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Assessment of heavy metals in *Cypress* (*Thuja orientalis L.*) in the Yazd Highway green belt

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Abstract

Dust storm is one of the criteria for air pollution, and pollution by Heavy Metal (HM) is one of the major environmental problems in the world. The objective of the present study was to assess some of HMs concentrations in the leaves and bark of cypress and atmospheric falling dust along the Yazd highway, Yazd Province, Iran. The total concentrations of cadmium (Cd), cobalt (Co), copper (Cu), nickle (Ni), lead (Pb), zinc (Zn), iron (Fe) and manganese (Mn) in the dust and plant samples were measured using atomic absorption spectrophotometry after digestion with acid. The results showed that the concentration of Zn and Cd metals in falling dust were the highest to the lowest, respectively. The distance from the highway significantly influenced the concentration of HMs in leaves and bark of the cypress tree. Moreover, the effect of HMs on the bark of this tree was higher than that of leaves, except for Cd, Co, Cu and Mn. Concentrations of Zn, Co, Ni and Fe increased with the increase in the distance from the highway due to multi-directional winds and the presence of other contaminants. The Pearson correlation analysis between the HMs found in the falling dust and *Thuja orientalis L.* showed that the input and controlling factors of these metals in the cypress tree were probably the same as the dust. The results further showed that the *Thuja orientalis L.* leaves with a metal accumulation index of 1973.16 mg/kg were more able to simultaneously absorb different metals. Therefore, since this green belt surrounds the Yazd urban area, it is expected that a significant amount of HMs will be absorbed by these trees.

Keywords: Falling dust; Heavy metals; *Thuja orientalis* L.; Yazd green belt

1. Introduction

Due to rapid the urbanization and industrialization over the past few decades, heavy metal concentrations in urban areas have reached a toxic level due to anthropogenic activities, such as vehicle exhaust emissions, pesticide and fertilizer application, and sewage sludge amendment, releasing traces of HMsinto the air, water, and soil (Liu *et al.*, 2016; Peng *et al.*, 2016). "These HMs enter the environment through various human activities and affect the air quality and, by hanging and mating with dust particles, rainfall is deposited at the surface of the earth and vegetation, due to the wind speed or the precipitation of the heavens, and they will remain in human being life cycle" (Zhuanget *et al.*, 2018). Trees are living elements in the environment; via respiratory and absorption through the roots in addition to photosynthesis and different important functions, they are capable of converting certain pollutants into non-dangerous materials, maintain part of these materials within their tissues, and reduce their density in the environment (Chen and Haixiao, 2018). Dust storms are among the natural disasters taking place in warm and humid regions such as Yazd province (Esfandiari, 2018); typically, desert dust contains large quantities of toxic substances that pose a hazard to the health of living organisms and ecosystems; due to the high emissions of dust debris inside the environment doses, HMs may be released on a large scale by binding to these particles; HMs are important due to their physiological effects on humans and other residing organisms at significantly low concentrations (Wan *et al.*,

