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Investigation of Some Heavy Metal Contents of Soils at Different Distances and Depths in Agricultural Areas Near the Silopi Thermal Power Plant

Bedriye BİLİR[1*], Hava Şeyma İNCİ[2], Seyyid IRMAK[3], Mikail DOĞAN[4]

[1] Sirnak University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Şırnak, Türkiye
[2] Bingol University, Department of Crop and Animal Production, Vocational School of Food, Agriculture and Livestock, Bingöl, Türkiye
[3] Sirnak University, Faculty of Agriculture, Department of Horticulture, Şırnak, Türkiye
[4] Şırnak Provincial Directorate Of Agriculture And Forestry, Şırnak Türkiye
Bedriye BİLİR ORCID No: 0000-0002-0038-9509
Hava Şeyma İNCİ ORCID No: 0000-0002-2670-401x
Seyyid IRMAK ORCID No: 0000-0002-7839-7912
Mikail DOĞAN ORCID No: 0000-0003-4940-0147

**Corresponding author: bbilir@sirnak.edu.tr*

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Abstract: Silopi Thermal Power Plant is located in Şırnak province and uses asphaltite as its fuel source. Emissions from the power plant chimneys are likely to be dispersed in the region and accumulate on soils due to various factors. This could lead to an increase in the concentrations of some heavy metals (such as Cr, Ni and Cd) in soils. In this study, it was aimed to determine the plant-available (extractable) and total heavy metal contents of soils taken from areas close to the power plant where agriculture is intensively practiced. A total of 42 soil samples were collected from 7 different distance classes (D1, D2, D3, D4, D4, D5, D6 and D7) and 21 soil samples from 3 different points in each class and two different depths (0-30 cm and 30-60 cm) close to Thermal Power Plant. The concentrations of plant-available chromium (Cr), nickel (Ni), cadmium (Cd), cobalt (Co) and lead (Pb) were determined in soil samples. As a result of the research, the extractable concentrations were found to be in the ranges of Cr 0.11-0.29 mg kg^{-1}, Ni 0.4-1.71 mg kg^{-1}, Cd 0.02-0.1 mg kg^{-1}, Co 0.17-0.39 mg kg^{-1} and Pb 0.82-2.37 mg kg^{-1}; total Cr 22-55 mg kg^{-1}, Ni 56-102 mg kg^{-1}, Cd 0.6-0.7 mg kg^{-1}, Co 41-51 mg kg^{-1} and Pb 69-93 mg kg^{-1}. Statistically ($p<0.01$); Ni and Pb were found to be significant for depth and distance averages, while Cd, Cr and Co were not considered significant. The concentrations of Cr and Ni concentrations decreased with distance from the power plant. Pb and Ni concentrations were higher in the 0-30 cm depth than in the 30-60 cm depth, suggesting the possibility of an external contamination of the topsoil. However, as a result, both the total and extractable concentrations of all the heavy metals examined did not exceed the permissible limit values according to the Turkish Soil Pollution Control Regulation.

Silopi Termik Santrali Yakınlarındaki Tarım Alanlarında, Farklı Uzaklık ve Derinlikteki Toprakların Bazı Ağır Metal İçeriklerinin Araştırılması

Anahtar Kelimeler
Silopi, Termik santrali, Ağır metal, Toprak kirliliği

Öz: Silopi Termik Santrali Şırnak ilinde bulunmaktadır ve yakıt olarak asfaltit kullanmaktadır. Santral bacalarından çıkan emisyonlar çeşitli faktörlere bağlı olarak bölgeye dağılma ve toprakta birikme ihtimali taşımaktadır. Bu durum topraktaki bazı ağır metallerin (Cr, Ni ve Cd gibi) konsantrasyonunu arttırabilmektedir. Bu çalışmada, tarımın yoğun olarak yapıldığı santrale yakın alanlardan alınan toprakların bitki tarafından alınabilir (ekstrakte edilebilir) ve toplam ağır metal içeriklerinin belirlenmesi amaçlanmıştır. Silopi Termik Santraline yakın 7 farklı uzaklık sınıfı (U1, U2, U3, U4, U5, U6 ve U7) ve her sınıfta 3 farklı noktadan 21 adet ve 0-30 cm ve 30-60 cm olmak üzere iki farklı derinlikten toplam 42 adet toprak örneği alınmıştır. Toprak örneklerinde bitki tarafından alınabilir, krom (Cr), nikel (Ni), kadmiyum (Cd), kobalt (Co) ve kurşun (Pb) belirlenmiştir. Araştırma sonucunda ekstrakte edilebilir Cr 0.11-0.29 mg kg^{-1}, Ni 0.4-1.71 mg kg-

