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HEAVY METAL POLLUTION OF AGRICULTURAL SOILS AND VEGETABLES OF ABANDONED MINING DISTRICT IN NORTHERN CYPRUS

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ABSTRACT

It is common knowledge that untreated abandoned mining sites are one of the leading causes of elevated heavy metal levels in soil and as well as vegetables growing in these areas. Ingestion of heavy metal contaminated vegetables is one of the primary ways in which these elements get access to human body. Thus, it is a necessity to analyse heavy metal levels in crops and agricultural soils. The aim of this study was to investigate the levels of heavy metals in vegetables and agricultural soil samples and to calculate bioconcentration factors of samples from the abandoned mining district, Gemikonagi and to compare these results with a control area, Dipkarpaz. The most common vegetables used in the local human diet were collected from Gemikonagi (n=7) and Dipkarpaz (n=7) with 7 agricultural topsoil samples from each region and they were analysed using inductively coupled plasma mass spectrometer. According to the results obtained, it was seen that malva samples had the highest mean concentration of heavy metals in both Gemikonagi and Dipkarpaz (718.53 mg/kg and 240.47 mg/kg, respectively). In both regions, the highest mean heavy metal concentration in soil was Fe (Gemikonagi; 25073.74 mg/kg and Dipkarpaz; 15061.58 mg/kg). In accordance with the obtained data, it was found that Cr accumulation in lettuce grown in Dipkarpaz is the only Bioconcentration Factor value that is above the limit. The soil in both regions is concentrated with high levels of heavy metals. Therefore, a large-scale monitoring of the soil is mandatory, and remediation of the heavy metal contaminated soil is necessary.

KEYWORDS:
Heavy metals, pollution, environmental toxicology, ICP-MS.

INTRODUCTION

Heavy metal(oid)s occur ubiquitously in the environment in trace amounts (µg/kg to mg/kg) in different matrices and their distribution is facilitated by natural processes such as rock weathering and anthropogenic activities such as smelting, mining, application of fertilisers and pesticides, and irrigation with polluted water [1,2]. Plants are necessary for cycling many chemical elements in nature. They undertake an extremely specific step in primary organic production and the transformation of the inorganic compounds into organic compounds. In addition, plants are the main and unalterable part of human nutrition [3,4].

Anthropogenic activities are the main cause of the elevated levels of heavy metal(oid)s in the environment and heavy metal(oid) polluted soil accounted for more than half of the total polluted soil globally [5,6]. Specific heavy metals such as copper (Cu), chromium (Cr), nickel (Ni), zinc (Zn) etc. are named as micronutrients and they are fundamental elements for plant metabolism [7]. Nevertheless, excess amounts of the abovesaid micronutrients may act as toxicants for both plants, animals, and humans [3,8]. The uptake of heavy metal(oid)s by plants occurs through absorption via roots and foliage from polluted soils and air, respectively [2,9]. Several factors influence the uptake of metal(oid)s from the soil by the plants [10]. The chemical form and binding characteristics are key determinants for mobility and bioavailability of heavy metal(oid)s in soil [11]. Heavy metal(oid)s such as lead (Pb), arsenic (As), Cu, cadmium (Cd), mercury (Hg) and Cr are environmental pollutants of significant interest as their accumulation in agricultural soil is phytotoxic, and detrimental to the soil ecosystem [9,12].

Bioconcentration factor (BCF) is the ratio of the concentration of an element in plants to that in the surrounding soil, that is, heavy metal(oid) in plants/soil ratio. Recently, BCF is being used as an indicator of metal(oid)s transferred from soil to plants. Thus, BCF is an established matrix of the quantification of plant heavy metal(oid) uptake. Plants with a BCF higher than 1 are termed hyperaccumulator and those with a factor below 1 are non-

