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ORIGINAL ARTICLE

Variation of Ba concentrations in some plants grown in Pakistan depending on traffic density

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Abstract

Today, one of the most important problems in the world is environmental and especially air pollution. Among the components of air pollution, especially heavy metals are of particular importance because they do not deteriorate and disappear easily in nature, can be toxic and carcinogenic to humans even at low concentrations, and bioaccumulate in living organisms. Therefore, it is extremely important to determine the heavy metal concentrations in the air. Barium (Ba), which has been largely neglected in studies on heavy metals, plays a key role in the production of many products in the industry. However, Ba is one of the most dangerous heavy metals and all barium compounds are toxic. This study was aimed to determine the accumulation of Ba concentration in some plants used extensively in Pakistan depending on traffic density. For this purpose, the variation of Ba concentrations in leaves and branches of *Ficus bengalensis*, *Ziziphus mauritiana*, *Conocarpus erectus*, and *Azadrechta indica* species depending on traffic density was determined. As a result of the study, it was determined that the most suitable species to be used for monitoring Ba concentration were *Azadrechta indica* leaves, and the most suitable organs were *Azadrechta indica* leaves.

Keywords Heavy metal · Pakistan · Barium · Ba · Traffic

1 Introduction

The world population has increased significantly in the last century, exceeding 7.9 billion [1], and it has concentrated in urban areas due to the developments in the industrial field [2–10]. Developments in the field of the industry have led to a significant increase in air pollution, especially in some regions, and air pollution has become one of the biggest problems in the world today. It is reported that 92% of the world's population lives in areas with low air quality and approximately 1 in 8 deaths are caused by air pollution [11–29].

Among the components of air pollution, heavy metals are of particular importance in terms of human and environmental health, because heavy metals tend to bioaccumulate in living bodies. Some of them can be toxic, carcinogenic, and deadly even at low concentrations. Although some are essential nutrients for living organisms, they are harmful at high levels. In addition, heavy metals do not easily deteriorate and disappear in nature [14–32]. In addition, heavy metals in the air can be much more dangerous by entering the human body directly through the respiratory tract [24–40].

Due to the effects of heavy metals on humans and the environment, many studies have been carried out to monitor the concentrations of heavy metals, especially in the air. However, the studies mostly focused on heavy metals such as Pb, Ni, Cd, Cr, and Co [41, 42]. Barium (Ba) is an element that plays a key role in the production of many products in the industry. In the production of Zn, Pb, and Ag, rubber, ink, brake pads, paint, rat poison, medicine, radio vacuum tube and lamps, machine oil, optical glass, photographic paper, detergents, wax, plastic and textile products, drilling applications, glue Barium, its isotopes, compounds, and alloys are used in paper coatings, batteries, the production of special glasses, the production of oil paints, the petroleum industry, fireworks, and ceramic glazes.

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However, Ba is one of the most dangerous heavy metals and all barium compounds are toxic [43]. Therefore, it is of great importance to monitor the change in Ba concentration in the air. However, Ba has generally been neglected in studies conducted so far, and a very limited number of studies have been carried out to monitor the change in Ba concentration in the air. In this study, the usability of some plants used extensively in Pakistan in monitoring the change of various Ba concentrations was evaluated.

2 Material and method

This study was aimed to determine the accumulation of Ba concentration in some plants used extensively in Pakistan depending on traffic density. For this purpose, leaf samples from four species were collected. *Ficus bengalensis* (Fb), *Ziziphus mauritiana* (Zm), *Conocarpus erectus* (Ce), and *Azadirechta indica* (Ai) were used in the study.

The study was conducted on individuals in heavy traffic (TRCOK), moderately heavy traffic (TRAZ), and almost no traffic (TRYOK) areas. To determine the effect of particulate matter on the branch and leaf samples taken from the individuals subject to the study, the washing process was carried out and the study was carried out on the washed organs (Yk) and non-washed organs (Ykm). Thus, measurements were made with 3 replications on 48 samples of 4 species, 3 traffic densities, 2 organs, and 2 items of washing.

