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Concentration of Heavy Metals in Soil and Staple Crops and the Associated Health Risk

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Background & Aims of the Study: The main objectives of the current research were (1) to study the extent of soil pollution by heavy metals (Ag, Cd, Cr, Cu, Mn, Ni, Pb, Zn, Ba and Li) in sampling locations (2) to investigate the extent of heavy metal pollution and soil to plant transfer of these elements in wheat and barley (3) to study the health risk of heavy metals via consumption of wheat grains for adults and children.

Materials &Methods: The levels of heavy metals in 29 sampling locations in soil and different parts of wheat and grains of barley were quantified in Shahrood and Damghan of Iran by inductively coupled plasma (ICP) optical emission spectroscopy (ICP-OES). Different statistical methods including ANOVA were used for the comparison of heavy metals in different soil groups and plant's tissues.

Results: All of the bio concentration factors (BFs) were lower than one indicating the low level of accumulation in wheat and barley. The BFs were higher in aerial parts than that of grains showing the restricted translocation of these elements by wheat and barley. The highest accumulation was obtained for Zn, Ag and Cu.

Conclusions: Considering Hazard Quotients (HQs), there was not any detrimental effect due to the consumption of wheat grains in the study area. The HQs of all heavy metals for adults were higher than that of children. The highest and lowest HQs values were for Mn and Cr in both age groups, respectively. The Hazard Index (HI) associated with wheat grains for children and adults were 1.36 and 2.06, respectively which is indicated the adverse health effects due to the consumption of this staple crop.

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Background

The non-biodegradable and persistent nature of heavy metals results in their accumulation in human body and destruction of vital organs such as kidney, bones and liver (1). Accumulation of heavy metals in agricultural soils may not only result in soil contamination but also the subsequent transfer of these elements to food crops (2). One of the main food items in many countries around the world are cereals such as wheat, rice, barley, rye, corn etc. Among them, wheat and rice accounts for 4/5 parts of the total food consumption of the world's population (3). Total consumption of wheat in Iran has risen from 15.8 MT in 2010 to 17.5MT in 2015 (4). Iran is the ninth largest consumer of wheat in the world and wheat bread is a staple in the Iranian diet. Due to the high tolerance of wheat and barley against elevated levels of heavy metals in the soil, they have been proposed for the phytoremediation of heavy metal contaminated soils in earlier researches (5); however, this accumulation can pose a high risk to consumers as well. Since, wheat and barley are considered as staple products so; the health risk associated with their consumption has a great importance in view of the health of natives. There have been multiple studies on the levels of heavy metals in wheat and barley all of the world. In a study by Moradi et al. (6), the average concentrations of Cu, Mn and Zn of wheat grain in three different cities of Isfahan province (Zarinshahr, Mobarakeh, Natanz), Iran, were 4.8,34.0 and 38.3 $mgkg^{-1}$ DW, respectively. Singh et al. (7) considered the heavy metal concentrations, associated health risk of consumption of cereals (wheat and rice) and some other vegetable crops in India. Salehipour et al. (8) conducted a study to assess the risks of human health from exposure to arsenic, lead, nickel, zinc and copper through consumption of wheat, rice and some vegetables in Isfahan province, Iran, using the total non-carcinogenic hazard quotient (THQ) and cancer risk assessment estimates.

Aims of the study:

In the present study, the concentrations of heavy metals in locally produced wheat and barley plants in addition to soil samples in 29 locations of Shahrood and Damghan, Semnan province of Iran were quantified. The main objectives were (1) to study the extent of soil pollution by heavy metals (Ag, Cd, Cr, Cu, Mn, Ni, Pb, Zn, Ba and Li) in sampling locations in the study area (2) to investigate the extent of heavy metal pollution and soil to plant transfer of these elements in wheat and barley (3) to study the health risk of heavy metals via consumption of wheat grains for adults and children. To the best of our knowledge, it is one of the most comprehensive published papers on the health risk of wheat grains (as a staple crop) in Iran.

