DESERT 2021, 26(1): 127-138
DOI: 10.22059/jdesert.2020.311191.1006794

RESEARCH PAPER

Investigation of Cd, Pb, and Ni contamination in soil and wheat plant in alluvial lands of Tigris River in southern Baghdad, Iraq

T. Salman, A. Karimi*, E. Mahmoudabadi

Department Soil Science, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Kh. Razavi, Iran

Received: 3 October 2020, Revised: 20 November 2020, Accepted: 21 November 2020

Abstract
Accurate information on the concentration of heavy metals in the soil is essential to manage soil contamination. The objective of this study was to investigate the contamination of soil and wheat plants with Ni, Cd, and Pb in the alluvial plain of Tigris River in southern Baghdad. A total of hundred surface soil samples (0-30 cm) and aerial parts of the wheat plant were taken in an area of ~100 km^2 at an interval distance of 1000 meters. Heavy metals in air-dried soil samples and plant were extracted by the aqua regia solution and wet digestion method, respectively. The mean concentration of Cd in soil and wheat plant was 0.4 and 1.1 mg kg^{-1}, respectively. The amount of plant-Cd was higher than the allowable standards of FAO and WHO. Mean Pb concentration in the soil of the study area was 14.5 mg kg^{-1}. The concentration of Pb in the plant was less than the detection limit of the device. The mean concentration of Ni in the soil and plant was 214 and 17 mg kg^{-1}, respectively, which was more than the allowable standards of FAO and WHO. The source of Ni is fine sediments transferred from eroded ultramafic rocks in the upper part of the river. A positive correlation between Pb and Cd in the soil indicates a similar origin. They were added to the soil by agricultural activities and vehicles. The results showed that the studied soils are at the beginning of the contamination with Cd and Pb, which needs to be considered to prevent more contamination.

Keywords: Anthropogenic pollution, Tigris alluvial plain, Geostatistics, Heavy metals.

Introduction

Soil is an important component of agricultural ecosystems that need to be protected against contamination to ensure healthy and sustainable production. For this reason, soil pollution has become a major concern in most countries around the world. Heavy metals are one of the most dangerous and toxic pollutants in the soil, which has been considered by researchers and decision-makers in recent decades due to the increase in their concentration in the soil (Kumar et al., 2019; Dogra et al., 2019; Hu et al., 2013).

Parent materials are the primary source of heavy elements in the soil. The intrinsic properties of the sediments or rocks determine the concentration of elements in the soil (Karimi et al., 2017; Nael et al., 2009; Acosta et al., 2011). Human activities are another source that add heavy metals from outside the system to the soil and known as the anthropogenic source. Industrial activities, vehicle fuel, mining, and agricultural activities are the main factors in increasing heavy metals in the soil (Hu et al., 2013; Jalai and Khanlari, 2008; Taghipour et al., 2011; Meng et al., 2020). In recent decades, the use of effluents for irrigation, the use of compost and sewage sludge, fertilizers, and pesticides have increased heavy metal concentrations in the soil (Hu et al., 2013; Chen et al., 2005; Huang et al. 2015; Hu et al., 2017). Due to the absorption of heavy

* Corresponding author e-mail: karimi-a@um.ac.ir

metals, plants act as a carrier to transfer these elements to the human food chain that endangers human health (Säumel et al., 2012; Toth et al., 2016).

Continuous spatial distribution of heavy metals provides information concerning contamination sources. Geostatistics is one of the common and powerful tools to determine the pattern of the spatial distribution of heavy metals (Benhaddya and Hdjel, 2014; Wu et a*l.*, 2011). Karimi et al. (2017) indicated by the distance from the ultramafic rocks, in Mashhad plain in northeastern Iran, the Ni concentration of the soil gradually decreased which indicated that Ni concentration in the soil was controlled by lithogenic origin. Lv et al. (2016) according to the relationship of the hotspot of Cd, Zn, and Pb to geology as well as industrial and agricultural activities, attributed the spatial pattern of these metals to parent materials and human inputs.

Information on the concentration of heavy elements in water, soil, and plant systems is necessary to monitor the effect of these elements on the health of ecosystems and food chain health. There are few studies on the heavy metals concentration in the soil and plant along the Tigris River in Iraq. Al-Siwira Agricultural farms are located 80 km south of Baghdad, on the banks of the Tigris River. The predominant cultivation of these lands is mostly wheat and barley, and the water required for these lands is supplied from the River. The Tigris is one of the most important rivers in Iraq and plays an important role in providing water for marginal agricultural lands. The river mainly runs in Iraq, passing through major industrial cities such as Mosul and Baghdad. Agriculture in these areas may increase heavy elements both through irrigation and through agricultural activities, which could lead to contamination of agricultural products in the area. The objectives of this study were to i) determine the amount of Cd, Ni, and Pb in the water of Tigris River, ii) investigate the ability of geostatistics to relate the spatial patterns of heavy metals in the soil and plant to pollution sources and iii) found the factors which, control the concentrations the absorption heavy metals by the wheat plant in Al-Siwira Agricultural lands.

