Journal of Ankara Studies ▪ *Ankara Araştırmaları Dergisi*

Refereed Article ▪ *Hakemli Makale*

Received \ Geliş tarihi : 28.12.2022
Accepted \ Kabul tarihi: 31.05.2023

A Statistical Analysis of Traffic-Related Pollution and City Center Dynamics in Ankara: The Cases of Ulus and Kızılay

Ankara'nın Kent Merkezi Dinamikleri ve Trafiğe Bağlı Kirliliklerin İstatistiki Analizi: Ulus ve Kızılay Örnekleri

Öznur IŞINKARALAR

PhD., Kastamonu University, Faculty of Engineering and Architecture, Department of City and Regional Planning, Kastamonu, Türkiye
Dr., Kastamonu Üniversitesi, Mühendislik ve Mimarlık Fakültesi, Şehir ve Bölge Planlama Bölümü, Kastamonu, Türkiye
ORCID ID 0000-0001-9774-5137
obulan@kastamonu.edu.tr

Hakan ŞEVİK

Assoc Prof., Kastamonu University, Faculty of Engineering and Architecture, Department of Environmental Engineering, Kastamonu, Türkiye
Doç. Dr., Kastamonu Üniversitesi, Mühendislik ve Mimarlık Fakültesi, Çevre Mühendisliği Bölümü, Kastamonu, Türkiye
ORCID ID 0000-0003-1662-4830
hsevik@ kastamonu.edu.tr

DOI: 10.5505/jas.2023.38258

Abstract

Urban pollution, which reduces the quality of life of residents and poses a vital threat to human health, can be reduced by effective city planning. Pollution due to heavy metals is increasing in today's cities, and these heavy metals are of particular concern because as they do not naturally decompose on earth, they can bioaccumulate in the human body and cause serious diseases. It is, however, possible to reduce exposure to pollutants through making spatial decisions.

The research aims to determine the variation of concentrations of Mn by location, which is greatly affected by the poor air quality caused by traffic density. Within the scope of the study, the following species were analyzed: Robinia pseudoacacia, Platanus orientalis, Acer negundo, Fraxinus excelsior, Ailanthus altissima, Aesculus hippocastanum, and Tilia tomentosa. Samples were taken from Ulus, the traditional center of the political capital of Ankara, and Kızılay, its modern center. Although the two areas of research are close to each other, the traffic density had increased due to the current planning decisions in Kızılay, while Ulus was chosen as a region with relatively low vehicle density due to its historical structure. It was found that four wood species have higher values in their leaves and wood, and five wood species have higher values in their bark in the Kızılay region, as compared to Ulus. This demonstrates that motor vehicles have a significant effect in Kızılay. In addition, the values of the leaves and bark of the same wood are higher in Kızılay than Ulus. It has therefore been determined that A.negundo and F. excelsior are suitable species for use in urban planting design to monitor the concentrations of heavy elements in the air.

Keywords: City centers, Land use, Environmental pollution, Urban geography, Biomonitoring, Traffic, Ulus, Kızılay, Ankara

Öz

Kentsel çevresel kirlilik, şehir planlamanın müdahale alanlarından biri olup kentlinin yaşam kalitesini düşüren ve insan sağlığı için hayati tehdit oluşturan bir sorundur. Kirlilik kaynaklarından biri olarak ağır metaller, günümüz kentlerinde insan faaliyetleri sonucunda artmaktadır. Ağır metaller, yeryüzünde bozulmazlar ve insan vücudunda biyolojik olarak birikerek hayati hastalıklara *neden olabilirler. Bu noktada mekânsal kararlar, insanların kirleticilere maruziyet düzeyini etkileyebilecek müdahale biçimleridir. Araştırma, trafik yoğunluğu nedeniyle bozulan hava kalitesinden büyük ölçüde etkilenen Mn konsantrasyonlarının konuma göre değişimini belirlemeyi amaçlamaktadır.*

Çalışma kapsamında, Robinia pseudoacacia, Platanus orientalis, Acer negundo, Fraxinus excelsior, Ailanthus altissima, Aesculus hippocastanum ve Tilia tomentosa türleri analiz edilmiştir. Politik bir kararla başkent olan Ankara'nın geleneksel merkezi Ulus ile modern merkezi olan Kızılay'dan örnekler alınmıştır. Araştırma alanlarının birbirine yakın olmasına rağmen Kızılay'ın mevcut plan kararlarından sonra trafik yoğunluğu artmış ve Ulus, tarihî yapısı nedeniyle araç yoğunluğunun görece düşük olduğu bir bölge olarak seçilmiştir. Çalışma sonuçları, Kızılay bölgesinden alınan örneklerde Mn birikiminin Ulus'a göre genel olarak daha yüksek olduğunu ve Kızılay'da motorlu taşıtların etkisinin yüksek olduğunu ortaya koymaktadır. Ayrıca Ulus'ta aynı bitkinin yapraklarındaki, Kızılay'da ise kabuğundaki değerlerin daha yüksek olduğu görülmüştür. A. negundo ve F. excelsior türlerinin, havadaki ağır elementlerin konsantrasyonlarını izlemek için kentsel bitkilendirme tasarımında kullanılabileceği tespit edilmiştir.

Anahtar sözcükler: *Kent merkezleri, Arazi kullanımı, Çevre kirliliği, Kent coğrafyası, Biyoizleme, Trafik, Ulus, Kızılay, Ankara*

Introduction

The United Nations estimates that by 2050, 32% of people will live in rural areas, and 68% in urban (United Nations, 2019). Clearly this growth in population will affect urban development (Chen et al., 2021), in which correct site selection for urban uses, as well as careful planning of usage decisions, are essential to ensure the quality of life of a city's residents (Işınkaralar ve Varol, 2021). One important area of concern when managing the needs of the increasing population in urban areas (Öztürk and Işınkaralar, 2019) is the subsequent high density of motor vehicles in cities. An intensive use of fossil fuels, as well as dealing with unplanned and uncontrolled urbanization, causes various, and often very complex, problems (Isinkaralar, Varol and Yilmaz, 2022). Factors such as construction, the application of inappropriate and insufficient energy generation techniques, and a reduction in forests and other forms of open and green areas, can all be a cause of environmental problems (Eguiluz-Gracia et al., 2020; Umar et al., 2021; Roelich, 2019). Furthermore, environmental problems do not remain at the local and regional scale, they also contribute to national and global problems such as climate change and global warming (Ren et al., 2022; Pee and Pan, 2022). Air pollution is therefore a priority environmental problem in developing and transitioning economies in urban areas (Amiraslani, 2022; Lillio et al., 2022; Cassita and de Oliveira David, 2022; Pal et al., 2022), and poses a danger and risk to not only people, but all living things (Pajewska-Szmyt, 2019; Saravanan et al., 2021).