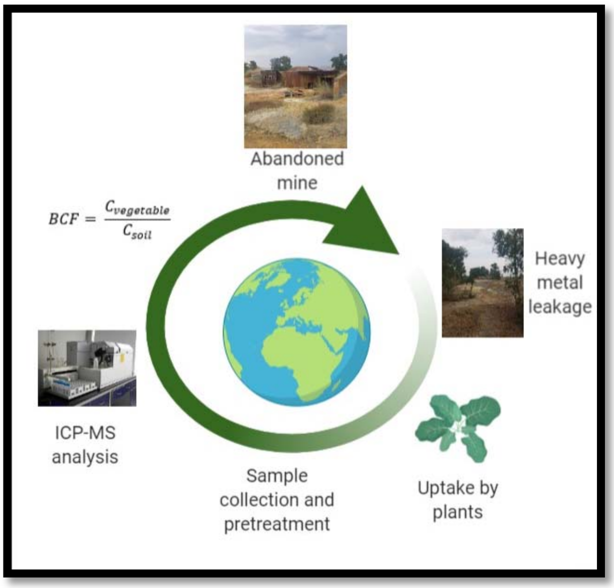

FIGURE 1
Graphical illustration of the study.

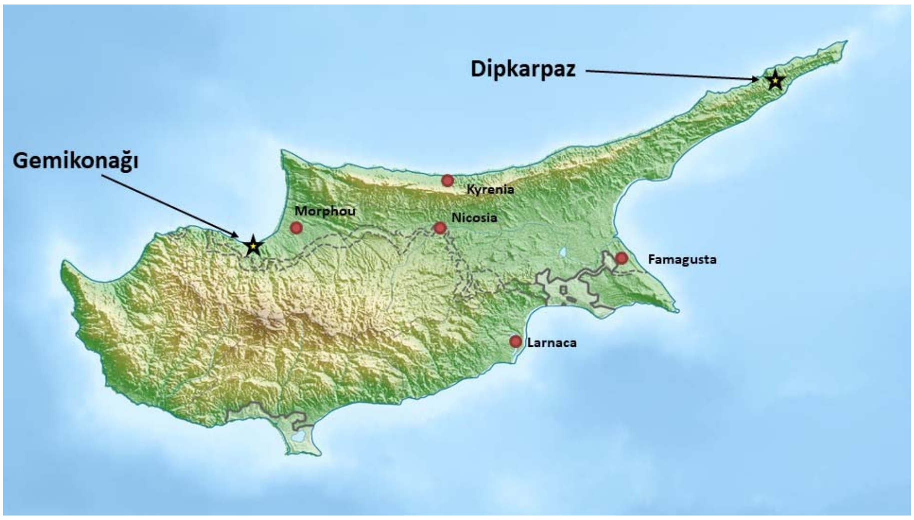

FIGURE 2
Gemikonagi (Karavostasi) and Dipkarpaz Location, Cyprus Map

accumulators [13]. The environmental persistence of heavy metals is a major problem for the remediation of heavy metal polluted soil [9, 14]. This global problem has induced scholars from different parts of the world to actively study remediation techniques [15, 16]. Heavy metal(oid)s are toxic to humans and can accumulate in the body tissues for long periods, exerting different toxic effects on target tissues [8,17,18].

Human exposure to heavy metal(oid)s is primarily through consumption of foodstuff such as vegetables, fruits, and cereals [19]. It is estimated that nearly 90% of metal intake is caused by consumption of contaminated vegetables [20]. It is, therefore, mandatory to analyse the level of heavy metal accumulation in crops such as vegetables and agricultural soils. Geochemical studies revealed that Cyprus is rich in copper and other metals. Gemikonagi is a port town in Northern Cyprus and was a site for copper mining during the 20th century. [21] Mining activities in the region mobilised not only copper, but also other heavy metals for absorption by plants [22]. In 1974, mining operations in Gemikonagi was abandoned and mining site was left to its fate without any remediation or governmental actions. On the other hand, Dipkarpaz is an incredibly old village, located at the end of Karpaz Peninsula in virtual isolation, has never had and does not have any industrial activities and remote to any potential source of contamination.

The previous heavy metal studies done around different parts in Northern Cyprus has been focus on soil and water bodies heavy metal analysis and lack the assessment of heavy metal accumulation and uptake in vegetables [21,23–25]. Thus, this study was designed around the goal of investigating the levels of accumulation in vegetables and agricultural soil samples, as well as calculating the BCF values of samples from the abandoned mining district, Gemikonagi, and comparing the results with a control area, Dipkarpaz (Figure 1).

