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Research Paper

Investigation of Heavy Metal Contamination in the Ornamental Plants of Green Spaces in the City of Yazd

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Abstract

Due to rapid industrialization and urbanization, environmental pollution has become a significant concern in developing countries; therefore, the main objective of the current study is to determine the concentration of some heavy metals (HMs) in the leaves of dusty miller (*Cineraria maritima*) and purstane (*Mesembryanthemum cordifolium*) in different general bus terminals along with the green spaces in the Yazd city. The total concentrations of cadmium (Cd), cobalt (Co), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), iron (Fe), and manganese (Mn) in the plant samples were measured using atomic absorption spectrophotometry after digestion with acid. All statistical analyses were conducted using SPSS 20.0 statistical package. The results showed that the concentration of some HMs in the ornamental plants was higher at the Ghadir passenger terminal and Quran gate terminal than at the other bus stands. Interactive effects of location and ornamental plants were significant on Mn, Co, Pb, Zn, and Cu ($P<0.01$). According to the factor analysis, four factors had the highest variances (Mn, Co, Pb, and Zn). The Pearson correlation analysis between heavy metals found in the ornamental plants showed a significant correlation between Pb and Co percentages and between Zn and Mn percentage ($P<0.01$) with the correlation coefficients being 0.88 and 0.62, respectively. According to the results, these plants are among the most resistant ornamental species. Therefore, they are suitable for green spaces, parks, and urban boulevards and for creating healthier air in dry and semi-arid areas like Yazd.

Keywords: *Cineraria maritima*, Green space, Heavy metals, *Mesembryanthemum cordifolium*, Yazd.

INTRODUCTION

Urban forests are an essential part of urban ecosystems and provide a myriad of ecological services that contribute to enhancing human welfare, but at the same time, they are profoundly influenced by urbanization (Barona, 2015). Trees and shrubs are a valuable addition to most properties. Adequately planted, well-maintained trees add beauty, wind protection, shade, wildlife habitat, visual screening, and other benefits to the landscape (Kuhns and Rupp, 2000). The rapid growth of industry and urbanization has produced dust, particulates, and million tons of pollutants that threaten the environment and human health (Hakimzadeh Ardekani *et al*., 2014). Traffic and transport, as a political and social phenomenon, play an essential role in the quality and socio-economic structure of a society. This phenomenon constitutes one of the foundations of the modern urban life and the social needs of populations (Cui *et al*., 2020).

The situation is significantly worsening in densely populated cities, which are highly influenced by anthropogenic activities. Artificially built environments are replacing natural vegetation cover leading to poorer self-monitoring and regulation of urban ecosystems, thereby contributing to poor air quality in cities (Hakimzadeh, 2014).

Some metals, such as Mn, Fe, Zn, Co, Ni, and Cu, are essential for living organisms including plants and animals as they are necessary in small quantities for the formation of red blood cells and the regulation of lipid contents in tissues. However, they become toxic at high levels, causing severe diseases like skin irritation, loss of vision, loss of body weight, and heart and liver failures (Shah *et al*., 2013).

Heavy metals are the most toxic pollutants that enter the environment through industrial and human activities (Esfandiari, 2018). The use of plants as passive biomonitors to collect information on trace elements deposition from fully or semiautomatic gauges, commonly used in current pollution monitoring programs, is growingly drawing attention (Petrova, 2011). Biomonitor plants are active collectors that reflect the accumulated effect of environmental pollution and the accumulation of toxicants from atmospheric pollution deposition, binding, and solubility of metals on the leaf surface and soil pollution concentration and bioavailability of elements in soil (Petrova, 2011).

Zare *et al.* (2016) used the leaves of the cypress trees to monitor the distribution of heavy metals Zn, Ni, and Cu in the atmosphere of Isfahan. They showed that the concentration of heavy metals was in the order of $Zn>Cu>Ni$. A higher accumulation of heavy metals was found in leaves than in roots in all studied sites.

