World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Variation of boron concentrations in the wood and bark of some trees

Nazli AK TUTUNCU [1,*], Halil Baris OZEL [2], Hakan SEVIK [3] and Ramazan ERDEM [4]

[1] *Department of Forest Engineering, Graduate School, Bartin University, Türkiye.*
[2] *Department of Forest Engineering, Faculty of Forestry, Bartin University, Türkiye.*
[3] *Department of Environmental Engineering, Faculty of Engineering and Architecture, Kastamonu University, Türkiye.*
[4] *Department of Forestry, Kastamonu University, Arac Rafet Vergili Vocational School, Kastamonu, Türkiye.*

World Journal of Advanced Research and Reviews, 2024, 24(02), 2242–2249

Publication history: Received on 16 October 2024; revised on 24 November 2024; accepted on 26 November 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.2.3589

Abstract

Air pollution has become one of the most critical threats to human health in the last century. Heavy metals are among the components of air pollution that threaten human health the most. Boron is one of the heavy metals whose use has been increasing in recent years due to its use in more than 250 fields in industry. Due to intensive use, boron concentrations in receiving environments are constantly increasing. However, boron, one of the important heavy metals, can cause significant health problems when inhaled from the air and taken into the human body. Therefore, monitoring the changes in boron concentration in the air is very important. In this study, species, organ, and directional changes of boron concentration in *Tilia tomentosa, Robinia pseudoacacia, Cedrus atlantica, Pseudotsuga menziesii*, and *Fraxinus excelsior* species growing in Düzce, one of the five most polluted cities in Europe. The study results show that boron concentrations are generally higher in the outer bark. Regarding species, the lowest values were obtained in *P. menziesii,* and the highest were obtained in *R. pseudoacacia*. The highest B concentrations in wood were obtained in *R. pseudoacacia,* and it is thought that this species can be used effectively to reduce B pollution.

Keywords: Heavy metal; Boron; Accumulator; Wood

1. Introduction

Throughout the world, urbanization [1-4] and global climate change [5-9] have become irreversible global problems due to the direct or indirect effects of industrial activities developed in the last century. Another global problem that has emerged in relation to these problems and is also largely caused by industrial and human activities is environmental pollution [10-13]. In particular, air pollution has become such a serious problem that World Health Organization (WHO) data show that almost the entire global population (99%) breathes air containing high levels of pollutants that exceed WHO-defined limits, with low- and middle-income countries suffering the highest exposure [14]. Studies indicate that air pollution causes approximately 6 million premature births, 3 million underweight babies, and 7 million premature deaths worldwide annually [15].

Among the components of air pollution, heavy metals threaten human and environmental health [16-18]. Some heavy metals can be dangerous, toxic, carcinogenic, and fatal for living organisms even at low concentrations [19-21]. Even those necessary as nutrients for living organisms can be harmful at high concentrations and can be much more dangerous by entering the human body, especially through the respiratory tract [22,23]. One of these heavy metals is boron (B), which has been increasingly used in recent years. Boron is one of the elements that has taken an important place on the agenda in recent years, both because it is a micronutrient element for plants and because it is used in more than 250 fields in the industry [24,25]. Due to its intensive use and the continuous expansion of these areas of use, the concentrations of boron, which is produced more and more, are constantly increasing in receiving environments.

* Corresponding author: Hakan SEVIK

However, boron, one of the important heavy metals, can cause significant health problems when inhaled from the air and taken into the human body. Therefore, reducing boron pollution in the air is of great importance.

Plants are the most effective instruments for reducing heavy metal pollution. The wood parts of high-structured trees are the largest plant organs and species that can accumulate heavy metals in the wood and can be used very effectively in reducing heavy metal pollution [26-28]. However, it is necessary to determine which plant is helpful in reducing heavy metal pollution. Because each plant has a different potential to accumulate different heavy metals [23,29]. This study aimed to determine the most suitable tree species that can be used to reduce B pollution.

2. Material and methods

Düzce province, where the study samples were collected, has Europe's 5th highest pollution level, according to the World Air Pollution Report 2021. Düzce province's topography and meteorological parameters increase air pollution in the Western Black Sea region of Türkiye. The main pollutants causing air pollution in Düzce are generally industrial facilities, domestic fuel use and vehicle traffic load [30,31].

