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An Investigation on Heavy Metal Pb, Zn, Cu, Ni and Cd Accumulation in Leaves of *Robinia Pseudoacacia* L. "Umbraculifera" Arising from Motor Vehicles

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ABSTRACT

The present study aims to determine the level of heavy metal contamination induced by the motor vehicles at Şanlıurfa city center using *Robinia pseudoacacia* L. "Umbraculifera" taxon encountered frequently at the urban landscape planning practices in Turkey. The quantities of the heavy metal levels such as Pb, Zn, Cu, Ni and Cd were determined using ICP OES (Inductively Coupled Plasma Optical Emission Spectrometer) on the leaf samples collected seasonally (spring, summer, autumn seasons). The SPSS 18 Packaged Software was used to determine the significant differences regarding accumulation of the heavy metal levels from the leaves of this plant according to the stations and the seasons, and the homogeneity test was implemented to measure the difference; and the data were analyzed using Kruskal - Wallis and Games - Howell tests. Based on the data acquired as a result of the study, it was concluded that this plant cannot be considered as an indicator for heavy metals originating from motor vehicles in Şanlıurfa.

Anahtar Kelimeler:
Ağır Metal Seviyesi,
Çevresel Kirlilik,
Robinia pseudoacacia "Umbraculifera",
Şanlıurfa,
Türkiye.

ÖZ

Bu çalışma ile Türkiye'de şehir peyzaj planlamasında çok sık rastlanılan *Robinia pseudoacacia* L. "Umbraculifera" taksonu kullanılarak Şanlıurfa il merkezinde motorlu taşıtların neden olduğu ağır metal kirliliği seviyesinin belirlenmesi amaçlanmıştır. Mevsimsel olarak toplanan yaprak örneklerinde ICP (Inductively Coupled Plasma) kullanılarak Pb, Zn, Cu, Ni ve Cd ağır metal miktarlarının tespiti yapılmıştır. Bu bitkinin yapraklarından ağır metal birikiminin istasyonlara ve mevsimlere göre anlamlı derecede birbirinden farklılığını tespit etmek için SPSS 18 Paket Programı ve farklılığını ölçmek için ise homojenlik testi uygulanmış, Kruskal – Wallis ve Games – Howell testleri ile veriler analiz edilmiştir. Çalışma sonucunda elde edilen verilere göre bu bitkinin Şanlıurfa'da motorlu taşıt kaynaklı ağır metaller için bir indikatör olamayacağı sonucuna varılmıştır.

1. Introduction

The environmental pollution problems have escalated in this era we live in due to consumption of the natural resources and the growth in production practices in order to satisfy the ever increasing needs of the human beings due to the increase in the world population, rapid progression of the technological advancements and improvement at the standards of living. Therefore, nowadays the pollutants have diversified, especially in developing countries due to development of the industry [1].

Such pollutants emanate from the mining practices, highway traffic, use of fossil fuels, incineration of garbage, use of pesticides and fertilizers, burning of coal for heating purposes and industrial operations, and the municipal waste [2, 3].

Considered to be one of the anthropogenic activities inducing environmental pollution, the vehicle traffic is the primary source of highway pollution [4]. Characteristics such as the exhaust gases, wear of car tires, number and types of cars, fast or slow progress of traffic, etc. leads to contamination by heavy metal such as Cd, Cu, Ni, Pb and Zn on the roadsides [2, 5]. Especially the plants planted for landscaping purposes, especially in the traffic islands, are considered to be most affected by such pollution. The volume of the traffic and the distance to the roadside are the most important factors affecting heavy metal accumulation in plants.

Although the heavy metals are defined as the elements that present metallic properties and have atomic number greater than 20 [6, 7], recently the term "heavy metal" is used to denote any metal and metalloids or semi-metals characterized by potential toxicity to the environment and living organisms [8].

According to WHO [9], 1998 protocol, the metals that are stable and have density greater than 4.5 g/cm^3, and in some cases, the metalloids are denoted as heavy metals. According to WHO [10], Cd (Cadmium), Pb (lead) and Hg (mercury) are the heavy metals that have highest impact on human health. Cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn), on the other hand, are considered as the basic nutritional (micronutrients) elements in terms of many biochemical and physiological functions. Insufficient intake of such elements through food causes ailments such as lack of food or lack of vitamins.

