THE POSSIBILITY OF USING SCOTS PINE (*PINUS SYLVESTRIS* L.) NEEDLES AS BIOMONITOR IN THE DETERMINATION OF HEAVY METAL ACCUMULATION

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(Received 11th Jan 2020; accepted 26th Mar 2020)

Abstract. Heavy metals can remain in nature for a long time without deterioration and their concentration in the environment is constantly increasing. In addition, some may have toxic or carcinogenic effects even at low concentrations, while some others which act as micronutrients can have toxic effects for humans at high concentrations. Therefore, determining heavy metal concentrations is of great importance towards identifying risk zones and risk levels. The main sources of heavy metals are industrial plants where heavy metal ores are processed. In this study, the Combine Magnesite operating in Russia which entails -”processing and mining of magnesite ore”- was examined for Mg, Al, Fe, Mn and Ca concentrations by analysing the samples taken from the 1- and 2-year-old needles of scots pines grown at 1, 3, 10 and 25 km distances. As a result of the study, it was determined that the concentrations of heavy metals subject to the study vary depending on the distance, especially the Mg concentration which exhibited a significant decrease the farther the trees were. We determined that the concentrations recorded in the 2-year-old needles at almost all points were higher than the 1-year-old needles, and could even exceed this difference several times.

Keywords: *pollution, Satkinsky Combine Magnesite, forest, Mg, Al, Fe*

Introduction

With the rapid increase in the world population, industrial activities have witnessed an identical rise, and the air pollution which increased in parallel with these activities has reached dangerous levels (Cetin and Sevik, 2016a, b; Cetin et al., 2017,2020; Turkyilmaz et al., 2020; Bozdogan Sert et al., 2019; Ozel et al., 2019; Kaya et al., 2019; Cetin, 2019; Zeren Cetin and Sevik, 2020). So much so that today air pollution has become a global problem that causes millions of deaths annually (Cetin, 2016a, b, c, 2017, 2019; Bozdogan Sert et al., 2019; Cetin et al., 2018a,b, 2019a, b; 2020).

Industrial activities are the biggest culprit for air pollution (Shahid et al., 2017). Although mineral resources are extremely important for socio-economic development, mineral extraction and its use in different industrial processes play a leading role in increasing environmental pollution, and air pollution in particular (Li et al., 2014; Goix et al., 2015; Niazi and Burton, 2016).

The change in heavy metal pollution can be determined by direct and indirect methods. The direct approach is expensive, and the direct impact of atmosphere

DOI: http://dx.doi.org/10.15666/aeer/1802_37133727

pollution on the ecosystem cannot be determined, and data about the measurement period cannot be examined (Yucedag et al., 2019a, b, c; Cesur, 2019; Gemici et al., 2019). These methods often require expensive measuring instruments and carry a higher risk of contamination than biomonitors. The use of biomonitors in the determination of air pollution is an inexpensive and easy method and provides more reliable data on the periodic changes of heavy metal concentrations (Aricak et al., 2019a, b). Plants that grow in areas with heavy pollution show heavy metals concentrations in the body, branches and hands, and show the increase in heavy metal concentrations in the air over time (Turkyilmaz et al., 2019; Bozdogan Sert et al., 2019). Therefore, instead of the direct detection of heavy metal pollution, biomonitors are frequently used (Sevik et al., 2019a; Cetin et al., 2018a, 2019 a, b, 2020; Turkyilmaz et al., 2019; Bozdogan Sert et al., 2019; Cetin, 2019; Ozel et al., 2019).

In this study, we aimed to determine the change of pollution level depending on distance and pointer age by using 1 and 2 wet hands of scotch pines grown in different distances around a process and mining of Magnesite ore operating in Russia.

Materials and methods

In the conditions of modern cities, aerotechnogenic pollution is a permanent environmental factor that has a negative impact on the environment and human health. One of the objects of large foci of destruction of forest vegetation is located in the Southern Urals in the Chelyabinsk region city Satka the Combine Magnesite in Russia, (the GPS coordinates of 55°6’10.663” N and 58°58’27.53” E) (*Fig. 1a, b*). Experimental sites (ES) were planting trees created in rows in 1980-1983. Employees of the Botanical Garden in order to study the suitability of soils for reforestation in various zones of magnesite pollution. ES are located at different distances from the Combine.