MATERIALS AND METHODS

Study Area. The most common vegetables used in the local human diet (artichoke; *Cynara scolymus*, cabbage; *Brassica oleracea var. capitata*, celery; *Apium graveolens*, lettuce; Lactuca *sativa*, malva; *Malva parviflora*, purple cabbage; *Brassica oleracea var. capitata f. rubra*, spring onion; *Allium fistulosum*) were collected from the abandoned mining district, Gemikonagi (n=7) and from a control district, Dipkarpaz (n=7). In addition to vegetable samples, a total of 14 topsoil samples, from Gemikonagi (n=7) and Dipkarpaz (n=7) were collected during early spring. Gemikonagi is in the western part of the Island of Cyprus and has an abandoned mine and tailings. On the other hand, Dipkarpaz is in the eastern part of Cyprus, at the edge of an isolated peninsula. The distance between these two selected areas is approximately 155 km (Figure 2).

Chemicals and reagents. Nitric acid, purity 70%, and hydrochloric acid, purity 37% (Fluka, Madrid, Spain); hydrogen peroxide solution for ultra-trace analysis, purity 35% (Sigma-Aldrich, Steinheim, Germany), Water obtained from a Milli-QTM system (Millipore, Bedford, MA, USA), Whatman #42 filter paper (Merck, Darmstadt, Germany), borosilicate glass digestion tubes (Foss, MN, USA).

Sample collection, storage, and pre-treatment. Vegetable samples. Vegetable samples were collected with a stainless-steel knife and sealed hermetically in pre-sanitised zipper bags, each weighing approximately 100 g. The vegetable samples were collected at the same location as the soil sample (within 0.5 metres) and their coordinates were recorded as shown on Table 1. The samples were kept at 4^{o} C and transferred to the Near East University Toxicology Laboratory within 3 hours. Upon arrival at the laboratory, the edible parts of samples were thoroughly washed with deionised water and rinsed again with deionised water and kept on clean surfaces for 24 hours to air dry. Then they were sealed in pre-sanitised airtight polyethylene storage bags, labelled clearly, and stored at -20^{o}C in a refrigerator.

Dual stage drying method was used to dry the sample to constant weight. Chopped vegetable samples were each put in crucibles and placed in an incubator for 30 minutes at 105^{o} C. At the second stage, the temperature of the incubator was set at 70^{o} C and the samples were allowed to dry for 12 hours. The dried samples were ground, pulverised in an agate mortar and filtered with an 80-mesh sieve. 0.5 g of each sample was weighed and 30 mL of acid mixture (HNO_3:$HClO_4$:H_2SO_4, 1:1:1) was added to each sample in an Erlenmeyer flask. They were kept in a fume hood for 24 hours. The mixtures were then heated to 90^{o} C on a hot plate until the volume reduced to 10 mL. An additional 10 mL acid mixture was added to the flask and heated to a final 4 mL volume. The flask was capped, allowed to cool to room temperature for 1 hour and 50 mL of deionised water was added to the flask. The sample mixtures were then filtered through a Whatman #42 filter paper using vacuum assisted Buchner apparatus. Deionised water was used to make up to 100 mL.

Soil samples. A total of 14 topsoil samples (0-10 cm) from Gemikonagi (n=7) and Dipkarpaz (n=7), each weighing 200 g were collected in pre-sanitised polyethylene zipper bags using a pre-sanitised PTFE-coated scoop. The samples were kept at 4^{o} C to minimise bacterial colonisation and loss of moisture and transferred to the Near East University Toxicology Laboratory within 3 hours and the storage temperature was maintained at 4^{o} C. Prior to analysis, soil samples were kept at room temperature in a controlled area to air dry. After 72 hours, they were ground and sieved through a 1.0 mm sieve. The sieved samples were tightly sealed pre-sanitized polyethylene bags and labelled clearly. Right before the analysis, 5 mL nitric acid (65%) was mixed with 0.25g of soil sample. The mixtures were heated up to 180^{o} C until the acid almost completely evaporated, and the nitric acid addition was repeated twice more. After the final heating process, deionised water was added, and the suspension was filtered with Whatman syringe filter (0.45 µm). The filtrate was made up to 50 mL with deionised water.

