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Determination of suitable species that can be used in declining niobium pollution in the atmosphere

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Abstract

This study aimed to determine the most suitable woody species that can be used to reduce niobium (Nb) pollution, which can be harmful and toxic to human and environmental health. Within the scope of the study, samples were taken from the wood part of 16 trees growing under similar growing conditions in Düzce province, one of the 5 most polluted cities in Europe according to the 2021 World Air Pollution Report, and Nb concentrations were determined. As a result, Nb concentration was below the detectable limits in the woods of *Pseudotsuga menziesii, Fraxinus excelsior*, and *Tilia tomentosa*. Apart from this, the lowest values were obtained in the woods of *Picea orientalis, Pinus pinaster*, and *Cupressus sempervirens*, and the highest values were obtained in the woods of *Robinia pseudoacacia* and *Cedrus atlantica*. It was calculated that there was an approximately 522-fold difference between the lowest determined Nb concentration (*P. orientalis* with 105.5 ppb) and the highest Nb concentration (*R. pseudoacacia* with 55117.2 ppb). In conclusion, suitable species that can be used to reduce Nb pollution in the air are *R. pseudoacacia* and *C. atlantica*.

Keywords: Heavy metal; Niobium; Phytoremediation; Wood

1. Introduction

The developments in industry and technology in the last century have caused significant changes in the global population. The world population, around 1.5 billion at the beginning of this century, has reached 8 billion todays [1,2]. In this process, the distribution of the population has also changed, and the urbanization rate, which was around 9% at the beginning of the century, is currently around 50% and is estimated to reach 90% by 2030 [3,4].

The concentration of the population in urban areas has brought many problems, such as infrastructure problems, pollution, traffic density, and high crime rates [5-8]. The most threatening of these problems is environmental and especially air pollution. Air pollution, which causes the death of approximately 7 million people yearly, has become one of the most critical global troubles [9,10].

Air pollution has become a threat to humans and other living creatures and ecosystems [11]. The change in the composition of the air due to the production of energy from fossil fuels, the use of which is increasing day by day, is shown to be the most important responsible for global climate change [12-14]. In addition, heavy metals found in small concentrations in the air are among the most critical threats to the health of living things [15,16]. Airborne concentrations of heavy metals, which can be toxic and fatal to living things even at low concentrations, are constantly increasing due to anthropogenic sources [17-21]. Therefore, studies on reducing heavy metal pollution in the air are

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among the priority research topics [22]. Although many studies have been conducted on this subject, the studies focus on more common elements such as Pb, Cr, Ni, Cu, Mn, and many other elements that can be highly harmful are neglected [23-25].

Nb of the elements neglected in studies on heavy metals and their compounds can be toxic [26]. Moreover, it is much more essential to decrease the concentrations of heavy metals in the air because it is known that heavy metals can be much more harmful if inhaled into the body [27]. When inhaled, Nb adheres mainly to the lungs and secondarily to the bones. It interferes with calcium as an activator of enzyme systems. In laboratory animals, it has been determined that inhalation of niobium nitride and/or pentoxide causes lung scarring at exposure levels of 40 mg/m3 [26]. Therefore, reducing Nb pollution in the air is of great importance. Within the scope of this study, the aim was to determine the potential of some trees frequently grown in urban areas to accumulate Nb heavy metal in their wood parts.

2. Material and methods

The study was carried out on trees growing in Düzce city center. Düzce is among Europe's five most polluted cities [28]. The species subject to the study are frequently used in landscape studies in Turkey and Europe. Within the scope of the study, *Pinus nigra, Juglans nigra, Gleditsia triacanthos, Cupressus arizonica, Prunus avium, Populus alba, Platanus orientalis, Abies nordmanniana, Tilia tomentosa, Robinia pseudoacacia, Fraxinus excelsior, Pinus pinaster, Cupressus sempervirens, Picea orientalis, Pseudotsuga menziesii* and *Cedrus atlantica* species were examined. The wood taken from the main trunk was used.

Samples taken from 5 different points of each tree with the help of a steel drill were dried at 45 °C, 65% HNO3, and 2 ml 30% H2O2 were added and pre-burned in a microwave oven. The prepared samples were analyzed with the ICP-OES device, and Nb concentrations were calculated by multiplying the obtained values with the dilution factor. The method used in the study is a method frequently used in studies conducted on this subject in recent years [29-31]. The obtained data were simplified, tabulated, and interpreted.

3. Results

The change in Nb concentration, lowest and highest values, standard deviation values , and average Nb concentrations in the wood of the 16 species subject to the study are given in Table 1.