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2018). Jahanbazy Goujani *et al*. (2018) measured the HMs (Pb, Cd, Ni, Ar, and Hg) in the leaves of *Quercus brantii* healthy and dry trees located in the Helen area of Chaharmahal and Bakhtiari province. Hassanvand *et al*. (2018) examined the amount of heavy metal adsorption (Pb, Cu, and Zn) in soil and leaves (*Q. brantii)* of oak trees in Alashtair-Khorramabad highway; they concluded that heavy metal concentrations in soil increased with the distance from the road; moreover, the concentrations of HMs in the leaves of oak trees were less than the standard values of the world, hence the fact that this tree has accumulated heavy metals. Saikachout *et al*. (2015) studied Pb poisoning in *Atriplex*, concluding that stem growth and dry weight of *Atriplex* plant root were exposed to high concentrations of Pb-contaminated soil. Following exposure to lead stress, a significant increase in chlorophyll content was observed in the leaves of type plants. Hassan Farid *et al*. (2017) specified Pb concentration in street falling dust on the leaves in 29 sites in Karachi; based on their conclusion, the amount of Pb found on the leaves was higher in areas with more printing, welding, soldering, and battery recycling shops. In regions such as Yazd, Iran, dust storms have had harmful impacts on human societies and caused economic, social, environmental and political. This has reduced people's income and forced them to migrate. Dust particle contains large quantities of toxic substances, posing a threat to the health of living organisms and ecosystems. Dust sources are also associated with an increase in the amount of radioactive contamination due to the high emission of dust particles in the environment; HMs might be released on a large scale by binding to these particles. They are also important because of their physiological effects on humans and other living organisms even at low concentrations (Wan *et al*., 2016; Hakimzadeh, 2014). Cao *et al*. (2015) evaluated the social, economic, and environmental impacts of dust storms in Iran. Lyu *et al*. (2017) studied the falling dust of three dust storms in 2010. They reported that these dust storms moved from northwestern to eastern regions of China. The ranges of dust deposition flux and soil D_{50} were 1.5-25.1 gm^{-2} and 9-26.1 µm, respectively. One of the most important air pollutants in Yazd city is suspended particles from the industries close to urban areas along with certain heavy elements. The absence of urban green space and the presence of pollutant industries in the Yazd-Ardakan plain have led to many problems in Yazd city. To develop green space and create forest parks, the green belt design has been studied and implemented in in western Yazd; one of the dominant species planted in the green belt of Yazd highway is cypress tree. The purpose of this research, carried out in Yazd province in 2017, was to investigate the effectiveness of cypress tree *(Thuja orientalis* L.) in reducing the pollutants of HMs in the environment. For this purpose, we determined the concentration of some HMs in the leaves and bark of the cypress tree and compared them with heavy metal concentrations in the falling dust.

2. Materials and Methods

2.1. Study area

Yazd is situated in Yazd-Ardakan plain with a dry weather in the coordinates of 54° 17' E and 31° 54' N (Ardakani and Vahdati, 2018). The precipitation in this region is low and irregular (average rainfall is 118 mm/y), and its evaporation rate is between 2200 and 3200 mm/y (Fathizad *et al.,* 2018). Yazd is an important city in terms of industry and tourism; the rapid growth of industries such as steel industry, the increase in the number of vehicles, urban traffic, and the desert climate have exacerbated the inflow of contaminated micro flora due to the lack of proper planting and vegetation cover, or vegetation loss in the western parts of Yazd. The western region of Yazd is an important transit port with industrial towns and factories; therefore, the construction of the green belt of Yazd city has been studied and implemented. The green belt area is irrigated with drip technique from well water in Shahid Bahonar Station (Fig. 1).

Thuja orientalis is an evergreen ~~Tree~~ tree. It is in leaf all year, and the seeds ripen from September to October. The species is monoecious (individual flowers are either male or female, but both sexes can be found on the same plant) and is pollinated by Wind. Suitable for: light (sandy), medium (loamy) and heavy (clay) soils and prefers well-drained soil. Suitable pH acid, neutral and basic (alkaline) soils and can grow in very alkaline soils. It can grow in semi-shade (light woodland) or no shade. It prefers dry or moist soil and can tolerate drought. It can tolerate atmospheric pollution (Fig. 2).

Deposition trap was used to collect falling dust with a 22 cm in diameter, poured into a three-row or glass marble with an average diameter of 1.6 cm, marble dust collector (MDCO) has the best efficiency for amassing dust (Gossen *et al*., 2008). The traps were installed at a height of 120 cm above the ground level in sampling sites (Fig. 3).