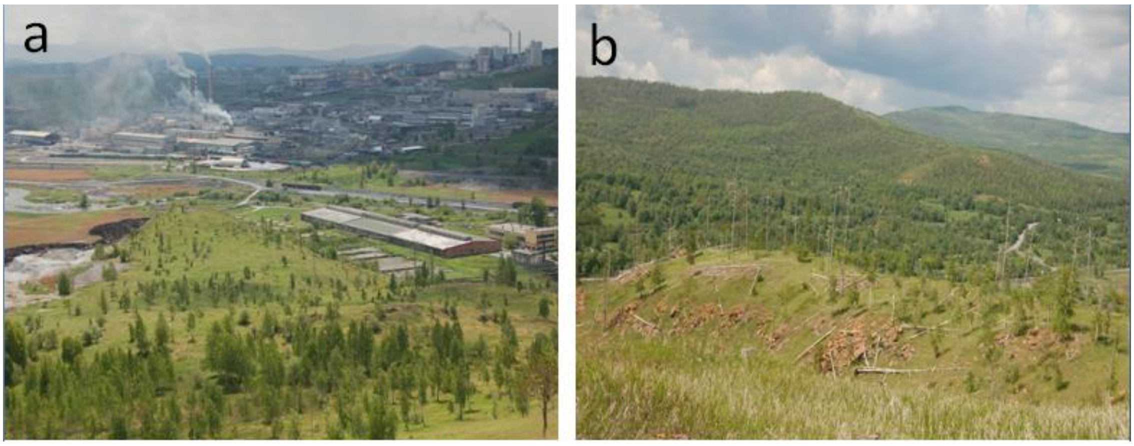

Figure 1. *Satkinsky Combine Magnesite (a) and the surrounding forests (b)*

In the pollution gradient to the northeast, in the direction of the prevailing winds from the emission source, the following areas are located: ES-2 at 1 km from the plant in the zone of strong influence, ES-5 at 3 km - zone of average influence and ES-4 at 10 km - zone of weak influence at the Combine Magnesite. Near the village of Sibirka settlement area (conditional control) - 25 km south of the Combine in background conditions is located Control. During planting of *Pinus sylvéstris* L., peat was deposited at ES-2 and ES-5 at a layer of 2 cm. Peat was not added to the site at ES-4. The type of forest in all ES is the Scots pine (*Fig. 2*).

The raw material for the production of sintered Pericles powders is raw magnesite. High-carbonate feedstock is burned in such a way that raw magnesite of Satkinsky groups of deposits (fractions 0–40 mm) is loaded into a rotary kiln. After burning natural magnesite, a large amount of caustic dust is formed which undergoes repeated burning. When burning dust, a large amount of flue gases, carbon monoxide, alkali, fluorine and sulfuric anhydride, nitrogen oxides are released into the atmosphere. Near the Combine Magnesit and within a radius of 1.5–2 km, the forest completely died (*Fig. 1b*). The maximum volumes of magnesite dust into the atmosphere in 1963 reached 182.5–328.5 thousand tons per day. In 1978, new electrostatic precipitators were installed at the plant, and dust emissions dropped to 70–90 tons per day.

Figure 2. *Location of experimental sites depending on the Combine Magnezit*

Samples were taken from the ends of the longest lateral branches of the trees at the designated points on the source of pollution by cutting branches with a needle. Under the conditions of the region, the pine needles can remain on the tree for two years and with the help of the formed nodes. The cut branches were then cut according to their age, and the shoots formed in the last year were classified as 1 year, shoots formed in the previous year were classified as 2 years, and labelled by packaging. This classification process in trees such as pine, spruce and fir has also been used in different studies (Turkyilmaz et al., 2018c; Cobanoglu, 2019; Kececi, 2019). The needle samples used in the study were collected at the end of the 2018 vegetation season and the study was carried out in 5 replications.