Materials & Methods

27 sampling locations were selected in arable fields of Shahrood and Damghan where wheat and barley as staple crops are cultivated. A view of the study area has been illustrated in Figure1.Top-soil samples (0-25) were collected from the same sampling locations to take into account the contribution of soil to the pollution of plants and calculate the associated bio concentration factor as well. In a laboratory, the collected soil samples were air-dried and sieved through a 2-mm stainless steel mesh to remove stones and plant roots. Following digestion of soil samples with nitric acid (HNO_3) and hydrochloric acid (HCl) in a ratio of 3:1 (HNO_3:HCl), the total heavy metal concentrations of Ag, Cd, Cr, Cu, Mn, Ni, Pb, Zn, Ba and Li were analyzed by inductively coupled plasma (ICP) optical emission spectroscopy(ICP-OES). Dried samples were grounded, using a stainless steel grinder (<0.25 mm) and the total content of the above-mentioned heavy metals were detected by ICP-OES.

In order to compare the heavy metal concentrations in the considered parts of wheat (grain, leave and stalk, aerial part) at the studied sites, a one-way analysis of variance (ANOVA) was performed. For this purpose, the normality requirement of data was assessed by Shapiro-Wilk test of normality before the ANOVA test and the transformation of data was implemented to fulfill the normality requirements for those data which were not normal according to this test. In addition, for each data set, the homogeneity of variance was tested by Levene statistic. The significant level was 5 percent for each test. Furthermore, to consider the significant difference between heavy metal levels in wheat and barley grains, a one-sample t-test was carried out. The significant difference among soil groups related to each plant part was considered, using ANOVA test. All of the statistical tests in this study were performed by SPSS.

Health risk associated with wheat grain consumption

Risk to human health due to the consumption of wheat grains is characterized, using a Hazard Quotient (HQ) (9) which is calculated by the following equations:

$$HQ = \frac{CDI}{RfDo} \qquad (1)$$

$$CDI\left(\frac{mg}{kgday}\right)=\frac{CF\times IR\times EF\times ED}{BW\times AT} \quad (2)$$

in which the Chronic Daily Intake (CDI) is the exposure expressed as the mass of a substance per unit body weight per unit time, averaged over a long period of time (a lifetime) whereas RfD_o is the oral reference dose (mg kg^{-1} day^{-1}). CF is the median concentration of a heavy metal in wheat grain (mg.kg^{-1}); IR is the ingestion rate of wheat grain (kg.$person^{-1}$.day^{-1}) in which the per capita wheat consumption is about 170 kg per year (10) for adults and for children (0-6 old) it was assumed to be one third of that of adults(11); EF is the exposure frequency (365 days $year^{-1}$); ED is the exposure duration (70 years for adults and 6 years for children); BW is the average body weight (70 kg for adults and 35 kg for children), and AT is the average exposure time for non-carcinogenic effects (ED × 365 days $year^{-1}$). If the CDI exceeds the threshold (i.e., if HQ exceeds unity), potential non-cancer effects may be a concern. The RfD_o values were 0.005,0.001,0.04,0.14,0.02,0.3,0.2,0.02 mg.$kg^{-1}$$day^{-1}$ for Ag, Cd, Cu, Mn, Ni, Zn, Ba and Li (12), 1.5 mg.kg^{-1}.day^{-1} for Cr (13) and 0.004 mg.kg^{-1}.day^{-1} for Pb (11), respectively.

Results

The concentrations of heavy metals in plants (wheat and barley) and soil samples have been given in Table1 and Table 2, respectively. Among the studied heavy metals in different parts of wheat samples, there was a significant different at 5 percent in the levels of Cu and Ba. A method for expressing the accumulation of metals from soil to above-ground tissues of plants is through bio concentration factor (BF) which is generally obtained by dividing the concentration of the element in plant tissues (grains, shoots, straw, etc) to the total concentration of the same element in the rooted soil (14). The bio concentration factors of wheat and barley have been shown in Table 3. On the contrary, the results of hazard quotient (HQ) for individual heavy metals related to adults and children have been illustrated in Figure 2.

