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A Comparative Study on the Capability of Tree Species in Urban Afforestation to Accumulate Heavy Metals

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ABSTRACT

Background: The present study investigated the concentrations of lead, nickel, copper, zinc, their toxicity potential, and their ecological hazard in surface soils of Hamedan City, Iran. Also, using the Bio-concentration Factor (BCF), concentration Comprehensive Bio-concentration Index (CBCI), and Metal Accumulation Index (MAI), was evaluated the ability of some tree and shrub species to absorb heavy metals in soil and air.

Methods: Sampling of leaves of nine tree species and shrubs (plane, acacia, elm, willow, mulberry, ash, redbud, pine, and cypress) was performed in six stations. After preparation and acid digestion of the samples, the concentrations of heavy metals were determined using an atomic absorption spectrometer.

Results: The trend of changes in soil heavy Mean±SD metal concentrations was in the order of nickel> zinc> copper> lead in the amounts of 61.41±11.34> 43.04±14.4> 42.87±8.36> 18.77±6.51 mg/kg. Evaluation of acute toxicity potential indicators and ecological risk of heavy metals indicated low soil pollution status. Findings of BCF, CBCI, and MAI ndices in the leaves of the species showed that the highest levels of BCF of heavy metals, i.e., zinc, copper, lead, and nickel, were in willow, elm, cypress, and pine species, respectively. Results show that heavy metal accumulation in different species.

Conclusion: Depends on soil type, tree species, climatic conditions, type of pollutant source, species age, and other factors. In this study, elm and acacia have the highest ability to absorb heavy metals from soil and air.

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1. Introduction

Today, air pollution is one of the most critical problems of the world because of its various health, environmental, and economic effects. Air pollution is a cross-border event that can affect areas far from the source of production and even around the world [1]. They cause adverse effects on human society and the world environment [2]. The health issues associated with air pollution include damage to the lungs, heart and arteries, nerves, cancer, even death [3]. In this regard, research shows that particulate matter of less than 2.5 µ in indoor air kills about 3.3 million people annually worldwide [4]. The Canadian Medical Association estimates that the number of air pollution-related deaths in the country in 2008 was around 21000 [3]. There is a positive and significant relationship between heavy metals, gastric cancer, and the upper aerodigestive tract [5]. Gouveia et al. stated that air pollution has a severe impact on child and infant mortality in Latin American societies, and O_3 increase is associated with an increased risk of respiratory death in children and infants in these areas [6]. These cases show the dangers of air pollution and its control more than before.

In the meantime, many methods and techniques have been developed to monitor, reduce, and eliminate pollutants using mechanical equipment, biosorbents, nanoparticles, electrical filters, etc. However, these techniques do not have the required efficiency for various reasons such as the need for high technology, limited application, the need for a skilled expert, and high cost [2, 7]. Therefore, researchers tend to use high-efficiency methods with the ability to absorb various pollutants at a low cost [8].

In this regard, one of the methods that can play an essential role in reducing various pollutants is the use of plant, tree, and shrub species. Studies show that trees have a good potential to receive, absorb, and reduce various contaminants [9]. They can absorb heavy metals from the air through their roots, leaves, and skin and purify the environment [10]. The extent and variety of tree species along with high leaf area introduce them as a suitable biological monitor as well as adsorbent of gaseous pollutants, heavy metals, and suspended particles [11]. Various studies show that trees are effective air filters by absorbing suspended particles on their leaves to reduce air pollution [12].

The sensitivity and response of different plants and trees to one contaminant are different [13]. Tree species eliminate air pollution by absorbing and depositing airborne particles on their leaves' surface. They absorb gaseous pollutants through the stomata. Computer simulation data from 86 tree species in Canada show that 16500 tons of air pollution were removed by trees in 2010 [3]. Therefore, identification and classification of trees as accumulators or repellents and sensitive and resistant groups are necessary to maximize their capacity and potential in reducing and eliminating pollutants in urban and industrial areas [14]. The present study, for the first time, investigated the toxicity and ecological hazards of metals in soil and also evaluated the potential for uptake and accumulation of heavy metals by nine tree species and shrubs and in various soil and air. For measuring their toxicity, we used the indexes of Bio-Concentration Factor (BCF), total metal concentration Comprehensive Bio-Concentration Index (CBCI), and Metal Accumulation Index (MAI) in the city of Hamedan Iran.