Heavy metals are one of the most dangerous pollutants for humans (Liu et al., 2019; Mehana, 2020; Pratush et al., 2018), and there has been a remarkable increase in the variation of heavy metal accumulation in air, water, and soil (Kumar and Khan 2021). Heavy metals do not naturally compose on earth and are not easily changed. When they are taken from the external environment by living organisms, they mainly bind to proteins and show physical storage behavior within cells (Briffa et al., 2020; Liu et al., 2021; Zhang, 2019). The amount of exposure and the person's characteristics can be the cause of many different illnesses (Bariffa, 2020). Including a wide variety of infectious and non-communicable diseases. These include respiratory diseases and allergies, which can be extremely life-threatening (Maio et al., 2022), even to necessary living organisms (Vardhan et al., 2019). Plants and woods can be particularly beneficial for their ability to reduce heavy metal pollution by absorbing heavy metals in soil, water, and air. (Arıcak et al., 2019; Asgari Lajayer, 2019). It is for this reason, that many studies have been carried out on removing heavy metal accumulation from industrial activities and its natural structure (Yıldız et al., 2018; Awa and Hadibarata, 2020; Dhaliwal, 2020; K. Isinkaralar, O. Isinkaralar and Sevik, 2022).

There are several factors involved in the extremely important issue of air quality. These include: the interventions of the planning discipline, the complexity and cost of data acquisition (Idrees, 2018; Liu et al., 2018), and many economic-based planning goals that have not been adequately researched (Collins, 2020; Musse, 2018). In this context, this study is concerned with:

- Determining the levels of Mn, which is known to be related to traffic density, and the reasons for their accumulation, in Kızılay and Ulus.

- Analysis of the suitability of possible species for use in biomonitoring,
- Determination of the accumulation levels in different organs of the species.

In line with the determined purposes, air quality was measured in the city of Ankara through biomonitoring. It was determined whether these woods could be used effectively or not by analyzing the Mn accumulation in the leaves, bark, and wood of different species.

Materials and Methods

Sampling Area

Urbanization is the most fundamental cause of air pollution in developing countries (Wu et al., 2020). Due to the rapid disintegration of rural areas in the post-republican period, population growth in urban areas, and unplanned construction, the spatial structure of Ankara has changed (Hosanlı and Resta, 2021). The city of Ankara is located in the middle latitude region between latitudes 38°33'N and 40°47'N and longitudes 30°52'E and 34°06'E, as depicted in Figure 1 (Atıcı et al., 2020).

Ankara became the capital of Türkiye in 1923, and is one of the country's most populated cities. The choice of Ankara for the capital was not due to the city's internal dynamics, but because of political reasons. However, being chosen as the capital activated a process of socio-spatial change, in addition to economic and political dimensions (Demiröz and Güçhan, 2021; Gökçe and Chen, 2019).

The rapidly increasing number of public buildings and the settlement of these government employees in the city,

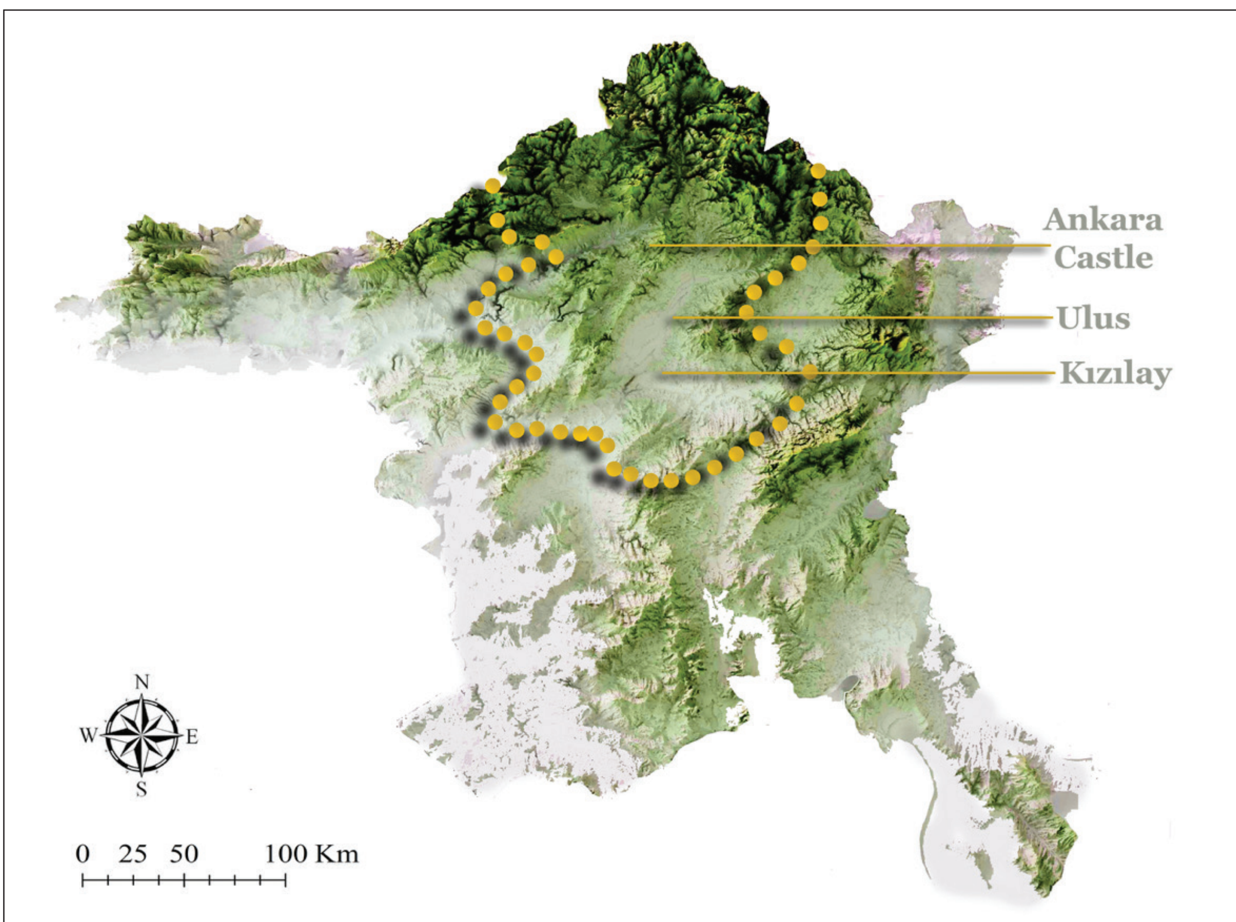

Figure 1. Location of the area studied.
Source: Created by the authors.

greatly complicated the process of urban planning (Ozlu-Diniz and Kasapoglu, 2021). The traditional city center has been exposed to population, construction, and traffic pressure due to the housing problem caused by migration. In the study, samples were first taken from Ulus and Kızılay to represent the accumulation levels. The research area is concave due to its topographic structure (Figure 2), with high-rise buildings reducing the effect of the prevailing wind.

