Contamination of Some Heavy Metals in Soil at Diyala/Sirwan River Banks

Abdulmutalib Raafat Sarhat1,2 and Basim Shakir Al-Obaidi1

1University of Tikrit, Collage of Agriculture, Soil and Water Science Department, Iraq.

2University of Garmian, Collage of Education, Chemistry Department, Iraq.

1E-mail: abdulmutalib.raafat@garmian.edu.krd

Abstract. This study investigated contamination of a number of heavy metals including (Cadmium, Cupper, Lead, Nickel, Zink and Cobalt) in the soils of agricultural lands within Sirwan/Diyala River Banks. To determine the soils contamination by the mentioned heavy metals, sampling process was conducted in different points of the river banks. The evaluation of soil contamination in the current area was conducted by using some indices such as ecological risk factor (ER), enrichment factor (EF), contamination factor (CF), and geo-accumulation factor (Igeo). The outcome indicated that the levels of these elements were with the following order: Ni>Zn>Pb>Co>Cu>Cd. The values of enrichment factor were ranged from deficiency of Cu with a value of (EF = 1.04) to significant enrichment of Ni (EF = 18.87). However, the values of contamination factor indicated low contamination of soil by Cu, Cd, Pb, Co and Zn with mean values of (0.15), (0.56), (0.65), (0.72) and (0.76) respectively, to significant contamination by Ni (3.07). In terms of ecological risk factor, the average values of (Er) of all the observed elements were under low ecological risk category. The values of (Igeo) index for Cd, Pb, Cu, Zn and Co were under (unpolluted) category; while, Ni was under (unpolluted to moderate) category with a mean value of (0.94 .(

Keywords. Sirwan/Diyala River Banks, heavy metals, contamination, Soil indices.

Introduction

Soil is considered as a fundamental part of the global ecosystem as it is an essential natural beside air, water and living things. Generally, the production of food and raw materials are its primary purpose [1]. Increasing the world population dramatically in last decades led to increase the need of huge amounts of food. While, soil production around the world has been influenced by the development of industrial production, road infrastructure and global warming [2]. It is thought that soil pollution, degradation and yield reduction are caused by chemical pollution, and as a result of using of irrigation water with poor quality, using excessive quantities of pesticides and herbicide as well as fertilizers [3-5]. The soil can be considered as contaminated when the concentrations of heavy metals in its horizons exceed the acceptable levels [6]. Pollution by heavy metals forming a significant threat to the ecosystem security of river basins around the world, which has led to attract the attention of scholars over the world [7]. Two major sources of heavy metals in soil have been observed including: natural sources and man-made or anthropogenic sources [8]. The natural sources consist of rock weathering, atmospheric sedimentation, forest fire and volcanic eruption which all suspend heavy metals in the environment and thus falling and interring soil system[9]. On the other hand, the man-made sources include mining processes, transportation, irrigation by wastewater, electronic waste, using chemical pesticides, herbicides and fertilizers which all lead to accumulate heavy metals in soil [10]. Also, it has been illustrated that the man-made activities are the major cause of pollution by

ISSN 2072-3857

heavy metals especially in agricultural lands [11]. There are two factors that make heavy metals poisonous and dangerous which are their non-biodegradability in nature and their tendency to accumulate in soil causing deterioration of land productivity and harmful effects on crops quality [12,13]. Furthermore, the accumulation of heavy metal in soils can easily passing into the food chain and causing harmful effects. Thus, some heavy metals cumulate in human body and lead to cause chronic diseases regarding brain, liver, spleen, etc. Some heavy metals with high concentrations like lead, cadmium and mercury are dangerous for all living things, and some them considered as carcinogenic including arsenic, cadmium, chromium and beryllium which causing different diseases to children [2,14,15]. However, some other heavy metals like copper, cobalt, zinc are essential micronutrients and significant for human [16 .[

Sirwan River's banks are considered as important agricultural areas; while, limited researches were conducted regarding its contamination by heavy metals. The objective of the current study is to conduct an assessment of some heavy metals contamination in agricultural lands of Sirwan River Banks, Iraq. In the current study also, integrated pollution indices including ecological risk factor (Er), geo-accumulation factor (Igeo), contamination factor (CF) and enrichment factor (EF) have been utilized to estimate the level of pollution.

