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Evaluation of Environmental Barium Concentration Biomonitoring in Tree Rings

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ABSTRACT

The effect of barium element that can be extremely harmful heavy metal to human and environmental health in urban centers. The barium can cause various environmental pollution due to its anthropogenic accumulation in the environment. Also, it has negative effects on plants, animals, and humans through atmospheric deposition. All Barium (Ba) compounds are harmful heavy metals and they show a poisonous effect on the environment. Thus, it is crucial to determine the Ba concentration in plants grown in areas with high pollution in the landscape, park, and roadside. Biomonitoring with the tree species can be determined which is the best passive biomonitoring method with the tree rings formed by the effect of seasonal differences. The barium has been accumulated in the tree rings for a long time that can provide critical knowledge about the atmospheric barium deposition. The temporal and spatial variations of Ba concentration were analyzed with organs of *Ailanthus altissima* (Mill.) as biomonitors. This study results show that the outer bark of *Ailanthus altissima* (Mill.) is a convenient biomonitor for Ba deposition.

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Introduction

Environmental heavy metal pollution monitoring and identifying risky are essential procedures in terms of human and environmental health (Isinkaralar et al., 2017; Jacob et al., 2018; Işınkaralar and Varol, 2021). Heavy metal concentrations in urban air are likely to increase over time due to continued improper urbanization and atmospheric heavy metal deposition (Kurnaz et al., 2016; Yilmaz and Isinkaralar, 2021a, b). In these periods of rapid urbanization, the emission resulting from the fuels used in industry, vehicles, and residences has accelerated by anthropogenic sources (Isinkaralar et al., 2021; Önaç and Sütçüoğlu, 2021). With the increase in environmental pollution, new methods for the removal of environmental pollutants have come to the fore (Şutan et al., 2020; Isinkaralar et al., 2022). Especially, Heavy metal pollution in the air, water, or soil has been one of the vital subjects for many years (Yalçın and Çimrin, 2019; Isinkaralar, 2020; Tokatli et al., 2021; Mutlu, 2021; Wei et al., 2021). Especially pollutants in soil and water are much easier than air pollutants because they can be determined by direct measurements (Sevik et al., 2018; Abacioglu et al., 2019; Manisalidis et al., 2020). They tend to accumulate in the environment due to their non-biodegradable properties. Although it is not easy to monitor environmental pollutants monitoring them and evaluating their status is very important (Turkyilmaz et al., 2020; Yang et al., 2021).

Among these pollutants, Barium (Ba) an abundant alkaline earth metal, belongs to Group 2A, a can be found more than zinc (Madejón, 2013). Ba is not found in nature in its form because it is an extremely active element (Peana et al., 2021). Therefore, it is generally seen as a form of barite ($BaSO_4$) and with rite ($BaCO_3$) (Böttcher et al., 2018). They have commonly used substance in drilling operations, which is generally applied in oil extraction operations. Ba^{+2} or its composites, used in many fields, are used in plastic and adhesive, ceramics and protection, hair dyes and cosmetics, medical engineering, white colorant, and fireworks (Aziz et al., 2017). Although the solubility of barium sulfate and barium salts can increase in reduced environments, their solubility varies such as barite due to easily oxidized by oxygen in air and water (Rye 2005). In some cases, (acidic, oxygen ninety, and when microbial activities are fast), their solubility may increase the possibility of environmental contamination (Landreau et al., 2021). Ba precipitates as a carbonate salt and/or sulfate at neutral or basic pH conditions (Cravotta 2008). Hence, Ba has negligible mobility under the same conditions, thus decreasing the adverse health effects and the risk of leaching. However, when it is not worked under appropriate conditions, Ba^{+2} can cause toxic effects by sulfate and sulfur residues. The Ba emission resulting from various industrial and industrial activities can easily mix with air, soil, and water (Boev and Lepitkova, 2021).