Miri *et al*. (2016) revealed that the leaves and barks of *Ulmus carpinifolia* could be used as bio-indicators of heavy metal pollution in the ambient air and the ecological risk imposed by them. Mansour (2014) demonstrated that massive traffic sites had high heavy metal concentrations. The highest level of heavy metals was related to Zn and Pb. The mean metal concentration values in the leaves and barks were in the order of $Cd<Cu<Pb<Zn$ and $Cd<Pb<Cu<Zn$, respectively. Esfandiari *et al.* (2019b) determined the concentration of some heavy metals in the Yazd highway green belt and concluded that the amounts $Cd < Co < Ni < Cu < Pb < Zn < Mn < Fe$ in falling dust were increased.

Gholami *et al.* (2012) reported that emissions from automobiles and anthropogenic activities changed the concentration of heavy metals in the surrounding atmosphere of studied areas. The primary source of heavy metal contamination was motor vehicle traffic intensity. Sawidis *et al.* (2011) showed higher amounts of trace metals in pine tree bark than in plane tree bark, implying its higher efficiency as bioindicators of urban pollution. Both indicator species were suitable as bioindicators of urban air pollution.

Esfandiari *et al.* (2019a) used the leaves of black locust (*Robinia pseudoacacia*) to monitor the distribution of some heavy metals in the atmosphere of the highway green belt and showed that the interactive effects of distance from the highway and concentration on tree leaves and barks were significant ($P \leq 0.01$). The results confirmed that the number of accumulated elements (Fe, Pb, Zn, Mn, Ni, Cu, and Co) was greater in the leaves than in the barks, except for Cd.

Cai and Li (2019) conducted a detailed investigation to determine the levels and sources of heavy metal contamination in street dust in Shijiazhuang, China. Their results showed that the mixed (traffic and industry) group accounted for the greatest amount of heavy metals in the dust. Qadeer *et al*. (2020) measured the concentrations and pollution indices of heavy metals in road dust from two urbanized cities of Pakistan **(**Lahore and Faisalabad). They showed that among the sites, the concentrations of heavy metals were the highest in dust obtained from the general bus stands in both cities.

Obviously, the massive increase in the number of motor vehicles in Yazd is leading to increasingly high levels of some toxic heavy metals in the urban environment, especially in plants. Therefore, the present study aimed to determine Pb, Cd, Zn, Ni, Fe, Mn, Cu, and Co pollution in the leaves of dusty miller (*Cineraria maritima*) and purstane *(Mesembryanthemum cordifolium*) in the green spaces of Yazd in 2020.

MATERIALS AND METHODS

Study area

Yazd is situated in the Yazd-Ardakan plain with a dry climate (Long. 54°17'E., Lat. 31°54' N.). The maximum and minimum elevations are 2677 m and 997 m above sea level, respectively. The rainfall in this region is low and temporally irregular (average rainfall is 118 mm per year), and the evaporation rate is between 2200 and 3200 mm per year (Fathizad *et al*., 2020). Yazd is famous for its industry and tourism. However, the rapid growth of industries such as the steel industry, the increase in the number of vehicles, urban traffic, and the desert climate have exacerbated the inflow of contaminated microflora due to the lack of proper planting and vegetation cover or the vegetation loss in the western parts of Yazd (Ardakani and Vahdati, 2018). The location of the study area is shown in Fig. 1.