It is a fact known for a long time that the plants accumulate trace elements from the atmosphere and are used in various sampling studies, especially because they offer cost-efficient information about environmental quality with the advantage of easy sampling. For this, especially mosses, lichens, herbs, agricultural products, ornamental plants and various tree species are used. [2, 11-15]. The trees are rather used for detecting the heavy metal pollution in the environment. The reasons for such use include more usable biological material, species identification, ease of application and sample collection, and the ubiquity of some species that make it possible to cover large areas [2].

Robinia pseudoacacia L. "Umbraculifera" has been used in many national and international studies as a heavy metal bio-indicator [3, 13, 16-23].

Furthermore, this plant is one of the plants denoted as bio-monitor in determining the heavy metal pollution. [13, 21, 23-26].

Upon reviewing the studies that investigated the potential bio-indication and phytoremediation characteristics of 9 different tree species planted for landscaping along the arterial streets at the downtown areas in central Europe [23], it has been determined that *Betula pendula* and *Robinia pseudoacacia* species are ideal and cost-efficient in terms of phytoremediation.

Accordingly, the fact that it is currently used for landscaping on roadsides with heavy traffic density also makes it extremely suitable plant sample for performing heavy metal measurements.

It is estimated that this plant, originating from Central and North America, was introduced to the Anatolia by the foreign railroad companies engaged with laying of railroad tracks during the Ottoman Empire era and was planted around the railroad stations, road slopes and embankments in order to stop the erosion. In addition to the parks, the plant is especially used at the central refuges and curbsides by the municipalities in Turkey. One of the primary reasons for preference of this plant is that it does not obstruct the sight of the vehicles travelling on the urban roads, thus avoiding any probable accident due to the extremely high body height from the ground to the crowning [27].

The present study aimed to determine the heavy metal pollution induced by motor vehicles in the areas where said plant is used for landscaping purposes at Şanlıurfa city center area, taking into consideration the notion that this plant acts as bio-indicator in terms of heavy metals.

2. Material and Method

Study Area

The leaf samples of *Robinia pseudoacacia* "Umbraculifera" species, used prevalently for afforestation efforts on the roadside and traffic islands in Şanlıurfa, were collected from four stations (Mehmet Hafız Boulevard, GAP Boulevard, Ring road, Mevlana street) comprising of boulevards and streets with intense traffic at the city center. Harran University Osmanbey Campus, 25 km away from the city center and presents low traffic density, was chosen as the control station.

Sampling and Analysis

Leaf samples were collected from the trees selected randomly at these five stations located in different localities throughout Şanlıurfa in the last months of the spring, summer and autumn seasons (May, August, November, 2015). When collecting the samples, 4 plants were selected from various distinct spots of the universe for each station in various seasons and then 3 leaf samples were collected from different points of each plant, and the results representing the ratio of the heavy metal in the leaf with 3 recurrent measurements for each leaf were achieved using ICP OES (Inductively Coupled Plasma Optical Emission Spectrometer).

The samples so collected were labeled individually and stored in separate bags in order to prevent contamination. The leaves on the lower branches of the trees, especially close to the road and exposed to the exhaust gases, were collected from the designated stations. The leaves so collected were washed with tap water and dried in the shade. The coordinates and lengths of the stations where the plant samples are collected are specified hereunder in Table 1.

Table 1. Stations used in the study

Stations	Station Length (km)	Coordinate
Osmanbey Campus	1	37°10'18.8"N 38°59'58.8"E
Gap Boulevard	4	37°12'47.1"N 38°47'49.8"E
Mehmet Hafız Boulevard	3,1	37°12'36.3"N 38°48'01.1"E
Ring Road	4,3	37°10'49.3"N 38°49'02.0"E
Mevlana Street	3,3	37°09'11.0"N 38°48'30.5"E

The samples dried for taking readings on the ICP OES device were maintained in the drying oven at 110^0C for 3 hours and dehydrated. The samples removed from the drying oven were pulverized by grounding in mortar. After collecting 0.5 g of the pulverized samples using precision scales, the samples were maintained in the muffle furnace at 550^0C for 5 hours to turn into ash, and then 7 ml of nitric acid was added to the samples and taken into the solution under high pressure and temperature in the microwave oven. The samples removed from the microwave oven were filtered. The samples were completed to 14 ml using distilled water and placed in the ICP OES device for getting readings.

