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Using Abies's Needles as Biomonitors of Recent Heavy Metal Accumulation

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ABSTRACT

In our modern age, heavy metals are one of the major causes of air pollution, which is one of the biggest problems facing the globe. This is due to the fact that heavy metals can stay in nature for a long time without dissolving, and that the concentration of these metals is ever increasing. Heavy metals tend to bioaccumulate and often present serious health hazards even at low concentrations. Therefore, the determination and monitoring of heavy metal concentrations is of great importance in terms of identifying risky areas and the levels of risk involved. In this study, the usability of fir organs in monitoring the change of the element of Barium (Ba), which is one of the very important elements for human and environmental health, was investigated. The change of Ba concentration in fir needles, organs and shells due to organ age and traffic density was evaluated. As a result of the study, it was determined that the accumulation of Ba concentration in fir organs is quite different, and there are great differences in terms of Ba concentration between organs of the same age, between organs of different ages and between organs of individuals grown at different traffic densities. This situation can be interpreted as fir organs being good biomonitors in examining Ba concentrations.

Anahtar Kelimeler:
Ağır metal,
Barium,
Abies,
Biomonitor.

ÖZ

Modern çağımızda ağır metaller, dünyanın karşı karşıya olduğu en büyük sorunlardan biri olan hava kirliliğinin en önemli nedenlerinden biridir. Bunun nedeni, ağır metallerin doğada uzun süre çözünmeden kalabilmeleri ve bu metallerin konsantrasyonlarının giderek artmasıdır. Ağır metaller biyolojik olarak birikme eğilimindedir ve düşük konsantrasyonlarda bile genellikle ciddi sağlık tehlikeleri sunar. Bu nedenle, ağır metal konsantrasyonlarının belirlenmesi ve izlenmesi, riskli alanların ve ilgili risk seviyelerinin belirlenmesi açısından büyük önem taşımaktadır. Bu çalışmada insan ve çevre sağlığı için çok önemli unsurlardan biri olan Barium (Ba) elementinin değişiminin izlenmesinde köknar organlarının kullanılabilirliği araştırılmıştır. Göknar iğneleri, organları ve kabuklarındaki Ba konsantrasyonunun organ yaşı ve trafik yoğunluğuna bağlı olarak değişimi değerlendirildi. Araştırma sonucunda köknar organlarında Ba konsantrasyonu birikiminin oldukça farklı olduğu, aynı yaştaki organlar arasında, farklı yaşlardaki organlar arasında ve bireylerin organları arasında Ba konsantrasyonu açısından büyük farklılıklar olduğu tespit edilmiştir. farklı trafik yoğunluklarında büyümüştür. Bu durum, köknar organlarının Ba konsantrasyonlarının incelenmesinde iyi biyometreler olduğu şeklinde yorumlanabilir.

1. Introduction

In addition to the increase in the world population in recent years, the increasing population in urban centers has brought many problems [1-4]. In this process, air pollution arising directly or indirectly due to human activities in city centers is one of the most important problems [5-6]. So much so that it is estimated that 1 out of 8 people worldwide die due to reasons related to air pollution. Air pollution manifests itself more in urban areas where the population density is high, and according to the World Health Organization data, it was reported that 92% of the world population lived in regions with low air quality in 2014 [7].

HMs tend to bioaccumulate in living bodies, and some of them can be toxic even at low concentrations. They are not easily degradable nor dissolvable in nature, and even metals necessary for living organisms such as Mn, Zn, Cr, Cu, Fe, Ni can cause harmful effects at high levels [8-10].

The most important heavy metals are mostly caused by industry and traffic [11]. Many studies have been conducted to monitor the concentrations of heavy metals due to their effects on humans and the environment. However, the studies conducted mostly focus on heavy metals such as Hg, Cd, Cr, Ni, Co and Pb [12-15]. Barium (Ba), which is largely neglected in studies on heavy metals, plays a key role in the production of many products in the industry. In the production of Zn, Pb and Ag, brake pads, rubber, ink, paint, rat poison, radio vacuum tube and lamps, medicine, optical glass, machine oils, detergents, photo papers, waxes, glues, drilling applications, paper coatings, batteries, plastic and textile products, oil paints, special glasses, fireworks and ceramic glazes, barium, isotopes, compounds and alloys are used. However, Ba is one of the most dangerous heavy metals and all of the Barium compounds are toxic [16]. Therefore, it is very important to monitor the change in Ba concentration in the air.