The log samples used in this study were obtained from the trunks of *Tilia tomentosa, Robinia pseudoacacia, Cedrus atlantica, Pseudotsuga menziesii, Fraxinus excelsior* trees, which are widely used in landscaping in Düzce province. The log samples were taken in 2022 outside the vegetation season at a height approximately 50 cm above the ground and 10 cm thick. The directions (North, South) were indicated on the logs when taking log samples of these species. The sections taken from the trunk logs were first sanded in the laboratory to smooth the upper surface so that the annual rings could be seen more clearly.

Samples were then taken from the outer bark, inner bark, and wood using a stainless steel drill and placed in glass Petri dishes. The wood samples were ground into wood chips without using any tools made of the metals examined in the study. After the samples were placed in glass containers without closing the lids, they were kept in the laboratory for 15 days until they were completely dry and then dried in an oven set at 45 °C for another week. Then 0.5 grams of the dried samples were taken, 6 ml of 65% HNO_3 and 2 ml of 30% H_2O_2 were added and placed in a microwave oven; the microwave oven was set to reach 200°C for 15 minutes and stayed at 200°C for 15 minutes. After the samples were incinerated, the samples were transferred into measured bottles, and the final volume was filled with 50 ml of ultrapure water. The samples were analyzed using ICP-OES, and Cr concentrations were determined by multiplying the results by the corresponding dilution factor. This method has been widely used in previous studies in this field [32-35].

Variance analysis was used to analyze the data using the SPSS package program. In addition, the Duncan test was applied for factors showing statistically significant differences at a minimum 95% confidence level ($p<0.05$). The data were tabulated and, analyzed and interpreted after considering the results of Duncan's test.

3. Results

The variation of B concentration in the species subject to the study on species and organ basis is given in Table 1.

Table 1 Variation of B concentration by species and organ

Species	OB	IB	Wood	F Value
T. tomentosa	13782.3 C	9380.2 B	3815.0 A	83.3***
R. pseudoacacia	31783.6 B	25581.1 A	30571.1 B	5.0**
C. atlantica	15035.8 A	19262.6 B	15444.3 A	4.8**
P. menziesii	6548.1 B	7340.6 B	3279.9 A	5.3**
F. excelsior	42116.8 B	8068.9 A	6181.5 A	90.9***

When the table values are examined, it is seen that the change in B concentration by organ in all species is statistically significant ($p<0.05$). When the values and Duncan test results were examined, it was determined that all species except *R. pseudoacacia* obtained the lowest B concentrations in wood. In general, the highest values were obtained in the outer bark. The variation of B concentration by species and direction is given in Table 2.

Table 2 Variation of B concentration by species and direction

Species	North	East	South	West
T. tomentosa	5640.5 a	8999.3 ab	10707.2 b	9405.9 ab
R. pseudoacacia	27937.5 c	30974.8 c	31913.7 c	30003.0 d
C. atlantica	19110.4 b	14016.3 b	15203.0 b	14319.7 c
P. menziesii	3441.2 a	4444.9 a	8814.7 a	4156.6 a
F. excelsior	7461.7 a	11878.3 b	9562.9 a	15489.2 c
F Value	35.1***	30.0***	94.3***	100.5***

As seen in Table 2, according to the mean values, the change in B by species in all directions was statistically significant ($p<0.05$). In general, the lowest values were obtained in *P. menziesii*, and the highest values were obtained in *R. pseudoacacia*. The variation of B concentration in species by organ and direction is given in Table 3.

Table 3 Variation of B concentration by organ and direction in species

Species	Organ	North	East	South	West	F Value
Tilia tomentosa	OB	13748.9 cB	14735.8 cC	12809.5 bA	13834.9 B	88.3***
	IB	7673.7 bB	6709.3 bA	14155.5 cD	8982.2 C	4366.0***
	Wood	2259.9 aA	5552.7 aB	5156.5 aB	5400.7 B	8.5**
	F Value	78.7***	3997.4***	4686.5***	2786.3***	
Robinia pseudoacacia	OB	33578.0 bC	31486.8 aB	32473.6 BC	29595.9 A	11.4**
	IB	6584.9 aA	33610.5 bD	31848.1 C	30281.0 B	885.1***
	Wood	29508.7 b	30712.4 a	31872.5	30013.7	1.4 ns
	F Value	8.2**	13.9***	0.5 ns	0.2 ns	
Cedrus atlantica	OB	14861.7 aB	14877.9 bB	15967.2 bC	14436.5 A	41.5***
	IB	33092.0 bC	14283.9 abA	15010.5 aB	14663.9 AB	2661.7***
	Wood	18299.3 aB	13913.7 aA	15155.4 aA	14281.2 A	11.8***
	F Value	8.3**	3.5*	5.0*	0.1 ns	
Pseudotsuga menziesii	OB	6513.9 bB	6997.4 cC	5425.4 bA	7255.8 cD	594.2***
	IB	Under Limit	2477.3 aB	17729.5 cC	1815.1 aA	20228.7***
	Wood	1904.8 aA	4152.5 bC	3289.2 aB	3777.7 bBC	21.0***
	F Value	82.5***	277.6***	14470.7***	347.2***	
Fraxinus excelsior	OB	21040.3 bA	72496.4 bC	37748.5 bB	37182.3 bB	8874.5***
	IB	6819.1 aA	10956.1 aB	6431.4 aA	Under Limit	2473.5***
	Wood	4227.8 a	6451.4 a	5983.7 a	8258.2 a	0.8 ns
	F Value	76.2***	160.2***	57.1***	35.3***	

