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ORIGINAL PAPER

Heavy metals pollution in the soils of suburban areas in big cities: a case study

H. Taghipour · M. Mosaferi · F. Armanfar · S. J. Gaemmagami

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Abstract Soil pollution in agricultural areas surrounding big cities is a major environmental problem. Tabriz is the largest city in the northwest of Iran and the fourth largest city in the country. Soil samples were taken from 46 sites in the suburbs of the Tabriz city, and separate samples were taken from control site and analyzed. The results indicated that the mean pH value of the soil samples was 9.29, while the mean EC value was 354.33 µs/cm and the amount of TOC and TOM was 0.99 and 1.7 %, respectively. The mean concentrations of Cd, Pb, Cu, Cr, Ni, and Zn in the soil were determined to be 1.61, 10.56, 101.25, 87.40, 38.73, and 98.27 mg/kg, respectively (dry weight). The concentrations of heavy metals (Cd, Pb, Cu, Cr, and Zn), with the exception of Ni, were higher than the concentrations of the same heavy metals at the control site. Despite these elevated concentrations, the concentrations of heavy metals were lower than the toxicity threshold limit of agricultural soils. The values of the pollution index revealed that the metal pollution level was Pb > Cr > Cu > Zn > Cd > Ni, and the mean value of the integrated pollution index was determined to be 1.81, indicating moderate pollution. Nevertheless, there were some sites that were severely polluted by Cr (maximum values of 1,364 mg/kg). It was concluded that city probably has affected the surrounding agricultural area. Application of wastewater (municipal and industrial) as irrigation water, using of sludge as soil fertilizer, and atmospheric perceptions have been considered as main reasons of increased heavy metals concentrations found in the studied area.

Keywords Agricultural area · Assessment · Heavy metals · Soil

Introduction

Soil pollution in agricultural areas surrounding big cities is a major environmental problem. Heavy metals pollution in the soil has become a serious issue due to a number of human activities, such as those related to the mining, mineral, smelting, and tannery industries (Moller et al. 2005; Kasassi et al. 2008). Heavy metals contribute to environmental pollution because of their unique properties; heavy metals are non-biodegradable, non-thermo-degradable, and generally do not leach from the topsoil and have the potential to accumulate in the different organs (such as the kidneys, bones, and liver) leading to unwanted side effects (Radwan and Salama 2006; Singh et al. 2010). Each heavy metal shows specific signs of its toxicity. For instance Pb, As, Hg, Zn, Cu, and Al poisoning have been implicated with gastrointestinal (GI) disorders, diarrhoea, stomatitis, tremor, hemoglobinuria causing a rust-red color to stool, ataxia, paralysis, vomiting and convulsion, depression, and

H. Taghipour
Department of Environmental Health Engineering, Tabriz Health Services Management Research Center and Nutrition Research Center, Tabriz University of Medical Sciences, Tabriz, Iran

M. Mosaferi
Tabriz Health Services Management Research Center, Department of Environmental Health Engineering, Tabriz University of Medical Sciences, Tabriz, Iran

F. Armanfar (✉)
Regional Water Organization of East Azerbaijan Province, Tabriz, Iran
e-mail: f_armanfar@yahoo.com

S. J. Gaemmagami
Nutrition Research Center and Department of Nutrition, Biochemistry and Diet Therapy, Tabriz University of Medical Sciences, Tabriz, Iran

pneumonia. Some effects of heavy metals can be toxic (acute, chronic or sub-chronic), neurotoxic, or even carcinogenic, mutagenic or teratogenic (Singh et al. 2010; European Union 2002). Unlike other pollutants such as petroleum, hydrocarbons, and litter that visibly accumulate on soils, heavy metals can go unnoticed while accumulating at concentrations that are toxic to plants and animals. Heavy metals can continue to contaminate the surrounding environment for hundreds or thousands of years, even after they are no longer being added to the soil (Mapanda et al. 2005). Several researchers have clearly demonstrated that human activities are a major cause of metal contamination in the ecosystem (Kasassi et al. 2008).

More than half of the world's population lives in urban areas. Substantial rural–urban migration in developing countries is causing a rapid expansion of the peri-urban interface, where domestic and industrial modifications of the environment interact strongly with agricultural production (Huang et al. 2006). Therefore there is growing concern regarding the contamination of water, soil, and agricultural produce throughout rapidly urbanizing areas in Asia (Huang et al. 2006).

