



# Atmospheric deposition of Pb and Cd in the *Cedrus atlantica* for environmental biomonitoring

Kaan Isinkaralar<sup>1</sup>

Received: 27 October 2021 / Revised: 14 February 2022 / Accepted: 7 March 2022 / Published online: 24 March 2022  
© The Author(s) under exclusive licence to International Consortium of Landscape and Ecological Engineering 2022

## Abstract

Atmospheric heavy metal deposition is widely occurring due to anthropogenic effects such as industrial activities and motor vehicles. As a result, it has increased significantly and reached a level that threatens human health and the environment. Among these deposition factors, it is of great importance to monitor the atmospheric concentrations of heavy metals that do not easily degrade in nature, tend to bioaccumulate, and can be toxic even at low concentration levels. Biomonitoring is one of the most impressive passive methods in determining the change of heavy metal concentrations in the atmosphere. This study investigates the effect of anthropogenic emission sources in urban areas using tree rings as a biomonitor. *Cedrus atlantica* was selected, because it is generally preferred in parks, roadside and landscape design. Samples were collected from parks near the road, densely populated, and close to the small-scale industry in Kastamonu, Türkiye. Atmospheric deposition of Lead (Pb) and Cadmium (Cd) in organs were analyzed based on years and directions. Their accumulation in the outer bark was determined to be quite high (Cd value is 2226.2 ppb and Pb value is 38201.1 ppb) compared to other organs. As a result, the traffic density and industrial emissions affect the Pb and Cd concentrations. This study will provide beneficial information for atmospheric heavy metal deposition in landscape plants.

**Keywords** Air pollution · Biomonitor · Heavy metals · Landscape plants · Tree ring

## Introduction

Air pollution has many components in cities due to rising population, industrialization, and urbanization (Lin and Zhu 2018). During unplanned urbanization, they are cutting off the regions' ventilation and setting a barrier in front of the prevailing wind direction reduces the air quality of cities (Yilmaz and Isinkaralar 2021a, b). In today's modern world, with technological developments, the construction of high-rise buildings has increased for enough residences to accommodate the rapidly growing population in cities (Cummings et al. 2022). However, while the developing technology was adapted to every city, the buildings were constructed similarly with modernism, away from being designed according to the urban character (Luo et al. 2018). Therefore, many adverse environmental pollutions emerge.

In particular, the decrease in air quality and the formation of heat islands trigger air pollution, because pollutants are not dispersed. (Civerolo et al. 2007). Currently, 7 million deaths and around 3.7 million premature deaths worldwide are derived from intense air pollutants per year (WHO 2014; Cohen et al. 2017). In addition, the beginning of the negativities in urbanization increases private cars and heavy traffic (Wang et al. 2014).

Small-scale playgrounds, gardens, and landscaping areas on the roadsides remained under dense construction in the cities, limiting the diversity of planted landscape plants (Han et al. 2022). We must determine how air pollutants interact with complex urban structures to identify how cities can be designed with parks, facilities, and industrial areas (Yuan et al. 2019). The main reason for this is the perishability of plants exposed to intense air pollutants against harsh conditions, including heavy metals, particulate matter, nitrogen oxides, sulfur oxides, etc. (Yang et al. 2020). Not every plant grows in these areas, and only those resistant to it by their nature survive. Humanity has tried different plants for landscaping works in many parks, gardens, and roadsides in cities (Sevik 2020). To investigate the reason for this, they

✉ Kaan Isinkaralar  
kisinkaralar@kastamonu.edu.tr

<sup>1</sup> Department of Environmental Engineering, Faculty of Engineering and Architecture, Kastamonu University, 37150 Kastamonu, Turkey

analyzed the species that had stopped growing and had no signs of life and found that the levels of heavy metals in their bodies were high. Thus, the search for durable species by the structure of the region to be used in landscape studies in these areas has begun (Karacocuk et al. 2021).

Reasonable methods should be chosen to monitor the sustainability of air quality in cities (Vos et al. 2013). Air monitoring stations and regional active sampling centers have been established in developed world countries (Chen et al. 2022). Various pollutants were detected in the analysis of the wet and dry samples taken (Tallis et al. 2011). It can be determined that the contaminants originate from traffic, industrial emissions, the metalworking industry, mines, gas stations, and many other facilities. Despite all this, some analyzes also found substances whose source could not be determined. As a result of the reactions of undetected pollutants with each other, they can be transformed into other compounds. However, air pollutants can be transported to remote areas, although the concentration in the available area is high (Hakkim et al. 2022). These relocation events also depend on climate, wind level, and weather events (Koç et al. 2021). The control of anthropogenic air pollutants is becoming more and more complex concerning atmospheric pollutants (Granier et al. 2011). Nevertheless, some critical natural oscillations can be brought under control, mainly by evaluating the emissions from the source and risks (Isinkaralar et al. 2022). Although various models, including emissions and short-term sampling, show the extent of air pollution, biomonitors have come to the fore due to the high cost of these methods, insufficient precision, and lack of simultaneous measurement (Shvetsova et al. 2019). The disruption caused by atmospheric pollution and acid rain on forests and their adverse effects on different plants and trees has been the subject of various studies for over a century (Likens 2021). With the discovery of the ability of plants used in urban landscaping to absorb air pollutants, it has become widespread (Ahmad et al. 2019; Koç 2021). Species with high absorption capacity are preferred in children's playgrounds, roadsides, and large parks. Heavy metals are the leading pollutants that accumulate in these areas. These toxic metals, released with various emissions, quickly get into the environment. Pb and Cd are the most important of these heavy metals (Sun et al. 2018; Liu et al. 2019; Raj and Maiti 2020).

