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(Research Article)

Monitoring Changes in Airborne Bismuth Pollution and the Feasibility of Using Robinia pseudoacacia for Pollution Reduction

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Abstract

Air pollution is one of the greatest threats to human health on a global scale today. Heavy metals, in particular, are harmful air pollutants even at low concentrations. Therefore, monitoring changes in the concentration of heavy metals in the air and reducing pollution are priority research topics. In this study, the feasibility of using *Robinia pseudoacacia*, cultivated in Düzce, where heavy metal pollution is known to be high, to monitor changes in Bi pollution in the air and reduce it was investigated. Within the scope of the study, changes in Bi concentration were evaluated based on organ, direction, and age range over the last 60 years. The study concluded that Bi pollution in the region is largely due to agricultural activities. The study determined that *Robinia pseudoacacia* is not a suitable species for monitoring changes in Bi pollution but can be used to reduce pollution.

Keywords: Heavy metal; Bismuth; Biomonitor; Phytoremediation; *Robinia pseudoacacia*

1. Introduction

Over the last century, industrial production has increased significantly due to the industrial revolution and developments in the technological field. The use of fossil fuels to provide the energy needed for production has significantly increased the CO2 levels in the atmosphere [1]. Thus, global climate change has become the most significant global issue of our time [2-4]. Mining activities carried out to supply the raw materials needed in industry and the production process have released various elements into nature in large quantities. As a result, pollution has increased significantly and has become a problem that threatens both living beings and ecosystems [5-8]. The job opportunities created by the labor force required for industrial production have caused people to gather in certain areas, thus giving rise to the problem of urbanization [9-11]. Thus, pollution, global climate change, and urbanization, which are interrelated today, have become the most important and pressing issues on a global scale [12-14]. Moreover, global climate change and urbanization are now considered irreversible problems [15].

Among these problems, air pollution is the one that most affects human health. According to World Health Organization (WHO) reports, approximately 92% of the world's population currently lives in areas with poor air quality [16]. One in every eight deaths is linked to air pollution. Air pollution is reported to cause approximately 4 million premature births and 7 million human deaths each year [17-19]. The most harmful component of air pollution is heavy metals. This is because some heavy metals can be harmful, toxic, carcinogenic, and lethal to humans even at low concentrations [20-22]. Furthermore, they can remain in nature for a long time without decomposing. Moreover, even those that are essential as nutrients for living organisms can be harmful to health at high doses [23,24]. Heavy metals can be even more harmful when they are inhaled into the human body through the air [25]. Therefore, monitoring changes in airborne heavy metal pollution is of great importance.

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This study also attempted to determine the applicability of *Robinia pseudoacacia* in identifying changes in airborne bismuth pollution over time. Metallic bismuth and bismuth compounds, widely used in various industries, have low toxicity for humans; however, bismuth toxicity can occur in excessive doses depending on the area of application [26]. Therefore, monitoring changes in Bi pollution in the air is of great importance. One of the most commonly used methods for monitoring changes in heavy metal pollution in the air is tree annual rings. Dendrochronological studies reveal the presence of heavy metals from the past to the present [27-29]. However, not every tree may be a suitable biomonitor for determining the change in each element. Therefore, it is necessary to separately determine the tree species suitable for determining the change in each element. In this study, the suitability of *Robinia pseudoacacia* as a biomonitor for Bi was also investigated.

2. Material and methods

The study was conducted on *Robinia pseudoacacia*, which is important in both forestry and landscaping studies in our country and across Europe. Wood and bark samples were obtained from Düzce province, one of the five cities with the most polluted air in Europe according to the World Air Pollution Report 2021 [30,31]. Samples were taken in 2022 at the end of the vegetation period by cutting approximately 50 cm above the ground from the main trunk, with the north direction determined. The surface of the log brought to the laboratory was cleaned, and samples were taken from the wood, inner bark, and outer bark using a steel drill. Since the tree was 60 years old, the wood was grouped from the outside to the inside in five-year increments. Thus, 14 samples were taken, consisting of 12 pieces of wood, 1 inner bark, and 1 outer bark from each direction. Since samples were taken from 4 directions, 48 samples were studied.