Materials and Methods

Study area

The study area (Al-Siwira) with and area of about 100 km^2 is located 100 km south of Baghdad and between 44° 53' 43" to 45° 02' 55" N and 32° 41' 33" to 32° 51' 01" E, on the bank of the Tigris River (Figure 1). The Tigris River originates from the Taurus Mountains in eastern Turkey and runs 400 km on the border between Syria and Turkey. The river after joining with the Arvand roud River along the border of Iran-Iraq enters the Persian Gulf.

The altitude of the area is 20 m above sea level and the depth of groundwater is 2 meters. Due to the salinity of the soil, most salinity-resistant plants such as wheat and barley are cultivated.

A hundred surface soil samples (0-30 cm) were taken in a regular grid cell of 1000×1000 m in cultivated and uncultivated lands. The aerial parts of the wheat plants were collected at each soil sampling location. Besides, water samples were taken from the Tigris River.

Laboratory analysis

The air-dried soil samples passed through a 2 mm sieve and fine earth fraction (<2 mm) used for laboratory analyses. The soil texture was determined by the pipette method (Gee and Bauder, 1986). Calcium carbonate equivalent was measured by the neutralization method (Allison, 1960). The 2:1 ratio of water to soil was used to measure the EC and pH. Soil organic carbon was determined by the modified Walkley- Black method (Nelson and Sommer, 1982).

Heavy metals of the powdered soil samples were extracted by aqua regia, which is a mixture of 3:1 HCl and HNO_3 (ISO / CDT, 1995). In this method, 15 ml of HCl was slowly added to 2 g of powdered soil sample. Then, 5 ml of HNO3 was added to the sample and was left overnight. Samples were heated for 1 h; after cooling, 10 ml of HNO3(0.5 N) was introduced into the suspension. Samples were centrifuged, and the extract was diluted to 50 ml with distilled water. The wet digestion method was carried using the dried plant to extract the heavy metals. The concentrations of the Pb, Cd, and Ni in the soil and plant extracts were measured using the atomic absorption spectrometry, PG-990 model.

Data analysis

Statistical description of data

Descriptive statistics included mean, minimum, maximum, standard deviation, coefficient of variations, skewness, and kurtosis were calculated. The normality of the data was examined using the Kolmogorov-Smirnov test. Statistical analyzes were performed using SPSS16 software.

Spatial structure analysis

In general, geostatistical analyses include two stages of variogrphy and interpolation. Variography characterizes the spatial structure of the variables by semivariogram (γ(h)) with the following formula (equation 1) presented by Goovaerts (1998).

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i) - Z(xi+h)]^2 \quad (1)$$

Wher γ (h) is the semivariogram, N (h) is the number of pairs of points with a distance of h, z(xi) is the value of the variable x observations in position i and z (xi + h) is the value of the variable observations at the distance h from xi.

Semivariogram analyses were performed using variowin software (2.2 version). The interpolation procedure was applied using ordinary kriging in the ArcGIS software (10.2 version). Indices of MAE (mean absolute error), MBE (mean bias error), and RMSE (root mean square error) were used to evaluate the accuracy of the interpolation (equation 2-4).

$$MAE = \frac{1}{N} \sum_{i=1}^{N} \{|\acute{Z}(X_i) - Z(X_i)|\} \quad (2)$$

$$MBE = \frac{1}{N} \sum_{i=1}^{N} \{\acute{Z}(X_i) - Z(X_i)\} \quad (3)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} \{Z(X_i) - \acute{Z}(X_i)\}^2} \quad (4)$$

If the MBE is zero, it indicates that the model estimate is good and there is no deviation. In general, the lower the values of the MBE, MAE, RMSE indicate the higher accuracy of the model used (Webster and Oliver, 2007).

Results

Descriptive statistics of soil characteristics and heavy elements

A summary of the descriptive statistics of soil characteristics is given in Table 1. The mean EC, pH, and the amount of calcium carbonate equivalent of the soils were 5.3 dS m^{-1}, 7.7, and 27.8%, respectively, indicating that the soil is saline and calcareous. The average amount of clay, silt, and sand were 52.2, 32.5, and 15%, respectively, which shows the heavy texture of the soils. The low soil organic carbon (0.7%) is due to the arid climate of the area. The EC and sand content with the coefficient of variation of 69 and 50%, respectively, had the highest variability among the soil properties.

The concentration of soil-Ni with a mean value of 214.8 mg kg^{-1} varied from of 164.8 to 256.7 mg kg^{-1} and with 10% coefficient variation, had the lowest variability. The mean, maximum and minimum concentrations of soil-Pb were 14.5, 22.2, and 7.6 mg kg^{-1}, respectively. The soil-Cd with a mean value of 0.38 mg kg^{-1} varied from 0.2 to 0.63 mg kg^{-1}, which had the highest coefficient of variation (33%).

The mean, maximum, and minimum of plant-Ni were 17.7, 40.4, and 1.9 mg kg^{-1}, respectively (Table 2). The mean concentration of plant-Cd was 1.1 mg kg^{-1}, which was higher than the concentration of Cd in the soil. The plant-Cd varied from zero to 4 mg kg^{-1}. The concentration of Pb in the plant was lower than the detection limit of the device.

