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Research Article

Assessment of Heavy Metal Contamination in Sugar Beet (*Beta Vulgaris*) Plant Along Erzincan–Erzurum Highway in Eastern Anatolia Region

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Abstract

In this study, it was aimed to determine the traffic and agricultural activity-induced heavy metal including arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr) and lead (Pb) pollution of sugar beet plants (*Beta Vulgaris*) grown along the Erzincan-Erzurum D100-25 highway and to reveal the possible change in the amount of heavy metals in sugar beet plants depending on distance to the highway. For this purpose, sugar beet plants were collected from 5 points of 10, 20, 30, 40 and 50 meters away from the highway and heavy metal levels of the samples were determined by inductively coupled plasma mass spectrometry (ICP-MS). The results showed that sugar beet plants were contaminated with various heavy metals such as Cr (585.5-2687.8 µg kg^{-1}) > Co (143.4-500.7 µg kg^{-1}) > Pb (52.1-476.7 µg kg^{-1}) > As (9.1-112.4 µg kg^{-1}) > Cd (4.4-65.2 µg kg^{-1}) depending on the distance from the highway. It was determined that heavy metal pollution levels in sugar beet plants decreased with distance from the motorway and there was a high correlation (As: 0.977; Cd: 0.944; Co: 0.995; Cr: 0.989 and Pb: 0.999) between distance and heavy metal content.

Keywords: Heavy metals, sugar beet, highways, pollution

Doğu Anadolu Bölgesi'ndeki Erzincan-Erzurum Karayolu Boyunca Şeker Pancarı Bitkisinde (*Beta Vulgaris*) Ağır Metal Kontaminasyonunun Değerlendirilmesi

Öz

Bu çalışmada, Erzincan-Erzurum D100-25 karayolu boyunca yetişen şeker pancarı bitkisinin trafik ve tarımsal faaliyet kaynaklı arsenik (As), kadmiyum (Cd), kobalt (Co), krom (Cr) ve kurşun (Pb) gibi ağır metal kirliliğinin belirlenmesi ve şeker pancarı bitkisindeki ağır metal miktarının karayoluna olan mesafeye bağlı olarak olası değişiminin ortaya konulması amaçlanmıştır. Bu amaçla, şeker pancarı bitkileri otoyoldan 10, 20, 30, 40 ve 50 metre uzaklıktaki 5 noktadan toplanmış ve örneklerdeki ağır metal seviyeleri indüktif eşleşmiş plazma kütle spektrometresi (ICP-MS) ile belirlenmiştir. Sonuçlar, şeker pancarı bitkilerinin otoyoldan uzaklığa bağlı olarak Cr (585.5-2687.8 µg kg^{-1})>Co (143.4-500.7 µg kg^{-1})>Pb (52.1-476.7 µg kg^{-1})>As (9.1-112.4 µg kg^{-1})>Cd (4.4-65.2 µg kg^{-1}) gibi çeşitli ağır metallerle kirlendiğini göstermiştir. Şeker pancarı bitkilerindeki ağır metal kirlilik seviyelerinin otoyola olan mesafe ile azaldığı ve mesafe ile ağır metal içeriği arasında yüksek bir korelasyon (As: 0.977; Cd: 0.944; Co: 0.995; Cr: 0.989 ve Pb: 0.999) olduğu tespit edilmiştir.

Anahtar Kelimeler: Ağır metaller, şeker pancarı, otoyollar, kirlilik

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1. Introduction

Heavy metals are generally defined as metals with a density greater than 5 g cm^{-3} and naturally occurring elements characterized by high atomic weights and densities. Some authors have indicated that agricultural applications such as pesticide usage, improper fertilizer application, and the overuse of manure and compost can lead to soil contamination with heavy metals [1-5]. Contaminants present in polluted agricultural soil can migrate into food products, posing substantial health risks [6-8]. This is particularly concerning due to the persistence, non-biodegradability, and irreversible nature of the contamination [9-11].

They present serious environmental and health risks if present in excess. Heavy metals have been introduced into the environment through various activities such as vehicle emissions, industrial processes, and agricultural practices. These activities release heavy metals into the environment, where they can persist for extended periods and accumulate in soil, water, and living organisms.

These metals are also released throughout a variety of road transport processes, including combustion, component wear, fluid leakage, and metallic corrosion. It can be stated that heavy metals from motor vehicle traffic include lead, nickel, mercury, cadmium, chromium, iron, copper, manganese and zinc [12]. Lead, cadmium, copper, and zinc are the primary metal pollutants in roadside environments, originating from sources such as fuel combustion, tire wear, oil leaks, and the corrosion of batteries and metallic components like radiators [13].