Heavy metal analyses

The samples, which were classified and labeled in the laboratory, were stored and air dried for 15 days. The air-dried samples were then dried in a drying oven at 45 °C for a week. Experiments were started for heavy metal analysis in dried samples on the same day. Plant samples were pulverized and were weighed as 0.5 g and put into tubes designed for microwave. 10 mL of 65% HNO_3 were added to the samples. During this process, the fume cupboard was used. The prepared specimens were then burnt at 280 PSI pressure in a microwave and at 180 °C for 20 min. The tubes were removed from the microwave after being processed and left to cool. Deionized water was added to the cooled samples and tubes were filled until 50 ml was completed. The filtered solutions were analyzed for heavy metal concentrations of Mg, Al, Fe, Mn and Ca using GBC Integra XL–SDS-270 ICP-OES.

Statistical analyses

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

Results

The change in Mg levels according to distance and pointer age was determined and mean values and P value obtained by analysis of variance, error rate and groupings formed as a result of the Duncan test are given in *Table 1*.

Table 1. *The element of Mg (ppm) of the change depending on distance and needle age variance*

Distance	1 Age needle	2 Age needle	P value	Error
1 km	3659.24 Ad	4566.64 Bd	42.598	0.000
3 km	2907.08 Ac	4179.28 Bc	50.364	0.000
10 km	2687.33 Ab	2902.48 Bb	9.415	0.007
25 km	2282.17 Aa	2597.37 Ba	12.012	0.003
P Value	65.505	83.040		
Error	0.000	0.000		

It is statistically different from the values contained in different groups, starting with the letter A-a, the numerical value grows

When the results of the table are examined, it is observed that the concentration changes of Mg element are statistically significant ($p < 0.001$). When the average values and Duncan test results are examined, it is seen that Mg concentration decreases significantly in both 1-year-old and 2-year-old needles depending on the distance, Mg concentration values determined at 25 km distance are more than 1.6 times of Mg concentration values determined at 1 km. It is seen that the changes in all distances in terms of pointer age are statistically significant ($p < 0.01$ in 1 and 3 km at other distances $p < 0.001$), and the values determined in 2-year-old needles at all distances are higher than those determined in 1-year-old needles.

The change of Al element according to distance and pointer age was determined and the mean values and P value obtained by the analysis of variance, error rate and the groupings formed as a result of Duncan test are given in *Table 2*.

Table 2. *The element of Al (ppm) of the changing depending on distance and needle age*

Distance	1 Age needle	2 Age needle	P value	Error
1 km	23.64 Aa	62.57 Bb	116.168	0.000
3 km	20.97 Aa	65.52 Bb	197.77	0.000
10 km	16.42 Aa	39.28 Ba	262.687	0.000
25 km	71.48 Ab	125.29 Bc	22.618	0.000
P Value	65.32	47.825		
Error	0.000	0.000		

The letters A, B, a, b, c, etc. means according to Duncan’s test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a, the numerical value grows

Al-element concentration in both 1- and 2-year-old needles is statistically significant ($p < 0.001$), but it is difficult to say that there is a linear relationship between distance and Al concentration when the mean values and groupings formed by Duncan test are examined, because, the lowest value is determined at 10 km and the highest value is 25 km at both 1-year and 2-year-old needles. As a result of the variance analysis, it was observed that the changes in all distances were statistically significant ($p < 0.001$) in terms of pointer age, and the values determined in the 2-year-old needles were higher than those determined in the 1-year-old needles. In fact, it was calculated that this difference was quite high and the difference, which was 1.75 times at a distance of 25 km, could reach up to 3.12 times.

The change of Fe element according to distance and pointer age was determined and P values, error rate and groupings resulting from Duncan test obtained from mean values and variance analysis are given in *Table 3*.