Pb is released to the atmosphere from anthropogenic sources such as wood-burning, fossil fuels use, industrial processes, and mining activities. The Pb has four stable isotopes ( $^{204}\text{Pb}$ ,  $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ , and  $^{208}\text{Pb}$ ) that are abundant in the environment with the latter three radiogenic products of the U and Th decay series (Weiss et al. 1999; Sangster et al. 2000). Most of the lead that causes environmental pollution results from tetraethyl lead produced because of the burning of gasoline used in motor vehicles. Essential sources of

cadmium affecting human life are cigarette smoke, refined foodstuffs, water pipes, coffee, tea, coal burning, shellfish, fertilizers used in the seed stage, and flue gases formed during industrial production stages (Kubier et al. 2019). Therefore, it is vital to monitor the change of heavy metal pollution in urban areas where industrial, mining, and agricultural activities and vehicle emissions (Isinkaralar and Erdem 2021a, b). Monitoring heavy metal pollution can be done directly or indirectly in the atmosphere. Atmospheric heavy metal deposition is released from their source. They first accumulate in that region and then move to other areas by transport. Depending on the absorption capacity of the soil structure in the region, it first penetrates the surface and then the lower part of the soil (Feng et al. 2019). Thus, polluted agricultural lands have been formed in many parts of the world (Feng et al. 2018).

About 20% of the total arable land in China, 20 million hectares, is contaminated with Cd and Pb and over 13 million hectares of Cd-contaminated cultivated land in China (Xue et al. 2014; Hu et al. 2016). In line with the data obtained from agricultural lands in various parts of the world, there is an average accumulation of 20–80% of Pb and Cd from atmospheric deposition (dry and wet deposition) (Nicholson et al. 2003; Hou et al. 2014). However, determining the pollution directly is not preferred often as it is expensive, and the direct effect of atmospheric pollution on the ecosystem cannot be determined (Posch et al. 2008). Biomonitors are the most effective method to monitor the indirect effects of heavy metal pollution (Cetin et al. 2021). The increasing amount of heavy metals to air, soil, and water have been investigated by scientific area with sediments, ice cores, peat bogs, moss, and plants. Especially landscape plants can passively accumulate heavy metals in various organs. Due to their high metal-binding capacity, they have gained dry and wet deposition of heavy metals in these organs. Therefore, they give essential information about the concentration of heavy metals in air pollution as biological indicators (Shahid et al. 2017; Gustin et al. 2022). It is known that the species whose suitability to use as a biomonitor are investigated over a long period are healthier. The main reason for this is that accumulation is seen in almost every living species (Lichens, mosses, algae, plants, perennial trees, etc.). However, it is unclear which of these creatures is correct to take samples continuously or represents the time intervals from the samples taken. For example, it can look at the accumulation in algae, but it is not clear what level of pollutants can accumulate at what time intervals. For this, the species that do not lose their leaves can grow in harsh conditions for many years, and showing their accumulation in a single vegetation period is very important (Savas et al. 2021). However, the heavy metal concentrations determined in the organs of these plants cannot be easily interpreted since many factors are effective in

this process as heavy metal accumulation in plants is shaped by the effect of genetic factors and environmental conditions. The data obtained cannot be appropriately interpreted because these factors are not equalized (Cetin et al. 2020). It is stated that, regarding the monitoring of heavy metal pollution and the comparison of its changes over the years, the most reliable information is obtained by using the organ of tree for many years (Arıcak et al. 2020). Comparing the number of heavy metals accumulated in different years in organs on the same tree can provide much healthier results. However, information about a maximum of 8–10 years of history can be obtained with this method. In areas where the trees enter dormancy, the development of the trees according to the season is at different levels, and thus annual rings are formed in the woody part. By comparing the number of heavy metals that trees accumulate in their rings over a long period, unequal genetic structure and environmental factors are equalized. The change in the long process can be compared (Vickers et al. 2010). In line with the studies on the accumulation of heavy metals in the annual rings, clear information for the transition and expansion of heavy metals is unknown (Shahid et al. 2017).

In this study, *Cedrus atlantica* (Endl.) Manetti ex Carrière was evaluated as a biomonitor by using landscape vegetation in areas with high emissions from vehicles, residences, and small-scale industries. The atmospheric Pb and Cd deposition is mainly associated with several emissions in the organ of a *Cedrus atlantica* in medium-size children's playground and park, Kastamonu, Türkiye. The heavy metal concentration in the tree's outer bark, inner bark, and wood was also compared with the directional variation of the heavy metal concentrations. Objectives of the study were (i) to assess the accumulation levels in the organs; (ii) to investigate the changes in different directions (facing the road, residences, industry, or free space); (iii) tree rings can be used as biomonitors or not every year (1987–2019) for Pb and Cd contamination.

## Materials and methods

### Study area

This study was carried out in Kastamonu, which is at a mean elevation of 775 m above sea level and is located in the north of Türkiye (41° 23' 20.6" N, 33° 46' 46.1" E). The city occupies an area of 13,108.1 km<sup>2</sup> that primarily consists of rough lands with about 375,592. It is generally mountainous; it does not have vast plains. But, on the other hand, there are plains around the valleys. It has a semi-humid climate, cold in winters, warm in summers, no excess water, and close to the effect of the sea. The main sources of air pollution are: industry within the city

in different sectors, mainly timber and forestry products; it is the excess of motor vehicles used in transportation and transportation works. According to the data, there are 138,887 vehicles registered to traffic in Kastamonu.

Atlas cedar (*Cedrus atlantica* (Endl.) Manetti ex Carrière) used as a landscape plant in parks in Kışla Park area, Kastamonu city center in Fig. 1. It has grown with vehicle emissions, and coal is used for heating residences. A medium-sized car industry site is located at the rear of the park. The Atlas cedar, a coniferous tree, is in the family of pine trees. In addition, it is used for medicine in the healthcare field, which is herbal medicine for people. Besides, it is an indispensable species of landscaping work in parks, etc. It is resistant to harsh climatic conditions and has lived for many years.

### Sample collection

Samples were collected, processed, and analyzed by the laboratory techniques cleanly. The cleaning of the equipment used is done with precision to avoid contamination. The main arterial road passes through the center of Kastamonu city in the east direction of the area where the *Cedrus atlantica* (Endl.) Manetti ex Carrière grows, and a secondary road with four lanes is connected to this road in the north direction. The direction was determined on the north side of the log, and all directions were marked. The log sample was collected with an approximate thickness of 10 cm, get from the body part with a height of 50 cm from the ground by marking the directions. It was brought to the laboratory, sanded, and smoothed to see the tree rings clearly. The tree rings of the *Cedrus atlantica* (Endl.) Manetti ex Carrière was determined to be 33 years old (between 1987 and 2019) by rings. They were grouped to be three years each by considering their width, and it was noted which period belonged to which year in Table 1.



