	11.18	14.28	0.00972	0.03051
Cr	4093.70	5226.20	5.93145	18.61387
Co	61.71	78.79	0.00894	0.02806
Cu	386.54	493.47	0.00343	0.01076
Pb	563.72	719.67	0.01021	0.03204
Mn	1810.41	2311.25	0.15739	0.49391
Mo	225.15	287.44	0.00489	0.01536
Ni	850.55	1085.86	0.26408	0.82874
Se	2.80	3.57	0.00024	0.00076
U	5.59	7.14	0.00081	0.00254
V	494.89	631.80	0.04302	0.13501
Zn	1321.02	1686.48	0.00191	0.00601
		Cucumber		
As	0.89	1.13	0.00129	0.00404
Cd	8.57	10.95	0.00745	0.02339
Cr	16.07	20.51	0.02328	0.07306
Co	17.15	21.90	0.00249	0.00780
Cu	95.89	122.42	0.00085	0.00267
Pb	4.15	5.30	0.00008	0.00024
Mn	1222.05	1560.12	0.10624	0.33340
Mo	15.28	19.51	0.00033	0.00104
Ni	83.78	106.96	0.02601	0.08163
Se	2.80	3.57	0.00024	0.00076
U	3.54	4.52	0.00051	0.00161
V	39.67	50.65	0.00345	0.01082
Zn	263.70	336.65	0.00038	0.00120
		Eggplant		
As	19.65	25.09	0.02847	0.08935
Cd	10.51	13.42	0.00914	0.02868
Cr	619.93	791.43	0.89823	2.81878
Co	67.81	86.57	0.00983	0.03083
Cu	176.98	225.94	0.00157	0.00493
Pb	53.78	68.65	0.00097	0.00306
Mn	2314.53	2954.84	0.20121	0.63144
Mo	26.50	33.84	0.00058	0.00181
Ni	593.12	757.20	0.18415	0.57790
Se	2.80	3.57	0.00024	0.00076
U	9.84	12.56	0.00143	0.00447
V	358.32	457.45	0.03115	0.09776
Zn	461.08	588.64	0.00067	0.00210
		Okra		
As	27.72	35.39	0.04016	0.12604

Cd	12.12	15.47	0.01053	0.03305
Cr	859.78	1097.63	1.24575	3.90937
Co	47.79	61.01	0.00692	0.02173
Cu	167.51	213.85	0.00149	0.00466
Pb	48.79	62.29	0.00088	0.00277
Mn	263.29	336.13	0.02289	0.07183
Mo	41.56	53.06	0.00090	0.00283
Ni	431.06	550.31	0.13384	0.42000
Se	2.80	3.57	0.00024	0.00076
U	3.91	5.00	0.00057	0.00178
V	448.95	573.15	0.03903	0.12248
Zn	363.42	463.96	0.00053	0.00165
Onion				
As	8.21	10.48	0.01190	0.03734
Cd	8.25	10.53	0.00717	0.02250
Cr	316.87	404.53	0.45912	1.44079
Co	23.86	30.46	0.00346	0.01085
Cu	236.75	302.24	0.00210	0.00659
Pb	81.11	103.54	0.00147	0.00461
Mn	915.67	1168.99	0.07960	0.24981
Mo	29.08	37.12	0.00063	0.00198
Ni	314.84	401.94	0.09775	0.30676
Se	2.80	3.57	0.00024	0.00076
U	4.47	5.71	0.00065	0.00203
V	194.20	247.92	0.01688	0.05298
Zn	624.20	796.88	0.00090	0.00284

6. Discussion

Vegetable consumption is a major route of human heavy metal poisoning. Many biological and metabolic systems in the human body may be disrupted by chronic exposure to hazardous levels of heavy metals in diet (Mengistu, 2021). Our result showed that the majority of TEs were observed in carrots, whereas other TEs showed a descending trend in the following order: Zn> Cr> V> Ni> Cu> Mn> Pb> Mo> Co> As> Cd> U> Se.

In agreement with our results, Mafuyai et al. (2019) reported that all of the metals investigated (Pb, Cu, Cd, Zn, Cr, Fe, Mn, and As) had greater quantities in the carrots that were analyzed from the sampled farms. However, the total hazard quotient (HQ) of these TEs indicated that their levels are not of high risk for health, except Cr, which was higher in all plant samples, making all these vegetables safe with no threat to human health except for Cr.