Table 1. Summary of statistical parameters of soil properties in the study area

Statistic	pH	EC	Sand	Silt	Clay	CCE	SOC
		dS m^{-1}	%				
Minimum	7.20	1.20	1.00	19.30	35.70	23.00	0.14
Maximum	8.20	15.10	33.00	45.30	69.10	33.30	1.30
Mean	7.70	5.30	15.00	32.50	52.20	27.80	0.70
Median	7.80	3.71	14.30	33.30	53.40	27.90	0.70
Skewness	-.09	0.97	0.73	-0.34	-0.15	-0.05	0.22
SD	0.21	3.66	7.53	6.64	7.74	2.42	0.26
CV (%)	3.00	67.00	50.00	20.00	15.00	9.00	39.00
K-S	0.07	0.04*	0.03*	0.10	0.01*	0.009**	0.05

CCE: Carbonate calcium equivalent, SOC: soil organic carbon, SD: Standard deviation, CV: Coefficient of variation, *,** Asymptotic significance >0.01 and >0.05 (2-tailed)

Table 2. Summary of statistical parameters of heavy metals concentrations (mg kg^{-1}) in the soil and plant

Statistic	Soil			Plant		
	Ni	Cd	Pb	Ni	Cd	Pb
Minimum	164.8	0.2	7.6	1.9	0	LD
Maximum	256.7	0.63	22.2	40.4	4	LD
Mean	214.8	0.38	14.5	17.7	1.1	LD
Median	215.5	0.34	13.9	16.7	0.9	LD
Skewness	-0.24	0.8	0.53	0.46	0.9	LD
SD	22.11	0.12	4.09	8.43	1.03	LD
CV (%)	10	33	28	48	93	LD
K-S	0.09	0.002*	0.0007**	0.03	0.001**	LD

LD: lower than the detection limit, *,** Asymptotic significance >0.01 and >0.05 (2-tailed)

Spatial distribution

The Kolmogorov-Smirnov test (Table 1) indicated the abnormal distribution of EC, sand content, calcium carbonate equivalent, and soil organic carbon. To normalize these variables, the logarithmic conversion was used. The best model for EC, clay, and sand was linear and for pH and silt was Gaussian and exponential, respectively (Table 3). The clay had the highest range value (20680 m), which indicates the high extent of its spatial dependency. The lowest range was for the silt (1050 m), which is approximately equal to the sampling distance. Due to high spatial variations of calcium carbonate equivalent, its distance of spatial dependency was less than the sampling interval (1000 m) and therefore was not suitable to be modeled.

The logarithmic conversion was applied to normalize the distribution of soil- and plant- Cd, Ni, as well as plant-Pb (Table 2. The best model fitted to soil-Ni was the exponential model with moderate dependency. The plant-Ni data did not fit to any model due to the large variations of Ni in the wheat crop grown in the study area, which was less than the sampling distance (1000 m). The best model for soil-Cd and plant-Cd were spherical and Gaussian models, respectively, and had strong spatial dependence (Table 3). Due to the high correlation coefficient between plant- and soil-Cd (table 4), the spatial dependence of plant-Cd was high as was observed for soil-Cd. Soil-Pb data did not fit any experimental model, indicating that Pb variations in the sampling distance were random was less than 1000 m.

Table 3. Variogram models, interpolation parameters and cross-validation statistics of heavy metals in the study area (n=100).

Variable	Model	Range (m)	Nugget	Sill	Nugget/Sill	Spatial dependency	MBE	MRE	RMSE
EC	Linear	8140	10.77	14.20	0.76	Weak	-0.06	2.82	3.56
pH	Gaussian	7780	0.02	0.08	0.25	Strong	0.00	0.15	0.18
OC	Exponential	3500	0.02	0.033	0.55	Moderate	0.01	0.21	0.25
Clay	Linear	2068	45.50	118.40	0.38	Moderate	0.00	5.09	7.56
Silt	Exponential	1050	20.80	47.57	0.43	Moderate	0.38	5.09	6.37
Sand	Linear	8140	43.93	60.20	0.72	Moderate	-0.27	5.86	7.41
Soil-Ni	Exponential	1720	259.80	519.70	0.50	Moderate	-0.48	17.35	21.27
Soil-Cd	Spherical	5540	0.02	0.08	0.25	Strong	0.00	0.08	0.09
Plant-Cd	Gaussian	7500	0.004	0.15	0.03	Strong	0.01	0.17	0.20

CCE: Carbonate calcium equivalent, SOC: soil organic carbon

Table 4. Correlation matrix of between heavy metals and soil properties (n= 100)

Variable	EC	pH	Clay	Silt	Sand	CCE	SOC	Soil-Cd	Soil-Ni	Soil-Pb	Plant-Cd
pH	-0.04										
Clay	0.07	-0.25*									
Silt	-0.15	0.01	-0.47**								
Sand	0.03	0.23*	-0.61**	-0.37**							
CCE	0.03	-0.06	0.18	0.02	-0.22*						
SOC	-0.19	-0.30**	-0.03	0.29**	-0.20*	-0.06					
Soil-Cd	0.20*	-0.39**	0.01	0.03	-0.02	-0.00	0.17				
Soil-Ni	0.05	-0.02	0.62**	-0.46**	-0.26**	0.04	-0.17	0.06			
Soil-Pb	0.07	-0.23*	0.14	0.02	-0.15	-0.06	0.22*	0.51**	0.23*		
Plant-Cd	0.32**	-0.60**	0.17	0.21*	-0.34**	0.04	0.31**	0.46**	-0.12	0.16	
Plant Ni	0.08	-0.07	-0.04	0.04	0.03	-0.11	0.04	0.01	-0.10	0.02	0.00