Table 3. *The element of Fe (ppm) of the changing depending on distance and needle age*

Distance	1 Age needle	2 Age needle	P value	Error
1 km	66.56 Ac	110.41 Ba	21.641	0.000
3 km	55.20 Ab	156.48 Bb	224.086	0.000
10 km	31.15 Aa	91.34 Ba	901.938	0.000
25 km	38.69 Aa	108.86 Ba	29.160	0.000
P Value	28.092	4.367		
Error	0.000	0.011		

The letters A, B, a, b, c, etc. means according to Duncan’s test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

According to the analysis of variance, the change of Fe element concentration depending on distance was statistically significant ($p < 0.001$ in 1-year-old needles and $p < 0.01$ in 2-year-old needles). According to the average values and Duncan test results, it can be said that Fe concentration decreases in 1-year-old needles while it is difficult to say that there is a significant change in 2-year-old needles. As a result of variance analysis, it was seen that the changes in all distances were statistically significant ($p < 0.001$) in terms of pointer age, and the values determined in 2-year-old needles were higher than those determined in 1-year-old needles. In fact, this difference is quite high, ranging from 1.6 times to 2.9 times.

The variation of Mn element according to distance and pointer age was determined and the mean values and P value obtained by analysis of variance, error rate and the groupings formed as a result of Duncan test are given in *Table 4*.

Table 4. *The element of Mn (ppm) of the changing depending on distance and needle age*

Distance	1 Age needle	2 Age needle	P value	Error
1 km	40.95 Ab	77.78 Bb	28.326	0.000
3 km	65.52 Ac	100.52 Bc	62.199	0.000
10 km	28.18 Aa	48.10 Ba	13.131	0.002
25 km	95.42 Ad	169.47 Bd	81.932	0.000
P Value	172.674	72.060		
Error	0.000	0.000		

The letters A, B, a, b, c, etc. means according to Duncan’s test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

It was determined that the concentration of Mn element was statistically significant ($p < 0.001$). However, it is difficult to say that there is a linear relationship between distance and Mn concentration when the mean values and the groupings formed by Duncan test are examined because the lowest value is determined at 10 km and the highest value is 25 km at both 1 year and 2-year-old needles. As a result of the analysis of variance, it was found that the changes in all distances were statistically significant ($p < 0.01$ at 10 km distance, $p < 0.001$ at other distances) in terms of pointer age, between 5 and 1.9 times.

It was determined that the concentration of Mn element was statistically significant ($p < 0.001$). However, it is difficult to say that there is a linear relationship between the distance and the Mn concentration because the lowest value is determined at 10 km and the highest value is 25 km at both 1 year and 2-year-old needles. ($P < 0.01$ at 10 km distance, $p < 0.001$ at other distances) in terms of pointer age. Between 5 and 1.9 times.

According to the variance analysis results, are given in *Table 5*, it was found that the change of Ca element depending on distance was statistically significant ($p < 0.01$) in both 1 and 2 year old needles, and when the mean values and Duncan test results were examined, it was found that there was an inverse relationship between Ca concentration and distance. As a result of the analysis of variance, it was found that the changes in all distances were statistically significant ($p < 0.001$) in terms of pointer age, and the values determined in 2-year-old needles were 1.9 times to 2.3 times higher than those in 1-year-old needles.

***Table 5.** The element of Ca (ppm) of the changing depending on distance and needle age*

Distance	**1 Age needle**	**2 Age needle**	**P value**	**Error**
1 km	1298.71 Aa	2985.44 Ba	28.489	0.000
3 km	2002.73 Ab	4312.44 Bb	26.576	0.000
10 km	1992.97 Ab	4538.26 Bb	51.147	0.000
25 km	2451.64 Ab	4750.71 Bb	44.374	0.000
P Value	7.126	6.025		
Error	0.001	0.002		

The letters A, B, a, b, c, etc. means according to Duncan’s test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

Discussion

The concentrations of Mg, Al, Fe, Mn and Ca elements in the 1 and 2-year-old needles of the scots pine grown around 1, 3, 10 and 25 km distances around the “process and mining of magnesite ore” were determined. Although many studies on heavy metals have studied some of these elements, it is noticeable that in general, studies focus on elements such as Pb, Ni, Cd, Cr, Zn, Co (Turkyilmaz et al., 2019, 2018a, b, c, d; Sevik et al., 2019b). The reasons that these elements may cause toxic effects and are carcinogens even at low concentrations can be shown as the main factors in the prominence of these elements (Turkyilmaz et al., 2019, 2018a, b, c, d; Saleh, 2018). Some recent studies are shown that conform the temporal changes in magnesite pollution released by the factory to the air (Blanár et al., 2019; Pišút and Pišút, 2006).

