Hindawi
Applied and Environmental Soil Science
Volume 2021, Article ID 8884718, 9 pages
https://doi.org/10.1155/2021/8884718

Research Article

Changes in the Heavy Metal Levels in Highway Landscaping and Protective Effect of Vegetative Materials

Hüccet Vural, Alperen Meral, and Sülem Şenyiğit Doğan

Department of Landscape Architecture, Faculty of Agriculture, Bingöl University, Bingöl 12000, Turkey

Correspondence should be addressed to Hüccet Vural; hvural@bingol.edu.tr

Received 8 September 2020; Revised 13 February 2021; Accepted 10 March 2021; Published 14 April 2021

Academic Editor: Bon-Jun Koo

Anthropogenic activities due to increasing population and traffic density are responsible for a great portion of highway pollution. The heavy metal accumulation in highway routes poses a risk both for agricultural areas and residential areas. The study investigated the changes in heavy metal accumulation along a 200 km long portion of the D300 highway passing through Elazığ, Bingöl, and Muş, cities located in the Eastern Anatolia region of Turkey. The heavy metal accumulation in 46 soil samples collected in 2018 and 2019 from 5 different land classes was analyzed using the ICP-MS device in an accredited laboratory. The analysis results were explained using different statistical methods depending on the standard, annual change, land class, and vegetation. Although the majority of the soil samples were within acceptable levels, the chromium (Cr) and nickel (Ni) levels of certain samples were above the standard levels. Considering the land classes, compared with other areas, residential areas (RA) contained higher levels of zinc (Zn); agricultural areas (AA) contained higher levels of chromium (Cr), cobalt (Co), nickel (Ni), zinc (Zn), cadmium (Cd), and lead (Pb); and unqualified areas (UA) contained higher levels of copper (Cu). Considering vegetation, the tree- and bush-covered soil samples contained lower amounts of Cr, Co, Ni, Cu, and Cd but higher levels of Zn and Pb compared with herbaceous or bare soil samples. A similar case also applies to the soil samples that were covered with *Quercus* sp., a natural plant cover on the route. The results and other similar studies have shown that there should be at least 15 m long ecological corridors (pollution-resistant tree-bush vegetation) between highway routes and both agricultural and residential areas.

1. Introduction

Air pollution is among the most important environmental problems faced by the modern world. Millions of people worldwide suffer health problems and some even lose their lives due to air pollution each year [1–3]. Heavy metals are the leading cause of air pollutants that create health problems. They can remain intact for a long time and accumulate without biodegradation [1, 4]. Heavy metals are released into the atmosphere due to anthropogenic activities since ancient ages and pollute natural environments such as waters, plants, and soils. Industrialization and heavy metal pollutants stemming from motor vehicles gradually reached great magnitudes [5]. The naturally found metals are divided into two groups. One of these groups is micronutrients that are needed by plants for normal growth iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), magnesium (Mg), molybdenum (Mo), and nickel (Ni)), while the other group is not essential for plant growth (cadmium (Cd), antimony (Sb), chromium (Cr), lead (Pb), arsenic (As), cobalt (Co), silver (Ag), selenium (Se), and mercury (Hg)). Both the aerial and underground organs of plants are exposed to these heavy metals [4].

There are numerous studies on the heavy metal accumulation in soils [5–13] and plants [1, 2, 8, 9, 14–17]. Heavy metal studies in the soil focus on the determination of pollution sources, while in plants the focus is on the use of plants as biomonitors. For example, Xia et al. [5] analyzed the heavy metal content of Beijing urban soils according to 5 different land classes. In this study, it was determined that the contents of Cd, Cu, Pb, and Zn originate from anthropogenic sources, while Cr and Ni contents are based on natural resources. Karim et al. [7] discussed the heavy metal

changes before and after the monsoon and determined that Cu, Zn, and Pb contents were of anthropogenic origin. Lin et al. [6] stated that urbanization and industry are responsible for 34.5% of the heavy metal (Cd, Cr, Cu, Ni, and Zn) contents of the Changhua city soils. The age of the residential areas, the distance from the city center, and population density have a high effect on the heavy metal content at Beijing urban lands, and the height of the building and the number of green areas have a low effect [13]. In the analysis of heavy metal content in soil or plant samples, Özkan [9], Arıcak et al. [16], and Bilge and Çımrın [14] discussed the changes according to the distance on the highway and Mossi [15]; Sevik et al. [2] investigated according to the traffic density. In the use of plants as a biomonitor, it was determined that plant species such as *Elaeagnus angustifolia* [17], *Pinus sylvestris* [16], *Picea pungens* [18], *Aesculus hippocastanum* L. [3], and *Ailanthus altissima*, *Biota orientalis*, *Platanus orientalis*, and *Pyracantha coccinea* [2] were used.

Industrialization, motor vehicle emission, the chemical industry, energy wastes, urban wastes, dust in the atmosphere, and plastic products are the leading causes of heavy metal pollution [5]. Increasingly using motor vehicles especially as a result of the changing life standards is responsible for a great portion of highway pollution [3]. Pollutants originating from motor vehicles are carbon monoxide, carbon dioxide, hydrocarbons, nitrogen oxides, sulfur oxide, and particle heavy metals [14]. Heavy metals can be defined as metals with a density greater than 5 g/cm^3 and an atomic number greater than 20, creating toxicity and pollution [12, 19]. More than 60 metals are included in this group including lead, Pb, Cd, Cr, Fe, Co, Cu, Ni, Hg, and Zn [10, 19]. Among the heavy metals, Pb, Ni, Hg, Cd, Cr, Fe, Cu, Mn, and Zn originate from motor vehicles, and Cd, Cr, Cu, and Zn originate from agricultural activities [5, 9, 14].