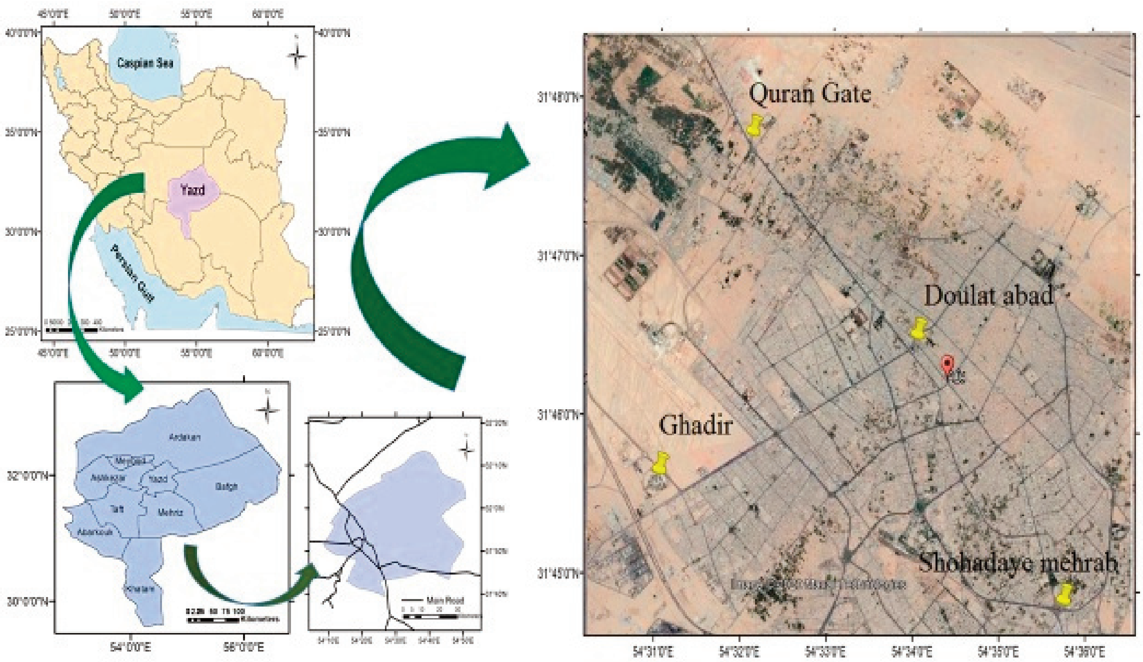

Fig. 1. The location of the study area.

Dusty miller (*Cineraria maritima*) is a species of *Senecio* from the family Asteraceae with six different botanical names (Fig. 2). *Cineraria* is native to the western and central Mediterranean region, where it grows in arid, scrub-like habitats. It prefers warm and dry summers and cool (not cold) and wet winters. Growing by the sea, many plants are similarly felty-white to protect them against the dry salt sea winds) Peruzzi *et al*., 2006). It has been used in pharmaceutical preparations and homeopathy. It is widely cultivated as an ornamental plant for its white, felt-like tomentose leaves. It is also sometimes called dusty miller, a name shared with several other plants that also have silvery tomentose leaves (Ababsa *et al*., 2018) (Fig. 2).

Purstane (*Mesembryanthemum cordifolium),* formerly known as *Aptenia cordifolia*, is a species of succulent plant in the ice plant family. It is known as the heartleaf ice plant in the USA. It is a creeping plant that forms a carpet of flat-growing perennial herbs in groups on the ground from a base (Brickell, 1994). The genus name means middle-embryo flower about the position of the ovary in flower. The actual species of *M. cordifolium* has magenta-purple flowers and more heart-shaped, mid-green, textured leaves. The stems are green and stalk-round. The fleshy, small leaves are opposite, ovate to cordate, about 2.5 cm long, and covered with fine papillae (Haage, 1989(.

M. cordifolium can be planted as a fast-growing, groundcover in flower boxes and around traffic roads. The plant needs a sunny spot and well-drained soil. Due to its fast growth, it is useful to prevent the growth of weeds in the field where it is planted (Klak *et al*., 2004) (Fig. 3).

Sampling and laboratory analysis

The samples were taken from four central bus terminals in Yazd city. The leaves were collected from *M. cordifolium* and *C. maritima*at in each site. Then, the plants were rinsed with distilled water three times to remove surface contamination, and the vegetative samples were dried and milled in an oven at 70 °C for 72 hours. Then, 1 g of dust was weighed with a precision of ±0.001 to measure the total concentration of heavy metals in accordance with ISO 11446 International Standard Procedure. According to the extraction procedure of trace elements, 4 mL of H_2SO_4 and 13 mL of H_2O_2 were used in a closed Digesdahl Apparatus (Hach Co., USA) at 440 °C to obtain a total extraction of heavy metals. The solution was completely filtered through Whatman 42 filter paper and adjusted to the volume of 50 mL by adding deionized distilled water. The total concentrations of heavy metals (Zn, Pb, Cd, Co, Fe, Mn, Cu, and Ni) in the leaves of ornamental plant samples were measured by Analytic Jena 330 Flame Atomic Absorption Spectrophotometer (ISO, 1995).

Fig. 2. Dusty miller (*Cineraria maritima*).