The samples were first left on cardboard in a ventilated room for two weeks to dry to room temperature. The samples were then placed in glass Petri dishes and dried for 2 weeks in an oven at 45 °C. At the end of the drying process, a pre-combustion process was applied in a specially designed microwave oven. Bi analyses of the samples were performed using an ICP-OES device. The study was conducted in triplicate. The method used in this study has been widely used in related studies in recent years [32-34]. The data obtained were analyzed using the SPSS 22.0 software package, and variance analysis and Duncan's test were applied to the data. After the data were presented in tabular form, taking into account the results of the Duncan test, analyses and interpretations were made.

3. Findings

The mean values and statistical analysis results regarding the change in Bi concentration in *Robinia pseudoacacia* based on organ and direction are given in Table 1.

Table 1 Change in Bi concentration in *Robinia pseudoacacia* based on organ and direction

Organ	North	East	South	West	F Value	Average
OB	70571,5 AB	73412,2 aB	76893,6 C	69694,7 A	12,1**	72643,0
IB	70569,9 A	77840,5 bC	74865,1 B	71834,5 A	8,5*	74846,7
Wood	70710,2 A	73202,8 aB	75572,7 C	70602,7 A	17,6***	72451,2
F Value	0,7 ns	7,2**	0,8 ns	0,6 ns		1,4 ns
Average	70690,2 A	73549,0 B	75616,5 C	70625,8 A	22,6***	

Looking at the values in the table, it can be seen that the change in Bi concentration in *Robinia pseudoacacia* is statistically significant ($p<0.05$) in all organs based on direction. The lowest values based on direction were obtained in the west and north directions, while the highest values were obtained in the south direction in wood and outer bark and in the east direction in inner bark. According to the average values, the highest value was obtained in the south direction. The change in Bi concentration based on organ was statistically significant only in the east direction ($p<0.01$). In this direction, the values were grouped into two groups according to the Duncan test; the value obtained in the inner bark was in the second group, while the value obtained in the wood and outer bark was in the first group. The change in Bi concentration in *Robinia pseudoacacia* based on period and direction is given in Table 2.

Table 2 Change in Bi concentration in *Robinia pseudoacacia* based on period and direction

Period	North	East	South	West	F Value	Average
2018-2022	74258,6	74364,2	75265,5	73730,2 c	0,6 ns	74453,3
2013-2017	74012,5	71936,7	76197,1	73581,2v c	1,9 ns	73905,0
2008-2012	72483,2	73266,0	75717,4	71861,3 bc	2,4 ns	73614,9
2003-2007	60368,4	73165,7	76181,1	73669,2 c	1,3 ns	70846,1
1998-2002	70727,2 A	71707,1 A	75681,8 B	69829,2 abA	5,8*	71986,3
1993-1997	74465,8 B	74364,5 B	76282,4 B	69521,1 abA	6,9*	73658,5
1988-1992	71209,0 A	71774,5 AB	74915,5 B	69527,9 abA	4,4*	71856,7
1983-1987	70142,8 AB	73380,0 BC	75148,4 C	69250,5 abA	5,2*	71980,4
1978-1982	70320,0 A	73192,2 A	76557,6 B	70266,5 abA	9,4**	72584,1
1973-1977	69767,5 A	72979,1 B	75074,5 B	69224,0 abA	9,4**	71761,3
1968-1972	70645,0 AB	73701,5 B	73804,3 B	68113,7 aA	5,2*	71566,1
1963-1967	70122,2 A	74601,8 B	76047,2 B	68657,4 aA	13,9**	72357,1
F Value	0,8 ns	0,6 ns	0,3 ns	4,6**		0,6 ns

According to the results of the variance analysis, it was determined that the change in Bi concentration in *Robinia pseudoacacia* was only significant in the western direction based on organ. It can be said that Bi concentration has increased from the past to the present in this direction. Based on the average values, the change in Bi concentration by period is not statistically significant ($p>0.05$). Changes by direction are statistically significant in all periods before 2022. During these periods, the lowest direction-based values were obtained in the west, while the highest values were generally obtained in the south.