Samples were collected from Kızılay, the post-Republican center of the city, which connects Ulus and Atatürk Boulevard, which is the historical center of the town, and Çankaya, which is located on the outskirts of Ankara Castle. It can therefore be stated that the examples were taken from the axis and its surroundings, which constitute the traditional and modern centers of a metropolitan city. The main materials of the study are *Robinia pseudoacacia* (RP), *Platanus orientalis* (PO), *Acer negundo* (AN), *Fraxinus excelsior* (FE), *Ailanthus altissima* (AA), *Aesculus hippocastanum* (AH) and *Tilia tomentosa* (TT). These species were selected to investigate their usability as possible bioindicators (Figure 3). As heavy metals accumulate in plants as well as in all living things, it is very difficult to identify the exact sources of pollution. However, the usability of woods in monitoring for comparison purposes and providing quantitative information on environmental quality in areas where externalities are similar has been demonstrated by many studies (Markert et al., 2003; Madejón et al., 2006).

Analysis Procedure

The research consists of five primary stages that are depicted in Figure 4: collecting the woods, drying, decomposition, calibrating the values, and reading the measurements. Approximately 25-30 cm of branch samples were taken during the collection stage. Care was taken to collect the branch samples at the end of the growing season. The samples were placed in sealed bags to reduce contact with the air as much as possible, and then taken to the laboratory for research. Depending on the purpose of the study, the leaves, bark, and other parts of the tree, were separated for examination. All experiments were

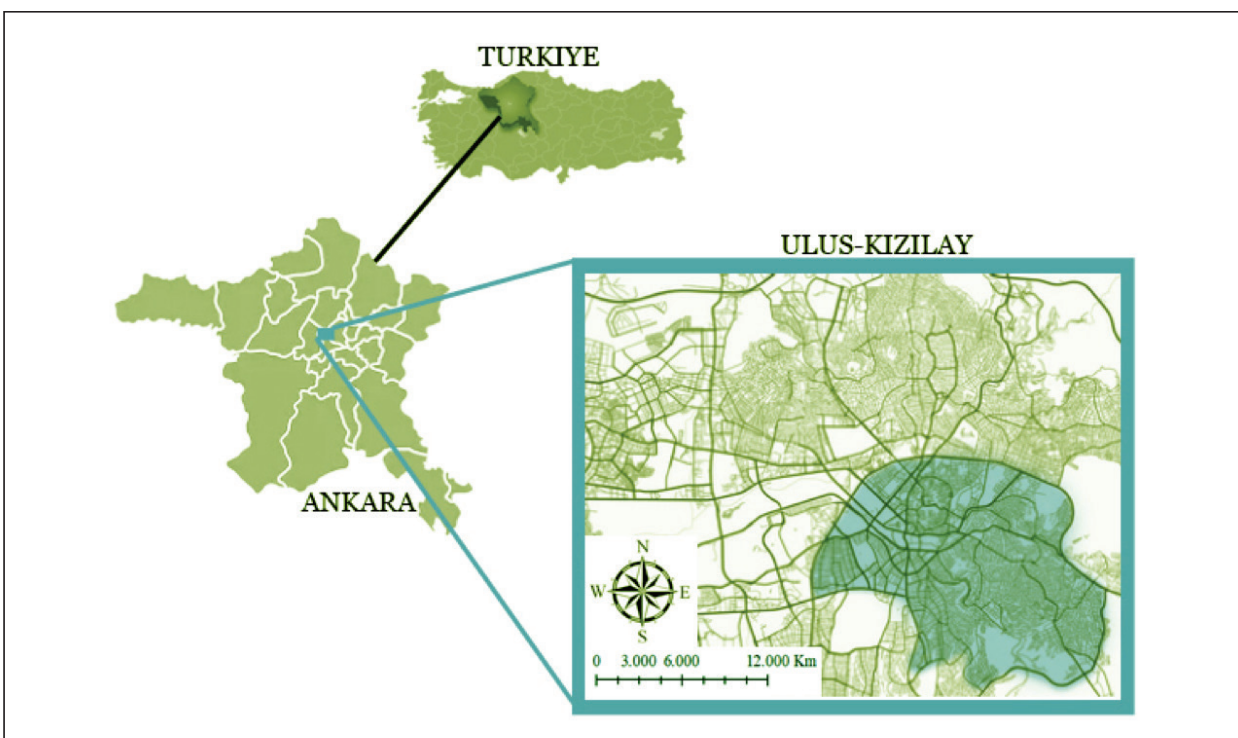

Figure 2. Topographic structure of the area studied.
Source: Created by the authors.

