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RESEARCH ARTICLE

Variation of Al concentrations depending on the growing environment in some indoor plants that used in architectural designs

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Abstract
Today, most of people's time is spent indoors. Air pollution indoors is much higher than outdoors. Therefore, the effect of indoor air on human health is much more than the outside air. One of the most effective methods of reducing indoor air pollution is the use of plants. However, in order for the plants to be used effectively for this purpose, it is first necessary to determine which plants are the most effective in reducing which pollutants. Within the scope of this study, the Al accumulation potential of seven ornamental plants, which are frequently used in interior architectural designs, was evaluated. Within the scope of the study, the variation of Al concentrations on the basis of species and environment was determined in plants grown in control, smoking environment, and traffic environment. As a result of the study, it was determined that Al concentrations changed statistically significantly both on the basis of environment and species, and the species with the highest Al accumulation potential was difenbahya.

Keywords Aluminum · Cigarette · Heavy metal · Indoor plant · Traffic

Introduction

In the modern world, atmospheric conditions continue to deteriorate every year due to pollution caused by various sources, especially industries and automobiles (Cetin et al. 2019a, b). Although air is an indispensable resource for life, many people are unaware of the seriousness of air pollution. However, air pollution, which causes significant changes in the composition of the atmosphere, is one of the most important factors threatening human health, as well as having radically changing effects on life in the world such as climate change (Varol et al. 2021a; Cetin 2019; Cetin et al. 2020; Cantürk and Kulaç 2021; Elsunousi et al. 2021; Cetin et al. 2022a, b). According to the World Health Organization (WHO), approximately 90% of the population worldwide now breathes polluted air, and air pollution is the cause of death of approximately 7 million people each year (Varol et al. 2022a, b; Ghoma et al. 2022).

Air pollution is a more serious problem, especially indoors. About 90% of the time of modern society is spent indoors, and studies show that indoor air is 100 times more polluted than outdoors (Cetin et al. 2017a, b; Yao et al. 2020). Because people spend most of their time indoors, indoor air has a much greater impact on human health than outdoor air (Jo et al. 2020).

One of the most effective methods of reducing indoor air pollution is the use of plants. Plants are the most important living groups in the world and form the basis of the food pyramid. Therefore, life on Earth is largely dependent on plants, directly or indirectly (Yigit et al. 2021; Ozel et al. 2021a, b). Plants also fulfill many ecological, economic, and social functions (Ozkazanc et al. 2019; Yucedag et al. 2019; Ertugrul et al. 2021). Studies show that plants reduce all kinds of air pollution (Cetin et al. 2021).

In order for plants to be used effectively in reducing air pollution, it is first necessary to determine which plant is more suitable for the reduction of which pollutants. Within the scope of this study, the Al accumulation potential of

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some plants, which are frequently used as indoor plants in the world and as ornamental plants in landscaping in tropical climates, were evaluated.

Materials and methods

Within the scope of the study, it was determined that the individuals of camel sole (DT), difenbahya (DB), drasena (DC), rubber (KC), chiefsera (SF), spatiphyllium (SP), and yukka (YK) plants, which are frequently used as indoor plants, grown in different environments. Deposition potentials were tried to be determined. Within the scope of the study, first of all, plants suitable for the purpose of the study were obtained. These plants were selected from plants that continued their normal development in pots with a diameter of 30 cm. The plants subject to the study were placed in three different environments:

a) Control environment; an environment that is suitable for growing indoor plants, does not receive direct sunlight, but is bright,
b) Smoking environment; suitable for growing indoor plants, but where at least 10 cigarettes a day are smoked,
c) Traffic environment; it was chosen as the curbside environment at a distance of approximately 2 m from the main road with continuous vehicle traffic, and the plants were placed in the last week of May.

The plants were grown in the mentioned environments for three months by performing regular weekly irrigation and maintenance operations. Then, leaf samples were taken from the plants in the first week of September and brought to the laboratory. Al concentration in leaf samples was determined with the help of the ICP-OES device, with the method used in many studies (Aricak et al. 2019; Cetin et al. 2020; Cesur et al. 2021, 2022). The obtained data were evaluated with the analysis of variance and Duncan test using the SPSS package program.

Results

Within the scope of the study, the variation of the Al concentration in plants grown in different environments was determined on the basis of species, and the average concentration values, the F value obtained as a result of the variance analysis and the error rate and the groups formed as a result of the Duncan test are given in Table 1.