CCE: Carbonate calcium equivalent, SOC: soil organic carbon, *and**: Significant at $P<0.01$ and $P<0.05$

According to the spatial distribution maps (Figure 2), the highest EC was in the northern part of the region, near the Tigris River, and the lowest in the southern regions (away from the river). According to Qureshi and al-Falahi (2015) stated that irrigation with relatively saline water of the Tigris River, high evaporation, and the absence of natural drainage are the main factors of soil salinization in this region. The spatial distribution pH (Figure 2) showed that the highest soil pH was in the northwest, near the river, and the lowest in the central and southern parts of the area. Organic carbon is one of the factors, which affect soil pH. This is consistent with a negative and significant correlation ($P < 0.01$) between soil organic carbon and soil pH. Therefore, in those parts of the region where drainage and agricultural operations were carried out and had more organic carbon, lower pH values were observed.

The amount of soil organic carbon was the highest in the south of the area and the lowest was in the north, near the Tigris River (Figure 2). In the southern parts of the study area, due to drainage operations, the salinity was lower than the northern part, close to the river, which provides suitable conditions for farming and consequently increasing soil organic carbon. The highest amount of clay and the lowest amount of sand occurred in the center of the area and the lowest amounts of these properties were observed near the Tigris River. Silt distribution did not show any clear trend (Figure 2).

Fig. 1. The location of the study area in southern Baghdad and sampling locations

The highest soil-Ni concentration was observed in the center and south of the area (Figure 3). Comparing the spatial distribution maps of clay and Soil-Ni, as well as the high correlation coefficient of clay and soil-Ni (Table 4), the amount of clay seems to control the distribution of Ni in the soil of the area. The highest amount of soil-Cd was in the southern area (Figure 3) which is likely due to human activities, especially intensive agricultural activities and the use of chemical fertilizers. The highest amount of plant-Cd was consistent with the spatial distribution of the soil-Cd (Figure 3).

Correlation

There is a positive and significant correlation ($P < 0.05$) between EC with soil- and plant-Ni (Table 4). The increase in Cd concentration in the plant is probably due to the increased solubility of Cd with increasing salinity. The Cd complexation in the presence of soluble salt such as NaCl, reduces the absorption of Cd by soil particles, increases the concentration of Cd in the soil solution phase, and consequently increases the absorption by the plant (EL-Hefnawy et al., 2014; Acosta et al., 2011).