Increasing population and intense anthropogenic activities lead to the degradation of the ecosystem due to the release of heavy metals. Heavy metals in soils cause negative outcomes such as decreased microbial activity, soil productivity, biological diversity, product yield and quality, and bioaccumulation [10, 12]. Thus, monitoring heavy metal pollution and determining high-risk areas are greatly important for protecting human health [2]. Particularly periodically monitoring the routes of motor vehicles and taking certain measures are responsibilities of both the science world and environmental organizations because highway routes pass through agricultural areas and pastures that supply the nutritional needs of humans and other organisms. Urban life and natural landscape on highway routes are also potentially risky areas.

The study examines the effects of heavy metals originating from the motor vehicle traffic on different areas of use on the highway route (residential areas (RA), natural landscape (NL), agricultural areas (AA), road slope (RS), and unqualified areas (UA)). Also, the differences between the tree- or bush-covered soils and bare soils were examined. Moreover, the effect of the naturally growing oak species (*Quercus* sp.) in the highway landscape on decreasing the heavy metal accumulation was investigated.

2. Materials and Methods

2.1. Description of the Study Area. The study examines the D300 highway passing through Elazığ, Bingöl, and Muş located in the Eastern Anatolian region of Turkey (Figure 1). The highway has national and international importance and a length of 1888 km. It is known that this highway has a history of 2800 years and goes back to the Urartu period [20]. However, in the last 10 years, it has lost its historical feature with road widening and route changes. The sample collection locations start at the historical Murat Bridge on Bingöl–Muş highway and end at Bingöl-Elazığ-bound Keban Dam. The study area involves a highway route of about 200 km long. Soil samples were collected from 23 locations on the left and right sides of the highway route. There is a maximum of 10 km distance between the sample stations. On the study route, 3243 vehicles daily pass through the 1st sample location (Murat Bridge junction, Turkey), 9658 vehicles daily pass through the 12th sample location (central Bingöl, Turkey), and 7069 vehicles daily pass through the 23rd sample location (Keban Dam, Turkey) by annual average [21]. Traffic density of the research route can be defined as "traffic light density." However, regarding the vehicle class, the ratio of medium- and heavy-duty commercial vehicles is high. Accordingly, 30% of the vehicles using the route in sampling point 1, 35% at sampling point 12, and 31% at sampling point 23 were medium- and heavy-load commercial vehicles. Also, this route has international importance since it is one of the highway routes linking Iran and Turkey.

2.2. Collection of Soil Samples and Preparation for Analyses. The samples were collected from the soil covers that had a depth of 0–15 cm and were at a 0–5-meter distance from the highway. The samples were collected two times in August 2018 and August 2019 from the same locations. Of the sample locations, 9 represented residential areas, 4 represented natural landscape areas (dominant plant cover: *Quercus* sp.), 2 represented wheat-planted agricultural areas, 5 represented road slopes, and 3 represented unqualified areas. Eleven of the sample collection areas had trees and bushy cover, while 12 were plant free (bare or herbaceous vegetation) (Table 1).

The soil samples were dried at room temperature between two months and 1 year and sieved with a 2 mm steel sieve. However, following the normal drying process, soil samples were kept in a dry environment until the time of analysis. Also, considering that the humidity rate of the area where soil samples were taken was very low, soil samples were taken in summer and there was no precipitation in at least for the last two-month-period, it was understood that sufficient dryness was achieved in the soil.

2.3. The Physical and Chemical Analyses Methods of Soil Samples. The pH ($pH_{1:2.5}$), electrical conductivity ($EC_{1:2.5}$), organic matter content (OM), and lime content ($CaCO_3$) were determined according to the methods explained by [22]. The lime percentages of the soil samples were analyzed