In this study, the highest concentration of Fe was in carrots, followed by onion, cucumber, and eggplant, and the lowest in okra. In a study conducted by Hassoon (2018), the Fe in imported vegetables to Baghdad had the maximal values in lettuce samples (411.625 mg/kg) as Fe largely accumulates in plant leaves (Gupta et al., 2008). The result showed that the mean concentration of Fe in carrots was lower than the Fe concentrations reported by Hassoon (2018), which was 8.64 mg/kg in carrot (roots). Hassoon (2018) also reported that the Co in imported vegetables to Baghdad had similar concentrations in tomato and onion, about 3.1 mg/kg, and about 3.09 mg/kg in lettuce, potatoes, carrots, and turnips. Interestingly, Co concentrations in local vegetables were similar to those recorded in imported types (3.1 mg/kg) but lower in local potatoes (2.8375 mg/kg).

Cr is a crucial element for insulin activity and DNA transcription, and an intake below 0.02 mg/day could reduce cellular insulin response (Makanjuola et al., 2019). According to our results, Cr was higher in adults and children for all plant samples. Hassoon (2018) reported that the Cr in imported vegetables was present at slightly similar values in almost all collected samples except with turnips, which had the highest concentration (1.7475 mg/kg). Another study by Mutune et al., (2014) in an industrial area found that Cr concentrations were between 1.19 and 1.24 mg/kg for spinach and spider plants, respectively. Chrome plate corrosion in vehicle motors may be the reason for the increased emissions of Cr (Essa and Al-jibury, 2017).

