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RESEARCH ARTICLE

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

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Abstract

The use of certain types of plants to determine the accumulation of HMs (heavy metals) has yielded quite consistent results in the research fields. Many researches have focused on particular types of HMs due to their common presence in the air (Pb, Cd, Ni, Co, Cr to name a few). However, it is equally as important to shed light on other types of HMs and the scale of their existence in our atmosphere, hence this paper. Blue spruce (*Picea pungens*) tree organs were used in an experiment to calculate the recent concentration of HMs. The research concentrates on Ca, Cu, and Li elements in the washed and unwashed needles, branches, and barks, and these organs were evaluated depending on the organ age. The study results showed that the concentration of the elements subjected to the research changed depending on the organ, washing status and organ age, and that the lowest concentrations of Ca and Cu elements were obtained in the barks in general. In relation to the organ age, it was found that there was an increase in the concentration of Ca with age, and that the concentration of Li element was inversely proportional to age.

Keywords Bio indicator · Ca · Cu · Li · Organ · *Picea pungens*

Introduction

Population growth is one of the most prominent problems of the world today. The world total population, which was around 717 million in 1750, exceeded 1.5 billion in 1900 and reached 6 billion in 2000. It is estimated that the world population will reach 8.5 billion by 2030 (Gultekin 2020). With the increase in the world population, industrial activities have increased at the same rate, and parallel to these activities, increasing air pollution has reached dangerous levels to the environment (Kaya 2009; Yucedag and Kaya 2016; Yucedag and Kaya 2017; Cetin 2019; Cetin et al. 2019a; Kaya et al. 2019; Adiguzel et al. 2020). Increasing air pollution causes destruction of nature, pollution of air, water and soil, and deterioration to the ecological balance (Ozel et al. 2019; Bayraktar et al. 2019; Bayraktar 2019). Air pollution also significantly affects human health. So much so that today air pollution has become a global problem that causes millions of deaths every year (Sevik et al. 2019a; Sevik et al. 2020c; Bozdogan Sert et al. 2019).

Although there are many components of air pollution, heavy metals are of particular importance because they tend to bioaccumulate and can be toxic even at low concentrations in terms of human health (Aricak et al. 2020; Sevik et al. 2019b, c). In addition, heavy metals do not easily deteriorate and disappear in nature. Metals such as Hg, Cd, As, and Pb have serious toxic effects on organisms even at low levels (Shahid et al.,2017; Turkyilmaz et al. 2019; Turkyilmaz et al. 2018a, b). Although micronutrients such as Mn, Zn, Cr, Cu, Fe, and Ni are required for living organisms including plants, they can also produce harmful effects in high concentrations. Studies show that almost all metals have a toxic effect when taken over a certain amount (Shahid et al. 2017; Turkyilmaz et al. 2020).

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Industrial activities are shown as the most important responsible for air pollution (Shahid et al. 2017). Although mineral resources are extremely important for socio-economic development, extraction of minerals and their use in different industrial processes play a leading role in increasing environmental pollution and especially air pollution (Turkyilmaz et al. 2018a, b, c; Sevik et al. 2019a). For this reason, the determination of the damage caused by industrial facilities, which are shown as the most important source of heavy metal pollution, is of great importance for all living organisms, especially humans, and the ecosystem.

The industrial activities are observed to be increasing at the same rate with the rapid increase in the world population. Air pollution, which increases in parallel with the use of fossil fuels in particular, has reached an extent where it is posing imminent dangers for the environment (Cetin et al. 2018a, b; Cetin et al. 2019b).

Lichen and algae are the leading plants most frequently used as biomonitors for monitoring heavy metal pollution. Numerous studies have been conducted on the use of lichen and algae as biomonitors (Carreras et al. 2005; Harmens et al. 2010). However, one of the major problems of using lichen and algae as biomonitors is the inability to determine the duration of exposure of these plants to pollution. It is unclear how long it takes for a detected metal to accumulate, and this affects the reliability of the data obtained.