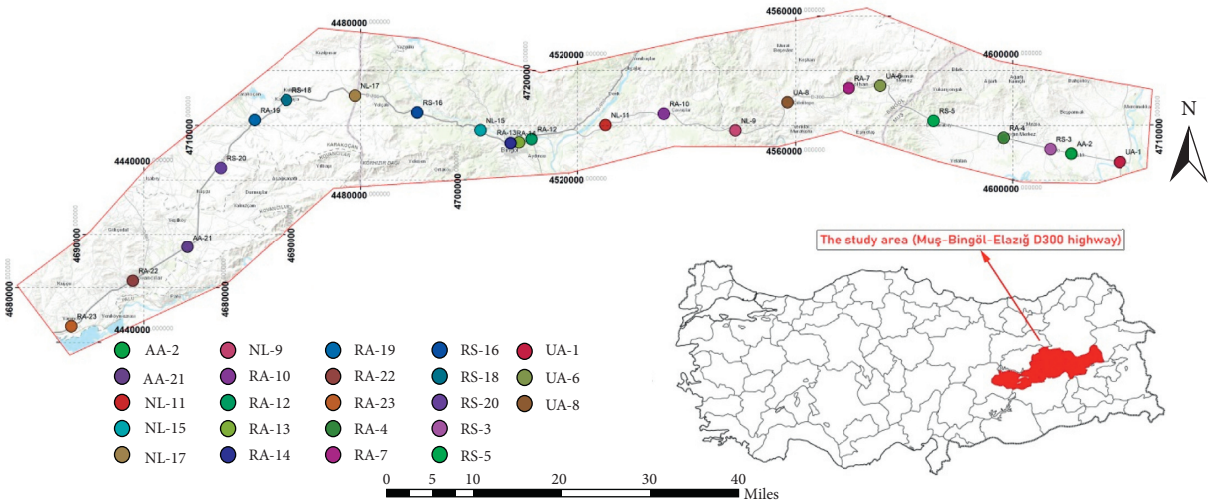


Figure 1: Research area and location of sampling points.

Table 1: Classification of soil samples.

Sample class-land use type	Sample number	Description	Vegetation (tree and shrub cover)
Residential area (RA)	4[a], 7[a], 10[a], 19[a], 22[a], 23[a], 12[b], 13[b], 14[b]	[a]Population <50.000 [b]Population >50.000	4, 7, 12, 13, 14, 19, 22
Agriculture area (AA)	2, 21	Plowed wheat field	—
Natural landscape (NL)	9, 11, 15, 17	Natural vegetation (*Quercus* sp.)	9, 11, 15, 17
Road slope (RS)	3, 5, 16, 18, 20	At least 30% slope	—
Unqualified areas (UA)	1, 6, 8	Useless land	—

using the calcimeter method [23], organic matter contents were analyzed using the modified Walkley–Black method [24], and pH values were determined according to Jackson [25].

2.4. Heavy Metal Content Analyses of the Soil Samples (ICP-MS). Heavy element (Pb, Cd, Ni, Cr, Co, Cu, and Zn) contents of soils were determined by using HNO_3:HCl (3:1) acid mixture with Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) [26]. The analyses were carried out in the Central Laboratory of Bingöl University. One gram of the soil samples was transferred to the Teflon cups of the microwave oven (CEM brand Mars 6, OneTouch-USA model); 10 ml concentrated nitric acid (65%) was added to each sample, and the mixture was burnt at 200°C in 20–25 minutes and rested for 10 minutes. ICP-MS calibration solutions were obtained by diluting the commercially available multielement standards with 1% supra pure nitric acid-ultrapure water. The ICP-MS NexION® 2000 C (PerkinElmer® Inc., USA) device, which contained a quartz nebulizer, cyclonic spray chamber, and an integrated autosampler, was used for the element analysis of the samples. Syngistix for ICP-MS software version 2.2 was used to control the device, including adjustment, data acquisition, and data analysis in the analyses. The ICP-MS was calibrated before each measurement. For the control of the element analyses, 100 ppb ^{45}Sc, ^{89}Y internal standard was used [27].

2.5. Statistical Analysis of the Soil Samples. In addition to basic statistical parameters such as minimum, maximum, standard deviation, and mean and paired and multiple comparison analysis methods were used in the analyses of the soil samples. The normality test was carried out separately for each element. The Kolmogorov–Smirnov normality test was applied to determine the testing method for the comparisons. According to the results of the Kolmogorov–Smirnov normality test, it was found necessary to use parametric tests for the analysis of Cr, Co, Zn, and Pb analyses, whereas nonparametric tests for the analysis of Cu and Ni. The heavy metal accumulation levels of the land classes were analyzed using one-way ANOVA for Cr, Co, Zn, and Pb and the Kruskal–Wallis H test for Cu and Ni. Also, the statistical significance of heavy metal accumulation values in terms of vegetation was analyzed using the Mann–Whitney U test, while the heavy metal accumulation with respect to the vegetation structure was analyzed using the Mann–Whitney U test.

3. Results and Discussion

3.1. Physical and Chemical Properties of the Soil Samples. The pH, organic matter (%), $CaCO_3$ (%), and electrical conductivity (EC) (dS/m) values of the soil samples collected from the study area were determined (Table 2). The pH values of the soil samples varied from 6.85 to 7.96; organic matter contents varied from 1.5% to 6.36, lime contents

Table 2: The physical and chemical analyses of soil samples.

Land-use type	Sample number	pH	EC (dS/m)	$CaCO_3$ (%)	Organic matter (%)
AA	2	7.56	0.54	2.83	1.69
	21	7.65	0.53	18.85	2.03
NL	9	7.02	0.22	1.51	3.63
	11	7.74	0.35	4.24	1.72
	15	7.76	0.21	1.18	1.32
	17	6.87	0.59	1.84	3.00
RA	4	6.85	1.02	6.50	1.72
	7	7.57	0.41	3.96	3.05
	10	7.64	0.20	1.88	1.14
	12	7.82	0.43	2.36	2.42
	13	7.25	0.44	1.27	2.56
	14	7.41	0.40	2.07	1.46
	19	7.64	0.48	8.06	1.51
	22	7.83	1.24	20.35	6.36
	23	7.96	0.26	47.12	2.37
RS	3	7.85	0.28	28.27	4.40
	5	7.72	0.39	2.36	1.53
	16	7.61	0.13	1.98	0.21
	18	7.62	0.10	1.23	0.28
	20	7.41	0.15	1.41	1.19
UA	1	7.43	0.79	19.69	3.18
	6	7.62	0.17	1.37	1.06
	8	7.8	0.18	1.41	4.06
AA_Mean		7.61	0.53	10.84	1.86
NL_Mean		7.35	0.34	2.19	2.42
RA_Mean		7.55	0.54	10.40	2.51
RS_Mean		7.64	0.21	7.05	1.52
UA_Mean		7.62	0.38	7.49	2.77