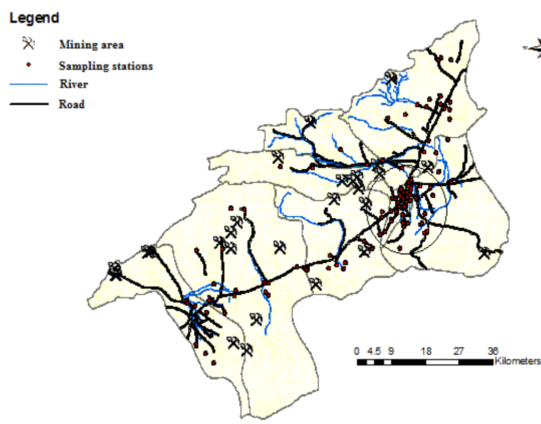

Figure1) A view of the study area in which the regions with intensive agricultural activity has been highlighted

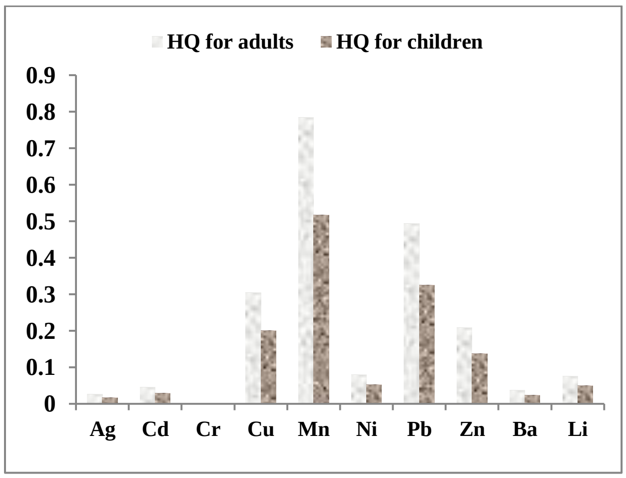

Figure 2) The HQs of individual heavy metals for adults and children due to the consumption of wheat grains

Table1) Concentrations of heavy metals in different parts of wheat and barley. The values that exceeded standard levels were shown by bold font.

Heavy metals	Wheat						Barley		Standard values
	Grain		Leave and stalk		Aerial parts		Grain		mg/kg DW
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Ag	0.055	0.018	0.043	0.028	0.063	0.026	0.043	0.012	-
Cd	0.018	0.008	0.030	0.020	0.032	0.019	0.016	0.007	0.070
Cr	0.850	0.783	0.533	0.153	0.811	0.800	0.489	0.105	0.020
Cu	*5.012[a]	0.485	7.666[b]	2.900	7.666[a]	1.980	4.756	0.945	73.300
Mn	45.25	8.137	37.000	18.520	42.555	23.885	**32.556	8.278	25.000
Ni	0.663	0.478	0.533	0.208	0.622	0.179	0.500	0.229	67.900
Pb	0.713	0.934	0.327	0.170	0.356	0.092	0.220	0.053	0.300
Zn	25.75	7.950	28.367	4.272	27.344	8.264	23.833	9.396	99.400
Ba	*3.050[a]	1.726	6.833[a]	1.401	5.978[b]	3.983	2.889	1.649	3.200
Li	0.623	0.259	1.490	0.940	1.000	0.680	0.701	0.308	-

*:Significant at 5 percents
**:Significant at 1 percents

Table2) Concentrations of heavy metals in different soil groups. The values higher than standard levels have been highlighted by bold font.