The time problem is relatively eliminated in high-structure deciduous plants. This is because in these plants, leafing occurs at the beginning of the vegetation season, in spring months, and they are exposed to heavy metals, and thus air pollution, until the leaves fall. Therefore, the amount of heavy metals accumulated in the leaf structure can be determined. Deciduous plants are also often used for monitoring of the pollution of heavy metal (Cetin 2019; Piczak et al. 2003; Sevik et al. 2020c; Tomasevic and Anicic 2010;).

By using non-evergreen plants as biomonitors, the amount of heavy metals accumulated in the leaves of the samples during the vegetation period of the year, in which the samples are collected, can be determined. However, determination of the heavy metal concentration is as important as the determination of the annual change of this concentration. There exist few studies on determining the amount of heavy metals accumulated by the plants in the past years. The studies conducted are usually carried out by taking samples from the annual rings available on tree trunks (Turkyilmaz et al. 2018a, b; Yigit et al. 2016; Akarsu 2019; Turkyilmaz et al. 2019).

This type of sampling usually involves the analysis of heavy metals accumulated on the annual rings available in tree trunks by cutting the trees. Since it is necessary to cut the trees in this method, it is not an appropriate method for sustainable monitoring.

In evergreen plant species, needles can remain on the plant for many years. However, in studies carried out on these plants, since the leaf age is unknown, some problems are encountered in interpreting the heavy metal concentration. In fact, in many coniferous tree species, the needles remain on the tree for a few years. Also, it is possible to determine the needle ages by using the nodes formed. There are some studies conducted on determining the 3-year change in larches, Scots pines, spruces, and firs by using this method (Turkyilmaz et al. 2018c). Whereas, in species such as spruce and firs, the needles can stay on the plant for much longer years, their ages, hence the duration of exposure to air pollution can clearly be determined.

This study was conducted on *Picea pungens* (blue spruce) individuals. It is possible to determine the ages of blue spruce's shoots, and the fact that its needles stay in the shoot for many years makes blue spruce a biomonitor that is suitable for monitoring the changes in recent HM pollution. In addition to this, the facts that the heavy metals, which cause traffic-induced air pollution, accumulate on the needles that remain on the tree throughout the year, and that it is a good indicator of annual heavy metal pollution in the air are deemed to be other advantages of the blue spruce.

Blue spruce is considered to have a significant potential of determining the recent heavy metal accumulation. The aim of this study was to determine the heavy metal concentration in different-aged needles of blue spruce saplings grown in Ankara province. Thus, the usage potential of this species in determining the recent heavy metal concentration was tried to be found.

Material and method

Material

Samples

The work was applied on the lateral branches of a blue spruce tree grown in Ankara province. The location of the study is 390 56′ 11.812″ N and 320 51′ 46.767″ E (Fig. 1). The tree from which the samples were taken is about 25 years old, yet it has not started pruning natural branches, that is, it is a tree that branches out from the bottom. The samples were taken from the side of the tree facing the road and the distance of the tree to the road is about 3 m. The road in question is a very busy road. Samples were taken on the side facing the road by cutting 3 branches upwards from a height of 1 m from the ground, and 5 repetitions were studied in these branches. The branches were taken towards the end of the vegetation season at the end of September. The samples were obtained by cutting and were brought to the lab. The points from which the samples were taken are shown in Fig. 1.

Fig. 1 The locations of the trees where the samples were taken

Preparation of samples and pretreatments

According to their age, the branches were classified and cut. The samples classified were divided into 2 groups; one of the groups was washed. In the process of washing, first the needles, branches, and barks were washed with water, after that, one third of a large glass was filled up with water and the pieces were put into the glass. The washing was performed by shaking the jar powerfully for several minutes, and then, the process was repeated 3 times until the water was completely clear. This process was repeated 3 times with pure water, in the aim to completely remove particulate matter adhering to the organs. Then, the washed samples were spread on paper towels, and excess water was removed by lightly pressing with the help of paper towels.

After washing some of the organs, the needles, branches, and barks of all samples were separated from each other. The samples of barks were taken from the scaffold of the branch, and branch samples from the lateral branches. The samples of barks were taken by stripping them from the branch, whereas the branch samples were taken together with the wood part, since they were taken from thinner branches, and the bark and the wood were not separated.