varied from 1.17% to 47.1%; and EC values varied from 0.10 dS/m to 1.24 dS/m. Soil samples were composed of different, neutral, or slightly alkaline and low-lime soils. Examining the physical and chemical contents of soil samples according to the land class, it was seen that the organic substance content was the highest in the UA soils, whereas it was the lowest in the RS classes. Also, the organic matter content of agricultural soils was low. This indicates that agricultural lands are inefficient and exhausted. It was observed that pH and EC values of soil samples were similar according to the average of the land class. In terms of lime, it was determined that AA and RA soils were similar and higher than those of the other classes, whereas NL soils had the lowest value.

3.2. Heavy Metal Contents of the Soil Samples. Table 3 shows the heavy metal accumulation values (for 7 elements, min., max., and mean) of the soil samples that were collected in 2018 and 2019 from 23 locations in 5 different land classes on the study route. When the change in heavy metal accumulation by years is considered, according to the mean values of 23 soil samples, Cr, Cu, and Pb increased, while Co, Ni, Zn, and Cd decreased. The increase is mostly attributed to motor vehicles and the increase due to agricultural activities are estimated to be limited [9, 14]. A greater portion of the highway route has low-density traffic compared with the conditions in Turkey. Locations no. 12 and 23 had the highest-density traffic. The Cr, Cu, Ni, and Pb concentrations at these locations were above the mean value. Only 3 of the samples collected in 2018 (nos. 13, 15, and 21) had low concentrations of Cd. No trace of Cd was detected in the soils collected in 2019 and 20 soil samples collected in 2018 (not detected: ND).

Heavy metal accumulation values in the soil alone do not make sense. Each country sets permissible limit values in line with its own conditions. In Turkey, the standards related to soil pollution are determined according to the "Control of Soil Pollution Regulation" (Table 4).

According to the results of the Table 3, the majority of the heavy metal levels of the analyzed soil samples were below the limit values given in Table 4. However, the Cr and Ni levels of some samples were above the standard levels. The Cr level exceeded the standard in agricultural soil no. 2 in 2018 (104.5 mg/kg) and soil sample no. 23 in 2019 (212.63 mg/kg). The high Cr value of the sample from the location no. 23 is attributable to the ferrochromium factory at a 500 meter distance from the sample collection location. In 2018, the Cr value was measured to be 69.48 mg/kg at the ferrochromium factory location (sample no. 23). The reason for this can be explained as the factory stopped production in 2018. According to Table 3, most of the minimum values are seen at station 18 (road slope). The stations 12, 13, and 14 in the Bingöl city center had higher values than those of the other stations.

The Ni values exceeded the standards in locations no. 1, 2, 4, 8, and 21 in 2018 and locations no. 1, 2, 17, 19, and 21 in

Table 3: Heavy metal content values of all soil samples (mg/kg).

S.N.	2018							2019						
	Cr	Co	Ni	Cu	Zn	Cd	Pb	Cr	Co	Ni	Cu	Zn	Cd	Pb
1	83.9	16.5	106.7	22.7	91.5	ND	106.0	91.3	12.3	93.6	66.3	94.2	ND	136.2
2	104.5	23.3	138.7	27.4	77.6	ND	68.5	87.6	20.0	112.8	22.9	66.1	ND	79.7
3	38.3	10.3	54.7	10.5	20.1	ND	21.5	33.4	7.8	47.3	8.8	19.7	ND	20.7
4	92.7	12.3	97.5	22.1	83.0	ND	59.1	23.8	3.8	28.0	16.9	54.7	ND	71.8
5	17.3	7.0	23.1	10.4	47.5	ND	42.9	28.4	11.0	34.1	15.4	82.4	ND	77.3
6	48.7	18.0	32.1	16.5	38.5	ND	11.6	14.2	18.4	28.3	21.2	52.3	ND	32.1
7	27.9	12.9	38.4	12.2	175.4	ND	31.8	20.3	6.8	25.0	9.9	72.6	ND	36.2
8	72.5	27.3	115.7	24.5	56.2	ND	34.1	8.4	5.5	11.9	9.3	48.7	ND	25.7
9	27.0	9.9	40.8	13.7	66.9	ND	76.3	20.7	8.0	28.0	9.6	51.7	ND	46.9
10	25.0	16.7	30.1	12.0	50.5	ND	87.2	17.9	13.2	18.9	10.0	50.6	ND	50.3
11	12.9	5.6	17.9	6.9	34.0	ND	44.3	27.9	12.1	31.1	12.8	66.4	ND	44.7
12	39.3	13.4	44.0	20.8	81.5	ND	70.9	22.3	9.1	27.3	19.8	63.7	ND	68.9
13	47.6	17.6	62.8	25.6	122.5	1.4	205.3	23.1	10.5	34.6	14.6	52.3	ND	50.2
14	42.2	10.9	54.9	20.7	130.5	ND	147.7	25.3	8.6	37.7	17.1	84.9	ND	152.9
15	47.6	13.1	49.3	14.1	99.1	0.1	77.8	41.2	16.3	52.0	18.2	56.8	ND	131.2
16	52.4	33.7	50.3	15.9	46.3	ND	42.9	24.8	13.9	34.4	21.2	26.1	ND	21.6
17	33.7	17.9	38.6	13.1	42.0	ND	51.0	65.4	33.3	76.8	28.4	105.3	ND	118.6
18	2.1	0.5	1.7	1.4	22.2	ND	18.7	7.7	1.6	5.3	4.0	66.7	ND	58.7
19	35.0	9.2	44.9	15.3	121.2	ND	34.6	81.9	23.2	110.1	27.7	114.4	ND	74.2
20	6.8	10.4	8.3	8.3	45.0	ND	31.2	54.6	19.6	38.4	17.9	94.9	ND	64.8
21	74.4	23.8	123.9	32.4	55.8	2.3	93.7	68.7	18.0	100.9	23.4	49.7	ND	38.1
22	43.8	8.7	53.6	21.1	46.7	ND	27.5	62.1	11.6	67.1	25.5	72.5	ND	41.4
23	69.5	8.9	53.5	15.8	40.1	ND	19.6	212.6	8.7	50.0	14.7	29.2	ND	13.6
Mean	45.4	14.3	55.7	16.7	69.3	.2	61.1	46.3	12.8	47.6	18.9	64.2	.0*	63.3