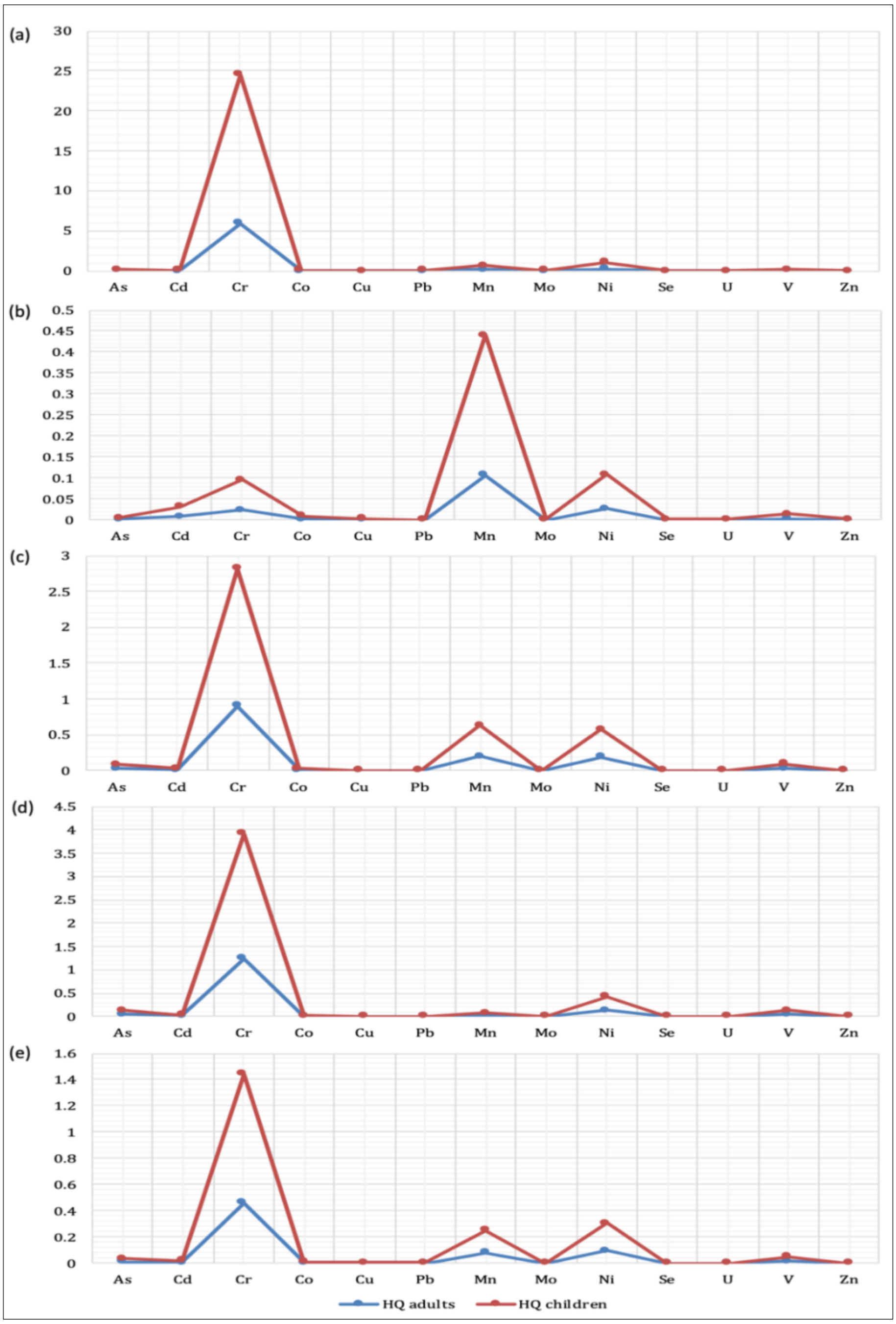


Fig. 5. The THQ values of plants used in this study. (a) Carrot; (b) Cucumber; (c) Eggplant; (d) Okra; (e) Onion.

High absorption rates of heavy metals by plants can lead to high storage of heavy metals in their tissues, increasing the risk among consuming individuals, especially children. Ingesting these heavy metal-contaminated foods over lengthy periods may increase that risk and hugely impact individuals' lives (Gupta et al., 2010). The absorption and transport of metals in plants may account for the diversity in metal concentrations (Sultana et al., 2015). Metals may be ingested by vegetables from the soil or through exposure to polluted air (Bahiru, 2021).

The study revealed that the dietary intake (DI) of heavy metals in children exceeded that of adults. The findings presented in this study were found to be incongruous with the results reported in prior research conducted by Zheng et al. (2007); Liu et al. (2011), and Satpathy et al. (2014). This observation is incongruent with the fact that adults tend to consume a comparatively larger number of vegetables in comparison to children. The FAO and WHO have established specific thresholds for the daily consumption of certain heavy metals, which are referred to as the Provisional Tolerable Daily Intake (PTDI) (FAO, 1999).

According to the study conducted by Mutter (2016) in Baghdad city (at Al-Taji, north of Baghdad and Al-Rashid, south of Baghdad), the major elements (Ca, K, and Mn) and trace elements (Fe, Cu, Pb, Sr, and Zn) in six plant samples (lettuce, bean, apples, potato, cabbage, and pear) were analyzed and found to be within acceptable ranges when compared to concentrations in neighboring countries and International Atomic Energy Agency (IAEU) standards. Precision represents the degree to which repeated measurements show the same results, also called reproducibility or repeatability (Maxwell, 1968). Precision is usually expressed in terms of the deviation of a set of results from the arithmetic mean of the set. However, it sounds reasonable to assume otherwise (Stoodley et al., 1980). Precision (P) is expressed as the coefficient and calculated using Eq. (1).

$$P = \left(2 \times \frac{Std.Deviation}{Mean}\right) \times 100\% \tag{3}$$

P is presented at a 95% confidence interval. The XRF precision was evaluated using 3 samples to ensure the high detectability of the XRF instrument towards TEs (Table 7). The permissible limit of TEs is ≤ 25.

Table 7. Precision values (95% confidence interval) of the presence of elements in soil.

TEs	X1	X2	X3	Mean	SD	2×SD	95%CI
As	0.00106	0.00122	0.0012	0.00116	0.00009	0.00017	15.03%
Cd	0.0002	0.0002	0.0002	0.00020	0.00000	0.00000	0.00%
Co	0.00328	0.00344	0.00342	0.00338	0.00009	0.00017	5.16%
Cr	0.03731	0.03747	0.03803	0.03760	0.00038	0.00076	2.01%
Cu	0.00519	0.00589	0.00589	0.00566	0.00040	0.00081	14.29%
Mn	0.00125	0.00141	0.00139	0.00135	0.00009	0.00017	12.92%
Mo	0.00087	0.00103	0.00101	0.00097	0.00009	0.00017	17.97%
Ni	0.02584	0.02774	0.02812	0.02723	0.00122	0.00244	8.97%
Pb	0.00145	0.0015	0.00152	0.00149	0.00004	0.00007	4.84%
Se	0.00005	0.00005	0.00005	0.00005	0.00000	0.00000	0.00%
Th	0.00056	0.00058	0.00058	0.00057	0.00001	0.00002	4.03%
U	0.00008	0.0001	0.00009	0.00009	0.00001	0.00002	22.22%
V	0.0231	0.02	0.0228	0.02197	0.00171	0.00342	15.57%
Zn	0.01188	0.01319	0.0133	0.01279	0.00079	0.00158	12.35%