2. Materials and Methods

Study area, plant selection, and sample collection

The study area is the city of Hamedan, Iran. To determine the sampling stations, the data related to air pollution in Hamedan (prepared by the air pollution monitoring stations of the Environment and Medical Sciences Organization) were used, and after numerous visits and field observations, the crowded, polluted, and busy streets were identified. Finally, six stations (Imam Khomeini Square, Bouali Tomb Square, Sepah Square, Farhangian Bridge, Baghe Behesht, and Abbasabad Hill) and nine tree species (broadleaf and conifers) and shrubs that have been planted in large numbers in parks, streets, and other green spaces of Hamedan were selected (Table 1).

Nine species of trees and shrubs that have been planted more in different areas of Hamedan city were selected as follows: plane tree (*Platanus orientalis*), acacia (*Robinia pseudoacacia*), elm (*Ulmus minor 'Umbraculifera'*), willow (*Salix alba*), mulberry (*Morus nigra*), ash (*Fraxinus excelsior*), redbud (*Cercis siliquastrum*), pine (*Pinus eldarica*) and cypress (*Thuja Orientalis*). In September 2017, the leaves of tree species planted in study stations and the soil under them were sampled. Pest and unhealthy leaves were not harvested, and as much as possible, healthy and mature leaves were sampled. For each species in each station, three leaves were harvested from three trees in four main directions and at the height of 1.5 to 2.5 m above the ground. After collecting the leaves in the city, the samples were transferred to the laboratory in paper packages and digested.

Table 1. Specifications of sampling stations in Hamadan

No.	Stations	Specifications
1	Bagh-e Behesht	Heavy traffic due to its location in Bagh-e Behesht, as well as the exit of the city and the transit route to Malayer and Tehran cities, stone-cutting and workshop industries, and repair shops, low population density
2	Bouali Tomb Square	One of the most crucial city centers with heavy traffic, large population, the existence of the university, school, hospital and clinics, shopping center, high density of banks and offices
3	Imam Khomeini Square	One of the most crucial city centers with heavy traffic, crowded population, the existence of the university, school, hospital and clinics, shopping center, high density of banks and offices
4	Farhangian Town Bridge	Heavy traffic, the main route to Tehran and from Tehran to Kermanshah and Kurdistan, international exhibition of Hamadan, near three suburban areas and 39 industrial units, close to Payame Noor University and bus passenger terminal
5	Sepah Square	Very high population density, Heavy traffic, close to Imam Sadegh University, Babataher Tomb and administration and banks, the way to the west of the country and three passenger terminals of bus, minibus, and personal vehicles, car repair shops
6	Abbas Abad Hill	Clean environment with suitable climate, tourist and tourism area, with very low population density, very low pollution

In the laboratory, first, the tree leaf samples were washed with distilled water, then placed in an oven at 60°C for 24 hours to dry completely. After drying, the samples were ground by an electric mill and then sieved. One gram of each dried sample was poured into Polytetrafluoroethylene (PTFE) digestion tubes, and 10 mL of 65% nitric acid (Merck, Germany) and 70% perchloric acid (Merck, Germany) was added in a ratio of 1:4. PTFE tubes were placed on a heater at 40°C for one hour, after which the temperature was slowly increased to 140°C for 3 hours. The contents of each tube were passed through Whatman No. 1 filter paper and made up to 25 mL with deionized water. To control the quality of the analyses, three blank control samples were placed next to the other samples [15]. Finally, the concentration of heavy metals in the samples was measured according to the specific limit of the 797 VA Computrace atomic absorption device and the graphite furnace made by Metrohm, Switzerland. Also, to measure the concentration of soil metals, soil air samples were first dried and passed through a sieve with 63 µ pours to remove rock particles and plant debris. Then, for the preparation and digestion of the samples, one gram of each dried sample was processed as the method of digestion of tree leaf samples.

It should be noted that a blank sample was used to correct the errors caused by their preparation and digestion. The Limit of Detection (LOD) for measuring zinc, lead, nickel, and copper was 0.209, 1.385, 0.292, and 0.231 mg/L, respectively, and the recovery results were in the range of 91% to 96%. Statistical analysis was down using SPSS V. 21.The normality of the results was confirmed and then to investigate the existence of significant differences Tukey test used.