However, the studies show that although micronutrients such as Mn and Fe, which are considered in this study, are necessary, they can create harmful effects at high levels (Shahid et al., 2017). Fe and Al are defined as carcinogenic to humans (Goney, 2018). In addition, it is stated that the elements that are required as a nutrient can cause serious health hazards if taken by mouth or respiration (Batır, 2019). For example, Mn, which reaches people through the food chain, causes hallucinations, fatigue, insomnia, weakness, forgetfulness and nerve damage by causing damage to the respiratory system and brain, and may cause Parkinson’s, lung embolism and bronchitis, and impotence in men (Pak, 2011; Mossi, 2018). It is therefore very important to monitor the concentrations of these elements in the air.

The results of the study show that Mg concentration decreases significantly depending on the distance. In studies conducted to date, it has been shown that the concentration of heavy metals in plants decreases as they move away from the source (Turkyilmaz et al., 2018c; Aricak et al., 2019a, b). However, as a result of the study, no linear relationship was found between distance and concentration decrease in other elements. This has been demonstrated in other similar studies and it has been stated in many studies that there is no significant difference between the distance to the source of pollution and the concentration of heavy metals (Mossi, 2018; Saleh, 2018; Sevik et al., 2019a).

There are two possible explanations for this situation. The first is that the source of pollution is not a source of pollution in terms of these elements. The second explanation is that the change in heavy metal concentration in plants is a complex mechanism that has not been fully solved under the influence of many factors (Sevik et al., 2019b; Turkyilmaz et al., 2019). Indeed, studies show that heavy metals can be transported hundreds of kilometers away from their original source (Shahid et al., 2017). However, the accumulation of heavy metal concentrations in plants is shaped by the interaction of many factors and their sub-factors (Mossi, 2018; Turkyilmaz et al., 2018b, c).

Studies carried out to this day have shown that the diffusion of heavy metals in the atmosphere and entry into the plant is a very complex process. The heavy metal accumulation potential of the plants grown in the same environment as well as plant species and plant organ, organelle structure, physico-chemical properties of metals, organelle morphology and surface area, organelle surface texture and size, plant habitus, duration of exposure to heavy metal and amount of particulate matter (Pearce et al., 2006; Xu and Zhou, 2008; Schreck et al., 2012).

The accumulation of heavy metals in the plant is closely related to environmental conditions. It is stated that there is a significant relationship between the entry of heavy metals into the plant and especially air humidity and precipitation (Shahid et al., 2017; Ozel, 2019). In addition, environmental factors directly affect plant growth and there is a significant relationship between plant growth and heavy metal uptake. Therefore, the introduction of heavy metals into the plant and its accumulation in organs are shaped under the interaction of many factors and their sub factors (Shahid et al., 2017; Aricak et al., 2019a).

The study shows that the concentration of all elements subject to the study at 2-years-old needles is higher than their concentration at 1-years-old needles at all distances. This can be explained by the longer exposure of the 2-year-old needles to the same environmental conditions and therefore to heavy metals. Similarly, similar results were obtained from studies on different aged needles on the same plant (Turkyilmaz et al., 2018c; Cobanoglu, 2019; Kececi, 2019).

Although a number of studies have been conducted on the use of plants as biomonitor for monitoring heavy metal pollution in the air, it is not yet possible to determine which plants are most suitable for monitoring heavy metal concentrations. There are many reasons for this, but the most obvious is the limited number of plants, since it is very difficult and costly to work with many plants at the same time. The studies can be done by comparing 8-10 plants at most and in this case only the plants subject to the study can be compared with each other. However, studies show that there is a very high-level difference between the species growing in the same environment (Mossi, 2018; Sevik et al., 2019a, b; Saleh, 2018).