^{1}, Cd 0.02-0.1 mg kg^{-1}, Co 0.17-0.39 mg kg^{-1} ve Pb 0.82-2.37 mg kg^{-1}; toplam Cr 22-55 mg kg^{-1}, Ni 56-102 mg kg^{-1}, Cd 0.6-0.7 mg kg^{-1}, Co 41-51 mg kg^{-1} ve Pb 69-93 mg kg^{-1} aralığında değişmektedir. Topraklarda istatistiksel anlamda ($p<0.01$); derinlik ve uzaklık ortalamaları için Ni ve Pb çok önemli bulunurken, Cd, Cr ve Co önemsiz bulunmuştur. Uzaklık bakımından ise santralden uzaklaşıldıkça Cr ve Ni konsantrasyonu azalma göstermiştir. Pb ve Ni konsantrasyonu 0-30 cm derinliğinde 30-60 cm derinliğine göre daha yoğun ölçülmüş ve bu da üst topraklara dışarıdan bir katılım riski ihtimalini düşündürmüştür. Fakat sonuç olarak incelenen tüm ağır metallerin hem toplam hem de ekstrakte edilebilir konsantrasyonlarının Türkiye Toprak Kirliliği Kontrol Yönetmeliği'nde izin verilen sınır değerleri altında olduğu görülmüştür.

1. INTRODUCTION

Since natural gas and fuel oil reserves are limited in Turkey, coal is utilized in electricity generation. Coal is a fossil fuel material that is very difficult at every stage from mining to storage [1]. In Turkey, 37% of electricity generation is generated from coal, 30% from natural gas and 20% from hydraulic energy [2, 3].

Thermal power plants consume substantial quantities of coal in the process of generating electricity. The combustion of coal leads to the release of a considerable amount and variety of trace elements, some of which are potentially toxic, are transferred to the environment through different pathways [4, 5]. The main environmental impacts of thermal power plants include soil, air and water pollution, and negative effects on human health, land use and natural areas [6, 7].

Millions of slag, ash, and various particles resulting from coal combustion in thermal power plants are transported to high altitudes, affecting thousands of hectares of land and subjecting agricultural areas, forests and settlements to significant pollution [8]. Heavy metals such as Cd, Cu and As concentrate in the ashes emitted by flue gases and are carried through the air [9]. In addition, the harmful components that accumulate on the soil surface with fly ashes extend their harmful effects over a broader area by leaching with rainwater, consequently polluting groundwater [10].

The concentrations of heavy metal in the soil near thermal power plants increase depending on the wind direction (with the spread of fly ash from the chimneys of the power plants), and heavy metal concentrations further away from the power plant decrease depending on the distance [11]. Rosenstein [12] reported that the levels of Pb, Cd and As heavy metals emitted from the power plant decreased to normal concentrations at a distance of 30 km from the power plant. Determining the presence of heavy metal pollution in agricultural areas is also important in determining the type of crop production to be carried out there [13]. Potential toxic elements such as Cu, Zn, Ni, Cd, Cr, Pb and Co are among the factors that cause pollution in agricultural areas and pose an increasingly dangerous threat [14, 15].

According to the Turkish Soil Pollution Control Regulation, the limit values of some heavy metals in soil are given in Table 1.1.

Table 1.1. Limit values of some heavy metals in soil according to the Turkish Soil Pollution Control Regulation [22].

