



# Using Topsoil Analysis to Determine and Map Changes in Ni Co Pollution

Mehmet Cetin · Akram Mohamed Omar Aljama ·  
Osama B. Muragaa Alrabiti · Fatih Adiguzel · Hakan Sevik ·  
Ilknur Zeren Cetin

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**Abstract** The change in soil quality due to soil pollution significantly affects the ecosystem. The pollutants in the air also pass to the soil after a while, and therefore the soil is also the environment that best reflects the pollution level. Heavy metals are among soil and environmental pollutants; they are especially notorious because many of them can be toxic to living things even at low concentrations, tend to bioaccumulate in living things, and stay in nature for a long time. Therefore, monitoring heavy metal concentrations is of great importance. In this study, it is aimed to determine and map the Ni and Co pollution with the help of top soils in the city center. Top soil samples were taken from these regions and Ni and Co analyses were made, and the obtained values were evaluated statistically. Additionally, the data were transferred to geographic information systems (GIS)

using ArcGIS 10.7 software, and then modeled with the kriging method, one of the interpolation methods, and pollution maps were created. As a result of the study, it was determined that the areas with the highest Ni and Co concentrations were generally located in the center of the study area. This shows that Ni and Co pollution increases in areas with high levels of human activities.

**Keywords** Soil · Heavy metal · Ni · Co

## 1 Introduction

As in the whole world, environmental problems have increased with the increase in residential areas

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M. Cetin  
Department of City and Regional Planning, Faculty of Architecture, Ondokuz Mayıs University, Samsun, Turkey  
e-mail: mehmet.cetin.landscape.architect@gmail.com; mehmet.cetin@omu.edu.tr

A. M. O. Aljama (✉) · O. B. M. Alrabiti  
Department of Materials Sciences and Engineering, Institute of Science, Kastamonu University, Kastamonu, Turkey  
e-mail: akramaljamakastam@gmail.com

F. Adiguzel  
Department of Geography, Faculty of Arts and Sciences, Nevsehir Haci Bektas Veli University, Nevsehir, Turkey

H. Sevik  
Department of Environmental Engineering, Faculty of Engineering and Architecture, Kastamonu University, Kuzeykent Campus, 37150 Kastamonu, Turkey

*Present Address:*  
I. Zeren Cetin  
Program of Landscape and Ornamental Plants Cultivation, Department of Park and Garden Plants, Samsun Vocational School, Ondokuz Mayıs University, Samsun, Turkey  
e-mail: ilknur.zerencetin@ogrenci.bartın.edu.tr; ilknur.cetin@omu.edu.tr

I. Zeren Cetin  
YOK 100/2000 Scholarship, Program of Sustainable Forestry, Department of Forest Engineering, Institute of Graduate School, Bartın University, Bartın, Turkey

due to the increasing population in Turkey, and this situation has brought many problems with it (Kalayci Onac et al., 2021; Kilicoglu et al., 2021). The most important among these problems is considered to be heavy metal pollution (Arıcak et al., 2020; Cesur et al., 2021, 2022). Because some of the heavy metals can be toxic and deadly for living things even at low concentrations, they bioaccumulate in living organisms, and the concentrations of these heavy metals in nature are constantly increasing (Sevik et al., 2019a, b; Turkyilmaz et al., 2019). The most important reason for this is that, depending on the increasing industrial activities, the heavy metals in the underground are extracted and used as raw materials in the industry and thus released into the nature (Koc, 2021a; Savas et al., 2021). Therefore, especially in regions where industry and traffic activities are intense, soil (Bayraktar et al., 2019a, b; Gencel et al., 2021a, b), air (Cetin et al., 2019a, b; Elsunousi et al., 2021), and water (Ucun Ozel et al., 2019) heavy metal concentrations increase due to anthropogenic activities (Arıcak et al., 2019).

Soil is one of the elements most affected by the increase in pollution. Soils are both a nutrition and living environment for plants and one of the most important components of the environment. Turkey is described as one of the 19 countries whose arable land resources are depleted. Soil resources, which are so limited, are exposed to pollutants from various sources in Turkey as well as all over the world. Soil pollution is an increasing threat to human health and environmental quality (Özdel, 2010).

Heavy metals released into the air from polluting sources, after a while, descend to the soil surface with the effect of gravity and thus accumulate in the top soil. Therefore, top soils are the most important indicators showing the level of heavy metal pollution in the air. For this reason, many studies have been carried out on the determination of heavy metal pollution with topsoil analysis, especially in urban areas (Rybak et al., 2020; Sutkowska et al., 2020).

