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Research Article

Heavy metal contamination in the leaves of some evergreen trees in urban parks in Karaj, Iran

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Abstract

Lead (Pb^{2+}), cadmium (Cd^{2+}), and chromium (Cr^{3+}) are heavy metals that in excess quantities, affect human health. This study was conducted to find suitable plant species for controlling the heavy metal levels in healthy environmental spaces. To ensure spatial representation, 3 parks in Karaj, Alborz province; Hamon, Jahanshahr, and Chamran; were sampled. A total of 12 samples were collected from each park, with a total of 36 samples across all study sites. The measurements were done with flame atomic absorption spectrophotometry (FAAS). For mean comparison of values, different methods of analysis of variance and Tukey's test were used to assess the significance level of 0.05. The highest mean and standard deviation of total Pb^{2+} and Cd^{2+} were recorded in *Cupressus sempervirens* (1.24±0.05 ppm; 0.82±0.04 ppm), and the lowest mean and standard deviation in *Chamaecyparis* sp. (0.81±0.06 ppm; 0.81±0.06 ppm). The highest mean and standard deviation of total Cr^{3+} were also recorded in *C. sempervirens* (0.45±0.05 ppm) but the lowest mean and standard deviation of total Cr^{3+} were in *Ligustrum ovalifolium* cv. Aureomarginatum (0.35±0.08 ppm).

Keywords: Cadmium, Chromium, Lead, Phytoremediation, Trees, Urban Parks.

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Introduction

Soil constitutes the primary source of nutrition for plants and plays a key role in sustaining plant growth. Plants are among the first organisms that react to changes in soil and climate, making them excellent biomarkers for undesired changes in the environment, such as an accumulation of heavy metals [1 - 6]. Heavy metals are the most important pollutants of the environment, mainly originating from anthropogenic industrial and agricultural activities [7 - 17]. Their presence in the atmosphere, water, and soil, even at very low concentrations, ends up with their accumulation in the food chain, endangering the lives of living beings [18 - 22]. Heavy metal pollution refers to concentrations higher than the dangerous levels. Their natural levels and limits in the soil vary in different regions [23 - 27]. The presence of heavy metals in the rhizosphere region and their entry into the plant reduces growth and disrupts cellular metabolism, which has a negative impact on important physiological processes such as water transport, mitochondrial oxidative phosphorylation, photosynthesis, and chlorophyll [4]. However, some high-accumulating plants that grow in soils polluted with heavy metals can absorb these metals by roots and accumulate in their different parts [28 - 30].

Phytoremediation has emerged as an environmentally sustainable technology in which plants are used to remove environmental pollutants such as heavy metals [10, 28, 31 - 35]. The most destructive effect of heavy metals is caused by an increase in free radical oxidation, which is a free and energetic molecule that has an unpaired electron attracting another electron from other molecules to reach equilibrium [36]. Naturally, when cell molecules react with oxygen (oxidation), free radicals are produced. However, in the presence of toxic metals or a lack of antioxidants, they are produced in an uncontrolled manner and can destroy different body tissues, causing tissue damage [37]. The heavy metals like Pb^{2+} and Cd^{2+} are particularly hazardous due to their bioaccumulation in the tissues of living beings, so the risks of consuming a food polluted with these elements, even in small amounts, are high [23].

Materials and Methods

In this study, the oxidation states Pb^{2+}, Cd^{2+}, and Cr^{3+} were considered based on their predominant ionic forms in plant tissues under the studied conditions, as detectable by FAAS.

Preparation of samples

The samples were cleaned, washed, and isolated separately, and each sample was dried at a temperature of about 60 °C. Then, 5 g were selected from each dried sample, transferred to a porcelain crucible, and placed in a furnace; the first temperature was set to 250 °C, then raised to 450 °C, and the samples were left at this temperature for 24 hours. They were then cooled, taken out, and the volume was adjusted to 25 mL by hydrochloric acid (1 M). All samples were kept at 4 °C in the refrigerator until preparation. The Pb^{2+}, Cd^{2+}, Fe^{3+}, and Cr^{3+} in the samples were measured by FAAS (Perkin Elmer 100) with high accuracy and sensitivity to measure even small amounts. The hollow cathode of the lamp and the wavelength of each lamp corresponded to each metal; thus, the concentration of these metals was determined [38].