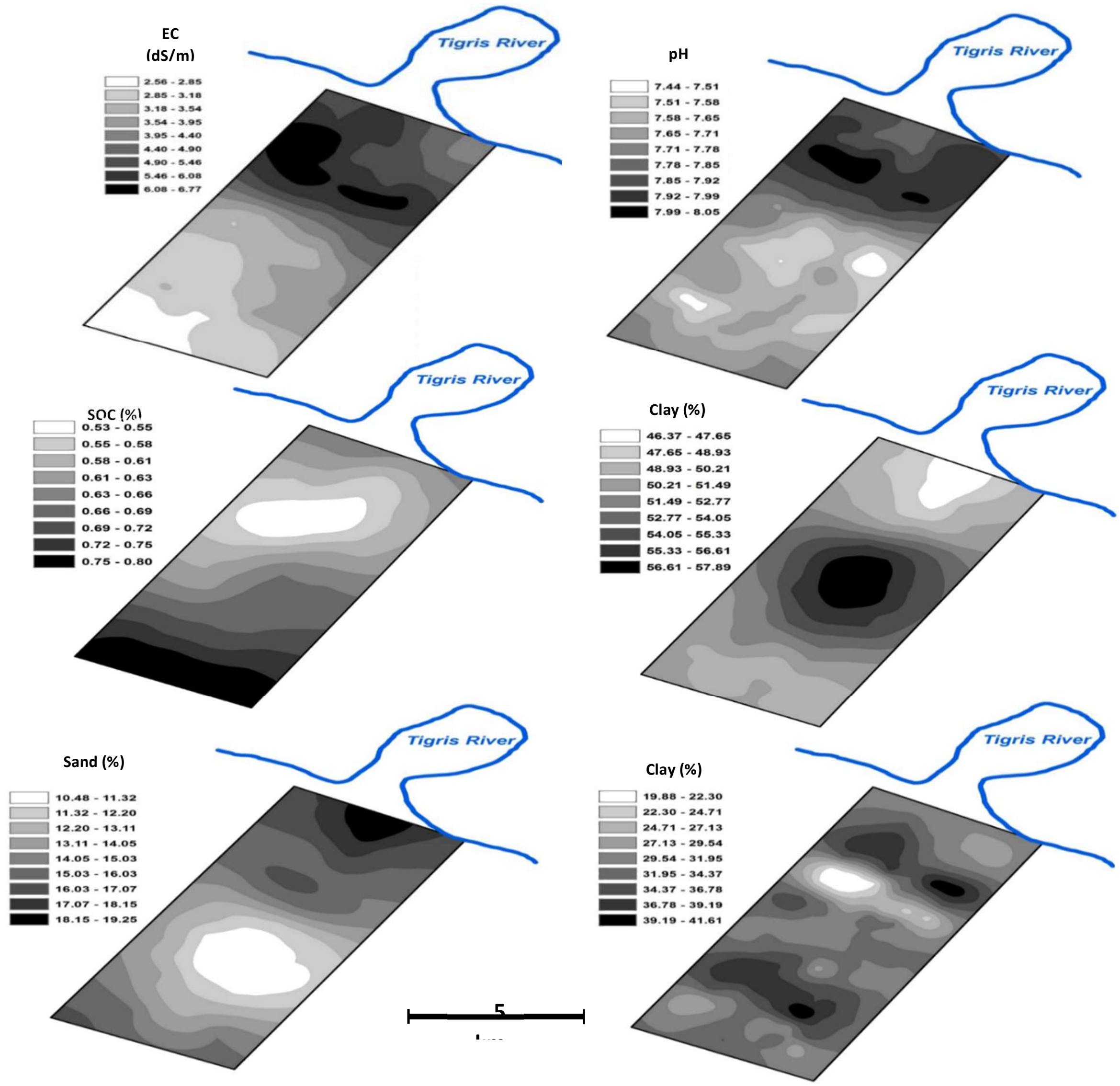

Fig. 2. Spatial distribution of the soil properties in the study area

The correlation of soil pH with soil- and plant-Cd was negative and significant (P <0.01). Toribio and Romanyà (2006) reported that decreasing the soil pH increases the solubility of Cd in the soil. Besides, in low pH, the H^+ ions in the soil solution compete with Cd in ion-exchange sites, which increases the Cd in the soil solution, thereby increasing plant uptake. The correlation between soil pH and soil-Pb was negative and significant (P <0.05). Ni in the soil usually has a lithogenic origin that does not easily affect by pH. Therefore, there was no correlation between soil-Ni and pH. The correlation between soil-Ni with clay and sand was positive and negative (P <0.01), respectively, indicating that this heavy metal had accumulated in the clay fraction.

The significant positive correlation between Soil-Cd and -Pb (P <0.01) indicates the similar variations of these two elements in the soil. A significant positive correlation was observed between soil-Cd and plant-Cd, which shows that as the amount of cadmium in the soil increases, its uptake by the plant increases. There was no relationship between soil- and plant-Ni.