When the variation of B concentrations by organ and direction in species was examined, B concentrations in the northern direction in the inner bark of *Pseudotsuga menziesii* and in the western direction in the inner bark of *Fraxinus excelsior* remained below the determinable limits. Otherwise, B concentrations ranged between 1815.1 ppb and 72496.4 ppb. The lowest values were obtained in *Pseudotsuga menziesii* inner bark in the west direction (1815.1 ppb),

Pseudotsuga menziesii wood in the north direction (1904.8 ppb) and *Tilia tomentosa* wood in the north direction (2259.9 ppb). The highest values were obtained in the east direction (72496.4 ppb), south direction (37748.5 ppb), and west direction (37182.3 ppb) in the outer bark of Fraxinus excelsior. Notably, the highest values were obtained in the outer bark of Fraxinus excelsior. The highest values in wood were obtained in *Robinia pseudoacacia* in the south direction (31872.5 ppb), east direction (30712.4 ppb), and west direction (30013.7 ppb). Notably, the highest values in the woods were obtained in *Robinia pseudoacacia*, and these values were much higher than those in the woods of other species.

4. Discussion

As a result of the study, it was determined that B concentrations accumulated significantly in the outer bark, inner bark, and wood of the species subject to the study. B concentrations were below the determinable limits only in the inner bark of *Pseudotsuga menziesii* in the north direction and *Fraxinus excelsior* in the west direction. Apart from this, it was determined that B concentration accumulated in all organs of all species at rates exceeding one ppm, reaching up to 72496.4 ppb in the outer bark and 31872.5 ppb in the wood.

Within the scope of the study, it was determined that the values obtained in the outer bark were higher than those in the inner bark and wood. The high level of heavy metal concentrations in the outer bark in heavy metal-contaminated areas is related to the structure and contamination of the bark. In areas close to the pollution source, heavy metals in the air adhere to particulate matter and contaminate particulate matter with heavy metals, and this particulate matter settles on plant organs and increases heavy metal concentrations in these organs [16-18]. Since the outer bark has a rough surface structure, particulate matter can easily adhere to it, and thus, heavy metal concentrations are high in the bark in the direction of heavy metal pollution [30-32]. Therefore, in areas with high levels of heavy metal pollution, high levels of heavy metal concentrations in the barks are normal, and this situation has been reported in many studies [19-21].

Within the scope of the study, it was determined that B concentration differed significantly in the species subject to the study. Studies frequently state that heavy metal accumulation capacity can vary greatly on a species basis [23]. This result is normal. Because all phenotypic characters of living organisms, including heavy metal accumulation potential, are shaped under the interaction of genetic structure [36-42] and environmental factors [43-52]. Since the genetic structure also varies significantly according to the plant species, the heavy metal accumulation potential of different species of plants is different even if they grow in the same environment.

As a result of the study, it was determined that B concentrations were at very high levels in plant organs. This shows that B pollution is quite high in the study area. In similar studies conducted in the same area, heavy metals such as Bi, Cr, As, and Sb were found to be at very high concentrations [30,31,33,53]. These studies stated that the main sources of heavy metals in the region are traffic and urban areas. As a matter of fact, in many studies, it is frequently emphasized that a large number of people live in a limited area in urban areas. Therefore, urban areas bring many problems [54-63], and one of the most important of these problems is pollution [64-71]. The most effective materials that can be used to reduce pollution in these areas are plants. Because while plants fulfill many ecological, economic, and social functions in the area where they grow, they also reduce all kinds of air pollution [72-78]. Therefore, plants can be used effectively to reduce heavy metal pollution.