When the table values are examined, it is seen that the variation of Al concentration on the basis of species in all environments has changed at a statistically significant level (at least $p < 0.01$) as a result of the analysis of variance. The lowest value was obtained in the DT type with 34.15 ppm in the species grown in the control environment, while the highest value was obtained in the DB type with 70.20 ppm. It is seen that the values obtained in other species are 41.97 ppm in DC, 51.13 ppm in SP, 52.73 ppm in YK, 56.62 ppm in KC, and 58.96 ppm in SF, in ascending order. As a result of the Duncan test, each of the species formed a separate group.

Table 1 Variation of Al concentration (ppm) by species

Species	Environment			Average
	Control	Cigarette	Traffic	
DT	34.15 a	21.36 a	17.23 a	24.24 a
DB	70.20 g	43.27 e	35.45 d	49.64 c
DC	41.97 b	22.91 b	21.21 a	28.69 ab
KC	55.62 e	25.69 c	28.08 c	36.46 ab
SF	58.96 f	31.76 d	29.79 c	40.17 bc
SP	51.13 c	31.85 d	25.83 bc	36.27 ab
YK	52.73 d	34.61 e	26.62 bc	37.98 bc
F value	2479.012	956.313	8.414	3.802
Error	0.000	0.000	0.001	0.003

While the lowest Al concentration was obtained in the DT type with 21.36 ppm in the smoking environment, it was followed by DC with 22.91 ppm, KC with 25.69 ppm, SF with 31.76 ppm, and SP with 34.82 ppm, respectively. The highest Al concentrations in smoking environments were obtained in DB with 43.27 ppm and in QC with 34.61 ppm. As a result of Duncan test, SF and SP grown in smoking environments formed the fourth group, while each of the other species formed a separate group.

On the other hand, the lowest Al concentration was obtained in the DT species with 17.23 ppm in the plants grown in the environments with traffic, while the next lowest values were obtained in DC with 21.21 ppm, SP with 25.83 ppm and YK with 26.62 ppm, respectively. As a result of the KC and SP Duncan test from these species, each of the other species, which were included both in the same group and in the second and third groups, formed a separate group. The highest values were obtained in DB with 35.45 ppm, SF with 29.79 ppm and KC with 28.08 ppm in plants grown in environments with traffic, and KC and SF were in the same group as a result of Duncan test.

When the average of the values in all three environments is taken, it is seen that the species are collected in only three groups as a result of the Duncan test. According to the mean values, DT (24.24 ppm) with the lowest Al concentrations is only in the first group, and DB with the highest value is only in the last group, while DC (28.69 ppm), KC (36.46 ppm) and SP (36.27 ppm) were in the first two groups, while SF (40.17 ppm) and YK (37.98 ppm) were in the last two groups. It is noteworthy that the lowest Al concentrations were obtained in DT species and the highest Al concentrations were obtained in DB species in all environments and according to the average values.

The graph showing the variation of Al concentration by species in different environments is given in Fig. 1

Within the scope of the study, the changes in the concentrations of Al in each species on the basis of the environment were determined separately, the average concentration values, the *F* value obtained as a result of the variance analysis and the error rate and the groups formed as a result of the Duncan test are given in Table 2.

When the variation of the Al concentration on the basis of the environment is examined, it is seen that the change on the basis of environment is statistically significant at the 99.9% confidence level, both in all species and according to the average values. When the mean values and the groups formed as a result of the Duncan test are examined, it is noteworthy that all the values obtained in the traffic environment are in the first group as a result of the Duncan test. The values obtained in the smoking environment for DC, KC, and SF types were also included in the first group as a result of the Duncan test. The highest values in all species were obtained in the control environment. The graph showing the variation of the Al concentration on the basis of the medium is given in Fig. 2.

Table 2 Change of Al concentration (ppm) by medium

Species	Environment			*F* value	Error
	Control	Cigarette	Traffic		
DT	34.15 c	21.36 b	17.23 a	153,598	0.000
DB	70.20 c	43.27 b	35.45 a	139,110	0.000
DC	41.97 b	22.91 a	21.21 a	134,359	0.000
KC	55.62 b	25.69 a	28.08 a	189,351	0.000
SF	58.96 b	31.76 a	29.79 a	142,660	0.000
SP	51.13 c	31.85 b	25.83 a	134,043	0.000
YK	52.73 c	34.61 b	26.62 a	133,005	0.000
ORT	52.11 b	30.21 a	26.31 a	56,900	0.000

Discussions

Within the scope of the study, the variation of Al concentration in some plants grown in different environments on the basis of species and habitat was determined. Al, the element that is the subject of the study, is one of the important and common heavy metals, and as with every heavy metal, it creates a toxic effect when taken in high concentrations and brings serious health problems with it (Teyin and Nizamlıoğlu 2020). Aluminum causes allergic effects in the body and Alzheimer's