Materials and Methods

Study Area

It is located at the northern east of Iraq, and extends from Darbandikhan District to Jalawlaa sub-district, figure (1). The Sirwan River receives huge quantities of wastewater from residential, industries, poultry projects and agricultural lands without any treatment. This is one of the main reasons for the pollution of the river and its banks.

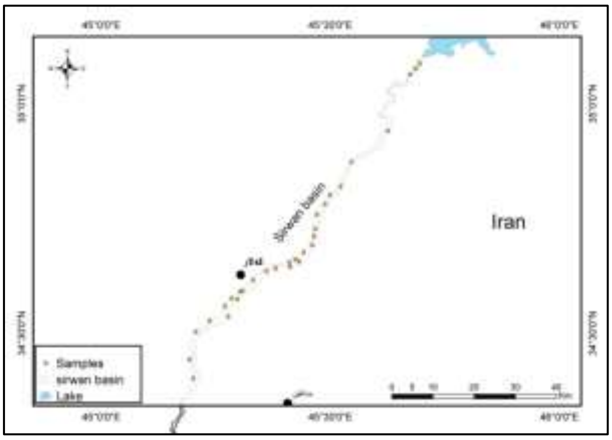

Figure 1. The study area including sampling points.

Sampling and Analysis

Thirty samples of surface soil at depths 0–30 cm were collected from different locations at Sirwan River banks, figure (1) and table (1). All the samples were taken from wheat and barley fields which both are widely grown in the study area. A device of (GPS) has been used to determine the coordinates. The sampling process was conducted in December 2021, near the Sirwan riverbed at distances up to (50-100) m. All the samples were transferred to laboratory at Garmian University and were subjected to air-dry and then were sieved by a (2 mm) sieve. The heavy metals levels including (Pb, Ni, Zn, Cu, Cd and Co) were determined by (ICP-OES) device .

ISSN 2072-3857

Table 1. The details of sampling stations within Sirwan/Diyala River Bank.

Locations	E	Locations	E
1	"16.8'05°35N 45°41'41.6"E	16	"18.4'39°34N 45°24'37.3"E
2	"39.3'04°35N 45°41'07.4"E	17	"41.5'38°34N 45°24'44.0"E
3	"52.0'03°35N 45°40'26.6"E	18	"31.2'38°34N 45°22'48.5"E
4	"28.9'56°34N 45°37'33.2"E	19	"10.3'38°34N 45°21'37.5"E
5	"25.9'52°34N 45°32'43.5"E	20	"58.9'36°34N 45°19'51.6"E
6	"06.1'48°34N 45°29'55.7"E	21	"34.6'35°34N 45°18'29.5"E
7	"13.4'49°34N 45°31'19.6"E	22	"28.2'35°34N 45°18'10.0"E
8	"53.6'46°34N 45°29'17.0"E	23	"28.2'34°34N 45°17'50.3"E
9	"33.6'45°34N 45°28'13.0"E	24	"35.0'34°34N 45°17'04.3"E
10	"40.4'43°34N 45°27'59.9"E	25	"33.7'33°34N 45°16'10.5"E
11	"43.6'42°34N 45°27'49.2"E	26	"12.3'32°34N 45°16'36.9"E
12	"33.5'41°34N 45°27'37.4"E	27	"38.7'31°34N 45°14'11.3"E
13	"37.6'40°34N 45°26'30.2"E	28	"13.8'30°34N 45°12'23.3"E
14	"41.3'39°34N 45°25'22.2"E	29	"34.4'26°34N 45°11'34.2"E
15	"24.9'39°34N 45°25'53.2"E	30	"07.3'24°34N 45°12'00.8"E