Among the heavy metals, Ni and Co are the most dangerous and deadly ones in terms of human and environmental health (Cetin et al., 2020). In the studies, it has been determined that the concentrations of Ni and Co elements are at very high levels, especially in urban areas (Koc et al., 2021). The high density of people living in a unit area in these areas causes the number of people affected by this pollution to be

high. Therefore, it is of great importance to determine the polluted areas in terms of Ni and Co, especially in areas with high population density. In this study, it is aimed to determine and map the Ni and Co pollution in the city center with the highest population density in Ankara, the capital and the second largest city of Turkey, with the help of top soils.

## 2 Materials and Methods

Within the scope of the study, first of all, the region with the highest population density in the city center of Ankara was determined. Later, this region was divided into sub-regions with different characteristics by grid method, and then the points where the traffic density was at different levels were determined in these sub-regions. Five different points were determined according to the traffic density in the sub-regions and the points to be taken as examples were determined to represent these regions. Thus, samples were taken from 50 different points in accordance with the purpose of the study.

Soil samples were taken from the top soil (0–5 cm depth) from the points determined by the preliminary studies, three from each point, and the samples were labeled and brought to the laboratory. Soil brought to the laboratory was sieved and placed in glass petri dishes, and dried for 15 days until room dry, and then in an oven at 45 °C for 15 days. Since it is difficult to homogenize the soil samples used in the study, 6 replications were studied. Thus, the study was completed on 900 samples as 50 points, 3 samples, and 6 replications.

The collected samples were weighed 0.5 g after pretreatment and placed in tubes designed for microwave, and 10 mL of 65% HNO<sub>3</sub> was added. The prepared samples were then burned in a microwave device at 280 PSI and 180 °C for 20 min. After the processes were completed, the tubes were removed from the microwave and allowed to cool, and after cooling, deionized water was added to make up to 50 mL.

The samples prepared for analysis were analyzed with the help of ICP-OES device and Ni and Co concentrations were determined. The obtained data were first evaluated using the SPSS package program. In the meantime, the averages of the values obtained as a result of replications were used. By applying variance analysis and Duncan test to the obtained data, it

was determined whether there was a statistically significant ( $p < 0.05$ ) difference between the factors, and the obtained data were interpreted by simplified and tabulated.

Then, the Ni and Co values of the soil samples taken from different locations were transferred to the geographic information systems (GIS) using ArcGIS 10.7 software, and first of all, the coordinates and projections of the data were defined. Then, it was modeled with the kriging method, one of the interpolation methods, and pollution maps were created. The area and percentages of each map made were also calculated in the Excel program.

### 3 Results

The F value, error rate, average values, and Duncan test results obtained as a result of the variance analysis regarding the variation of Ni concentrations in the top soils depending on the region and traffic density are given in Table 1.

Ni, which is the subject of the study, is one of the first elements that come to mind in heavy metal studies in terms of its effect on human health and ecosystem, as well as its relationship with traffic density. The fact that it can pose a threat to human health even at low concentrations makes the element Ni even more important. Within the scope of the study, it was determined that the change of Ni element in all traffic densities on the basis of region and on the basis of traffic density in all regions was statistically significant ( $p < 0.001$ ) at the 99.9% confidence level.