In the meantime, there are some risks in some Iranian cities, especially in large cities, for a number of reasons. First, a large urban population generate a large amount of waste, (such as sludge from industries and sometimes from municipal wastewater treatment plants) some of which is applied to surrounding lands. Second, the water shortage in these cities exacerbates heavy metals contamination. Because the society municipal or industrial wastewaters are discharged with little or no treatment in natural water bodies, which can become highly polluted, farmers in urban and peri-urban areas who are in need of water for irrigation have often little or no choice than using wastewater or polluted water as irrigation water (Qadir et al. 2010). On the other hand, intensive peri-urban vegetable and crop production leads to use of large quantities of organic wastes, fertilizers, pesticides, and likely contaminated irrigation water (which became polluted by municipal and industrial wastewater). In addition, many industries (such as battery production, metal products, dye and pigment, power plants, electroplating industries metal smelting & Cable coating industries, etc.) are being constructed in urban areas, posing a high risk of industrial pollution of water and air that may have direct impacts on public health, as well as indirect effects via vegetable production and soil pollution (Kaushik et al. 2009).

The selected area for the present study is Tabriz, Iran. Tabriz is the largest city in the northwest of Iran and the fourth largest city in the country, with a population of 1,523,085 people (2006) and an area of 45,481 km^2. The city is located on the north of Sahand volcanic cone and south of the Eynali Mountain at an altitude of 1,340 m above sea level, latitude of 38.07° N, and a longitude of 46.28° E. The dominant winds in the Tabriz are from east and northeast. The average raining amount is 289 mm/year (Koshhal and Gavidel 2009). The region has undergone heavy urbanization and development in recent decades. The largest industrial areas, such as areas focused on tractor manufacturing, car industry, industrial machines, tannery, chemical, petrochemical, refinery, cement, food, and agricultural farms, are located in the suburbs, and particularly in the western suburbs of the city. On the other hand, urban populations in the city and suburbs are increasing, and residents are seeking better living standards as those in other economically developing countries. Consequently, larger amounts of freshwater are diverted to domestic, commercial, and industrial sectors, which generate greater volumes of wastewater. Commonly, surface polluted water from the city and wastewaters from some suburban industrial areas that have received little or no treatment are being discharged into natural water bodies, which can become highly polluted. Farmers in urban and peri-urban areas of cities who are in need of water for irrigation have often no other choice (with the exception of farms with well water) but to use wastewater and surface polluted water. Of course, due to the strict control and mentoring by health and agricultural officials, as well as an increasing awareness of the pollution of the water and soil, the use of wastewater and surface polluted water in the irrigation of farms in the suburbs of cities has recently been limited, especially for vegetable and other commonly consumed crops. However, there is a concern about the soil pollution in areas with heavy metals, especially in the western suburb of city. This concern likely comes from the past applications or present stealth uses of wastewater for the irrigation of farmland, and other sources of heavy metals pollution, such as the use of large quantities of organic wastes, fertilizers, pesticides, and atmospheric perceptions. On the other hand, there are no reported research studies on the soil heavy metals conditions in this area. The main objective of this study was to characterize heavy metals levels of the soil (lead, cadmium, copper, zinc, nickel, and chromium) in western industrial and agricultural areas of Tabriz.

Materials and methods

The sites (on the Tabriz suburban agricultural areas) used for soil sampling are shown in Fig. 1 (it should be explained that, all of the sites are not visible in the figure; due to limited size of figure some numbered points are hidden behind the other points). A total of 46 samples were taken from the western suburb of Tabriz city. In addition, control samples were taken from land near to the study area which has never been used as farmland (No 47). As shown in Fig. 1, the sites were selected in such a way to cover all the agricultural areas of the city suburbs. Composite samples were made up of three sub-samples from each site. A