Soil Indices

Enrichment Factor (EF(

This is considered as one of the most significant indexes that indicate the environmental contamination degree. Also, it measures the possible effects of man-made activity on heavy metals concentrations in soil [17,18]. This factor was calculated by the following equation [19,20:[

$$EF = \left(\frac{(Me/Fe)_{sample}}{(Me/Fe)_{background}} \right) \quad (1($$

Where, (Me/Fe)samples is the concentration of an observed heavy metal divided by the concentration of iron (Fe) in observed sample, and (Me/Fe)background is the natural background of the same heavy metal and iron (Fe). As normalization element, Fe was selected as natural sources dominate its inputs [21]. Enrichment factor can be classified into five categories, table (2 .(

Contamination Factor

This index also can be carried out to evaluate soil contamination. It is calculated by the following equation [22:[

$$CF = \left(\frac{Cm_{sample}}{Cm_{background}} \right) \quad (2($$

) Cm)sample represents the heavy metals concentration in an observed sample. (Cm)background represents the background value of the same heavy metal. Values of

ISSN 2072-3857

contamination factor can be classified into four classes, table (2.(

Potential Ecological Risk (Er(

This factor is usually used to evaluate the soil ecological risk that caused by concentrations of heavy metals. The following equation was introduced by Hakanson (1980:(

$$E_r = T_r \times PI \quad (3($$

Where, Tr represents the (toxic response factor), each metal has an individual Tr value. PI represents Single Pollution Index [22.[

Geo-Accumulation Index (Igeo(

This factor was proposed to evaluate the contamination of sediments by heavy metals [23]; then, it has been utilized in soil pollution researches [24]. It can be calculated by the equation below:

$$Igeo = \log_2 \left(Cm_{sample} / (1,5\ Cm_{background}) \right) \quad (4($$

Cmsample is the concentration of an observed heavy metal in a sample; Cmbackground is the same heavy metal's concentration in uncontaminated sample. While, (1.5) represents the factor that that used to modification the influence of any possible variations regarding the permissible values[25][26][27]. This index is also classified the heavy metal pollution into seven (0 to 6) categories as mentioned in table (2.(

Table 2. The classifications of (CF), (EF), (Er) and (Igeo) indices [22,24,28,29.[

)CF) and Status	)EF) and Status	)Er) and Status	)Igeo) and Status
= 1>No contamination	2>Deficiency to minimum	30>Low	0≥Unpolluted
≥1CF<3 = Reasonable	≥2EF<5 Reasonable	60–30Reasonable	1–0unpolluted to moderate
≥3CF<6 = Significant	≥5EF<20 Significant	120–60Moderate to high	2–1Moderate
CF>6 = Very high	≥20EF<40 Very high	240–120High	3–2moderate to strong
	EF>40 Extremely high	240≤Extremely high	4–3Strong
			5–4strong to extreme
			6<Extreme

Results and discussion

3.1

Concentrations of Heavy Metals

The heavy metals concentrations in the soil of Sirwan River Banks in the sampling stations were ranged Cd (0.12-0.41mg/kg), Cu (2-8.65mg/kg), Pb (3.23-13.2mg/kg), Ni (101.55-318mg/kg), Zn (47.98-102.1mg/kg) and Co (2.13-11.9mg/kg). The average values of the observed heavy metals have been calculated and found to be (0.229, 4.54, 6.74, 153.58, 68.24 and 5.74mg/kg) respectively as presented in table (3) and figure (2.(

ISSN 2072-3857

Table 3. The concentrations of the heavy metals in the samples along Sirwan River banks.