Heavy Metals (Total)	Oven Dry Soil (mg kg^{-1}) pH 5- 6	Oven Dry Soil (mg kg^{-1}) pH > 6
Cadmium (Cd)	1**	3**
Lead (Pb)	50**	300**
Cobalt (Co)	40**	-
Chromium (Cr)	100**	100**
Nickel (Ni)*	30**	75**

* If the pH value is greater than 7, the Ministry may increase the limit values by up to 50% in cases where it is not harmful to the environment and human health, especially groundwater.
** In areas where fodder crops are grown, these limit values may be allowed to be posted if it is proven by scientific studies that they are not harmful to the environment and human health.

Silopi thermal power plant is located in Şırnak province and has been operating since 2009 using asphaltite as fuel [16]. Asphaltite is a substance that separates from the oil deposit as a result of tectonic movements and settles in cracks and crevices around it and differentiates under the influence of pressure and temperature [17] Asphaltites have high ash contents containing metals such as Ni [18, 19]. Emissions from the power plant chimneys are likely to be dispersed throughout the region by various factors and then deposited on soils. This transport may increase the concentrations of some heavy metals (Cr, Ni, Cd, Co and Pb) that cause pollution in soils.
In this study, it was aimed to determine the plant-available concentrations of some heavy metals in soil samples collected at various distances and depths in areas where agriculture is intensively practiced around the Silopi thermal power plant in Şırnak province.

2. MATERIAL AND METHOD

2.1. Study Area

A large part of the southern and southwestern part of Silopi District, located between 37°31' north latitude and 42°28' east longitude in Şırnak province, is located in the Southeastern Anatolia Region, while the northern and northeastern lands are in the Eastern Anatolia Region [20]. The study was conducted in the Silopi Plain, which is located in the Southeastern Anatolia Region, where there are flat or nearly flat areas with high agricultural potential that may be affected by Silopi Thermal Power Plant emissions. The study was conducted in Çardaklı, Başverimli, Ortaköy, Atak, Bostancı, Çiftlik, Yeniköy, Yolağzı, Üçağaç villages, Şehit Harun Boy neighborhood and Keruh, Bozalan and Doruklu villages located between Cizre-Silopi borders. A total of 42 soil samples were taken from the study area in 7 different distance classes (D1: 9-11 km; D2: 11-14 km; D3: 14-17 km; D4: 17-20 km; D5:

20-23 km, D6: 23-26 km, D7: 26-29 km) and at 3 different points (21 soil samples) and 2 different depths (0-30 cm and 30-60 cm) in each distance class (Figure 2.1).

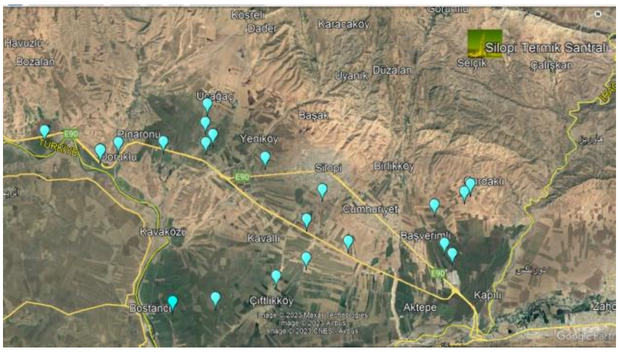

Figure 2.1. Location of the study area and the soil samples taken on the map

The prevalent wind directions of Silopi district of Şırnak province are shown in Figure 2.2.