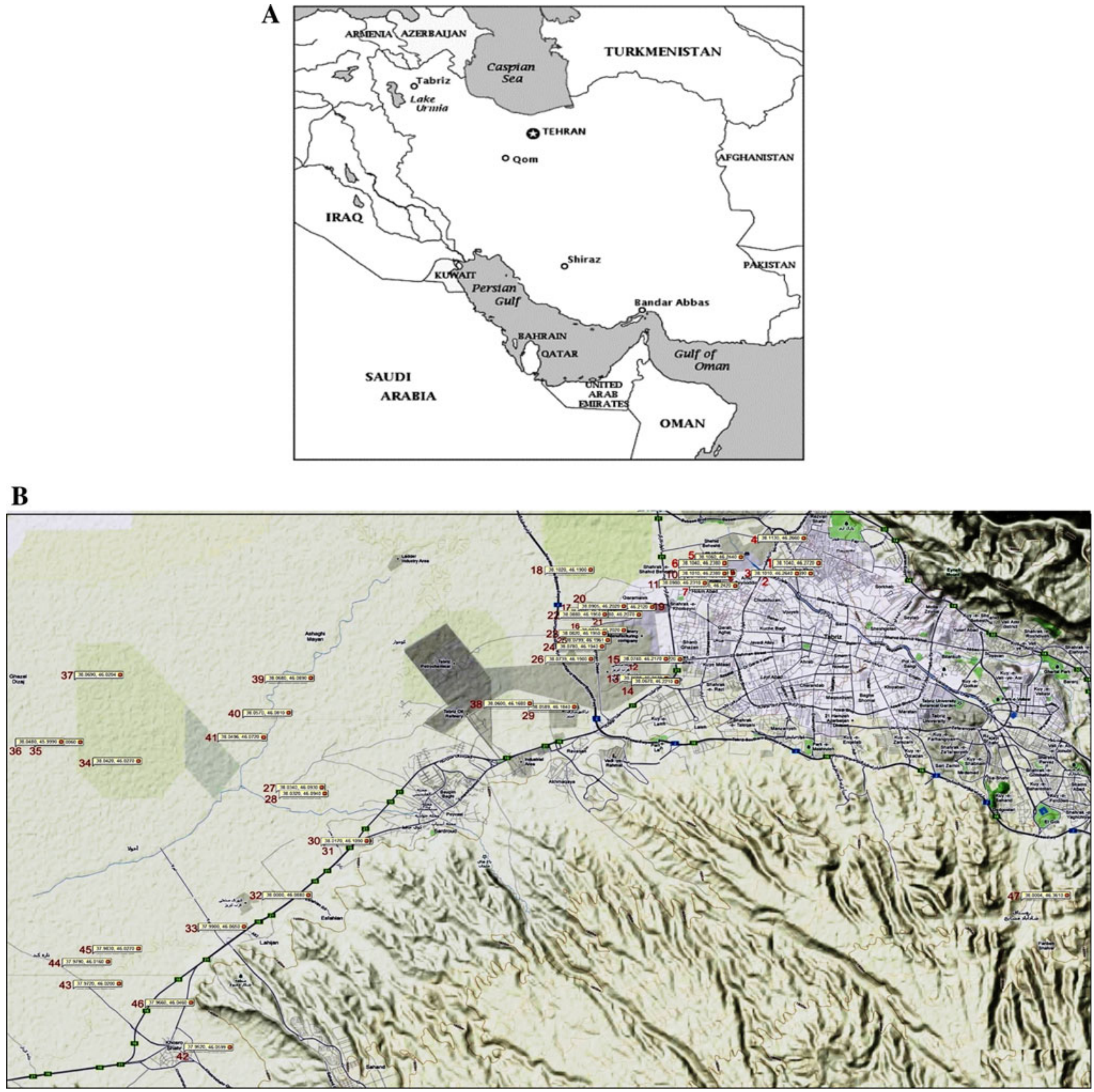

Fig. 1 Location of the study area (Tabriz) (**a**) and soil sampling locations in the suburbs of city (**b**)

monolith of approximately 10, 10, 15 cm (length, breadth, and depth values respectively) was dug for the collection of soil. A stainless steel trowel was used to collect samples that were stored in plastic bags while being transferred to the laboratory. Soil samples were air-dried for 72 h, crushed, passed through a 2-mm-mesh sieve, and stored at ambient temperature before soil properties and concentrations of heavy metals were analyzed (Sharama et al. 2007). The general soil properties of studied area indicated clay (32.76 % SD ±4.57), sand (33.68 % SD ±4.57), and silt (33.56 %) (Asgharszadeh et al. 2001).