Instrumentation. The inductively coupled plasma mass spectrometry (ICP-MS) analysis was conducted at the Advanced Technology Education Research and Application Centre Laboratory of Mersin University. The method was adopted from Alkas *et al.* [25].The ICP-MS instrument used was an Agilent 7500ce Octupole Reaction System with 99.99% helium from Agilent Technologies (Tokyo, Japan), consisting of an ICP source with a plasma-shielded torch (grounded metal plate), an octopole reaction system operated in radiofrequency (RF)-only mode and a quadrupole mass analyser with a secondary electron multiplier operating in dual mode (i.e. either a pulse-counting mode or analogue mode, depending on the ion intensity). The operating conditions were as follows: nebuliser type, concentric nebuliser; nebuliser gas (argon) flow rate, 0.9 L/min; auxiliary gas (argon) flow rate, 0.14 L/min; plasma gas (argon) flow rate, 15 L/min; reaction gas (helium) flow rate, 0.14 L/min; spray chamber (S/C) temperature, 2 °C; and ICP RF power, 1500 W. The argon gas utilised was of spectral purity (99.998%). Validation parameters for the ICP-MS method are shown in Table 2.

Data Analysis. Arithmetic mean and standard deviation were calculated using PASW Statistics 18 (SPSS Inc, Hong Kong).

BCF Calculation. BCF was calculated as follows:

$$BCF = \frac{C_{vegetable}}{C_{soil}}$$

Where $C_{vegetable}$ is the total concentration of a particular heavy metal(oid) in the vegetable (mg/kg dry weight), and C_{soil} is the corresponding heavy metal(oid) concentration in the soil around the vegetable (mg/kg).

TABLE 1
Location of sampling sites determined by global positioning system.

S/N	Sample	Coordinates in Gemikonagi	Coordinates in Dipkarpaz
1	Malva; Soil	35°15'63"N, 32°80'99"E	35°59'86.39"N, 34°39'26.67"E
2	Lettuce;Soil	35°14'55.03"N, 32°85'56.52"E	35°59'86.39"N, 34°39'26.67"E
3	Spring Onion; Soil	35°14'55.03"N, 32°85'56.82"E	35°59'86.39"N, 34°39'26.67"E
4	Celery; Soil	35°14'55.03"N, 32°85'56.82"E	35°59'86.39"N, 34°39'26.67"E
5	Purple Cabbage; Soil	35°14'62.76"N, 32°85'68.29"E	35°59'86.39"N, 34°39'26.67"E
6	Cabbage; Soil	35°14'57.57"N, 32°85'63.54"E	35°59'86.39"N, 34°39'26.67"E
7	Artichoke; Soil	35°14'69.09"N, 32°85'48.75"E	35°59'86.39"N, 34 °39'26.67"E

TABLE 2
Comparison of mean concentration of heavy metals in vegetable samples.

	Cd (µg/kg)	**Hg (mg/kg)**	**Pb (mg/kg)**	**As (mg/kg)**	**Ni (mg/kg)**	**Cr (mg/kg)**	**Al (mg/kg)**	**Mg (mg/kg)**	**Fe (mg/kg)**	**Cu (mg/kg)**
Artichoke										
Gemikonagi	11.41	ND	ND	ND	ND	ND	ND	613.25	4.55	4.63
Dipkarpaz	7.26	ND	ND	ND	ND	82.34 [a]	ND	543.28	10.59	1.68
Cabbage										
Gemikonagi	3.38	ND	ND	ND	ND	25.63 [a]	4.50 [a]	875.71	713.48	3.42
Dipkarpaz	ND	ND	ND	ND	ND	0.14	ND	227.98	42.48	0.45
Celery										
Gemikonagi	7.73	ND	ND	ND	ND	42.55 [a]	6.49 [a]	1678.71	23.14	2.28
Dipkarpaz	0.01	ND	ND	ND	ND	8.66 [a]	43.03 [a]	552.68	42.43	11.34
Lettuce										
Gemikonagi	12.77	ND	ND	ND	ND	43.76 [a]	5.46 [a]	512.39	21.21	2.40
Dipkarpaz	224.32[a]	ND	ND	ND	ND	1025.93 [a]	2.17 [a]	414.40	15.79	2.19
Malva										
Gemikonagi	19.23	ND	ND	0.76 [a]	ND	11.60 [a]	128.49 [a]	4247.44	175.65	7.44
Dipkarpaz	7.50	ND	ND	ND	ND	19.52 [a]	75.48 [a]	1349.29	82.41	2.88
Purple Cabbage										
Gemikonagi	2.91	ND	ND	ND	ND	13.20 [a]	ND	850.44	7.12	0.77
Dipkarpaz	ND	ND	ND	ND	ND	8.25 [a]	ND	219.41	4.12	0.32
Spring Onion										
Gemikonagi	0.38	ND	ND	ND	ND	0.83 [a]	ND	288.57	2.26	0.79
Dipkarpaz	0.92	ND	ND	2.77 [a]	ND	36.97 [a]	ND	119.12	5.68	0.49
Accepted Limits	50 mg/kg[b]	Below LOD (1µg/kg)	Below LOD (1µg/kg)	0.10 mg/kg[c]	Below LOD (1µg/kg)	0.50 mg/kg[d]	1 mg/kg[e]	Macro-nutrient	Macro-nutrient	Macro-nutrient

