Research on the ability of urban trees to retain heavy metals. A silvicultural approach

Vordoglou M.[1,*], Samara T.[2], Tsitsoni T.[1]

[1] Aristotle University of Thessaloniki, School of Forestry and Natural Environment, Laboratory of Silviculture, P.O. Box 262, 54124 Thessaloniki, Greece
[2]Forest Research Institute of Thessaloniki, ELGO-DEMETER, 57006 Vassilika, Thessaloniki, Greece;
*corresponding author: e-mail:vordogloumaria@gmail.com

Abstract
The purpose of the present research was to study the ability of urban trees' leaves to retain heavy metals. Three major heavy traffic streets of Thessaloniki were chosen. Two tree species were studied: *Ailanthus altissima* (Mill.) Swingle and *Catalpa bignonioides* Walt. and 360 leaf samples were collected from 20 trees. The selection of the species was carried out according to their leaf morphology and silvicultural characteristics. Also, for each tree were measured: breast diameter, tree height, crown height, crown's diameter and then crown volume was calculated. Two treatments were applied (washed and unwashed leaves). The following heavy metals were measured: iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), cadmium (Cd), cobalt (Co), chromium (Cr), nickel (Ni) and lead (Pb) and the metal concentration was determined with the use of ICP-OES inductively coupled plasma optical emission spectrometry. The concentrations of heavy metals were significantly related to the species for the heavy metals: iron (Fe), manganese (Mn), cobalt (Co), chromium (Cr), nickel (Ni), lead (Pb). *Catalpa bignonioides* captured the highest concentrations of heavy metals. Finally, the morphological characteristics of leaves and not the silvicultural characteristics of species are the factors that influence their ability to retain heavy metals.
Keywords: urban trees, air pollution, heavy metals, morphology of leaf, silvicultural characteristics

1. Introduction

Air pollution constitutes a major environmental problem concerning mainly big cities worldwide. Although the environment is extremely important for every living organism, it is destroyed by human activities (Davis 2006). World's ecosystems have been severely affected by human activities since the mid-20th century. Recent studies demonstrate that urban trees not only beautify the landscape, but often play a major role in moderating the environmental impact of urban settlements (Seamans 2013). Trees are able to remove air pollution by the interception of particulate matter on plant surfaces and the absorption of gaseous pollutants through the leaf stomata (Nowak et al. 2014). The purpose of the present research is to study the ability of urban tree leaves to capture heavy metals in three heavy traffic streets in Eastern Thessaloniki. The aim is the detection of the pollution levels of iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), cadmium (Cd), cobalt (Co), chromium (Cr), nickel (Ni), lead (Pb), using leaves from two tree species in Thessaloniki; *Ailanthus altissima* (Mill.) Swingle and *Catalpa bignonioides* Walt. Finally, the ultimate goal is the selection of the most suitable forest species for urban and peri-urban use, which will contribute to the reduction of heavy metal pollution and will improve life quality.

2. Material and Methods

2.1. Study area

The research was carried out in Thessaloniki during summer, in August 2016. The three sites which were chosen for the present research are three major streets located in the Eastern part of the city (Foinikas and Kalamaria area). The three streets were the following: Voulgari Street, Ethnikis Antistaseos Avenue and Andrianoupoleos Street. They are heavy traffic roads of Eastern Thessaloniki.

2.2. Experimental design and sampling

Two tree species were selected according to leaf size and their different leaf morphology (simple or compound, pilled leaf or not) for the detection of heavy metal pollution (Martin and Coughtrey 1982; Beckett et al. 2000; Pal et al. 2002; Pourkhabbaz et al. 2010); *A. altissima* and *C. bignonioides*. *A. altissima* has bipinnately compound leaves with many leaflets while *C. bignonioides* has big, simple and pilled leaves. The 360 leaf samples (200gr/sample) were collected uniformly from around the trees and then were placed in paper bags. The leaves were mature without cuticle cracks, necrotic spots or lesions The heavy metals that were measured in the leaves were iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), cadmium (Cd), cobalt (Co), chromium (Cr), nickel (Ni) and lead (Pb). The following trees' silvicultural characteristics were measured: breast diameter, tree height, crown height, crown diameter. Then, the crown volume was calculated.

2.3 Chemical analysis

The leaves that were collected were divided into two groups: the leaves of the first group (180 samples) were washed with distilled water and the leaves of the second group (180 samples) remained untreated (non-washed). All the leaf samples were dried in the oven at 75^{o} C for 48 hours. About 2 gr of dried and milled matter samples were ignited at 560^{o} C for 4 hours and left to be reintroduced to environmental temperature. Next, 5ml HCl 6N were added in each sample to dissolve the ash and were transferred to 50ml volumetric flask and make up volume with H_2O.Finally, the metal concentration was determined in the diluted ash by using an ICP-OES inductively coupled plasma optical emission spectrometry.