Minimum; Maximum; Mean; Detection above limit; ND Not detected

Table 4: Heavy metal limits in Turkey soil [9].

Elements	pH 5-6 (mg/kg dried soil)	pH > 6 (mg/kg dried soil)
Pb	50	300
Cd	1	3
Ni	30	75
Cr	100	100
Co	80	80
Cu	50	140
Zn	150	300

2019. It is noteworthy that the Ni values in the agricultural soils (sample nos. 2 and 21) were above the standard levels in both years. The sources of Ni in the soil are phosphorus fertilizers and volcanic host rocks [10]. Thus, we think that uncontrolled fertilization is carried out in the agricultural soils. Moreover, industrial organizations and urbanization also play a role in high Cr and Ni levels [6].

3.3. The Heavy Metal Contents of Soil Samples Based on the Land-Use Classification. The study also examined the changes in the soil samples with respect to the land-use classes (Figure 2). The majority of the soil samples were excluded from the evaluation since the Cd value was below the limit.

According to the results in Figure 2, RS soils were better than the other land classes. It can be argued that the decrease in metal contents as a result of leaching due to precipitation is associated with this result. Considering the results both in terms of years and mean values, the residential areas had higher levels of Zn, agricultural areas had higher levels of Cr, Co, Ni, Zn, Cd, and Pb, and unqualified areas had higher levels of Cu compared with other areas. In contrast, the Co levels of the residential areas and Cr, Ni, Cu, Zn, and Pb levels in road slopes were lower compared with other areas. As an element found in parchment papers, glass, car tires, tv screens, dry batteries, and electrical equipment, higher levels of Zn were detected in the residential areas [12]. Both the agricultural activities-originated pollutants (Cr and Zn) and motor vehicle-originated pollutants (Pb, Ni, Cd, and Co) rendered agricultural areas riskier [8, 10, 11]. Heavy metal accumulation values in terms of land classes are as follows:

For Cr: AA > UA > RA > NL > RS

For Co: AA > UA > NL > RS > RA

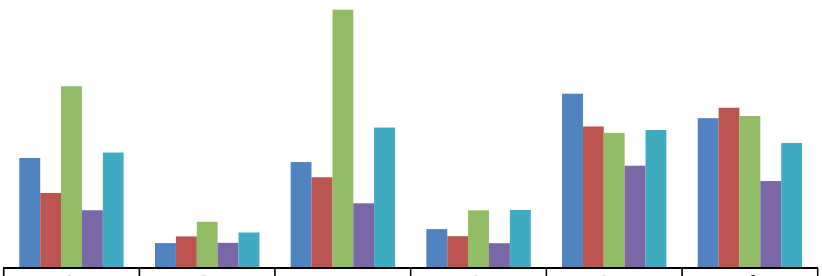
For Ni: AA > UA > RA > NL > RS

For Cu: UA > AA > RA > NL > RS

For Zn: RA > NL > UA > AA > RS

For Pb: NL > AA > RA > UA > RS

The significance levels of the changes in the soil samples with respect to the land classes were tested. According to the Kolmogorov–Smirnov test that was applied to determine the method for the changes in land soil heavy metal levels with respect to land structure, the Kruskal–Wallis H test was used for Cu and Ni and ANOVA was used for Cr, Co, Zn, and Pb. Since



	Cr	Co	Ni	Cu	Zn	Pb
RA	50.69	11.45	48.8	17.88	80.35	69.07
NL	34.54	14.53	41.82	14.61	65.27	73.86
AA	83.77	21.27	119.09	26.52	62.3	70.01
RS	26.57	11.57	29.76	11.38	47.09	40.03
UA	53.2	16.34	64.71	26.73	63.57	57.61

Figure 2: Heavy metal mean values of soil samples according to the land-use class (mg/kg).