a Above the accepted limit values.
b (“EUR-Lex - 02006R1881-20150521 - EN - EUR-Lex,” n.d.)
c (U.S. Food and Drug Administration Supporting Document for Action Level for Inorganic Arsenic in Rice Cereals for Infants, 2016)
d (USDA Foreign Agricultural Service, 2006)
e (“Safety of aluminium from dietary intake - Scientific Opinion of the Panel on Food Additives, Flavourings, Processing Aids and Food Contact Materials (AFC),” 2008)

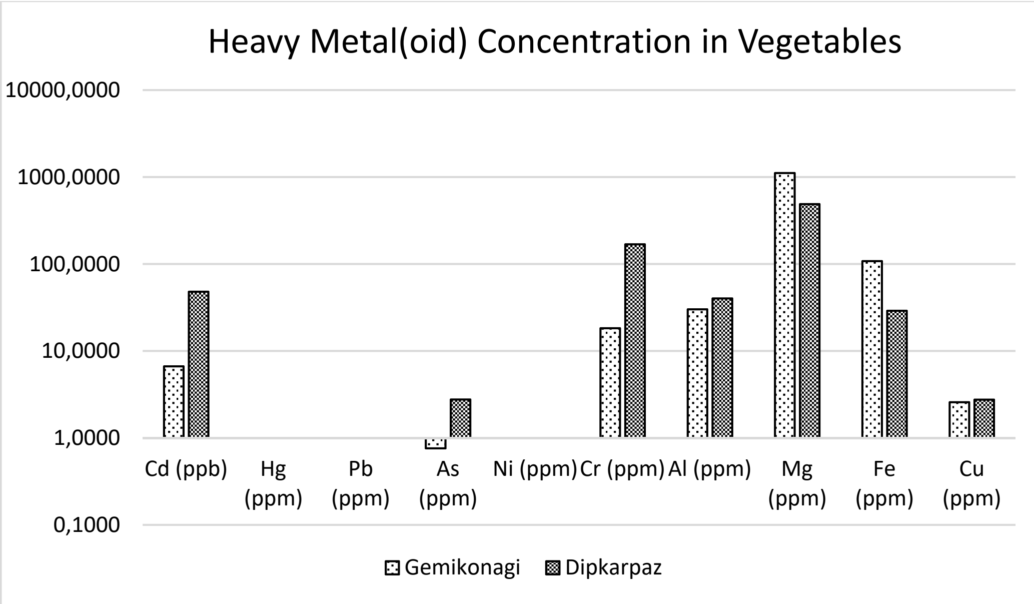

FIGURE 3
Heavy metal concentration in vegetables

TABLE 3
Comparison of mean concentration of heavy metals in sediment samples.