Data Analysis

When determining the sample size of the study, the data were analyzed using G-Power 3.1.9.4 packaged software. The sample size was determined by analyzing the samples that will represent the universe size for each station during various seasons with 80% power and 5% error rate after determining the effect size.

The data were analyzed using SPSS 18 Packaged Software in order to determine the significant differences regarding accumulation of heavy metals in the leaves based on stations and seasons. In the analysis, Kruskal - Wallis, Games - Howell and Homogeneity tests were employed to measure the significant differences regarding accumulation of heavy metals in the leaves of the plant under study during various seasons based on the stations and at the designated stations based on various seasons.

It was determined that the values read for Cd (Cadmium) did not produce any statistically significant (<0.05) result. Therefore, said element is not shown in the assessment table.

3. Results

In this study, G-Power power analysis has been used to determine the sample number that shall represent the universe size under study from the available sample results by computing the effect sizes.

Based on the findings from this analysis, the acceptable sample number for each station was determined for each season when the study was conducted for 4 elements (Pb, Zn, Cu, Ni). When determining the sample number, the highest sample number for said elements was preferred (Table 2).

Table 2. Sample Numbers for the Elements according to G-Power Power Analysis

Seasons	Stations	Sample Number				
		Pb	Zn	Cu	Ni	Accepted
Spring	Osmanbey Campus	68	60	76	198	198
	Gap Boulevard	108	160	100	48	160
	Mehmet Hafız Boulevard	96	148	100	168	168
	Ring Road	60	68	64	60	68
	Mevlana Street	76	52	120	104	120
Summer	Osmanbey Campus	72	72	68	176	176
	Gap Boulevard	92	52	80	92	92
	Mehmet Hafız Boulevard	120	88	160	172	172
	Ring Road	116	52	144	60	144
	Mevlana Street	124	96	80	104	124
Autumn	Osmanbey Campus	60	108	72	88	108
	Gap Boulevard	52	92	44	76	92
	Mehmet Hafız Boulevard	144	184	128	48	184
	Ring Road	128	104	108	52	128
	Mevlana Street	60	160	76	172	172

Evaluation of Statistical Analysis

The distribution of heavy metal concentrations in the washed leaf samples of the plant according to the stations used for sampling in line with the results of the analysis is given in Table 3.

Table 3. The element concentrations in *Robinia pseudoacacia* leaves from the stations ($mg*kg^{-1}$)

Sampling Station	Pb	Zn	Cu	Ni
Osmanbey Campus	2.076±0.1131	36.12±3.736	4.330±0.2522	1.467±0.728
GAP Boulevard	4.202±0.3127	21.67±1.341	4.994±0.3244	3.058±0.1369
Mehmet Hafız Boulevard	3.717±0.2042	19.02±0.529	4.418±0.3461	3.231±0.1584
Ring Road	4.527±0.1718	17.91±1.493	4.732±0.3426	3.492±0.2197
Mevlana Street	4.064±0.1743	21.90±1.976	4.623±0.3388	3.224±0.1232

All metal concentrations shown as Mean±SD

Accordingly, the station with the highest measured Pb value is the Ring Road, followed by GAP Boulevard, Mevlana Street and Mehmet Hafız Boulevard stations, respectively. The lowest measured Pb value was achieved from Osmanbey Campus selected as the control station.

The highest Zn value was measured in Osmanbey Campus, which is the ground control station, and the lowest value was obtained from the Ring Road.

The highest of Cu was measured in GAP Boulevard station, followed by the Ring Road, Mevlana Street and Mehmet Hafız Boulevard stations, respectively. The lowest value for the Cu element was measured also from the control station, Osmanbey Campus.

When we look at the values for the Ni element, the highest value was measured at the Ring Road station and the lowest value was measured from the control station, Osmanbey Campus.