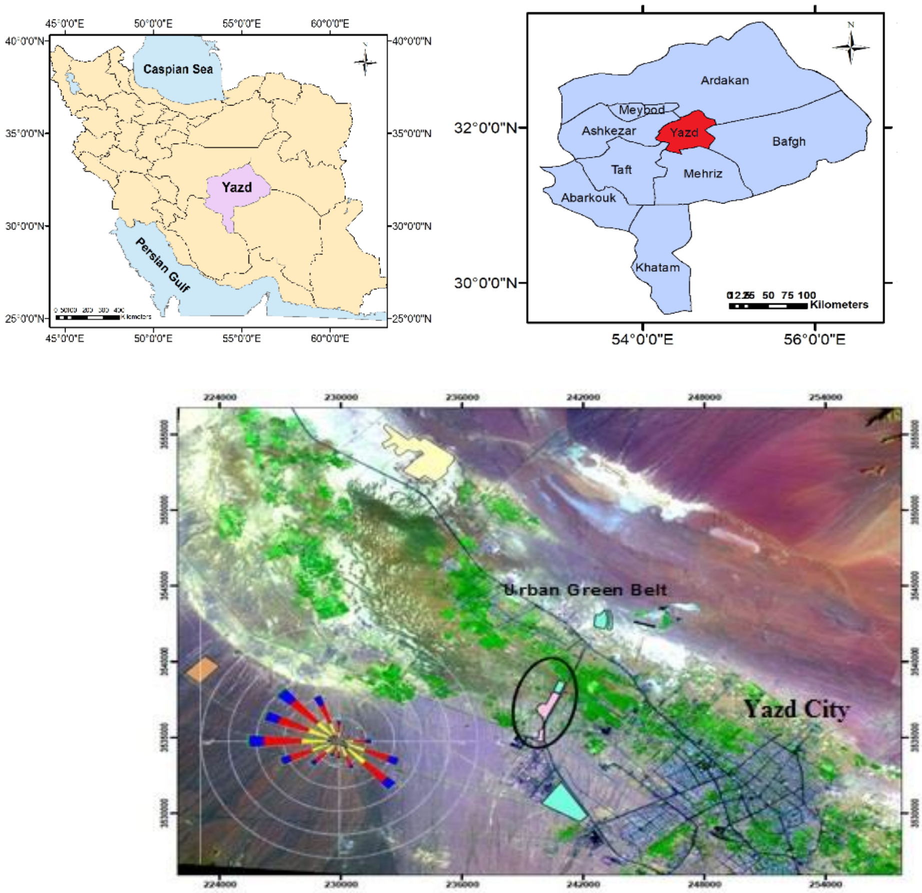

Fig. 1. Location of the study area in Iran and Yazd province

Fig. 2. Cypress (*Thuja orientalis* L.)

Fig. 3. Specimen of the Marble Dust Collector

2.2. Research Methodology

After three months of autumn, the trapped dust samples were transferred to the laboratory, and heated at 70°C for 48 hours. Then, 1 g of dust was weighed with a precision of ±0.001 to measure the total concentration of HMs in accordance with ISO 11446 international standard procedure. According to the extraction procedure of trace elements, 7 mL of concentrated chloride acid plus 2.5 mL of concentrated nitric acid (1:3 ratio) and then, 5 mL of diluted nitric acid (0.5 M) drop by drop were added to each sample. The adsorption vessel and condenser were installed and rinsed with a further 10 mL of nitric acid after reaction time. In the final step, after cooling the samples, 33.3 mL of diluted nitric acid was added and the solution was completely filtered by Whatman 42 filter paper and reached the volume of 50 mL by adding deionized distilled water. We also determined the concentration of HMs like Cd, Fe, Zn, Co, Cu, Mn, Ni, and Pb after digestion with acid. Vegetative samples were dried and then milled in an oven at $70^{\circ C}$ for 72 hours. Afterwards, the concentrations of HMs (Zn, Pb, Cd, Co, Fe, Mn, Cu and Ni) in leaves and bark of Cypress tree samples were measured by Analytic Jena 330 Flame Atomic Absorption Spectrophotometer (Klute, 1986).

Metal Accumulation Index (MAI)

Plant organs can be combined of numerous varieties of metals (Sharma, 1999); therefore, the metal accumulation index using Eq. 1 was employed (Liu *et al*., 2007) to determine the simultaneous accumulation of various metals by *Thuja Orientalis L.*

$$MAI=\left(\frac{1}{N}\right)\sum_{i=0}^{n} Ij \quad (1)$$

Where N is the total number of measured elements and Ij= X/ δX is the sub-index for variable j, an outcome by dividing the mean value (X) of each metal by its standard deviation (δX). MAI value of leaves and bark was obtained from Eq. 2

$$MAI = MAI = 1/8 \times [\ (XCd/\delta Cd) + (XZn/\delta Zn) + (XNi/\delta Ni) + (XPb/\delta Pb) + (XCo/\delta Co) + (XMn/\delta Mn) + (XFe/\delta Fe) + (XCu/\delta Cu)]. \quad (2)$$

Data were analyzed using SPSS (version 20). The descriptive statistics of variables were calculated. Then the normality of data was also investigated using the Shapiro Wilk test.