Heavy Metal	Min.	Max.	Ave.	World median soil [30[	World average soil [31[	Earth crust [32[
Cd	0.12	0.41	0.229	0.35	0.35	0.15
Cu	2	8.65	4.54	30	30	50
Pb	3.23	13.2	6.74	12	35	12.5
Ni	101.55	318	153.58	50	50	75
Zn	47.98	102.1	68.24	90	90	70
Co	2.13	11.9	5.74	8	8	22

It is very difficult to distinguish the anthropogenic from the natural sources of increasing metals in soil samples. The natural sources generate stronger imprint compared to anthropogenic sources for instance Ni, Co and Cu are developed from basaltic rocks into soil as a result of soil forming and rock weathering processes. The natural local background must be taking into account to estimate the heavy metals concentrations that are produced from the man-made sources. Since there is no available data or any study regarding the heavy metals in soils of the current area; therefore, the authors have been compelled to compare the present results with the world average soil, world median soil and the normal composition of earth crust. The results clearly demonstrated that the observed heavy metals concentrations from different sources (natural and man-made) were with the following order: Ni>Zn>Pb>Co>Cu>Cd .

The results of comparison revealed that Ni has abnormally high concentration; while, Cd has lower concentration in comparing with the other observed heavy metals. The average content of heavy metals in the soils of the current area differs from the average of world median, world average soil and the content of earth crust. This is normal due to the difference in the parent materials, processes of weathering and leaching [33,34]. The table (3) illustrates that the average values of Cu, Cd, Zn, Pb and Co are lower than the world average values; this indicates their poor sources of lithogenic. However, it is noted that there is slight increasing in the concentrations of Cd, Zn and Co which could be as a result of man-made activities .

Figure 2. The concentrations of observed heavy metals along Sirwan/Diyala River Banks.

Contamination Assessment

ISSN 2072-3857

The table (4) below, shows that the assessment of studied factors and indices including contamination, enrichment factor, ecological risk and geo-accumulation index.

Table 4. Contamination index of the observed heavy metals in soil along Sirwan River banks.

Metals	Enrichment Factor		Contamination Factor		Ecological Risk		Geo-accumulation index	
	Mean	Status	Mean	Status	Mean	Status	Mean	Status
Cd	4.4	Moderate	0.65	Low	19.64	Low	1.29-	Unpolluted
Cu	1.04	Deficiency	0.15	Low	0.75	Low	3.43-	Unpolluted
Pb	3.81	Moderate	0.56	Low	2.81	Low	1.4-	Unpolluted
Ni	18.78	Significant	3.07	Considerable	15.36	Low	0.9	unpolluted to moderately
Zn	5.02	Significant	0.76	Low	0.76	Low	1.01-	Unpolluted
Co	4.9	Moderate	0.72	Low	21.5	Low	1.22-	Unpolluted

The values of enrichment factor ranges from deficiency of Cu (EF = 1.04) to significant enrichment of Ni at all the sampling stations (EF = 18.87). The EF of Zn also considered as significant enrichment with an average of (5.02). However, the EF of Cd, Pb and Co considered as moderate enrichment with mean values of (4.4), (3.81) and (4.9) respectively. The values of contamination factor indicate low contamination of soil by Cu, Pb, Cd, Co and Zn with mean values of (0.15), (0.56), (0.65), (0.72) and (0.76) respectively, to significant contamination by Ni with a mean value of (3.07 .(

Regarding ecological risk factor, the mean values of all the observed metals are fall under low ecological risk category. The values are ascending order Cu<Zn<Pb<Ni<Cd<Co with mean values of (0.75), (0.76), (2.81), (15.36), (19.64) and (21.5) respectively. Regarding geo-accumulation index values, Cd, Cu, Pb, Zn and Co are fall under (unpolluted) category; while, Ni falls under (unpolluted to moderate) category with a mean value of (0.94 .(

Discussion

In terms of Ni, it is noted that its average level is higher than the soil world average, world median and the composition of earth crust. This could probably be as a result of both natural and man-made sources; while, the natural sources of Ni could be stronger than anthropogenic sources. The contamination from municipal sewage, wastewater discharging and landfill stations are the anthropogenic sources of Ni in the present area. Also, the high concentrations of Ni may connected to the region's geochemical characteristics; weathering of the parent materials and hydrological erosion are the possible geogenic sources of Ni [3-37]. Fertilizers, pesticides, fungicides, animal manure, pigments and batteries are regarded as main sources of soil pollution by Zn [38,39]. A number of study observed that most of agricultural practices are significant sources of Zn, and it is as one host directly related to Fe and clay minerals[40]. The slightly high levels of Pb are attributed to the excessive application of fertilizer and insecticide as well as wastes of batteries [41]. Despite some sampling stations indicated abnormally high Pb concentrations; however, most of the sampling stations have moderate

ISSN 2072-3857

concentrations of Pb which almost delegating slight contamination either due to anthropogenic or natural sources.