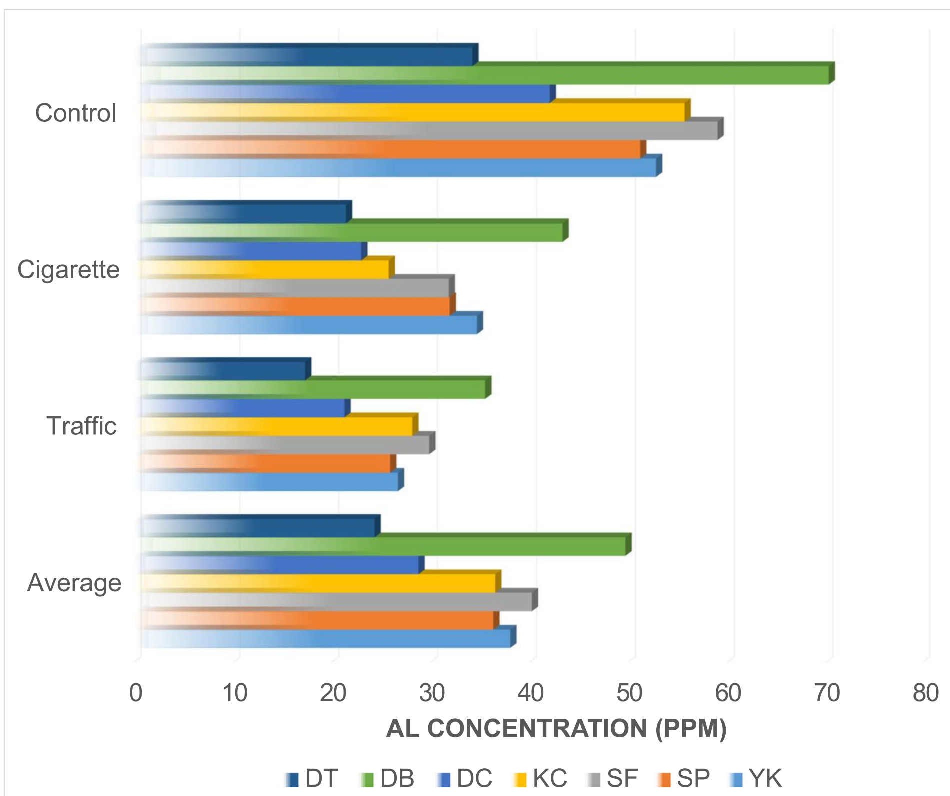

Fig. 1 Variation of Al concentration (ppm) by species

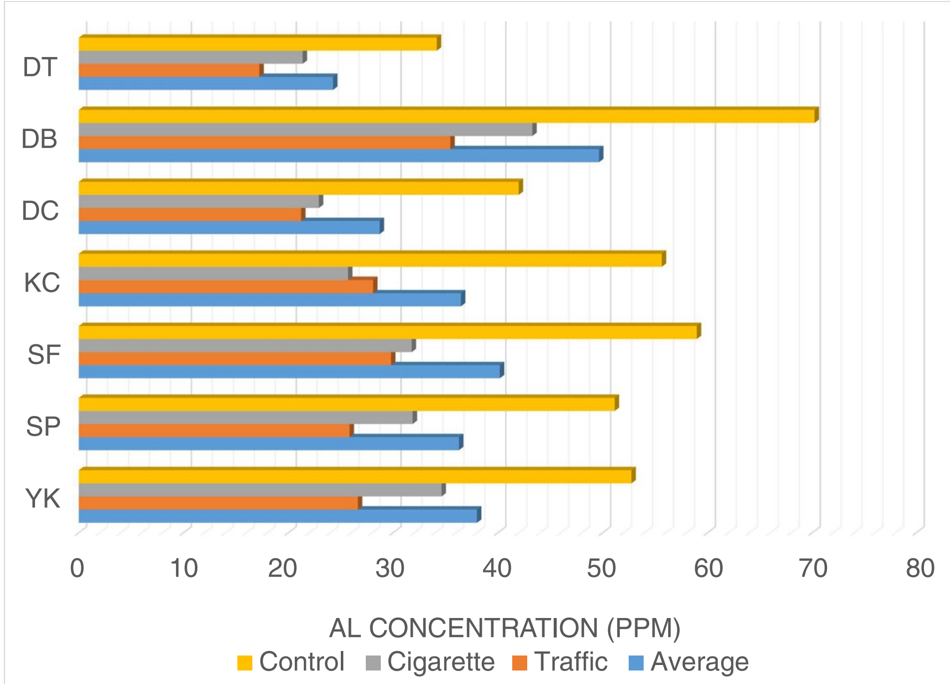

Fig. 2 Variation of Al concentration (ppm) by medium

disease by affecting the neurological system (Çelik 2014). Due to its widespread availability, Al is one of the most studied elements. Studies show that the Al concentration varies significantly depending on the species and growing environment (Hmeer 2020). In addition, it has been determined that the Al concentration varies significantly depending on the organ and organ age in plants (Çobanoğlu 2019).