The dried plant samples were ground into powder and weighed 0.5 g and placed in tubes designed for microwave. Ten milliliters of 65% HNO3 was added to the samples. The prepared samples were then burned in a microwave device at 280 PSI and 180 °C for 20 min. After the processes were completed, the tubes were removed from the microwave and left to cool. Deionized water was added to the cooled samples to make up to 50 ml. After the prepared samples were filtered through filter paper, they were read in the ICP-OES device at appropriate wavelengths. Ba concentrations were calculated by multiplying the obtained values with the dilution factor.

The obtained data were evaluated with the help of the SPSS package program, variance analysis was applied to the data, and homogeneous groups were obtained by applying the Duncan test to the groups that were statistically different at least 95% confidence level. The data obtained were simplified and interpreted by tabulating.

3 Results

The F value, error rate, mean values, and Duncan test results obtained as a result of the variance analysis regarding the variation of Ba concentrations depending on the type and traffic density are given in Table 1.

When the variation of Ba concentrations based on type and traffic density is examined, it is seen that the changes based on species in all traffic densities are statistically significant ($p < 0.001$). As a result of the Duncan test at all traffic densities, the values obtained in Zm and Ce types were in the first groups, and the values obtained in Ai were in the last groups.

It was determined that the variation of Ba concentrations on a species basis depending on traffic density was statistically significant ($p < 0.05$) only in Zm and Ai species. In both species, Ba concentration increases with traffic density. The F value, error rate, mean values, and Duncan test results obtained as a result of the variance analysis regarding the variation of Ba concentrations depending on the species, organ, washing status, and traffic density are given in Table 2.

When the table values are examined, it is seen that the change of Ba concentration based on organs in all traffic densities and based on traffic density in all organs is statistically significant at the 99.9% confidence level ($p < 0.001$). In TRYOK areas, the lowest values were obtained in Fb leaves washed with Zm branches; the highest values were obtained in unwashed Fb leaves and branches and unwashed Ai leaves. In TRAZ areas, the lowest values were obtained in washed Fb, Zm, and Ce branches; the highest values were obtained in unwashed Fb leaves and Ai leaves. In TRCOK areas, the lowest values were obtained in Ce leaves and washed Ce leaves, while the highest values were obtained in unwashed Fb leaves and Ai leaves. It is noteworthy that, in general, the values obtained in unwashed Fb and Ai leaves are among the highest in all three traffic densities. In addition, it is seen that the lowest values are obtained in TRYOK areas and the highest values in TRCOK areas in most of the organs.

4 Discussions

As a result of the study, it was determined that the changes in Ba concentrations based on species in all traffic densities were statistically significant ($p < 0.001$). As a result of the Duncan test at all traffic densities, the values obtained in Zm and Ce types were in the first groups, and the values

Table 1 Variation of Ba (ppb) concentrations by species and traffic density

TUR	TRYOK	TRAZ	TRCOK	F
Fb	2699.2 b	2341.0 b	3314.3 b	0.5 ns
Zm	445.7 Aa	1151.4 Aa	2779.8 Bab	20.8***
Ce	767.0 a	1240.0 a	1162.4 a	2.7 ns
Ai	2066.6 Ab	3341.7 ABc	3982.1 Bb	4.6*
F	12.0***	9.4***	4.4***	

Table 2 Variation of Ba (ppb) concentrations

Species	Organ	Washed	TRYOK	TRAZ	TRCOK	F value
Fb	Leaf	Yk	461.3 Ac	1547.1 Cf	984.2 Bb	1918.7***
		Ykm	5497.8 Bm	5148.6 Ak	7831.5 Cl	3142.6***
	Branch	Yk	2070.8 Cj	786.5 Ac	1071.5 Bc	17,344.9***
		Ykm	2766.8 Bk	1881.9 Ag	3370.1 Cg	9440.3***
Zm	Leaf	Yk	512.3 Ad	1329.2 Be	4143.8 Ch	125,820.9***
		Ykm	714.3 Ae	1865.7 Bg	4235.6 Ci	24,840.0***
	Branch	Yk	210.7 Aa	604.8 Bb	1387.3 Cd	31,808.9***
		Ykm	345.4 Ab	806.0 Bc	1352.4 Cd	40,739.3***
Ce	Leaf	Yk	519.1 Ad	1565.5 Cf	954.3 Bb	13,230.8***
		Ykm	1039.4 Ah	1911.3 Bh	2227.8 Cf	11,897.8***
	Branch	Yk	1005.8 Cg	508.6 Ba	497.6 Aa	23,611.2***
		Ykm	503.6 Ad	974.8 Bd	969.8 Bb	13,942.1***
Ai	Leaf	Yk	2065.4 Aj	3600.2 Bj	5842.3 Cj	177,552.4***
		Ykm	3353.6 Al	5331.1 Bl	6248.6 Ck	9413.8***
	Branch	Yk	922.2 Af	2529.6 Ci	2213.9 Bf	14,752.6***
		Ykm	1925.4 Bi	1905.8 Bh	1623.6 Ae	637.5***
F value			34,727,5***	42,648,9***	29,138.1***	