Heavy Metal	Region	Mean ± SD (mg/kg)	FAO/WHO MPL (mg/kg)
Cd	Gemikonagi	2.94 ± 0.75	3
	Dipkarpaz	3.32± 0.82	
Hg	Gemikonagi	0.55 ± 0.22	0.5
	Dipkarpaz	0.33 ± 0.05	
Pb	Gemikonagi	34.18 ± 1.22	100
	Dipkarpaz	66.59 ± 9.20	
As	Gemikonagi	22.36 ± 4.82	20
	Dipkarpaz	37.94 ± 8.89	
Ni	Gemikonagi	109.23 ± 43.63	50
	Dipkarpaz	146.19 ± 20.13	
Cr	Gemikonagi	63.25 ± 21.91	100
	Dipkarpaz	85.940± 24.560	
Al	Gemikonagi	11459.93 ± 1389.41	-
	Dipkarpaz	7146.80 ± 1025.79	
Mg	Gemikonagi	9335.18 ± 2161.08	-
	Dipkarpaz	2982.05 ± 395.36	
Fe	Gemikonagi	25073.74 ± 1450.56	50000
	Dipkarpaz	15061.58 ± 2286.40	
Cu	Gemikonagi	133.68 ± 14.70	100
	Dipkarpaz	38.19 ± 4.65	

FAO/WHO MPL; Food and Agricultural Organization of United States/World Health Organization Maximum Permissible Limits.

RESULTS

Vegetable Samples. There were large variations in the concentrations of heavy metal(oid)s in the vegetable samples depending on the type of vegetable as well as growth location. Table 2 and Figure 3 summarise the results obtained from the vegetable samples. Malva samples had the highest level of metal(oid)s whereas spring onion samples has the lowest heavy metal(oid)s in both regions. The vegetable samples from Gemikonagi had the higher mean concentration of heavy metals as compared to Dipkarpaz and the highest mean level in Gemikonagi (Malva; 718.53 mg/kg) almost tripled that of in Dipkarpaz (Malva; 240.47 mg/kg). Cr level of artichoke grown in Dipkarpaz (82.34 mg/kg) exceeded the legal limit (0.50 mg/kg). In contrast, Cr was not detected in arthichoke sample from Gemikonagi. Conversely, Cr level in cabbage was higher than the limit value in Gemikonagi (25.63 mg/kg) but lower in Dipkarpaz (0.14 mg/kg). All other Cr concentrations from the rest of the vegetable samples were found to be above the reference value of 0.50 mg/kg. In addition, Al values of celery, malva and lettuce from both regions were higher than the limit value of 1 mg/kg.

Soil Samples. The soil samples analysed from both Gemikonagi and Dipkarpaz showed varied concentrations in terms of heavy metal(oid)s and they were summarised in Table 3. In both regions, the highest mean concentration was Fe (Gemikonagi; 25073.74 mg/kg and Dipkarpaz; 15061.58 mg/kg) and the lowest was Hg (Gemikonagi; 0.55 mg/kg and Dipkarpaz; 0.33 mg/kg). The mean Cd level in Dipkarpaz (3.32 mg/kg) was slightly higher than the FAO/WHO limit value (3 mg/kg) but it was under the limit in Gemikonagi soil (2.94 mg/kg). Hg concentration in soil from Gemikonagi (0.55 mg/kg) was also over the limit value (0.50 mg/kg). Furthermore, it was observed that both As and Ni concentrations in soil from both regions exceeded the reference values (20 mg/kg and 50 mg/kg, respectively) and As and Ni concentrations in Dipkarpaz (As; 37.94 mg/kg and Ni; 146.19 mg/kg) were higher than As and Ni levels in Gemikonagi soil (As; 22.36 mg/kg and Ni; 109.23 mg/kg). The mean Cu concentration of Gemikonagi (133.65 mg/kg) was almost tripled that of Dipkarpaz (38.19 mg/kg), and only Cu level in Gemikonagi was exceeded the limit value of 100 mg/kg. Other values were varied but they were all below the reference values.

BCF of heavy Metal(oid)s in Vegetables. The data for BCF of the heavy metals analysed has been given in Table 4. According to data obtained, it is seen that the BCF values vary between the vegetables as well as their growth location. On individual metal base, Cr was observed to accumulate in lettuce grown in Dipkarpaz (BCF=11.94) to greater extent than it does in lettuce grown in Gemikonagi (BCF=0.69) and Cr accumulation in lettuce in Dipkarpaz was the only BCF value that is above 1. All other BCF values obtained in this study are all <1. Some BCF values could not be calculated as the metal under consideration could not detected in vegetable samples. Cd and Al showed no accumulation in lettuce and spring onion (BCF=0.00 each) for both regions.