Evaluation of accumulation of heavy metals from soil and air by trees

Bio-Concentration Factor (BCF)

This index is used to evaluate the ability of a tree species to absorb and accumulate a specific metal from the soil. Bio-concentration is the division of metals' concentration in plant tissues (leaves, stems, and bark) over their concentration in soil (Equation 1) [7].

$$1.\ BCF=\frac{C_{aerial\ tissue}}{C_{soil}}$$

Comprehensive Bio-Concentration Index (CBCI)

This index was presented by Zhao et al. in 2014 to assess the accumulation of total or multiple metals by a tree species. To calculate the CBCI index, a fuzzy membership function is used. First, the fuzzy set or the set of factor U is calculated as U= (u1, u2, u3,…, ni.). Second, the amount of the fuzzy membership function will be calculated using Equation (2) [16].

$$2.\ \mu(x)=\frac{x-x_{min}}{x_{max}-x_{min}}$$

In this Equation, x is the biological concentration factor for a particular metal, Xmin and Xmax are the minimum and maximum levels of this index (BCF), respectively. The minimum and maximum amount of metal concentration factor can be a numerical value of zero or one. Finally, in the third step, the CBCI rate will be calculated by Equation (3).

$$3.\ CBCI=\frac{1}{N}\sum_{i=1}^{N}\mu i$$

Table 2. Ecological hazard assessment and modified Hazard Quotient (mHQ) of heavy metals [23]

Modified Hazard Assessment		Ecological Hazard of any Metal		Environmental Hazard	
Pollution Status	**mHQ**	**Risk**	**E_r^i**	**Risk**	**Risk Index**
Very polluted	mHQ ≥3.5	Low	$E_r^i ≤40$	Low	$RI ≤150$
Very much	3≤ mHQ <3.5	Medium	$40≤ E_r^i ≤80$		
Very	2.5≤ mHQ <3	Considerable	$80≤ E_r^i ≤160$	mMedium	$150≤ RI ≤300$
Significant	2≤ mHQ <2.5				
Medium	1.5≤ mHQ <2	High	$160≤ E_r^i ≤320$	Considerable	$300≤ RI ≤600$
Low	1≤ mHQ <1.5				
Very low	0.5≤ mHQ <1	Very much	$E_r^i ≥320$	Very much	$RI ≥600$
Insignificant pollution	mHQ <0.5				

Metal Accumulation Index (MAI)

The heavy metal accumulation index was introduced by Liu et al. to evaluate the ability of different tree species to absorb heavy metals through the leaves. This index is calculated by Equation (4) [17].

$$4.\ MAI = \frac{1}{N}\sum_{i=1}^{N} Ij$$

, where the MAI index expresses the accumulation of heavy metals, N is the number of heavy metals, Ij is a sub-index for the variable j. Ij is calculated by dividing the mean concentration of each heavy metal by its standard deviation (xΔ) (Equation 5):

$$5.\ I_j = \frac{x}{\Delta x}$$

Assessing the ecological risk of heavy soil metals

This index was presented by Hakanson to assess the risk of soil contamination of heavy metals in the soil [18]. Modification methods based on the toxicity of metals have been used by researchers such as Yi et al. and Wang et al. [19, 20] (Table 2). According to the Hakanson approach, the toxicity response factors for mercury, cadmium, copper, lead, nickel, chromium, and zinc are 40, 30, 5, 5, 2, and 1, respectively. In this study, the ecological risk potential was calculated based on the following Equations (6, 7) [21].

$$6.\ E_r^i = \frac{C^i}{C_0^i} \times T_r^i$$

$$7.\ RI = \sum_{i=1}^{4} E_r^i$$

, where E_r^i is the ecological risk potential index, C^i and C_0^i are respectively the natural values of the elements (Background value). T_r^i is equal to the response factor of metal toxicity. Tables 3, 4, 5, 6 and 7 present the ecological and environmental hazards of heavy metals in the soil.