3. Results and Discussion

Table 1 shows the descriptive statistics of the heavy metal concentrations in the falling dust of the study area. The concentration of Fe, Mn, and Cd in falling dust was the highest to the lowest. The elemental averages found in this study were comparable with the global elemental means. The Cd contents observed in this study were significantly lower than those reported from urban settings: Nanjing (China), Hu *et al*. (2012); Lahore (Pakistan), Mohmand *et al*. (2015); Birmingham (England), Charlesworth *et al*. (2003); Zurich (Switzerland), Amato *et al*. (2011); Islamabad (Pakistan), Faiz *et al*. (2009); Rawalpindi (Pakistan), Abbasi *et al*. (2013); Hangzhou (China), Zhang and Wang (2009); Huludao (China), Zheng *et al*. (2010); Selangor (Malaysia), Latif *et al*. (2009); Barcelona (Spain), Amato *et al*. (2011); and higher than elsewhere WMZ (Pakistan), Eqani *et al.* (2016); Newcastle (UK), Okorie *et al*. (2012); Urumqi (China); Wei *et al*. (2009); Ottawa (Canada); Rasmussen *et al*. (2001). The Pb, Ni, and Zn averages of this study were also significantly lower than elsewhere.

The Scree Plot is presented in Figure 4. According to Fig. 4, two factors had the highest amounts of variances. Classification of variables in order to select factors are based on special values larger than one. The results exhibited that total variance between two eigenvalues was higher than one. exhibiting the two different groups which can be distinguished: 1) Fe, Co, Mn, Pb, Ni and Cu in the falling dust; and 2) Zn, Cd and Co in the falling dust (Figure. 5). Esfandiari, *et al.* (2019) used a dendrogram of clusters using euclidian distance, resulting in two clusters, as for the principal component scree plot. Demkova and Lenka (2017) once assessing the agricultural soil contaminations in two different periods (1997 & 2015), divided the HMs into two separate factors.

Table 1. Descriptive statistics of the concentration of HMs in falling dust

Matals		Minimum($mgkg^{-1}$)	Maximum($mgkg^{-1}$)	Mean ± Standard Deviation
Falling dust	Cd	0.35	3.28	1.56 ± 0.91
	Co	1.17	4.19	2.60 ± 0.29
	Cu	2.40	15.43	8.63 ± 3.65
	Ni	2.13	6.01	4.04 ± 0.86
	Pb	8.09	40.63	19.12 ± 3.92
	Zn	4.42	66.33	22.87 ± 3.98
	Fe	63.23	723000.00	160100 ± 2.62
	Mn	26.41	4220.83	2256 ± 12.76