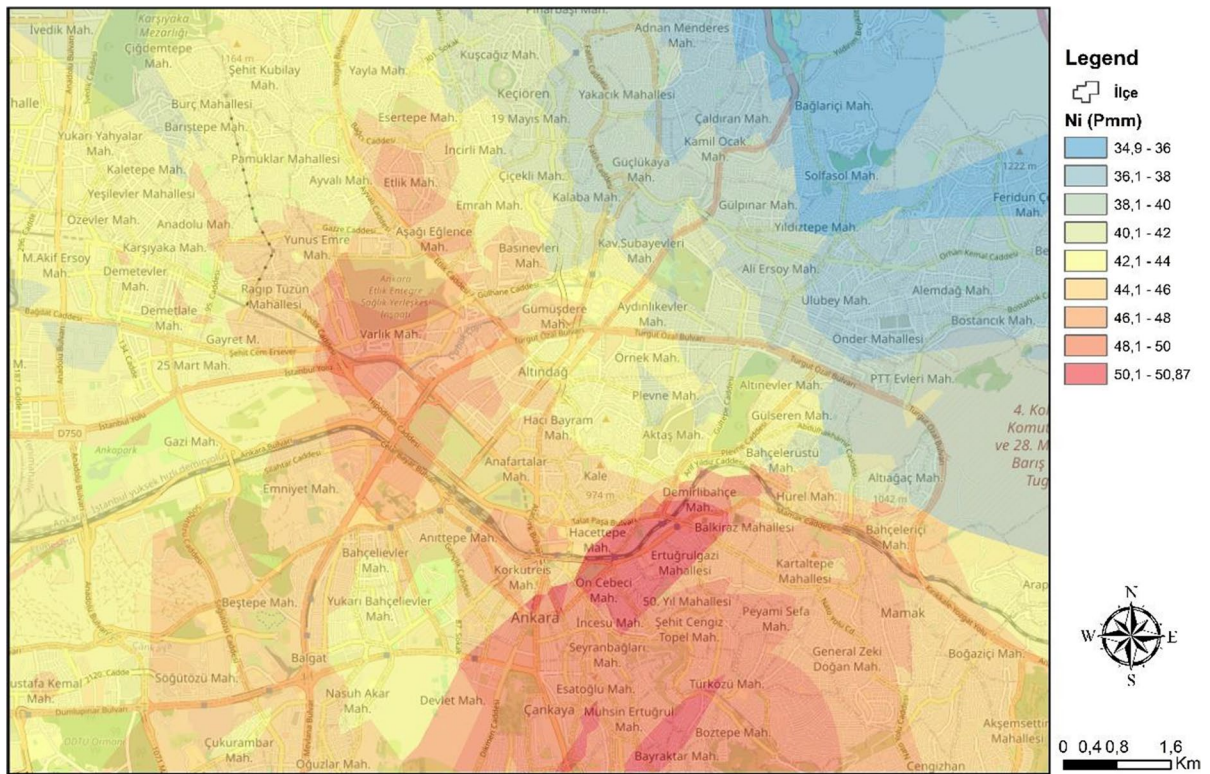
In areas where there is no traffic, the lowest Ni concentration values were obtained with 21.82 ppm in the 10th region, 25.77 ppm in the 3rd region, and 29.58 ppm in the 4th region, while the highest values were obtained with 51.52 ppm in the 2nd region, 51. It was obtained in the 7th region with 34 ppm and in the 8th region with 50.04 ppm. In areas with low traffic, Ni concentration varies between 29.47 and 59.27 ppm, and the lowest values were obtained with 29.47 ppm in the 5th region, 32.54 ppm in the 6th region, and 36.40 ppm in the 2nd region. The highest values were obtained in the 10th region with 59.27 ppm and in the 3rd region with 50.96 ppm.

It has been determined that the Ni concentration reaches up to 57.53 ppm at the most in areas with medium density of traffic, and this value is obtained in the 10th region. The next highest values in these areas were obtained in the 6th region with 53.88 ppm and in the 1st region with 43.63 ppm. In areas with medium traffic density, the lowest values were obtained in the 4th region with 26.86 ppm, in the 8th region with 33.82 ppm, and in the 7th region with 35.26 ppm.

It is seen that the Ni concentration in areas with heavy traffic varies between 33.14 and 70.82 ppm, the lowest value is in the 10th region, and the next lowest values are 36.75 ppm in the 5th region and 36.63 ppm in the 4th region. In this region, the highest values were obtained with 70.82 ppm in the 3rd region, 60.84 ppm in the 2nd region, and 49.52 ppm in the 7th region. In areas with heavy traffic, the lowest Ni concentration is 27.24 ppm in the 4th region, 27.68 ppm in the 4th region, and