Heavy metals	group1		group2		group3		group4		Standards mg/kg	Reference
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Ag	*0.205[a]	0.065	0.134[b]	0.031	0.130[a]	0.028	0.168[a]	0.054	4	IS[×]
Cd	0.313	0.464	0.183	0.074	0.245	0.120	0.190	0.110	1	IS
Cr	81.725	34.979	79.656	14.457	74.150	11.526	92.550	25.886	110	IS
Cu	22.556	4.057	20.567	4.984	18.900	0.707	24.838	6.408	100	IS
Mn	775.375	392.906	565.889	99.982	507.000	48.083	668.625	166.218	600	USEPA,1983
Ni	32.194	8.767	31.644	4.391	28.350	6.845	34.144	6.458	50	IS
Pb	18.493	6.641	13.412	1.220	14.545	1.223	18.309	5.374	50	IS
Zn	**96.787[a]	34.017	57.144[b]	8.950	59.550[a]	2.616	82.413[a]	25.383	200	IS
Ba	*345.125[a]	66.632	255.333[b]	31.666	284.000[a]	50.912	292.625[a]	52.312	300	IS
Li	37.020	6.387	29.236	5.171	31.585	1.308	34.979	11.906	-	

*:Significant at 5 percents
**:Significant at 1 percents
×:Iranian Standard for soil quality

Table3) Bioconcentration factors of wheat and barley

Heavy metals	Bioconcentration factor		
	Wheat		Barley
	Grains	Leave, stalk and aerial parts	Grains
Ag	0.284	0.480	0.230
Cd	0.110	0.210	0.130
Cr	0.005	0.010	0.005
Cu	0.215	0.402	0.210
Mn	0.060	0.077	0.050
Ni	0.011	0.021	0.015
Pb	0.011	0.026	0.012
Zn	0.254	0.492	0.338
Ba	0.007	0.025	0.009
Li	0.015	0.039	0.021

Discussion

The distribution pattern of copper in different soil horizons is mainly influenced by its accumulation in the top horizons (15) resulting in its subsequent uptake by plants. As a whole, the behavior, phytobio availability and toxicity of Cu are influenced by its species and are not the function of its total concentration (16). The rate of Cu uptake by plants completely depends on the plant species. For example, Chlopecka (17) concluded that anthropogenic sources of copper are more available for barley uptake than geogenic sources. Since, there was no significant difference between the copper levels in the four studied soil groups (Table 2) so, the variability among different parts with respect to the levels of copper is most likely due to the difference in the movement of Cu in various parts of the wheat and barley not because of the difference in the soil levels of Cu. The studies of Kumpulainen (18) and Eriksson (19) on wheat from seven countries have proved that the average values of copper in wheat grains fluctuate between 1.3-10 $mg.kg^{-1}$ with the mean value of 4.7 mgkg-1 whereas, according to the study of Kabata-Pendias and Pendias (20), the mean level of Cu in barley grains ranges between 4-5 mg/kg with mean value of 5.5 $mg.kg^{-1}$.

Contrary to the results of Cu, the significant difference of barium among the soil groups (Table 2) may be one of the reasons for the differences in the various parts of wheat samples. Barium concentration in most plants ranges from 2 to 13 mg kg^{-1}, with the exception of blueberries, in which highly elevated Ba levels were reported (21). There are few studies on the concentrations of Ba in crop plants. Nogueira et al.(21) analyzed the Ba levels in maize plants in a soil treated with sewage sludge for nine consecutive years. The results indicated that the concentration of Ba in the stem, leaf, straw, cob and grain was significantly influenced by sewage sludge application and there was a significant difference among the levels in different parts of the studied plant which is in consistent with the results of this study. The Ba concentrations in the leaves ranged from 90.65 to 105.7 $mg.kg^{-1}$ which were more higher than the results of this study; however, the concentration of Ba in the grains ranged from 0.06 to 1.05 $mg.kg^{-1}$ which is less than the findings of the present study, anyhow. The results of Smith et al. (22) on the accumulation of Ba in wheat showed that this accumulation was mostly occurred in the stalks and leaves rather than in the grains which is in agreement with the results of this study.