As a result of high concentration, it causes various health problems. It was observed that both acute poisoning and chronic exposure increased as the solubility of barium increased. The usage of Ba for industrial goals steadily increases, the importance of assessing the risks associated with barium exposure or poisoning is increasing (Jing et al., 2011). Here we want to provide a synopsis of the distinct exposure pathways for humans and their effects on health. Although it is seen as a bio-essential substance for human nutrition, it is absorbed by people in different ways such as ingestion, inhalation, and through the skin. In particular, it gets more through eating and drinking, that is, food depending on the barium level in food products and drinking water, the amount of intake may increase. While this value is s less than 2.0 µg/g for edible products, it is 200 µg/day for drinking water (Kravchenko et al., 2014). More than these amounts accumulate in humans' skeletal systems, teeth, and bones. It threatens organs that perform other vital (such as liver, kidney, heart) and gastrointestinal activities. It induces destructive cell processes such as hypokalemic paralysis, resulting in cardiac and respiratory arrest. Also, it can be seen in different tissues (such as the aorta, brain, pancreas, blood-urine-stool, placenta, muscles) although there is no accumulation there (Schroeder et al., 1972). approximately 90% of Ba taken into the body in various ways is excreted in the first two weeks in urine and feces. However, if insoluble compounds are inhaled, their levels can build up in the lungs causing a benign condition known as "Baritosis" (Peana et al., 2021). Tests that can measure the extent of barium exposure are still being studied. Ba has a toxic effect on humans and affects other living things, especially plants. Ba toxicity has been demonstrated in studies on plants from anthropogenic pollutants. Studies have revealed the accumulation of Ba in various species (Nagaraju and Karimulla, 2002). While there is 49 ppm in apple leaves, it has been determined that there is 63 ppm in tomatoes due to the continental crust being predicted to hold 425 ppm of Ba (Padilla and Anderson, 2002). Like other elements in the plant, they can accumulate with the root and the transfer system between each other (Usman et al., 2019).

Trees can be used as biomonitors that should be capable of accumulating heavy metals in their bodies, but should not die from the effects of heavy metals (Sevik et al., 2019; Maresca et al., 2020; Savas et al., 2021). In addition, they should live in the sample area, have enough samples, organs, or tissue for metal analysis, be easy to sample whenever desired, and there should be a correlation between organisms and the environment in terms of the heavy metal concentration (Koç, 2021; Rakib et al., 2021). In addition, it is known that the heavy metals accumulating in this tree are transmitted to humans, since people are trying to consume this tree in various ways, believing that this tree is beneficial (Turkyilmaz et al., 2019). Therefore, it is stated that the most suitable biomonitors are plants to trace heavy metal pollution changes (Barandovski et al., 2021; Jeddi et al., 2021). The primary problem with using plants as biomonitors is to determining which plant and its organs are more suitable for monitoring which metal (Karacocuk et al., 2021). Because plants accumulate different elements in different organs and at different levels. Although the annual tree rings are used effectively as biomonitors, the amount of information about the speciation of heavy metals in the plant and their transition between organs is quite limited, starting from their entry into the plant. The study aimed to evaluate the accumulation of Ba concentration in organs and its potential to use tree rings of *Ailanthus altissima* (Mill.) as a biomonitor.

Material and Method

Study Area and Sampling

Ailanthus altissima (Mill.) was used barks-wood and 69 years old. It was collected from the city center of Ankara province, Turkey. It is a malodorous tree from the *Simaroubaceae* family that blooms with greenish-yellow flowers between May and June. It is believed among the locals that it is healing various diseases when it is extracted. It has an antipyretic and emetic effect. It helps to reduce intestinal worms. Considering that it is beneficial in diarrhea and dysentery, it is either brewed or consumed like tea. It was aimed to determine atmospheric barium deposition by rings of the *Ailanthus altissima* (Mill.). Samples taken from the tree main trunk at a height of approximately 1.5 meters from the ground were kept in a controlled oven for 2 weeks to be dried at 45°C. The samples were not washed in some cases because it causes the elements to change.

Chemical Analysis

The dried samples were weighed as 0.5 g blended with 6 mL and 2 mL (65% HNO_3 and 30% H_2O_2), and inserted into the microwave for the digestion system (Milestone Ethos). The machine was programmed to raise the temperature to 200°C for 15 minutes and then replenish with 25 mL of deionized water, the GBC Integra XL-SDS-270 ICP-OES device was used in analyzing for Ba concentration.

Data Analysis

The data were analyzed by analysis of variance (ANOVA) using the SPSS 22.0 package software program. Also, Duncan's test was used for the factors that showed statistically significant differences ($P<0.05$). The obtained homogeneous groups were simplified, represented in tables, and interpreted. The data obtained were interpreted after simplification and tabularization. All the measurements were triplicated and the coefficient of variation was found to be within 11% for Ba.