Table 1 Variation of Nb (ppb) concentrations on a species basis

Species	Minimum	Maximum	St. Deviation	Average
P. nigra	12673.5	13981.0	365.2	13135.7
J. nigra	8624.0	11747.2	1074.8	10099.9
G. triacanthos	11479.9	12520.4	286.8	12162.2
C. arizonica	12320.5	13246.3	255.6	12716.4
P. avium	12430.9	13503.0	326.2	12881.0
P. alba	13357.3	14182.6	252.8	13710.3
P. orientalis	13123.0	14489.8	346.2	13689.1
A. nordmanniana	13901.2	15165.0	357.4	14528.8
R. pseudoacacia	52826.2	56818.8	1371.5	55117.2
P. pinaster	93.0	141.2	16.2	111.1
C. sempervirens	88.0	1000.0	373.8	278.0
P. orientalis	87.4	131.2	12.0	105.5
C. atlantica	25423.4	26995.4	514.2	26109.9

As a result, it was determined that the Nb concentration was below the detectable limits in the woods of *P. menziesii, F. excelsior,* and *T. tomentosa*. In other species, it was determined that the Nb concentration varied between 105.5 ppb and 55117.2 ppb on average. The lowest values were obtained in the woods of *P. orientalis* (105.5 ppb), *P. pinaster* (111.1 ppb), and *C. sempervirens* (278.0 ppb). In comparison, the highest values were obtained in the woods of *R. pseudoacacia* (55117.2 ppb), *C. sempervirens* (278.0 ppb), and *C. atlantica* (26109.9 ppb) woods. The Nb concentration determined in other species varies within a very narrow range, ranging between 10099.9 ppb (J. nigra) and 14528.8 ppb (*A. nordmanniana*).

4. Discussion

As a result, it was determined that the Nb accumulation potential in the wood of the trees subject to the study was at very different levels. There can be hundreds of fold differences between Nb concentrations in the wood of different species. In studies conducted to date, it has been determined that the accumulation rates of different heavy metals in the wood of different species vary significantly depending on the species [32-34].

The study primarily aims to determine suitable species for reducing Nb concentration in the air. The use of plants is one of the most effective methods for reducing heavy metal pollution in the air [35-37]. For this purpose, it is essential to determine hyperaccumulator plant species that can be used in phytoremediation studies. Species that can accumulate these heavy metals, especially in the wood part, are highly suitable for this purpose because the wood part is the largest organ of higher plants in terms of mass; it traps heavy metals within itself for many years and can remove heavy metals from the air to a large extent [38,39]. However, the most suitable species that can be used for this purpose must be determined separately for each element.

As a result of the study, it was determined that the Nb concentration was below the detectable limits in the woods of *P. menziesii, F. excelsior,* and *T. tomentosa*. Apart from this, the lowest values were obtained in the woods of *P. orientalis, P. pinaster,* and *C. sempervirens*, and the highest values were obtained in the woods of *R. pseudoacacia* and *C. atlantica*. It is thought that the Nb accumulation potential of these species is related to their anatomical structures. The potential of plants to absorb and accumulate heavy metals depends on many factors, such as organ structure, weather conditions, plant habitus, and the structure of the heavy metal and its interaction with the plant [38-41]. These factors are also linked to other factors. For example, plant physiology is shaped under the influence of genetic structure [42-48] and environmental conditions [49-58]. Therefore, all factors affecting plant physiology also affect the entry and accumulation of heavy metals into the plant, and plant physiology is shaped by the interaction of many factors affecting each other, such as edaphic [59], climatic factors [60-64] and stress factors [65-75], as well as genetic structure [61].

Heavy metals enter the plant body from the soil through the roots, air through the leaves, and direct adsorption from the stem parts [35]. The transport of elements within the wood part is primarily related to the cell structure, especially the cell wall (apoplastic pathway). In plants, cell wall proteins (CWP) are activated in various abiotic stresses [76]. Plants often face stress factors in their lives. The most common stress factors that plants encounter are climatic factors [13,58] such as high temperatures [71] and frost [68] which is resulting drought [56]. Heavy metal pollution is also one of the stress factors [77,78]. The presence of stress factors changes the environmental conditions where plants grow, thus affecting plant development in many ways. Because the plant is shaped mainly depending on the interaction of genetic structure [45,46] and environmental conditions [49,52], these factors are the main factors that determine the heavy metal accumulation potential of plants. However, the process of plants absorbing and accumulating heavy metals is a complex process shaped by the interaction of many factors affecting each other. This process still carries many unknowns [21, 79].

5. Conclusion

In conclusion, it was determined that there could be hundreds of times difference between the Nb accumulation potentials in the species' wood. *R. pseudoacacia* and *C. atlantica* are the species that can accumulate the most Nb in their wood. In areas where Nb pollution is high, these species can be used to reduce pollution. Since these species are durable, they can be grown in a wide area and reach large masses by branching; they are long-lived, and they can preserve heavy metals for hundreds of years, making them highly suitable for use.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they no conflict of interest. The none of the authors have any competing interests in the manuscript.

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