The phyto availability of Zn in soil depends on many soil parameters which vary greatly in different soils (22). Agricultural practices are among the factors that significantly influence the soil zinc content. In this field, Tyler and Olsson (23) reported that the concentrations of Zn in cultivated and natural soils solutions were 78 (12–223) $\mu g.l^{-1}$ and 35 (13–72) $\mu g.l^{-1}$, respectively. Despite the impacts of different parameters including genotype on uptake behavior of Zn, the levels in certain plants are roughly similar. According to the results of earlier studies (24-26) on the concentrations of Zn in cereals from various countries, the zinc concentrations in wheat grain fluctuated between 23 and 37 $mg.kg^{-1}$ with average value of 24 $mg.kg^{-1}$ while, for the case of barley grain it varied from 20 to 30 $mg.kg^{-1}$ with a mean value of 26 $mg.kg^{-1}$. Eisler (27) indicated that Zn concentration in plant parts follows the following pattern: roots>foliage>branch>trunk. The mobility of Zn within plant highly varies depending on species and Zn nutrition status. In most cases, however, Zn is likely to concentrate in mature leaves and in roots (28). This is in consistent with the results of this study as well. The tracking of Zn movement in plants by radionuclide showed that Zn has the highest mobility as compared with As, Cd and Cu (29). In summary, as an essential element, like that of Cu (which is also an essential element) none of the analyzed samples have exceeded the permissible limits recommended in this regard.

Cadmium is a metal with unknown essential function in higher plants but it is easily absorbed by plant roots and transferred to the above-ground parts (30). When the growing takes place on the same type of soil, the cadmium accumulation in different species decreases as follows:

Grains<Root<Vegetables<Leaf vegetables (31). In a similar research, Eriksson et al. (32) showed that Cd distribution in cereal grains is in the following order: wheat>oat>barley. The results of the current study indicated elevated levels of Cd in leave and stalk as compared to that of grain in wheat. Hornburg, Bümmer (33) and Adams et al. (34) showed that there is a linear relationship between soil and plant levels of cadmium; however, in this study there was a weak correlation (r=0.068) between the concentrations of cadmium in plant crops and its soil levels. Jafarnejadi et al. (35) considered the cadmium concentrations in 255 soil and wheat grain samples from Iran and concluded that the cadmium in 95 percents of samples were higher than the threshold value of 0.2 $mg.kg^{-1}$.

The background soil concentrations of Ag as reported by USEPA (36) range from 0.1 to 0.2 $mg.kg^{-1}$. As there are some Ag mines in the area (such as Gandy and Abolhassani) so, they can be attributed as one of the sources of Ag in the soil samples. In this field, soils from mineralized area have contained up to 2.5 and 3.2 $mg.kg^{-1}$ of Ag in the USA and Canada, respectively (37). Jones et al. (38) detected elevated levels of silver in the soil samples near derelict mine sites in Welsh soils. There are few studies on the concentrations of silver in plant species. The reported values of Cunningham and Stroube (39) in cereal products were in the range of 0.008 and 0.14 $mg.kg^{-1}$ which was higher than that of vegetables and fruits. The detected values in different parts of plants in this study fluctuated between 0.043 and 0.063 $mg.kg^{-1}$ in which the highest concentrations were in aerial parts.

In mining areas, Pb may be dispersed due to the erosion and chemical weathering of tailings. The severity of these processes depends on chemical characteristics, and the minerals present in the tailings. Like that of silver, the prevalent mining activities in the area are one of the main sources of lead next to motor vehicles in the soils of the region. These metals are continuously dispersed downstream and downslope from the tailings by movement through wind (40). Referring to plant samples, the Pb concentrations in all of the wheat samples were higher than the permissible value of 0.3 $mg.kg^{-1}$ set by WHO/FAO (Table 1). The mean concentration of lead in wheat grain in 16 different studies conducted in various countries was mostly high ranging from 0.015 to 22.6 $mg.kg^{-1}$ (41). The mean value of this element in wheat grain samples from Pakistan were at the same range as that of this study with the mean value of 0.35 $mg.kg^{-1}$ (41). In the study of Bermudez et al. (14) conducted in Argentina, the range of Pb in wheat samples fluctuated between 0.022 and 0.269 $mg.kg^{-1}$ with mean value of 0.088 $mg.kg^{-1}$ which was lower than the reported value in this study. In addition to soil, airborne Pb is a major source of Pb in plants through uptake by foliage. In this respect, Dalenberg and Van Driel (42) suggested that 73-95% of the concentration of Pb in wheat grain was a result of atmospheric deposition. By contrast, only 21% of the concentration of Cd measured in wheat grain was from atmospheric sources.