Cobalt is not considered as an essential nutrient for plants; while, it is one of the most pollutants that present in sewages [42]. It is accumulated in agricultural areas through using wastewater for irrigation and then causing toxic effects on plants [43,44]. As mentioned before, large amounts of wastewater are discharged daily into Sirwan River and this could be a source of increasing Co in some sampling station within the study area. Cadmium has a relative mobility, which make it to be less contaminant from both man-made and natural sources in the environment. Phosphate fertilizers, burning of oil, plastics, ceramics, glass and pigment are the most common sources of Cd in the environment [45,46 .[

In contrary, lower concentrations of Cu in the study area indicate absence of both natural and man-made sources of pollutants. The soil content of copper relies on parent materials, clay content, organic matter and the value of soil's pH [47 .[

Conclusion

The objective of this research is to assess the contamination of a number of heavy metals in agricultural lands within Sirwan/Diyala River Banks. Integrated pollution indices have been used including (Er), (Ef), (CF) and (Igeo) factors. The outcomes indicate that the concentrations of the observed heavy metals are with the following order: Ni>Zn>Pb>Co>Cu>Cd.

The values of enrichment factor ranges from deficiency of Cu (EF = 1.04) to significant enrichment of Ni at all the sampling stations (EF = 18.87). However, the values of (CF) indicate low contamination of soil by Pb, Cu, Cd, Co and Zn with mean values of (0.15), (0.56), (0.65), (0.72) and (0.76) respectively, to significant contamination by Ni with a mean value of (3.07). Regarding the ecological risk factor, the mean values of all the observed metals are fall under low category. The values of (Igeo) index of Cd, Cu, Pb, Zn and Co are fall under (unpolluted) category; while, Ni falls under (unpolluted to moderate) category with a mean value of (0.94 .(

References

[1] Peh Z, Miko S and Hasan O 2010 Geochemical background in soils: A linear process domain? An example from Istria (Croatia) Environ. Earth Sci. 59 1367–83

[2] Cipurkovic A, Tunjic J, Selimbasic V, Djozic A and Trumic I 2015 Assessment of heavy metal distribution and contamination in soils at Jala River Banks Eur. J. Sci. Res. 127(4) 392–405

[3] Kaur M, Kumar A, Mehra R and Mishra R 2018 Human health risk assessment from exposure of heavy metals in soil samples of Jammu district of Jammu and Kashmir, India Arab. J. Geosci. 11 411

[4] Zeid S A M, Seleem E M, Salman S A and Hafiz M A A 2017 Water quality index of shallow groundwater and assessment for different usages in El-Obour city, Egypt J. Mater. Environ. Sci. 9 1957–68

[5] Salman S A, Zeid S A M, Seleem E-M M and Abdel-Hafiz M A 2019 Soil characterization and heavy metal pollution assessment in Orabi farms, El Obour, Egypt Bull. Natl. Res. Cent. 43 1–13

[6] Proust D, Fontaine C and Dauger N 2013 Impacts of weathering and clay mineralogy on heavy metals sorption in sludge-amended soils Catena 101 188–96

ISSN 2072-3857

[7] Meng Z, Liu T, Bai X and Liang H 2022 Characteristics and Assessment of Soil Heavy Metals Pollution in the Xiaohe River Irrigation Area of the Loess Plateau, China Sustainability 14 6479

[8] Sikdar S and Kundu M 2018 A Review on Detection and Abatement of Heavy Metals ChemBioEng Rev. 5 18–29