5. Conclusion and Recommendations

As a result of the study, it was determined that B concentrations were relatively high in the species subject to the study, and the highest B concentrations were generally obtained in the outer barks. Otherwise, B concentrations ranged between 1815.1 ppb and 72496.4 ppb. The lowest values were obtained in *Pseudotsuga menziesii* inner bark in the west direction (1815.1 ppb), *Pseudotsuga menziesii* wood in the north direction (1904.8 ppb) and *Tilia tomentosa* wood in the north direction (2259.9 ppb).

The highest values were obtained in the east direction (72496.4 ppb), south direction (37748.5 ppb), and west direction (37182.3 ppb) in the outer bark of *Fraxinus excelsior*. It is noteworthy that the highest values were obtained in the outer bark of *Fraxinus excelsior*. The highest values in wood were obtained in *Robinia pseudoacacia* in the south direction (31872.5 ppb), east direction (30712.4 ppb), and west direction (30013.7 ppb). It is noteworthy that the highest values in the woods were obtained in *Robinia pseudoacacia*, and these values were much higher than the values in the woods of other species. Therefore, the use of *Robinia pseudoacacia,* which can accumulate high amounts of B in its wood in areas with high levels of B pollution, can contribute significantly to reducing B pollution.

Compliance with ethical standards

Acknowledgements

We thanks to Bartin University Faculty of Forestry and Kastamonu University Faculty of Architecture and Engineering.

Disclosure of conflict of interest

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

References

[1] Bayraktar, O. Y., Yılmazoğlu, M., Mütevelli, İ., Çetin, M., Çitoğlu, G. S., Dadula, C. P., & Dadula, D. P. (2022). Usability of organic wastes in concrete production; Palm leaf sample. Kastamonu University Journal of Engineering and Sciences, 8(1), 69-77.

[2] Kaplan, G., Bayraktar, O. Y., Li, Z., Bodur, B., Yılmazoglu, M. U., & Alcan, B. A. (2023). Improving the eco-efficiency of fiber reinforced composite by ultra-low cement content/high FA-GBFS addition for structural applications: Minimization of cost, CO2 emissions and embodied energy. Journal of Building Engineering, 76, 107280.

[3] Mütevelli Özkan, İ. G., Aldemir, K., Alhasan, O., Benli, A., Bayraktar, O. Y., Yılmazoğlu, M. U., & Kaplan, G. (2024). Investigation on the sustainable use of different sizes of sawdust aggregates in eco-friendly foam concretes: Physico-mechanical, thermal insulation and durability characteristics. Construction and Building Materials, 438, 137100.

[4] Zeyad, A. M., Bayraktar, O. Y., Tayeh, B. A., Öz, A., Özkan, İ. G. M., & Kaplan, G. (2024). Impact of rice husk ash on physico-mechanical, durability and microstructural features of rubberized lightweight geopolymer composite. Construction and Building Materials, 427, 136265.

[5] Aricak, B., Canturk, U., Koc, I., Erdem, R., Sevik, H. (2024). Shifts That May Appear in Climate Classifications in Bursa Due to Global Climate Change, Forestist. 74: 129-137. Doi:10.5152/ forestist.2024.23074

[6] Cobanoglu H, Canturk U, Koç İ, Kulaç Ş, Sevik H. (2023). Climate change effect on potential distribution of Anatolian chestnut (Castanea sativa Mill.) in the upcoming century in Türkiye. Forestist, 73(3);247-256.

[7] Ertürk, N., Arıcak, B., Şevik, H., & Yiğit, N. (2024) Possible Change in Distribution Areas of Abies in Kastamonu due to Global Climate Change. Kastamonu University Journal of Forestry Faculty, 24(1), 81-91.

[8] Ertürk, N., Arıcak, B., Yiğit, N., & Sevik, H. (2024). Potential Changes in the Suitable Distribution Areas of Fagus orientalis Lipsky in Kastamonu Due to Global Climate Change. Forestist, doi:10.5152/ forestist.2024.23024.

[9] Işınkaralar, Ö., Işınkaralar, K., Şevik, H., & Küçük, Ö. (2023). Bio-climatic Comfort and Climate Change Nexus: A Case Study in Burdur Basin. Kastamonu University Journal of Forestry Faculty, 23(3), 241-249.