7. Conclusions

The issue of metal contamination in ecosystems has gained growing global attention. Eighteen plant samples of vegetables from different farms in Abu-Ghraib, Baghdad, Iraq, including carrot, onion, eggplant, cucumber, and okra, were evaluated for the presence of TEs. Our findings indicated that the distribution of TEs differed based on the type of plant. The results of XRF indicated that the highest concentrations of As, Cr, Mo, Cu, Ni, Pb, Se, V, and Zn were in carrot, while eggplant exhibited the highest concentration of Mn and U. The total hazard quotient (THQ) of these TEs indicated that their levels did not cause a risk for health, except for Cr (HQ >1), which was high in all plant samples. Our findings highlight the importance of continued monitoring and regulations to preserve public health and ecosystem integrity. In a broader sense, legal authorities should require farmers to conduct soil evaluations for heavy metals. This can help identify high-absorbability plant species and avoid their cultivation in that specific farm to facilitate better public health practices and avoid the impact of a polluted environment on local consumers.

Acknowledgements

The authors would like to thank the Iraqi German Laboratory and the Library University of Baghdad, College of Science, Geology Department for providing references for machine calibration. Profound thanks to Senior Engineer Chief Abeer Faiq Harby from the Ministry of Science and Technology for her assistance during laboratory analysis, which was carried out in the XRF laboratory.

References

Afloog, H.A., Hassan, A.A., 2020. Environmental geochemistry and assessment of pollution by vanadium in top soil of Kirkuk, northern Iraq. Iraqi Geological Journal, 53, (2E), 74-95.

Ali, A.R., Naser, S.I., 2021. Potential source of heavy metals in the geophagic clay (Marl) and its implication on human health in NE Iraq: a pilot study. The Iraqi Geological Journal, 54(2C),80-87.

Al-Jumaily, H.A., Al-Berzanje, E.W., 2020. Health risk of zinc pollutant in agricultural soil in some leaves of selected leafy vegetables in Kirkuk, north Iraq. Iraqi Geological Journal, 53(2D), 64-76.

Arif, N., Yadav, V., Singh, S., Singh, S., Ahmad, P., Mishra, R. K., ... & Chauhan, D.K., 2016. Influence of high and low levels of plant-beneficial heavy metal ions on plant growth and development. Frontiers in environmental science, 4, 69.

Bahiru, D.B., 2021. Assessment of some heavy metals contamination in some vegetables (tomato, cabbage, lettuce and onion) in Ethiopia: A review. American Journal of Environmental Protection, 10(2), 53-58.

Bradney, L., Wijesekara, H., Palansooriya, K.N., Obadamudalige, N., Bolan, N.S., Ok, Y.S., ... & Kirkham, M.B., 2019. Particulate plastics as a vector for toxic trace-element uptake by aquatic and terrestrial organisms and human health risk. Environment international, 131, 104937.

Buringh, P., 1960. Soils and soil conditions in Iraq. Ministry of Agriculture, Directorate General of Agricultural Research and Projects, Baghdad.

Cervantes-Trejo, A., Pinedo-Álvarez, C., Santellano-Estrada, E., Cortes-Palacios, L., Rentería-Villalobos, M., 2018. Distribution of Chemical Species in the Water-Soil-Plant (Carya illinoiensis) System near a Mineralization Area in Chihuahua, Mexico—Health Risk Implications. International Journal of Environmental Research and Public Health, 15(7), 1393.

Cui, Y. J., Zhu, Y. G., Zhai, R. H., Chen, D. Y., Huang, Y. Z., Qiu, Y., Liang, J. Z., 2004. Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China. Environment international, 30(6), 785-791.

Essa, S.K., Al-jibury, D.A., 2017. Heavy metals pollution for soils in some of roads and squares of Baghdad city center. Iraqi Journal of Agricultural Science, 48(6), 1456-1472.

Gupta, S., Nayek, S., Saha, R.N., Satpati, S., 2008. Assessment of heavy metal accumulation in macrophyte, agricultural soil, and crop plants adjacent to discharge zone of sponge iron factory. Environmental geology, 55, 731-739.