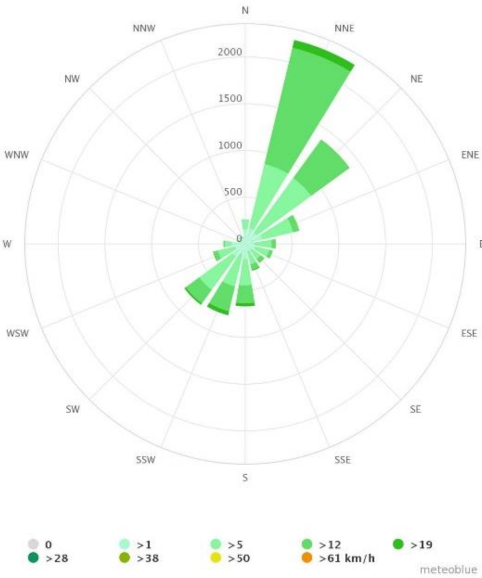

Figure 2.2. The wind vane of Silopi district of Şırnak province [21]

2.1.1. Some properties of the study area soils

The dominant texture class of the topsoil (0-30 cm) and subsoil (30-60 cm) of the study area is sandy clay loam. The pH is slightly and moderately alkaline and most of them do not have salinity problems. Organic matter content was classified as low and very low, while lime content was determined as high. While K, Ca, and Mg contents of the soils are high, Cu, Mn and Fe are sufficient. While phosphorus and Zn contents were sufficient in most of the soils, they were classified as low in some points where soil samples were taken.

2.2. Determination of Cr, Ni, Cd, Co and Pb Concentrations in Soils

Soil samples collected in plastic bags from the Silopi district of Şırnak province were brought to the laboratory and dried in the shade at air dry level. The dried soil samples were then crushed with a mallet sieved through a 2 mm steel sieve and prepared for analysis. The soil samples were prepared according to the DTPA method developed by Lindsay & Norvell [23] to determine the concentrations of extractable Cr, Ni, Cd, Co and Pb in calcareous soils with near-neutral pH [24] and total Cr, Ni, Cd, Co and Pb concentrations were prepared by digestion with acid mixtures (8 ml HNO_3, 5 ml HCl, 1 ml HF and 5 ml H_3BO_3 mixture) in a microwave sample preparation set. Cr, Ni, Cd, Co and Pb in the filtrates prepared for elemental measurements were determined by atomic absorption spectrophotometer (AAS).

2.3. Statistical Analyses

In the study conducted to determine the effect of Silopi thermal power plant emissions on the soils of the agricultural area, analysis of variance was performed by using the 'JMP 13.2.0' program. Soil samples were divided into groups according to distance and depth from the power plant and the differences between the groups were compared using Tukey test for distance and LSD test for depth [25].

3. RESULTS AND DISCUSSION

Total heavy metal concentrations determined in the study soils (0-30 cm) are shown in Table 3.1.

Table 3.1. Total heavy metal (Cr, Ni, Cd, Co and Pb) concentrations of soils at different distances

Total Concentration (mg kg^{-1})	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**
Cr	48.3	49	40.6	45.6	30.6	30.6	39
Ni	98.3	96	90.3	90.3	68.3	68.3	83
Cd	0.6	0.7	0.6	0.6	0.7	0.7	0.6
Co	47.6	47.3	48	47.6	42.6	42.6	46
Pb	77.6	74	79.3	74	90.6	74	76.5

Extractable concentrations of Cr, Ni, Cd, Co and Pb were determined according to the distance and depth of the soil samples. The extractable concentrations of heavy metals (mg kg^{-1}) and the coordinates of the sampling points were used to create an elemental map as shown in Figure 3.1.

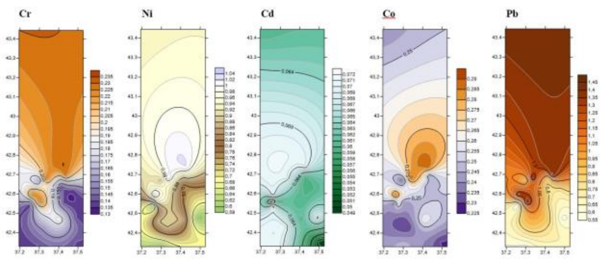

Figure 3.1. Elemental map of Cr, Ni, Cd, Co and Pb concentrations

The color changes in Figure 3.1 express the change in the concentrations of metals. Generally, dark areas represent the region where that metal is in higher concentration.