Intensive vehicle traffic on the highway and agricultural activities carried out in the vicinity bring with them problems that would threaten human health, especially with agricultural products (Zincirlioğlu 2013). Therefore, it is of great importance to determine the amount of heavy metals in plants grown close to motorways or highways. However, measuring the amount of heavy metals in the form that can be taken up by plants is much more important for the detection of environmental pollution and toxic effects of metals [14]. It is therefore determining the total quantities of heavy metals, and measuring the quantities of heavy metals that can be contaminated on plants is much more important for the detection of environmental pollution.

As, Cd, Co, Cr and Pb are important heavy metals and have significant negative effects on human health. Arsenic causes serious health problems such as bladder and liver cancer in the long term, while effects such as stomach pain, vomiting, decreased blood pressure, skin lesions are seen in the short term [15] while Cd is stated that prolonged exposure to low doses may contribute to the development of chronic lung diseases, including emphysema, asthma, and bronchitis, as well as elevated blood pressure [16]. Besides these, excessive exposure of Co has been shown to induce various adverse health effects [17] and the contamination of agricultural land and drinking water systems facilitates the entry of Cr into the food chain, posing direct and indirect health risks to all life forms [18]. As long as the concentration of lead in the soil does not exceed 150 ppm, it does not pose a danger to human and plant health. However, when it exceeds 300 ppm, it is potentially dangerous for human health [19].

Erzincan plain is known for its large areas of arable land devoted to cereal crops, vegetables, fruits and industrial crops. Sugar beet (*Beta vulgaris*) is the major industrial crop in this region and contributes with 30% to total agricultural production [20]. In these plants cultivated in agricultural areas, heavy metal pollution and accumulation exceeding the limits permitted by the World Health Organization (WHO) have been observed [21]. Sugar beet is reported to exhibit sensitivity to increasing concentrations of heavy metals, such as cadmium [22] and zinc

[23] and it is thought that sugar beet exposed to the motorway may pose various environmental risks depending on the distance to the roadways.

Therefore, the main objective of this study was to determine the levels of heavy metals (As, Cd, Co, Cr and Pb) in sugar beet grown in agricultural lands along the Erzincan-Erzurum highway and their changes depending on the distance to the highway. The highway receives heavy traffic pollutants due to the violent passage of a large number of vehicles. As far as we know, this is the first time that such a study has been carried out especially on sugar beet in this region with heavy metals evaluation.

2. Material and Methods

2.1. Study area and sampling

D100-25 highway, which is the most important international transport route of Turkey to Iran, is located within the borders of Erzincan province. Study area has an altitude of 1168 m and is located in coordinates of 39°43'26 ‘N 39°30'07 ’E (Figure 1).

Figure 1. The sampling sites (39°43'26"N 39°30'07"E) of the sugar beets of Erzincan-Erzurum motorway route.

Sugar beet samples collected by hand from a cultivated field at approximately 14th km of Erzincan-Erzurum D100-25 highway at five points of 10, 20, 30, 40 and 50 m away from the highway were used as material. Sugar beet samples were collected using plastic utensils and subsequently stored in plastic bags. The samples were immersed in a bath of distilled water and agitated for a specified duration to ensure thorough removal of particles adhering to the surface of the plant tissue.

2.2. Methods

2.2.1. Heavy metal analysis

Inductively coupled plasma mass spectrometry (ICP-MS) was performed to determine As, Cd, Co, Cr and Pb. Sugar beet samples were treated with a microwave degradation procedure according to a previously published by [24] with small changes prior to ICP-MS analysis. For this purpose, approximately 0.5 g of each sample was weighed into a 100 mL teflon microwave digestion vessel, and then 6 mL of nitric acid and 2 mL of hydrogen peroxide were added to the

Teflon tube. Subsequently, samples were digested using a two-step temperature program (Table 1).

Table 1. Temperature Controlled Microwave Digestion Program

Steps	Temperature	Heating Rate	Time
Steps 1	20 to 120°C	20°C min^{-1}	-
Steps 2	120 to 180°C	20°C min^{-1}	10 min

After digestion, the samples were transferred to a 100 mL volumetric flask and completed with ultrapure water to the target volume. The plasma power was set at 1550 W for the ICP-MS measurements, and the other measurement settings were obtained from the auto-tune report and are listed in Table 2. Potential isobaric interferences were avoided by using Helyum mode. A 500 µg L^{-1} concentration of Sc was used as an internal standard. Heavy metal concentrations were calculated based on the sample weight and expressed as µg kg^{-1} dry weight.