Results and Discussion

The accumulation of Ba element in *Ailanthus altissima* (Mill.) species was determined to be highest in the outer bark (37784.4 ppb), slightly less in the inner bark (26088.4 ppb), and least in wood (2936.9 ppb). According to the ANOVA test applied to the obtained data, it was determined that the change in all of the metals subject to the study on an organ basis was statistically significant at the 99.9% confidence level ($P<0.001$). When the groups formed as a result of the Duncan test are examined, it is seen that the values obtained in the outer bark are in the last group in Figure 1.

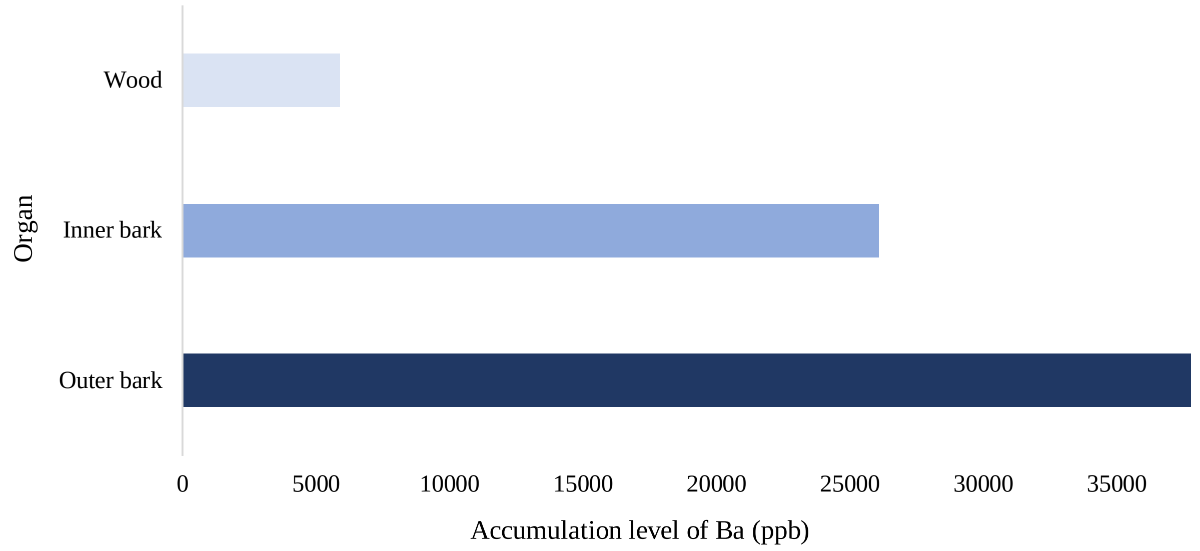

Figure 1. Ba concentrations (ppb) based on organ

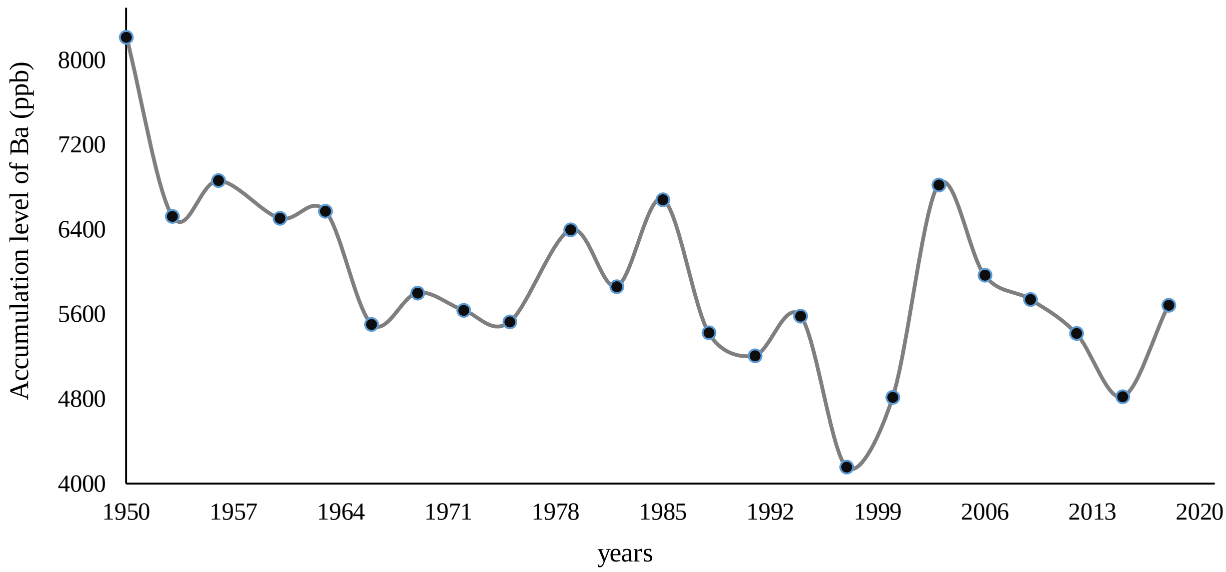

Figure 2. Ba concentrations (ppb) of tree rings in the plots

When the Ba concentration accumulation in the annual rings of *Ailanthus altissima* (Mill.) is examined, the highest Ba concentration was found in 1950 with 8219.7 ppb. Although the Ba level in its body decreased with a fluctuating course with the development of the plant species until 1995, it experienced a jump after 1995 and reached 6825.2 ppb in 2003. Although there were decreases afterward, there was no increase with the accumulation of Ba level approximately 30 years apart in Figure 2.

Discussion

There are many studies in which tree rings are used as a biomonitor for trace, nutrient, and toxic elements, especially heavy metals although studies following the change in barium accumulation and level of plants are very limited (Turkyilmaz et al., 2018; Goddard et al., 2019; Şevik, 2021). Kirchner et al. (2008) was determined using tree rings of 350 years old *Pinus jeffreyi* as a biomonitoring trace metal in Nevada, USA. Sr^{+2}, $Ba^{+2,}$ and Ca^{+2} were showed similar results due to having the greatest affinity. Balouet et al., (2009) were searched environmental contamination with dendrochronological methods for anthropogenic effect on species. Padilla and Anderson (2002) were examined tree rings of 350+ years old *Pinus ponderosa* as trace elements including Ba. It has a positive correlation for relatively constant from the mid-1600s to the early 1800s. Bardule et al., (2020) were studied stem