The distribution of heavy metal concentrations in the washed leaf samples of the plant according to the seasons in which the samples were taken is also given in Table 4.

Table 4 The element concentrations in *Robinia pseudoacacia* leaves for the seasons (mg*kg^{-1})

Sampling Season	Pb	Zn	Cu	Ni
Spring	2.650±0.1348	15.56±0.828	5.523±0.3079	3.310±0.1805
Summer	2.974±0.1443	31.67±3.364	6.038±0.2877	2.102±0.1029
Autumn	5.527±0.2429	22.74±1.072	2.297±0.2224	3.271±0.1746

All metal concentrations shown as Mean±SD

Accordingly, the season with the highest Pb value is observed to be the autumn, which is followed by the summer and spring seasons, respectively. On the other hand, the highest Zn and Cu values were measured in the summer season, while the lowest values were measured in spring for Zn and in autumn for Cu. The highest Ni value was also measured in the spring season.

The Statistical Evaluation of Heavy Metals According to the Stations

Homogeneity and Kruskal Wallis test results for accumulation of heavy metals, Pb, Zn, Cu and Ni, analyzed in the study in the leaves during three seasons according to five stations are given in Tables 5 and 6.

Table 5. Test of Homogeneity of Variances

Element	Levene Statistic	df1	df2	Sig.
Pb	2,000	4	10	,171
Zn	6,736E15	4	5	,000
Cu	3,892E16	4	5	,000
Ni	3,521E15	4	5	,000

Table 6. Kruskal Wallis Test Statistics

Element		Average Value
Pb (Lead)	-	-
Zn (Zinc)	Chi-square	54,475
	Df	2
	Asymp. Sig.	,000
Cu (Copper)	Chi-square	8,375
	Df	4
	Asymp. Sig.	,079
Ni (Nickel)	Chi-square	4,806
	Df	4
	Asymp. Sig.	,308

In the study, Homogeneity and Normality tests were implemented on accumulation of Pb, Zn, Cu and Ni on the leaves during three seasons according to five stations. Accordingly, the test results obtained for Zn, Cu and Ni revealed that the factor group of the data did not present normal distribution over the dependent group and was not distributed homogeneously, whereas, the factor group of the data were distributed normally and presented homogeneous distribution for Pb (Table 5).

The data for Pb were analyzed by One-Way Analysis of Variance, and it was observed that the accumulation of Pb on leaves was not significantly different (<0.05) between stations compared to five stations during three seasons (Table 7).

Table 7. ANOVA results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3,067	4	,767	1,438	,292
Within Groups	5,333	10	,533	-	-
Total	8,400	14	-	-	-

The data for Zn, Cu and Ni, on the other hand, were analyzed using the Kruskal Wallis Test, the Chi-Square value was determined, and it was observed that there was no significant difference (<0.05) in the accumulation of Cu and Ni in leaves, while a significant (<0.01) difference was observed (Table 6) for Zn between the stations compared to five stations in three seasons.

The data for Zn were analyzed using the Games-Howell Test in the non-parametric plane, and it was observed that accumulation of Zn in leaves presented significant (<0.05) difference between Osmanbey Campus and GAP Boulevard stations (Table 8 and Figure 1).

Table 8. Games-Howell Multiple Comparison Results for Zn

(I) Stations	(J) Stations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Osmanbey Campus	GAP Boulevard	-53,00000*	3,80789	,048	-104,6167	-1,3833
	Mehmet Hafız Boulevard	-25,00000	5,70088	,257	-132,6687	82,6687
	Ring Road	-19,00000	7,64853	,465	-184,9919	146,9919
	Mevlana Street	-25,50000	3,35410	,094	-64,9883	13,9883
GAP Boulevard	Osmanbey Campus	53,00000*	3,80789	,048	1,3833	104,6167
	Mehmet Hafız Boulevard	28,00000	6,51920	,178	-33,8316	89,8316
	Ring Road	34,00000	8,27647	,228	-69,8677	137,8677
	Mevlana Street	27,50000	4,60977	,084	-8,9369	63,9369
Mehmet Hafız Boulevard	Osmanbey Campus	25,00000	5,70088	,257	-82,6687	132,6687
	GAP Boulevard	-28,00000	6,51920	,178	-89,8316	33,8316
	Ring Road	6,00000	9,30054	,952	-73,4538	85,4538
	Mevlana Street	-,50000	6,26498	1,000	-68,5440	67,5440
Ring Road	Osmanbey Campus	19,00000	7,64853	,465	-146,9919	184,9919