Cd was not detected in the majority of the soil samples, it was not analyzed. According to ANOVA, the Cr, Co, Zn, and Pb contents of the soil samples did not vary depending on the land classes ($p > .05$). It was determined that the mean values of these elements did not vary according to the land-use class. The significance of the changes in Cu and Ni according to the land class was analyzed using the Kruskal–Wallis H test. According to the Kruskal–Wallis H test for the Cu and Ni levels, the changes were statistically significant ($p < .05$). However, the Dunn test was utilized to determine between which land classes the change was significant. Table 5 shows the Dunn test results for the direction and significance of the changes between paired groups.

According to the results of the Dunn test, the lower Cu concentration of RS compared with RA, UA, and AA and the high Cu concentration of AA compared with NL and RA were significant. In other words, the differences between RS and RA, UA, and AA in the mean values of Cu according to the land class were found to be statistically significant ($p < .05$). Similarly, the difference between the Cu contents of AA soils and RA and RL soils was found to be significant. Remarkably, AA soils had higher Cu content. Also, the Ni contents of AA soil samples were much higher compared to other land classes, and the difference was found to be statistically significant ($p < .05$).

3.4. The Heavy Metal Contents of Soil Samples Based on the Vegetation. In the research, the protective effect of vegetation on the heavy metal accumulation of the soil was also investigated. In line with another objective of the study, without any distinction, the differences between the tree-bush-covered areas and plant-free areas (bare lands or herbaceous vegetation) in terms of heavy metal accumulation were examined (Figure 3).

According to Table 5, the soil samples covered with trees and bushes had lower levels of Cr, Co, Ni, Cu, and Cd while having higher levels of Zn and Pb. A similar case was also observed for the mean values of the four, *Quercus* sp.-covered (the natural plant cover) soil samples. In our study, *Quercus* sp. shows the similar effect on the accumulation of heavy metal with the other plant cover. Also, various studies have highlighted the use of plants as biomonitors [1–3, 8, 9, 14–18], since plants are used as tools to remove heavy metals from the air and improve air quality [18]. The study investigates the role of plants in protecting soils. Green areas and vegetal arrangements can partially protect soils from the threat of heavy metals [13]. However, there is no numerical data on to what degree vegetation can protect soils against heavy metals. This is due to the lack of information on fertilizations made to the sample collection locations.

The significance levels of the changes in the soil samples with respect to the vegetation were tested. The Mann–Whitney U test, which was carried out to determine the effect of the structure of vegetation on heavy metal accumulation, revealed that there were no significant differences in the Cr, Co, Ni, and Cu concentrations ($p > .05$). However, the Zn and Pb contents of the soil samples varied depending on vegetation, and the differences were statistically significant (Table 6).

Various studies investigating the heavy metal pollution due to motor vehicles using soil and plant samples, the changes depending on the distance to highway, soil depth, soil structure, and content are considered [1, 2, 9, 14–16]. Particularly, it has been determined that heavy metal content decreases depending on the distance of the highway [9, 14, 16]. According to Bilge and Çımrın [14], it was observed that Pb, Cd, Ni, Cr, and Cu contents decreased as they were moved away from the highway. The concentration of some heavy metals was decreased at least 15 meters from the road such as Pb from 2.24 ppm to 1.06 ppm, Cd from 0.4 ppm to 0.30 ppm, Ni from 42 ppm to 32 ppm, Cr from 28 to 23, and Cu from 14.2 to 11.8 ppm [14]. On the other hand, the plants that can collect heavy metals within the body can also contribute to the cleaning of the heavy metal [15, 16, 18, 28, 29]. Likewise, the upper layers of the agricultural soils are exposed to a greater level of heavy metal accumulation than the lower layers [11]. Therefore, some

Table 5: Dunn's test results of Cu and Ni contents.

Sample 1-sample 2	Cu				Ni			
	Test statistic	Std. err.	Std. test statistic	p	Test statistic	Std. err.	Std. test statistic	p
RS-NL	4.20	6.37	.660	0.51	5.63	6.37	.88	0.38
RS-RA	11.37	5.29	2.15	0.03 *	8.33	5.29	1.57	0.12
RS-UA	−16.87	6.93	−2.43	0.02 *	−10.17	6.93	−1.47	0.14
RS-AA	26.70	7.94	3.36	0.01 *	28.00	7.94	3.53	0.00 *
NL-RA	7.17	5.70	1.26	0.21	2.71	5.70	.48	0.64
NL-UA	−12.67	7.25	−1.75	0.08	−4.54	7.25	−.63	0.53
NL-AA	−22.50	8.22	−2.74	0.00 *	−22.38	8.22	−2.72	0.01 *
RA-UA	−5.50	6.32	−.87	0.39	−1.83	6.33	−.29	0.77
RA-AA	−15.33	7.42	−2.07	0.04 *	−19.67	7.42	−2.65	0.01 *
UA-AA	9.83	8.66	1.14	0.26	17.83	8.66	2.06	0.04 *

* $p < .05$ (95%).

