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Comparison of Pb, Cd, Zn and Cr content of some mineral concrete admixtures

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Abstract

Today, the demand for urban areas due to population growth worldwide and migration from rural to urban areas increases the need for new residential areas and new housing construction. This need also increases the demand for concrete, which is an important raw material especially in the building sector and constitutes a significant portion of construction input costs. Therefore, studies on the use of various environmental wastes as concrete admixtures in order to both reduce the cost of concrete and to dispose of environmental wastes are gaining importance and many studies have been conducted on the subject in recent years. However, the lack of sufficient data on the chemical structure of concrete admixtures leads to a lack of information on the environmental impacts of construction activities as well as the health of people working in the sector. For these reasons, this study aimed to determine and compare the Pb, Cr, Cd and Zn contents of some materials used as concrete admixtures. As a result of the study, it was determined that these heavy metal contents can vary significantly on a material basis and can reach up to 37.36 ppm for Pb, 103.67 ppm for Cr, 446.18 ppm for Zn and 444.85 ppm for Cd. This result shows that workers in the sector working with these materials may face serious health problems. Therefore, it is necessary to take precautions by providing the necessary awareness.

Keywords: Concrete; Admixture; Chemical Content; Heavy metal

1. Introduction

Both increasing population and migration from rural to urban areas necessitate the creation of new residential areas in urban centers and therefore the construction of new buildings [1-3]. Concrete is the basic building block of most of the high-rise buildings designed to accommodate more people per unit area. Concrete, which is formed by combining cement, aggregate, water and some additives when necessary, is used in a wide variety of structures in our age [4-6]. Concrete is used so intensively today that it is stated to be the most consumed building material in the world after water [7-9].

Therefore, concrete, which is used in such large quantities, causes the resources used as raw materials to be extracted from underground deposits and released into the nature, sometimes over a long period of time. Considering how many buildings are being constructed and how many of them have a lifespan limited to 20-30 years, it will be better understood how big a role the construction industry plays in the cycle of many elements and how much raw materials it requires. In fact, concrete production uses about 18% of the global annual industrial water use. In addition, it is stated that approximately 10% of global carbon dioxide (CO_2) emissions are caused by cement production, which is the primary material of concrete production [10-16].

Especially in construction activities in urban centers, the amount of particulate matter in the air is significantly affected and increased during both construction and demolition phases [17]. The chemical structure of these particulate matter

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also affects environmental pollution. Environmental pollution, and especially air pollution, is shown as one of the most important global problems in the current century [17-26]. It is stated that air pollution has reached a dimension that will affect even the most remote ecosystems [27-29], and especially threatens human life seriously. In fact, it is reported that approximately 90% of the world's population now breathe polluted air, 99% are exposed to poor air quality, and air pollution causes approximately 6 million premature births, approximately 3 million underweight babies and approximately 7 million premature deaths worldwide every year [30-33].

The most important and harmful components of air pollution are heavy metals. Heavy metals, some of which are threatening to human health even at low concentrations, can cause very serious health problems such as cancer, respiratory diseases, heart attacks and even death [34-37]. Heavy metals can be even more harmful and fatal when they are inhaled into the human body [38]. Therefore, international organizations such as EPA and ATSDR have placed some heavy metals on the priority pollutant list [39-41]. It is of great importance for human health that these heavy metals do not exceed certain concentrations.

Various raw materials used in construction activities such as cement, sand, gypsum and bricks may contain high amounts of heavy metals. In addition, many additives used in recent years to reduce the cost of concrete are also reported to contain high amounts of heavy metals [42,43]. Many admixtures such as kiln slag, marble dust, brick dust, wood ash, silica fume can be substituted into concrete in order to prevent waste of resources by recycling and to reduce the cost of concrete [44-52]. However, there are very few studies on the heavy metal content of these admixtures. However, it is important to know the heavy metal contents of concrete admixtures both in terms of determining which heavy metals are eliminated by the use of these concrete admixtures, i.e. which heavy metals are eliminated as environmental pollutants, and how much these admixtures threaten human and environmental health. In this study, the contents of the ten most commonly used concrete admixtures were analyzed and the concentrations of Pb, Cr, Cd and Zn were compared. These heavy metals were chosen because they are both the most widely used and are on the priority pollutant list of EPA and ATSDR due to their potential hazards.