	GAP Boulevard	-34,00000	8,27647	,228	-137,8677	69,8677
	Mehmet Hafız Boulevard	-6,00000	9,30054	,952	-85,4538	73,4538
	Mevlana Street	-6,50000	8,07775	,905	-122,7642	109,7642
Mevlana Street	Osmanbey Campus	25,50000	3,35410	,094	-13,9883	64,9883
	GAP Boulevard	-27,50000	4,60977	,084	-63,9369	8,9369
	Mehmet Hafız Boulevard	,50000	6,26498	1,000	-67,5440	68,5440
	Ring Road	6,50000	8,07775	,905	-109,7642	122,7642

*. The mean difference is significant at the 0.05 level.

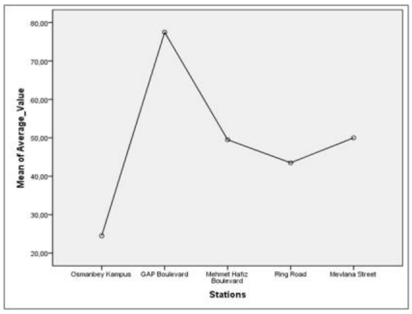

Figure 1. One-Way Analysis of Variance Diagram for Zn **(*** Every 1 unit on the diagram represents 0,5 mg / kg)

The Statistical Evaluation of Heavy Metals According to the Seasons

Homogeneity and Kruskal Wallis test results for accumulation of heavy metals, Pb, Zn, Cu and Ni, analyzed in the study in the leaves at five stations according to three seasons are given in Tables 9 and 10.

Table 9. Test of Homogeneity of Variances

Element	Levene Statistic	df1	df2	Sig.
Pb	12,750	2	132	,000
Zn	7,463	2	132	,001
Cu	9,174	2	132	,000
Ni	8,331	2	132	,000

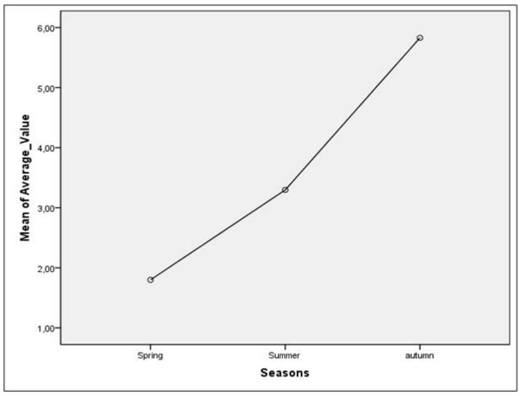

Figure 2. One-Way Analysis of Variance Diagram for Pb **(*** Every 1 unit on the diagram represents 2,5 mg / kg)

In the study, Homogeneity and Normality tests were implemented for accumulation of Pb, Zn, Cu and Ni in leaves at five stations according to three seasons. The test results revealed that the factor group of the data did not present normal distribution over the dependent group and was not distributed homogeneously (Table 9).

The data were analyzed using the Kruskal Wallis Test; the Chi-Square value was determined, and it was observed that the accumulation of Pb, Zn, Cu and Ni in leaves presented an extremely significant (<0.01) difference between the seasons at five stations according to three seasons (Table 10).

Table 10. Kruskal Wallis Test Statistics

Element		Average Value
Pb (Lead)	Chi-square	51,955
	Df	2
	Asymp. Sig.	,000
Zn (Zinc)	Chi-square	53,948
	Df	2
	Asymp. Sig.	,000
Cu (Copper)	Chi-square	53,891
	Df	2
	Asymp. Sig.	,000
Ni (Nickel)	Chi-square	55,676
	Df	2
	Asymp. Sig.	,000