As reported by Kabata-Pendias and Pendias (20), the mean concentration of lithium in soil samples is about 32 $mg.kg^{-1}$ which is within the range of the findings of this study. In the arid climatic zones like that of the study area, Li follows the upward movement of the soil solution and may precipitate at top horizons along with easily soluble salts of chlorites, sulfates, and borates. Since the lithium in soil solution is easily available for plant absorption so, the plant content of this element is believed to be a good guide to the Li status of the soil (43). The findings of the present study confirm this as the levels of lithium in leaves and stalk are far higher than that of wheat grains (Table 1).

In the absence of anthropogenic sources, the elevated levels of chromium next to nickel have been proved to originate from the ultramafic rocks and the developed soils over them (44). The presence of these formations in the study area may be one of the reasons for this higher than normal average levels of this element (e.g. 92.550) ,though less than the standard values, in the region. As it was concluded by Golovatyj et al. (45) the crop concentration of chromium does not depend on the soil concentration of this element and the maximum contamination was found in roots and the minimum in the vegetative and reproductive organs. One of the possible reasons for this higher accumulation may be due to the fact that Cr is immobilized in the vacuoles of the root cells, thus, rendering it less toxic, which may be a natural toxicity response of the plant (46). Pulford et al. (47) in a study on temperate trees confirmed that Cr was poorly taken up into the aerial tissues but was held in the root. Despite these conclusions, the results of the current study showed higher than standard values of Cr in all of the studied organs as compared with the permissible value of 0.02 $mg.kg^{-1}$ DW suggested by WHO/FAO (Table 1). Due to the carcinogenic properties of this element, it looms large for the consumers in the study area. In this field, López-Luna et al. (48) found that roots of wheat, oat and sorghum accumulated more Cr than shoots; however, in spite of that, wheat, oat and sorghum showed Cr translocation from roots to shoots. The mean reported chromium values of winter wheat and barley grains from Sweden ranged from 0.01 to 0.02 $mg.kg^{-1}$, respectively (19), which was less than the average values of this study.

Nickel is easily mobilized during the weathering however, its mobility is inversely related to the soil pH (49). Since all of the samples were taken from agricultural soils so, phosphate fertilizers may be an important source of Ni in this field. A study by Kratz et al. (50) on the application of phosphorous fertilizers in soils of Germany during a sixty years time period (from 1950 to 2010) showed that these fertilizers exclusively have amounted 54 ton/year of Ni to the soils of Germany. The nickel uptake of 13 plant species was investigated by Sauerbeck and Hein (51) who concluded that the Ni contents in grain and in storage organs were larger than in the vegetative parts. The value of Ni detected by Kirchmann et al. (52) varied between 0.1 to 0.3 $mg.kg^{-1}$ DW which is less than that reported in this study.