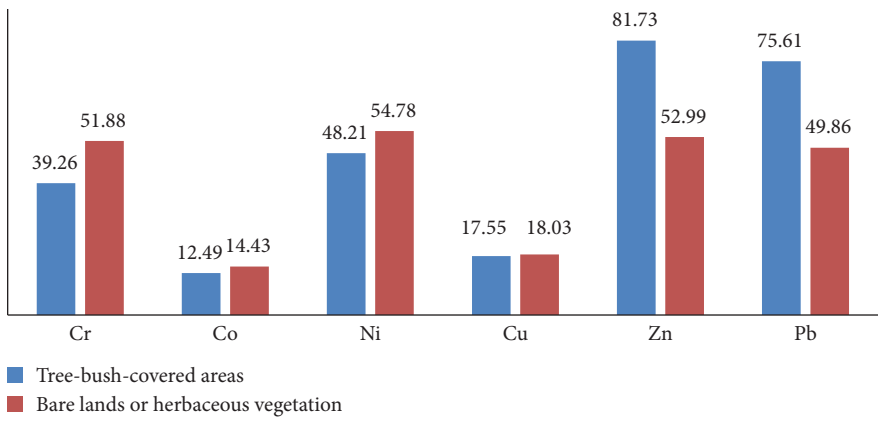


Figure 3: Heavy metal accumulation values of soil samples according to vegetation structure (mg/kg).

Table 6: Mann–Whitney U test results of Zn and Pb contents.

Element	Group	N	Mean rank	Sum of ranks	U	p
Zn	Yes	22	29.86	657	124	0.00 *
	No	24	17.67	424		
Pb	Yes	22	28.09	618	163	0.03 *
	No	24	19.29	463		

* $p < .05$.

researchers recommend not consuming plants that are grown near highways [30].

4. Conclusion

A general examination of the annual changes in the soil samples shows that there is not a great problem of concern in terms of heavy metal accumulation in the examined route. On the other hand, the results reveal a need for periodically monitoring the high-risk areas. For the study route, the sample location no. 23 near the chromium factory poses the greatest risk. The residential areas and agricultural areas near the factory carry the risk of Cr and Ni accumulation. Therefore, the heavy metal accumulation levels in these areas should be periodically (annually or semiannually) analyzed. The agricultural areas that are very close to the highway also have a similar risk. Both this research and the other research results reveal that a 15 m ecological corridor (pollution-resistant tree-bush vegetation) between the highway route and agricultural and residential areas is necessary. An ecological corridor will improve agricultural product quality and human health and contribute to environmental quality.

In conclusion, the heavy metal accumulation levels in the land classes on the highway route differed. This is a natural result of different pollution factors. Moreover, vegetation type affected the heavy metal accumulation in the soils. Tree and bush covers are estimated to partially protect the soils from heavy metals. However, more detailed and long-term scientific studies are needed to understand against which elements and to what degree the tree and bush covers protect the soils.

Data Availability

Research findings are available from Bingöl University Central Laboratory. They are accessible.

Additional Points

Highlights. (i) Vegetation type affected the heavy metal accumulation in the soils. (ii) Tree and bush covers are estimated to partially protect the soils from heavy metals. (iii) *Quercus sp*. did not have a different effect on heavy metal accumulation from the other plant cover. (iv) Zn and Pb contents varied depending on vegetation, and the differences were statistically significant. (v) 15 m ecological corridor between the highway route and both agricultural and residential areas is necessary.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

Acknowledgments

The authors would like to thank Asst. Prof. Dr. Yasin Demir and Prof. Dr. Ali Rıza Demirkiran from Bingöl University for their help with the analyses of the soil samples.

References

[1] A. Turkyilmaz, H. Sevik, M. Cetin, and E. Saleh, "Changes in heavy metal accumulation depending on traffic density in some landscape plants," *Polish Journal of Environmental Studies*, vol. 27, no. 5, pp. 2277–2284, 2018.

[2] H. Sevik, H. B. Ozel, M. Cetin, H. U. Özel, and T. Erdem, "Determination of changes in heavy metal accumulation depending on plant species, plant organism, and traffic density in some landscape plants," *Air Quality, Atmosphere & Health*, vol. 12, no. 2, pp. 189–195, 2019.

[3] A. A. Jawed and A. E. S. A. Aisha, "Usability of horse chestnut (Aesculus hippocastanum L.) as biomonitor for monitoring some heavy metal concentrations caused by traffic," *International Journal of Engineering, Design and Technology*, vol. 1, no. 1, pp. 16–23, 2019.

[4] A. Emamverdian, Y. Ding, F. Mokhberdoran, and Y. Xie, "Heavy metal stress and some mechanisms of plant defense response," *The Scientific World Journal*, vol. 2015, Article ID 756120, 2015.

[5] X. Xia, X. Chen, R. Liu, and H. Liu, "Heavy metals in urban soils with various types of land use in Beijing, China," *Journal of Hazardous Materials*, vol. 186, no. 2-3, pp. 2043–2050, 2011.

[6] Y.-P. Lin, T.-P. Teng, and T.-K. Chang, "Multivariate analysis of soil heavy metal pollution and landscape pattern in Changhua county in Taiwan," *Landscape and Urban Planning*, vol. 62, no. 1, pp. 19–35, 2002.

[7] Z. Karim, B. A. Qureshi, M. Mumtaz, and S. Qureshi, "Heavy metal content in urban soils as an indicator of anthropogenic and natural influences on landscape of Karachi-a multivariate spatio-temporal analysis," *Ecological Indicators*, vol. 42, pp. 20–31, 2014.

[8] N. B. Delia, "Assessing the degree of dispersion and distribution of heavy metals in soil and plants associated with area of influence of a coal power plant," *Journal of Environmental Protection and Ecology*, vol. 16, no. 2, pp. 453–460, 2015.