All the containers used in the analysis were cleaned with a detergent solution, rinsed with tap water, soaked in acid (2 + 1 HCl), and then rinsed with metal-free water. Metals in the soil that were extractable by aqua regia were measured. From each dried sample, portions of approximately 20 g were ground until fine particles were obtained, and 1.5-g samples were then weighed into a flask, In a hood, HNO_3 (4 ml) and concentrated HCl (12 ml, aqua regia) were added, covered with a watch glass, and allowed to stand overnight (for at least for 12 h). The next day, the mixture was heated progressively and boiled under reflux for 2 h, after which the digestion flask was cooled. The cooling column was rinsed with 15 ml of deionized water, and the rinse water was recovered in the digestion flask. After cooling and rinsing, the ingests were passed through a pre-washed filter (Whatman No. 540), and the digestion flasks were rinsed three times; the washings were passed through the filter, and the filtrates were used to make a volume of up to 100 ml using ultra pure 2 M HNO_3. The prepared samples were refrigerated in acid-washed polyethylene bottles at 4 °C before the final analysis of the heavy metals concentrations (APHA 2006; Alexander et al. 2006; Mapanda et al. 2005). The soil pH was measured in a suspension of 1:5 soil to water using a glass electrode (Sharama et al. 2007). In the same suspension, the conductivity was measured using a conductivity meter and the organic carbon was determined using Walkley and Black's method (Page et al. 1982).

The concentrations of heavy metals in digested soil samples were determined with an atomic absorption spectrophotometer fitted with a specific lamp of Pb, Cd, Cu, Zn, Ni, or Cr using appropriate drift blanks. Quality control measures in analyzing the procedure were taken to confirm the accuracy of the analytical data. Samples were carefully handled to avoid contamination. Glasswares were cleaned properly. Deionized water was used throughout the study. Reagent blank determinations were used to correct the instrument readings during in the analyzes. About 25 % of all samples were analyzed repeatedly to ensure the precision and accuracy of analysis. The detection limits for Cd and Pb were 0.33 and 1.01 mg/kg, respectively. During the analyzes, the Cd and Pb detection limits reported as concentration of those elements in the sample when the elements (Cd and Pb) were not determined due to their very low concentration. The other heavy metals concentrations were high in all samples and there was no problem with their detection limits. The mean, median, standard deviation, and range values were used to assess the contamination levels of heavy metals in soil (Excel 2007).

Results and discussion

Soil characteristics

The mean, maximum, minimum, standard deviation, pH, electrical conductivity (EC), total organic material (TOM), and total organic carbon (TOC) values of soils in the study area and control site are given in Table 1. As indicated in Table 1, the pH of all soil samples was greater than 8.63 and the mean and maximum values were 9.29 (SD ±0.28) and 9.83, respectively. It means the soil of the study area was alkaline. Alkaline soil (pH > 8) can limit the mobilization of heavy metals in soil and can decrease their uptake by plants (Sharama et al. 2007). In comparison with the control soil (pH = 8.82), the mean pH of the studied soil samples was higher. However, the pH and EC of soil may change due to the long-term application of chemical fertilizers (Zhen et al. 2009). According to documents from the agricultural department in the study area, a great deal of chemical fertilizer (sodium nitrates, ammonium sulphate, ammonium nitrate, ammonia, ammonium chloride and urea, diammonium phosphate, monoammonium phosphate, potassium nitrate, calcium nitrate, triple super phosphate, etc.) has been used in recent decades; therefore, the high pH was predictable. The mean, maximum, and minimum EC values of soil samples were determined to be 354.33 (±203.85) µs/cm, 1,100 and 120 µs/cm, respectively. The results indicated a mean, maximum, and minimum of 1.7 % (SD ±1.06), 4.45 % and 0.17 % for TOM and 0.99 % (SD ±0.62), 2.58 %, and 0.09 % for TOC, respectively. In comparison with the control soil, which had TOM and TOC values of 1.71 % and 0.99 %, there was no significant difference. Total organic material includes all the elements (hydrogen, oxygen, nitrogen, etc.) that are components of organic compounds, not just carbon. The term organic material is different to TOC, which refers specifically to the organic carbon fraction. A conversion factor of 1.72 is used to convert organic carbon to organic matter. Total organic matter contains about 58 % of organic carbon (Pluske et al. 2012). The result of this study with TOM/TOC of 1.717 and 0.582 was in agreement with the subject. Total organic material is sometimes incorrectly used to describe the same soil fraction as TOC. (Pluske et al. 2012). Organic matter plays a key role in soil physical, biological, and chemical properties, such as structural stability, porosity, nutrient availability, and ion-exchange capacity (Bellanger et al. 2004; Mao et al. 2011).