2. Material and methods

The aim of this study is to compare the chemical contents of some concrete mineral admixtures. For this purpose, some of the most commonly used mineral admixtures were selected as concrete raw materials. The concrete admixtures examined within the scope of the study are as follows;

- Fly ash
- Wood ash
- Silica fume
- Red Pumice
- Vermiculite
- Brick powder
- Tire powder
- Marble powder
- Zeolite
- Blast furnace slag

The materials obtained within the scope of the study were first prepared for preliminary analysis. The materials obtained at this stage were ground and sieved, then kept for about two weeks until room dry and then dried in an oven at 45 °C for two weeks. Then laboratory analyzes were carried out.

Elemental analyses were sent to Kastamonu University Central Research Laboratory Application and Research Center and performed with the help of ICP-OES device. Before elemental analysis, the dried samples were subjected to pre-incineration in a microwave oven specially designed for this process. The pre-burning samples were analyzed by ICP-OES to determine the concentrations of Pb, Cr, Cd and Zn and the heavy metal concentrations were calculated by multiplying the obtained values by the dilution factor. This method has been widely used in previous studies in this field [53,54]. The data obtained were analyzed using SPSS 22.0 package program and analysis of variance was applied to the data and Duncan test was applied for the factors showing statistically significant differences at a minimum 95% confidence level ($p < 0.05$). Taking into account the results of the Duncan test, the data were presented in tables and then interpretations were made.

3. Results

Analysis of variance and Duncan test results for the elemental contents of the materials subject to the study are given in Table 1.

Table 1 Analysis of variance and Duncan test results

Material	Pb (ppm)	Cr (ppm)	Zn (ppm)	Cd (ppm)
Fly ash	17.14f	33.02d	10.74ab	257.20a
Wood ash	9.66cd	103.67e	446.18c	444.85de
Silica fume	5.47b	5.48abc	10.19ab	440.09bc
Red Pumice	13.33e	97.66e	24.19ab	402.16de
Vermiculite	21.26g	11.95bc	23.12ab	540.59c
Brick powder	11.49de	13.40c	35.98b	498.26c
Tire powder	11.12de	2.15ab	0.00a	703.90d
Marble powder	7.63bc	2.40ab	9.64ab	684.49d
Zeolite	37.36h	8.88abc	18.31ab	352.97ab
Blast furnace slag	2.08a	1.16a	9.68ab	434.52bc
F Value	85.687***	153.386***	210.304***	19.005***

As a result of the analysis of variance, the materials differed statistically in all elements at 99.9% confidence level. As a result of Duncan test in Pb, the materials subject to the study were grouped in 8 homogeneous groups, the lowest value was obtained in blast furnace slag and the highest value was obtained in zeolite. The materials were grouped in 5 homogeneous groups in terms of Cr concentration, the lowest value was obtained in blast furnace slag and the highest values were obtained in Red Pumice and wood ash.

As a result of the analysis, the Zn concentration obtained in tire dust was below the determinable limits. As a result of the Duncan test, the materials subject to the study were grouped in 3 homogeneous groups in terms of Zn concentration, the highest value was obtained in wood ash and all other materials were in the first two groups. In terms of Cd concentration, the materials subject to the study were grouped into 4 homogeneous groups, the lowest values were obtained in Fly ash and Zeolite, and the highest values were obtained in Rubber dust, Marble dust, Red Pumice and Wood ash materials.