2. Material and Method

The study was carried out on the goose fir (Abies nordmanniana (Steven) Spach subsp. Equi-trojani (Asch. & Sint. Ex Boiss). In the scope of the study, fir individuals were determined primarily in areas with heavy traffic, low density and no traffic, and samples of these individuals' side branches. Organs were divided into ages first, then into needles, shell and wood. and the amount of heavy metals were determined by ICP Analysis at the Research Center.

3. Results

When the Table 1 values are examined, it is seen that the Ba concentration varies between 1100.67 ppb and 7835.67 ppb in the needles, 1132.00 ppb and 5166.33 ppb in the woods and 1655.00 ppb and 5204.33 ppb in the shells depending on the age in the areas where there is no traffic. Ba concentrations in areas with low traffic range from 938.00 ppb to 3714.33 ppb in needles, 2494.00 ppb to 6507.67 ppb in woods, and 1757.00 ppb and 6189.33 ppb in shells. In areas with high traffic, it ranges from 1414.00 ppb to 4010.00 ppb for the needles, 670.33 ppb to 6504.00 ppb for the wood, and 2012.00 ppb to 8565.00 ppb for the shells.

Table 1. Change of Ba (ppb) Element Dependent on Organ, Organ Age and Traffic Density

Organ	Needle Age	Density of Traffic			F Value
		Unavailable	Low intensive	Intense	
Needle	1	2832,33 Ce	1980,67 Bd	1414,00 Aa	17010,538***
	2	7835,67 Cg	1892,00 Bc	1590,67 Ab	93125,974***
	3	2825,00 Ce	2763,00 Be	1766,67 Ac	7625,837***
	4	2487,67 Ad	3714,33 Ch	2948,00 Bg	11971,687***
	5	1100,67 Aa	3486,33 Bg	4010,00 Ch	20919,567***
	6	1907,67 Ab	2830,00 Cf	2735,00 Be	10279,466***
	7	2338,67 Bc	938,00 Aa	2901,67 Cf	59884,388***
	8	4071,00 Cf	1296,33 Ab	2563,00 Bd	28975,404***
	F Value	56628,204***	16218,331***	20002,281***	
wood	1	1132,00 Ba	3348,67 Cc	998,00 Ac	66091,860***
	2	1291,67 Bb	3017,67 Cb	1226,00 Ad	15596,284***
	3	2026,00 Bd	3985,00 Cf	670,33 Aa	67672,723***
	4	1530,33 Ac	3568,67 Bd	6504,00 Ch	42186,341***
	5	2469,33 Bf	6507,67 Ch	788,00 Ab	33001,870***
	6	2200,00 Ae	3772,33 Be	4701,67 Cg	37608,039***
	7	5166,33 Bh	4945,00 Cg	2719,67 Af	63962,142***
	8	2500,33 Bg	2494,00 Aa	2539,67 Ce	14,211**
	F Value	44056,942***	10942,095***	67780,981***	
Bark	1	1655,00 Aa	3707,00 Ce	2012,00 Ba	23669,074***
	2	3049,00 Bd	3482,00 Cd	1994,00 Aa	24407,347***
	3	5204,33 Bg	1757,00 Aa	8565,00 Cf	14618,125***
	4	3004,33 Bc	6189,33 Ch	2016,00 Aa	32193,488***
	5	3264,33 Be	4567,33 Cf	2899,00 Ab	5413,389***
	6	3535,67 Bf	2530,67 Ac	4537,33 Ce	30100,028***
	7	2946,00 Bb	1965,67 Ab	3531,67 Cd	73495,074***
	8	3001,00 Ac	4654,33 Cg	3217,00 Bc	8128,000***
	F Value	5220,110***	26981,117***	22000,589***	

Uppercase letters show horizontal direction, however lowercase letters indicate vertical directions.
*Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level, *ns* not significant.

When the Table values are examined, no significant relationship between Ba concentration and organ ages can be observed. Similarly, it is not possible to say that the change in Ba concentration at different ages of different organs is also related to traffic density. In the same traffic density, there may be a 10-fold difference between organs of different ages in Ba concentrations, as well as more than 8-fold differences between samples taken from different traffic densities of organs of the same age.

4. Discussions

The results of the study reveal that the concentration of Ba varies considerably in terms of organ, organ age and traffic density. However, it is not possible to say that the change in Ba concentration is proportional, depending on both organ age and traffic density. This situation can be interpreted as that the passage of Ba concentration between organs is at a very limited level. This result shows that the fir subject to the study is a good biomonitor for monitoring the change in Ba concentration.