Fig. 3. Purstane (*Mesembryanthemum cordifolium*).

The statistical analysis of the data consisted of the Kolmogorov-Smirnov normality test, followed by the study of the variance homogeneity, using an ANOVA parametric test with a DMS post hoc and Duncan's multiple comparison tests at the 0.05 significance level.

RESULTS AND DISCUSSION

The results of the analysis of variance are presented in Table 1. They showed that spatial location (central bus stand) had a significant effect on the concentration of Pb and Zn ($P<0.01$) and Mn ($P<0.05$) in the leaves of *C. maritima* and *M. cordifolium*. The concentrations of Cd, Co, Fe, Cu, and Ni were not significantly different as influenced by this factor.

The rate of the absorption of metals in the leaves of the two ornamental plants indicates that the concentrations of Mn and Cu ($P<0.01$) and Fe ($P<0.05$) were different. The concentrations of Cd, Co, Pb, Zn, and Ni were not significantly different. The interactive effects of location and ornamental plants were significant on Mn, Co, Pb, Zn, and Cu. The means comparison between dusty miller and purstane in four central bus stands is presented in Table 2.

The concentration of heavy metals in four bus stations studied here revealed that the highest quantity of Mn was related to the leaves of *M. cordifolium* in the Doulatabad bus terminal (134.83 mg kg^{-1}) and the lowest to the leaves of *C. maritima* (29.66 mg kg^{-1}). The maximum Cu was observed in the Shohadaye Mehrab bus terminal in the leaves of *C. maritima* (13.94 mg kg^{-1}) and the lowest in the Quran bus terminal in the leaves of *M. cordifolium* (7.07 mg kg^{-1}). Esfandiari *et al*. (2020) showed that the highest amount of Mn and Cu concentrations in the leaves of *Thuja orientalis* were 44.5 mg kg^{-1} and 14.78 mg kg^{-1}, respectively. The highest concentration of Co was found in the leaves of *M. cordifolium* in the Doulatabad bus terminal (8.07 mg kg^{-1}). The lowest Co was observed in the leaves of *M. cordifolium* in the Ghadir passenger terminal (1.92 mg kg^{-1}). The most optimal amount of Pb was related to the leaves of *C. maritima* at the Ghadir passenger terminal (23.95 mg kg^{-1}) and the lowest was related to the Doulatabad bus Terminal (13.68 mg kg^{-1}). The most optimal amount of Zn was detected in the Doulatabad station in the leaves of *M. cordifolium* (46.41 mg kg^{-1}) and the lowest in the leaves of *C. maritima* at the Ghadir passenger terminal (16.16 mg kg^{-1}) (Table 2). Moameri *et al*. (2017) showed that Pb and Zn concentrations in the plants were higher than the standard range in rangelands around Zanjan.

Factor analysis is a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. Factor analysis aims to find independent latent variables. It is one of the most commonly used inter-dependency techniques employed when the relevant set of variables shows a systematic inter-dependence and the objective is to find out the latent factors that create a commonality (Child, 2006).

The KMO and Bartlett test results showed that the number of samples was sufficient for analysis. The data were suitable for factor analysis. The KMO was equal to 0.52, and the Chi-Square was significant ($P < 0.05$) (Table 3).

The scree plot is presented in Fig. 4. According to Fig. 4, four factors had the highest amounts of variances. The classification of variables to select factors is based on individual values more significant than one. Accordingly, Zn was in the first group, Co in the second group, Mn in the third group, and Pb in the fourth group.

The variables in each group were considered independent, and their relationship with the location of the ornamental plant as a dependent variable was investigated using the correlation method. The results obtained in Fig. 4 confirm the results of Table 4.

Table 1. Analysis of variance of the impact of the bus terminal on the concentration of some heavy metals in the leaves of dusty miller and purstane.