4. Result and Discussion

Within the scope of the study, Pb, Cr, Cd and Zn concentrations of 10 materials frequently used as concrete admixtures were determined. Heavy metals are elements whose concentrations in nature are constantly increasing and most of them are released into nature from anthropogenic sources such as mining, industry and traffic. They do not easily degrade or disappear in nature [55-59]. Therefore, heavy metal exposure and related health risks are constantly increasing and this issue is becoming more and more important every day. Due to the importance of the issue, many studies have been carried out in various fields to identify and reduce heavy metal pollution [27,29,31]. However, the number of studies on the subject in the field of civil engineering is almost negligible. However, as revealed in this study, the heavy metal content of concrete admixtures can be very high. As a result of the study, it was determined that heavy metal concentrations in the concrete admixtures subject to the study can reach up to 37.36 ppm for Pb, 103.67 ppm for Cr, 446.18 ppm for Zn and 444.85 ppm for Cd.

The values obtained as a result of the study show that they can even exceed the values obtained in traffic and industrial zones, which are shown as the main sources of heavy metal pollution. For example, in a study conducted on road dust, Cd concentration was found to vary between 2.5 ppm and 4.5 ppm [60]. Some concentrations determined in this study are much higher than this value.

It is stated that construction activities, especially in urban centers, are one of the factors that most affect the amount of particulate matter in the air during both construction and demolition [42,43]. These particulate matter act as a sink for heavy metals in urban areas. The chemical composition of particulate matter also greatly influences heavy metal pollution in air and subsequently in soil and water [18,21,54]. Therefore, concrete admixtures can pose a major risk to the health of workers in construction activities. In addition, these particles may also adversely affect the health of people and living organisms in urban areas.

As a result of the study, it was determined that there can be a significant difference between the lowest and highest values and this difference can reach hundreds of times. This result shows that the chemical content of waste materials used as concrete admixtures can be very variable. Similar results were obtained in other studies [42,43].

Recommendations

A total of 10 concrete admixtures were evaluated within the scope of the study. Most of the materials subject to the study are waste materials and the recycling of these materials contributes significantly to reducing their environmental impact. Therefore, besides the use of these materials as concrete admixtures, the possibilities of using these materials in different areas should be investigated. Some of the materials with very high concentrations of heavy metals are wastes of different sectors and therefore people working in some sectors other than the construction sector are also exposed to the dust of these materials. Other sectors where these materials are used should be warned and necessary precautions should be taken. People exposed to these materials should be made aware and precautions should be taken during work, especially in terms of inhalation.

Compliance with ethical standards

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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 OY, Sarıgül E, Yüksel M, Jamal AS, Kara HO, Ayyıldız MA, & Kaplan G. Recycling aerated concrete waste as aggregate to produce eco-friendly foamed mortar (EFM). Struct Conc. 2025. https://doi.org/10.1002/suco.202401353

[2] Ahıskalı A, Benli A, Ahıskalı M, Bayraktar OY, & Kaplan G. Sustainable geopolymer foam concrete with recycled crumb rubber and dual fiber reinforcement of polypropylene and glass fibers: A comprehensive study. Const Build Mater. 2025. 474:141137.

[3] Şen G, Güngör E, & Şevik H. Defining the effects of urban expansion on land use/cover change: a case study in Kastamonu, Turkey. Environ Monit Assess. 2018. 190:1-13.

[4] Bayraktar OY, Ahıskalı A, Ahıskalı M, Ekşioğlu F, Kaplan G, & Assaad J. Feasibility of foam concrete using recycled brick and roof tile fine aggregates. Eur J Environ Civ En. 2025. 29(3):548-566.

