Urban Forestry & Urban Greening 20 (2016) 12–19

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Influence of past industry and urbanization on elemental concentrations in deposited dust and tree leaf tissue

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ARTICLE INFO

Article history:
Received 14 January 2015
Received in revised form 12 July 2016
Accepted 27 July 2016
Available online 3 August 2016

Keywords:
Biomonitoring
Cement factory
Steel factory
Toxic elements
MP-AES

ABSTRACT

Elemental concentrations of deposited dust and leaf tissue are often used to assess the level of contamination, and for monitoring air pollution. Leaves of *Platanus x acerifolia, Fraxinus excelsior* and *Acer campestre* were used to assess the amount of deposited dust and the elemental concentrations of deposited dust and leaf tissue in and around the city of Miskolc, Hungary. Samples were collected from the nearby cement and steel factories and from urban, suburban and rural areas along an urbanization gradient. Both the cement and steel factories were in the suburban area of Miskolc, an influence the air quality of the city. The concentrations of Al, Ba, Cd, Cr, Fe, Na, Pb, Si, Sr and Zn were determined in the deposited dust and leaf tissue, using MP-AES. We found significant differences in the amounts of deposited dust between suburban and rural areas. There were no significant differences among the other areas compared to each other. Canonical discriminant analysis showed a good separation of areas and species based on the elemental concentrations of deposited dust and leaves. In the deposited dust, significant differences were found among studied areas in the case of Al, Ba, Cd, Cr, Fe, Na, Pb, Si, Sr and Zn. There were no significant differences among species in the elemental concentrations of deposited dust, with the exception of Na. However, the Al, Ba, Cr, Cu, Fe, Mn, Si, Sr and Zn concentrations in leaf tissue differed significantly among the studied areas. We found significant differences among leaves of various species in the case of Ba and Si. The organic matter content of leaf tissue was positively correlated with Zn concentration. In the cases of other elements there was no significant correlation between the organic matter content and the elements' concentration in leaf tissue. Our results suggested that industrial activities and urbanization caused remarkable air contamination. Our findings suggest that the dust deposits on leaf surface may be useful indicators of atmospheric element air pollution. The reconstruction of abandoned industrial buildings are needed because, in addition to general urbanization, they have been a potential air pollution source, and still remain so.

1. Introduction

Air pollution is one of the most important problems in city centres all over the world (Onder et al., 2007). Increasing anthropogenic activities lead to ever increasing level of air pollution which causes a number of negative effects on human health (Zheng et al., 2013). Air pollutants, especially heavy metals, are hazardous and toxic to humans and the terrestrial ecosystem (Trombulak and Frissell, 2000; Jaishankar et al., 2014). Heavy metals derive from many local sources, such as industry (Nagajyoti et al., 2010), road traffic (Serbula et al., 2012), and agriculture (Chopra et al., 2009).

Industrial activities (Streets and Waldhoff, 2000; Prasad et al., 2006) and urbanization (Nowak et al., 2006; Chan and Yao, 2008) are the main sources of heavy metal pollution in terrestrial ecosystems. In the case of air pollution there are several sources of heavy metals, such as mining, smelting, production and the use of metallic commercial products (Chopra et al., 2009). Goluchowska et al. (2012) demonstrated that cement dust contains high amounts of Zn, Cd, Cu and Pb and the magnetic susceptibility of dust was also higher in cement dust than in other samples. Józwiak and Józwiak (2009) also demonstrated that the cement industry produced additional pollutants, including heavy metals deposited in dust. The cement dust also decreased the activity of stomata and inhibited pollen generation (Abdel-Rahman and Ibrahim, 2012).

Among biomaterials, the bark and leaves of trees are frequently used to assess the deposition, accumulation of heavy metal

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http://dx.doi.org/10.1016/j.ufug.2016.07.017
1618-8667/

pollution (Serbula et al., 2012; Alyemeni and Almohisen, 2014). The dust accumulation uptake and translocation of atmospheric heavy metals by air depends on such factors as the morphometric and anatomical characteristics of leaves (Pourkhabbaz et al., 2010). Simon et al. (2014) reported that the density of trichome, and stomata size and density were important in controlling dust deposition. The surface geometry, phyllotaxy, epidermal and cuticular features and epicuticular waxes also influence the dust trapping capacity of leaves (Kulshreshtha et al., 2009).

Miskolc was a developed industrial city in previous decades. By the 1980s Miskolc was called as one of the "Dirty Dozen" because it was one of the most polluted Hungarian cities (Éri et al., 2001). The air was polluted by a metallurgic centre, a cement factory and transport. The coal mines and other industries were closed 2–3 decades ago and the level of pollution from remote regional and transboundary sources in Miskolc decreased (Éri et al., 2001). In spite of the decrease in the level of pollution the abandoned factory areas were still in their original locations, so they have been potential sources of air pollution, alongside urbanization itself.