3.1. Chromium (Cr) Concentration

The mean values of the effect of different depths and distances on Cr concentration in soil samples taken from the vicinity of Silopi Thermal Power Plant are given in Table 3.2. The Cr concentrations between the distance points (D1-D7), 0-30 cm and 30-60 cm were statistically significant at $p<0.01$ level. Average Cr concentrations of soil samples taken at different depths (0-30 and 30-60 cm) were found statistically non-significant.

Table 3.2. Effect of different depth and distance on Cr concentration of soils

Cr concentrations (mg kg^{-1})			
	Depths		
Distances	0-30 cm	30-60 cm	Mean
D1 (9-11 km)	0.23AB**	0.23A**	**0.23a****
D2 (11-14 km)	0.25A	0.20AB	**0.23a**
D3 (14-17 km)	0.19AB	0.20AB	**0.19b**
D4 (17-20 km)	0.16AB	0.16B	**0.16c**
D5 (20-23 km)	0.14B	0.14B	**0.14c**
D6 (23-26 km)	0.13B	0.14B	**0.14c**
D7 (26-29 km)	0.15AB	0.14B	**0.14c**
Mean	**0.18^{ns}**	**0.17**	
LSD $_{(0.05)}$	Depth:-	Distance:0.03	CV(%):8.21

**:$p<0.01$, ns: non significant

The Cr concentrations of soils at different distances from the power plant were ranked as D1=D2>D3>D4=D5=D6=D7. The highest Cr concentration (0.23 mg kg^{-1}) was measured at D1 and D2, the closest group to the power plant, while the lowest Cr concentration was measured at D5, D6 and D7, where the distance to the power plant increased. In general, Cr concentration decreased with increasing distance from the power plant. Cr concentration was higher in soil samples taken from the points closest to the power plant. Mehra et al. [26] reported that Cr concentration in soils around thermal power plants in India decreased with distance from the power plant. Turkmenoglu et al. [11] examined the distribution of Cr and some other heavy metals in the vicinity of thermal power plants about wind direction and distance and reported that Cr concentration decreased with distance in all directions and increased with distance from the power plant.

Cr concentration between soil samples taken from different depths was found to be statistically insignificant. It is thought that Cr pollution from the power plant is not effective on depth. None of the soil samples from the study area had total Cr (Table 3.1) concentrations (22-53 mg kg^{-1}) exceeding the permissible limit value (100 mg kg^{-1}) according to the Turkish Soil Pollution Control Regulation (Table 1.1).

3.2. Nickel (Ni) Concentration

The mean values of the effect of different depths and distances on Ni concentration in soil samples taken from the vicinity of Silopi Thermal Power Plant are given in Table 3.3. Pb concentrations of distance points (U1-U7), average depth, and 0-30 cm were statistically significant at $p<0.01$. Ni concentrations of soil samples taken at 30-60 cm were statistically insignificant ($p<0.01$).

Table 3.3. Effect of different depths and distances on Ni concentration of soils

Ni concentrations (mg kg^{-1})			
	Depths		
Distances	0-30 cm	30-60 cm	Mean
D1 (9-11 km)	1.27A**	0.77^{ns}	**1.02a****
D2 (11-14 km)	1.09AB	0.76	**0.92ab**
D3 (14-17 km)	1.05AB	0.69	**0.87abc**
D4 (17-20 km)	1.06AB	0.70	**0.88abc**
D5 (20-23 km)	0.83ABC	0.71	**0.77abc**
D6 (23-26 km)	0.68BC	0.71	**0.70bc**
D7 (26-29 km)	0.53C	0.63	**0.58c**
Mean	**0.93a****	**0.71b**	
LSD $_{(0.05)}$	Depth:0.11	Distance:0.32	CV(%):20.83