disc samples of six-year-old hybrid aspen (*Populus tremuloides* Michx. × *P. tremula* L.) in the spring of 2011. They were analyzed major elements and toxic heavy metal content in the disc of species. They found a correlation between the accumulation of various elements in soil and tree species. Perone et al., (2018) were evaluated atmospheric pollution from several sources. They hypothesized that tree–rings of *Quercus pubescens* could accumulate heavy metal from anthropogenic activities in the period 1958–2009. The type used was useful in describing the types of welds of each heavy metal and other elements, as well as the types of welds. Cetin et al., (2021) was assessed Ba concentration in fir organs of some species and were found Ba concentration varies considerably in organs and age. Cetin and Jawed (2022) were determined the variation of Ba concentrations in leaves and branches of *Ficus bengalensis*, *Ziziphus mauritiana*, *Conocarpus erectus*, and *Azadrechta indica* species depending on traffic density. They were found the most suitable organs were *Azadrechta indica* leaves. Heavy metals released into the atmosphere because of traffic and industrial activities accumulate in different plant species (Monaci et al., 1997; Frati et al., 2005; Jabłońska et al., 2016). About the Ba and Sb elements show that they are released from non-exhaust vehicle emissions and have a positive association of their levels (Gietl et al., 2010). It has been discovered that plant and tree species can adsorb heavy metals and toxic metals according to their environment. The recent studies have been carried out that several species of plants have been used as a very successful environmental biomonitoring tool for passive sampling of atmospheric heavy metal deposition in urban areas (Oliva and Rautio, 2004; Vergel et al., 2019; Isinkaralar and Erdem, 2021). There have been studies that used passive sampling, not only an urban scale, but also in indoor air (Ghoma et al., 2022). In particular, plants and tree species in areas close to traffic accumulate in their bodies through adsorption. At the same time, it has been revealed in studies that trees and plants in areas close to industrial areas commonly contain heavy metals.