**Table 1** Change of Ni element

Region	Traffic density					F value
	No Traffic	Low	Medium	High	Very high	
1	42.28 Ce	39.67 Bd	43.63 Dh	40.13 Bd	27.48 Aab	790.1***
2	51.52 Bi	36.40 Ac	36.56 Ad	60.84 Dg	54.32 Cf	6060.3***
3	25.77 Ab	50.96 Df	41.21 Ce	70.82 Eh	38.10 Bc	8588.8***
4	29.58 Cc	31.89 Db	26.86 Aa	36.63 Eb	27.24 Ba	5863.3***
5	34.48 Bd	29.47 Aa	42.64 Df	36.75 Cb	48.72 Ee	5038.7***
6	43.71 Dg	32.54 Bb	53.88 Ei	39.93 Cd	27.68 Ab	6621.7***
7	51.34 Di	42.43 Be	35.26 Ac	49.52 Cf	99.56 Eh	2510.0***
8	50.04 Dh	42.25 Be	33.82 Ab	45.29 Ce	54.33 Ef	6898.2***
9	43.08 Cf	41.47 Be	43.29 Cg	39.09 Ac	45.07 Dd	402.3***
10	21.82 Aa	59.27 Dg	57.53 Cj	33.14 Ba	59.19 Dg	11,943.7***
F value	3929.6***	533.6***	8532.7***	11,028.5***	42,871.3***	



**Fig. 1** Change of Ni concentration

38.10 ppm in the 3rd region, while the highest values are 99.56 ppm in the 7th region, 59.19 ppm was obtained in the 10th region, and 54.33 ppm in the 8th region (Fig. 1).

When the variation of Ni concentration on a regional basis is evaluated in general, it is noteworthy that the highest value was obtained in areas with high traffic. Apart from this, it can be said that the difference between the lowest and highest values in general is quite small. There is less than 5 times difference between the highest and lowest values.

When the distribution of Ni concentration, which is one of the most harmful elements in the study is examined, it is seen that the values are higher in the southern parts of the study area, and the regions with the lowest values are located in the northeast of the study area. As a result of the calculations, it was determined that the Ni concentration was below 36 ppm in approximately 5.02% of the study area and above 50 ppm in 1.86% of the study area. Apart from that, the Ni concentration is between 36 and

38 ppm in about 8.80% of the study area, between 38 and 40 ppm in 10.08%, between 40 and 42 ppm in 7.67%, and 42 in 31.26%. It was determined that it was between – 44 ppm, between 44 and 46 ppm in 19.48%, between 46 and 48 ppm in 8.39%, and between 48 and 50 ppm in 7.44%.

The F value, error rate, average values, and Duncan test results obtained as a result of the variance analysis regarding the variation of Co element, another element subject to the study, depending on the region and traffic density are given in Table 2.

When the table values are examined, it is seen that the changes in the Co element in all traffic densities, on the basis of regions and on the basis of traffic density in all regions, are statistically significant at the 99.9% confidence level. In areas where there is no traffic, Co concentrations vary between 7.74 and 14.43 ppm, with the highest concentrations in the 9th region (14.43 ppm), 5th region (13.54 ppm), and 6th region (12.87 ppm). In areas where there is no traffic, the lowest values were obtained in the 3rd region

**Table 2** Change of Co element

Region	Traffic density		Region	Traffic density		F value
	No traffic	Low		No traffic	Low	
1	11.95 De	10.16 Bb	13.09 Ei	10.69 Cb	8.04 Aa	1032.4***
2	11.08 Cc	11.90 Dd	10.38 Bd	17.50 Eh	9.5 Ab	2978.2***
3	7.74 Aa	13.43 Cf	12.12 Bh	23.10 Di	12.15 Bd	15,465.8***
4	10.00 Bb	10.92 Cc	8.58 Ab	14.25 Ed	11.19 Dc	1658.2***
5	13.54 Ch	11.91 Bd	11.73 Af	14.89 Dg	16.26 Eh	1869.3***
6	12.87 Eg	10.65 Ac	10.98 Be	11.53 Dc	11.17 Cc	327.8***
7	12.32 Cf	9.62 Aa	11.96 Bg	14.96 Dg	19.02 Ei	1069.0***
8	11.68 Bd	12.98 Ce	6.64 Aa	13.42 De	13.71 Ee	3642.8***
9	14.43 Ci	13.56 Bf	9.43 Ac	14.51 Cf	14.69 Dg	2016.2***
10	7.87 Aa	15.32 Eg	13.81 Cj	9.36 Ba	14.00 Df	3786.7***
F value	1672.8***	342.9***	3822.7***	7519.2***	7108.4***	

(7.74 ppm), 10th region (7.87 ppm), and 4th region (10.00 ppm).

In areas with low traffic, the highest values are obtained in the 10th region (15.32 ppm), the 9th region (13.56 ppm), and the 3rd region (13.43 ppm), while the lowest values in these areas are in the 7th region (9, 62 ppm), zone 1 (10.16 ppm), and zone 4 (10.92 ppm). In areas with medium traffic density, the highest values are obtained in the 10th region (13.81 ppm), the 1st region (13.09 ppm), and the 3rd region (12.12 ppm), while the lowest values are obtained in the 8th region (6.64 ppm), region 4 (8.58 ppm), and region 9 (9.43 ppm).