Extraction of elements

The method used to prepare the samples is based on the AOAC book, recorded as a digestion or extraction method [39]. We used an oven, an atomic absorption device, a Miller for distilled water, and a heater. To safeguard from possible contamination, all laboratory containers were washed with 5 percent nitric acid, rinsed with deionized water, and dried in an oven. From each of the 500 g of sample, 2 g were weighed and placed in an oven at 105 °C for 48 hours to dry completely. A total of 10 ml of 70 percent perchloric acid, 5 ml of sulfuric acid, and 30 ml of 70 percent nitric acid were added to each of the samples. These were kept at laboratory temperature for 90 min, then placed on a heater until the solution boiled slowly and reached a clear solution with a volume of approximately 3 ml. The solution was brought to a volume of 25 ml using deionized distilled water [40]. Until all the samples were prepared, they were placed in the refrigerator. To measure the heavy metal contents in the samples, FAAS, with high accuracy and sensitivity, was used; very small amounts were used. To prepare deionized water, MiliPore direct-Q3 and the acids were used, all purchased from Merck, Germany [41].

Evaluation of samples

FAAS, with high accuracy and sensitivity in measuring small amounts of elements, was used. The samples were first dissolved, then fed to the device in a solution state (except for special research cases where a sample can be analyzed as a solid). Following the dissolution and digestion stage of the samples, no restriction on the type of sample left; water, soil, food, alloys, ore, plastic, etc. This technique is based on the use of an absorption device to evaluate the concentration in the sample. There is a need for a relationship between the amount of light absorbed by the sample and the concentration of the sample, which is the same as the Beer-Lambert law [42].

Calculation method

The first mean and standard deviation were calculated, followed by using SPSS, analysis of variance, and Tukey's test. The statistical analysis of sampling regions was done and compared with plant species for each heavy metal. It should be noted that the device measured each sample 3 times, and finally the results were reported as X ± SEM in each sample, and 5 percent error was determined as the measurement limit [43].

Results and Discussion

Table 1 demonstrates the amount of Cr^{3+}, Pb^{2+} and Cd^{2+} in plant samples of Hamon Park. The highest Cr^{3+} was associated with *C. sempervirens* (0.46 ppm) and the lowest with *L. ovalifolium* cv. Aureomarginatum (0.30 ppm).

Table 1: Mean and standard deviation of Pb^{2+}, Cd^{2+} and Cr^{3+} in plant samples of Hamon Park in Karaj in 2014 in parts per million (ppm).

Plant metal	**Pb^{2+}**	**Cd^{2+}**	**Cr^{3+}**
Cupressus sempervirens	0.94±0.05	0.34±0.03	0.46±0.08
Ligustrum ovalifolium cv. Aureomargi-natum	0.72±0.08	0.29±0.07	0.30±0.03
Chamaecyparis sp.	0.71±0.07	0.38±0.02	0.38±0.07

In the Hamon Park locality highest Pb^{2+} was associated with *C. sempervirens* (0.94 ppm) and lowest with *Chamaecyparis* sp., whereas the highest Cd^{2+} was associated with *Chamaecyparis* sp. (0.38 ppm) and lowest with *L. ovalifolium* cv. Aureomarginatum (0.29 ppm).

Table 2 demonstrates the content of Cr^{3+}, Pb^{2+} and Cd^{2+} in plant samples of Jahanshahr Park. The highest Cr^{3+} was recorded in *C. sempervirens* (0.56 ppm); the lowest in *L. ovalifolium* cv. Aureomarginatum (0.43 ppm).

Table 2: Mean and standard deviation of Pb^{2+}, Cd^{2+} and Cr^{3+} in plant samples of Jahanshahr Park in Karaj in 2014 (ppm).

Plant metal	**Cd^{2+}**	**Pb^{2+}**	**Cr^{3+}**
Cupressus sempervirens	0.94±0.04	1.10±0.03	0.56±0.04
Ligustrum ovalifolium cv. Aureomargi-natum	0.68±0.05	0.93±0.02	0.43±0.03
Chamaecyparis sp.	0.78±0.04	0.87±0.04	0.45±0.03

The highest Pb^{2+} in this park was associated with *C. sempervirens* (1.10 ppm) and the lowest with *Chamaecyparis* sp. (0.87 ppm); whereas the highest Cd^{2+} was associated with *C. sempervirens* (0.94 ppm) and the lowest with *L. ovalifolium* cv. Aureomarginatum (0.68 ppm). A statistical analysis of the data has revealed a significant difference in the Pb^{2+} between *C. sempervirens* and *Chamaecyparis* sp. ($p<0.05$); whereas a significant difference was found in Cd^{2+} between *C. sempervirens* and *L. ovalifolium* Aureomarginatum ($p<0.05$). In the case of Cr^{3+} a significant difference was found between *L. ovalifolium* cv. Aureomarginatum and *C. sempervirens* ($p<0.05$).