Fig. 1 Location of the study area

**Table 1** ID number of tree rings according to year ranges

Tree ring ID	Year ranges
1	1987–1989
2	1990–1992
3	1993–1995
4	1996–1998
5	1999–2001
6	2002–2004
7	2005–2007
8	2008–2010
9	2011–2013
10	2014–2016
11	2017–2019

### Analytical procedures

The *Cedrus atlantica* (Endl.) Manetti ex Carrière were obtained from the barks (outer and inner) and the wood part of all age ranges and placed in glass Petri dishes; tools made of metals that are the subject of the study were not used in these operations. The wood samples taken were shredded and turned into sawdust and kept in glass Petri dishes with lids open in the laboratory environment for 15 days to become air-dried. Then, the samples were oven-dried at 45 °C for a week. 0.5 g of the dried samples were taken, and 6 mL of 65% HNO<sub>3</sub> (Merck), 2 mL of 30% H<sub>2</sub>O<sub>2</sub> (Merck) were added and placed in the microwave oven (Ethos One, Milestone GmbH, Germany). It was set up four steps: 1 min at 1000 W—75 °C, 4 min at 1000 W—180 °C, 10 min at 1000 W—180 °C, 0 W for 15 min according to 3052 Method USEPA. After the samples were burned in the microwave oven designed for digestion, the solution samples were taken into balloons, and ultrapure water filled up to 50 mL level. Pb and Cd concentrations were analyzed using inductively coupled plasma optical emission spectrometry (ICP-OES device from SpectroBlue, Spectro, Analytical Instruments GmbH, Germany).

### Data analyses

In this study, the one-way analysis of variance (ANOVA) and Duncan's multiple range test were used to test the difference of the variables statistically. Homogeneous groups were obtained by applying the Duncan multiple range test for the factors that were found to have statistically significant differences with at least 95% confidence level ( $p < 0.05$ ) using the SPSS Version-22.0 (IBM SPSS Statistics software for Windows). After simplifying the data, tables were drawn and interpreted. All measurements were made in triplicate in the study.

## Results

### Pb concentrations in the organs and their statistical analysis based on years and direction

The mean concentrations and  $F$  value of Pb in organ (Outer bark (Ob), Inner bark (Ib), and Wood (W)) of *Cedrus atlantica* (Endl.) Manetti ex Carrière at four directions (South (S), West (W), North (N) and East (E)) from collection sites are given in Table 2.

The variation of Pb is examined that there are significant differences among organs in the east directions at a confidence level of at least 99% based on organ and direction. The highest values were obtained in the outer bark in all directions. According to the Duncan test, two groups were formed in the eastern directions, and the values obtained in the inner bark and wood were located in the same groups. The lowest values were obtained in wood in the east and north directions. It is noteworthy that the value obtained in the outer bark in the south and west directions was approximately 1.5 times that of the wood, while it was more than 1.9 times in the east direction and about 2.7 times in the east direction. There is a statistically significant difference among the four approaches in all organs. In the outer bark, four homogeneous groups were formed according to the Duncan test; the west was in the first, the south was in the second, the north was in the third, and the east was in the last group. The variation of Pb concentrations in wood based on years and directions is given in Table 3.

When the table values showing the change of Pb concentrations based on years and directions are examined, it is seen that there is a statistically significant difference ( $p < 0.001$ ) among years in all directions per year. When the values are concerned, there is an irregular change generally until 1996–1998. The highest values were obtained in the north direction between 1987 and 1992, while the highest values were obtained in the south direction in 1993–1998.

**Table 2** Changes in organs Pb concentrations (ppb) under four direction

Organ	Directions				$F$ value
	S	W	N	E	
Ob	14,597 B	9681.5 A	23,679.2 C	38,201.1 D	71.29***
Ib	10,279.2 B	5641 A	14,596.7 C	15,687.6 Ca	38.81***
W	10,340.6 AB	6307.1 A	12,165.1 B	14,155.4 Ba	4.89**
$F$ value	0.42NS	1.42NS	2.18NS	7.059**	

Uppercase letters express horizontal direction even though lowercase letters state vertical direction for each variable, NS no significant difference, significance at \*\* $p < 0.01$ , \*\*\* $p < 0.001$

**Table 3** Pb concentrations (ppb) based on year and direction in wood

Tree ring ID	Directions				<i>F</i> value
	S	W	N	E	
1	3641.2 Bc	5017.7 Cb	33,573.5 Dj	1544.8 Aa	6676.51***
2	6999.4 Be	1467.1 Aa	18,687.4 Dh	8327 Cd	1167.47***
3	20,247.8 Dh	6401.4 Ac	8877.1 Be	16,065.6 Cf	1490.84***
4	15,059.1 Dg	11,593.8 Ce	1191.4 Aa	1507.3 Ba	1666.20***
5	1501 Ab	1200.7 Aa	2082.1 Bb	4810.6 Cb	68.91***
6	2533.6 Ab	6866.9 Dd	3256.9 Bc	6205.7 Cc	663.78***
7	4889.1 Bd	1541.1 Aa	6885.0 Cd	13,618 De	898.42***
8	4967.4 Ad	7173.7 Bd	10,890.6 Cf	14,847.3 Def	303.04***
9	7554.6 Af	9083.3 Bd	11,311.6 Cfg	20,930.1 Dg	216.71***
10	20,922.4 Ci	7165.8 Ad	12,023.2 Bg	32,988.4 Dh	1654.35***
11	25,431 Bj	11,865.8 Af	25,037.2 Bi	34,864.8 Ci	394.81***
<i>F</i> value	6887.45***	885.18***	1480.81***	760.59***	

Uppercase letters express horizontal direction even though lowercase letters state vertical direction for each variable, \*\*\*Significance at  $p < 0.001$

In the year 1999, the lowest Pb concentrations were obtained in general, and it was observed that there had been a steady increase since this date. After 1999, the highest concentrations were obtained in the east direction, while the subsequent highest concentrations were in the north direction until 2011–2013, and then in the south direction. In this period, the lowest concentrations were obtained in the west direction. The increase in Pb emission due to gasoline use was reflected in the trend of the concentration data up to 2000.