Potential acute toxicity assessment

The acute metal toxicity potential index is used to evaluate the toxicity of heavy metals in soil. This index can be evaluated as a total of toxic units. In this index, the

Table 3. Descriptive statistics of heavy metals in the soil of the region (mg/kg)

Heavy Metal	Mean±SD	Minimum	Maximum
Zinc	43.04±14.04	28.5	60.13
Copper	42.87±8.36	43.5	83.91
Lead	18.77±6.51	12.0	30.03
Nickel	61.51±11.34	52.25	78.88

Table 4. Results of ecological and environmental hazard index values for metals measured at different stations

Stations	Ni	Pb	Zn	Cu	Risk Index
1	6.31	4.78	0.63	4.83	16.55
2	6.54	3.38	0.38	4.33	14.64
3	7.03	6.05	0.30	4.14	17.51
4	4.49	3.44	0.26	3.06	11.25
5	5.73	3.00	0.51	2.90	12.14
6	5.23	7.51	0.63	9.32	22.68
Total	35.33	28.51	2.72	28.58	94.79

Toxic Unit (TU) is calculated as the ratio of the concentration of the desired metal to the amount of Probable Effect Level (PEL) of that metal (Equation 8). The value of PEL indicates the high concentration of chemicals that can cause adverse effects on the sediments of the region. The PEL values for lead, nickel, zinc, and copper are 112, 42.8, 271, and 108, respectively [22].

$$8.\ TU=\frac{Metals}{PEL}$$

It should also be noted that it can be used to evaluate the acute toxicity of a total of several metals in the sample. In this case, if the values are more than 4, there is acute toxicity, and if it is less than 4, there is no toxicity [22].

Modified Hazard Quotient Index (mHQ)

The modified Hazard Quotient index (mHQ) is a tool that determines the degree of danger of each metal to aquatic environments and organisms. To evaluate the pollution of sediments in the region, the mHQ index is obtained by comparing the concentration of metals in sediments with the distribution of unfavorable ecological synoptic of Threshold Effect Level (TEL) , PEL, and Severe Effect Level (SEL). TEL levels for lead, nickel, copper, and zinc are 35, 18, 35.7, and 125, respectively [23, 24] (Equation 9).

$$9.\ mHQ=[\,C_i\frac{1}{TEL_i}+\frac{1}{PEL_i}+\frac{1}{SEL_i}]^{\frac{1}{2}}$$

In this regard, Ci is the measured metal concentration in the sediment sample, TEL, PEL, and SEL. Tables 3, 4, 5, 6 and 7 shows the soil hazard rate based on the modified risk assessment index.

3. Results and Discussion

The results of measuring the concentration of metals in the soil of the region

The results of measuring the mean, minimum, and maximum concentrations of heavy metals (nickel, lead,

Table 5. Results of acute metal toxicity potential index values and modified Hazard Quotient (mHQ) in the soil of different stations

Stations	Modified Hazard Quotient (mHQ)				Potential Acute Toxicity				
	Zn	Cu	Ni	Pb	∑TU	Zn	Cu	Ni	Pb
1	0.88	1.77	1.84	0.75	2.02	0.22	0.40	1.22	0.17
2	0.69	1.67	2.05	0.63	2.15	0.13	0.36	1.53	0.12
3	0.61	1.64	2.13	0.85	2.31	0.11	0.34	1.64	0.22
4	0.57	1.41	1.70	0.64	1.52	0.09	0.25	1.05	0.12
5	0.80	1.37	1.92	0.60	1.87	0.18	0.24	1.34	0.11
6	0.88	2.46	2.26	0.94	3.11	0.22	0.78	1.84	0.27

Table 6. Mean and standard deviation of metal concentrations in the leaves of different tree species (mg/kg)