It is noteworthy that Co concentrations in areas with heavy traffic are higher than in areas with moderate traffic. The highest Co concentrations in areas with heavy traffic are obtained in the 3rd region (23.10 ppm), 2nd region (17.50 ppm), 7th region (14.96 ppm), and 5th region (14.89 ppm). Lower Co concentrations were obtained in zone 10 (9.36 ppm), zone 1 (10.69 ppm), and zone 6 (11.53 ppm). In areas with high traffic, the highest values were obtained in the 7th region (19.02 ppm), the 5th region (16.26 ppm), and the 9th region (14.69 ppm). The lowest values in these areas were obtained in the 1st region (8.04 ppm), the 2nd region (9.50 ppm), and the 4th region (11.19 ppm).

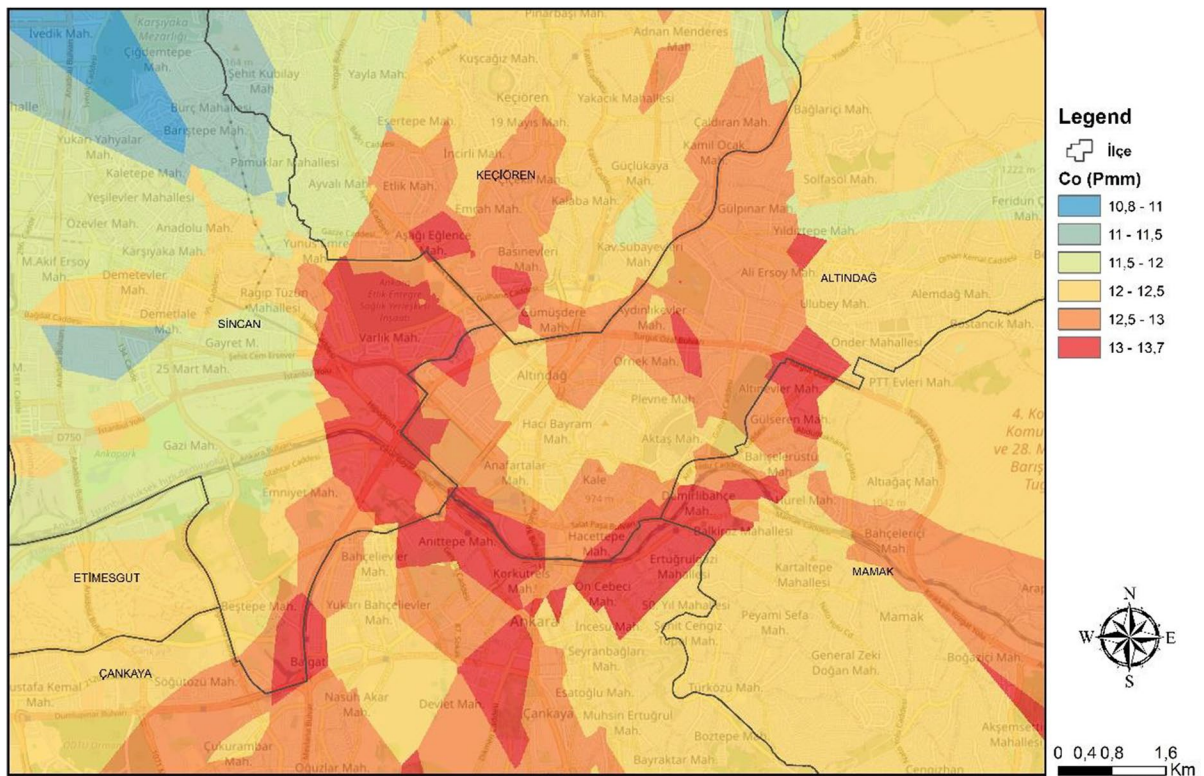
When the variation of Co concentration by region is evaluated in general, the first point that draws attention is that the highest values are generally obtained in areas with heavy traffic. Another remarkable point is that the values obtained in some regions are quite variable. For example, in the 10th

region, the values obtained in the areas with very heavy and no traffic are among the lowest values, while the values obtained in the areas with low density, medium density, and very dense traffic in the same region are among the highest values. Another remarkable point is that the difference between the lowest and highest values is not very high. There is less than 3.5 times difference between the lowest value of 6.64 ppm and the highest value of 23.10 ppm. The variation of Co concentration is given in Fig. 2.