### Cd concentrations in the organs and their statistical analysis based on years and direction

The mean concentrations and *F* value of Cd in organ (Outer bark (Ob), Inner bark (Ib), and Wood (W)) of *Cedrus atlantica* (Endl.) Manetti ex Carrière at four directions (South (S), West (W), North (N) and East (E)) from collection sites are given in Table 4.

The difference of Cd was examined that no statistically significant difference was observed among the organs in the south, west, and north directions. In the east directions, the highest values were acquired in the outer bark, and the inner bark and wood in both directions were in the first group according to the Duncan test. When evaluated in direction, the highest values in all organs were gained in the east direction. All the values obtained in the west and south direction as a result of the Duncan test were included in the first group, and the change of Cd concentration in the outer bark and wood was listed as west > southeast. The variation of Cd concentrations in wood based on years and directions is given in Table 5.

The change of Cd concentration based on years and directions examined shows that the change in all directions based on years and in all years based on directions is statistically

**Table 4** Changes in organs Cd concentrations (ppb) under four directions

Organ	Directions				<i>F</i> value
	S	W	N	E	
Ob	397.8 A	413.6 A	644.6 B	2226.2 Cb	624.02***
Ib	362 A	349.7 A	328.2 A	627.6 Ba	33.45***
W	345.1 A	290.3 A	452.8 B	581.2 Ca	15.38***
<i>F</i> value	0.13NS	1.89NS	2.49NS	71.27***	

Uppercase letters express horizontal direction even though lowercase letters state vertical direction for each variable, NS no significant difference, \*\*\*Significance at  $p < 0.001$

significant (at least  $p < 0.01$ ). When the average values are examined, it is seen that the Cd concentration followed a fluctuating course until 2005–2007; it was generally at the lowest level in the period 1999–2001. After this year, Cd concentration reached the highest level in all directions. When the directional variation of the Cd concentration is examined, it is seen that the highest values were obtained in the north from 1987 to 1989, in the west in the period of 1996–1998, and in the east direction in all other years. Particularly in the period after 1999, the Cd concentration, in general, is ranked as east > north > south > west based on the direction.

## Discussion

Past trends of Pb and Cd concentrations in *Cedrus atlantica* (Endl.) Manetti ex Carrière has followed with wet and dry deposition of the emissions of their levels. Bioaccumulation and translocation are among the critical factors in the

**Table 5** Data of Cd concentrations (ppb) in wood based on age and direction

Tree ring ID	Directions				<i>F</i> value
	S	W	N	E	
1	350.2 Be	286.8 Ab	660 Cef	282.4 Aa	523.35***
2	406 Cg	143.5 Aa	363.8 Bbc	578.8 De	763.68***
3	468.7 Ch	362 Bd	216.6 Aa	680.9 Dg	529.45***
4	118.3 Aa	539.4 Cf	201.1 Ba	251.7 Ba	75.39***
5	141.5 Ab	131.5 Aa	357.6 Bbc	452.2 Cb	1183.64***
6	160.6 Ac	275.2 Ab	464.8 Bcd	495.3 Bc	9.02**
7	242.1 Bd	133.8 Aa	323 Cab	529.3 Dd	175.82***
8	357.5 Ae	318.8 Ac	434.2 Abc	584.9 Be	11.80**
9	364.2 Be	327.8 Ac	577.8 Cde	620.4 Df	566.96***
10	386.8 Bf	289.9 Ab	606.5 Ce	742 Dh	305.66***
11	799.8 Bi	384.3 Ae	775.8 Bf	1175 Ci	1741.81***
<i>F</i> value	1635.18***	461.79***	20.75***	480.86***	

Uppercase letters express horizontal direction even though lowercase letters state vertical direction for each variable, Significance at \*\* $p < 0.01$ , \*\*\* $p < 0.001$

growth of plants (Alaboudi et al. 2018; Ghoma et al. 2022). As a result of the study, the highest values in both Pb and Cd concentrations were obtained in the east direction, and the following highest values were obtained in the north direction. Based on these results, it can be said that Pb and Cd concentrations increase significantly depending on fossil fuel combustion and motor vehicle exhaust. The total Pb emissions until the 2000s were picked due to directly related to the discharge of gasoline. With the abolition of the use of lead-added gasoline, the lead accumulation rate decreased. According to the years in the tree ring, it is seen that the amount of lead decreased in parallel with the popularization of unleaded gasoline. Cadmium is mainly emitted from point emission sources such as non-ferrous metal smelters, power plants, and waste incinerators, while lead emissions come primarily from field sources such as traffic (Cheng et al. 2014; Zhao et al. 2020; Cetin and Jawed 2022). A medium-sized car industry site is located at the rear of the park. Here, ironworking, metal alloying, and welding are small plants. According to studies on heavy metals, Pb and Cd are among the heavy metals most associated with traffic density (Arıcak et al. 2019). Sevik et al. (2020) determined that the Pb concentration in the wood on the roadside was 2161 ppm, whereas the Pb concentration in the wood on the other side was 980 ppm. Similarly, Akarsu (2019) determined that the Cd concentration was 157 ppm in the wood, 176.8 ppm in the inner bark, and 2601.2 ppm in the outer bark on the roadside, whereas it was 139.7 ppm in the wood, 166.5 ppm in the inner bark, and 116.6 ppm in the outer bark on the other side.

Published reports and studies have also stated that Pb and Cd concentrations increase with traffic density (both of non-exhaust and exhaust emissions) (Viard et al. 2004; De Silva et al. 2016; Du et al. 2019). Jeong et al. (2022)