Leaves are sensitive and highly exposed to air pollution (Prusty et al., 2005). Thus, in our study the amount of deposited dust on leaf surface and the elemental concentration of deposited dust and leaves were used as indicators to assess the effects of earlier industrial activities and urbanization on the air pollution in Miskolc city, Hungary. *Platanus x acerifolia*, *Fraxinus excelsior* and *Acer campestre* were chosen as test species because these trees are typical species in the studied areas. Our hypothesis was that the amount of dust and elemental concentrations in deposited dust and leaves was higher in the area of the cement and steel factories, and the urban area, than in the suburban and rural areas. The abandoned cement and steel factories may be potential sources of air pollution besides urbanization. We also studied a correlation between the organic matter and elemental concentrations in deposited dust and in leaves because of the organic matter in dust has significant environmental and human health implications (Xie et al., 2000; Shen et al., 2009). Thus, our aim was to determinate which elements may be accumulated in leaf tissue from deposited dust.

2. Material and methods

2.1. Study areas and sample collection

Miskolc is an industrial city in North Hungary, an important regional centre. We selected five sampling areas (the cement and steel factories, and urban, suburban and rural areas) to assess the effects of abandoned industrial buildings and urbanization on the elemental concentration of deposited dust and leaves. Within each sampling area two subsampling sites were selected.

Platanus x acerifolia occurred in all areas, while *Fraxinus excelsior* (L.) and *Acer campestre* (L.) were present in the urban, suburban and rural areas. Samples were collected in April 2013. In each sampling site five tree specimens were chosen randomly and two pooled samples were collected from each study site. The number of leaves was 15 in each pooled sample. Samples were collected in plastic bags, and stored at 4 °C in the dark until sample processing.

2.2. Sample preparation of deposited dust and leaves

A bed scanner was used to determinate the surface area of the leaves. The deposited dust was washed down from the leaves by using deionised water. Leaves were put into a 500 ml plastic box and 250 ml of deionised water was added. Samples were shaken for 10 min. The dust containing suspension was filtered through a 150 mm sieve. The leaves were washed with 50 ml deionised water again, and this was filtered and added to the samples. This 300 ml of dust containing suspension was transferred into a microwave oven where the volume of water was reduced to 20–30 ml. Then the suspension was transferred into 50 ml glass beakers and the rest of the water was evaporated at 105 °C. The beakers were reweighted to determine the dry weight of the dust. Samples were prepared for analysis in the same vessels. They were digested using 5 ml 65% (m/m) nitric acid (Merk Millipore, analytical grade) and 2 ml 30% (m/m) hydrogen-peroxide (Merk Millipore, analytical grade) at 80 °C for 4 h. Digested samples were diluted to 10 ml using 1% (m/m) nitric acid (Simon et al., 2011, 2014).

The leaf samples were dried for 4 h at 60 °C. Then the samples were homogenised with an electric mixer and stored in plastic tubes. For elemental analysis, 0.2 g of leaf tissue was digested using 4.5 ml 65% (m/m) nitric acid and 0.5 ml 30% (m/m) hydrogen-peroxide in a microwave digestion unit (Milestone 1200 Mega) for 5 min at 300 W and subsequently 5 min at 600 W. Digested samples were diluted to 25 ml with deionised water (Simon et al., 2011). The elemental analysis was performed by Microwave plasma atomic emission spectrometry (MP-AES 4100, Agilent Technology). We used six point calibration procedures with multi-element calibration solutions (Merck ICP multi-element standard solution IV).

2.3. Determination of organic matter in deposited dust and leaves

The organic matter content of deposited dust and leaves was assessed with the loss on ignition (LOI) method. In the case of deposited dust, a 50 ml portion of the above mentioned 300 ml dust suspension was dried at 105 °C overnight. The samples were reweighed and then combusted at 550 °C for 5 h in a muffle furnace (Nabertherm L5/C6, Germany). The samples were reweighed after combustion. The organic matter of the deposited dust was calculated using the following equation: $OM = ((DW_{105\,°C} - DW_{550\,°C})/DW_{105\,°C})^{*}100$, where OM means the weight of organic matter, $DW_{105\,°C}$ is the dry weight of the deposited dust at 105 °C, and $DW_{550\,°C}$ is the weight loss on ignition at 550°. In the case of leaf samples, a 0.2 g sample was used for the organic matter determination.

2.4. Statistical analysis

The homogeneity of variances was tested by the Levene test. The elemental concentrations of deposited dust, leaves and organic matter contents in the studied areas (cement and steel factories, and urban, suburban and rural areas) and the studied species (*P. x acerifolia, F. excelsior* and *A. campestre*) were compared with two-way GLM ANOVA. In the case of significant differences, Tukey's Multiple Comparison test was used. Canonical Discriminant Analysis (CDA) was also used to evaluate the elemental concentrations of deposited dust and leaves according to the studied areas and species. The Pearson correlation was used to test the correlation between the organic matter contents of deposited dust and leaves, as well as that between the elemental concentration of deposited dust and leaves (Landau and Everitt, 2003).

3. Results

3.1. Amount of deposited dust

Significant differences among the studied areas were found in the amounts of deposited dust on leaves, for all species by GLM ANOVA ($F = 6.938$; $P = 0.044$) (Fig. 1A). Significantly lower amounts of deposited dust on leaves were found in the suburban area than in the rural area ($P = 0.020$). Similar to the differences between the studied areas, significant differences were also found in the