TABLE 4
Comparison of BCF values calculated from the obtained data.

	Cd	Hg	Pb	As	Ni	Cr	Al	Mg	Fe	Cu
Artichoke										
Gemikonagi	0.004	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.066	0.000	0.035
Dipkarpaz	0.002	N.A.	N.A.	N.A.	N.A.	0.958	N.A.	0.182	0.004	0.045
Cabbage										
Gemikonagi	0.001	N.A.	N.A.	N.A.	N.A.	0.405	0.000	0.094	0.010	0.026
Dipkarpaz	N.A.	N.A.	N.A.	N.A.	N.A.	0.001	N.A.	0.076	0.014	0.016
Celery										
Gemikonagi	0.003	N.A.	N.A.	N.A.	N.A.	0.673	0.001	0.180	0.000	0.017
Dipkarpaz	0.000	N.A.	N.A.	N.A.	N.A.	0.101	0.006	0.185	0.014	0.297
Lettuce										
Gemikonagi	0.004	N.A.	N.A.	N.A.	N.A.	0.692	0.000	0.049	0.000	0.018
Dipkarpaz	0.068	N.A.	N.A.	N.A.	N.A.	11.938*	0.000	0.139	0.005	0.057
Malva										
Gemikonagi	0.007	N.A.	N.A.	0.034	N.A.	0.183	0.011	0.455	0.002	0.056
Dipkarpaz	0.002	N.A.	N.A.	N.A.	N.A.	0.227	0.010	0.452	0.028	0.075
Purple cabbage										
Gemikonagi	0.001	N.A.	N.A.	N.A.	N.A.	0.209	N.A.	0.091	0.000	0.006
Dipkarpaz	N.A.	N.A.	N.A.	N.A.	N.A.	0.096	N.A.	0.074	0.001	0.008
Spring Onion										
Gemikonagi	0.000	N.A.	N.A.	N.A.	N.A.	0.013	N.A.	0.031	0.000	0.006
Dipkarpaz	0.000	N.A.	N.A.	0.073	N.A.	0.430	N.A.	0.040	0.002	0.012

*BCF>1.
N.A.; BCF calculation is not applicable.

DISCUSSION AND CONCLUSION

The natural concentration of heavy metals in the Earth's core has little or no effect on the soil and plants. The major cause of high levels of heavy metals in the soil is anthropogenic activities. The presence of heavy metals in the soil above the maximum allowable limit does not just affect the soil alone but also affects the productivity of plants and the health of the consumers of crops, which includes humans and animals (Tran & Nguyen, 2018). Except occupational exposure, the major route by which humans take in heavy metals is through ingestion in food and the effect of heavy metals consumed in food has been seen in the consumption of rice (Itai Itai Japan 1912), [26] and fish (Minamata disease in Japan 1956) [27].

This study conducted in Gemikonagi and Dipkarpaz assessed the distribution of heavy metals in vegetable and agricultural soil samples. This is first research in North Cyprus that investigated heavy metals in both agricultural soil and vegetable samples, however, heavy metals in soil, water and fish samples has been analysed independently.

There were wide range of differences in the concentrations of heavy metal(oid)s in the vegetable samples. Malva samples had the highest level of metal(oid)s whereas spring onion samples has the lowest heavy metal(oid)s in both regions. The vegetable samples from Gemikonagi had the higher mean concentration of heavy metals as compared to Dipkarpaz and this might be primarily due to the abandoned mining site in Gemikonagi. Cr level of artichoke sample collected from Dipkarpaz was found to be above the permissible limit (0.50 mg/kg), but Cr was not detected in artichoke sample from Gemikonagi. In addition, Al values of celery, malva and lettuce from both regions were higher than the limit value of 1 mg/kg. These findings suggest that human activities such as application of fertilisers may cause the elevated metal accumulation in vegetables.