Gupta, S., Satpati, S., Nayek, S., Garai, D., 2010. Effect of wastewater irrigation on vegetables in relation to bioaccumulation of heavy metals and biochemical changes. Environmental monitoring and assessment, 165, 169-177.

Hasan, H.R., Jeber, J.N., 2016. Determination of Lead Metal in roadside plants in some of Baghdad's Highways, Iraq. Journal of Chemical and Pharmaceutical Research, 8(4), 186-191.

Hassoon, H.A., 2018. Heavy metals contamination assessment for some imported and local vegetables. Iraqi Journal of Agricultural Sciences, 49(5), 794- 802.

Hussein, R.F., 2018. Environmental Geochemistry of Al-Mishkhab Rice Agricultural Fields at Al-Najaf Governorate–South West Iraq. Baghdad: University of Baghdad, Iraq.

Khathi, M.T., Farhood, A.T., Issmer, A.H., 2016. Determination of some heavy metals in extraction of plants by using AAS Technique. Journal of Natural Sciences Research, 6, 130-137.

Mafuyai, G. M., Eneji, I. S., Sha'Ato, R., & Nnamonu, L.A., 2019. Heavy metals in soil and vegetables irrigated with ex-tin mining ponds water in Barkin-Ladi Local Government Area Plateau State, Nigeria. Agriculture and Food Sciences Research, 6(2), 211-220.

Makanjuola, O.M., Bada, B. S., Ogunbanjo, O.O., Olujimi, O.O., Akinloye, O.A., Adeyemi, M.O., 2019. Heavy Metal Speciation and Health Risk Assessment of Soil and Jute Mallow (Corchorus Olitorus) Collected from a Farm Settlement in Ikorodu, Lagos, Nigeria. Journal of Agricultural Chemistry and Environment, 8(04), 201.

Matejkovič, P., Jurkovič, Ľ., Jankulár, M., Hiller, E., Šottník, P., n.d., 2014. Accumulation and bioavailability of arsenic and zinc in native plants at tailings impoundment. Acta Environmentalica Universitatis Comenianae (Bratislava), 22 (2), 42-49.

Maxwell, J.A., 1968. Rock and mineral analyses John Wiley and Sons. New York, 584.

Mengistu, D.A., 2021. Public health implications of heavy metals in foods and drinking water in Ethiopia (2016 to 2020): systematic review. BMC public health, 21, 1-8.

Mohammed, I.J., Kamel, E.H., Al-Falahi, A.A., Saliem, K.A., 2014. Study of Soils Suitability for Various Crops Production in Abu-Ghraib Using Gis Techniques. Iraqi Journal of Agricultural Science (Special Issue), 19(6), 218-228.

Muhaimeed, A.S., Al-Falihi, A.A., Al-Aini$_2$, E., & Taha, A. M. 2014. Developing land suitability maps for some crops in Abu-Ghraib using remote sensing and GIS. Remote Sensing and GIS, 2, 16-23.

Mutter, M.M., 2016. Using X-ray fluoresces analysis to assess level of major and trace elements in cultivated vegetables at Baghdad City. International Letters of Natural Sciences, 52, 84-87.

Mutune, A.N., Makobe, M.A., Abukutsa-Onyango, M.O.O., 2014. Heavy metal content of selected African leafy vegetables planted in urban and peri-urban Nairobi, Kenya. African Journal of Environmental Science and Technology, 8(1), 66-74.

Papadakis, J. 1975. Climates of the world and their potentialities. Climates of the world and their potentialities.

Stoodley, K.D., Lewis, T., Stainton, C.L.S., 1980. Applied statistical techniques. Chichester, England: Horwood.

Sultana, M.S., Jolly, Y.N., Yeasmin, S., Islam, A., Satter, S.,Tareq, S.M., 2015. Transfer of heavy metals and radionuclides from soil to vegetables and plants in Bangladesh. Soil Remediation and Plants: Prospects and Challenges, 331-366.

Yaqub, M.T., Hassan, M.A., Aljaberi, S.A., 2021, November. Effect Variation in Agricultural System on Some Alluvial Soil Characteristics in Abu Ghraib Region-Iraq. In IOP Conference Series: Earth and Environmental Science, 904(1), 012056. IOP Publishing.

Zheng, N., Wang, Q., Zhang, X., Zheng, D., Zhang, Z., Zhang, S., 2007. Population health risk due to dietary intake of heavy metals in the industrial area of Huludao city, China. Science of the Total Environment, 387(1-3), 96-104.