Al is one of the important heavy metals. Heavy metals are the elements emitted into the atmosphere mainly from mining activities, industry and traffic (Ucun Ozel et al. 2019; Alaqouri et al. 2020a, b). Studies show that many of the heavy metals can be toxic, poisonous and lethal even at low concentrations (Turkyilmaz et al. 2018a, b; Aricak et al. 2020), and that even those that are necessary as nutrients for living things are harmful at high concentrations (Isinkaralar et al. 2022; Tekin et al 2022; Savas et al. 2021). Heavy metals are included in the priority pollutant list of the “Agency for Toxic Substances and Disease Registry” (ATSDR) because they are toxic to living organisms at high concentrations. Silver (Ag), aluminum (Al), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), palladium (Pd), plutonium (Pu), antimony (Sb), selenium (Se), strontium (Sr), thallium (Tl), thorium (Th), uranium (U), vanadium (V), and zinc (Zn) are these elements (Badea et al. 2018).

Heavy metals are elements that have been studied extensively due to their importance for human and environmental health. In order to monitor the changes in the concentrations of heavy metals in the air and to reduce heavy metal pollution, it is necessary to separately determine which heavy metals are accumulated more intensely by which plants (Koç 2021a). Therefore, many studies have been conducted on the accumulation levels of different heavy metals in various plants (Sevik et al. 2019a, b; Turkyilmaz et al. 2020; Isinkaralar 2022a, b). In the studies, it was tried to determine the plants with the highest capacity to accumulate each heavy metal.

Heavy metal accumulation in plants can be from roots or airborne leaves. There are many factors that affect the entry and accumulation of heavy metals in the plant body (Turkyilmaz et al. 2019). The most important of these factors is environmental conditions. Because plant development and all phenotypic characters are shaped by the mutual interaction of genetic structure (Sevik et al. 2012; Güney et al. 2019a, b) and environmental factors (Yigit et al. 2019; Koç 2021b, c; Varol et al. 2021b). One of the most important environmental factors is climatic (Sevik et al. 2016; Cetin et al. 2018a, b, 2022a, b). Heavy metals in the air can both adhere to the leaf surface and enter the plant through stomata (Karacocuk et al. 2022; Ghoma et al. 2022). Therefore, it is stated that leaves are the most suitable organs to be used for monitoring heavy metal pollution in the air (Sevik et al. 2020a, b; Cetin and Jawed 2021, 2022). The design of indoor plant used in the reach showing in Fig. 3.

Fig. 3 Design of indoor plants

Conclusions

Within the scope of this study, the change of Al concentration in seven plants was determined. The plants that are the subject of the study are plants that can be easily grown in pots, are very easy to grow and reproduce, and are fast in development. Therefore, they can be used effectively in reducing heavy metal pollution, especially in indoor environments. As a result of the study, it was determined that the species with the highest Al accumulation capacity was difenbahya. Therefore, difenbahya can be used effectively to reduce Al pollution in the air in areas with high Al pollution.

Within the scope of the study, it was determined that the Al concentrations determined in most of the plants in the smoking environments were higher than the concentrations in the plants grown in the areas with heavy traffic. This result shows that heavy metals such as Pb, Co, and Cd, which are extremely dangerous for human health, can also accumulate in high concentrations due to smoking. Therefore, it is recommended to carry out comprehensive studies on heavy metal accumulation due to smoking, especially indoors.

Heavy metals in the air enter the plant body mostly through the leaves. Therefore, it is stated that leaves are the most suitable organs to be used for monitoring air pollution. In addition, leaves are the most suitable organs that can be used to reduce heavy metal pollution in the air. Therefore, it is recommended to concentrate studies on the subject, especially on broad-leaved species.

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Authors' contributions MC and AESAA designed the study and performed the experiments. AESAA and MC performed the experiments, analyzed the data and wrote the manuscript. All authors read and approved the final manuscript.

Data availability 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 All authors declare that they have no competing interests.

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