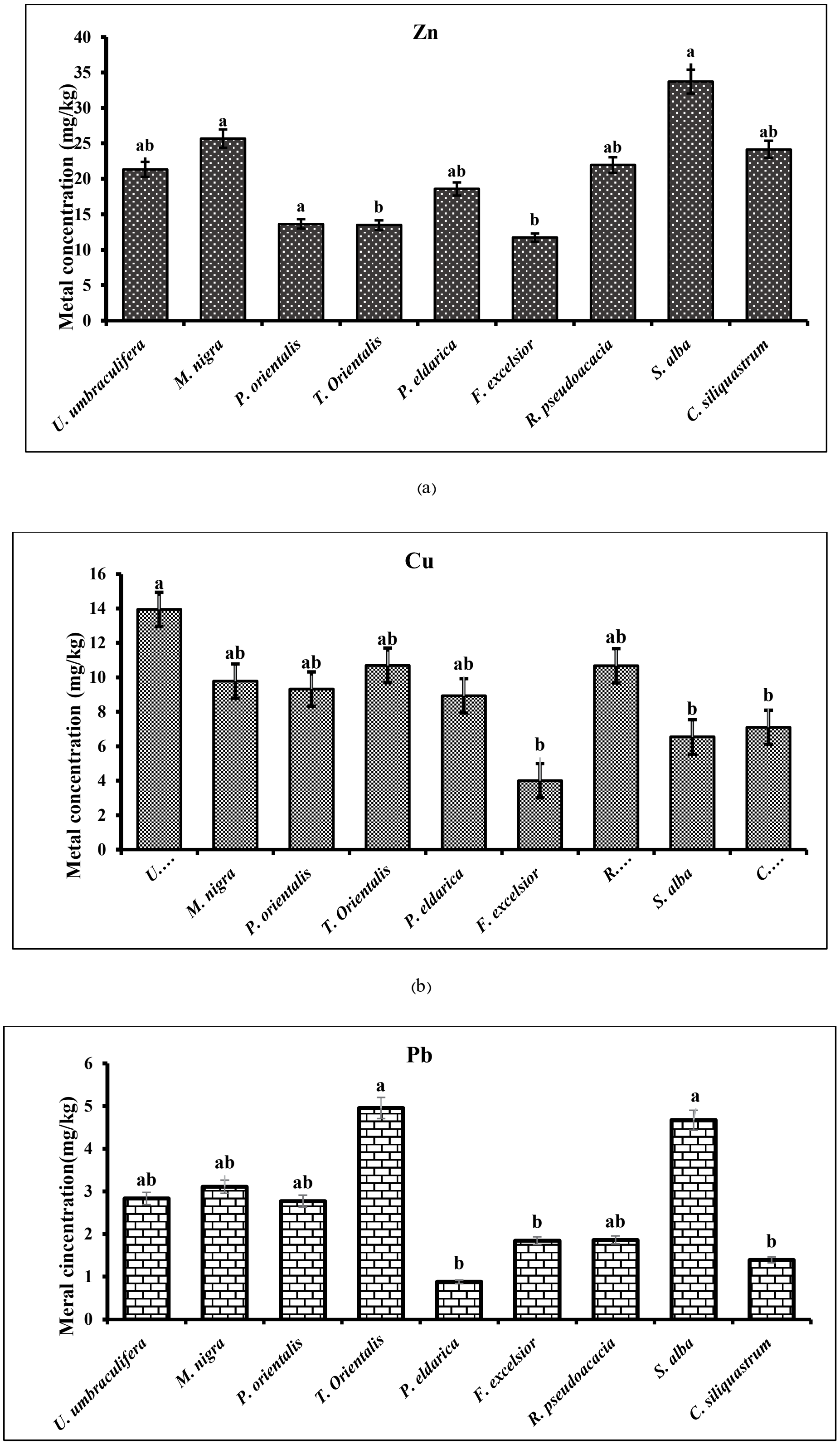
Trees	Ni	Pb	Cu	Zn
Mulberry	11.08±2.08	3.11±2.23	9.7±4.80	25.68±4.63
Redbud	9.51±3.12	1.39±0.54	7.01±0.84	24.15±3.13
Willow	10.56±4.99	4.67±3.3	6.54±3.48	33.71±7.33
Ash	6.23±3.77	1.84±0.24	4.01±1.23	11.72±2.28
Pine	11.73±2.73	0.88±0.23	8.93±3.05	18.59±7.62
Elm	12.58±4.53	2.83±2.11	13.95±4.38	21.32±3.14
Cypress	9.91±3.87	4.59±1.07	10.70±1.53	13.49±4.31
Acasia	11.21±3.4	2.77±1.22	14.67±2.35	21.95±1.1
Plane	5.76±1.24	1.86±0.44	9.33±3.01	13.3±3.39

copper, and zinc) in the study area soil are presented in Table 3. Based on the research findings, the trend of changes in soil heavy metal Mean±SD concentrations are as follows: nickel> zinc> copper> lead at the rate of 61.41±11.34> 43.04±04.04> 42.87±8.36> 6.51±18.77 mg/kg (Table 3).