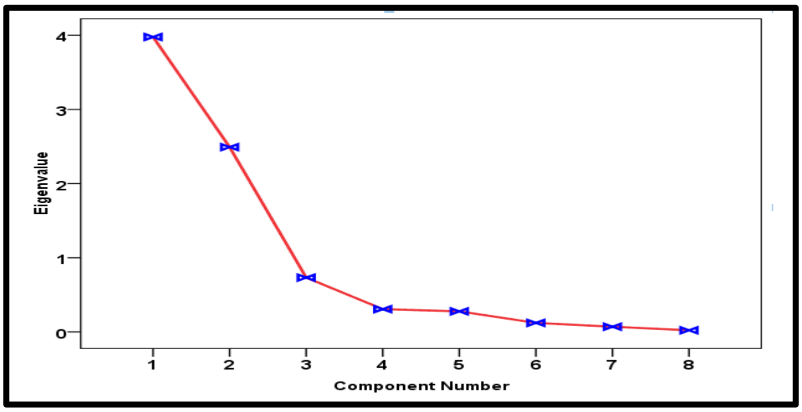

Fig. 4. Classification of variables with an eigenvalue > 1

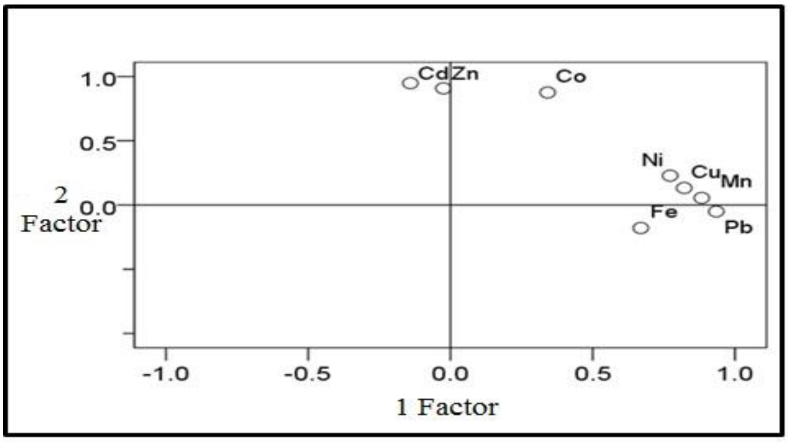

Fig. 5. Two dimensional plot of factors (F_1 and F_2) for heavy metals in dust of the study area

The results of the analysis of variance (mean square) showed that distance from the highway had a significant effect on the concentration of some HMs in the leaf and bark of *Thuja orientalis* (P≤ 0.01) with the exception of Fe, (Table 2). The concentrations of Zn, Cd, Co, Pb, Mn, Cu, and Ni in the leaves and bark of *Thuja orientalis* were different at (p≤0.01), (Table 2). According to the outcomes presented in (Table 3), the interaction among the concentration of HMs confirmed that inside the three studied intervals, the most optimal amount of Ni was detected at a distance of 35 meters from the highway in the leaf of the *Thuja orientalis* (25.66 $mgkg^{-1}$) and the lowest of Ni in the tree bark were determined on 170 meters (11.82 $mgkg^{-1}$). The maximum of Zn was in 35 meters from the highway (127.46 $mgkg^{-1}$), the least concentration of Zn was in *the Thuja orientalis* leaves in 170 meters' highway (15.02 $mgkg^{-1}$). The results of Moameri *et al*. (2017) showed that Pb and Zn concentrations in the plants were higher than the standard range in rangelands around Zanjan.

The most optimal amount of Fe was located in barks at 350 meters from the highway (1072.5 $mgkg^{-1}$). The highest quantity of Co was found in leaf at 350 meters from the highway (10.91 $mgkg^{-1}$), and the least it found at170 meters (3.57 mg kg^{-1}). The highest amount of Cu metal was found in the tree leaves 35 meters from the highway (14.78 $mgkg^{-1}$), and its lowest value was detected in the barks of the cypress tree at a distance of 170 meters from the highway (1.05 $mgkg^{-1}$). The best quantity of Mn metal was obtained 350 meters from the highway in leaves (44.50 $mgkg^{-1}$), and the lowest amount belonged to the bark of the *Thuja orientalis* at 170 meters from the highway (15.85 $mgkg^{-1}$). The highest amount of Cd metal was observed at 350 meters in the leaves of *Thuja orientalis* (14.96 $mgkg^{-1}$), and the lowest amount was found in the barks at 170 meters from the highway (1.52 $mgkg^{-1}$). The highest concentration of lead metal was found at 35 meters from the highway in the barks of *Thuja Orientalis* (10.97 $mgkg^{-1}$), and the lowest quantity of lead was observed in the leaves at 170 meters from the highway (5.58 $mgkg^{-1}$).

The correlation coefficients between metals can provide useful information about the origin and their source (Facchinelli *et al*., 2001; Lu *et al*., 2010; Maisto *et al.*, 2004).

According to the Table 4, there was a positive and significant correlation between the percentages of Pb and Co and Zn ($p \leq 0.01$).