[9] Chen T, Chang Q, Liu J, Clevers J G P W and Kooistra L 2016 Identification of soil heavy metal sources and improvement in spatial mapping based on soil spectral information: A case study in northwest China Sci. Total Environ. 565 155–64

[10] Ran J, Wang D, Wang C, Zhang G and Zhang H 2016 Heavy metal contents, distribution, and prediction in a regional soil-wheat system Sci. Total Environ. 544 422–31

[11] Tóth G, Hermann T, Da Silva M R and Montanarella L 2016 Heavy metals in agricultural soils of the European Union with implications for food safety Environ. Int. 88 299–309

[12] Huang Y, Li T, Wu C, He Z, Japenga J, Deng M and Yang X 2015 An integrated approach to assess heavy metal source apportionment in peri-urban agricultural soils J. Hazard. Mater. 299 540–9

[13] Zhang J, Wang Y, Liu J, Liu Q and Zhou Q 2016 Multivariate and geostatistical analyses of the sources and spatial distribution of heavy metals in agricultural soil in Gongzhuling, Northeast China J. Soils Sediments 16 634–44

[14] Shi P, Xiao J, Wang Y and Chen L 2014 Assessment of ecological and human health risks of heavy metal contamination in agriculture soils disturbed by pipeline construction Int. J. Environ. Res. Public Health 11 2504–20

[15] Zhang Y, Wu D, Wang C, Fu X and Wu G 2020 Impact of coal power generation on the characteristics and risk of heavy metal pollution in nearby soil Ecosyst. Heal. Sustain. 6

[16] Mitra S, Chakraborty A J, Tareq A M, Emran T Bin, Nainu F, Khusro A, Idris A M, Khandaker M U, Osman H, Alhumaydhi F A and Simal-Gandara J 2022 Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity J. King Saud Univ. - Sci. 34 101865

[17] Kowalska J B, Mazurek R, Gąsiorek M and Zaleski T 2018 Pollution indices as useful tools for the comprehensive evaluation of the degree of soil contamination–A review Environ. Geochem. Health 40 2395–420

[18] Gąsiorek M, Kowalska J, Mazurek R and Pająk M 2017 Comprehensive assessment of heavy metal pollution in topsoil of historical urban park on an example of the Planty Park in Krakow (Poland) Chemosphere 179 148–58

[19] Sinex S A and Helz G R 1981 Regional geochemistry of trace elements in Chesapeake Bay sediments Environ. Geol. 3 315–23

[20] Barbieri M 2016 The Importance of Enrichment Factor (EF) and Geoaccumulation Index (Igeo) to Evaluate the Soil Contamination J. Geol. Geophys. 5 1–4

[21] Djordjević L, Živković N, Živković L and Djordjević A 2012 Assessment of Heavy Metals Pollution in Sediments of the Korbevačka River in Southeastern Serbia Soil Sediment Contam. 21 889–900

[22] Hakanson L 1980 An ecological risk index for aquatic pollution control.a sedimentological approach Water Res. 14 975–1001

[23] Müller G 1969 Index of geoaccumulation in sediments of the Rhine River Geol. J. 2 108–18

ISSN 2072-3857

[24] Yaylali-Abanuz G 2011 Heavy metal contamination of surface soil around Gebze industrial area, Turkey Microchem. J. 99 82–92

[25] Fang, L., Liu, Y., Tian H 2017 Proper land use for heavy metal-polluted soil based on enzyme activity analysis around a Pb-Zn mine in Feng County, China Env. Sci Pollut Res 24 28152–28164

[26] Rong Jiang, Meie Wang, Weiping Chen, Xuzhi Li, María Balseiro-Romero P C B 2019 Ecological risk of combined pollution on soil ecosystem functions: Insight from the functional sensitivity and stability Environ. Pollut. 255 113184

[27] Abouian Jahromi M, Jamshidi-Zanjani A and Khodadadi Darban A 2020 Heavy metal pollution and human health risk assessment for exposure to surface soil of mining area: a comprehensive study Environ. Earth Sci. 79