When the map showing the change of Co concentration is examined, it is seen that the Co concentration is higher in the middle parts of the study area, and the areas with the lowest Co concentration are located in the northwestern parts of the study area, within the borders of Sincan district. According to the calculations, Co concentration is below 11 ppm in approximately 1.44% of the study area, in the range of 11–11.5 ppm in 4.11%, in the range of 11.5–12 ppm in 16.99%. It is in the range of 12–12.5 ppm in 47.29%, in the range of 12.5–13 ppm in 21.49%, and over 13 ppm in 8.68%.

#### 4 Results and Discussions

The results of the study reveal that both Ni and Co concentrations vary significantly on the basis of region and traffic density. When the pollution maps produced within the scope of the study are examined, it is seen that the pollution level in the central parts of the study area is higher. These areas are the areas



**Fig. 2** Change of Co concentration

with the highest human activities and traffic density. Studies conducted to date show that Ni and Co concentrations increase with anthropogenic factors and traffic is an important source (Karacocuk et al., 2021; Koc, 2021a).

The elements subject to the study are among the most toxic and harmful elements in terms of human and environmental health. Nickel compounds are strong carcinogens in humans (Cetin & Jawed, 2021, 2022; Cetin et al., 2022; Cicek et al., 2022; Kaya, 2009, 2010; Yucedag et al., 2021). In addition to its natural emission, Ni is also found in nature due to human activities. Prolonged exposure to nickel in the air adversely affects human health. It spreads to the atmosphere with the combustion of nickel fuels, mining, and burning of urban wastes, and abnormal functions related to the respiratory defense system occur with the inhalation of Ni compounds in the air. The main health risk posed by Ni exposure is cancers of the respiratory system. In addition to negative health effects such as asthma, nose and larynx cancers are also seen in workers exposed to Ni for a long time

(Seven et al., 2018). Nausea, vomiting, diarrhea, shortness of breath, liver, and kidney damage may occur, and allergic reactions may occur with chronic poisoning, according to the acute consequences observed as a result of excessive intake of Ni into the human body (Çağlarırnak & Hepçimen, 2010).

Co is obtained as a by-product by mining methods, especially from copper, nickel, and silver, as well as gold, lead, and zinc ores. Co is mostly used in super alloys and special steels used in the rocket industry, as well as in rechargeable batteries of portable electronic devices such as mobile phones and laptops. Co poisoning occurs as a result of inhalation of dust in the air and skin contact with Co salts. Element Co, taken in powder form, dissolves in the lungs and mixes with blood and urine, and when exposed to Co dust for a long time, it can cause allergic reactions and chronic bronchitis (Seven et al., 2018). According to the evaluation of IARC, cobalt has a carcinogenic effect for humans (Boğa, 2007).

Since Ni and Co are extremely dangerous elements for human and environmental health, and the release of

these elements in nature due to anthropogenic effects, they have been the subject of many studies. Chen and Lu (2018) evaluated the Co and Ni concentrations in samples taken from the top soils in the region around the city of Xi'an in China, and identified four sources of contamination using the positive matrix factorization (PMF) method within the scope of the study. As a result of the evaluation made using the PMF method, the contribution rates of these sources to heavy metal pollution were calculated as 25.04% for natural resources, 24.71% for traffic sources, 24.99% for mixed sources, and 25.26% for industrial sources.

Acar and Özkul (2020) calculated the Ni concentration in roadside soil and dust samples as 38.0–1981.10 mg/kg, and as a result of the study, they stated that the roadside soils and dusts of the highway mostly showed high-range pollution and enrichment degrees for Ni. He et al. (2019) created soil heavy metal distribution maps for Co and Ni using 213 soil samples collected from Daye (Hubei Province, China). The results of the study showed that 46.1% of the soils in the study area are moderately polluted, 32.1% are high, and 0.5% are heavily polluted. Pan et al. (2017), in their study examining heavy metal pollution in road dust collected from four regions in the Xi'an region of Northwest China, calculated the average concentrations of the elements as 30.9 mg kg<sup>-1</sup> for Co and 30.8 mg kg<sup>-1</sup> for Ni. At the end of the study, principle component analysis and multiple linear regression were applied to determine the resource distribution and the results showed that traffic was the main resource with a contribution margin of 53.4%. Similarly, Zhang et al. (2018) stated that the main source of Ni pollution is vehicles.