S.o.V	df	MS							
		Ni	Zn	Fe	Cu	Co	Mn	Cd	Pb
Location (L)	3	119.84 ^{ns}	356.87 **	979378.106 ^{ns}	7.31 ^{ns}	5.710 ^{ns}	1586.70 *	3.58 ^{ns}	50.72 **
Ornamental plants (O)	1	34.01 ^{ns}	16.58 ^{ns}	4435794.18 *	166.37**	7.55 ns	7720.37 **	1.61 ^{ns}	3.39 ^{ns}
L × O	3	182.48 ^{ns}	16950.06**	874108.78 ^{ns}	19.60*	23.29 **	3606.03**	8.79 ^{ns}	29.69*
Error	19	159.25	87.33	660392.04	5.30	4.09	245.53	4.37	8.44
CV (%)		12.06	15.16	11.92	21.37	24.36	14.46	23.55	16.54

*, ** and ^{ns}: Significant at $P < 0.05$, $P < 0.01$ and insignificant, respectively.

Table 2. The interacive effect of the bus terminal and plant species (dusty miller and purstane) on the concentration of heavy metals.

Central bus terminal	Ornamental plants	Measured metals (mg kg^{-1})							
		Ni	Zn	Fe	Cu	Co	Mn	cd	Pb
Ghadir passenger terminal	*Mesembryanthemum cordifolium*	3.82±1.74^{a}	20.12±4.67^{c}	346.93±101.30^{ab}	10.09±0.33^{ab}	1.92±0.63^{c}	45.72±3.40^{cd}	7.25±2.43a	17.15±2.78^{bc}
Ghadir passenger terminal	*Cineraria maritima*	11.2± 2.08^{a}	16.16±1.19^{c}	1888.33±226.27^{a}	10.23±3.98^{ab}	4.24±2.70^{bc}	39.68±11.59^{cd}	4.89±1.72^{a}	23.95±4.47^{a}
Shohadaye Mehrab	*Mesembryanthemum cordifolium*	25.09±4.91^{a}	26.07±10.34^{bc}	281.59±70.38^{b}	10.57±2.31^{ab}	5.55±2.63^{abc}	64.94±26.11^{bc}	3.24±0.85^{a}	14.48±3.14^{bc}
Shohadaye Mehrab	*Cineraria maritima*	11.26±0.91^{a}	24.72± 3.84^{bc}	507±5.98^{ab}	13.94±2.71^{a}	2.66±2.21^{bc}	68.05±22.14^{bc}	5.56±0.71^{a}	14.64±1.32^{bc}
Doulatabad	*Mesembryanthemum cordifolium*	8.19±1.45^{a}	46.41±9.98^{a}	419.53±112.17^{ab}	12.35±2.82^{a}	8.07±1.52^{a}	134.83±10.57^{a}	4.78±2.46^{a}	17.61±3.18^{bc}
Doulatabad	*Cineraria maritima*	13.5±2.23^{a}	27.28±1.99^{bc}	592.43±49.43^{ab}	9.48±1.48^{ab}	2.23±0.87^{bc}	29.66±1.25^{d}	4.19±2.28^{a}	13.68±2.22^{c}
Quran gate	*Mesembryanthemum cordifolium*	7.6±1.63^{a}	17.02±1.37^{c}	421.4±37.41^{ab}	7.07±0.67^{b}	4.12±3.14^{bc}	82.46±15.89^{b}	3.79±0.97^{a}	19.51±2.55^{ab}
Quran gate	*Cineraria maritima*	18.27±1.60^{a}	34.8± 7.95^{b}	1921±543.33^{a}	12.41±1.80^{a}	6.06±0.55^{ab}	47.07±16.75^{cd}	6.5±3.57^{a}	19.49±2.59^{ab}

*In each column, means with the similar letter(s) are not significantly different ($P < 0.05$) using the LSD test.

Table 3. The result of KMO and Bartlett's test.

KMO and Bartlett's test		
Kaiser-Meyer-Olkin measure of sampling adequacy	0.529	
Bartlett's test of sphericity	Approx. Chi-Square	30.632
	df	28
	Sig.	0.034

Table 4. Correlation coefficients between heavy metals in the leaves of ornamental plants.

Variable		Cd	Co	Cu	Mn	Ni	Pb	Zn	Fe
Ornamental plants	Cd	1							
	Co	0. 11	1						
	Cu	0.14	0.33	1					
	Mn	-0.19	-0.39	0.01	1				
	Ni	-0.02	0.14	0.07-	0.07-	1			
	Pb	-0.05	0.88**	0.24	0.39-	0.14	1		
	Zn	-0.07	- 0.28	0.23	0.62**	0.21	- 0.22	1	
	Fe	0.08	0.44*	- 0.02	-0.03	0.12	- 0.46*	- 0.25	1

*, ** and ns: Significant at P < 0.05, P < 0.01 and insignificant respectively.