Table 2. Measurement parameters used in the ICP MS system

Parameter	Value
Ar flow rate (L min^{-1})	15
He flow rate (mL min^{-1})	4
Carrier gas flow rate (mL min^{-1})	1.1
Sampling Depth (mm)	10
Internal standard	Sc

2.2.2. Statistical analysis

All samples were analyzed in duplicate. Data were analyzed using SPSS software (version 20.0, Chicago, USA). Independent variables, such as soaking methods and soaking times, were tested using multiple linear regression models with heavy metals in cooked rice as the dependent variable.

3. Results and Discussion

The annual average daily traffic (AADT) values of Erzincan-Erzurum D100-25 highway were given in Table 3. As shown in Table 3, the traffic density of the Erzincan-Erzurum D100-25 highway, which is located next to the sugar beet plants grown, where a total of 13.336 vehicles pass on an average day, is quite high. It can be stated that metal-rich road dust from vehicle passage can be an important source of roadside pollution, particularly on roads with high traffic volumes and a high proportion of heavy vehicles [25,26].

Table 3. AADT values of Erzincan-Erzurum D100-25 highway in the studied region [27]

2023	Car	Medium load commercial vehicle	Bus	Truck	Truck+TrailerTowing+ Semi trailer	Total
AADT	9280	1500	210	779	1567	**13.336**

The changing in heavy metal levels (As, Cd, Co, Cr and Pb) in sugar beet plants depending on the distance was given in Table 4. As can be seen in Table 4, all heavy metal levels decreased with increasing distance to the motorway. It can be stated that this showed that the heavy metals present in the plant may be originated from the motorway. Similar results were found in other studies [28-30]. Numerous studies have been conducted to assess heavy metal contamination in soil and plants [31-34]. Generally, it was observed that the total heavy metal content in soil and plants significantly increased near the motorway and gradually decreased with increasing distance. In addition to the contamination of the soil with heavy metals due to the density of motor vehicles throughout the year, airborne contamination during the growth and harvesting of the plant also plays an important role in these contaminations in sugar beets plants

Table 4. Changing in heavy metal levels depending on distance in sugar beet plants

Distance	**Concentrations (μg kg^{-1})**				
(m)	**As**	**Cd**	**Co**	**Cr**	**Pb**
10	112.4	65.2	500.7	2687.8	476.7
20	107.1	31.2	416.3	1989.1	364.4
30	60.3	25.8	356.1	1680.9	256.7
40	25.1	15.9	232.8	1293.4	140.0
50	9.1	4.4	143.4	585.5	52.1

As and Pb concentrations in sugar beet plants that were taken from all distances were below the permissible limits by Food and Agriculture Organization of the United Nations (FAO)/(WHO) limit of 200 μg kg^{-1} [35] and by WHO limit of 2000 μg kg^{-1} [36], respectively. Cd and Cr concentrations in sugar beet plants that were taken from distances of 40 and 50 m were also below the permissible limits by WHO limit of 20 μg kg^{-1} [36] and by FAO/WHO limit of 1300 μg kg^{-1} [35], respectively while Cd and Cr concentrations in sugar beet plants that were taken from distances of 10, 20 and 30 m exceeded the permissible limits. Co concentrations in sugar beet plants that were taken from all distances were above the permissible limits by FAO/WHO limit of 100 μg kg^{-1} [35]. Although cobalt exhibits a low level of toxicity across all studied species including humans [37] and is essential element, a high concentration of cobalt may pose a risk to human health [38]. In other words, excessive exposure has been linked to various adverse health effects while cobalt plays a vital biological role as a metal constituent of vitamin B12 (Leyssens et al., 2017).

As shown in Table, the concentrations of As and Cd in sugar beet plants in all distances were found to be lower compared to those of Co, Cr and lead. This is due to the fact that these plants have a more advanced detoxification mechanism against some heavy metals [39]. An examination of the highly toxic elements arsenic (As) and lead (Pb) in sugar beet plants, based on WHO/FAO limit values, indicates that they pose no risk to human health except for Co [35-36].