The making of heavy metal analysis

After obtaining the washed and unwashed needle, bark, and branch samples, the samples were kept waiting for 15 days in order to become air-dried, and then they were dried in the oven at 50 °C for 1 week. After dried samples, weighing 2 g each, were kept waiting inside 10 ml of concentrated HNO_3 for 1 day at room temperature, they were boiled at 180 °C for an hour. Afterwards, 20 ml of distilled water was added to the solution, and the solution was filtered through a filter paper of 45 μm. In the solutions obtained from the filtrate, element analysis and heavy metal analysis were performed using GBC Integra XL ESSDS-270 ICP-OES instrument.

Statistical analysis

The data obtained were assessed with the help of SPSS package program, and the F value and error rate were determined by applying variance analysis to the data, and thus, the difference of the factors were found to be at a 95% confidence level. Duncan test was applied to the factors that were statistically significant at a minimum of 95% confidence level. The obtained results were simplified and interpreted.

Results

Heavy metals are extremely dangerous to human health, as they can remain intact for a long time in nature, tend to bioaccumulate in the body, some are toxic to living things even at low concentrations, and even those that act as food elements for living organisms can have harmful effects in higher concentrations. Although many studies have been conducted on heavy metals to date, the studies mostly focused on elements such as Pb, Cd, Ni, Co, Cr, and the elements subject to the study have been largely neglected (Mossi 2018; Saleh 2018; Pinar 2019).

The elements subject to this study are also dangerous elements to the human health. For example, copper (Cu) is a highly toxic metal. Cu poisoning in plants has effects such as tissue damage, roots degradation and plant color darkening, loss of ion in stem cells, DNA damage, and disruption of photosynthesis. In humans, abdominal pain, nausea, vomiting, and diarrhea are observed in acute copper poisoning (Asri and Sönmez 2006). Low levels of copper ions taken include liver cirrhosis, Wilson's disease, systematic rheumatic diseases, and kidney disorders; high levels of copper ions can cause blood cancer (Hayta 2006). Similarly, excess Li is also reported to cause very dangerous symptoms (Köybaşı and Gülpek 2012). However, there have not been enough studies to determine the concentrations of these heavy metals in the air. Therefore, Cu, Ca, and Li heavy metals were evaluated within the scope of the study.

Changes of Ca element

The organ-based changes of Ca depending on organ age and the Duncan test results are shown in Table 1.

It is notable that, apart from 1-year-old needles, the lowest values were obtained in the washed bark samples in all ages. Yet, the values obtained in the unwashed bark samples were quite high. Apart from this, there is no remarkable difference between washed and unwashed individuals in other organs. In some organs, the values obtained in the washed samples were higher, and in some organs the values obtained in the unwashed samples were also higher.

When the age-related changes are examined, it is seen that, despite some exceptions, Ca concentration generally increases with the needle age in all organs. Especially when the youngest and oldest needles are compared, a significant difference is observed between them. For instance, the Ca concentration of 5323 ppm in the washed 1-year-old needles reached to 20,091 ppm in the oldest needles, and the Ca concentration of 7767 ppm in the washed 1-year-old needles reached to 37,607 ppm in the oldest needles. A similar situation is observed in other organs as well. However, this increase is observed to be much higher in branch samples than in bark samples. The average increase in branch samples is more than four times. In order to ensure a better perception of the data, the changes in Ca concentration based on organs and year are given in Fig. 2.

Changes of Cu element

The organ-based changes of Cu depending on organ age and the Duncan test results are shown in Table 2.

The concentration of Cu element between organs at all ages and the changes between ages in all organs are statistically significant at 99.9% confidence level. It is notable that, apart from 5-year-old organs, the lowest values are obtained in unwashed bark samples at all ages. The second lowest second values are obtained in 5-year-old unwashed bark samples. Another noteworthy finding is the fact that the values obtained in the needles are generally higher than the values obtained in the wood.