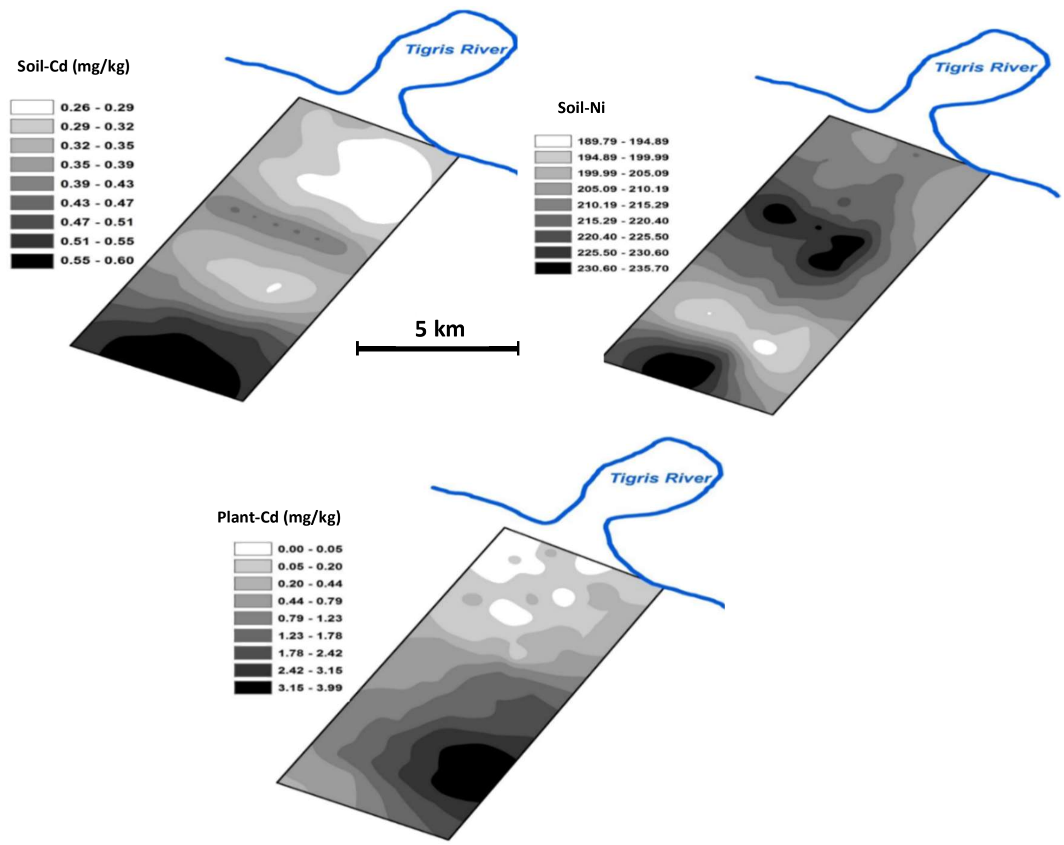

Fig. 3. Spatial distribution of soil-Ni, soil-Cd and plant-Cd in the study area

Discussion

Although the soil-Ni concentration is within the normal range of soils, it is higher than the allowable limit (Table 5). The mean concentration of soil-Ni (214.8 mg kg^{-1}) is more than 5 times the mean concentration in the soils (40 mg kg^{-1}) (Tables 2 and 5). The concentrations of Ni in the soils formed on ultramafic rocks are higher than other soils. Ni concentrations in ultramafic soils in Taiwan are more than 4,000 mg kg^{-1} (Cheng et al., 2011) and in northern Iran more than 2,000 mg kg^{-1} (Nael et al., 2009). The high concentration of soil-Ni in the area is probably due to the sediments, which originated from ultramafic rocks. Al-Juboury (2009) stated that the ultramafic rocks of northeastern Iraq are the origin of some heavy metals in the Tigris River. Al-Obaidy et al. (2016) reported the amount of nickel in water and sediments of Tigris River was 0.77 and 88 mg kg^{-1}, respectively. In this study, the concentration of Ni in river water was 0.07 mg kg^{-1}, which is less than the allowable limit (Table 6).

Table 5. Range and mean concentration (mg kg^{-1}) of studied heavy metals in the soil and lithosphere as well as allowable limits in soil and plant

Heavy metal	Lithosphere	Range in soils	Mean in soils	Allowable limit in the soils	Allowable limit in the plant
Cd	0.20	0.01-0.07	0.06	3.00	0.20
Ni	100.00	10-1000	40.00	50.00	67.9
Pb	16.00	2-200	10.00	100.00	0.30
Reference	Agrawal (2009)			Lacatusu (1998)	FAO/WHO (2001)

Table 6. Concentration (mg kg^{-1}) of studied Heavy metals in the Tigris River water and allowable limit in irrigation water

Heavy metal	Tigris River	allowable concentration in irrigation water
Cd	0.008	0.01
Ni	0.07	0.2
Pb	0.3	5
Reference	Present study	Pais and Jones (1997)

In ultramafic soils in northeastern Iran, with arid climates, due to low weathering, Ni accumulated in coarse fractions, which resulted a strong correlation of sand and Ni contents (Karimi et al., 2017); Whereas in the humid climate of Taiwan, Ni in the correlated with clay content (Cheng et al., 2011). In the studied soils, there is a significant positive correlation between Ni concentration with clay and a negative with silt and sand (Table 4), which shows that despite the arid climate of the area the clay particles containing Ni have been transported over long distances.

The mean concentration of soil-Cd was in the usual range of the normal soil (0.01-0.7 mg kg^{-1}) and was less than the allowable limit in the soil (3 mg kg^{-1}) (Tables 2 and 5). The concentration of the Cd in the Tigris river's water was 0.008 mg l^{-1}, which is less than the maximum allowable value (0.01 mg l^{-1}) (Table 6) in irrigation water. Despite the low Cd concentration in the Tigris River, the concentration of this element would be increased by long time irrigation. The spatial distribution pattern indicated the high concentration of soil-Cd in intensive agricultural areas (Figure 3), which, shows chemical fertilizers application such as phosphate fertilizers are the main source of Cd in the studied soils. Atafar et al. (2010) stated that phosphate chemical fertilizers, especially triple superphosphate, has contaminated the agricultural soils in western Iran and increase the Cd concentration to 1.5 mg kg^{-1}. Tawfiq and Ghazi (2017) stated that chemical fertilizers are the main factor in increasing the amount of Cd in agricultural lands in southern Iraq.

The mean concentration of soil-Pb in the area was 14.5 mg kg^{-1}, and in some parts reaches up to 22 mg kg^{-1} (Table 2), which is slightly higher than the average concentration in the usual soils (Table 5). The amount of Pb in the water of the Tigris River was 0.3 mg l^{-1}, which is less than the maximum allowable limit (5 mg kg^{-1}) in irrigation water (Table 6). Al-Obaidy et al. (2016) reported the concentration of Pb in water and sediments of the Tigris River in Baghdad was 0.4 mg l^{-1} and 78 mg kg^{-1}, respectively. They believed that the runoff from the oil fields and refineries transfer the pollutants containing heavy metals to the River. Karbasi et al. (2015) also examined the pollution of heavy metals in Ahwaz oil fields and reported that the amount of Pb in the soil had increased due to lead-containing petroleum products.

The concentration of Cd in the plant was higher than in the soil. The mean and maximum concentration of Cd in the plant is 1.1 and 4 mg kg^{-1} (Table 2), which is much higher than the allowable limit in plants (Table 5). A higher concentration of Cd in the plant than in the soil indicates the high tendency of plants to absorb Cd. The significant positive correlation between plant and soil-Cd shows that there is a good relationship between extracted Cd with aqua regia and its absorbable form.

The mean concentration of Ni in the plant is 17.5 mg kg^{-1}, which the maximum is 40.4 mg kg^{-1} (Tables 2 and 5). Wheat is one of the plants that tend to absorb heavy metals (Eskandari and Alizadeh, 2016). Although the concentration of Ni in wheat in the study area is less than the allowable limit (Table 2), it is high due to the high concentration of Ni in the soil. For example, in Hamedan in western Iran, the average concentration of Ni in soil was 61.9 mg kg^{-1}, but its concentration in wheat was less than one mg kg^{-1}. Interestingly, no correlation was observed between soil- and plant-Ni, indicating that the Ni measured aqua regia was not as an index of its absorbable form.