Werkenthin *et al*. (2014) also reported that Pb is a metal with a significant correlation with traffic intensity. Cd metal had a positive and significant correlation with Cu, Zn, Mn, and Ni metals with correlation coefficients of0.79, 0.64, 0.76, and 0.71. Co at ($p \leq 0.05$) confirmed a significant positive relationship between Cu and Fe metals with correlation coefficients of 0.53 and 0.55). Ni in the falling dust at ($p \leq 0.01$) had a significant positive correlation with Mn with a correlation coefficient of0.71; Mn also had a significant positive association with the Zn (0.51) also with the Cu and Fe metals (0.59, 0.58). There was also a significant positive correlation (0.56) with Cu and Zn metals ($p \leq 0.05$). Additionally, Addo *et al*. (2012) stated that increasing the quantity of HMs inter-cities comparison with previous data established that Cr levels in their study was very high while Pb. Metal contamination assessment status of the metals was made using mathematical models in terms of enrichment factor, geo-accumulation index and contamination factor.

The analysis of the correlation between the concentrations of HMs within the cypress tree in Table (4), showed that there is The highest correlation between the concentration of Cd and Fe (0.47) at ($p \leq 0.05$).

Other studies have also confirmed the direct relationship between roadside contamination of HMs and the traffic volumes of the plants (Azeem Jadoon *et al*., 2018; Skrbic *et al*., 2012). There may be an advantageous and significant correlation among some of the HMs at ($p \leq 0.01$); according to Table (4), the highest correlation (0.88) was between Cd and Co in *Thuja orientalis* L. Cd with Fe, Cu, and Mn (0.47, 0.73, 0.88), Co metal with Fe and Mn (0.66, 0.67), Ni with Cu and Zn (0.53, 0.71), and Mn with Cu (0.83).

4. Conclusion

Whether sprawling over a large area or a small belt, these green belts are detected in all cities and play a vital role in reducing the industrial pollution in urban areas. The objective of this research was to investigate the capability of urban green belt vicinity of Yazd highway regarding the absorption of some HMs (Ni, Zn, Co, Cd, Mn, Fe, Cu and Pb) in the leaves and bark of the tree at different distances from the highway and its correlation with the falling dust. The results showed that the average concentration of HMs Cd < Co < Ni < Cu <Pb < Zn < Mn < Fe in falling dust was increased. Evaluation of plant samples at different distances from the highway showed that the concentration of Zn, Co, Fe, and Ni increased with increase in the distance from the highway. This can be attributed to other pollutants and the reduction in road traffic and wind blow in the province. Investigating plant samples at different intervals of highway showed that the concentrations of Zn, Co, Fe, and Ni metals increased with the distance from the highway; however, in the case of other metals, this result was not applicable, possibly due to the existence of pollutants other than those of traffic.

Highest correlation in falling dust was found between Cd and Mn (0.76). In cypress tree *(Thuja orientalis L.)* had the highest correlation among Cd with Co (0.88). The metal accumulation index (MAI) within the bark and leaves of *Thuja orientalis L.* was 1378.89 and 1973.18, respectively.

According to the accumulation index of metals in the cypress tree, it can be concluded that this type of tree is resistant to the accumulation of HMs in its barks and leaves owing to its adaptation to hard environmental conditions, such as hot water, heat, and drought. It is one of the most resistant tree species; therefore, in arid and semi-arid areas such as Yazd, wind turbines and green spaces are suitable regarding the construction of streets, parks, and urban boulevards.

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Table 2. Analysis of variance (mean square) the impact of distance from the highway on the concentration some of HMs in the leaves and bark of cypress (*Thuja orientalis L.*)

Sources of changes	df	mean square							
		Ni	Zn	Fe	Cu	Co	Mn	Cd	Pb
Distance	2	83.01^{**}	6590.44^{**}	1480352.83^{**}	53.46^{**}	48.93^{**}	1260.95^{**}	11626.95^{**}	34.38^{**}
Organ	1	282.70^{**}	12614.71^{**}	74811.08^{ns}	374.6^{**}	25.01^{**}	6945.18^{**}	417.75^{**}	136.85^{**}
Organ * Distance	2	24.33^{**}	5202.94^{**}	122802.85^{ns}	22.64^{**}	8.13^{**}	35.50^{*}	49.11^{**}	0.20^{ns}
Error	18	0.94	1.21	54054.57	0.116	0.302	3.87	0.22	0.23
CV %		4.91	6.41	1.72	16.57	11.36	4.72	15.31	8.17