**:$p<0.01$, ns: non significant

The Ni concentrations of soils at different distances from the power plant were ranked as D1>D2>D3=D4=D5>D6>D7. The highest Ni concentration was determined in D1 (1.02 mg kg^{-1}), the closest group to the power plant, while the lowest Ni concentration was determined in D7 (0.58 mg kg^{-1}), the farthest point. Polat et al. [27] and Koseoglu et al. [28] reported that fly ash released as a result of coal combustion contains significant amounts of heavy metals with different mobility. In this study, it was observed that Ni concentration decreased as the distance from the thermal power plant decreased. With these results, it can be said that the Ni element originated from the power plant and was transported with fly ash. At the same time, Yilmaz et al. [1] reported in a study conducted in the Elbistan thermal power plant that the Ni content of the plants in the region, which they thought to be more polluted, was high and the Ni concentration decreased as they moved away from the power plant and that the fly ash had an effect on this pollution. Simsek et al. [29] determined the concentration of available Ni between 0.02-29.8 mg kg^{-1} in a study conducted in Osmaniye agricultural areas. Haktanir et al. [30] reported that the extractable Ni content of agricultural and forest soils under the influence of Mugla-Yatagan thermal power plant emissions was between 0.24 mg kg^{-1}-1.65 mg kg^{-1}. The average DTPA-Ni content of surface soils under the influence of the Elbistan Thermal Power Plant was determined as 1.21 mg kg^{-1} [31].

In the study, the Ni concentration of the topsoil (0-30 cm) was 0.93 mg kg^{-1} higher than the Ni concentration of the subsoil (30-60 cm) (0.71 mg kg^{-1}). With these results, it can be said that the Ni concentration does not originate from the parent material and that there is an external contribution. Akbay et al. [31] reported that the elements that are not mobile in the soil should decrease from the surface to the depth if there is pollution caused by the power plant and reported the DTPA-Ni concentration as 1.51 mg kg^{-1}; 1.18 mg kg^{-1}; 1.09 mg kg^{-1} from top to bottom at three different depths in their study. Kabata-Pendias and Pendias [32] reported that in general, metals such as Ni, Cd, Cu, Hg, Pb, Zn and Cr are taken up by plants by adhering to the soil surface. Plants need trace amounts of nickel, but nickel has high mobility and can be easily taken up by plants in soils with high concentrations and may cause toxic effects [33, [34]. The total Ni concentration (56-102 mg kg^{-1}) of the soil samples taken from the study area (Table 3.1) did not exceed the permissible limit value (75 mg kg^{-1}), taking into account the Turkish Soil Pollution Control Regulation, which states that the ministry may increase the limit values up to 50% if the pH value is greater than 7 and it is not harmful to the environment and human health, especially groundwater (Table 1.1).

3.3. Cadmium (Cd) Concentration

The mean values of the effect of different depth and distance on Cd concentration in soil samples taken from the vicinity of Silopi Thermal Power Plant are given in Table 3.4. Cd concentrations between the distance points (D1-D7), 0-30 cm and 30-60 cm were not statistically significant. Average Cd concentrations of soil samples taken at different depths (0-30 and 30-60 cm) were found statistically non-significant.

Table 3.4. Effect of different depth and distance on Cd concentration of soils

Cd concentrations (mg kg^{-1})			
	Depths		
Distances	**0-30 cm**	**30-60 cm**	**Mean**
D1 (9-11 km)	0.07^{ns}	0.07^{ns}	**0.07^{ns}**
D2 (11-14 km)	0.07	0.06	**0.06**
D3 (14-17 km)	0.07	0.05	**0.06**
D4 (17-20 km)	0.07	0.07	**0.07**
D5 (20-23 km)	0.07	0.06	**0.06**
D6 (23-26 km)	0.05	0.05	**0.05**
D7 (26-29 km)	0.07	0.07	**0.07**
Mean	**0.07^{ns}**	**0.06**	
LSD $_{(0.05)}$	Depth:-	Distance:-	CV(%):18.17