Conclusion

Heavy metals are highly hazardous that can be extremely harmful to both living things and ecosystems, especially humans. Therefore, it is crucial to monitor the change in heavy metal concentrations in the air. However, an effective, easy, inexpensive, and effective method has not been developed yet to trace the change of heavy metals concentrations in the air. The environmental pollutant is Ba, which mixes with the water, is filtered, and accumulates in the atmosphere deposition from the soil into the ants. It is released into the atmosphere that releases non-exhaust vehicle emissions by forming compounds with radicals. Accordingly, the *Ailanthus altissima* (Mill.) usability as a biomonitor was investigated for Ba concentration with tree bark and trunk wood. As a result, the effect of Ba on soil-grown plant Ba-containing still needs to be investigated further. However, it was hard to say that Ba, which has a high variability rate according to years, can be a very good biomonitor. It is foreseen that, if possible, a clearer conclusion can be reached with the analysis of the soil data of the analyzed years. Despite this, it is thought that the increase in specific years is the precipitation of pollutants by atmospheric deposition. However, detailed scientific data on how elements are physiologically incorporated into tree rings are still needed to draw precise conclusions from temporal trends in tree ring element content.

References

Abacioglu E, Akarsu H, Genç ÇÖ, Öztürk A. 2019. Changes in Some Heavy Metal Concentratıons Due to Organ and Traffic Density in Tilia tomentosa. Turkish Journal of Agriculture-Food Science and Technology, 7(12), 2275-2281. https://doi.org/10.24925/turjaf.v7i12.2275-2281.3043

Aziz HA, Ghazali MF, Hung YT, Wang LK. 2017. Toxicity, Source, and Control of Barium in the Environment. In Handbook of Advanced Industrial and Hazardous Wastes Management (pp. 463-482). CRC Press.

Balouet JC, Smith KT, Vroblesky D, Oudijk G. 2009. Use of dendrochronology and dendrochemistry in environmental forensics: does it meet the Daubert criteria?. Environmental Forensics, 10(4), 268-276. https://doi.org/10.1080/15275920903347545

Bardule A, Bertins M, Busa L, Lazdina D, Viksna A, Tvrdonova M, Vaculovic T. 2020. Variation of major elements and heavy metals occurrence in hybrid aspen (Populus tremuloides Michx.× P. tremula L.) tree rings in marginal land. iForest-Biogeosciences and Forestry, 13(1), 24. https://doi.org/10.3832/ifor2869-012

Boev I, & Lepitkova S. 2021. Barium in airconditioner filters in the city of Skopje (Republic of North Macedonia). Geologica Macedonica, special issue, (5), 253-266.

Böttcher ME, Neubert N, Von Allmen K, Samankassou E, Nägler TF. 2018. Barium isotope fractionation during the experimental transformation of aragonite to witherite and of gypsum to barite, and the effect of ion (de) solvation. Isotopes in environmental and health studies, 54(3), 324-335. https://doi.org/10.1080/10256016.2018.1430692

Çetin M, Şevik H, Türkyılmaz A, Işınkaralar K. 2021. Using Abies's Needles as Biomonitors of Recent Heavy Metal Accumulation. Kastamonu University Journal of Engineering and Sciences, 7(1),1-6. Retrieved from https://dergipark.org.tr/en/pub/kastamonujes/issue/63105/892118

Cravotta III CA. 2008. Dissolved metals and associated constituents in abandoned coal-mine discharges, Pennsylvania, USA. Part 2: Geochemical controls on constituent concentrations. Applied Geochemistry, 23(2), 203-226. https://doi.org/10.1016/j.apgeochem.2007.10.003

Frati L, Brunialti G, Loppi S. 2005. Problems related to lichen transplants to monitor trace element deposition in repeated surveys: a case study from central Italy. Journal of Atmospheric Chemistry, 52(3), 221-230. https://doi.org/10.1007/s10874-005-3483-5

Ghoma WEO, Sevik H, Isinkaralar K. 2022. Using indoor plants as biomonitors for detection of toxic metals by tobacco smoke. Air Quality, Atmosphere & Health, https://doi.org/10.1007/s11869-021-01146-z.