4. Result and Discussion

The study determined that the Bi concentration was above the detectable limits in all samples. This indicates that the Bi concentration in the environment is high. However, the lack of variation in Bi concentration between organs prevents obtaining information about Bi uptake into the plant body. This is because heavy metals can enter the plant body through leaves, roots, or stem sections [35]. The lack of variation between organs can be interpreted as indicating that Bi uptake through these pathways occurs at similar rates.

The study determined that the highest Bi concentrations were obtained in the wood and outer bark in the southern direction. Agricultural areas are located to the south of the study area. As is known, anthropogenic heavy metals originate primarily from industry [36], mining activities [37], vehicles [38], human activities in urban areas [39], and agricultural activities [40]. Various heavy metals are released into the environment as a result of fertilizers, pesticides, hormones, etc. used in agricultural production [40]. Based on these results, it can be assumed that the Bi contamination in the study area is due to agricultural activities.

The study found that the Bi concentrations in wood tissues were quite similar. This indicates that the Bi element can be transferred between wood tissues. As is known, in tree species that can be used to monitor changes in atmospheric heavy metal concentrations, the limited transport of heavy metals within the wood tissue is a desirable characteristic. Studies conducted to date have shown that each tree species can be suitable as a biomonitor for different heavy metals. For example, *Cedrus deodora* is suitable for Cu, *Picea orientalis* for Tl, *Cedrus atlantica* for Ni, Cr, and Mn, *Cupressus arizonica* for Cd, Ni, Cr, Tl, Fe, and Zn, *Corylus colurna* for Cd, Ni, Zn, Co, Pb, Cr, Mn, and Zn, and *Pseudotsuga menziesii* for Cr. This is because the transfer of these elements in the wood of these species is limited. However, Cedrus deodora is not a suitable biomonitor for tracking changes in Pb and Zn concentrations, *Pinus nigra* As, Sr, Pd, V, Ag, Se, Sb, and Tl concentrations, *Cedrus atlantica* Co concentrations, and *Cupressus arizonica* Bi, Li, and Cr concentrations [1,36,41].

Heavy metal accumulation can vary significantly between species and between organs within the same species [42]. This is because many factors simultaneously play a role in the uptake and accumulation of heavy metals in plants. The entry and movement of heavy metals within plants are influenced by various factors, including plant species, organ structure, surface area, interactions between heavy metals and plants, and weather conditions [36,43]. This is because plant development is shaped by environmental factors [44,45]. However, the responses of plants to the same environmental conditions vary significantly depending on the plant species, i.e., its genetic structure [46-49]. The fundamental environmental factors affecting plant development are primarily climatic and edaphic factors [50-54]. Studies have shown that microclimatic and micro edaphic factors affect plant development and plant phenotypic characteristics more than macro factors [55-59]. Because plants can be stressed by many factors such as temperature, water deficit, frost, disease and pests, air pollution, and unsuitable climatic and edaphic factors, and in this case, plant growth and phenotypic characteristics are greatly affected [60,61]. In addition, activities such as hormone applications, pruning, irrigation, and fertilization can significantly affect plant development [62-64]. All these factors can directly or indirectly affect the entry and accumulation of heavy metals in plants.

5. Conclusion

Within the scope of this study, the concentrations of bismuth in the bark and wood of Robinia pseudoacacia were evaluated. The results of the study show that Bi concentrations in these organs are quite high. Based on this result, the Robinia pseudoacacia species can be used for phytoremediation to reduce Bi contamination.

The study found that the Bi concentration in wood varied within a narrow range. This result indicates that Bi can be transferred between wood tissues. Therefore, it can be said that the Robinia pseudoacacia species studied is not suitable for monitoring changes in Bi contamination.

It was determined that the Bi contamination in the study area was largely due to agricultural activities. It is recommended that the relevant authorities in the region conduct the necessary investigations and take effective measures against Bi contamination.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declare that they no conflict of interest.

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