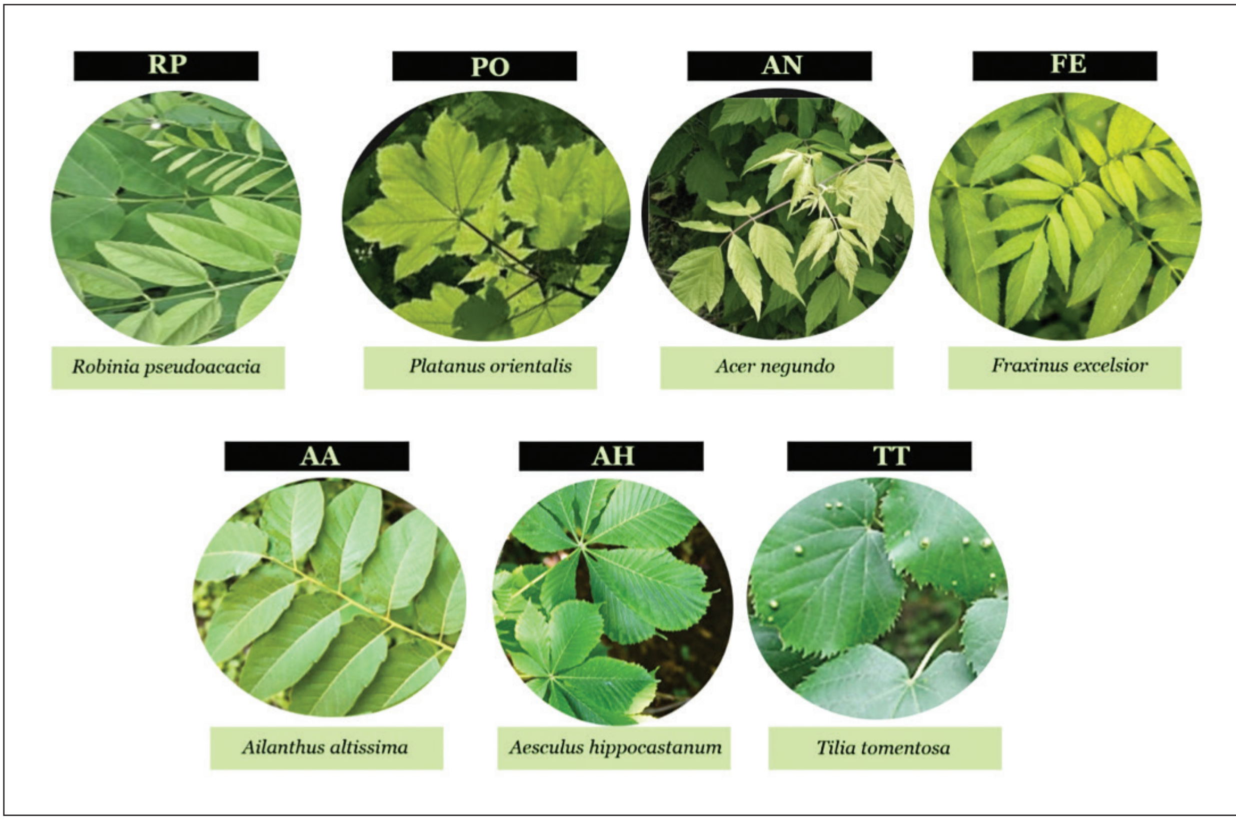

Figure 3. Abbreviations of selected species.
Source: Created by the authors.

validated using the limit of detection (LOD), the limit of quantification (LOQ), and the relative standard deviation (RSD). The blank method was used to specify the LOD and LOQ values of 0.00 - 0.02 ppb.

The samples were placed into glass tubes for preparation analysis. They were first put into a heat controller oven at a temperature of 60 °C for 15 days without any contamination until it was certain that all humidity had been removed from the samples. 0.5-g portions were separated for the acid digestion process and impregnated by pouring 6 mL of 65% and 2 mL of 65% HNO_3. As stated in the USEPA 3052 Method, the samples were stabilized at 200 °C at a heating rate of 15 °C/min for 15 minutes while using a microwave (Millstone Ethos One) oven, and then a microwave-based digestion system step was applied (Method 3052, 1996). The dissolved samples were then placed into volumetric flask. Mn values of the samples were determined with the GBC Integra XL-SDS-270 ICP-OES device and a five-point calibration curve was used at concentrations of 0.02-200 μg/mL. Distilled water was added until the levels of the samples were 50 mL before being placed in the instrument. Before initiating the calibration process, the plasma of the ICP-OES device was first matched. For the device to again reach equilibrium, ultrapure water was passed through it for 15 minutes. Calibration curves were drawn with a value of R^2:0.99 standard solutions of Mn concentration. Since this is widely preferred as an indicator in traffic-based studies (Karacocuk et al., 2022), it was chosen to measure Mn concentrations. After the calibration lines were created, the samples were placed in the device, and the values were obtained three times to validate the result. Measurements with high deviation were renewed. Since the mass value (0.5 g) used at the beginning was completed to calculate the result concentration, the results obtained were multiplied by 100 to achieve normalization was achieved. Analysis of variance was applied to the obtained data with the help of the SPSS package program.

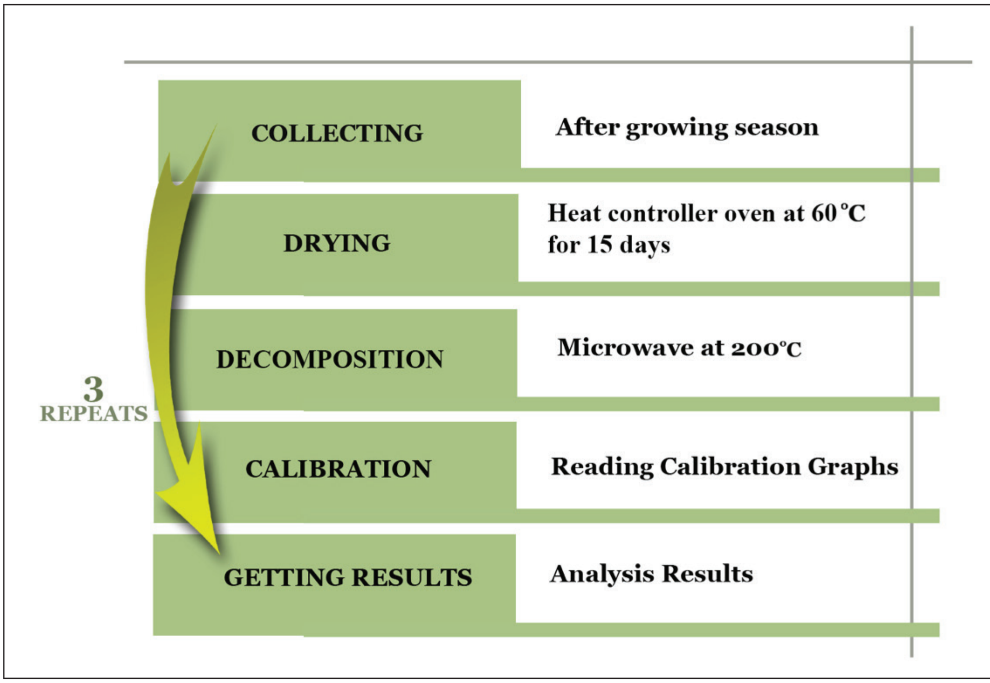

Figure 4. Stages of the experimental process. Source: Created by the authors.

Homogeneous groups were obtained using the Duncan test for the factors in which statistically significant differences existed to achieve at least a 95% confidence level (*$p<0.05$). The data was then simplified and interpreted by being added to the tables.

Results

Results are given below in Table 1. The mean values of the Mn concentration selected in the study are based on species and organs, while the F value is obtained from the analysis of variance, the error rate, and the groups formed as a result of the Duncan test.