Gietl JK, Lawrence R, Thorpe AJ, Harrison RM. 2010. Identification of brake wear particles and derivation of a quantitative tracer for brake dust at a major road. Atmospheric Environment, 44(2), 141-146. https://doi.org/10.1016/j.atmosenv.2009.10.016

Goddard SL, Williams KR, Robins C, Brown RJC. 2019. Determination of antimony and barium in UK air quality samples as indicators of non-exhaust traffic emissions. Environmental monitoring and assessment, 191(11), 1-12. https://doi.org/10.1007/s10661-019-7774-8

Harrison RM, Jones AM, Gietl J, Yin J, Green DC. 2012. Estimation of the contributions of brake dust, tire wear, and resuspension to nonexhaust traffic particles derived from atmospheric measurements. Environmental Science & Technology, 46, 6523–6529. https://doi.org/10.1021/es300894r

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.

Isinkaralar K, Gullu G, Turkyilmaz A. 2022. Experimental study of formaldehyde and BTEX adsorption onto activated carbon from lignocellulosic biomass. Biomass Conversion and Biorefinery, 1-11. https://doi.org/10.1007/s13399-021-02287-y

Isinkaralar O, Isinkaralar K, Ekizler A, Ilkdogan C. 2017. Changes in the amounts of CO2 and particulate matter in Kastamonu Province depending on weather conditions and locations. Journal of Chemical, Biological and Physical Sciences, 7(3), 643-650. https://doi.org/10.24214/jcbps.D.7.3.64350

Isinkaralar O, Tonuk GU, Isinkaralar K, Yilmaz D. 2021. An analysis on sustainability assessment at neighborhood scale. Social, Humanities and Administrative Sciences, Education Press, First Edition, Konya, pp: 517-531.

Işınkaralar K, Erdem R. 2021. Changes of Calcium accumulation in some trees in Kocaeli. Kastamonu University Journal of Engineering and Sciences, 7(2), 148-154.

Işınkaralar, K. 2020. Removal of Formaldehyde and BTEX in Indoor Air Using Activated Carbon Produced from Horse Chestnut (*Aesculus Hippocastanum* L.) Shell. PhD Dissertation. Graduate School of Science and Engineering, Hacettepe University, Ankara, Türkiye.

Işınkaralar, Ö. Varol, C. 2021. Kent Merkezlerinde Ticaret Birimlerin Mekânsal Örüntüsü Üzerine Bir Değerlendirme: Kastamonu Örneği, Journal of Architectural Sciences and Applications, 6 (2), 396-403 . DOI: 10.30785/mbud.927529

Jabłońska M, Kramarczyk M, Smieja-Król B, Janeczek J. 2016. Barium concentration in cast roe deer antlers related to air pollution caused by burning of barium-enriched coals in southern Poland. Environmental Science and Pollution Research, 23(6), 5978-5982. DOI 10.1007/s11356-016-6154-y

Jacob JM, Karthik C, Saratale RG, Kumar SS, Prabakar D, Kadirvelu K, Pugazhendhi A. 2018. Biological approaches to tackle heavy metal pollution: a survey of literature. Journal of environmental management, 217, 56-70. https://doi.org/10.1016/j.jenvman.2018.03.077

Jeddi K, Fatnassi M, Chaieb M, Siddique KH. 2021. Tree species as a biomonitor of metal pollution in arid Mediterranean environments: case for arid southern Tunisia. Environmental Science and Pollution Research, 28(22), 28598-28605. https://doi.org/10.1007/s11356-021-12788-y

Jing X, Shen X, Song H, Song F. 2011. Magnetic and dielectric properties of barium ferrite fibers/poly (vinylidene fluoride) composite films. Journal of Polymer Research, 18(6), 2017-2021. https://doi.org/10.1007/s10965-011-9610-x

Karacocuk T, Sevik H, Isinkaralar K, Turkyilmaz A and Cetin M. 2021. The change of Cr and Mn concentrations in selected plants in Samsun city center depending on traffic density. Landscape and Ecological Engineering, 1-9. https://doi.org/10.1007/s11355-021-00483-6

Kirchner P, Biondi F, Edwards R, McConnell JR. 2008. Variability of trace metal concentrations in Jeffrey pine (Pinus jeffreyi) tree rings from the Tahoe Basin, California, USA. Journal of forest research, 13(6), 347-356. https://doi.org/10.1007/s10310-008-0093-5

Koç I. 2021. Using Cedrus atlantica's annual rings as a biomonitor in observing the changes of Ni and Co concentrations in the atmosphere. Environ Sci Pollut Res.