[10] Özel, H. B., Şevik, H., Yıldız, Y., & Çobanoğlu, H. (2024). Effects of Silver Nanoparticles on Germination and Seedling Characteristics of Oriental Beech (Fagus orientalis) Seeds. BioResources, 19(2).

[11] Savaş, D. S., & Şevik, H. (2024). Al and Fe Changes in Cedrus atlantica Depending on Organ, Age Range, and Direction. Journal of Green Technology and Environment, 2(1), 9-15.

[12] Isinkaralar, K., Isinkaralar, O., Özel, H. B., & Şevik, H. (2024). A Comparative Study About Physical Properties of Copper Oxide and Zinc Oxide Nanoparticles on Fagus orientalis L. as Bioindicator. Water, Air, & Soil Pollution, 235(11), 738.

[13] Sevik, H., Ozel, H. U., Yildiz, Y., & Ozel, H. B. (2025). Effects of Adding Fe2O3 and Fe3O4 Nanoparticles to Soil on Germination and Seedling Characteristics of Oriental Beech. BioResources, 20(1), 70-82.

[14] WHO (2024). https://www.who.int/health-topics/air-pollution#tab=tab_1

[15] Sevik, H., Yildiz, Y., Ozel, H.B. (2024). Phytoremediation and Long-term Metal Uptake Monitoring of Silver, Selenium, Antimony, and Thallium by Black Pine (Pinus nigra Arnold), BioResources, 19(3). 4824-4837.

[16] Sulhan, O. F., Sevik, H., & Isinkaralar, K. (2023). Assessment of Cr and Zn deposition on Picea pungens Engelm. in urban air of Ankara, Türkiye. Environment, development and sustainability, 25(5), 4365-4384.

[17] Key K, Kulaç Ş, Koç İ, & Sevik H. (2022). Determining the 180-year change of Cd, Fe, and Al concentrations in the air by using annual rings of Corylus colurna L. Water, Air, & Soil Pollution, 233(7); 244.

[18] Key K, Kulaç Ş, Koç İ, & Sevik H. (2023). Proof of concept to characterize historical heavy-metal concentrations in atmosphere in North Turkey: determining the variations of Ni, Co, and Mn concentrations in 180-year-old Corylus colurna L. (Turkish hazelnut) annual rings. Acta Physiologiae Plantarum, 45(10); 1-13.

[19] Erdem, R., Koç, İ., Çobanoglu, H., & Şevik, H. (2024). Variation of Magnesium, One of the Macronutrients, in Some Trees Based on Organs and Species. Forestist, 74(1). 84-93

[20] Cobanoglu H, Sevik H, & Koç İ. (2023). Do annual rings really reveal Cd, Ni, and Zn pollution in the air related to traffic density? An Example of the Cedar Tree. Water, Air, & Soil Pollution, 234(2); 65.

[21] Yayla EE, Sevik H, & Isinkaralar K. (2022). Detection of landscape species as a low-cost biomonitoring study: Cr, Mn, and Zn pollution in an urban air quality. Environmental Monitoring and Assessment, 194(10); 1-10.

[22] Ghoma WEO, Sevik H, & Isinkaralar K. (2023). Comparison of the rate of certain trace metals accumulation in indoor plants for smoking and non-smoking areas. Environmental Science and Pollution Research, 30(30): 75768-75776.

[23] Koç, İ., Canturk, U., Isinkaralar, K., Ozel, H. B., & Sevik, H. (2024). Assessment of metals (Ni, Ba) deposition in plant types and their organs at Mersin City, Türkiye. Environmental Monitoring and Assessment, 196(3), 282.

[24] Erdem R, Çetin M, Arıcak B, & Sevik H. (2023). The change of the concentrations of boron and sodium in some forest soils depending on plant species. Forestist, 73(2); 207-212.

[25] Arıcak, B., & Kulaç, Ş. (2023). The Feasibility of using Annual Rings to Monitor Changes in Boron Concentrations in Air. Kastamonu University Journal of Engineering and Sciences, 9(2), 73-82.

[26] Sevik, H., Koç, İ., & Cobanoglu, H. (2024). Determination of Some Exotic Landscape Species As Biomonitors That Can Be Used for Monitoring and Reducing Pd Pollution in the Air. Water, Air, & Soil Pollution, 235(10), 615.

[27] Pulatoglu, A. O., Koç, İ., Özel, H. B., Şevik, H., & Yıldız, Y. (2025). Using Trees to Monitor Airborne Cr Pollution: Effects of Compass Direction and Woody Species on Cr Uptake during Phytoremediation. BioResources, 20(1), 121-139.