Heavy metals, many of them are extremely dangerous and harmful elements for human and environmental health, and monitoring the change of their concentrations in the air is of great importance. Although many studies have been carried out on the monitoring of heavy metal concentrations to date, the studies have mostly focused on elements such as Pb, Cd, Ni, Co, Cr [17-21]. However, Ba, which is the subject of this study, is both widely used in many areas and an extremely toxic element [16]. However, it has been addressed in quite a few studies to date.

The results of the study show that the accumulation of Ba concentration in different organs is quite different. In studies carried out so far, it has been determined that, in general, heavy metal concentrations vary significantly on organ basis. It is known that there can be a significant difference between the heavy metal concentrations in the same organs of different species grown in similar environments. For example, Saleh [22] stated that the difference between species is more than 5 times in Cu and more than 24 times in Cd. Akarsu [23] generally states that there is a very high difference between the outer crust and the inner crust, this difference is 10 times more in Mn, and the Mn concentration value obtained in the outer crust is 50 times that of wood. Similarly, it is stated that there may be significant differences between different ages of the same organ [24-25].

In many studies, it has been determined that different heavy metals are more concentrated by different plants and different organs of plants [11,26]. This situation is mostly shaped by the anatomical structure of the plant and the interaction between the plant and heavy metals. Heavy metal uptake from leaves varies depending on factors such as physical and chemical properties of the metals, forms, morphology of organs, surface area, surface texture, habitus of the plant, exposure time to heavy metals, environmental conditions and gas exchange [11,3,4,27,28].

The accumulation of heavy metals in the plant is closely related to environmental conditions. Heavy metals can be carried far away from their source with the help of wind. Apart from this, environmental conditions directly affect plant metabolism and in this process, the entry of heavy metals into the plant structure also differs. Additionally, it is stated that there is a significant relationship between the entry of heavy metals into the plant structure, especially air humidity and rainfall [11,23,29].

Studies show that some of the heavy metal concentration in plants varies depending on factors such as plant species, organ, washing status, traffic density [11,30,31]. However, apart from these factors, there are also factors that may affect the change of heavy metal concentration in plants. For example, different levels of heavy metal concentrations can be expected in the subspecies, forms, varieties and origins of the same plant. Because the studies conducted reveal that many phenological, morphological and anatomical structures change depending on these features. In this case, it is inevitable that plant metabolism will also change and this will affect heavy metal absorption [25,32-40].

5. Suggestions

Heavy metal accumulation in plants is shaped under the interaction of many factors and these factors, from plant genetic structure to plant phenology, from the structure of heavy metal to air conditions. The mechanisms that shape heavy metal accumulation in plants have not been fully resolved. Therefore, studies on the subject should be continued in detail.

Competing Interest / Conflict of Interest

The authors declare that they have no competing interests.

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Author contribution

We declare that all Authors equally contribute.

4. References

[1] Bayraktar, O. Y. (2020). Use of geosynthetics in road construction. Kastamonu University Journal of Engineering and Sciences, 6(2): 107-113

[2] Kilicoglu, C., Cetin, M., Aricak, B., Sevik, H. (2021) Integrating multicriteria decision-making analysis for a GIS-based settlement area in the district of Atakum, Samsun, Turkey. Theor Appl Climatol. 143, 379–388. https://doi.org/10.1007/s00704-020-03439-2

[3] Sert, E. B., Turkmen, M., & 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), 553.

[4] Sert, E. B., Kaya, E., Adiguzel, F., Cetin, M., Gungor, S., Zeren Cetin, I. & Dinc, Y. (2021). Effect of the surface temperature of surface materials on thermal comfort: a case study of Iskenderun (Hatay, Turkey). Theoretical and Applied Climatology, 1-11.

[5] Cetin, M., Onac, A. K., Sevik, H., & Sen, B. (2019). Temporal and regional change of some air pollution parameters in Bursa. Air Quality, Atmosphere & Health, 12(3), 311-316.

[6] Aricak, B., Cetin, M., Erdem, R., Sevik, H., & Cometen, H. (2020). The usability of Scotch pine (Pinus sylvestris) as a biomonitor for traffic-originated heavy metal concentrations in Turkey. Polish Journal of Environmental Studies, 29 (2): 1051-1057

[7] Elsunousi, A.A.M. (2020). Temporal and Spatial Variation of Air Quality in Misurata, Kastamonu University Graduate School of Natural and Applied Sciences. MsC Thesis. 100 p.