Kravchenko J, Darrah TH, Miller RK, Lyerly HK, Vengosh A. 2014. A review of the health impacts of barium from natural and anthropogenic exposure. Environmental geochemistry and health, 36(4), 797-814. DOI 10.1007/s10653-014-9622-7

Kurnaz A, Mutlu E, Uncumusaoğlu AA. 2016. Determination of water quality parameters and heavy metal content in surface water of Çiğdem Pond (Kastamonu/Turkey). Turkish Journal of Agriculture-Food Science and Technology, 4(10), 907-913. https://doi.org/10.24925/turjaf.v4i10.907-913.942

Landreau M, You H, Stahl DA, Winkler MK. 2021. Immobilization of active ammonia-oxidizing archaea in hydrogel beads. npj Clean Water, 4(1), 1-8. https://doi.org/10.1038/s41545-021-00134-1

Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. 2020. Environmental and health impacts of air pollution: a review. Frontiers in public health, 8, 14. https://doi.org/10.3389/fpubh.2020.00014

Maresca V, Sorbo S, Loppi S, Funaro F, Del Prete D, Basile A. 2020. Biological effects from environmental pollution by toxic metals in the "land of fires"(Italy) assessed using the biomonitor species Lunularia cruciata L.(Dum). Environmental Pollution, 265, 115000. https://doi.org/10.1016/j.envpol.2020.115000

Monaci F, Bargagli R. 1997. Barium and other trace metals as indicators of vehicle emissions. Water, Air, and Soil Pollution, 100(1), 89-98. https://doi.org/10.1023/A:1018318427017

Mutlu E. 2021. Determination of Seasonal Variations of Heavy Metals and Physicochemical Parameters In Kıldır Pond (Yıldızeli-Sivas). Fresenius Environmental Bulletin, 30(6):5573-5580.

Nagaraju A, Karimulla S. 2002. Accumulation of elements in plants and soils in and around Nellore mica Belt, Andhra Pradesh, India–a biogeochemical study. Environmental Geology, 41(7), 852-860.

Oliva SR, Rautio P. 2004. Could ornamental plants serve as passive biomonitors in urban areas?. *Journal of Atmospheric Chemistry*, *49*(1-3), 137-148.

Önaç AK, Sütçüoğlu GG. 2021. Effect of urban change on place attachment: evidence from two locations from a city in Turkey with similar historical landscape values. Arabian Journal of Geosciences, 14(11), 1-17. https://doi.org/10.1007/s12517-021-07318-6

Padilla KL, Anderson KA. 2002. Trace element concentration in tree-rings biomonitoring centuries of environmental change. Chemosphere, 49(6), 575-585. https://doi.org/10.1016/S0045-6535(02)00402-2

Peana M, Medici S, Dadar M, Zoroddu MA, Pelucelli A, Chasapis CT, Bjørklund G. 2021. Environmental barium: potential exposure and health-hazards. Archives of Toxicology, 1-8. https://doi.org/10.1007/s00204-021-03049-5

Rye RO. 2005. A review of the stable-isotope geochemistry of sulfate minerals in selected igneous environments and related hydrothermal systems. Chemical Geology, 215(1-4), 5-36.

Rakib M, Jahan R, Jolly YN, Dioses-Salinas DC, Pizarro-Ortega CI, De-la-Torre GE, ... Bradley DA. 2021. Macroalgae in biomonitoring of metal pollution in the Bay of Bengal coastal waters of Cox's Bazar and surrounding areas. Scientific reports, 11(1), 1-13. https://doi.org/10.1038/s41598-021-99750-7

Savas DS, Sevik H, Isinkaralar K, Turkyilmaz A and Cetin M. 2021. The potential of using Cedrus atlantica as a biomonitor in the concentrations of Cr and Mn. Environmental Science and Pollution Research, 1-8. https://doi.org/10.1007/s11356-021-14826-1

Schroeder HA, Tipton IH, Nason AP. 1972. Trace metals in man: strontium and barium. Journal of chronic diseases, 25(9), 491-517. https://doi.org/10.1016/0021-9681(72)90150-6

Sert EB, Turkmen M and Cetin M. 2019. Heavy metal accumulation in rosemary leaves and stems exposed to traffic-related pollution near Adana-İskenderun Highway (Hatay, Turkey). Environmental Monitoring and Assessment, 191(9), 1-12. https://doi.org/10.1007/s10661-019-7714-7