was investigated non-exhaust emissions sources of heavy metals in road dust. They found that asphalt has a dramatically greater Pb concentration than other heavy metals, and heavy traffic with congestion, brake pads, and tire wear caused emissions of some heavy metals. Several researchers reported that Pb and Cd had been widely used elements for leading heavy metals to monitor anthropogenic sources and to understand biogeochemical processes in environments. In the beginning, traffic density, vehicle wear, industrial emissions, and road dust worldwide in urban environments. Cai and Li (2019) were conducted some heavy metals, including Pb and Cd elements, in street dust from Shijiazhuang, China. They enter the human body through the respiratory system and can accumulate from traffic and industry contributed with 53.55% and 59.70%. Jeong et al. (2021) were examined potentially toxic elements in the different sizes of road deposited sediments in the Onsan industrial zone, Korea. They found highly toxic elements such as Pb and Cd, which assessed the potential ecological risk level. Mean metal concentration of Pb and Cd elements was released to the road as 13,561 and 225 mg/kg during the transportation of raw ore for smelting activity. Ariapak et al. (2022) were studied 44 sites (528 samples) for seasonal and spatial variations of heavy metals in the dust of Tehran, Iran. They indicated that air pollution sources are traffic, fossil fuel use, and several industrial activities. Also, Ni, Cr, Cd, Pb, and Zn were in the same group derived from natural and anthropogenic sources. The main source is Cd, which was reported in vehicle motor emissions although Pb was gained combustion and burning activities of fossil fuel containing Pb. Kafle et al. (2022) determined twenty elements including Pb and Cd toxic metals in the surface soil of Kathmandu Valley, Nepal. They showed the pollution of metals in open areas and results obtained as Cd > As > Pb > Zn > Cr > Mn >

Ni > Cu from anthropogenic sources. The literature studies show that the potential to hold heavy metals that are bound to the reducible fraction in atmospheric deposition (dust, deposition, transportation, etc.) in each plant species varies by various soil conditions (soil pH and redox conditions). Although the transport and accumulation of pollutants is not known clearly, we assume that they represent the areas where they are found except their anthropogenic sources and transport pathways. Consequently, more attention should be paid to the extensive influences of atmospheric deposition on several plants. However, the structure of each plant and its interaction with each heavy metal may be at different accumulation levels. The durability and absorbate capacity of the landscape plants should be investigated for atmospheric toxic metals.

In this study, the highest Pb and Cd concentrations formed in different years were generally obtained in the directions with heavy traffic in the wood. In addition, it was determined that there was an increase in the concentrations of both heavy metals in general after 1999 and this increase continued until today. Until this date, the concentrations of both heavy metals had been generally high and had changed irregularly. Principally, this decrease in Pb concentration in the early 2000s is related to the ban on regular gasoline with high Pb content in these years. It is stated that 90% of lead in the atmosphere has been formed by leaded petrol since 1925. Therefore, the increase after the 2000s is probably proportional to the rise in the number of vehicles.

## Conclusion

Focusing on the biomonitoring, this paper shows that the highest concentrations of Pb and Cd toxic metals are generally obtained in the outer bark. In contrast, the concentrations do not differ statistically in the wood and inner bark. Statistical analysis based on directions was made to understand better the Pb and Cd sources in the case area. The difference in Pb and Cd concentrations on a directional basis indicates that both the concentration of these heavy metals are linked to traffic, and the transfer of heavy metals among organs (and among cells in the same organ) is quite limited. Examining the time intervals in the tree rings, Pb and Cd concentrations have been changed significantly every year due to an increase in the number of vehicles in traffic emission. Consequently, the passive method is used effectually in biomonitoring of Pb and Cd concentrations using the *Cedrus atlantica* rings. They can indicate how heavy metal pollution has been changed from the past and even the effects of traffic density, industrial revolution and urbanization. Therefore, *Cedrus atlantica* (Endl.) Manetti ex Carrière is a convenient biomonitor for detecting of Pb and Cd pollution. It is recommended to be commonly used in the parks, roadside,

refuge, and other landscape areas for absorbed heavy metals. Atmospheric deposition is essential for heavy metals' transformation from the atmosphere to soil. Heavy metals from atmospheric deposition can indirectly or directly influence ecosystems and human health from anthropogenic and other activities such as industrial activities, incineration of waste and corrosion, and use of lead-containing metals. Mineral sources occur at high temperatures such as combustion, fossil fuels, roasting and melting of ores, kiln processes in cement, incineration of wastes, and enormous amount of trace metals into the atmosphere. Pb and Cd have been given a particular concern in biomonitoring studies, and they became priority environment contaminants. Minimizing their effects and monitoring accumulation have been promulgated to various international conventions to reduce Pb and Cd emissions levels. Numerous studies have been shown the impact of their toxicity on the environment and human health, although information about the sources and flows of these pollutants is much less specific. It has been observed that the plant species can be used as biomonitors in cities due to their high absorbing capacity of contaminants. Due to these features, it is thought that they can be helpful in the follow-up of environmental pollutants.

**Acknowledgements** I would like to acknowledge Kastamonu Municipality, Ferhat Sahin and Dr. Hakan Sevik for their support for this research.

**Funding** There is no financial support and commercial support.

**Availability of data and materials** Not applicable.

## Declarations

**Conflict of interest** The authors declare that they no conflict of interest. None of the authors have any competing interests in the manuscript.

**Ethics approval** Not applicable.

**Consent to participate** Not applicable.

**Consent to publish** Not applicable.

## References

- Ahmad I, Abdullah B, Dole JM, Shahid M, Ziaf K (2019) Evaluation of the air pollution tolerance index of ornamentals growing in an industrial area compared to a less polluted area. *Hortic Environ Biotechnol* 60(4):595–601. <https://doi.org/10.1007/s13580-019-00141-9>
- Akarsu H (2019) Determination of heavy metal accumulation in atmosphere by being aid of annual rings. MSc. thesis, Kastamonu University Institute of Science Department of Sustainable Agriculture and Natural Plant Resources
- Alaboudi KA, Ahmed B, Brodie G (2018) Phytoremediation of Pb and Cd contaminated soils by using sunflower (*Helianthus*