As a result of the analysis of variance, it was determined that the change in Mn concentration in all species and all organs based on species was statistically significant (***$p<0.001$). When the data is examined, it is seen that the lowest values in organs were obtained in wood in all species except *P. orientalis* and *A. altissima*. The highest values were obtained in the leaves in *A. negundo* and *A. altissima* and the bark in other species. When the changes based on species are examined, the lowest value in the leaves is *P. orientalis*; the highest value is in *A. altissima*, the lowest value in *T. tomentosa*, the highest value in *A. hippocastanum*, the lowest value in *R. pseudoacacia*, and the highest value in *A. altissima* in wood. The variation of Mn concentration based on species and organs according to samples taken from locations close to the Ulus region is given in Table 2.

As a result of the analysis of the variance of the samples taken from the area close to the Kızılay region, it was determined that the change in Mn concentration in all species and all organs was statistically significant (***$p<0.001$). The lowest values in organs are obtained in wood in all species except *P. orientalis* and *A. altissima*. The highest values are in wood in *A. altissima* in the bark at *P. orientalis* and *T. tomentosa*, while in all other species, the highest values were obtained in leaves. When the changes based on species were examined, the lowest value was obtained in *T. tomentosa*, the highest value in *A. negundo*, the lowest value in *A. altissima*, the highest value in *A. negundo* in bark, the lowest value in *F. excelsior*, and the highest value in *A. altissima* in wood. When the samples taken from different parts of the city are compared, the accumulation in the leaves of *F. excelsior*, *A. hippocastanum*, *A. altissima* and *T. tomentosa*, in the bark of *R. pseudoacacia*, *F. excelsior*, *A. hippocastanum*, *A. altissima* and *T. tomentosa*, and in the woods of *R. pseudoacacia*, *F. excelsior*, *A. hippocastanum*, and *T. tomentosa* from the Kızılay region is higher than the average values in Ulus, and it is significantly high.

Table 1. *Values of Mn Concentrations (ppb) in Ulus by Species and Organs*

Species	Leaf	Bark	Wood	F value
RP	12709.1 eC	6776.5 eB	398.9 aA	10215.006***
PO	2894.2 cA	25468.9 fC	17150.7 eB	63597.274***
AN	82626.2 gC	57040.5 gB	8567.1 dA	79543.426***
FE	5637.4 dC	2563.7 dB	377.3 aA	13467.600***
AA	43970.2 fB	822.8 aA	95601.1 fC	670401.490***
AH	2330.5 bC	1320.3 bB	1043.5 bA	2071.927***
TT	1352.2 aB	1650.8 cC	1218.9 cA	131.795***
F value	212215.087***	81023.825***	584643.658***	
Robinia pseudoacacia (RP), *Platanus orientalis* (PO), *Acer negundo* (AN), *Fraxinus excelsior* (FE), *Ailanthus altissima* (AA), *Aesculus hippocastanum* (AH) and *Tilia tomentosa* (TT)				

Note: Uppercase letters show a horizontal direction, whereas lowercase letters indicate vertical directions.
***significant at 0.001 level

Table 2. *Values of Mn Concentrations (ppb) in Kızılay by Species and Organs*

Species	Leaf	Bark	Wood	F value
RP	10789.0 cB	10986.5 cB	1672.5 aA	6877.455***
PO	1824.3 aA	11471.9 dB	11626.2 eC	21319.000***
AN	31247.1 fC	20457.3 fB	3117.2 dA	49441.455***
FE	16683.3 eB	16733.7 eC	1784.1 aA	100131.500***
AA	66666.3 gC	9160.5 bA	38576.2 fB	26572.607***
AH	14225.2 dB	25367.0 gC	2212.3 cA	45177.875***
TT	2743.3 bB	3865.4 aC	2074.0 bA	2251.000***
F value	40191.767***	15090.808***	102079.510***	
Robinia pseudoacacia (RP), *Platanus orientalis* (PO), *Acer negundo* (AN), *Fraxinus excelsior* (FE), *Ailanthus altissima* (AA), *Aesculus hippocastanum* (AH) and *Tilia tomentosa* (TT)				

Note: Uppercase letters show horizontal direction, whereas lowercase letters indicate vertical directions.
***significant at 0.001 level

Discussion

Urban processes occur through interaction within a multidimensional, complex, and dynamic structure (Isinkaralar and Varol, 2023). It is impossible to make inferences about the dependent variable by preparing the urban internal and external dynamics under similar conditions, as in an experimental setup. The analysis of urban pollutants is complicated, especially since weather studies are extremely vulnerable to external factors, such as forms of urban settlement and natural elements.

All processes affecting cities also influence air quality. After 1980, due to the effect of neoliberal policies, consumption habits changed, and public spaces and commercial activities shifted to the periphery. It is now accepted that the functions in the city center have become decentralized. However, while low-carbon city centers are targeted in developed countries (Wu et al., 2018), the main arteries that have been enlarged over the years for the flow of vehicular traffic in Kızılay have fragmented the pedestrian zones and encouraged the use of private vehicles. As a result, open spaces have emerged that have moved away from their role as a square, and Kızılay has lost its former significance and turned away from being a socio-political center and turned into a traffic intersection (Sarıkahya and Tuğral, 2022; Topal et al., 2019). There is no doubt that air quality has been adversely affected due to the increase in the use of motor vehicles, the limitation of the city's air corridor, which can be said to be in the form of a bowl, as well as adjacent-order construction due to the topographic structure of the town.

Past studies have demonstrated that the air pollution level of Ankara varies significantly due to the large area of the city (Yildiz et al., 2008). For this reason, centers that are thought to have similar external conditions, but differ relatively in terms of traffic, were selected for analysis. Many studies have determined that different heavy metals are more concentrated in other plants and species (K. Isinkaralar, O. Isinkaralar and Sevik, 2022; Isinkaralar, 2022a; Mahapatra et al., 2019), and in the related literature, traffic is one of the essential heavy metal sources (Çetin et al., 2020; Shahid et al., 2017) Turkyilmaz et al. (2018) investigated the usability of *T. tomentosa, E. angustifolia, P. cerasifera,* and *A. altissima* as traffic-dependent bioindicators. The amount of Pb measured in other species grown in areas with heavy traffic was found to be high. Using *Abies* ' Needles, Cetin et al. (2021) investigated the relationship of Ba concentration with organ, organ age, and traffic density and found a significant correlation. Past trends of Pb and Cd concentrations, *Cedrus atlantica* (Endl.) Manetti ex Carrière have followed the wet and dry accumulation of emissions of their levels (Isinkaralar, 2022b). It was determined, using the chosen type as a bioindicator, that the amount of lead decreased in parallel with the widespread use of unleaded gasoline in the tree ring over the years.