The first question to be answered is which kind of heavy metal pollution should be used. Lichen and algae are the most important plant groups in biomarkers for heavy metal pollution.

Bryophytes covering these plants, especially algae, have been used as biomonitor since the 1970s (Ayres et al., 2006; Harmens et al., 2010). However, one of the biggest problems in using lichen and algae as biomonitors is that it is not easy to determine how long these plants have been exposed to pollution. Therefore, it is not known clearly how long any concentration of metal accumulates, and this results in questioning the reliability of the data obtained (Cobanoglu, 2019).

In deciduous high-structured plants the problem of time is relatively eliminated. Because the foliage in these plants occurs at the beginning of the vegetation season, which is in the spring and is exposed to air pollution, i.e. heavy metals, until the leaves are shed. Therefore, the amount heavy metals accumulation in the leaves can be known. Therefore, deciduous plants are often used to monitor heavy metal pollution (Anicic et al., 2011; Petrova et al., 2014; Mossi, 2018).

By using deciduous plants as biomonitors, the amount of heavy metals deposited on the leaves during the vegetation period of the year in which the samples collected can be determined. However, as much as the determination of the concentration of heavy metal is possible, it is extremely important to determine the change of this concentration depending on the year. Few studies have been conducted to determine the amount of heavy metal accumulation in plants in the past years. Rather, the studies are done on the trunks of trees by taking samples from annual rings. This type of sampling usually involves the analysis of heavy metals deposited on annual rings in the trunks of trees (Panyushkina et al., 2016; Xu et al., 2017; Turkyilmaz et al., 2018b, c). This method is not suitable for sustainable monitoring because trees need to be cut down.

In some variegated species, the leaves can remain on the plant for many years. However, there is a problem in interpreting what heavy metal concentration means because the leaf age is not known in these studies. However, in many types of hands, the hands remain on the tree for a few years, and it is possible to know the age of hands by the means of the nodes formed. In addition, since the hands of these plants are exposed to the same environmental conditions outside the vegetation season, the accumulation in the old hands can be much higher (Cobanoglu, 2019; Kececi, 2019). As a matter of fact, in this study, it was found that the concentrations obtained in the 2-year-old hands were much higher than the 1-year-old hands.

Heavy metals can enter the plant through root or leaf uptake, but it is very difficult to distinguish whether heavy metals in the plant’s internal tissues are taken from the soil or atmosphere, because both intake pathways can work simultaneously (Pourrut et al., 2013; Shadid et al., 2017). Therefore, it is thought that leaves are the most suitable organs especially for monitoring heavy metal pollution in the air. Because the leaves are the most exposed to heavy metal pollution in the air and are affected most by them due to the entry of air through their stomata during photosynthesis (Cetin et al., 2019a,b, 2020; Turkyilmaz et al., 2018c; Shahid et al., 2017; Saleh, 2018).

There is also a significant relationship between heavy metal accumulation in the plant and particulate matter in the air. Studies show that the interaction of fine particles with plant leaves is especially important in contamination with heavy metals (Temmerman et al., 2012; Schreck et al., 2012). Particulate matter acts as a pharynx for heavy metals in the air, and the concentration of heavy metals in these organs can vary significantly with the adherence of particulate matter contaminated with these heavy metals to plant surfaces and especially leaves (Mossi, 2018; Turkyilmaz et al., 2018d). Heavy metals in the air may accumulate in plant leaves by leaf transfer following precipitation of atmospheric particles on leaf surfaces. The potential for absorbing nutrients, water and metals from leaf parts of plants has long been recognized. However, information about the uptake of metal by plant leaves from the atmosphere is very limited (Shahid et al., 2017). To date, there have been few studies on leaf or pointer ages in determining the concentration of heavy metals in the past (Turkyilmaz et al., 2018c; Cobanoglu et al., 2019; Kececi, 2019).