Regression analysis was performed to determine the mathematical form of the relationship between distance and heavy metal contents (Table 5) and 5 linear regression models were established. Regression analyses showed that all heavy metal concentrations were significant against distance. All models were significant at the 0.01 level for As, Co, Cr and Pb, while at the 0.05 level for Cd. In other words, the regression results also support that heavy metal concentrations decreased as the distance from the motorway increased.

Table 5. Regression models for heavy metal

Model	T value	Significant
As = -23.780+2.886*distance	7.856	0.01
Cd = -12.570+1.369*distance	4.978	0.05
Co = 60.430+8.981*distance	16.617	0.01
Cr = 177.250+49.003*distance	11.774	0.01
Pb = -64.100+10.736*distance	40.631	0.01

According to regression analysis results, there is a linear relationship between distance and heavy metal contents (Figure 2).

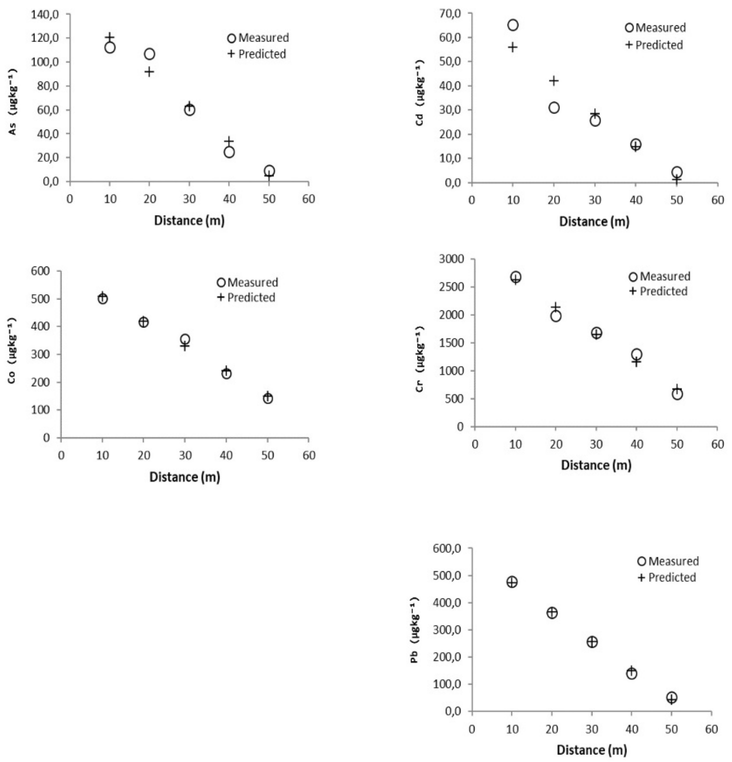

Figure 2. Measured and predicted values of heavy metals (As, Cd, Co, Cr and Pb) by regression analysis

At the same time, the correlation analysis was performed to determine whether there is a relationship between distance and heavy metal content variables, and if there is a relationship, its strength and direction. Accordingly, a strong positive correlation (r=0.944-0.999) was found between distance and heavy metal content (Table 6).

Table 6. Correlation analysis between distance and heavy metal levels

Heavy metals	Correlation (*r*)	Significant
As	0.977	0.004**
Cd	0.944	0.016*
Co	0.995	0.001**
Cr	0.989	0.001**
Pp	0.999	0.001**

* P<0.05, ** P<0.01

As shown in Table 6, there was a high correlation in the same direction between the distance and all heavy metal levels. Among these correlation values, the correlation between distance and Cd is significant at $P<0.05$, while the correlations between distance and other heavy metal levels are significant at $P<0.01$. Most studies have reported a correlation between high metal concentrations in soil and plants [40,41].

4. Conclusion

All heavy metal levels decreased with increasing distance to the Erzincan-Erzurum D100-25 highway and it can be said that this showed that the heavy metals present in the plant may be originated from the motorway. The concentrations of As and Cd in sugar beet plants in all distances were found to be lower compared to those of Co, Cr and Pb. It can be concluded that sugar beet plants grown in the soils around Erzincan-Erzurum D100-25 highway do not have any heavy metal pollution in terms of As and Pb that would require precautions to be taken for the time being. Besides, the study revealed that the reason for the presence of heavy metals such as As, Cd, Co, Cr and Pb in sugar beet plants is road traffic. However, such studies should be repeated at certain time intervals to examine the possible change of heavy metal accumulation over time and precautions should be taken when necessary.

Ethics in Publishing

This study does not involve any ethical concerns related to its publication.

Author Contributions

All authors contributed equally to the writing of this manuscript

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