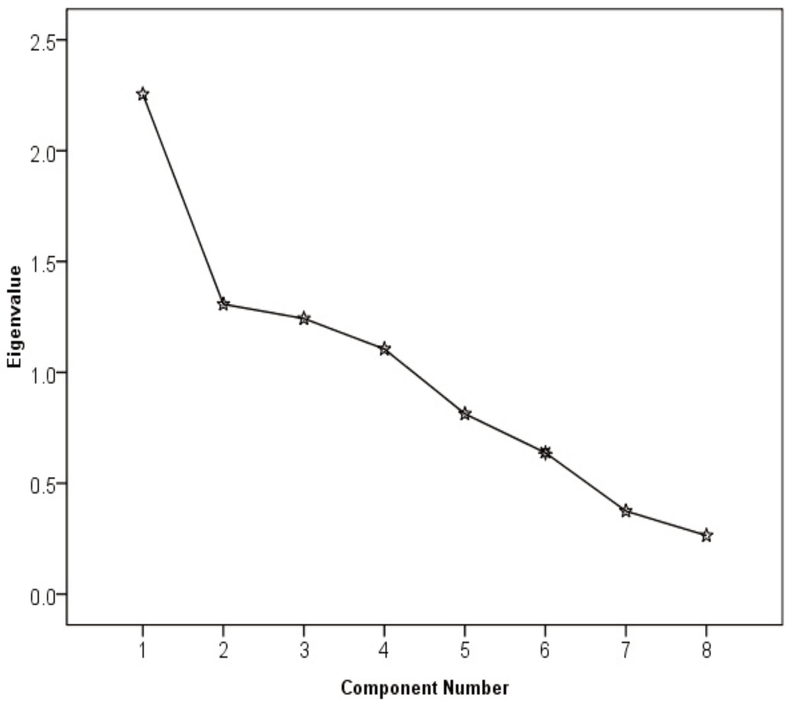

Fig. 4. The classification of variables with an eigenvalue >1.

The correlation coefficients between metals can provide useful information about the origin and source (Facchinelli *et al*., 2001; Lu *et al*., 2010; Maisto *et al.,* 2004). According to Table 4, there was a positive and meaningful correlation between the percentages of Pb and Co ($P<0.01$), implying a significant positive relationship between Zn and Mn with correlation coefficients of 0.88 and 0.62. Also, Pb and Co were positively correlated with Fe ($P<0.05$) (correlation coefficient=0.46 and 0.44, respectively). Werkenthin *et al*. (2014) and Esfandiari *et al*. (2019b) also reported that Pb had a significant correlation with traffic intensity.

CONCLUSION

Green spaces have a leading role in human life. In this respect, urban green spaces provide a suitable living environment. Hence, it is essential to monitor the quality of bus stations. The present study analyzed and compared the contents of Cd, Co, Cu, Ni, Pb, Zn, Fe, and Mn in the plant samples of dusty miller and purstane collected from the green spaces of four bus stations in Yazd city.

Based on the results, Pb concentration was high in the ornamental plants due to the traffic volume and multi-directional winds, and other contaminants. Pb concentration of the ornamental plants was higher in the Ghadir passenger terminal and Quran gate than in the other stations. According to the factor analysis, four factors had the highest roles in variances. The Pearson correlation analysis between heavy metals found in the ornamental plants showed a positive and significant correlation between the percentages of Pb and Co and between Zn and Mn ($P < 0.01$). Therefore, according to the results of this study, it can be concluded that the contents of heavy metals in leaves are significantly influenced by the location of green spaces within an urban setting at any point in time. According to the results, the studied plant species are among the most resistant ornamental species. Therefore, they are appropriate for streets, green spaces, parks, and urban boulevards of arid and semi-arid regions, like Yazd. These results provide a good theoretical basis for Yazd authorities to address heavy metal pollution management.

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