[5] Yılmazoğlu MU, Kara HO, Benli A, Demirkıran AR, Bayraktar OY, & Kaplan G. Sustainable alkali-activated foam concrete with pumice aggregate: Effects of clinoptilolite zeolite and fly ash on strength, durability, and thermal performance. Const Build Mater. 2025. 464:140160. https://doi.org/10.1016/j.conbuildmat.2025.140160

[6] Bayraktar OY, Özel HB, Benli A, Yılmazoğlu MU, Türkel İ, Dal BB, ... & Kaplan G. Sustainable foam concrete development: Enhancing durability and performance through pine cone powder and fly ash incorporation in alkali-activated geopolymers. Const Build Mater. 2024. 457:139422. https://doi.org/10.1016/j.conbuildmat.2024.139422

[7] Bayraktar OY, Tunçtan M, Benli A, Türkel İ, Kızılay G, & Kaplan G. A study on sustainable foam concrete with waste polyester and ceramic powder: Properties and durability. J Build Eng. 2024. 95:110253. https://doi.org/10.1016/j.jobe.2024.110253

[8] Ahıskalı A, Ahıskalı M, Bayraktar OY, Kaplan G, & Assaad J. 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. Const Build Mater. 2024. 440:137492. https://doi.org/10.1016/j.conbuildmat.2024.137492

[9] Özkan İGM, Aldemir K, Alhasan O, Benli A, Bayraktar OY, Yılmazoğlu MU, & Kaplan G. Investigation on the sustainable use of different sizes of sawdust aggregates in eco-friendly foam concretes: Physico-mechanical, thermal insulation and durability characteristics. Const Build Mater. 2024. 438:137100. https://doi.org/10.1016/j.conbuildmat.2024.137100

[10] Zeyad AM, Bayraktar OY, Tayeh BA, Öz A, Özkan İGM, & Kaplan G. Impact of rice husk ash on physico-mechanical, durability and microstructural features of rubberized lightweight geopolymer composite. Const Build Mater. 2024. 427:136265.

[11] Kaplan G, Bayraktar OY, Li Z, Bodur B, Yılmazoglu MU, & Alcan BA. 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. J Build Eng. 2023. 76:107280. https://doi.org/10.1016/j.jobe.2023.107280

[12] Bayraktar OY, Turhal S, Benli A, Shi J, & Kaplan G. Application of recycled aggregates and biomass ash in fibre-reinforced green roller compacted concrete pavement-technical and environmental assessment. Int J Pavement Eng. 2025. 26(1):2458140.

[13] Bayraktar OY, Jamal AS, Öz A, Shi J, Bodur B, & Kaplan G. Effects of metakaolin and waste tire aggregate on the properties of pumice-based lightweight geopolymer. Adv Cem Res. 2025. 1-39. https://doi.org/10.1680/jadcr.23.00183

[14] Bodur B, Benli A, Bayraktar OY, Alcan HG, Kaplan G, & Aydın AC. Impact of attapulgite and basalt fiber additions on the performance of pumice-based foam concrete: mechanical, thermal, and durability properties. ACME. 2025. 25(2):74.

[15] Benli A, Bayraktar OY, Karataş M, Bodur B, Yılmazoğlu MU, & Kaplan G. (2025). Dunite powder as a green precursor in one-part alkali-activated composites: Effects on mechanical and durability properties. Sustain Chem Pharm. 2025. 44: 101964.

[16] Gencel O, Harja M, Sarı A, Hekimoğlu G, Ustaoğlu A, Sutcu M, ... & Bayraktar OY. Development, characterization, and performance analysis of shape-stabilized phase change material included-geopolymer for passive thermal management of buildings. Int J Energy Res. 2022. 46(15):21841-21855.

[17] Yaman, Ö. Ü. K., & Özçelik, Y. L. Ö. Ö. (2019). Türkiye’de Kentsel Dönüşüm Uygulamaları: Karabük Merkez İlçe Örneği. Cataloging-In-Publication Data, 428.

[18] Koc I, Cobanoglu H, Canturk U, Key K, Kulac S, & Sevik H. Change of Cr concentration from past to present in areas with elevated air pollution. IJEST. 2024. 21(2):2059-2070.

[19] Ozturk Pulatoglu A, Koç İ, Özel HB, Şevik H, & Yıldız Y. Using trees to monitor airborne cr pollution: effects of compass direction and woody species on Cr uptake during phytoremediation. BioRes. 2025. 20(1):121-139.