[8] Turkyilmaz, A., Sevik, H., Isinkaralar, K., & Cetin, M. (2018a). Using Acer platanoides annual rings to monitor the amount of heavy metals accumulated in air. Environ Monit Assess 190:578.

[9] Sevik, H., Cetin, M., Ozel, H. B., & Pinar, B. (2019a). Determining toxic metal concentration changes in landscaping plants based on some factors. Air Quality, Atmosphere & Health, 12 (8), 983-991.

[10] Aricak, B., Cetin, M., Erdem, R., Sevik, H., & Cometen, H. (2019). The change of some heavy metal concentrations in Scotch pine (Pinus sylvestris) depending on traffic density, organelle and washing. Applied Ecology and Environmental Research, 17 (3), 6723-6734.

[11] Shahid, M., Dumat, C., Khalid, S., Schreck, E., Xiong, T., & Niazi, N. K. (2017). Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake. Journal of hazardous materials, 325, 36-58.

[12] Sevik, H., Cetin, M., Ozturk, A., Ozel, H. B., & Pinar, B. (2019b). Changes in Pb, Cr and Cu concentrations in some bioindicators depending on traffic density on the basis of species and organs. Applied Ecology and Environmental Research, 17 (6), 12843-12857.

[13] Sevik, H., Ozel, H. B., Cetin, M., Özel, H. U., & Erdem, T. (2019c). Determination of changes in heavy metal accumulation depending on plant species, plant organism, and traffic density in some landscape plants. Air Quality, Atmosphere & Health, 12 (2), 189-195.

[14] Turkyilmaz, A., Cetin, M., Sevik, H., Isinkaralar, K., & Saleh, E. A. A. (2020). Variation of heavy metal accumulation in certain landscaping plants due to traffic density. Environment, Development and Sustainability, 22 (3), 2385-2398.

[15] Shammi, S. A., Salam, A., & Khan, M. A. H. (2021). Assessment of heavy metal pollution in the agricultural soils, plants, and in the atmospheric particulate matter of a suburban industrial region in Dhaka, Bangladesh. Environmental Monitoring and Assessment, 193(2), 1-12.

[16] Aktaş, S. (2019) Gümüş Endüstrisi Cevher ve Atıklarında Bazı Elementlerin ICP-OES ile Tayini. Kütahya Dumlupınar Üniversitesi Fen Bilimleri Enstitüsü Kimya Anabilim Dalı Yüksek Lisans Tezi. 82 s.

[17] Turkyilmaz, A., Sevik, H., & Cetin, M. (2018b). The use of perennial needles as bio-monitors for recently accumulated heavy metals. Landsc Ecol Eng 14 (1):115–120.

[18] Turkyilmaz, A., Sevik, H., Cetin, M., & Ahmaida Saleh E. A. (2018c). Changes in heavy metal accumulation depending on traffic density in some landscape plants. Pol J Environ Stud 27 (5):2277–2284.

[19] Alaqouri, H. A. A., Genc, C. O., Aricak, B., Kuzmina, N., Menshikov, S., & Cetin, M. (2020a). The possibility of using Scots pine needles as biomonitor in determination of heavy metal accumulation. Environmental Science and Pollution Research International.

[20] Alaqouri, H. A. A., Ozer Genc, C., Aricak, B., Kuzmina, N., Menshikov, S., Cetin, M. (2020b) The Possibility of Using Scots Pine (Pinus sylvestris L.) Needles as Biomonitor in the Determination of Heavy Metal Accumulation Applied Ecology and Environmental Research, 18 (2):3713-3727.

[21] Giannakoula, A., Therios, I., & Chatzissavvidis, C. (2021). Effect of Lead and Copper on Photosynthetic Apparatus in Citrus (Citrus aurantium L.) Plants. The Role of Antioxidants in Oxidative Damage as a Response to Heavy Metal Stress. Plants, 10(1), 155.

[22] Saleh, E.A.A. (2018). Determination of Heavy Metal Accumulation in Some Landscape Plants, Kastamonu University Institute of Science Department of Forest Engineering, Phd Thesis, 123 pages

[23] Akarsu, H. (2019). Determination of Heavy Metal Accumulation in Atmosphere by Being Aid of Annual Rings, Kastamonu University Graduate School of Natural and Applied Sciences Department of Sustainable Agriculture and Natural Plant Resources, MsC Thesis, 71 pages

[24] Turkyilmaz, A., Sevik H., Isinkaralar K, & 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.