- annuus*) plant. *Ann Agric Sci* 63(1):123–127. <https://doi.org/10.1016/j.aos.2018.05.007>
- Ariapak S, Jalalian A, Honarjoo N (2022) Source identification, seasonal and spatial variations of airborne dust trace elements pollution in Tehran, the capital of Iran. *Urban Climate* 42:101049. <https://doi.org/10.1016/j.uclim.2021.101049>
- Aricak B, Cetin M, Erdem R, Sevik H, Cometen H (2019) The change of some heavy metal concentrations in Scotch pine (*Pinus sylvestris*) depending on traffic density, organelle and washing. *Appl Ecol Environ Res* 17(3):6723–6734. [https://doi.org/10.15666/aeer/1703\\_67236734](https://doi.org/10.15666/aeer/1703_67236734)
- Aricak B, Cetin M, Erdem R, Sevik H, Cometen H (2020) The usability of Scotch pine (*Pinus sylvestris*) as a biomonitor for traffic-originated heavy metal concentrations in Turkey. *Pol J Environ Stud* 29(2):1051–1057. <https://doi.org/10.15244/pjoes/109244>
- Cai K, Li C (2019) Street dust heavy metal pollution source apportionment and sustainable management in a typical city—Shijiazhuang, China. *Int J Environ Res Public Health* 16(14):2625. <https://doi.org/10.3390/ijerph16142625>
- Cetin M, Jawed AA (2022) Variation of Ba concentrations in some plants grown in Pakistan depending on traffic density. *Biomass Convers Biorefin*. <https://doi.org/10.1007/s13399-022-02334-2>
- Cetin M, Sevik H, Cobanoglu O (2020) Ca, Cu, and Li in washed and unwashed specimens of needles, bark, and branches of the blue spruce (*Picea pungens*) in the city of Ankara. *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-020-08687-3>
- Cetin M, Sevik H, Turkyilmaz A, Isinkaralar K (2021) Using Abies's needles as biomonitors of recent heavy metal accumulation. *Kastamonu Univ J Eng Sci* 7(1):1–6
- Chen Y, Gu P, Schulte N, Zhou X, Mara S, Croes BE, Herner JD, Vijayan A (2022) A new mobile monitoring approach to characterize community-scale air pollution patterns and identify local high pollution zones. *Atmos Environ*. <https://doi.org/10.1016/j.atmosenv.2022.118936>
- Cheng K, Tian HZ, Zhao D, Lu L, Wang Y, Chen J, Liu XG, Jia WX, Huang Z (2014) Atmospheric emission inventory of cadmium from anthropogenic sources. *Int J Environ Sci Technol* 11(3):605–616
- Civerolo K, Hogrefe C, Lynn B, Rosenthal J, Ku JY, Solecki W et al (2007) Estimating the effects of increased urbanization on surface meteorology and ozone concentrations in the New York City metropolitan region. *Atmos Environ* 41(9):1803–1818. <https://doi.org/10.1016/j.atmosenv.2006.10.076>
- Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K et al (2017) Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *Lancet* 389(10082):1907–1918. [https://doi.org/10.1016/S0140-6736\(17\)30505-6](https://doi.org/10.1016/S0140-6736(17)30505-6)
- Cummings LE, Stewart JD, Kremer P, Shakya KM (2022) Predicting citywide distribution of air pollution using mobile monitoring and three-dimensional urban structure. *Sustain Cities Soc* 76:103510. <https://doi.org/10.1016/j.scs.2021.103510>
- De Silva S, Ball AS, Huynh T, Reichman SM (2016) Metal accumulation in roadside soil in Melbourne, Australia: effect of road age, traffic density and vehicular speed. *Environ Pollut* 208:102–109. <https://doi.org/10.1016/j.envpol.2015.09.032>
- Du X, Zhu Y, Han Q, Yu Z (2019) The influence of traffic density on heavy metals distribution in urban road runoff in Beijing, China. *Environ Sci Pollut Res* 26(1):886–895. <https://doi.org/10.1007/s11356-018-3685-4>
- Feng W, Guo Z, Peng C, Xiao X, Shi L, Han X, Ran H (2018) Modeling mass balance of cadmium in paddy soils under long term control scenarios. *Environ Sci Process Impacts* 20:1158–1166. <https://doi.org/10.1039/C8EM00153G>
- Feng W, Guo Z, Xiao X, Peng C, Shi L, Ran H, Xu W (2019) Atmospheric deposition as a source of cadmium and lead to soil-rice system and associated risk assessment. *Ecotoxicol Environ Saf* 180:160–167. <https://doi.org/10.1016/j.ecoenv.2019.04.090>
- Ghoma WEO, Sevik H, Isinkaralar K (2022) Using indoor plants as biomonitors for detection of toxic metals by tobacco smoke. *Air Qual Atmos Health*. <https://doi.org/10.1007/s11869-021-01146-z>
- Granier C, Bessagnet B, Bond T, D'Angiola A, Denier van der Gon H, Frost GJ et al (2011) Evolution of anthropogenic and biomass burning emissions of air pollutants at global and regional scales during the 1980–2010 period. *Clim Change* 109(1):163–190. <https://doi.org/10.1007/s10584-011-0154-1>
- Gustin MS, Ingle B, Dunham-Cheatham SM (2022) Further investigations into the use of tree rings as archives of atmospheric mercury concentrations. *Biogeochemistry*. <https://doi.org/10.1007/s10533-022-00892-1>
- Hakkim H, Kumar A, Sinha B, Sinha V (2022) Air pollution scenario analyses of fleet replacement strategies to accomplish reductions in criteria air pollutants and 74 VOCs over India. *Atmos Environ X*. <https://doi.org/10.1016/j.aeaoa.2022.100150>
- Han Y, Lee J, Haiping G, Kim KH, Wanxi P, Bhardwaj N, Oh JM, Brown RJ (2022) Plant-based remediation of air pollution: a review. *J Environ Manag* 301:113860. <https://doi.org/10.1016/j.jenvman.2021.113860>
- Hou Q, Yang Z, Ji J, Yu T, Chen G, Li J, Xia X, Zhang M, Yuan X (2014) Annual net input fluxes of heavy metals of the agroecosystem in the Yangtze River delta, China. *J Geochem Explor* 139:68–84. <https://doi.org/10.1016/j.gexplo.2013.08.007>
- Hu Y, Cheng H, Tao S (2016) The challenges and solutions for cadmium-contaminated rice in China: a critical review. *Environ Int* 92–93:515–532. <https://doi.org/10.1016/j.envint.2016.04.042>
- Isinkaralar K, Erdem R (2021a) Landscape plants as biomonitors for magnesium concentration in some species. *Int J Progress Sci Technol* 29(2):468–473
- Isinkaralar K, Erdem R (2021b) Changes of calcium content on some trees in Kocaeli. *Kastamonu Univ J Eng Sci* 7(2):148–154
- Isinkaralar O, Tonuk GU, Isinkaralar K, Yilmaz D (2021) An analysis on sustainability assessment at neighborhood scale. *Social, humanities and administrative sciences*, 1st edn. Education Press, Konya, pp 517–531
- Isinkaralar K, Gullu G, Turkyilmaz A (2022) Experimental study of formaldehyde and BTEX adsorption onto activated carbon from lignocellulosic biomass. *Biomass Convers Biorefin*. <https://doi.org/10.1007/s13399-021-02287-y>
- Jeong H, Choi JY, Ra K (2021) Potentially toxic elements pollution in road deposited sediments around the active smelting industry of Korea. *Sci Rep* 11(1):1–12. <https://doi.org/10.1038/s41598-021-86698-x>
- Jeong H, Ryu JS, Ra K (2022) Characteristics of potentially toxic elements and multi-isotope signatures (Cu, Zn, Pb) in non-exhaust traffic emission sources. *Environ Pollut* 292:118339. <https://doi.org/10.1016/j.envpol.2021.118339>
- Kafle HK, Khadgi J, Ojha RB, Santoso M (2022) Concentration, sources, and associated risks of trace elements in the surface soil of Kathmandu Valley. *Nepal Water Air Soil Pollut* 233(2):1–18. <https://doi.org/10.1007/s11270-021-05444-1>
- Karacocuk T, Sevik H, Isinkaralar K, Turkyilmaz A, Cetin M (2021) The change of Cr and Mn concentrations in selected plants in Samsun city center depending on traffic density. *Landsc Ecol Eng*. <https://doi.org/10.1007/s11355-021-00483-6>
- Koç İ (2021) Changes that may occur in temperature, rain, and climate types due to global climate change: the example of Düzce. *Turk J Agric Food Sci Technol* 9(8):1545–1554. <https://doi.org/10.24925/turjaf.v9i8.1545-1554.4467>
- Koç İ, Nzokou P, Cregg B (2021) Biomass allocation and nutrient use efficiency in response to water stress: insight from experimental