Comparison of heavy metal concentrations measured in the present study with similar studies showed that the amount of different metals depends on the type of metal and the environmental and edaphic conditions of the region, such as the amount and type of production source and urban and industrial activities around the study area. Kamani et al. reported the Mean±SD concentrations of heavy metals of copper, nickel, lead, and zinc in the surface soil of Zahedan City, Iran as 29.68±10.25, 51.9±8.53, 28.37±6.52, and 184.30±25.94 mg/kg, respectively [25]. In urban areas, the concentration of heavy metals can be due to both natural and human resources, so the role of human resources is much greater. In this regard, previous studies have emphasized various human activities such as transportation, development of industrial and workshop activities, waste incineration, municipal and service activities. The use of municipal wastewater in irrigation of green space in urban areas

Table 7. Comparison results of heavy metal accumulation in leaves of different species using 1-way Analysis of Variance (ANOVA) at 95% significance level

Element		Sum of Squares	df	Mean of Squares	F	The Significance Level
Zinc	Between groups	1563.87	8	195.48	3.92	0.003
	Within groups	1444.62	29	49.81		
	Total	3008.50	37	-		
Copper	Between groups	363.58	8	45.48	3.35	0.006
	Within groups	373.10	29	12.87		
	Total	763.96	37	-		
Lead	Between groups	174.77	9	21.84	2.48	0.035
	Within groups	255.2	29	8.8		
	Total	429.97	37	-		



(a)

(b)

(c)

Figure 1. Results of comparing the accumulation of heavy metals

A: Zinc; B: Copper; and C: Lead in leaves of different species using 1-way ANOVA at a significance level of 95%.

Table 8. Results of Bio-concentration factor (BCF), Comprehensive Bio-concentration index (CBCI), and Metal Accumulation Index (MAI) indices in the leaves of different tree species and soil of the region

Tree	BCF				CBCI	MAI
	Ni	Pb	Cu	Zn		
Mulberry	0.18	0.17	0.23	0.61	0.64	3.58
Redbud	0.15	0.07	0.17	0.56	0.39	5.45
Willow	0.17	0.25	0.15	0.78	0.72	2.50
Ash	0.10	0.10	0.09	0.27	0.08	4.38
Pine	0.19	0.05	0.21	0.43	0.42	3.37
Elm	0.20	0.15	0.33	0.50	0.73	3.27
Cypress	0.16	0.26	0.25	0.31	0.59	4.34
Acacia	0.18	0.15	0.25	0.51	0.60	7.53
Plane	0.09	0.10	0.22	0.32	0.22	3.99

also increases the concentration of various heavy metals such as lead, copper, zinc, nickel in the soil.

Similarly, Taghipour attributed the high concentration of heavy metals in the soil of urban areas of Hamedan to human activities. Also, the low concentration of metals in urban areas of Hamedan compared to the control station (Abbas Abad hill) can confirm this claim [26]. Chen et al., in a study conducted in Beijing, reported that the origin of the metals of cadmium, copper, lead, and zinc in the urban environment can be due to urban transport and traffic activities so that lead is significantly related to traffic [27]. Kleckerová et al. reported that most of the metal pollution in the city center is due to transportation and high traffic congestion. Heavy traffic also could be the primary source of heavy metal pollution, such as lead, nickel, and cadmium, in urban areas of Berno. They considered traffic as human urban activities [28].

Evaluation of toxicity potential and ecological hazard of heavy metals

The results of the ecological and environmental risk of heavy metals are presented in Table 4. The trend of metal hazard changes in the region is zinc> lead> copper> nickel. The findings show that the studied stations are in the low-risk category regarding the ecological risk of heavy metals. The highest and lowest hazards are related to nickel and zinc, respectively. Also, the findings of the environmental risk index of metals showed (less than 150) that the risk of these metals in the study area is low.