[28] Mmolawa K B, Likuku a S and Gaboutloeloe G K 2011 Assessment of heavy metal pollution in soils along major roadside areas in Botswana Afr. J. Environ. Sci. Technol. 5 186–96

[29] Al-Khuzaie M M and Maulud K N A 2022 Evaluation of Soil Pollution Levels in Al-Qadisiyah Governorate, Iraq Using Contamination Index and GIS J. Ecol. Eng. 23 206–13

[30] Lindsay W L and Doxtader K G 1981 Environmental Chemistry of the Elements vol 10 (Academic Press(

[31] Martin J M and Whitfield M 1983 Significance of the River Input of Chemical Elements To the Ocean. NATO Conference Series, (Series) 4: Marine Sciences vol 9 (Springer International Publishing) pp 265–96

[32] Krauskopf, K.B. and Bird D K 1971 Introduction to Geochemistry vol 5 (New York: McGraw-Hill(

[33] Zhang X, Zha T, Guo X, Meng G and Zhou J 2018 Spatial distribution of metal pollution of soils of Chinese provincial capital cities Sci. Total Environ. 643 1502–13

[34] Bi C, Zhou Y, Chen Z, Jia J and Bao X 2018 Heavy metals and lead isotopes in soils, road dust and leafy vegetables and health risks via vegetable consumption in the industrial areas of Shanghai, China Sci. Total Environ. 619–620 1349–57

[35] Srinivasa Gowd S and Govil P K 2008 Distribution of heavy metals in surface water of Ranipet industrial area in Tamil Nadu, India Environ. Monit. Assess. 136 197–207

[36] Teng Y, Wu J, Lu S, Wang Y, Jiao X and Song L 2014 Soil and soil environmental quality monitoring in China: A review Environ. Int. 69 177–99

[37] Wang C, Yang Z, Zhong C and Ji J 2016 Temporal-spatial variation and source apportionment of soil heavy metals in the representative river-alluviation depositional system Environ. Pollut. 216 18–26

[38] Romic M and Romic D 2003 Heavy metals distribution in agricultural topsoils in urban area Environ. Geol. 43 795–805

[39] Luo W, Wang T, Lu Y, Giesy J P, Shi Y, Zheng Y, Xing Y and Wu G 2007 Landscape ecology of the Guanting Reservoir, Beijing, China: Multivariate and geostatistical analyses of metals in soils Environ. Pollut. 146 567–76

[40] Kabata-Pendias A 2000 Trace Elements in Soils and Plants (CRC press(

[41] Sayadi M H and Sayyed M R G 2011 Comparative assessment of baseline concentration of the heavy metals in the soils of Tehran (Iran) with the comprisable reference data Environ. Earth Sci. 63 1179–88

[42] El-Sharkawy R M and El-shora H M 2020 Egyptian Journal of Botany Egypt. J. Bot. 60 423–35

ISSN 2072-3857

[43] Ugulu I 2015 Determination of heavy metal accumulation in plant samples by spectrometric techniques in Turkey Appl. Spectrosc. Rev. 50 113–51

[44] Khan Z I, Ugulu I, Sahira S, Ahmad K, Ashfaq A, Mehmood N and Dogan Y 2018 Determination of Toxic Metals in Fruits of Abelmoschus esculentus Grown in Contaminated Soils with Different Irrigation Sources by Spectroscopic Method Int. J. Environ. Res. 12 503–11

[45] Demlie M and Wohnlich S 2006 Soil and groundwater pollution of an urban catchment by trace metals: Case study of the Addis Ababa region, central Ethiopia Environ. Geol. 51 421–31

[46] Srinivasa Gowd, S. and Govil P K 2008 Distribution of heavy metals in surface water of Ranipet industrial area in Tamil Nadu, India Environ. Monit. Assess. 136 197–207

[47] Alloway B J ed. 2013 Heavy metals in soils: trace metals and metalloids in soils and their bioavailability vol 50 (Springer Science & Business Media(

ISSN 2072-3857