This paper investigation of Mn accumulation in plants, contributes to the many studies about heavy metals (Yildiz et al., 2011; Isinkaralar, 2022c). Savas et al. (2021) investigated the potential of using *C. atlantica* at Cr and Mn concentrations. The research results showed that their concentrations are relatively high in the east and north directions, where the traffic is heavy. This paper measured the Mn values of *C. atlantica* between 1929 and 29531.7 ppb. Igwe et al. (2022) revealed the Mn concentration in the mining area. In this research, *A. negundo* and *F. excelsior* were determined as being the most suitable species that can be used to reduce the concentrations of Mn elements in the air. In addition to plant structure and environmental factors such as plant species, the amount of rainfall and moisture, plant habitus, organ structure, heavy metal species, and interaction with the plant are also significant factors which affect the accumulation of heavy metals in the plant (Aricak et al., 2020; Sevik et al., 2020). However, the information about the structural change and displacement of heavy metals after they enter an area is minimal (Shahid et al., 2017).

Conclusion

This paper aims to increase understanding of urban air pollution in city centers and bioindicators. It also helps in the extremely complex subject, which includes many dynamics, to identify land-use selection decisions in urban planning. According to the values obtained from the plant samples taken from the area, the average values of plants brought from Kızılay are higher than Ulus. Therefore, it has been determined that using motor vehicles is an influential factor in heavy metal accumulation. While the values in the bark of the same plant were high in Kızılay, even higher values were obtained in the leaves in Ulus. This finding reflects the possibility of introduction of heavy metals from the soil or air. Research results reveal poor traffic-induced air quality in a capital's central areas that have become dilapidated and transformed into transit areas.

Monitoring heavy metals regularly in cities is of critical value in terms of spatial location selection. Determination of the pollution values in the planning of uses such as nurseries, hospitals, and rehabilitation centers used by disadvantaged groups, such as the elderly and children, is a compassionate issue in terms of health. However, it is not considered to be a criterion in planning analysis for future land use. The main reasons for this are that air values are affected by many complex dynamics, as well as the difficulties in monitoring them technically and economically. That said, an implementation of plants as indicators of pollution would create a new direction to urban planning research.

References

Amiraslani, F. (2022). Climate change and urban citizens: the role of media in publicising the conservation of green spaces and mitigation of air pollution. *Conservation, 2*(2), 219-232. https://doi.org/10.3390/conservation2020014.

Aricak, B., Cetin, M., Erdem, R., Sevik, H. and Cometen, H. (2019). The change of some heavy metal concentrations in Scotch pine (pinus sylvestris) depending on traffic density, organelle, and washing. *Applied Ecology and Environmental Research,17*(3), 6723-6734. http://dx.doi.org/10.15666/aeer/1703_67236734

Aricak, B., Cetin, M., Erdem, R., Sevik, H. and Cometen, H. (2020). The usability of Scotch pine (pinus sylvestris) as a biomonitor for traffic originated heavy metal concentrations in Türkiye. *Pol J Environ Stud. 29*(2), 1051–1057. https://doi.org/10.15244/pjoes/109244

Asgari Lajayer, B., Khadem Moghadam, N., Maghsoodi, M. R., Ghorbanpour, M. and Kariman, K. (2019). Phytoextraction of heavy metals from contaminated soil, water and atmosphere using ornamental plants: mechanisms and efficiency improvement strategies. *Environmental Science and Pollution Research*, *26*(9), 8468-8484. https://doi.org/10.1007/s11356-019-04241-y

Atıcı, R., Aytaş, A. and Sağır, S. (2020). The effect of solar and geomagnetic parameters on total electron content over Ankara, Türkiye. *Advances in Space Research*, *65*(9), 2158-2166. https://doi.org/10.1016/j.asr.2019.07.018

Awa, S. H. and Hadibarata, T. (2020). Removal of heavy metals in contaminated soil by phytoremediation mechanism: a review. *Water, Air, and Soil Pollution*, *231*(2), 1-15. https://doi.org/10.1007/s11270-020-4426-0

Briffa, J., Sinagra, E. and Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon, 6*(9), e04691. https://doi.org/10.1016/j.heliyon.2020.e04691

Cassita, M. L. C. and de Oliveira David, J. A. (2022). Historical analysis of environmental pollution in santos estuary: histological study of mytella falcata (Orbigny, 1846) gills as bioindicator. *Water, Air, and Soil Pollution, 233*(3), 1-10. https://doi.org/10.1007/s11270-022-05525-9

Cetin, M., Şevik, H., Turkyilmaz, A., and Isinkaralar, K. (2021). Using Abies's Needles as biomonitors of recent heavy metal accumulation. *Kastamonu University Journal of Engineering and Sciences*, 7(1), 1-6.

Chen, B., Wang, W., Dai, W., Chang, M., Wang, X. and You, Y. (2021). Refined urban canopy parameters and their impacts on simulation of urbanization-induced climate change. *Urban Climate, 37*, 100847. https://doi.org/10.1016/j.uclim.2021.100847

Collins, R.M., Spake, R., Brown, K. A., Ogutu, B. O., Smith, D. and Eigenbrod, F. (2020). A systematic map of research exploring the effect of greenspace on mental health. *Landscape and Urban Planning,* 201, 103823. https://doi.org/10.1016/j.landurbplan.2020.103823

Demiröz, M. and Güçhan, N. Ş. (2021). Urban conservation legacy of the Turkish planning system: tracing spatial change in the Ankara Acropolis, from 1923 onwards. *Planning Perspectives, 36*(2), 337-362. https://doi.org/10.1080/02665433.2020.1753102

Dhaliwal, S. S., Singh, J., Taneja, P. K. and Mandal, A. (2020). Remediation techniques for removal of heavy metals from the soil contaminated through different sources: a review. *Environmental Science and Pollution Research, 27*(2), 1319-1333. https://doi.org/10.1007/s11356-019-06967-1

Gokce, D. and Chen, F. (2019). A methodological framework for defining 'typological process': the transformation of the residential environment in Ankara, Türkiye. *Journal of Urban Design, 24*(3), 469-493. https://doi.org/10.1080/13574809.2018.1468215

Hosanlı, D. A. and Resta, G. (2021). Building a nation, building a modern capital city: a comparative study of Ankara's and Tirana's first master plans. *İdealkent, 12*(34), 1693-1721. https://doi.org/10.31198/idealkent.980111

Eguiluz-Gracia, I., Mathioudakis, A.G., Bartel, S., Vijverberg, S. J. H., Fuertes, E. and Comberiati, P. (2020). The need for clean air: the way air pollution and climate change affect allergic rhinitis and asthma. *Allergy, 75*(2020), 2170-2184. https://doi.org/10.1111/all.14177

Idrees, Z., Zou, Z. and Zheng, L. (2018). Edge computing based IoT architecture for low cost air pollution monitoring systems: a comprehensive system analysis, design considerations and development. *Sensors, 18*(9), 3021. https://doi.org/10.3390/s18093021

Igwe, E. O., Ede, C. O., Eyankware, M. O., Nwachukwu, C. M. and Williams, O. B. (2022). Assessment of potentially toxic metals from mine tailings and waste rocks around mining areas of Oshiri-Ishiagu region, Southeastern Nigeria. *Earth Syst Environ 6*, 597–615. https://doi.org/10.1007/s41748-022-00306-0

Isinkaralar, K. (2022a). Some atmospheric trace metals deposition in selected trees as a possible biomonitor, *Rom Biotechnol Letters 27*(1), 3225-3234, https://doi.org/10.25083/rbl/27.1/3225-3234.