The heavy metals analysed in the soil samples from both Gemikonagi and Dipkarpaz showed large variation. In both regions, the highest mean concentration was Fe (Gemikonagi; 25073.74 mg/kg, and Dipkarpaz; 15061.58 mg/kg) and the least was Hg (Gemikonagi; 0.55 mg/kg, and Dipkarpaz, 0.33mg/kg). The higher metal concentrations in Gemikonagi were a result of the heavy metals leaching from the tailing sources to distant areas around the region of Gemikonagi. Comparing the mean concentration of Pb (34.18 - 66.59 mg/kg) in soil samples to other studies done by Alkas et al. [25] (32.60 mg/kg) and Akun *et al.* [24] (8.02-44.29 mg/kg), they were slightly different partly because they were sampled from different regions and all the different concentrations were below the maximum permissible limit of WHO. A remarkable difference was seen in the concentration of Al and Cu in both regions, the mean concentration of Al in Gemikonagi was double that in Dipkarpaz whereas the mean concentration of Cu was quadruple that of Dipkarpaz. The mean Ni and As concentration in both regions were above the maximum permissible limit (MPL) of WHO and this is an alarming situation as subsistence agriculture is practiced widely in this region. In Dipkarpaz, the mean Cd concentration was above the MPL of WHO. Compared with the MPL of WHO, the mean Hg concentration in Gemikonagi was higher. The factors that contributed to the high concentrations of metals in Gemikonagi was the use of insecticides, organic fertilizers and pesticides containing metals in agriculture and also the leaching of heavy metals from tailings of abandoned mining facility to the sea and other water bodies that are used to irrigate farmlands.

Higher BCF values signify greater transfer ability of the metals from soil to plants and the BCF of vegetables vary with the species [1]. Generally, the uptake of heavy metals is higher in leafy vegetables than non-leafy vegetables as they have faster and greater transpiration rate which aid the transfer of heavy metals from soil through the roots to the shoots [13]. Among the different vegetables studied, only Cr was observed to accumulate in lettuce sample from Dipkarpaz (BCF=11.94). Apart from Cr in lettuce samples that were found to be not consistent, all other BCF values for both regions showed consistency and they were all below 1. It is known that the accumulation of heavy metals in vegetables is significantly influenced by the species of vegetable, and the metal concentration in soil [13].

North Cyprus practice subsistence agriculture producing and supplying vegetables and fruits in large quantity to meet up with the everyday demand of the inhabitants. Based on the Agency for Toxic Substances and Disease Registry (ATSDR) priority list of hazardous substance in 2013; As, Ni, and Cd which are amongst the top 4 substances exceeded the MPL of WHO in both soil and vegetable samples ("Substance Priority List | ATSDR," 2013). Hg also exceeded the safe limit. Increased cancer cases in this region signified the presence of carcinogenic substances in the environment and a study by Akun *et al.* [24] showed high concentration of heavy metals such as Arsenic, Lead and Cadmium in soil which are all carcinogens [24]. The soil in Gemikonagi and Dipkarpaz is concentrated with heavy metals of high priority and the vegetables uptake heavy metals mainly through the roots from soil. The source of heavy metal soil pollution in Gemikonagi is partly by irrigation of farmland with the heavily contaminated sea water, chemical fertilizers and tailings from the abandoned mine whereas Dipkarpaz heavy metal soil pollution might possibly be traced to chemical fertilizers, sewage water irrigation and pesticide usage. Sewage sludge and chemical fertilizer with heavy metal content should not be used for crop cultivation as the soil already contain unacceptable high level of heavy metals. The conducted study has two main limitations. Firstly, as the study was designed to be a pilot study, the number of samples cannot give a confidential statistical analysis. Secondly, ICP-MS was used to analyse a wide range of chemical elements including micro and macronutrients of the soil and as well as the vegetables. Nevertheless, due to the aim of the study, only heavy metals were discussed herein. Therefore, a large-scale monitoring of the soil and vegetables with high number of samples is mandatory, and remediation of the heavy metal contaminated soil is necessary to prevent the accumulation of heavy metals in humans through vegetables consumption in these regions.

Conflict of Interest. The authors declare that there is no conflict of interests.

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