Table 1 The mean, maximum, minimum, and standard deviation of pH and EC, TOM and TOC of soil samples

	pH	EC (µs/cm)	TOC (%)	TOM (%)
Mean	9.29	354.33	0.99	1.70
Max	9.83	1,100.00	2.58	4.45
Min	8.63	120.00	0.09	0.17
SD (±)	0.28	203.85	0.62	1.06
Control site (plot no. 47)	8.82	48	0.99	1.71

Soils, as filters of toxic chemicals, may adsorb heavy metals. However, when the capacity of these soils is reduced because of the continuous entrance of pollutants or because of changes in pH, heavy metals can be released into groundwater or soil solution available for plant uptake. The mobilization of heavy metals in the soil may depend on a number of factors, such as the pH, clay content, organic matter content, and cation exchange capacity (Mapanda et al. 2005). With the exception of Mo, Se, and

As, heavy metals mobility decreases as the soil pH increases due to the precipitation of hydroxides, carbonates, or the formation of insoluble organic complexes. Also, heavy metals are able to form insoluble complex compounds with soil organic matter (Mapanda et al. 2005).

Heavy metals contents in the soils

The soil sampling locations in the Tabriz city suburbs are shown in Fig. 1. The mean, maximum, minimum, and standard deviation of Pb, Cd, Cu, Zn, Ni, and Cr and also the concentration of analyzed metals in the control soil are presented in Table 2 (Excel 2007). Also, the results of the present study were compared with the results of other studies conducted in different cities around the world and within Iran (Table 3). As indicted in Table 2, there was a wide range in the concentrations of heavy metals. The mean concentration of Cd was 1.61 (±1.52), and the maximum and minimum values were 5.33 and 0.33 (detection limit was 0.33 mg/kg). The mean concentrations of Cd in the studied samples were higher than those in the control site (1.17 mg/kg), though the maximum concentration of Cd was much higher. The Cd concentration in suburban areas of Tabriz city was higher than the global mean concentration (0.5 mg/kg) and was also higher than values observed in other cities and in regions of other countries (Table 3) for example, Alicante (Spain), Trace (Turkey), Zagreb (Croatian), and Xuzhou (China) showed Cd concentrations of 0.3, 0.2, 0.66, and 0.54 mg/kg, respectively. Mapanda et al. (2005) carried out research in Harare, Zimbabwe in regions where wastewater was used for irrigation and reported a Cd concentration of 0.5–3.4 mg/kg, which is very near to the values observed in the present study (Mapanda et al., 2005). From the results shown above, this study concluded that anthropogenic Cd pollution sources (metal smelting, sewage waters, the use of phosphate fertilizers, etc.) might currently be occurring in the study area or have been occurred in the past.

Table 2 The mean, maximum, minimum, and standard deviation of heavy metals (Pb, Cd, Cu, Zn, Ni, and Cr) in the soil samples (mg/kg in dry weight) in comparison with control soil and toxicity threshold limit of agricultural soils

	Cd	Pb	Cu	Cr	Ni	Zn
Mean	1.61	10.56	101.25	87.40	38.73	98.27
Max	5.33	53.86	265.67	1,364.00	72.50	163.80
Min	0.33	1.01	13.17	25.08	2.50	49.80
SD (±)	1.44	13.38	39.24	221.30	17.71	24.82
Plot no. 47 (control soil)	1.17	3.05	69.00	38.31	47.50	69.80
TTLAS[a] (Uosefian et al. 2006)	–	1,500	400	1,500	2,000	5,000

[a] Toxicity threshold limit of agricultural soils

According to Table 2, the mean concentration of Pb in the suburbs of Tabriz city was 10.56 (± 13.38), with minimum and maximum values of 1.01 (The detection limit was 1.01 mg/kg) and 53.86 mg/kg. In comparison with the control site (Pb concentration of 3.05 mg/kg), the mean Pb in the study area was higher. However, the mean Pb value in the suburbs of Tabriz city was lower in comparison with that of other countries and cities (Table 3), such as Mexico (top soil, 140.5 mg/kg), Bangkok (24.8 mg/kg), Hamburg (32.5 mg/kg), Madrid (14.1 mg/kg), and Isfahan (Iran, 75 mg/kg), as well as with the global mean (30 mg/kg). The lower concentrations of Pb in the soil of the control site may indicate that there are some anthropogenic sources in the area, such as atmospheric perceptions and wastewater. The dominant winds in the city, which are from east and northeast toward west and southwest, respectively, probably played an important role in atmospheric perceptions in the area, especially in the past (Fig. 1). Most of the sites on the Tabriz suburban agricultural areas that are used for soil sampling are located in west and southwest. So the emissions transported by air from polluted atmosphere of city due to the huge car traffic are considered to be responsible for the increased Pb concentrations found in the soils. Of course, currently the using of Pb is banned in the gasoline.