[28] Ozyurt, G., Ozel, H. B., Sevik, H., & Cobanoglu, H. (2024). Determination of suitable species that can be used in declining niobium pollution in the atmosphere. World Journal of Advanced Research and Reviews, 23(1), 605-611.

[29] Ghoma, W. E. O., Sevik, H., & Isinkaralar, K. Using indoor plants as biomonitors for detection of toxic metals by tobacco smoke. Air quality, atmosphere & health, 2022. 15(3), 415-424.

[30] Canturk, U., Koç, İ., Ozel, H. B., & Sevik, H. (2024). Identification of proper species that can be used to monitor and decrease airborne Sb pollution. Environmental Science and Pollution Research, 1-11.

[31] Koc, I., Cobanoglu, H., Canturk, U., Key, K., Kulac, S., & Sevik, H. (2024). Change of Cr concentration from past to present in areas with elevated air pollution. International Journal of Environmental Science and Technology, 21(2), 2059-2070.

[32] Erdem, R., Aricak, B., Cetin, M., & Sevik, H. (2023). Change in some heavy metal concentrations in forest trees by species, organ, and soil depth. Forestist, 73(3), 257-263.

[33] Yaşar İsmail, T.S., İsmail, M.D, Çobanoğlu, H., Koç, İ., & Sevik, H. (2024). Monitoring arsenic concentrations in airborne particulates of selected landscape plants and their potential for pollution mitigation, Forestist. https://doi.org/10.5152/forestist.2024.24071

[34] Kuzmina N, Menshchikov S, Mohnachev P, Zavyalov K, Petrova I, Ozel HB, Aricak B, Onat SM, and Sevik H. (2023). Change of aluminum concentrations in specific plants by species, organ, washing, and traffic density, BioResources, 18(1); 792-803.

[35] Istanbullu SN, Sevik H, Isinkaralar K, & Isinkaralar O. (2023). Spatial Distribution of Heavy Metal Contamination in Road Dust Samples from an Urban Environment in Samsun, Türkiye. Bulletin of Environmental Contamination and Toxicology, 110(4); 78.

[36] Hrivnák, M., Krajmerová, D., Paule, L., Zhelev, P., Sevik, H., Ivanković, M., Goginashvili, N., Paule, J., Gömöry, D. (2024). Are there hybrid zones in Fagus sylvatica L. sensu lato?. European Journal of Forest Research, 143, 451–464. https://doi.org/10.1007/s10342-023-01634-0

[37] Sevik H, Yahyaoglu Z, & Turna I. (2012). Determination of genetic variation between populations of Abies nordmanniana subsp. bornmulleriana Mattf according to some seed characteristics, genetic diversity in plants. Chapter, 12; 231-248.

[38] Imren E, Kurt R, Yucedag C, Bilir N, Ozel HB, Cetin M, Sevik H. (2021). Selection of superior clones by the multi-dimensional decision making techniques in scots pine seed orchard. Journal of forests. 8(1):13-22.

[39] Kurz M, Koelz A, Gorges J, Carmona BP, Brang P, Vitasse Y, ... & Csillery K. (2023). Tracing the origin of Oriental beech stands across Western Europe and reporting hybridization with European beech–Implications for assisted gene flow. Forest Ecology and Management, 531; 120801.

[40] Sevık, H. (2012). Variation in seedling morphology of Turkish fir (Abies nordmanniana subsp. bornmulleriana Mattf). African Journal of Biotechnology, 11(23), 6389-6395.

[41] Bayraktar, A., Atar, F., Yıldırım, N. E. B. A. H. A. T., & Turna, I. (2018). Effects of different media and hormones on propagation by cuttings of European yew (Taxus baccata L.). Sumarski List, 142.

[42] Sevik H, Cetin M, Ozturk A, Yigit N, & Karakus O. (2019). Changes in micromorphological characters of Platanus orientalis L. leaves in Turkey. Applied Ecology and Environmental Research, 17(3);5909-5921.

[43] Yigit N, Öztürk A, Sevik H, Özel HB, Ramadan Kshkush FE, & Işık B. (2023). Clonal Variation Based on Some Morphological and Micromorphological Characteristics in the Boyabat (Sinop/Turkey) Black Pine (Pinus nigra subsp. pallasiana (Lamb.) Holmboe) Seed Orchard. BioResources, 18(3): 4850-4865

[44] Cantürk, U., Koç, İ., Özel, H. B., & Şevik, H. (2024). Possible changes of Pinus nigra distribution regions in Türkiye with the impacts of global climate change. BioResources, 19(3), 6190-6214

[45] Dogan, S., Kilicoglu, C., Akinci, H., Sevik, H., Cetin, M., & Kocan, N. (2024). Comprehensive risk assessment for identifying suitable residential zones in Manavgat, Mediterranean Region. Evaluation and program planning, 106, 102465.