Potential index of acute toxicity of metals and modified hazard assessment (mHQ)

Findings from the study of acute toxicity potential of heavy metals in the soil of different stations in Hamedan showed that the toxicity potential of metals in all studied stations was less than 4, which indicates the absence of acute toxicity of metals in the soil of the region (Table 5). The results of the modified metal hazard assessment index for nickel showed significant pollution in Baghe behesht, Bu Ali Square, and Sepah Square (2.5≥ mHQ ≥2) and the soil of Imam Khomeini Square, Farhang Bridge, and Abbasabad hill (2> mHQ >1.5) has moderate pollution. The amount of copper pollution in the soil of Sepah Square was considerable, in the area of Imam Khomeini Square, Baghe Behesht, and Babataher Square, moderate and in the soil of Farhang Bridge and Abbas Abad hill (1.5> mHQ ≥1) was low. Also, the rate of modified risk assessment index of zinc and lead in the soil of the region was in a very low pollution category (1≥ mHQ ≥0.5) (Table 5). Nickel and copper metals seem to pose an ecological risk to living organisms in the soil of Hamedan. In this regard, several studies indicate that metals such as nickel and copper are causative factors in kidney disease, liver cancer, etc., in humans. These metals can affect the ecological performance of areas with high concentrations [29].

Table 9. Comparison of heavy metal concentrations in different species in the present study with the standard range reported by Kabata-Pendias and Pendias (Kabata-Pendias-Pendias) for plants (mg/kg)

Element	Plane	Acacia	Cypress	Elm	Pine	Ash	Willow	Redbud	Mulberry	Permitted Limit in Plants	Critical Range in Plants
Ni	5.76^{*}	11.21^{**}	9.91^{*}	12.58^{**}	11.73^{**}	6.23^{*}	10.56^{**}	9.51^{*}	11.08^{**}	0.1-5	10-100
Pb	1.86^{*}	2.77^{*}	4.95^{*}	2.83^{*}	0.88^{*}	1.84^{*}	4.67^{*}	1.39^{*}	3.11^{*}	0.2-20	30-300
Cu	9.32^{*}	14.67^{*}	10.70^{*}	13.95^{*}	8.93^{*}	4.01^{*}	6.54^{*}	7.10^{*}	9.78^{*}	7.8-53.44	25-90
Zn	13.64^{*}	21.95^{*}	13.49^{*}	21.32^{*}	18.59^{*}	11.72^{*}	33.71^{*}	24.15^{*}	25.68^{*}	1-400	100-400

*0.05; **0.01.

Results of measuring the concentration of metals in the leaves of different tree species

The results of measuring the concentration of heavy metals in the leaves of different tree species are presented in Table 6. For zinc, from the highest to the lowest, the average concentration of metals were in willow leaves> mulberry > redbud > acacia> elm> pine> plane> cypress> ash. The highest to the lowest mean concentrations of copper were in acacia> elm> cypress> mulberry > plane> pine> redbud > willow> ash. The highest to the lowest mean concentrations of lead were in the leaves of different tree and shrub species as follows: cypress> willow> mulberry > elm> acacia> plane> ash> redbud> pine. Also, the highest to the lowest mean nickel concentrations were seen in elm> pine> acacia> mulberry> willow> cypress> redbud> ash> plane. The results show that in different tree species, depending on the type of metal, their absorption and accumulation are also different (Table 6) (Figure 1).

Confirming the normality of the results, comparing the difference between the accumulation of heavy metals by different tree species using (ANOVA) showed there are significant differences (95%) between different species in the accumulation of zinc, copper, and lead but not for nickel (Table 7).

Results of BCF, CBCI, and MAI index measurements

The results of BCF, CBCI, and MAI indices in leaves of different tree species are presented in Table 8. The results of mean values of BCF of heavy metals (nickel, lead, copper, and zinc) from soil to leaves in tree and shrub species showed the highest BCF in zinc, copper, lead, and nickel metals. There is order in willow, elm, cypress, and pine species.

The results of calculating the CBCI, which is used to assess the accumulation of total or several heavy metals by a tree species, showed that the highest comprehensive concentrations belong to elm, willow, mulberry, acacia, cypress, pine, redbud, plane, and ash. Among them, the highest amount of CBCI was related to elm as 0.73, and the lowest value as 0.8 in the Ash tree.

Findings of MAI, which was introduced to evaluate the ability of different tree species to absorb air metals through the leaves, showed that among tree species, the highest amount of heavy metal uptake was related to acacia species (53.7), and after that redbud, ash, cypress, plane, mulberry, pine, elm, and willow, in the descending order.