As a whole, the levels of Mn in soils is very different however, soils derived from mafic rocks and soils in arid and semi-arid regions (like that of the study area) usually contain elevated levels of this element (53), this may partly justify the high detected levels of this heavy metal in soil samples of this study. Hajizadeh Namaghi et al. (54) detected elevated level (higher than permissible levels) of Mn in soil samples in their study. Mn oxides, due to both reducing and oxidizing properties can affect the mobilization of other heavy metals. For instance, manganese oxides have a particularly strong affinity for Pb adsorption and probably to a lesser extent for Cd adsorption (55). Since Mn is mainly accumulated in the top horizons of soils as a result of its fixation by organic matter so, its subsequent accumulation in plants is most likely (15). On the contrary, the Mn concentrations in all of the studied samples were higher than the standard value and there was a highly significant different between the wheat and barley grain levels which were 45.25 and 32.56 $mg.kg^{-1}$ for the latest samples, respectively. The results of this study are comparable with those reported by Bermudez et al. (14) in which the mean value of Mn in wheat grain samples was equal to 49.8 $mg.kg^{-1}$ however, the concentration value of Mn found in wheat grain in a study conducted by Hassan et al. (41) in Pakistan was 4.9 $mg.kg^{-1}$ which is significantly less than that found in the current research. Regarding the barley grain samples analysis in Sweden, the minimum and maximum values of manganese were 12 and 34 $mg.kg^{-1}$, respectively with a mean concentration of 18 $mg.kg^{-1}$ (19). According to Kabata-Pendias and Pendias (20), among food plants the highest values of Mn are found in food grains (between 27 to 50 $mg.kg^{-1}$) whereas the least amounts have been detected in fruits (between 1.3 to 1.5 $mg.kg^{-1}$) mainly due to the complex of large organic molecules that affects Mn transport through the phloem vessels. As claimed by Skinner et al. (56), in area that elevated levels of Mn is found the passive next to active absorption of Mn is happening across the soil–root interface resulting in its accumulation in plants.

In this study, the order of bio concentration factors for aerial parts of wheat was as follows: Zn>Ag>Cu>Cd>Mn>Li>Pb>Ba>Ni>Cr. And for the wheat and barley grains the orders of BFs were the following:

Ag>Zn>Cu>Cd>Mn>Li>Ni=Pb>Ba>Cr and Zn>Ag>Cu>Cd>Mn>Li>Ni>Pb>Ba>Cr, respectively. All of the calculated bio concentration factors were lower than one indicating the low amount of accumulation of heavy metals in wheat and barley.As a whole, the BFs were higher in aerial parts than that of grains showing the restricted translocation of these elements by the wheat and barley in the study area.The highest accumulation were obtained for Zn, Ag, Cu and the following order belonged to Cd.The results of this study agreed with that of Boussen et al. (57), in which Zn was the most abundant element in wheat grains and also higher BFs were found in aerial compared with that of grains. The bio concentration capabilities of silver have been earlier discussed by Ratte (58).The least accumulated elements in this study were Cr next to Ba in wheat and barley grains.This finding completely confirms the results of Huang et al. (11) and Gigliotti et al. (59)who found that Cr is the least mobile element in wheat grains and corn plants,respectively.The results of this study were also in consistent with that of Brunetti et al. (60) who found that Cr next to Ni are the least mobile elements in wheat and barley samples in Italy. As can be seen in Figure2, the HQs of all heavy metals for adultsare higher than that of children. The HQs decreased in the following order for adults: Mn(0.78)>Pb(0.49)>Cu(0.30)>Zn(0.21)>Ni(0.08)>Li(0.07)>Cd(0.05)>Ba(0.04)>Ag(0.03)>Cr(0.001) and the order for children they were as follows:Mn(0.50)>Pb(0.33)>Cu(0.20)>Zn(0.14)>Ni(0.05)>Li(0.04)>Cd(0.03)>Ba(0.02)>Ag(0.01)>Cr(0.001). If the risk exceeds unity there will be a concern for potential health hazard for the consumers (11). The HI associated with wheat grains consumption for children and adults were 1.36 and 2.06, respectively indicating adverse health effects due to the consumption of wheat grains with respects to the levels of all considered heavy metals in both age groups.The values obtained for HI in this study were higher than those reported by Huang et al. (11) but less than the HI values in Zheng et al. (61) and Bermudez et al. (14).

Conclusion

The results of this study indicated that zinc next to silver have the highest bio concentration capabilities to transfer from soil to wheat and barley.The hazard quotients of heavy metals in wheat grain decreased in the following order: Mn>Pb>Cu>Zn>Ni>Li>Cd>Ba>Ag>Cr. Considering the hazard quotient of individual heavy metals considered in this study, there is no health threat due to the consumption of wheat grains for adults and children whereas, hazard index for combined heavy metals was higher than one indicating that children and adults will probably experiencing health risks due to the dietary intake of heavy metals.

Footnotes

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Conflict of Interest:

The authors declared no conflict of interest.

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