3. Results

The main silvicultural characteristics of the tree species *A. altissima* and *C. bignonioides* are represented in Table 1. Also, shape constant is given for the calculation of crown volume.

Table 1. Means and standard deviations of the silvicultural characteristics of the studied tree species.

Forest species	*Ailanthus altissima*	*Catalpa bignonioides*
Tree diameter (cm)	20.07±3.5	17.27±2.54
Tree height (m)	6.5±0.5	5.3±0.45
Crown height (m)	2.65±0.23	2.33±0.15
Crown diameter (m)	7.31±1.2	5.26±0.87
Crown length (m)	3.85±0.39	2.96±0.47
Shape constant	0.5891	0.5236
Crown volume (m^3)	174.6±42.04	57.15±25.58

The concentrations of the heavy metals were statistically significant between the two species that leaves were collected from, in the following heavy metals: iron (Fe), manganese (Mn), cobalt (Co), chromium (Cr), nickel (Ni), lead (Pb). The rest of them do not present statistically significance.

The concentration of the heavy metals concerning the two treatments were statistically significant in the case of iron (Fe), copper (Cu), cobalt (Co), chromium (Cr), nickel (Ni), and lead (Pb). The rest of them do not present statistically significance.

For all metals, higher concentrations were measured at *C. bignonioides* except for zinc (Zn) and copper (Cu). There was not a tree species with the highest values in all metals measured. Specifically, the highest values for all metals concerning the unwashed leaves are: iron (Fe) 386.668ppm, manganese (Mn) 136.019ppm, cadmium (Cd) 2.60415ppm, cobalt (Co) 0.21808ppm, chromium (Cr) 2.54758ppm, nickel (Ni) 2.3887ppm and lead (Pb) 1.486ppm, respectively. For zinc (Zn) and copper (Cu) the highest values for washed leaves were measured at *A. altissima*, 23.9438ppm and 16.435ppm, respectively, but they were not statistically significant.

4. Discussion

The leaves of *C. bignonioides* are pubescent on the down leaf surface. Many researchers (Sawidis et al. 1995; Beckett et al. 2000; Samara and Tsitsoni 2014) reported that higher accumulation of metals was presented in species that had rough leaf surface. In the present research, metals' mean concentration in leaves was the following, in declining order: iron (Fe)> manganese (Mn)> zinc (Zn)>copper (Cu) > nickel (Ni) > chromium (Cr) > cadmium (Cd) > lead (Pb) > cobalt (Co).The high concentration of iron (Fe), zinc (Zn) and manganese (Mn) are due to traffic air pollution (Sawidis et al. 1995; Sawidis et al. 2001; Celik et al. 2005). Another remarkable result is the concentration of copper (Cu) for both species that reach high levels, instead of concentrations of cadmium (Cd), cobalt (Co), chromium (Cr), nickel (Ni), lead (Pb) which seem not to be so aggravating.

5. Conclusions

The following conclusions can be drawn from the present study concerning the ability of two urban trees to retain heavy metals:

- Both studied species fulfill some important criteria for the selection of species as biomonitors.
- *C. bignonioides* captured the highest concentrations of heavy metals, because the big pilled leaves of this species can retain air pollutants effectively.
- *A. altissima* (compound leaves) captured heavy metals in satisfying levels.
- *A. altissima* presents three times greater crown volume than *C. bignonioides*, but it retained lower concentrations of heavy metals than *C. bignonioides*.
- Therefore, the morphological characteristics of leaves (simple or compound, pilled leaves or not) and not the silvicultural characteristics of species (crown length and volume) are the factors that influence their ability to capture heavy metals.

References

Beckett KP. Freer Smith PH. and Taylor G (2000) Effective tree species for local air-quality management. *J. Arboric*. **26**, 12-19.

Davis E.B. (ed) (2006) Trends in Environment Research, Nova Science Publishers, Inc., New York, USA.

Nowak DJ, Hirabayashi S, Bodine A, Greenfield E (2014) Tree and forest effects on air quality and human health in the United States. *Environ. Pollut*. **193**, 119-129.

Samara T, Tsitsoni T (2014) Selection of forest species for use in urban environment in relation to their potential capture to heavy metals. *Global Nest J*. **16**(5), 966-974.

Sawidis T, Marnasidis A, Zachariadis G, Stratis J (1995) A study of air-pollution with heavy-metals in Thessaloniki City (Greece) using trees as biological indicators. *Arch. Environ. Contam. Toxicol*. **28**, 118-124.

Seamans GNS (2013) Mainstreaming the environmental benefits of street trees. *Urban For. Urban Green*. **12**,2–1.