When the age-related changes in values are examined, no regular change is observed. The lowest values in the washed needles are obtained in the oldest needles, while the highest values are obtained in the youngest needles, whereas the lowest values in the unwashed needles are obtained in 1-year-old needles, and the highest values are obtained in the oldest needles. Similarly, the lowest value is observed in 2-year-old washed bark samples, while the highest value is obtained in 3-

Table 1 Changes of Ca (ppm) on the basis of organ

Age	Organ						*F* value	Error
	Needle		Bark		Branch			
	+	–	+	–	+	–		
1	5323 aB	7767 aC	8834 dE	12,272 aF	7894 aD	4100 aA	14,033	0.000
2	9506 bB	12073bD	6104 aA	14,636 bF	11,454 bC	13,412 bE	19,660	0.000
3	13,816 cB	16691dD	6346 bA	26,236 gF	16,530 dC	19,176 eE	15,688	0.000
4	16,025 eC	16074cC	6377 bA	17,266 cD	19,410 fE	15,656 dB	33,182	0.000
5	15,670 dC	27280eF	6836 cA	23,522 fE	17,386 eD	14,424 cB	24,080	0.000
6	16,958 fC	30572fF	9187 eA	21,702 eE	15,842 cB	20,566 gD	22,434	0.000
7	20,091 eC	37607gE	12,091 fA	21,242 dD	42,326 gF	19,432 fB	8953	0.000
F value	14,391	54,929	10,199	11,974	9041	45,124		
Error	0.000	0.000	0.000	0.000	0.000	0.000		

"+" refers to the washed samples and "–" to the unwashed ones. According to Duncan's test results, letters A, B, a, b, c, etc. refer to the different group locations. It is statistically different from the values contained in different groups, the bigger the letter, the numerical value grows

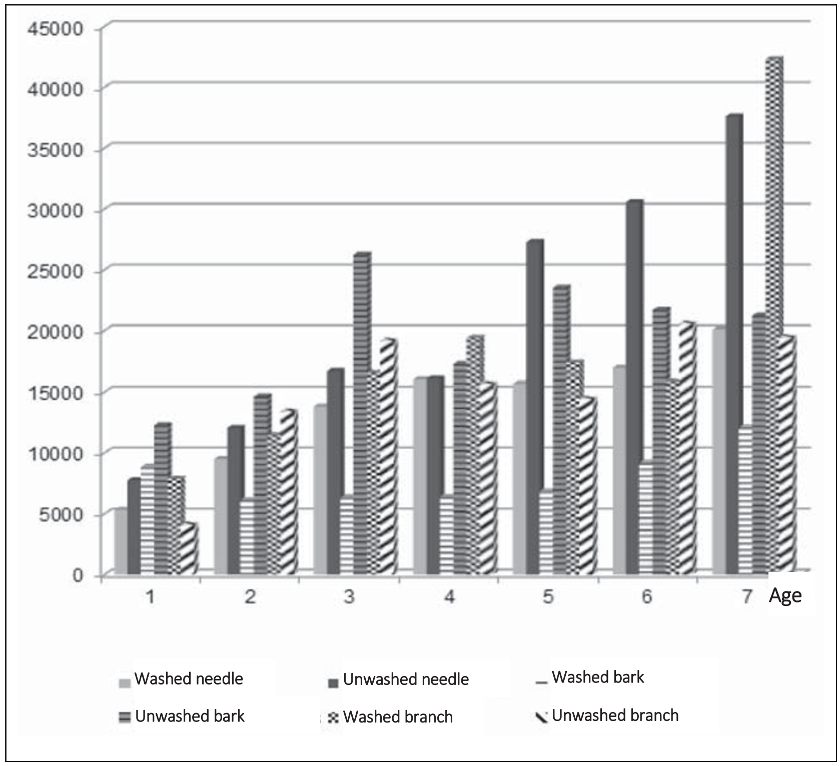

Fig. 2 Changes in Ca concentration on organ and yearly bases

year-old barks. Similar results are observed in other organs as well. Therefore, it is quite difficult to say that Cu concentration shows a significant change depending on age. The changes in Cu concentration based on organs year are given graphically in Fig. 3.

Changes of Li element

The organ-based changes of Li depending on organ age and the Duncan test results are shown in Table 3.