Heavy metal accumulation in plants varies significantly on organ basis. However, there are many factors that affect this accumulation. Particularly with the adhesion of particulate materials contaminated with heavy metals to plant organs, heavy metal concentrations in these organs increase significantly. Adhesion of particulate materials contaminated with heavy metals causes heavy metal concentrations to be quite high, especially in the bark of trees with cracks. However, heavy metal concentrations in branches, leaves and fruits other than this vary significantly by species. In the wood, which is located in the interior of the tree and does not have a direct connection with the external environment, many heavy metal concentrations remain at lower levels (Sevik et al., 2020a, b, c).

As a result, there are many factors that affect the penetration and accumulation of heavy metals in the air. These factors include plant species, rainfall and moisture content, plant habitus, organelle structure, type of heavy metal and interaction with the plant (Sevik et al., 2019a; Aricak et al., 2019a) There are also many factors that may directly or indirectly affect the concentration of heavy metals. For example, the change in heavy metal concentration depending on plant species has been demonstrated in many studies (Sevik et al., 2019a, b, c, 202a, b, c; Saleh, 2018; Erdem, 2018; Bozdogan Sert et al., 2019; Cetin et al., 2019a). However, it can be expected that the heavy metal concentrations in the subspecies, forms, varieties and origins of the plant will be at different levels. Because, studies show that many phenological, morphological and anatomical structures change depending on these characteristics (Yucedag et al., 2019a; Cetin et al., 2018a; Sevik et al., 2019c). In this case, it is inevitable that plant metabolism changes and this affects heavy metal absorption (Shahid et al., 2017; Sevik et al., 2019a, b).

Heavy metal absorption in plants is also closely related to plant metabolism (Shahid et al., 2017; Sevik et al., 2019a, b). Therefore, the stress level of the plant significantly affects plant metabolism (Sevik and Cetin, 2015; Yigit et al., 2016), plant origin (Sevik and Topacoglu, 2015), and the genetic structure of the plant (Hrivnak et al., 2017), and many other factors such as heavy metal absorption and thus heavy metal concentration. However, the factors affecting the accumulation of heavy metal concentrations in plants and their effect levels have not been clearly determined yet. Therefore, studies on this subject should be continued, diversified and increased.

Conclusions

We have attempted to determine the change of some heavy metal concentrations depending on the distance to the point which is thought to be the source of pollution and the age of the pointer in *Pinus sylvestris* L. whose needles can remain on the tree for a few years. The results of the study showed that Mg concentration decreased significantly in relation the distance. Considering that the source of pollution is “processing and mining of magnesite ore”, this result is very logical and also shows that *Pinus sylvestris* L. needles are very suitable for monitoring the change of Mg concentration in the air.

One of the most important results of the study is that the concentrations obtained in the 2-year-old needles in all elements are significantly higher than in the 1-year-old needles. This can be explained by the fact that older needles are exposed to heavy metals in the air longer than younger needles. According to this result, the needles of trees such as *Abies* and *Picea*, whose needles can remain on the trees for up to 8-10 years and the age of the pointer can be calculated clearly, can be good biomonitor in monitoring the recent heavy metal pollution.

No connection between the distance and the Al, Fe, Mn and Ca could be observed, but sometimes those concentrations were lower close to the factory. This shows that there is no direct connection between the source of pollution and the elements, and the source of these elements is probably soil. It is suggested that the source of these elements should be determined clearly by doing soil analysis in further studies.

It has been determined that Mg concentration varies significantly depending on the distance to the source. While the concentration of Mg in 1-year-old hands taken at a distance of 1 km from the source is 3659 ppm, it decreases to 2907 ppm at 3 km distance, 2687 ppm at 10 km distance and 2282 ppm at 25 km distance. In the 2-year-old hands, the concentration of 4566 ppm in 1 km distance to the source decreased to 4179 ppm at 3 km, 2902 ppm at 10 km and 2597 ppm at 25 km. However, in order to determine how much of this decrease originates from air and how much from soil, it is recommended to make measurements in soil samples and evaluate the results comparatively.

Acknowledgements. The work was carried out as part of the state assignment of the Botanical Garden of the Ural Branch of the Russian Academy of Sciences and Kastamonu University, Faculty of Forestry and Faculty of Architecture and Engineering.

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