***$p < 0.001$. Yk, washed; Ykm, unwashed

obtained in Ai were in the last groups. It has been stated in many studies that the accumulation level of heavy metals in different species is at different levels [44–46], and the most important factor affecting heavy metal accumulation in plant species has been emphasized [42].

This situation is largely shaped by the anatomical structure of the plant and the mutual interaction of the plant and the heavy metal. Plant metabolism, like all phenotypic characters, depends on plant genetic structure [47–49], and environmental conditions [50–53] are shaped under their mutual interaction. Therefore, the stress level, which significantly affects plant metabolism [54–59], the genetic structure of the plant [60–62], hormone applications [63–65], cultural processes such as pruning and shading [66–68] and many factors affect the accumulation of elements in plants [69, 70]. In addition, the changing environment and soil structure due to human influence in urban areas and micro-ecological factors caused by human influence [71–73] affect the change of element concentration in plant organs.

Within the scope of the study, it was determined that there was a significant difference in Ba concentrations between plant organs. It is stated that besides the plant species, heavy metal concentrations in different organs of the same plant can vary significantly [74]. Heavy metal concentrations in different organs of plants grown in the same environment vary depending on factors such as the structure, morphology, surface area, surface texture, and size of the plant organ [75]. For example, plant leaves can absorb heavy metals in the air through stomata during air entry and exit, and in this case, the stomatal structure affects the uptake of heavy metals into the leaf structure. Similarly, the rough and cracked shell surface can facilitate the adhesion of heavy metals there [76, 77]. Therefore, the structure and characteristics of the organ can significantly affect heavy metal intake.

The results of the study generally show that Ba concentration increases with traffic density. Heavy metals can be emitted into the atmosphere from different sources. However, it is stated that the most important heavy metal sources are mines, industrial facilities, and traffic sources [78–81]. Therefore, it has been stated in various studies that heavy metal concentrations are higher in plants grown in regions close to heavy metal sources [82].

The entry of heavy metals into the plant body can be mainly through roots and leaves [40, 83]. However, it is not easy to determine the source of the elements determined in the plant, because these uptake pathways can work simultaneously [42]. Therefore, factors affecting soil and air composition also affect element concentrations in plants [84]. For example, air pollution in urban areas increases the concentration of heavy metals, many of which act as micronutrients, in the air [40, 58, 85]. Air pollution and anthropogenic factors in urban areas can also cause soil pollution [86, 87]. Therefore, since the soil is one of the important factors in the growth of plants [88–90], the concentrations of these elements are higher in plants grown in these areas [83, 91, 92]. As a result, the change of element concentration in plant organs is the result of a complex mechanism dependent on the interaction of many factors, and this mechanism has not been fully resolved yet [14, 32, 33, 91].

5 Conclusions

Heavy metals are elements that can be extremely dangerous and harmful to human and environmental health, and one of them, Ba, is an element that has a wide range of uses and is extremely poisonous. Therefore, it is extremely important to monitor the change in its concentration in the air during the process. However, very few studies have been carried out to monitor the change in Ba concentration. Therefore, it is recommended that studies on elements such as Ba, which are very harmful to human and environmental health, should be continued by diversifying and increasing.

Species that can be used in monitoring the change of heavy metals should be determined separately for each heavy metal. Among the species subject to this study, it was determined that the most suitable species to be used for monitoring Ba concentration was Ai, and the most suitable organ was Ai leaves. It is recommended to use this species and organ for monitoring Ba concentration.

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Author contribution MC and AAJ designed the study and performed the experiments; AAJ and MC performed the experiments, analyzed the data, and wrote the manuscript.

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Availability of data and materials The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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