[9] A. Özkan, "Antakya-cilvegözü karayolu etrafındaki tarım arazilerinde ve bitkilerdeki ağır metal kirliliği," *Çukurova Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi*, vol. 32, no. 3, pp. 9–18, 2017.

[10] E. E. Kara and E. Kara, "Effects of soil heavy metal contamination on human health and solution offers," *Turkish Journal of Scientific Reviews*, vol. 11, no. 1, pp. 56–62, 2018.

[11] M. A. Kurt, "Comparison of trace element and heavy metal concentrations of top and bottom soils in a complex land use area," *Carpathian Journal of Earth and Environmental Sciences*, vol. 13, no. 1, pp. 47–56, 2018.

[12] T. Seven, B. Can, B. N. Darende, and S. Ocak, "Heavy metals pollution in air and soil," *Ulusal Çevre Bilimleri Araştırma Dergisi*, vol. 1, no. 2, pp. 91–103, 2018.

[13] T. Xie, M. Wang, W. Chen, and H. Uwizeyimana, "Impacts of urbanization and landscape patterns on the accumulation of heavy metals in soils in residential areas in Beijing," *Journal of Soils and Sediments*, vol. 19, no. 1, pp. 148–158, 2019.

[14] U. Bilge and K. M. Çimrin, "Heavy metal pollution in soils adjacent to the Kızıltepe–viranşehir road," *Journal of Agricultural Sciences*, vol. 19, pp. 323–329, 2013.

[15] M. M. M. Mossi, *Determınatıon of heavy metal accumulatıon in the some of landscape plants for shrub forms*, Ph.D. thesis, Kastamonu University, Graduate School of Natural and Applied Sciences, Department of Forest Engineering, Kastamonu, Turkey, 2018.

[16] B. Aricak, M. Cetin, R. Erdem, H. Sevik, and H. Cometen, "The change of some heavy metal concentrations in scotch pine (Pinus sylvestris) depending on traffic density, organelle and washing," *Applied Ecology and Environmental Research*, vol. 17, no. 3, pp. 6723–6734, 2019.

[17] M. Zengin and N. Yıldız, "Kentsel Mekânlarda Kullanılan "elaeagnus angustifolia L." Nin Yaprak Örneklerinde Ağır metal birikimi: Erzurum Örneği," *Kahramanmaraş Sütçü İmam Üniversitesi Tarım Ve Doğa Dergisi*, vol. 22, no. 4, pp. 517–525, 2019.

[18] O. Çobanoğlu, "The possibilities of using blue spruce (picea pungens engelm) as a bio-monitor by measuring the recent accumulation of heavy metals in its leaves," M.Sc. thesis, Kastamonu University Institute of Science, Kastamonu, Turkey, 2019.

[19] Ö. Kahvecioğlu, G. Kartal, A. Güven, and S. Timur, *Metallerin Çevresel Etkileri-I*, İTÜ Metalurji Ve Malzeme Mühendisliği Bölümü, İstanbul, Turkey, 2004.

[20] Anonymous, https://www.gunisigigazetesi.net/dunyanin-en-eski-yolu-bingol-elazig-karakocan-makale,10693.html, 2019.

[21] Anonymous, "General directorate of highway, traffic data," 2019, https://www.kgm.gov.tr/Sayfalar/KGM/SiteEng/Root/Traffic.aspx.

[22] A. L. Page, R. H. Miller, and D. R. Keeney, *Methods of Soil Analysis Part 2. Chemical and Microbiological Properties*, Academic Press, Inc, Cambridge, MA, USA, 2nd edition, 1982.

[23] L. E. Allison and C. D. Moodie, "Carbonate," in *Methods of Soil Analysis. Part 2*, et al.pp. 1379–1400, ASA, CSSA, and SSSA, Madison, WI, USA, 2nd edition, 1965.

[24] A. Walkley, "A critical examination of a rapid method for determining organic carbon in soils-effect of variations in digestion conditions and of inorganic soil constituents," *Soil Science*, vol. 63, no. 4, pp. 251–264, 1947.

[25] M. L. Jackson, *Soil Chemical Analysis*, Prentice Hall Inc. EngleWood Cliffs, Upper Saddle River, NJ, USA, 1962.

[26] M. Chen and L. Q. Ma, "Comparison of three aqua regia digestion methods for twenty Florida soils," *Soil Science Society of America Journal*, vol. 65, no. 2, pp. 491–499, 2001.
[27] Anonymous, *The ICP-MS Analysis Report*, The Central Laboratory of Bingöl University, Bingöl, Turkey, 2020.
[28] E. A. A. Saleh, *Determination of heavy metal accumulation in some landscape plants*, Ph.D. thesis, Kastamonu University Institute of Science Department of Forest Engineering, Kastamonu, Turkey, 2018.
[29] T. Erdem, "The change of heavy metal concentrations in some plants due to species, organelles and traffic densities," Master thesis, Kastamonu University Institute of Science Department of Forest Engineering, Kastamonu, Turkey, 2018.
[30] K. Gezer and O. Kaygusuz, "An assessment of the heavy metal content of various wild edible mushrooms in the Denizli province, Turkey," *Journal of Environmental Protection and Ecology*, vol. 15, no. 2, p. 425, 2014.