As presented in Table 2, the mean concentration of Cu taken from 46 samples from the suburbs of the city was determined to be 101.25 (±39.24), and the maximum and minimum values were 265.67 and 13.17 mg/kg, respectively. According to Table 2, the concentration of Cu in the control site in the area was determined to be 69 mg/kg. Thus, the concentration of Cu in the study area was higher than that of the control site in the same area. Also, as indicted in Table 3, the comparison of the results of this study with other studies showed that the Cu concentration in the study area was higher than the concentrations of that element in other cities in Iran and in other countries except for Hamburg in Germany (Cu concentration of 146.6 mg/kg). Due to the achieved concentration for Cu, it can be assumed that the anthropogenic sources of pollution, such as industrial wastes and effluents, fertilizers, and sludge were already in the area or have been there in the past.

The Cr concentration in the soil of the study area is presented in Table 2, and compared with other cities in Iran as well as with other countries in Table 3. The mean concentration of Cr was 87.40 mg/kg (±221.3 mg/kg), and the maximum and minimum values were 1,364 and 25.08 mg/kg, respectively.

The concentration of Cr in the control site was 38.31 mg/kg. Again, a comparison of Cr concentration with that in other places [e.g., Mexico, 117 mg/kg (top soil); Bangkok, 26.4 mg/kg; Hamburg, 95.4 mg/kg; Madrid, 74.7 mg/kg; Isfahan (Iran), 177 mg/kg; Alicante (Spain), 27 mg/kg and Damascus (Syria), 57 mg/kg] and

Table 3 Average concentration of studied heavy metals (mg/kg) in soils of different cities in the world

Places	Cd	Pb	Cu	Cr	Ni	Zn
Tabriz (present study)	1.69	10.86	101.25	87.40	38.73	98.27
Mexico (Morton-Bermea et al. 2009)	–	140.5	100.8	117	39.8	306.7
Bangkok (Wilcke et al. 1998)	–	24.8	41.7	26.4	24.8	118
Hamburg (Lux 1986)	–	62.5	146.6	95.4	62.5	516
Madrid (De Miquel et al. 1997)	–	14.1	62.5	74.7	14.1	210
Isfahan (Iran) (Uosefian et al. 2006)	–	75	95	177	34	78
Alicante (Spain) (Mico et al. 2006)	0.3	23	23	27	21	53
Trace (Turkey) (Sun et al. 2010)	0.2	33	20	–	–	45
Zagreb (Croatian) (Sun et al. 2010)	0.66	25.9	20.8	–	–	77.9
Xuzhou (China) (Sun et al. 2010)	0.54	43.3	38.2	–	–	144.1
Damascus (Syria) (Moller et al. 2005)	–	17	34	57	39	103
World (mean) (Athar and Vohora 1995)	0.5	30	23	60	20	60

with the global mean soil Cr concentration (60 mg/kg) indicted that the Cr concentration in the suburbs of Tabriz city was higher than that of the other cities and places except for Mexico, Hamburg, and Isfahan (Iran). There were two sites (points 23 and 26 at N 38 04 55.2–E 046 11 44.7 and N 38 04 27.3–E 046 11 24.2 in Fig. 1) that showed very high pollution values of Cr, with concentrations of 780.5 and 1,364 mg/kg, respectively. The wastewater and sludge from the tanning, electroplating industry, in the area was likely a major source of Cr entering into the soil in the western suburbs of the city.