[20] Özel HB, Şevik H, Yıldız Y, & Çobanoğlu H. Effects of silver nanoparticles on germination and seedling characteristics of oriental beech (Fagus orientalis) seeds. BioRes. 2024. 19(2):2135-2148

[21] Koç İ, Canturk U, Cobanoglu H, Kulac S, Key K, & Sevik H. Assessment of 40-year Al deposition in some exotic conifer species in the urban air of Düzce, Türkiye. Water Air Soil Pollut. (2025). 236(2):1-14.

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

[23] Sevik H, Ozel HU, Yildiz Y, & Ozel HB. Effects of Adding Fe2O3 and Fe3O4 nanoparticles to soil on germination and seedling characteristics of oriental beech. BioRes. 2025. 20(1): 70-82.

[24] Key K, Kulaç Ş, Koç İ, & Sevik H. 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 Physiol Plant. 2023. 45(10):1-13.

[25] Sevik H, Cetin M, Ozel HB, & Pinar B. Determining toxic metal concentration changes in landscaping plants based on some factors. Air Qual Atmosp Health. 2019. 12:983-991.

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

[27] Sevik H, Cetin M, Ozturk A, Ozel HB, & Pinar B. Changes in Pb, Cr and Cu concentrations in some bioindicators depending on traffic density on the basis of species and organs. Appl Ecol Environ Res. 2019. 17(6):12843-12857.

[28] Isinkaralar K. Some atmospheric trace metals deposition in selected trees as a possible biomonitor. Rom Biotech Lett. 2022. 27(1):3227-3236.

[29] Koç İ, Canturk U, Isinkaralar K, Ozel HB, & Sevik H. Assessment of metals (Ni, Ba) deposition in plant types and their organs at Mersin City, Türkiye. Environ Monit Assess. 2024. 196(3):282.

[30] Ghoma WEO, Sevik H, & Isinkaralar K. Comparison of the rate of certain trace metals accumulation in indoor plants for smoking and non-smoking areas. Environ Sci Pollut Res. 2023. 30(30): 75768-75776.

[31] Cobanoglu H, Sevik H, & Koç İ. 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 Pollut. 2023. 234(2): 65.

[32] Gültekin Y, Bayraktar MK, Sevik H, Cetin M, & Bayraktar T. Optimal vegetable selection in urban and rural areas using artificial bee colony algorithm: Heavy metal assessment and health risk. J Food Composition Analysis. 2025. 139:107169.

[33] Sevik H, Yildiz Y, Ozel HB. Phytoremediation and long-term metal uptake monitoring of silver, selenium, antimony, and thallium by Black Pine (Pinus nigra Arnold), BioRes. 2024. 19(3): 4824-4837.

[34] Canturk U, Koç, İ, Ozel HB, & Sevik H. Identification of proper species that can be used to monitor and decrease airborne Sb pollution. Environ Sci Pollut Res. 2024. 1-11.

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

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

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

[38] Koç İ, Cobanoglu H, Canturk U, Key K, Sevik H, & Kulac S. Variation of 40-year Pb deposition in some conifers grown in the air-polluted-urban area of Düzce, Türkiye. Environ Earth Sci. 2025. 84(7):186.

[39] Sevik H, Koç İ, & Cobanoglu H. Determination of some exotic landscape species As biomonitors that can be used for monitoring and reducing Pd pollution in the air. Water Air Soil Pollut. 2024. 235(10):615.

[40] Yaşar İsmail TS, İsmail MD, Çobanoğlu H, Koç İ, & Sevik H. Monitoring arsenic concentrations in airborne particulates of selected landscape plants and their potential for pollution mitigation, Forestist. 2025. 75,1-6

[41] Isinkaralar K, Isinkaralar O, Koc I, Sevik H, & Ozel HB. Atmospheric trace metal exposure in a 60-Year-Old Wood: A sustainable methodological approach to measurement of dry deposition. Int J Environ Res. 2025. 19:112 (2025). https://doi.org/10.1007/s41742-025-00783-x

[42] Elajail ISI, Sevik H, Ozel HB, Isik B. Examining the chemical compositions of mineral concrete agents in terms of their environmental efects. Fre Environ Bull. 2022. 31(9):9784–9790

[43] Elajaıl, İ. S., & Şevik, H.. Evaluation of As, Cd, Ni and Se Content of Some Mineral Concrete Agents. Kastamonu University Journal of Engineering and Sciences. 2024. 10(1), 44-51.