ns:non significant

It is thought that the Silopi thermal power plant does not affect the Cd concentration of soil samples both in terms of distance and depth. As seen in Table 3.4, the concentration of Cd available for uptake by plants varied between 0.05-0.07 mg kg^{-1} in terms of both distance and depth, while the total Cd concentrations of the soil samples taken in Table 3.1 varied between 0.6-0.7 mg kg^{-1}. Although the power plant did not statistically affect the Cd content, both total Cd and the concentrations of Cd are below the permissible limit value (3 mg kg^{-1}) according to the Turkish Soil Pollution Control Regulation (Table 1.1). Although the Cd concentration in world soils varies between 0.01-1.0 mg kg^{-1}, the average has been reported as 0.36 mg kg^{-1} [35]. Mejstřík and Švácha [36] took soil and plant samples from 1, 5, 10, and 15 km distances from 3 different thermal power plants in Czechoslovakia for 7 years and investigated the distribution of Cd and some other heavy metals in the samples. Researchers reported that certain amounts of heavy metal accumulation were detected in the soil and plants around the 3 thermal power plants examined, but the source of this metal accumulation could not be determined with a 7-year monitoring period, and longer periods of investigation were required to determine whether this was due to emissions. Çancı [37] analyzed Pb, Cd and some other heavy metals in fly ash and bottom ash samples from the Seyitömer thermal power plant and soil samples in the vicinity of the power plant and compared the concentrations of soil samples with the upper limits determined for agricultural purposes in different countries and found that Cd and some other heavy metals were below the given values.

3.4. Cobalt (Co) Concentration

The mean values of the effect of different depths and distances on Co concentration in soil samples taken from the vicinity of Silopi Thermal Power Plant are given in Table 3.5. Co concentrations between the distance points (D1-D7), 0-30 cm and 30-60 cm were not statistically significant. Average Co concentrations of soil samples taken at different depths (0-30 and 30-60 cm) were found statistically non-significant.

Table 3.5. Effect of different depths and distances on Co concentration of soils

Co concentrations (mg kg^{-1})			
	Depths		
Distances	**0-30 cm**	**30-60 cm**	**Mean**
D1 (9-11 km)	0.33^{ns}	0.25^{ns}	**0.29^{ns}**
D2 (11-14 km)	0.26	0.21	**0.24**
D3 (14-17 km)	0.27	0.25	**0.26**
D4 (17-20 km)	0.24	0.22	**0.23**
D5 (20-23 km)	0.26	0.25	**0.25**
D6 (23-26 km)	0.21	0.25	**0.23**
D7 (26-29 km)	0.26	0.23	**0.25**
Mean	**0.26^{ns}**	**0.24**	
LSD $_{(0.05)}$	Depth:-	Distance:-	CV(%):15.38

ns:non significant

Sushil and Batra [38] reported that total Cr and Zn content in fly ash and total Mn content in bottom ash were the highest while total Co concentration was the lowest in both. In this study, it is clearly seen that the change in distance does not affect the transport of Co at a statistically significant level. This is related to the fact that heavy metals of lower mass can be transported and precipitated by fly ash, whereas elements of higher mass, such as Co, can precipitate immediately after combustion, thus enriching the bottom ash in Co [38]. The total Co concentration (41-51 mg kg^{-1}) of soil samples from the study area (Table 3.1) did not exceed the permissible limit value considering the Soil Pollution Control Regulation of Turkey (Table 1.1).

3.5. Lead (Pb) Concentration

The mean values of the effect of different depths and distances on Pb concentration in soil samples taken from the environment of Silopi Thermal Power Plant are given in Table 3.6. Pb concentrations between the distance points (D1-D7) were statistically significant at $p<0.01$ level. Average Pb concentrations of soil samples taken at different depths (0-30 and 30-60 cm) were found statistically significant ($p<0.01$) while the 0-30 cm and 30-60 cm were found non-significant.