The high concentration of Cd in wheat is a serious environmental concern in the study area. Wheat is a vital cereal in the world. Therefore, the accumulation of Cd in wheat plant cause risk to human health (Abedi and Mojiri, 2020). It is better to stop wheat cultivation until resolving this concern. The first step to overcome this problem is determining the factors that cause the accumulation of Cd in the soil and plant. As previously discussed the concentration of Cd in the soil increased by human activities. The application of Cd-free fertilizers is proposed to decree the input of the metal to the soil. Besides, knowledge of the factors affecting the Cd accumulation in the plants is necessary to decrease Cd absorption. According to correlation coefficients (Table 4) pH, EC, and SOC are the three manageable properties, which affect the Cd absorption. By decreasing pH (increasing acidity), the solubility of the Cd compound increases the Cd in the exchangeable sites and soil solution (Nylund, 2003). SOC both by increasing pH (table 3) and by chelation mechanism cause increasing the bioavailability of Cd in the soil. On the other hand, high amount of SOC could complex heavy metals and reduce their availability (Sebastian and Prasad, 2014). Therefore, it is not easy to suggest management practice for organic carbon in the area and needs more researches in this regards. The positive correlation of EC and plant-Cd indicated that drainage could improve the soil salinity and consequently decreasing plant-Cd.

Conclusion

The results of this study showed that in the cultivated lands of Al-Siwira region in southern Baghdad, the concentration of Ni in the soil was higher and the Cd and Pb were less than the allowable limit. The concentration of Ni and Cd in the plant was lower and lower than allowable limits and Pb was lower than the device detection limit. The high concentration of Ni in the soil was probably due to sediments originated from ultramafic rocks. According to spatial distribution maps, the highest concentrations of Pb and Cd were in densely farmed areas. The most important concern in the area was the accumulation of Cd in the wheat plant. Using suitable chemical fertilizers is the best way for decreasing the cadmium in the soil. pH, SOC, and EC are the most important properties affecting the bioavailability of the Cd for the plant. Increasing pH and decreasing the EC reduces the uptake of Cd by the plant. However, the effect of the amount and types of SOC on Cd availability needs more investigation for Cd monument. Although the concentration of Cd and Pb is currently lower than the allowable soil level, the trend in the area shows that there is a risk of contamination with these elements in the future, which should be prevented with proper management.

Acknowledgment

This paper is the result of the research of Mr. Taher Salman (first author), a graduate student who passed away shortly after defending his thesis. This paper is dedicated to his soul.

References

Abedi T, Mojiri A. 2020. Cadmium uptake by wheat (Triticum aestivum L.): An overview. Plants, 9 (4); 500-513.

Acosta J, Jansen B, Kalbitz K, Faz A, Martínez-Martínez S. 2011. Salinity increases mobility of heavy metals in soils. Chemosphere, 85; 1318-1324.

Agarwal SK. 2009. Heavy Metal Pollution. APH publishing.

Al-Juboury AI. 2009. Natural pollution by some heavy metals in the Tigris River, Northern Iraq. International Journal of Environmental Research, 3; 189-198.

Allison LE. 1960. Wet combustion apparatus and procedure for organic and inorganic carbon in soil. Soil Science Society America Proceeding, 24; 36-40.

Al-Obaidy A, Al-Janabi ZZ, Al-Mashhady AA. 2016. Distribution of some heavy metals in sediments and water in Tigris River. Journal of Global Ecology and Environment, 4; 140-146.

Atafar Z, Mesdaghinia A, Nouri J, Homaee M, Yunesian M, Ahmadimoghaddam M, Mahvi AH. 2010. Effect of fertilizer application on soil heavy metal concentration. Environmental Monitoring and Assessment, 160; 83.

Chen TB, Zheng YM, Lei M, Huang ZC, Wu HT, Chen H, Fan KK, Yu K, Wu X, Tian QZ. 2005. Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. Chemosphere, 60; 542-551.

Codex Alimentarius Commission (FAO/WHO): Food Additives and Contaminants, ALINORM 01/12A. 2001; 1–289

Cheng CH, Jien SH, Iizuka Y, Tsai H, Chang YH, Hseu ZY. 2011. Pedogenic chromium and nickel partitioning in serpentine soils along a toposequence. Soil Science Society of America Journal, 75: 659-668.

Dogra N, Sharma M, Sharma A, Keshavarzi A, Minakshi Bhardwaj R, Thukral AK, Kumar V. 2019. Pollution assessment and spatial distribution of roadside agricultural soils: a case study from India. International Journal of Environmental Health Research, 30: 1-14.

EL-Hefnawy ME, Selim EM, Assaad FF, Ismail AI. 2014. The Effect of Chloride and Sulfate Ions on the Adsorption of Cd^{2+} on Clay and Sandy Loam Egyptian Soils. The Scientific World Journal, 806252.

Eskandari H, Alizadeh-Amraie A. 2017. Comparison of the ability of wheat, clover and rapeseed in phytoremediation of cadmium from soils for reducing heavy metal stress. Environmental Stresses in Crop Sciences, 10; 345-349.