* Significance at 0.05 level, ** Significance at 0.01 level. ns: No significant difference

Table 3. The effect of distance from the highway within the bark and leaves of cypress (*Thuja orientalis L.*) at the concentration of heavy metals

Distance from the highway (m)	Organ	Measured metals ($mgkg^{-1}$)							
		Ni	Zn	Fe	Cu	Co	Mn	Cd	Pb
35 meters	Leaf	16.93 ± 1.15^{d}	23.60 ± 0.38^{d}	612.6 ± 0.83^{b}	14.78 ± 0.37^{a}	7 ± 0.72^{b}	55.6 ± 4.66^{a}	11.89 ± 0.50^{b}	9.23 ± 0.50^{b}
35 meters	Bark	25.66 ± 0.72^{a}	127.46 ± 0.59^{a}	229 ± 38.79^{a}	3 ± 0.29^{d}	5.64 ± 0.54^{c}	36.45 ± 0.58^{c}	4.98 ± 0.55^{d}	10.97 ± 0.40^{a}
170 meters	Leaf	11.82 ± 1.17^{e}	15.02 ± 2.49^{e}	214.55 ± 0.7^{c}	6.92 ± 0.38^{c}	4.03 ± 0.40^{d}	26.57 ± 0.55^{d}	3.04 ± 0.34^{c}	5.58 ± 0.59^{e}
170 meters	Bark	20.85 ± 0.58^{c}	23.02 ± 0.14^{d}	160.58 ± 0.57^{c}	1.05 ± 0.2^{f}	3.57 ± 0.58^{d}	15.85 ± 0.5^{e}	1.52 ± 0.46^{e}	6.82 ± 0.52^{d}
350 meters	Leaf	20.95 ± 0.38^{c}	25.70 ± 0.39^{c}	970.31 ± 2.79^{c}	8.03 ± 0.45^{b}	10.91 ± 0.41^{a}	44.50 ± 0.57^{b}	14.96 ± 0.45^{a}	6.02 ± 0.45^{e}
350 meters	Bark	23.79 ± 0.14^{b}	51.40 ± 0.59^{b}	1072.5 ± 39.18^{a}	2 ± 0.25^{e}	6.59 ± 0.54^{b}	29.43 ± 0.55^{d}	3.52 ± 0.51^{d}	7.85 ± 0.42^{c}

Means followed by the same letter in each column are not significantly different at 5% of probability level

Table 4. Correlation coefficients among HMs concentrations in falling dust and *Thuja orientalis L.*

	Metal	Fe	Cu	Zn	Mn	Ni	Co	Cd	Pb
Falling dust	Fe	1							
	Cu	-.042	1						
	Zn	0.006	0.56^{*}	1					
	Mn	-0.58^{*}	0.59^{*}	0.51^{**}	1				
	Ni	-0.64^{**}	0.48	0.27	0.71^{**}	1			
	Co	-0.55^{*}	0.53^{*}	-0.35	0.33	0.33	1		
	Cd	-0.49	0.79^{**}	0.64^{**}	0.76^{**}	0.71^{**}	0.31	1	
	Pb	-0.64	0.003	-0.75^{**}	-0.10	0.13	0.75^{**}	-0.13	1
Thuja Orientalis L. orientalis	Fe	1							
	Cu	0.15	1						
	Zn	-0.14	-0.38	1					
	Mn	0.37	0.83^{**}	0.04	1				
	Ni	0.24	-0.53^{**}	0.71^{**}	-0.05	1			
	Co	0.66^{**}	0.39	0.05	0.67^{**}	0.22	1		
	Cd	0.47^{*}	-0.73^{**}	-0.18	0.85^{**}	-0.03	0.88^{**}	1	
	Pb	-0.12	0.03	0.79^{**}	0.37	0.54^{**}	0.04	0.01	1

* Significance at 0.05 level, ** Significance at 0.01 level

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