[46] Isinkaralar, O., Isinkaralar, K., Sevik, H., & Küçük, Ö. (2024). Spatial modeling the climate change risk of river basins via climate classification: a scenario-based prediction approach for Türkiye. Natural Hazards, 120(1), 511-528.

[47] Güney, D., Bayraktar, A., Atar, F., & Turna, İ. (2020). Effects of root undercutting, fertilization and thinning on seedling growth and quality of oriental beech (Fagus orientalis Lipsky) seedlings. 21(2). 214-222

[48] Tandoğan, M., Özel, H. B., Gözet, F. T., & Şevik, H. (2023). Determining the taxol contents of yew tree populations in western Black Sea and Marmara regions and analyzing some forest stand characteristics. BioResources, 18(2), 3496-3508.

[49] Kravkaz-Kuscu, I. S., Sariyildiz, T., Cetin, M., Yigit, N., Sevik, H., & Savaci, G. (2018). Evaluation of the soil properties and primary forest tree species in Taskopru (Kastamonu) district. Fresenius Environmental Bulletin, 27(3), 1613-1617.

[50] Guney, D., Koc, I., Isinkaralar, K., Erdem, R. Variation in Pb and Zn concentrations in different species of trees and shrubs and their organs depending on traffic density. Baltic Forestry, 2023. 29(2), id661-id661.

[51] Koç İ. (2022). Determining the biocomfort zones in near future under global climate change scenarios in Antalya. Kastamonu university journal of engineering and sciences. 8(1):6-17.

[52] Kulaç, Ş., Nzokou, P., Guney, D., Cregg, B. M., & Turna, I. (2012). Growth and physiological response of Fraser fir [Abies fraseri (Pursh) Poir.] seedlings to water stress: seasonal and diurnal variations in photosynthetic pigments and carbohydrate concentration. HortScience, 47(10), 1512-1519.

[53] Isinkaralar, K., Isinkaralar, O., Koç, İ., Özel, H. B., & Şevik, H. (2024). Assessing the possibility of airborne bismuth accumulation and spatial distribution in an urban area by tree bark: A case study in Düzce, Türkiye. Biomass conversion and biorefinery, 14(18), 22561-22572.

[54] Dogan S, Kilicoglu C, Akinci H, Sevik, H, & Cetin, M. Determining the suitable settlement areas in Alanya with GIS-based site selection analyses. Environmental Science and Pollution Research, 2023. 30(11); 29180-29189.

[55] Şen, G., Güngör, E., & Şevik, H. (2018). Defining the effects of urban expansion on land use/cover change: a case study in Kastamonu, Turkey. Environmental monitoring and assessment, 190, 1-13.

[56] Bayraktar, O. Y., Ahıskalı, A., Ahıskalı, M., Ekşioğlu, F., Kaplan, G., & Assaad, J. (2024). Feasibility Of Foam Concrete Using Recycled Brick And Roof Tile Fine Aggregates. European Journal Of Environmental And Civil Engineering, 1-19.

[57] Aluç, S., & Ahıskalı, A. (2023). Application Of Mastic Asphalt Using Rubber Added Modified Bitumen. Sürdürülebilir Mühendislik Uygulamaları Ve Teknolojik Gelişmeler Dergisi, 6(1), 95-107.

[58] Bayraktar, O. Y., Tunçtan, M., Benli, A., Türkel, İ., Kızılay, G., & Kaplan, G. (2024). A study on sustainable foam concrete with waste polyester and ceramic powder: Properties and durability. Journal of Building Engineering, 95, 110253.

[59] Doğan, O., Ahıskalı, A., & Vurdu, C. D. (2023). Köprülü Kavşak Sistemlerinin Kazaları Azaltmadaki Etkisi: Devrekani Kavşağı Örneği. Trafik Ve Ulaşım Araştırmaları Dergisi, 6(1), 44-58.

[60] Kocaer, M., & Ahıskalı, A. (2011). Inportance Hydropower Resources of Turkey. Energy Education Science and Technology Part A-Energy Science and Research, 27(2), 395–400.