Gee GW, Bauder JM. 1986. Particle-size analysis. In: Klute A, (Ed.), Methods of Soil Snalysis.Part 1. Physical and Mineralogical Methods, second ed. Agronomy Monogroph, No. 9 American Society of Agronomy and Soil Science Society of America, Madison, WI, pp. 383–411.

Goovaerts P. 1997. Geostatistics for Natural Resources Evaluation. Oxford University Press, New York, USA, p.83.

Hu WY, Zhang Y, Huang B, Teng Y. 2017. Soil environmental quality in greenhouse vegetable production systems in eastern China: current status and management strategies. Chemosphere, 170; 183-195.

Hu Y, Liu X, Bai J, Shih K, Zeng EY, Cheng H. 2013. Assessing heavy metal pollution in the surface soils of a region that had undergone three decades of intense industrialization and urbanization. Environmental Science and Pollution Research, 20; 6150-6159.

Huang Y, Li TQ, Wu CX, He ZL, Japenga J, Deng M, Yang X. 2015. An integrated approach to assess heavy metal source apportionment in peri-urban agricultural soils. Journal of Hazardous Materials, 299; 540-549.

ISO/CD 11466. 1995. Soil quality-extracti on of trace metals soluble in aqua-regia. (The International Organization for Standardization: Geneva)

Karbassi A, Tajziehchi S, Afshar S. 2015. An investigation on heavy metals in soils around oil field area. Global Journal of Environmental Science and Management, 1; 275-282.

Karimi A, Haghnia GH, Safari T, Hadadian H. 2017. Lithogenic and anthropogenic pollution assessment of Ni, Zn and Pb in surface soils of Mashhad plain, northeastern Iran. Catena, 157; 151-162.

Kumar V, Pandita S, Sharma A, Bakshi P, Sharma P, Karaouzas I, Bhardwaj R, Thukra AK, Cerda A. 2019. Ecological and human health risks appraisal of metal (loid) s in agricultural soils: a review. Geology, Ecology and Landscapes, 3; 1-13.

Lacatusu R. 1998. Appraising levels of soil contamination and pollution with heavy metals. In: Heinike H J, Eckelman W, Thomasson A J, Jones R J A, Buckley B, (Eds), Land information System for Planning the Sustainable use of Land Resources. European Soil Bureau, Research report NO.4, office for official publications of the European Communities Luxembourg, pp. 393-402.

Lv J, Liu Y, Zhang Z, Dai J, Dai B, Zhu Y. 2015. Identifying the origins and spatial distributions of heavy metals in soils of Ju country (Eastern China) using multivariate and geostatistical approach. Journal of Soils and Sediments, 15; 163-178.

Meng Y, Cave M, Zhang C. 2020. Identifying geogenic and anthropogenic controls on different spatial distribution patterns of aluminum, calcium and lead in urban topsoil of Greater London Authority area. Chemosphere, 238; 124541.

Nael M, Khademi H, Jalalian A, Schulin R, Kalbasi M, Sotohian F. 2009. Effect of geo-pedological conditions on the distribution and chemical speciation of selected trace elements in forest soils of western Alborz, Iran. Geoderma, 152; 157-170.

Nelson DW, Sommers LE. 1982. Total carbon, organic carbon, and organic matter. In: Page A l, (Ed.). Methods of soil analysis, Part 2. Chemical and microbiological properties. Agronomy Monograph, No. 9.2., 2nd Ed. pp. 539-579. American Society of Agronomy and Soil Science Society of America: Madison, WI.

Nylund E. 2003. Cadmium uptake in willow (Salix viminalisL.) and spring wheat (Triticum aestivumL.) in relationto plant growth and Cd concentration in soil solution. Ph.D. Thesis, Department of Soil Science, SwedishUniversity of Agricultural Sciences, Swedish, Sweden.

Pais I, Jones Jr JB. 1997. The Handbook of Trace Elements. CRC Press.

Qureshi AS, Al-Falahi A. 2015. Extent, characterization and causes of soil salinity in central and southern Iraq and possible reclamation strategies. International Journal o Engineering Research and Applications, 5; 84-94.

Säumel I, Kotsyuk I, HÖlscher M, Lenkereit C, Weber F, Kowarik I. 2012. How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighbourhoods in Berlin, Germany. Environmentl Pollution, 165; 124-132.

Sebastian A, Prasad MNV. 2014. Cadmium minimization in rice. A review. Agronomy Sustainable Development, 34; 155-173.

Taghipour M, Ayoubi S, Khademi H. 2011. Contribution of lithologic and anthropogenic factors to surface soil heavy metals in western Iran using multivariate geostatistical analyses. Soil and Sediment Contamination, 20; 921-937.

Tawfiq LNM, Ghazi FF. 2017. Heavy metals pollution in soil and its influence in south of Iraq. International Journal of Discrete Mathematics, 2; 59-63.

Toth G, Hermann T, Da Silva MR, Montanarella L. 2016. Heavy metals in agricultural soils of the European Union with implications for food safety. Environmental International, 88, 299-309.

Toribio M, Romanyà J. 2006. Leaching of heavy metals (Cu, Ni and Zn) and organic matter after sewage sludge application to Mediterranean forest soils. Science of the Total Environment, 363; 11-21.

Webster R, Oliver MA. 2007. Geostatistics for Environmental Scientists. Second Edition, Wiley Press, p. 330.