It is seen that the highest values are obtained in the washed needles at all ages. Although Li concentration in the washed needles is the highest at all ages, the difference between other organs is quite high at some ages. For instance, while Li concentration in the 1-year-old needles ranges between 4.54 and 10.54 ppm on the basis of organ, the concentration determined in the washed needles is at 48.32 ppm level. The difference between the washed needles and the other organs generally decreases at the advancing ages. While Li concentration in the oldest organs ranges between 3.81 and 11.19 ppm, the concentration determined on the washed needles is 16.02 ppm.

Table 2 Changes of Cu (ppm) on the basis of organ

Age	Organ						*F* value	Error
	Needle		Bark		Branch			
	+	–	+	–	+	–		
1	64.26 gF	30.25 aD	19.62 cB	11.76 dA	21.69 cC	60.64 gE	4485.3	0.000
2	47.24 dE	48.53 dF	15.39 aB	9.01 aA	16.83 aC	20.57 cD	23,198.0	0.000
3	48.49 eD	37.45 bC	96.76 gE	18.98 eA	22.72 dB	37.83 fC	19,498.0	0.000
4	37.26 cC	39.79 cD	57.96 fE	11.89 dA	37.24 fC	17.94 aB	22,332.5	0.000
5	52.18 fC	75.50 eD	17.30 bA	18.92 eB	17.90 bA	19.34 bB	11,504.5	0.000
6	28.90 aD	113.30 fF	20.85 dB	11.03 cA	31.40 eE	28.32 eC	100,941.9	0.000
7	33.78 bD	92.34 gE	25.77 eC	10.14 bA	93.01 gF	24.76 dB	94,595.6	0.000
F value	1223.645	27,260.057	49,624.248	2309.118	64,515.630	8802.490		
Error	0.000	0.000	0.000	0.000	0.000	0.000		

"+" refers to the washed samples and "–" to the unwashed ones. According to Duncan's test results, letters A, B, a, b, c, etc. refer to the different group locations. It is statistically different from the values contained in different groups, the bigger the letter, the numerical value grows

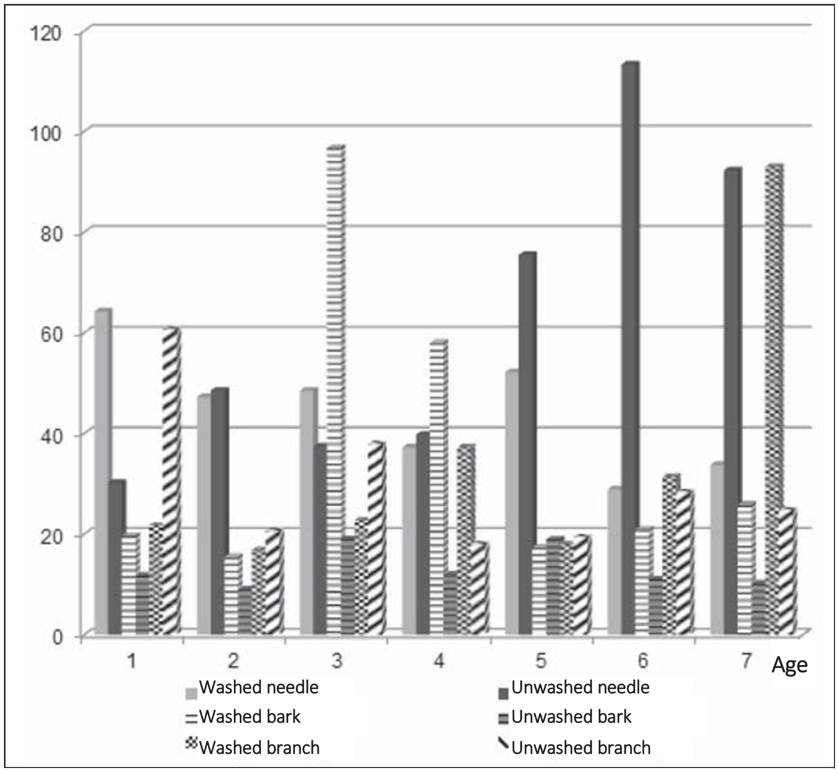

Fig. 3 Changes in Cu concentration on organ and yearly bases

In general, the lowest values are obtained in the unwashed branch samples, and the second lowest values in the washed branch samples. Consequently, it is possible to say that generally the highest Li concentrations are obtained at the needles, then in the barks, whereas the lowest concentrations are in the branches.