Table 3.6. Effect of different depths and distances on Pb concentration of soils

Pb concentrations (mg kg^{-1})			
	Depths		
Distances	0-30 cm	30-60 cm	Mean
D1 (9-11 km)	1.53^{ns}	1.25^{ns}	**1.39d****
D2 (11-14 km)	1.43	1.44	**1.43cd**
D3 (14-17 km)	1.47	1.48	**1.47bcd**
D4 (17-20 km)	1.72	1.61	**1.67b**
D5 (20-23 km)	1.32	1.27	**1.30d**
D6 (23-26 km)	1.63	1.55	**1.59bc**
D7 (26-29 km)	2.03	1.79	**1.91a**
Mean	**1.59a****	**1.48b**	
LSD $_{(0.05)}$	Depth:0.07	Distance:0.20	**CV(%):6.34**

**:p<0.01, ns:non significant

The Pb concentrations of the soils at different distances from the power plant were ranked as D7>D4>D6>D3>D2>D1=D5. The highest Pb concentration (1.91 mg kg^{-1}) was measured at D7, the furthest group from the power plant, while the lowest Pb concentration was measured at D1 and D5. There was no linear increase or decrease in Pb concentration with increasing distance from the power plant, which can be attributed to the location of the sampling points. Habur Border Gate is located in the Silopi district, so there is heavy vehicle traffic on the highway. Especially since the points in the D7 group are very close to the main road, the Pb elevation may have been caused by this. Seven et al. [39] reported that the extractable Pb concentration in the soil was at the level of 0.05-5 mg kg^{-1} and that most of the lead causing environmental pollution was caused by tetra ethyl lead resulting from the combustion of gasoline used in motor vehicles. Haktanır et al. [30] determined that the extractable Pb values in the soils of power plant emissions in their study were the lowest 0.09 mg kg^{-1} and the highest 1.04 mg kg^{-1} and stated that these values were too low to talk about Pb pollution.

Pb concentration in soil samples taken from different depths decreases with increasing depth. The Pb concentration in the topsoil (0-30 cm) was 1.59 mg kg^{-1} while it was 1.48 mg kg^{-1} in the subsoil. Turer et al. [40] in their study on heavy metal contents in the soils around the highway, concluded that heavy metals such as Pb were higher, especially in the topsoil at 0-15 cm depth and that the heavy metal concentration decreased with increasing depth. Akbay et al. [31] found that DTPA-Pb concentration decreased from top to bottom as 1.04 mg kg^{-1}; 0.99 mg kg^{-1}; 0.88 mg kg^{-1} at three different depths. The total Pb concentration (69-93 mg kg^{-1}) (Table 3.1) of the soil samples taken from the study area did not exceed the permissible limit value (300 mg kg^{-1}) according to the Turkish Soil Pollution Control Regulation (Table 1.1).

4. CONCLUSION

In this study, the variation of plant-available heavy metals such as Pb, Ni, Co, Cr and Cd in the soils of the Thermal Power Plant, which was established very close to the Silopi district where agriculture is intensively practiced, with the distance from the power plant and the depth of the soils was investigated. In this study, the wind direction (Figure 2.2) was not taken into consideration due to safety precautions in soil sampling and the areas where agriculture is intensively practiced were preferred. Among the elements examined, Ni and Cr concentrations decreased significantly at $p<0.01$ level as the distance from the thermal power plant, confirming the hypothesis of fly ash origin. However, Pb and Ni concentrations were higher in the topsoil (0-30 cm). It is possible to say that these elements are not sourced from the bedrock but are provided by an external contribution. The total concentrations of heavy metals were found to be below the total limit values accepted in soils with pH>6 according to the Regulation on Soil Pollution Control in Turkey. Although the total values of heavy metals measured in the soil were found to be below the limit values, it should be determined by new studies whether there is a transition from the concentration in the soil to the plant and if so, at what level. Although thermal power plants are one of the most talked about issues with their effect on soil pollution today, studies on this issue are very limited in the Silopi district, especially in agricultural areas. For this reason, it is recommended to conduct more comprehensive and long-term studies to determine the heavy metal content of soils and whether heavy metals are added to the food chain by the emissions of Silopi Thermal Power Plant, which has an important place in energy production in the region. The values obtained from the sampling points in this study will constitute a database for monitoring the changes that will occur in the soils of the region.

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