Results of measuring the concentration of metals in the leaves of different tree species

Based on the findings, the rate of metal uptake and accumulation in different tree species varies depending on the type of metal, the potential of different species of pollutants, climatic conditions, soil, and the amount and spread of pollution. Comparing the differences between the accumulation of heavy metals in different tree species also showed that the accumulation of zinc, copper, and lead in different species is different. General climatic conditions of the region, status, and type of pollutant sources in the environment, and physical and chemical characteristics of the environment, including pH, soil texture, percentage of organic matter, the topographic status of the area, accumulation, and density of pollutants around tree species are involved in the accumulation of metals in different plants and trees. Besides, the age of tree species can be effective in accumulating heavy metal concentrations in the leaves and other various organs of trees. According to the available evidence, the rate of metal accumulation in older rootstocks is much higher than in younger rootstocks. In explaining the obtained results, it can be stated that different species have different mechanisms in relation to a pollutant and, as a result, absorb or accumulate pollutants from the environment in their organs [1].

According to the results of calculating the index in the present study and comparing them with the proposed classification of Ma et al. (if the BCF level is equal to zero, the plant is a repellent species, if it is less than one, if it is less than one, the plant is accumulating [30], in this study, it was found that each species can act as a cumulative plant for the metals nickel, copper, lead, zinc.

The results of calculating the CBCI showed that the highest comprehensive concentration of metals is related to elm and the lowest the ash tree, which (CBCI) index was less in Zhao et al and Alahabadi et al [16, 31]. Evidence shows that species with a higher CBCI index can filter the soil and be used in the phytoremediation process.

The MAI index obtained in the present study is higher than the value reported in Hu et al. study [32]. However, this index may be more or less than its values in the study of Alahabadi et al. [31], depending on the type of tree or shrub species. One of the most important reasons for this discrepancy is the difference in local atmospheric chemistry and its climatic and meteorological characteristics. Besides, other effective factors in removing air pollutants from urban plants are the height of the tree species, sampling time, and the characteristics of the tree species [17]. It should also be noted that the leaves of tree species with slower growth rates are more exposed to air pollutants than trees with faster growth rates. Therefore, the accumulation of pollutants in these species will also be. Besides, the morphology of the leaf surface and the density of the surface hairs can increase the potential to trap air pollutants and absorb heavy metals from the epidermal pores [33].

The results of comparing the average concentrations of heavy metals in leaf specimens of different tree and shrub species with the values of international standards Kabata-Pendias and Pendias (Kabata-Pendias-Pendias) showed that in all species, the concentrations of lead, copper, and zinc is within the permitted standard range (Kabata-Pendas and Pendias) (Table 9). However, in mulberry, willow, Tehran pine, elm, and acacia species, the nickel concentration is higher than the allowable limit. Naderi et al. in 2017 found that the average concentration of nickel in sycamore species higher than the allowable limit reported by Kabata and Pendias in Hamadan parks. Besides, the average concentrations of lead, copper, and zinc in both species were within the standard range, which is also consistent with the findings of Romiayei and Payandeh in 1997, Mortazavi et al. in 1998 [34, 35].

4. Conclusion

Increasing the concentration of heavy metals in the environment can have many adverse effects on the health of ecosystems. This study was conducted to measure the concentration, potential toxicity, and ecological risk of lead, nickel, copper, and zinc in surface soils of Hamedan and evaluate the adsorption capacity of metals in the leaves of tree species from soil and air using BCF, CBCI, MAI measures. Based on the obtained results, the urban soils of the study areas are low in terms of potential toxicity, ecological risk, and pollution status. However, for the concentration of nickel and copper metals in terms of modified hazard (mHQ), they are in the hazardous and moderate to contamination status, which indicates the risk of these metals for soil organisms. Based on the findings of measuring the concentration of heavy metals and BCF in the leaves of different species, the amount of metal accumulation in different species depends on soil type, tree species, climatic conditions, source type contaminants, species age, and other factors. The results of CBCI and MAI showed that the highest total metal concentrations are seen in elm, willow, mulberry, acacia, cypress, pine, redbud, plane, and ash in the descending order. Among different species, acacia has the highest ability to absorb heavy metals from the air through its leaves. Therefore, it is suggested to use these species in urban and industrial afforestation to reduce the concentration of heavy metals in soil and air and prevent the potential danger of these pollutants in the urban environment.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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