Table 3 demonstrates the content of Pb^{2+}, Cr^{3+} and Cd^{2+} in plant samples of Chamran Park. The highest Cr^{3+} was associated with *C. sempervirens* (0.43 ppm) and the lowest with *Chamaecyparis* sp. (0.26 ppm).

Table 3: Mean and standard deviation of Pb^{2+}, Cd^{2+} and Cr^{3+} in plant samples of Chamran Park in Karaj in 2014 (ppm).

Plant metal	**Cd^{2+}**	**Pb^{2+}**	**Cr^{3+}**
Cupressus sempervirens	1.20±0.05	1.70±0.07	0.43±0.02
Ligustrum ovalifolium cv. Aureomarginatum	0.98±0.02	1.20±0.02	0.33±0.02
Chamaecyparis sp.	0.61±0.07	0.87±0.05	0.26±0.03

The highest Pb^{2+} in this park was recorded in *C. sempervirens* (1.70 ppm) and the lowest in *Chamaecyparis* sp. (0.87 ppm); however, the highest Cd^{2+} was in *C. sempervirens* (1.20 ppm) and the lowest in *Chamaecyparis* sp. (0.61 ppm). The statistical analysis of the data has revealed a significant statistical difference in Pb^{2+} between *C. sempervirens* and *L. ovalifolium* cv. Aureomarginatum ($p<0.05$) as well as between *C. sempervirens* and *Chamaecyparis* sp. ($p<0.05$). The statistical analysis reveals a significant difference in Cd^{2+} between *C. sempervirens* and *L. ovalifolium* cv. Aureomarginatum ($p<0.05$) as well as between *C. sempervirens* and *Chamaecyparis* sp. ($p<0.05$). A significant difference was recorded in Pb^{2+} between *L. ovalifolium* cv. Aureomarginatum and *Chamaecyparis* sp. In the case of Cd^{2+} *L. ovalifolium* cv. Aureomarginatum and *Chamaecyparis* sp. ($p<0.05$) too showed a significant difference.

Table 4 presents mean and standard deviation of Pb^{2+}, Cr^{3+} and Cd^{2+} in *C. sempervirens* in Hamon, Jahanshahr and Chamran parks. The highest Pb^{2+} has been recorded in *C. sempervirens* in Chamran Park (1.7±0.07 ppm) and the lowest in *C. sempervirens* in Hamon Park (0.94±0.05 ppm); whereas the highest Cd^{2+} was recorded in *C. sempervirens* in Chamran Park (1.2±0.05 ppm) and the lowest in *C. sempervirens* in Hamon Park (0.34±0.03 ppm). The highest Cr^{3+} in *C. sempervirens* was recorded in Jahanshahr Park (0.56±0.04 ppm) and the lowest in *C. sempervirens* in Chamran Park (0.34±0.02 ppm).

Table 4: Mean and standard deviation of Pb^{2+}, Cr^{3+} and Cd^{2+} in *C. sempervirens* in Hamon, Jahanshahr and Chamran Parks in Karaj in 2014 in ppm.

Park metal	**Pb^{2+}**	**Cd^{2+}**	**Cr^{3+}**
Hamon	0.94±0.05	0.34±0.03	0.48±0.08
Jahanshahr	1.1±0.03	0.94±0.04	0.56±0.04
Chamran	1.7±0.07	1.2±0.05	0.34±0.02

Table 5 demonstrates mean and standard deviation of Pb^{2+}, Cd^{2+} and Cr^{3+} in *L. ovalifolium* cv. Aureomarginatum in Hamon, Jahanshahr and Chamran Parks. The highest Pb^{2+} was recorded in *L. ovalifolium* cv. Aureomarginatum in Chamran Park (1.2±0.02 ppm) and the lowest in *L. ovalifolium* cv. Aureomarginatum in Hamon Park (0.72±0.08 ppm).

Table 5: Mean and standard deviation of Pb^{2+}, Cr^{3+} and Cd^{2+} in *L. ovalifolium* cv. Aureomarginatum in Hamon, Jahanshahr and Chamran Parks in Karaj in 2014 in ppm.

Park metal	**Pb^{2+}**	**Cd^{2+}**	**Cr^{3+}**
Hamon	0.72±0.08	0.29±0.07	0.30±0.03
Jahanshahr	0.93±0.02	0.68±0.05	0.43±0.03
Chamran	1.20±0.02	0.98±0.02	0.33±0.02

Cd^{2+} was the highest in *L. ovalifolium* cv. Aureomarginatum in Chamran Park (0.98±0.02 ppm) and lowest in *L. ovalifolium* cv. Aureomarginatum in Hamon Park (0.29±0.07 ppm). The highest Cr^{3+} was determined in *L. ovalifolium* cv. Aureomarginatum in Jahanshahr Park (0.43±0.03 ppm) and the lowest in *L. ovalifolium* cv. Aureomarginatum in Hamon Park (0.30±0.03 ppm).