- manipulation of balsam fir, concolor fir and white pine transplants. New for. <https://doi.org/10.1007/s11056-021-09894-7>
- Kubier A, Wilkin RT, Pichler T (2019) Cadmium in soils and groundwater: a review. *Appl Geochem* 108:104388. <https://doi.org/10.1016/j.apgeochem.2019.104388>
- Likens GE (2021) Acid rain. In: *Fundamentals of ecosystem science*. Academic Press, p 293–299. <https://doi.org/10.1016/B978-0-12-812762-9.00016-2>
- Lin B, Zhu J (2018) Changes in urban air quality during urbanization in China. *J Clean Prod* 188:312–321. <https://doi.org/10.1016/j.jclepro.2018.03.293>
- Liu HL, Zhou J, Li M, Hu YM, Liu X, Zhou J (2019) Study of the bioavailability of heavy metals from atmospheric deposition on the soil-pakchoi (*Brassica chinensis* L.) system. *J Hazard Mater* 362:9–16. <https://doi.org/10.1016/j.jhazmat.2018.09.032>
- Luo M, Hou X, Gu Y, Lau NC, Yim SHL (2018) Trans-boundary air pollution in a city under various atmospheric conditions. *Sci Total Environ* 618:132–141. <https://doi.org/10.1016/j.scitotenv.2017.11.001>
- Nicholson FA, Smith SR, Alloway BJ, Carlton-Smith C, Chambers BJ (2003) An inventory of heavy metals inputs to agricultural soils in England and Wales. *Sci Total Environ* 311:205–219. [https://doi.org/10.1016/S0048-9697\(03\)00139-6](https://doi.org/10.1016/S0048-9697(03)00139-6)
- Posch M, Seppälä J, Hettelingh JP, Johansson M, Margni M, Joliet O (2008) The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. *Int J Life Cycle Assess* 13(6):477–486. <https://doi.org/10.1007/s11367-008-0025-9>
- Raj D, Maiti SK (2020) Sources, bioaccumulation, health risks and remediation of potentially toxic metal (loid)s (As, Cd, Cr, Pb and Hg): an epitomised review. *Environ Monit Assess* 192(2):1–20. <https://doi.org/10.1007/s10661-019-8060-5>
- Ruschioni S, Riolo P, Minuz RL, Stefano M, Cannella M, Porrini C, Isidoro N (2013) Biomonitoring with honeybees of heavy metals and pesticides in nature reserves of the Marche Region (Italy). *Biol Trace Elem Res* 154(2):226–233. <https://doi.org/10.1007/s12011-013-9732-6>
- Sangster DF, Outridge PM, Davis WJ (2000) Stable lead isotope characteristics of lead ore deposits of environmental significance. *Environ Rev* 8(2):115–147. <https://doi.org/10.1139/a00-008>
- Savas DS, Sevik H, Isinkaralar K, Turkyilmaz A, Cetin M (2021) The potential of using *Cedrus atlantica* as a biomonitor in the concentrations of Cr and Mn. *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-021-14826-1>
- Sekabira K, Origa HO, Basamba TA, Mutumba G, Kakudidi E (2011) Application of algae in biomonitoring and phytoextraction of heavy metals contamination in urban stream water. *Int J Environ Sci Technol* 8(1):115–128
- Sevik H (2020) Change of Cu concentration in some edible landscape plants grown in Ankara City Center. *Kastamonu Univ J Eng Sci* 6(1):1–7
- Sevik H (2021) The variation of chrome concentration in some landscape plants due to species, organ and traffic density. *Turk J Agric Food Sci Technol* 9(3):595–600
- Sevik H, Ozel HB, Cetin M, Özel HU, Erdem T (2019) Determination of changes in heavy metal accumulation depending on plant species, plant organism, and traffic density in some landscape plants. *Air Qual Atmos Health* 12(2):189–195. <https://doi.org/10.1007/s11869-018-0641-x>
- Sevik H, Cetin M, Ozel HB, Akarsu H, Cetin IZ (2020) Analyzing of usability of tree-rings as biomonitors for monitoring heavy metal accumulation in the atmosphere in urban area: a case study of cedar tree (*Cedrus* sp.). *Environ Monit Assess* 192(1):23. <https://doi.org/10.1007/s10661-019-8010-2>
- Shahid M, Dumat C, Khalida S, Schreck E, Xiong T, Nabeel NK (2017) Foliar heavy metal uptake, toxicity and detoxification in plants: a comparison of foliar and root metal uptake. *J Hazard Mater* 325:36–58. <https://doi.org/10.1016/j.jhazmat.2016.11.063>
- Shvetsova MS, Kamanina IZ, Frontasyeva MV, Madadzada AI, Zinicovscaia II, Pavlov SS, Vergel KN, Yushin NS (2019) Active moss biomonitoring using the “moss bag technique” in the park of Moscow. *Phys Part Nucl Lett* 16(6):994–1003. <https://doi.org/10.1134/S1547477119060293>
- Sun Z, Xie X, Wang P, Hu Y, Cheng H (2018) Heavy metal pollution caused by small-scale metal ore mining activities: a case study from a polymetallic mine in South China. *Sci Total Environ* 639:217–227. <https://doi.org/10.1016/j.scitotenv.2018.05.176>
- Tallis M, Taylor G, Sinnett D, Freer-Smith P (2011) Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. *Landsc Urban Plan* 103(2):129–138. <https://doi.org/10.1016/j.landurbplan.2011.07.003>
- Turkyilmaz A, Sevik H, Isinkaralar K, Cetin M (2018) Using *Acer platanoides* annual rings to monitor the amount of heavy metals accumulated in air. *Environ Monit Assess* 190:578. <https://doi.org/10.1007/s10661-018-6956-0>
- Turkyilmaz A, Sevik H, Isinkaralar K, Cetin M (2019) Use of tree rings as a bioindicator to observe atmospheric heavy metal deposition. *Environ Sci Pollut Res* 26(5):5122–5130. <https://doi.org/10.1007/s11356-018-3962-2>
- Turkyilmaz A, Cetin M, Sevik H, Isinkaralar K, Saleh EAA (2020) Variation of heavy metal accumulation in certain landscaping plants due to traffic density. *Environ Dev Sustain* 22(3):2385–2398. <https://doi.org/10.1007/s10668-018-0296-7>
- US Environmental Protection Agency (1996) Soil screening guidance: technical background document. USEPA Rep. 540/R-95/128. US Gov. Print. Office, Washington, DC
- Vaverková MD, Maxianová A, Winkler J, Adamcová D, Podlasek A (2019) Environmental consequences and the role of illegal waste dumps and their impact on land degradation. *Land Use Policy*. <https://doi.org/10.1016/j.landusepol.2019.104234>
- Viard B, Pihan F, Promeyrat S, Pihan JC (2004) Integrated assessment of heavy metal (Pb, Zn, Cd) highway pollution: bioaccumulation in soil. *Graminaceae and Land Snails Chemosphere* 55(10):1349–1359. <https://doi.org/10.1016/j.chemosphere.2004.01.003>
- Vickers CE, Possell M, Nicholas Hewitt C, Mullineaux PM (2010) Genetic structure and regulation of isoprene synthase in poplar (*Populus* spp.). *Plant Mol Biol* 73(4):547–558. <https://doi.org/10.1007/s11103-010-9642-3>
- Vos PE, Maiheu B, Vankerom J, Janssen S (2013) Improving local air quality in cities: to tree or not to tree? *Environ Pollut* 183:113–122. <https://doi.org/10.1016/j.envpol.2012.10.021>
- Wang Y, Yao L, Wang L, Liu Z, Ji D, Tang G, Zhang J, Sun Y, Hu B, Xin J (2014) Mechanism for the formation of the January 2013 heavy haze pollution episode over central and eastern China. *Sci China Earth Sci* 57(1):14–25. <https://doi.org/10.1007/s11430-013-4773-4>
- Weiss D, Shotyk W, Kramers JD, Gloor M (1999) Sphagnum mosses as archives of recent and past atmospheric lead deposition in Switzerland. *Atmos Environ* 33(23):3751–3763. [https://doi.org/10.1016/S1352-2310\(99\)00093-X](https://doi.org/10.1016/S1352-2310(99)00093-X)
- WHO (2014) Burden of disease from ambient and household air pollution for 2012, public health, environmental and social determinants of health (PHE). [https://www.who.int/phe/health\\_topics/outdoorair/databases/FINAL\\_HAP\\_AAP\\_BoD\\_24March2014.pdf?ua=1](https://www.who.int/phe/health_topics/outdoorair/databases/FINAL_HAP_AAP_BoD_24March2014.pdf?ua=1). Accessed 16 Sept 2021
- Xue D, Jiang H, Deng X, Zhang X, Wang H, Xu X, Hu J, Zeng D, Guo L, Qian Q (2014) Comparative proteomic analysis provides new insights into cadmium accumulation in rice grain under cadmium stress. *J Hazard Mater* 280:269–278. <https://doi.org/10.1016/j.jhazmat.2014.08.010>