A survey of concentrations of Ni in the area indicted that the mean Ni concentration was 38.73 (±17.71) mg/kg with a range of 2.50–72.50 mg/kg. As presented in Table 3, the following Ni concentrations were reported for different countries: Mexico, 39.8 mg/kg (top soil); Bangkok, 24.8 mg/kg; Hamburg, 62.5 mg/kg; Madrid, 14.1 mg/kg; Isfahan (Iran), 34 mg/kg; Alicante (Spain), 21 mg/kg and Damascus (Syria), 39 mg/kg, with a global mean value of 20 mg/kg. With the exception of Hamburg in Germany, the Ni concentration in this study was equal to or greater than that of Iran and other countries. As shown in Table 2, the Ni concentration was higher in the control site than the mean from the other 46 samples taken. That indicates the control site has been polluted accidentally due to unknown reasons in the past time or the background concentration of Ni in that site naturally was higher. Understanding the exact reason might need more study in that site.

The mean, maximum, and minimum concentrations of Zn were determined to be 98.27 (± 24.82), 163.80, and 49.8 mg/kg, respectively. In some cases, the Zn concentration in this study (Table 3) was lower and in other cases, higher than in other cities and places (Mexico, 306.7 mg/kg (top soil); Bangkok, 118 mg/kg; Hamburg, 516 mg/kg; Madrid, 210 mg/kg; Isfahan (Iran), 78 mg/kg; Alicante (Spain), 53 mg/kg; Trace (Turkey) 45 mg/kg; Zagreb (Croatian) 77.9 mg/kg; Xuzhou (China) 141.1 mg/kg and Damascus (Syria), 103 mg/kg, with a global mean value of 60 mg/kg). In addition, Zn values were higher than the control site, with a value of 69.80 mg/kg and a global mean concentration of 60 mg/kg. Fertilizers, sewage sludge, and atmospheric industrial dust can be considered to be an anthropogenic source of Zn accumulation in soils.

Soil pollution indices

Many indices and calculation methods, such as geoaccumulation index (Igeo), pollution index (PI), and integrated pollution index (IPI) have been proposed for quantifying the degree of metal enrichment or pollution in soils, sediments (Faiz et al. 2009; Chen et al. 2005; Sun et al. 2010; Wei and Yang 2011; Lu et al. 2009; Abanuz 2011).

The PI and IPI are commonly used to assess environmental quality (Lu et al. 2009). In general, the PI was defined as the ratio of the heavy metals concentration in environment to the geometric means of the natural background concentration of the corresponding metal (Chen et al. 2005; Sun et al. 2010; Wei and Yang 2011). PI was calculated as:

$$\mathrm{PI} = \frac{C_{\mathrm{i}}}{S_{\mathrm{i}}}$$

where PI is the evaluation score corresponding to each sample, C_{i} is the measured concentration of the examined metals in the soils, and S_{i} is the geochemical background concentration of the metals (in this study due to the unavailability of geometric background concentration of studied area the geometric mean concentrations of control site was taken as natural background concentration). The PI value of each metal was calculated and classified as either having a low contamination ($\mathrm{PI} \leq 1.0$), a moderate contamination ($1.0 < \mathrm{PI} \leq 3.0$) or a high contamination ($\mathrm{PI} > 3.0$) (Chen et al. 2005, Lu et al. 2009). IPI was defined as the mean values for all PI values of all of the considered metals and then classified as having a low contamination ($\mathrm{IPI} \leq 1.0$), a moderate contamination ($1.0 < \mathrm{IPI} \leq 2.0$) or a high contamination ($2 < \mathrm{IPI} \leq 5$), and extremely high level of contamination ($\mathrm{IPI} > 5$) (Chen et al. 2005; Lu et al. 2009; Sun et al. 2010; Wei and Yang 2011; Abanuz 2011).

The PI and IPI values for all of the heavy metals in the study area are presented in Table 4. The PI was different across the surveyed heavy metals. For Cd, the PI values varied from 0.28 to 4.56 mg/kg with a mean value of 1.45 mg/kg (1.0 mg/kg $<$ PI $\leq$ 3.0 mg/kg was considered to be moderate pollution). A total of 17.39 % (8 samples) and 21.73 % (10 samples) of analyzed soil samples had moderate and high pollution values, respectively. The mean PI for Pb was determined to be 3.56 mg/kg ($>$3 high pollution) with a range of 0.33–17.66 mg/kg. According to Table 4, 15.21 and 39.13 % of Pb samples, respectively, had moderate and high pollution conditions. The Cu and Cr values of PI were determined to be 1.47 and 2.28, indicating moderate pollution levels for both of these substances. For Cu, 89.13 % of samples showed moderate pollution levels and 2.17 % showed high pollution levels, while for Cr, 56.52 % showed moderate pollution levels, 4.34 % showed high pollution levels, and the remaining samples showed low pollution conditions. Ni values were better in terms of pollution index because the mean value of PI for Ni was determined to be 0.82 (PI $\leq$ 1.0), indicating low pollution in the area regarding this element. Of the 46 samples, 76.09 % showed low levels of Ni, 23.91 % showed moderate Ni levels, and 0 % showed high Ni pollution levels. Finally, for Zn, the mean value of PI was 1.41 and moderate pollution was observed throughout most of the study area. In total, 10.87 % (5 samples), 89.13 % (41 samples), and 0 % (0 samples) showed low, moderate, and high pollution levels, respectively.