Sevik H, Isinkaralar K and Isinkaralar O. 2018. Indoor Air Quality in Hospitals: The Case of Kastamonu Turkey, Journal of Chemical, Biological and Physical Sciences; Section D, 9(1), 067-073. https://doi.org/10.24214/jcbps.D.9.1.06773

Sevik H, Cetin M, Ozel HB, Pinar B. 2019. Determining toxic metal concentration changes in landscaping plants based on some factors. Air Quality, Atmosphere Health, 12 (8), 983-991. https://doi.org/10.1007/s11869-019-00717-5

Şevik H. 2021. The Variation of Chrome Consantration in Some Landscape Plants Due to Species, Organ and Traffic Density. Turkish Journal of Agriculture-Food Science and Technology, 9(3), 595-600. https://doi.org/10.24925/ turjaf.v9i3.595-600.4113

Şuţan NA, Soare LC, Mutlu E, Dobre R, Yanik T., Şuţan C. 2020. Water Qualıty Assessment Through Cytogenotoxıc Parameters – A Case Study of Karaçomak Rıver, Turkey. Current Trends in Natural Sciences, 9(17):23-30.

Turkyilmaz A, Cetin M, Sevik H, Isinkaralar K and Saleh EAA (2020) Variation of heavy metal accumulation in certain landscaping plants due to traffic density. Environment, Development and Sustainability, 22 (3), 2385-2398. https://doi.org/10.1007/s10668-018-0296-7

Turkyilmaz A, Sevik H, Isinkaralar K and Cetin M. 2018. Using Acer platanoides annual rings to monitor the amount 520 of heavy metals accumulated in air. Environ Monit Assess 190:578. https://doi.org/10.1007/s10661-018-521 6956-0

Turkyilmaz A, Sevik H, Isinkaralar K and Cetin M. 2019. Use of tree rings as a bioindicator to observe atmospheric heavy metal deposition, Environmental Science and Pollution Research, 26 (5), 5122-5130. https://doi.org/10.1007/s11356-018-3962-2

Tokatli C, Mutlu E, Arslan N. 2021. Assessment of the potentially toxic element contamination in water of Şehriban Stream (Black Sea Region, Turkey) by using statistical and ecological indicators. *Water Environment Research*. DOI: 10.1002/wer.1576

Usman K, Al-Ghouti MA, Abu-Dieyeh MH. 2019. The assessment of cadmium, chromium, copper, and nickel tolerance and bioaccumulation by shrub plant Tetraena qataranse. Scientific reports, 9(1), 1-11. https://doi.org/10.1038/s41598-019-42029-9

Wei Z, Van Le Q, Peng W, Yang Y, Yang H, Gu H, ... Sonne C. 2021. A review on phytoremediation of contaminants in air, water and soil. Journal of hazardous materials, 403, 123658. https://doi.org/10.1016/j.jhazmat.2020.123658

Vergel K, Zinicovscaia I, Yushin N, Frontasyeva MV. 2019. Heavy metal atmospheric deposition study in Moscow region, Russia. Bulletin of environmental contamination and toxicology, 103(3), 435-440. https://doi.org/10.1007/s00128-019-02672-4

Yang H, Wang F, Yu J, Huang K, Zhang H, Fu Z. 2021. An improved weighted index for the assessment of heavy metal pollution in soils in Zhejiang, China. Environmental Research, 192, 110246. https://doi.org/10.1016/ j.envres.2020.110246

Yalçın M, Çimrin KM. 2019. Determination of molybdenum contents and relation of some heavy metals in the soil of meadow-pasture terraces between Kırıkhan-Reyhanlı. Turkish Journal of Agriculture-Food Science and Technology, 7(1), 13-21. https://doi.org/10.24925/ turjaf.v7i1.13-21.1997

Yılmaz D, Işınkaralar Ö. 2021a. Climate Action Plans Under Climate-Resilient Urban Policies . Kastamonu University Journal of Engineering and Sciences, 7(2), 140-147.Retrieved from https:// dergipark.org.tr /tr/pub/ kastamonujes/ issue/ 66389/ 1014599

Yılmaz D, Işınkaralar Ö. 2021b. How Can Natural Environment Scoring Tool (Nest) be Adapted for Urban Parks? . Kastamonu University Journal of Engineering and Sciences,7(2),127-139. Retrieved from https:// dergipark.org.tr/tr/pub/ kastamonujes/issue/66389/1013821