- Yang J, Shi B, Shi Y, Marvin S, Zheng Y, Xia G (2020) Air pollution dispersal in high density urban areas: research on the triadic relation of wind, air pollution, and urban form. *Sustain Cities Soc* 54:101941. <https://doi.org/10.1016/j.scs.2019.101941>
- Yilmaz D, Isinkaralar O (2021a) How can natural environment scoring tool (nest) be adapted for urban parks? *Kastamonu Univ J Eng Sci* 7(2):127–139
- Yilmaz D, Isinkaralar O (2021b) Climate action plans under climate-resilient urban policies. *Kastamonu Univ J Eng Sci* 7(2):140–147
- Yuan M, Song Y, Huang Y, Shen H, Li T (2019) Exploring the association between the built environment and remotely sensed PM<sub>2.5</sub> concentrations in urban areas. *J Clean Prod* 220:1014–1023. <https://doi.org/10.1016/j.jclepro.2019.02.236>
- Zhao S, Yu Y, Yin D, Qin D, He J, Dong L (2018) Spatial patterns and temporal variations of six criteria air pollutants during 2015 to 2017 in the city clusters of Sichuan Basin, China. *Sci Total Environ* 624:540–557. <https://doi.org/10.1016/j.scitotenv.2017.12.172>
- Zhao Y, Deng Q, Lin Q, Zeng C, Zhong C (2020) Cadmium source identification in soils and high-risk regions predicted by geographical detector method. *Environ Pollut* 263:114338. <https://doi.org/10.1016/j.envpol.2020.114338>