[61] Kaplan, G., & Bayraktar, O. Y. (2021). The effect of hemp fiber usage on the mechanical and physical properties of cement based mortars. Res. Eng. Struct. Mater, 7, 245-258.

[62] Yaprak, H., Memis, S., Kaplan, G., Yilmazoglu, M. U., & Ozkan, I. G. M. (2018). Effects on compressive strenght of accelerated curing methods in alkali activated mortars. Int J Sci Technol Res, 4.

[63] Memis, S., Kaplan, G., Yaprak, H., Yilmazoglu, M. U., & Mütevvelli Özkan, I. G. (2018). Some durability properties of alkali activated materials (AAM) produced with ceramic powder and micro calcite. Ceram. Silik, 62, 342-354.

[64] Ahıskalı, A., Ahıskalı, M., Bayraktar, O. Y., Kaplan, G., & Assaad, J. (2024). Mechanical And Durability Properties Of Polymer Fiber Reinforced One-Part Foam Geopolymer Concrete: A Sustainable Strategy For The Recycling Of Waste Steel Slag Aggregate And Fly Ash. Construction And Building Materials, 440, 137492.

[65] Isinkaralar, K. (2022). Some atmospheric trace metals deposition in selected trees as a possible biomonitor. Romanian Biotechnological Letters, 27(1), 3227-3236.

[66] Isinkaralar, K., & Erdem, R. (2021). Landscape plants as biomonitors for magnesium concentration in some species. International Journal of Progressive Sciences and Technologies, 29(2), 468-473.

[67] Isinkaralar, K. (2020). Removal of formaldehyde and BTEX in indoor air using activated carbon produced from horse chestnut (Aesculus Hippocastanum L.) Shell (Doctoral dissertation, Ph. D. Thesis Hacettepe University Institute of Science Department of Environmental Engineering. Ankara, Turkey).

[68] Isinkaralar, O., Isinkaralar, K., & Bayraktar, E. P. (2023). Monitoring the spatial distribution pattern according to urban land use and health risk assessment on potential toxic metal contamination via street dust in Ankara, Türkiye. Environmental Monitoring and Assessment, 195(9), 1085.

[69] Pirinc Bayraktar, E., Isinkaralar, O., & Isinkaralar, K. (2022). Usability of several species for monitoring and reducing the heavy metal pollution threatening the public health in urban environment of Ankara. World Journal of Advanced Research and Reviews, 14(3), 276-283.

[70] Isinkaralar, K. (2023). A study on the gaseous benzene removal based on adsorption onto the cost-effective and environmentally friendly adsorbent. Molecules, 28(8), 3453.

[71] Isinkaralar, K., & Turkyilmaz, A. (2022). Simultaneous adsorption of selected VOCs in the gas environment by low-cost adsorbent from Ricinus communis. Carbon Letters, 32(7), 1781-1789.

[72] Özel, H. B., Şevik, H., Onat, S. M., & Yigit, N. (2022). The effect of geographic location and seed storage time on the content of fatty acids in stone pine (Pinus pinea L.) seeds. BioResources, 17(3), 5038.

[73] Güney, D., Yahyaoglu, Z., Bayraktar, A., Atar, F., & Turna, I. (2019). Genetic diversity of Picea orientalis (L.) Link populations in Turkey. Sumarski List, 143.

[74] Özdikmenli, G., Yiğit, N., Özel, H. B., & Şevik, H. (2024). Altitude-dependent Variations in Some Morphological and Anatomical Features of Anatolian Chestnut. BioResources, 19(3). 4635-4651

[75] Yıldırım, N., Bayraktar, A., Atar, F., Güney, D., Öztürk, M., & Turna, I. (2020). Effects of different genders and hormones on stem cuttings of Salix anatolica. Journal of Sustainable Forestry, 39(3), 300-308.

[76] Atar, F., Güney, D., Bayraktar, A., Yıldırım, N., & Turna, İ. (2020). Seasonal change of chlorophyll content (spad value) in some tree and shrub species. Turkish Journal of Forest Science, 4(2), 245-256.

[77] Güney, D., Chavoshi, S. H., Bayraktar, A., & Atar, F. (2021). The effects of temperature and exogenous auxin on cutting propagation of some junipers. Dendrobiology, 86. 29-38

[78] Ozel, H. B., Sevik, H., Cetin, M., Varol, T., & Isik, B. (2024). Impact of employment policies on disabled individuals in silvicultural activities. Environment, Development and Sustainability, 1-14.