The data for Pb, Zn, Cu and Ni were analyzed using the Games-Howell Test in the non-parametric plane (Table 11). It was observed that accumulation of Pb in the leaves presented an extremely significant (<0.01) difference between spring, summer and autumn seasons, that accumulation of Zn in the leaves did not present any significant difference between spring and autumn seasons, but presented an extremely significant (<0.01) difference between summer and spring and autumn seasons, that accumulation of Cu in the leaves did not present any significant difference between spring and summer seasons, but presented an extremely significant (<0.01) difference between autumn and spring and summer seasons, and, finally, accumulation of Ni in the leaves did not present any significant difference between spring and autumn seasons, but presented significant (<0.05) difference between summer and spring seasons, and presented an extremely significant (<0.01) difference between summer and autumn seasons (Figure 2, 3, 4, 5).

Table 11. Games-Howell Multiple Comparison Results

	(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Pb	Spring	Summer	-1,49665*	,23997	,001	-2,1790	-,8143
		Autumn	-4,02860*	,33407	,000	-4,8588	-3,1984
	Summer	Spring	1,49665*	,23997	,001	,8143	2,1790
		Autumn	-2,53195*	,29864	,000	-3,2432	-1,8207
	Autumn	Spring	4,02860*	,33407	,000	3,1984	4,8588
		Summer	2,53195*	,29864	,000	1,8207	3,2432
Zn	Spring	Summer	3,39566*	,56779	,006	1,4923	5,2990
		Autumn	,63294	,62673	,595	-1,2250	2,4909
	Summer	Spring	-3,39566*	,56779	,006	-5,2990	-1,4923
		Autumn	-2,76272*	,33938	,000	-3,5710	-1,9544
	Autumn	Spring	-,63294	,62673	,595	-2,4909	1,2250
		Summer	2,76272*	,33938	,000	1,9544	3,5710
Cu	Spring	Summer	,19566	,41857	,889	-1,1875	1,5788
		Autumn	-2,42860*	,47341	,002	-3,7898	-1,0674
	Summer	Spring	-,19566	,41857	,889	-1,5788	1,1875
		Autumn	-2,62426*	,28163	,000	-3,2951	-1,9534
	Autumn	Spring	2,42860*	,47341	,002	1,0674	3,7898
		Summer	2,62426*	,28163	,000	1,9534	3,2951
Ni	Spring	Summer	4,05720*	,93738	,025	,7806	7,3338
		Autumn	1,40217	,96362	,389	-1,8163	4,6206
	Summer	Spring	-4,05720*	,93738	,025	-7,3338	-,7806
		Autumn	-2,65503*	,29538	,000	-3,3581	-1,9519
	Autumn	Spring	-1,40217	,96362	,389	-4,6206	1,8163

	Summer	2,65503*	,29538	,000	1,9519	3,3581

*. The mean difference is significant at the 0.05 level.

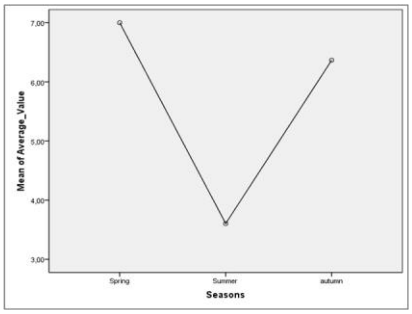

Figure 3. One-Way Analysis of Variance Diagram for Zn **(*** Every 1 unit on the diagram represents 2,5 mg / kg)

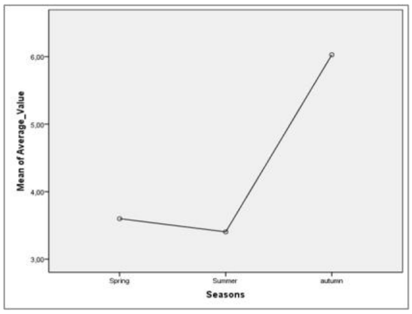

Figure 4. One-Way Analysis of Variance Diagram for Cu **(*** Every 1 unit on the diagram represents 0,5 mg / kg)

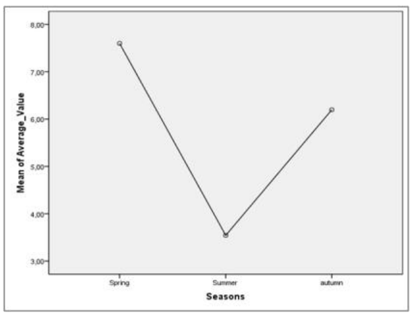

Figure 5. One-Way Analysis of Variance Diagram for Ni (* Every 1 unit on the diagram represents 0,5 mg / kg)

4. Discussion

Robinia pseudoacacia L. has been used as heavy metal bioindicator within both domestic and foreign [3, 13, 16-23, 26] many studies. It is currently used for landscaping on the roadsides with heavy traffic density so this makes it a very suitable plant sample for heavy metal measurements.