Table 6 presents the mean and standard deviation of Pb^{2+}, Cr^{3+} and Cd^{2+} in *Chamaecyparis* sp. in Hamon, Jahanshahr and Chamran Parks. The highest Pb^{2+} is present in *Chamaecyparis* sp. in Jahanshahr Park (0.87±0.06 ppm) and the lowest in *Chamaecyparis* sp. in Hamon Park (0.71±0.07 ppm).

The highest Cd^{2+} in *Chamaecyparis* sp. has been recorded in Jahanshahr Park (0.78±0.04 ppm) and the lowest in Hamon Park (0.38±0.02 ppm). The highest Cr^{3+} in *Chamaecyparis* sp. is found in Jahanshahr Park (0.45±0.03 ppm) and the lowest in *Chamaecyparis* sp. in Chamran Park (0.26±0.03 ppm).

Table 6: Mean and standard deviation of Pb^{2+}, Cr^{3+} and Cd^{2+} in *Chamaecyparis* sp. in Hamon, Jahanshahr and Chamran Parks in Karaj in 2014 (ppm).

Park metal	**Pb^{2+}**	**Cd^{2+}**	**Cr^{3+}**
Hamon	0.71±0.07	0.38±0.02	0.38±0.07
Jahanshahr	0.87±0.06	0.78±0.04	0.45±0.03
Chamran	0.87±0.05	0.61±0.07	0.26±0.03

Our investigations undertaken here in 2014 present the data on the absorption of heavy metals in some of the most used species in 3 big parks namely: Hamon, Jahanshahr and Chamran in Karaj. We have found a statistically significant difference in the Pb^{2+} content in the plant species of Chamran and Hamon parks. The same has been observed in the comparison of Pb^{2+} absorption in *C. sempervirens* and *Chamaecyparis* sp.

Heavy metals enter ecosystems following the weathering of rocks and soils, volcanic and human activities. The toxic nature of several mineral compounds, especially heavy metals, has been known for years. The distribution of these materials in the environment includes materials containing Pb^{2+}, Hg, Cd^{2+}, Cr^{3+}, and Ni [4, 14, 21]. These metals accumulate in the body of living organisms, remain for a long time, and end up with toxicity. The toxic metals in small amounts are harmful for many of the living beings. The metals accumulating in the human body (such as Pb^{2+}, As) are highly dangerous; being concentrated via food chain, leading to an important risk for the organisms in the upper level of the food chain. Generally, toxic metals are low in most natural waters, but their high concentrations in the environment are usually related to industrial activities, mining, and agricultural extraction operations. Heavy metal pollution is one of the most important environmental problems and highly important health concerns for our food [16, 17, 44 - 46].

We investigated here the Pb^{2+}, Cd^{2+}, and Cr^{3+} contents in the plant samples in the parks of Karaj. In another study conducted in Gilan-Rasht, the pollution of plane tree leaves and the soil of with Pb^{2+} and Cd^{2+} was studied in the spring of 2014. These results report that Pb^{2+} in the plant was 8.99 ppm, and most of the data exceeded the toxicity limit except for 2 cases. Our results show the highest Pb^{2+} in *C. sempervirens* in Chamran Park (1.7±0.07 ppm). The reason could be absorption between *Platanus* and *C. sempervirens*; probably the wide leaves of *Platanus* absorb higher Pb^{2+} [47]. Another study concerning Pb^{2+} in the leaves of trees in Zanjan, has revealed that Pb^{2+} concentration in *Robinia* and *Fraxinus syriaca* was higher than the other trees investigated here [48]. Our findings reveal that the highest Pb^{2+} is found in the plant samples of Chamran Park and the lowest in the plants of Hamon Park; the highest Cd^{2+} is in the plant samples of Jahanshahr Park and the highest Cr^{3+} in the plant species of Jahanshahr Park.

Our investigations have revealed that the highest Pb^{2+} absorption is in *C. sempervirens* and the lowest in *Chamaecyparis* sp., whereas the highest Cd^{2+} absorption is in *C. sempervirens* and the lowest in *Chamaecyparis* sp. Moreover, the highest Cr^{3+} absorption has been recorded in *C. sempervirens* and the lowest in *L. ovalifolium* cv. Aureomarginatum. Our studies have revealed that the location of the parks in terms of distance and proximity to polluting sources such as highways and industrial areas, as well as urban centers, has a great effect on the difference in the amount of pollution measured in the plant species studied [49].

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