Isinkaralar, K. (2022b). Atmospheric deposition of Pb and Cd in the cedrus atlantica for environmental biomonitoring. *Landscape Ecol Engineering 18*, 341–350. https://doi.org/10.1007/s11355-022-00503-z

Isinkaralar, K. (2022c). Temporal variability of trace metal evidence in cupressus arizonica, platanus orientalis, and robinia pseudoacacia as pollution-resistant species at an industrial site. *Water, Air, and Soil Pollution, 233*(7), 250. https://doi.org/10.1007/s11270-022-05743-1

Işınkaralar, Ö. and Varol, C. (2021). Kent merkezlerinde ticaret birimlerin mekânsal örüntüsü üzerine bir değerlendirme: Kastamonu örneği. *Journal of Architectural Sciences and Applications, 6*(2), 396-403. https://doi.org/10.30785/mbud.927529

Isinkaralar, K., Isinkaralar, Ö. and Şevik, H. (2022). Usability of some landscape plants in biomonitoring technique: an anaysis with special regard to heavy metals. *Kent Akademisi, 15*(3), 1413-1421. https://doi.org/10.35674/kent.1078472

Isinkaralar, O., Varol, C. and Yilmaz, D. (2022). Digital mapping and predicting the urban growth: integrating scenarios into cellular automata—Markov pajewschain modeling. *Applied Geomatics,* 1-11. https://doi.org/10.1007/s12518-022-00464-w

Isinkaralar, O. and Varol, C. (2023). A cellular automata-based approach for spatio-temporal modeling of the city center as a complex system: the case of Kastamonu, Türkiye. *Cities,* 132, 104073. https://doi.org/10.1016/j.cities.2022.104073

Karacocuk, T., Sevik, H., Isinkaralar, K., Turkyilmaz, A. and Cetin, M. (2022). The change of Cr and Mn concentrations in selected plants in Samsun city center depending on traffic density. *Landscape and Ecological Engineering 18,* 75-83. 1-9. https://doi.org/10.1007/s11355-021-00483-6

Kumar, D. and Khan E. A. (2021). Remediation and detection techniques for heavy metals in the environment. In *heavy metals in the environment* (p. 205-222). Elsevier. https://doi.org/10.1016/B978-0-12-821656-9.00012-2

Liu, J., Zhao, L., Liu, Q., Li, J., Qiao, Z. and Sun, P. (2021). A critical review on soil washing during soil remediation for heavy metals and organic pollutants. *International Journal of Environmental Science and Technology*, 1-24. https://doi.org/10.1007/s13762-021-03144-1

Liu, L., Luo, X. B., Ding, L. and Luo, S. L. (2019). Application of nanotechnology in the removal of heavy metal from water. In *Nanomaterials for the removal of pollutants and resource reutilization* (p. 83-147). Elsevier. https://doi.org/10.1016/B978-0-12-814837-2.00004-4

Liu, Z., Cheng, K., Li, H., Cao, G., Wu, D. and Shi, Y. (2018). Exploring the potential relationship between indoor air quality and the concentration of airborne culturable fungi: a combined experimental and neural network modeling study. *Environmental Science and Pollution Research, 25*(4), 3510-3517.

Madejón, P., Maranón, T., Murillo, J. M. and Robinson, B. (2006). In defence of plants as biomonitors of soil quality. *Environmental pollution, 143*(1), 1-3. https://doi.org/10.1016/j.envpol.2005.11.008

Mahapatra, B., Dhal, N. K., Dash, A. K., Panda, B. P., Panigrahi, K. C. S., and Pradhan, A. (2019). Perspective of mitigating atmospheric heavy metal pollution: using mosses as biomonitoring and indicator organism. *Environmental Science and Pollution Research, 26*(29), 29620-29638. https://doi.org/10.1007/s11356-019-06270-z

Maio, S., Baldacci, S., Tagliaferro, S., Angino, A., Parmes, E. and Pärkkä, J (2022). Urban grey spaces are associated with increased allergy in the general population. *Environmental Research, 206,* 112428. https://doi.org/10.1016/j.envres.2021.112428

Markert, B. A., Breure, A. M. and Zechmeister, H. G. (2003). Definitions, strategies and principles for bioindication/biomonitoring of the environment. In B. A. Markert, A. M. Breure and H. G. Zechmeister (Eds.), *Trace metals and other contaminants in the environment, Vol. 6* (p. 3-39). Elsevier. https://doi.org/10.1016/S0927-5215(03)80131-5.

Mehana, E. S. E., Khafaga, A. F., Elblehi, S. S., El-Hack, A., Mohamed, E. and Naiel, M. A. (2020). Biomonitoring of heavy metal pollution using acanthocephalans parasite in ecosystem: an updated overview. *Animals, 10*(5), 811. https://doi.org/10.3390/ani10050811

Method 3052. (1996). Microwave-assisted acid digestion of siliceous and organically based matrices. Accessed from *EPA* webpage: https://www.epa.gov/sites/default/files/2015-12/documents/3052.pdf

Musse, M. A., Barona, D. A. and Rodriguez, L. M. S. (2018). Urban environmental quality assessment using remote sensing and census data. *International journal of applied earth observation and geoinformation*, *71,* 95-108. https://doi.org/10.1016/j.jag.2018.05.010

Ozlu-Diniz, S. and Kasapoglu, A. (2021). Urban happiness and gardening relationship: the case of Ankara Capital. *Advances in Applied Sociology, 11*(12), 695-715. https://doi.org/10.4236/aasoci.2021.1112057

Öztürk, S. and Işınkaralar, Ö. (2019). Kastamonu kent merkezinde otopark sorunsalı: eleştirel bir değerlendirme. *Uluslararası Sosyal Araştırmalar Dergisi, 12*(67), 506-511.