When the changes of the values are examined on yearly basis, it can be said that the concentrations in the washed needle, unwashed branch, and washed branch samples are inversely proportional with age; in other words, the concentration of Li element decreases as the age increases. In other organs, no significant change is observed in connection with age. The change of Li concentration on the basis of organ age and organ is shown graphically in Fig. 4.

Discussions

The elements assessed within the scope of the study are extremely important in terms of human health, and they are

Table 3 Changes of Li (ppm) on the basis of organ

Age	Organ						F value	Error
	Needle		Bark		Branch			
	+	–	+	–	+	–		
1	48.32 gD	8.28 bB	10.54 dC	8.67 aB	4.54 eA	4.81 dA	1184	0.000
2	29.93 eF	11.04 cE	7.22 aC	9.62 bD	5.12 fB	2.12 bA	8853	0.000
3	31.42 fE	7.65 aC	7.90 bC	13.49 fD	3.67 bcB	2.93 cA	6398	0.000
4	20.65 cE	20.35 fE	14.93 eD	12.69 eC	4.15 dB	1.45 aA	2314	0.000
5	27.34 dF	11.48 dE	8.16 cC	11.05 dD	3.45 bB	2.25 bA	7709	0.000
6	14.39 aF	11.75 eE	7.83 bC	11.41 dD	1.64 aA	2.16 bB	4454	0.000
7	16.02 bF	11.19 cE	9.85 cC	10.16 cD	3.81 cB	1.96 bA	6247	0.000
F value	633.359	2161.348	624.376	202.911	3.595	56.293		
Error	0.000	0.000	0.000	0.000	0.000	0.000		

"+" refers to the washed samples and "–" to the unwashed ones. According to Duncan's test results, letters A, B, a, b, c, etc. refer to the different group locations. It is statistically different from the values contained in different groups, the bigger the letter, the numerical value grows

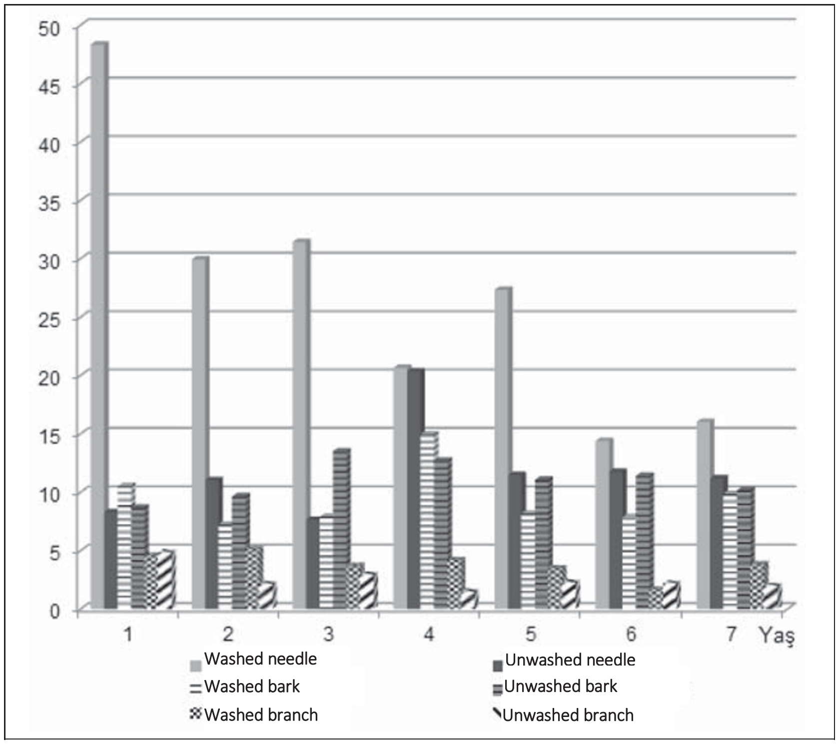

Fig. 4 Changes in Li concentration on organ and yearly bases

harmful at high concentrations. Therefore, monitoring the concentrations of these metals is also very important in terms of forestalling the possible adverse effects. For this reason, these elements have also been the subject of many studies related to heavy metals (Kardel et al. 2018; Liv d., 2015; Qian et al. 2018).