[25] Cetin, M., Sevik, H., & Cobanoglu, O. (2020). Ca, Cu, and Li in washed and unwashed specimens of needles, bark, and branches of the blue spruce (Picea pungens) in the city of Ankara. Environmental Science and Pollution Research, 1-10.

[26] Sevik, H. (2020). Change of Cu Concentration in Some Edible Landscape Plants Grown in Ankara City Center. Kastamonu Üniversitesi Mühendislik ve Fen Bilimleri Dergisi. 6 (1), 1-7.

[27] Sevik, H., Cetin, M., Ozel, H. B., Akarsu, H., & Zeren Cetin, I. (2020a). Analyzing of usability of tree-rings as biomonitors for monitoring heavy metal accumulation in the atmosphere in urban area: a case study of cedar tree (Cedrus sp.). Environmental Monitoring and Assessment, 192 (1), 23.

[28] Sevik, H., Cetin, M., Ozel, H. B., Ozel, S., & Zeren Cetin, I. (2020b). Changes in heavy metal accumulation in some edible landscape plants depending on traffic density. Environmental Monitoring and Assessment, 192 (2), 78.

[29] Sevik, 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.

[30] Sevik, H., Cetin, M., Ozel, H. U., Ozel, H. B., Mossi, M. M. M., & Zeren Cetin, I. (2020c). Determination of Pb and Mg accumulation in some of the landscape plants in shrub forms. Environmental Science and Pollution Research, 27 (2), 2423-2431.

[31] Sevik, H., Cetin, M., Ozel, H. B., Erbek, A., & Cetin, I.Z. (2021). The effect of climate on leaf micromorphological characteristics in some broad-leaved species. Environment, Development and Sustainability, 23(4), 6395-6407.

[32] Cesur A, Zeren Cetin I, Abo Aisha AES, Alrabiti OBM, Aljama AMO, Jawed AA, Cetin M, Sevik H, Ozel HB (2021) The usability of Cupressus arizonica annual rings in monitoring the changes in heavy metal concentration in air. Environmental Science and Pollution Research, DOI: 10.1007/s11356-021-13166-4

[33] Ozel HB, Cetin M, Sevik H, Varol T, Isik B, Yaman B (2021) The effects of base station as an electromagnetic radiation source on flower and cone yield and germination percentage in Pinus brutia Ten. Biologia Futura (2021). https://doi.org/10.1007/s42977-021-00085-1

[34] Sevik, H., Cetin, M., Yigit, N., Aricak, B., Ozturk, S., Onac, A. K., & Kuscu, I. S. K. (2021). The effect of shadow conditions on stomatal characters of several plants used in landscape design. World Journal of Advanced Research and Reviews, 9(3), 109-115. DOI:10.30574/wjarr.2021.9.3.0086

[35] Varol T, Canturk U, Cetin M, Ozel HB, Sevik H (2021) Impacts of climate change scenarios on European ash tree (Fraxinus excelsior L.) in Turkey. Forest Ecology and Management. Forest Ecology and Management 491 (2021) 119199. DOI: 10.1016/j.foreco.2021.119199

[36] Koc, I. (2021). Using Cedrus atlantica's annual rings as a biomonitor in observing the changes of Ni and Co concentrations in the atmosphere. *Environmental Science and Pollution Research*, 1-7. DOI:10.1007/s11356-021-13272-3

[37] Isinkaralar, O., Isinkaralar, K., Ekizler, A. and 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.

[38] Sevik, H., Isinkaralar, O. and Isinkaralar, K. (2018). Indoor Air Quality in Hospitals: The Case of Kastamonu-Turkey. Journal of Chemical, Biological and Physical Sciences, 9(1), 67-73.

[39] Isinkaralar, K. (2020). Removal of Formaldehyde and BTEX in Indoor Air Using Activated Carbon Produced from Horse Chestnut (*Aesculus Hippocastanum* L.) Shell. Ph.D. Thesis Hacettepe University Institute of Science Department of Environmental Engineering. Ankara, Turkey.

[40] Savas, D. S., Sevik, H., Isinkaralar, K., Turkyilmaz, A., & Cetin, M. (2021). The potential of using Cedrus atlantica as a biomonitor in the concentrations of Cr and Mn. *Environmental Science and Pollution Research*, 1-8.