The results of the study also show that Ni and Co concentrations are quite high in some regions. Heavy metal pollution in top soils is extremely important. Because heavy metal pollution in the upper soils is one of the most important indicators of heavy metal pollution in the air. After spreading from the source, heavy metals can hold on to the particulate matter in the air and descend to the soil surface with the effect of gravity (Turkyilmaz et al., 2018a, b). Therefore, heavy metal pollution in the topsoil is largely due to heavy metal pollution in the air.

Heavy metals on the upper surface of the soil then go deep into the soil and shape the soil structure with the effect of the main precipitation waters. Heavy metal concentrations are also high in plants grown

in soils with high levels of heavy metal pollution (Turkyilmaz et al., 2020). Because soil is the main source of nutrients in plant development (Kravkaz Kuscü et al., 2018a, b; Varol et al., 2021a) and plant growth is largely climatic (Canturk & Kulac, 2021; Koc et al., 2021; Varol et al., 2021b) and edaphic. It is shaped depending on factors (Yigit et al., 2021). Therefore, the change in soil quality due to soil pollution significantly affects plant development and therefore the ecosystem. Because all living things directly or indirectly depend on plants (Ertugrul et al., 2021; Yigit et al., 2019; Yucedag et al., 2019), plant growth is also highly dependent on the soil.

Increasing heavy metal concentrations in soils is an important stress factor for plants (Alaqouri et al., 2020a, 2020b). Plant development also includes drought (Kulaç et al., 2012; Koc, 2021b, c), frost (Murphy et al., 2020; Sevik & Karaca, 2016; Yildiz et al., 2013), radiation (Ozel et al., 2021a, b), and pollution (Sevik et al., 2020a, b; Turkyilmaz et al., 2018c) that can cause stress. Thus, as the pollution level in the soil increases, plant growth is adversely affected.

Heavy metal concentrations in the organs of plants grown in soils with high levels of heavy metal pollution are also high (Karacocuk et al., 2021), and the consumption of these plants as food brings with it important health problems. Therefore, it is recommended that plants grown in regions with high levels of Ni and Co pollution should not be consumed as food.

## 5 Conclusions

Today, population density has increased significantly in urban areas and continues to increase due to the fact that there are more job opportunities and social opportunities in general. As a result, many problems occur in areas with high population density. Among these problems, the environment and especially air pollution have reached dimensions that threaten human health and ecological balance. Among the pollution factors, especially heavy metal pollution is one of the most important factors affecting human and environmental health, and therefore it is extremely important to monitor heavy metal pollution, especially in regions with high population density. In this study, the change of Ni and Co concentrations in the city center of Ankara, which is the capital city of Turkey and one of the cities with the

highest population density, was determined and pollution maps were created.

Necessary precautions should be taken in areas where Ni and Co pollution is intense by using the results of the study. In this context, first of all, people living in these regions, especially the risk group should be warned, and then necessary measures should be taken to reduce the level of pollution. As some of the measures that can be taken in this context, it can be recommended to reduce the traffic density in the region and therefore the level of traffic-related pollution, not to use the plants grown in the regions with high pollution levels for food purposes, and to use the plants that contribute to reducing the pollution level by accumulating Ni and Co in landscaping studies. In addition, due to the importance of the subject, it is recommended that similar studies be carried out in other cities and in terms of other heavy metals such as Pb, Cr, Cd, Ba, and Hg, which are extremely important for human health.

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**Author Contribution** Mehmet Cetin designed the study and performed the experiments, performed the experiments, analyzed the data, and wrote the manuscript; Akram Mohamed Omar ALJAMA performed the experiments, analyzed the data, and wrote the manuscript; Osama B Muragaa ALRABITI designed the study and performed the experiments, performed the experiments, analyzed the data, and wrote the manuscript; Fatih ADIGUZEL designed the study and performed the experiments, performed the experiments, analyzed the data, and wrote the manuscript; Hakan Sevik performed the experiments, analyzed the data, and wrote the manuscript; Ilknur ZEREN CETIN designed the study and performed the experiments;

**Data Availability** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Code Availability** Not applicable.

**Declarations**

**Ethics Approval and Consent to Participate** Not applicable.

**Consent for Publication** Not applicable.

**Conflict of Interest** The authors declare no competing interests.

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