When evaluating the differences between organs according to the study results, it is observed that different results are obtained in different elements. The study results generally show that the lowest values are obtained in the washed barks of Ca element, whereas they are obtained in the unwashed barks of Cu element and branches of Li element.

In studies related to heavy metals, the change of heavy metal concentrations depending on organs often becomes the subject of studies. In studies conducted on this subject, Mossi (2018) identified differences in leaf and branch organs, while Turkyilmaz et al. (2019, 2018a, b) found differences in bark and wood organs; Erdem (2018) and Sevik et al. (2020c) in leaf, seed, and branch organs; Elfantazi et al. (2018a, b) in leaf and branch organs; Ozel et al. (2019) in leaf, branch, and fruit organs; Pinar (2019) in leaf, branch, and seed organs; and Akarsu (2019) in inner bark, outer bark, and wood organs. In these studies, it was found that heavy metal concentrations changed significantly on the basis of organs.

The change of heavy metals based on organs is a complex and yet unresolved mechanism that is shaped by the structure of the plant, as well as the structure of the heavy metal, environmental conditions, and the interaction between these. Also, there is limited information on this subject (Tomaševič et al. 2005; Shahid et al. 2017; Turkyilmaz et al. 2020; Yigit et al. 2016).

Heavy metals can enter the plant through roots or leaves; however, it is very difficult to distinguish whether heavy metals in the inner tissues of the plant were taken from the soil or from the atmosphere since two intake pathways can work simultaneously (Kozlov 2005; Schreck et al. 2012; Pourrut et al. 2013; Shadid et al., 2017). Thus, it is very difficult to determine the source of metal accumulation in the branches.

The changes of the elements were attempted to be evaluated according to the washing status as well. As a result of the study, it was determined that washing changed the values in many organs. While the lowest values in the Ca element were obtained in the washed bark samples, the values obtained in the unwashed bark samples were quite high. It was also found that the Li concentration in the washed samples was higher than the concentrations in the unwashed samples.

The change of heavy metal concentrations in the organs depending on washing status is mainly related to the amount and structure of particulate matter in the atmosphere. In many studies, it is reported that heavy metal concentrations in highly polluted areas are higher in unwashed samples than in washed ones (Mossi 2018). It is stated that the interaction of fine particles with plant leaves is of great importance in the contamination with heavy metals (Temmerman et al. 2012; Schreck et al. 2012). Particulate matters serve as a pharynx for the heavy metals in the air, and when the particulate matter contaminated with these heavy metals adheres to the plant surfaces, the heavy metal concentration in these organs may change significantly. Similarly, adhesion of particulate matter not contaminated with heavy metals to plant organs may also lead to lower levels of heavy metal concentrations in these organs (Mossi 2018; Turkyilmaz et al. 2020).

The amount of contaminated PM and its structure adhering to the surface of the plant are effective in the introduction of heavy metals into the plant. Therefore, many studies have been conducted to determine the amount, chemical composition, spatial and temporal variation of PM and the level of exposure in humans, and studies have shown that variable size organic or inorganic colloids play a key role in the biogeochemical cycle of pollutants (Souza et al. 2014; Chen et al. 2016; Shahid et al., 2017; Mossi 2018).

It is inevitable that humans are exposed to heavy metals along with particulate matter through dermal, inhalation, or swallowing. Environmental nanoparticles are reported to have high absorption capacity for heavy metals such as As, Zn, and Pb. Particulate matter is considered a serious health hazard, especially due to its very small size, which can be inhaled deep into the lungs and sometimes into the bloodstream. There is a relationship between high levels of respirable PM and the rate of illness and death (Chen and Lippmann 2009; Brook et al. 2010; Mossi 2018).