The present study was conducted in contemplation that investigating accumulation of the heavy metals, Pb, Zn, Cu, Ni and Cd, in the leaves of *Robinia pseudoacacia* L. "Umbraculifera" in Şanlıurfa (Central District) due to motor vehicles would yield significant results. Accordingly, it was investigated whether the heavy metal accumulation in the leaves differs significantly from each other according to the stations (Osmanbey Campus, GAP Boulevard, Mehmet Hafız Boulevard, Ring Road, Mevlana Street) and various seasons (spring, summer, autumn). According to the results obtained from the leaf samples read on the ICP OES device, it was seen that all readings for the Cd element did not present any results at the level of statistical significance, and thus it was concluded that accumulation of Cd in the leaves did not present any difference according to the stations and seasons.

Upon reviewing the results obtained from the analysis in terms of seasonality, it was determined that, although accumulation of Pb and Cu elements in leaves was at lower values during the spring months when the leaves first started to form, said value increased towards the summer and autumn months due to exposure to the heavy metals originating from the external environment. Accordingly, it was seen that the plant could not remove Pb and Cu elements from its leaves.

Several other studies conducted with this plant [18, 28] further revealed that the level of Pb, Zn and Cu in the leaves increased in autumn, corresponding to the end of the growth phase.

When we look into the Ni and Zn elements, it is seen that the accumulation in the leaves is at high levels in the spring, then declines towards the summer months, and then rises again towards the autumn months.

The review on acquired data in terms of stations revealed that the Pb, Zn and Cu values in the samples from GAP Boulevard and Ring Road, which feature the highest traffic density in terms of motor vehicles among the stations, are higher than the other samples. Determination of the statistically significant difference between GAP Boulevard, Ring Road and Mevlana Street stations, where motor vehicles are more concentrated, and Osmanbey Campus station, where motor vehicle traffic is relatively less intense, in terms of the Pb quantity in the leaves reveals that motor vehicles also have an impact on accumulation of Pb in the leaves apart from the natural factors.

On the other hand, according to the analysis results, Pb and Ni values were found to be within the normal range for plants, while Cu and Zn values were found to be lower than normal values.

In similar studies [16, 17, 19, 20] using the same plant on this subject, the heavy metal amounts of the samples from the research area were higher than the samples from the control areas, and consequently this plant has been indicated as a bioindicator.

However, in the light of the data from our study, in which the same plant and similar methods were used , we determined that this plant is not suitable as a bioindicator in our study areas.

Based on the aforementioned result, the concept of bioindicator species as propounded for this plant by the past studies as set forth in the introduction chapter of the study does not coincide with the outcome of this study conducted specifically for Şanlıurfa. Numerous reasons underlining this result can be sought. First of all; the difference in the field of study, such as the fact that past studies regarding determination of the heavy metal accumulation on this plant were carried out at the old mine and industrial zones or along the route of the international road might have led to such outcome. Secondly, achievement of different results despite conducting the studies at the city centers as is the case for several other previous studies can be attributed to the factors such as the size of the city centers, the number of vehicles in the traffic, the age of the vehicles in the traffic, vehicle maintenance, the quality of the fuel used in the vehicles, and traffic density.

In conclusion, it is contemplated that indicating situations such as the annual number of vehicles introduced to the traffic in the region, the daily vehicle density at the sampling area, the length of the boulevard or street used for sampling etc. when conducting studies on the traffic-based heavy metals similar to the study presented herein would provide more realistic and robust opportunity for comparing the results from the studies conducted in different fields.

Competing Interest / Conflict of Interest

"The authors declare that they have no competing interests"

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