[44] Evirgen B, Kara HO, Ucun MS, Gültekin AA, Tos M, & Öztürk V. The effect of the geometrical properties of geocell reinforcements between a two-layered road structure under overload conditions. Case Studies in Const Mater. 2024. 20:e02793.

[45] Turkoglu, M., Bayraktar, O. Y., Benli, A., & Kaplan, G.. Effect of cement clinker type, curing regime and activator dosage on the performance of one-part alkali-activated hybrid slag/clinker composites. Journal of Building Engineering. 2023. 68, 106164.

[46] Bayraktar, O. Y., Yarar, G., Benli, A., Kaplan, G., Gencel, O., Sutcu, M., ... & Kadela, M. Basalt fiber reinforced foam concrete with marble waste and calcium aluminate cement. Structural Concrete. 2023. 24(1), 1152-1178.

[47] Bayraktar, O. Y., Yakupoglu, U., & Benli, A. Slag/diatomite-based alkali-activated lightweight composites containing waste andesite sand: mechanical, insulating, microstructural and durability properties. Archives of Civil and Mechanical Engineering. 2023. 23(4), 230.

[48] Bayraktar, O. Y., Bozkurt, T. H., Benli, A., Koksal, F., Türkoğlu, M., & Kaplan, G. Sustainable one-part alkali activated slag/fly ash Geo-SIFCOM containing recycled sands: Mechanical, flexural, durability and microstructural properties. Sustainable Chemistry and Pharmacy. 2023. 36, 101319.

[49] Gencel, O., Harja, M., Sarı, A., Hekimoğlu, G., Ustaoğlu, A., Sutcu, M., ... & Bayraktar, O. Y. Development, characterization, and performance analysis of shape-stabilized phase change material included-geopolymer for passive thermal management of buildings. International Journal of Energy Research. 2022. 46(15), 21841-21855.

[50] Bodur, B., Bayraktar, O. Y., Benli, A., Kaplan, G., Tobbala, D. E., & Tayeh, B. Effect of using wastewater from the ready-mixed concrete plant on the performance of one-part alkali-activated GBFS/FA composites: Fresh, mechanical and durability properties. Journal of Building Engineering. 2023. 76, 107167.

[51] Gencel, O., Nodehi, M., Bayraktar, O. Y., Kaplan, G., Benli, A., Koksal, F., ... & Ozbakkaloglu, T. The use of waste marble for cleaner production of structural concrete: A comprehensive experimental study. Construction and Building Materials. 2022. 361, 129612.

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

[53] Isinkaralar O, Isinkaralar K, & Sevik H. Health for the future: spatiotemporal CA-MC modeling and spatial pattern prediction via dendrochronological approach for nickel and lead deposition. Air Qual Atmosp Health. 2025. 1-13.

[54] Erdem R, Koç İ, Çobanoglu H, & Şevik H. Variation of magnesium, one of the macronutrients, in some trees based on organs and species. Forestist, 2024. 74(1): 84-93.

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

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

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

[58] Yayla, E. E., Sevik, H., & Isinkaralar, K. Detection of landscape species as a low-cost biomonitoring study: Cr, Mn, and Zn pollution in an urban air quality. Environmental monitoring and assessment. 2022. 194(10), 687.

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

[60] Istanbullu, S. N., Sevik, H., Isinkaralar, K., & Isinkaralar, O. Spatial distribution of heavy metal contamination in road dust samples from an urban environment in Samsun, Türkiye. Bulletin of environmental contamination and toxicology. 2023. 110(4), 78.