The amount of PM poses greater risks, especially in areas with high HM pollution. As a result of diseases related to respiratory diseases such as pneumonia and bronchitis in London between 5 and 9 December 1952, around 4000 people died, and the effects of polluted air in the next few months caused about 8000 more deaths. Samples from the victims showed that their lungs were contaminated with very high levels of very small particles containing heavy metals such as Pb, Zn, and Fe (Shahid et al. 2017; Chris Deziel 2016).

The fraction of different heavy metals attached to different PM varies according to the type of metal. The holding of heavy metals with different sizes of PM also varies depending on the type of welding (Shahid et al. 2017). In a large number of studies on biomonitors, it was determined that there was a significant difference between heavy metal concentrations in washed and unwashed samples, and this was due to the amount of PM adhering to the plant surface and the infection with heavy metals (Mossi 2018; Aricak et al. 2019; Sevik et al. 2020a, b).

Heavy metals in the air can accumulate in the leaves of the plants through leaf transfer following precipitation of atmospheric particles on leaf surfaces. The potential of plant leaves to absorb nutrients, water, and metals has long been known. However, the information on the metal intake from the atmosphere by the plant leaves is very limited (Shahid et al. 2017).

It was found that the Ca concentration increased with the age of the needle in all organs, and that there was a significant difference between the youngest and oldest needles. Li concentration was found to be inversely proportional to age in general, that is to say it decreased as the age increased.

Among the studies conducted on the determination of heavy metal concentrations, there are no many studies available regarding the leaf or needle age. In a study conducted on this subject (Turkyilmaz et al. 2018c), changes of some heavy metal concentrations in 1, 2, and 3-year-old needles of *Pinus nigra*, *Pinus sylvestris*, *Abies bornmulleriana*, and *Picea pungens* species were evaluated, and it was found that in almost all values, the amount of heavy metal increased in relation to age.

Studies are often conducted on the annual rings of trees in order to determine the change of heavy metal concentrations from past to present. The aim of these studies is to determine the change of heavy metal concentrations on a yearly basis. The studies carried out with the help of annual rings are relatively higher (Turkyilmaz et al. 2019; Turkyilmaz et al. 2018a, b; Yigit et al. 2016; Akarsu 2019). Akarsu (2019) stated that there was generally a horizontal change in Ba, Li, Ca, Mg, and Mn elements found in Kastamonu province, but an increase had been observed in recent years. As a result of the study conducted by Yigit (2019), it is stated that the concentration of all heavy metals, which adversely affect human health, is increasing depending on the age.

Conclusions

In this study, it was tried to determine the change of some heavy metal concentrations in *Picea pungens*, of which needles remain on the tree for a long time, depending on organ and organ age. The results of the study showed that the heavy metal concentrations of the elements subjected to the study changed significantly depending on the organ and organ age. This result suggests that *Picea pungens* organs can be used effectively in determining the effect level of the factors to cause a sharp change in recent metal accumulation. For instance, they can be used in order to determine how the amount of heavy metals in the air changes after the installation of a factory, which releases heavy metals into the air, or to determine the environmental impacts of a recently built highway.

The method used in the study is a sustainable method that does not cause any vital harm to the tree from which the sample is taken. As in *Picea pungens*, this method can be used for perennial trees such as *Picea* or *Abies*, as well as *Pinus*, whose needles can remain on the tree for about 3 years and whose exact organ age can be determined, and for all other species with similar characteristics.

The change in heavy metal concentrations is of vital importance for human health, and biomonitors can be used effectively for monitoring the change in this regard. However, there is no adequate information available on the mechanisms, which are effective in taking heavy metals into the plant body, and on the factors that are effective in this process.

Continuation and diversification of the studies on this subject is recommended.

Heavy metals subjected to the study are generally defined as the elements that are the building blocks for both plants and animals. However, the studies conducted show that the concentrations of these elements in the air are increased, and the studies on the possible damages of taking these elements into the bodies of humans and other living beings are not sufficient. The studies on this subject should also be diversified and increased.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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