Pajewska-Szmyt, M., Sinkiewicz-Darol, E. and Gadzała-Kopciuch, R. (2019). The impact of environmental pollution on the quality of mother's milk. *Environmental Science and Pollution Research, 26*(8), 7405-7427. https://doi.org/10.1007/s11356-019-04141-1

Pal, S. C., Chowdhuri, I., Saha, A., Ghosh, M., Roy, P., Das, B. and Shit, M. (2022). COVID-19 strict lockdown impact on urban air quality and atmospheric temperature in four megacities of India. *Geoscience Frontiers, 101368*. https://doi.org/10.1016/j.gsf.2022.101368

Pee, L. G. and Pan, S. L. (2022). Climate-intelligent cities and resilient urbanisation: Challenges and opportunities for information research. *International Journal of Information Management, 63,* 102446. https://doi.org/10.1016/j.ijinfomgt.2021.102446

Pratush, A., Kumar, A. and Hu, Z. (2018). Adverse effect of heavy metals (As, Pb, Hg, and Cr) on health and their bioremediation strategies: a review. *International Microbiology, 21*(3), 97-106. https://doi.org/10.1007/s10123-018-0012-3

Ren, Z., Fu, Y., Dong, Y., Zhang, P. and He, X. (2022). Rapid urbanization and climate change significantly contribute to worsening urban human thermal comfort: a national 183-city, 26-year study in China. *Urban Climate, 43*, 101154. https://doi.org/10.1016/j.uclim.2021.100910

Saravanan, A., Kumar, P. S., Vo, D. V. N., Jeevanantham, S., Karishma, S. and Yaashikaa, P. R. (2021). A review on catalytic-enzyme degradation of toxic environmental pollutants: microbial enzymes. *Journal of Hazardous Materials*, *419,* 126451. https://doi.org/10.1016/j.jhazmat.2021.126451

Sarıkahya, M. and Tuğral, F. (2022). Examination of the effect of indoor design of metro buildings on circulation: Ankara example. *Applied Nanoscience*, 1-14. https://doi.org/10.1007/s13204-021-02202-x

Savas, D. S., Sevik, H., Isinkaralar, K., Turkyilmaz, A. and Cetin, M. (2021). The potential of using cedrus atlantica as a biomonitor in the concentrations of Cr and Mn. *Environmental Science and Pollution Research, 28*(39), 55446-55453. https://doi.org/10.1007/s11356-021-14826-1

Sevik, H., Ahmaida, E. A. and Cetin, M. (2017a). Change of the air quality in the urban open and green spaces: Kastamonu sample. In I. Koleva, U. Yuksel and Benaabidate, L. (Eds.), *Ecology, planning and design* (p. 409–422). Sofia: St. Kliment Ohridski University Press.

Sevik, H., Cetin, M, Ozel, H. B., Ozel, S. and Cetin, I. Z. (2020). Changes in heavy metal accumulation in some edible landscape plants depending on traffic density. *Environ Monit Assess, 192*(2), 78. https://doi.org/10.1007/s10661-019-8041-8

Shahid, M., Dumat, C., Khalida, S., Schreck, E., Xiong T. and Nabeel, N. K. (2017). Foliar heavy metal uptake, toxicity and detoxification in plants: a comparison of foliar and root metal uptake. *J Hazard Mater, 325,*36–58. https://doi.org/10.1007/s11356-019-06519-7

Topal, A., Yalman, G. L. and Çelik, Ö. (2019). Changing modalities of urban redevelopment and housing finance in Türkiye: Three mass housing projects in Ankara. *Journal of Urban Affairs, 41*(5), 630-653. https://doi.org/10.1080/07352166.2018.1533378

Turkyilmaz, A., Sevik, H., Cetin, M. and Saleh, E. A. A. (2018). Changes in heavy metal accumulation depending on traffic density in some landscape plants. *Polish Journal of Environmental Studies, 27*(5), 1–8. https://doi.org/10.15244/pjoes/78620

Umar, M., Ji, X., Kırıkkaleli, D. and Alola, A. A. (2021). The imperativeness of environmental quality in the United States transportation sector amidst biomass-fossil energy consumption and growth. *Journal of Cleaner Production, 285*, 124863. https://doi.org/10.1016/j.jclepro.2020.124863

United Nations, Department of Economic and Social Affairs, Population Division. (2019). *World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420)*. New York: United Nations.

Vardhan, K. H., Kumar, P. S. and Panda, R. C. (2019). A review on heavy metal pollution, toxicity and remedial measures: Current trends and future perspectives. *Journal of Molecular Liquids*, 290, 111197. https://doi.org/10.1016/j.molliq.2019.111197

Wood, N. and Roelich, K. (2019). Tensions, capabilities, and justice in climate change mitigation of fossil fuels. *Energy Research and Social Science*, *52,* 114-122. https://doi.org/10.1016/j.erss.2019.02.014

Wu, H., Gai, Z., Guo, Y., Li, Y., Hao, Y. and Lu, Z. N. (2020). Does environmental pollution inhibit urbanization in China? A new perspective through residents' medical and health costs. *Environmental Research*, *182,* 109128. https://doi.org/10.1016/j.envres.2020.109128

Wu, J., Wang, L. and Li, W. (2018). Usage patterns and impact factors of public bicycle systems: Comparison between city center and suburban district in Shenzhen. *Journal of Urban Planning and Development, 144*(3), 04018027. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000471

Yildiz, A., Aksoy, A., Akbulut, G., Demirezen Yılmaz, D., İşlek, C. and Altuner, E.M. (2011). Correlation between chlorophyll degradation and the amount of heavy metals found in pseudevernia furfuracea in Kayseri (Türkiye). *Ekoloji, 20*(78), 82-88. DOI: 10.5053/ekoloji.2011.7813

Yildiz, A., Aksoy, A., Tug, G. N., Islek, C. and Demirezen, D. (2008). Biomonitoring of heavy metals by Pseudevernia furfuracea (L.) Zopf in Ankara (Türkiye). *Journal of Atmospheric Chemistry*, *60,* 71-81. https://doi.org/10.1007/s10874-008-9109-y

Yıldız, A., Vardar, Ç., Aksoy, A. and Ünal, E. (2018). Biomonitoring of heavy metals deposition with Pseudevernia furfuracea (L.) Zopf in Çorum City, Türkiye. *Journal of Scientific Perspectives, 2*(1), 9-22. DOI: 10.26900/jsp.2018.02

Zhang, Q., Han, G., Liu, M. and Liang, T. (2019). Spatial distribution and controlling factors of heavy metals in soils from Puding Karst Critical Zone Observatory, southwest China. *Environmental Earth Sciences, 78*(9), 1-13. https://doi.org/10.1007/s12665-019-8280-6