The mean value of the IPI was determined to be 1.83 mg/kg (1.0 mg/kg $<$ IPI $\leq$ 2.0 mg/kg) with a range of 0.05–35.36 mg/kg, indicating a moderate pollution condition. There were 111 (40.22 %) samples with an IPI value less than 1.0 (low contamination), 121 (43.84 %) samples with IPI values between 1.0 and 2.0 (moderate contamination), 32 (11.59 %) samples with IPI values (2 $<$ IPI $\leq$ 5) (high contamination), and 12 (4.35 %) samples with IPI values greater than 5 (extremely high contamination). In terms of the IPI criteria, the study area was found to be moderately to highly polluted with heavy metals. In comparison with IPI $<$ 1.0 of Beijing city (china) (Wei and Yang, 2011) the studied area was more contaminated. But in comparison with five other heavy industrial cities of China (Changchun, Shenyang, Changsha, Baoji and Jinchang) with IPI $>$ 5.0, had better condition (Wei and Yang, 2011). However, the results indicated that the soils around of Tabriz city may be significantly influenced by traffic sources and industrial sources such as smelting, power plants, metallurgical industry, tanning and electroplating industry chemical plant, auto repair shop, waste disposal, urban effluent, vehicle exhausts, sewage sludge, pesticides, and fertilizers application, etc.

Conclusion

The soil of the study area was alkaline, and the organic material content (TOC and TOM) showed almost the same conditions in comparison with other study results. With the exception of Ni, the average concentrations of the studied heavy metals (Cd, Pb, Cu, Cr, and Zn) were greater than those in the control soil (No 47). In addition, the average concentrations of the studied heavy metals, with the exception of Pb, were greater than the global average concentrations. However, most of the concentrations of studied heavy metals were lower than the toxicity threshold limit of agricultural soils. Of course, there were some farms that were severely polluted with chromium. Currently, the IPI showed a moderate level of pollution in the area. Due to a lack of past data regarding the concentrations of heavy metals in the area, it was not possible to determine the trend of changes. However, the concentrations of heavy metals are likely to be increasing in the area because of the increase in anthropogenic sources and rapid urbanization. The use of wastewater (municipal and industrial) as irrigation water and sludge as fertilizer in farms and using of sludge as soil fertilizer and atmospheric perceptions have been considered as main reasons for increased heavy metals concentrations found in the studied area.

According to the condition of region, several factors, including the following, can be proposed to improve management and decrease the source of pollutants: educating the farmers; more control and monitoring for the non-application of wastewater as irrigation water and sludge as fertilizer

Table 4 Pollution index (PI) and integrated pollution index (IPI) of heavy metals in suburb soil of Tabriz city

Heavy metals	PI			Number of samples			IPI			Number of samples			
	Mean	Max	Min	Low	Moderate	High	Mean	Max	Min	Low	Moderate	High	Extremely high
Cd	1.45	4.56	0.28	28	8	10	1.83	35.60	0.05	111	121	32	12
Pb	3.56	17.66	0.33	21	7	18							
Cu	1.47	3.85	0.19	4	41	1							
Cr	2.28	35.6	0.65	18	26	2							
Ni	0.82	1.53	0.05	35	11	0							
Zn	1.41	2.35	0.71	5	41	0							

in farms; and accelerating the completion of industrial and municipal wastewater collection and treatment systems.

Future research should be conducted using the same conditions to determine the trend of heavy metals concentrations and their accumulation in the soil. Due to other likely pollution source of heavy metals, such as agricultural fertilizers, pesticides, fungicides, etc., there should be more control over and research on these sources.

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