Science of the Total Environment 616–617 (2018) 417–426

Contents lists available at ScienceDirect

Science of the Total Environment

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

An investigation of the leaf retention capacity, efficiency and mechanism for atmospheric particulate matter of five greening tree species in Beijing, China

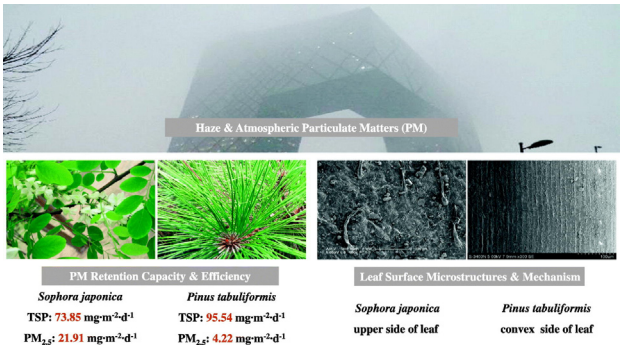
Jinqiang Liu [a,1], Zhiguo Cao [b,1], Songyan Zou [a,1], Huanhuan Liu [a], Xiao Hai [b], Shihua Wang [b], Jie Duan [d,*], Benye Xi [a,*], Guangxuan Yan [b], Shaowei Zhang [c], Zhongkui Jia [a]

[a] Ministry of Education Key Laboratory of Silviculture and Conservation, Beijing Forestry University, Beijing 100083, China
[b] School of Environment, Henan Normal University, Key Laboratory for Yellow River and Huai River Water Environment and Pollution Control, Ministry of Education, Henan Key Laboratory for Environmental Pollution Control, Xinxiang, Henan 453007, China
[c] Henan Vocational College of Agriculture, Zhengzhou, Henan 451450, China
[d] National Energy R&D Center for Non-food Biomass, Beijing 100083, China

HIGHLIGHTS

- An accurate method for PM retention assessment was proposed and evaluated.
- *S. chinensis* could retain the ERP of PM_1 and $PM_{1-2.5}$ with the highest efficiencies.
- *S. japonica* represented the highest retention capacity to all PM fractions in TSP.
- Leaf surface microstructures were investigated to illustrate PM retention mechanism.
- The results could serve selecting tree species with high air purification abilities.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 4 August 2017
Received in revised form 19 October 2017
Accepted 30 October 2017
Available online xxxx

Editor: Lidia Morawska

Keywords:
Particulate matter
Particle diameter distribution
Retention efficiency
Ultrasonic cleaning

ABSTRACT

Urban trees have the potential to reduce air pollution, but the retention capacity and efficiency of different tree species for atmospheric particulate matter (PM) accumulation and the underlying mechanism hasn't been well understood. To select tree species with high air purification abilities, the supplementing ultrasonic cleaning (UC) procedure was first introduced into the conventional leaf cleaning methods [single water cleaning (WC) or plus brush cleaning (BC)] for eluting the leaf-retained PM. Further updates to the methodology were applied to investigate the retention capacity, efficiency, and mechanism for PM of five typical greening tree species in Beijing, China. Meanwhile, the particle size distribution of PM on the leaves, the PM retention efficiencies of easily removable (ERP), difficult-to-remove (DRP) and totally removable (TRP) particles on the leaf (AE_{leaf}), and the individual tree scales were estimated. The experimental leaf samples were collected from trees with similar sizes 4 (SDR) and 14 days (LDR) after rainfall. When the leaves were cleaned by WC + BC, there was, on average, 29%–46% of the PM remaining on the leaves of different species, which could be removed almost completely if UC was supplemented. From SDR to LDR, the mass of the leaf-retained PM increased greatly, and the particle size distribution changed markedly for all species except for *Sophora japonica*. *Pinus tabuliformis* retains particles with the largest average diameter (34.2 μm), followed by *Ginkgo biloba* (20.5 μm), *Sabina chinensis* (16.4 μm), *Salix*

* Corresponding authors at: Ministry of Education Key Laboratory of Silviculture and Conservation, Beijing Forestry University, 35 East Qinghua Road, Beijing 100083, China.
E-mail addresses: duanjiebfu@vip.qq.com (J. Duan), benyexi@bjfu.edu.cn (B. Xi).
[1] These authors contributed equally to this work as first co-authors.

https://doi.org/10.1016/j.scitotenv.2017.10.314
0048-9697/© 2017 Elsevier B.V. All rights reserved.

babylonica (16.0 μm), and *S. japonica* (13.1 μm). *S. japonica* and *S. chinensis* had the highest AE_{leaf} to retain the TRP and ERP of both PM_1 and $PM_{1-2.5}$, respectively. Conversely, *S. babylonica* and *P. tabuliformis* could retain both TRP and ERP of $PM_{2.5-5}$ and PM_{5-10}, and $PM_{>10}$ and TSP with the highest AE_{leaf}, respectively. In conclusion, our results could be useful in selecting greening tree species with high air purification abilities.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Particulate matter (PM) is defined as various solid or liquid particles suspended in an atmospheric aerosol system, and it makes a significant contribution to air pollution. PM not only can lead to irritability, bronchitis, angiocardiopathy and other diseases (Cohen et al., 2005; Chen et al., 2013; Hofman et al., 2013) but can also cause early mortality in humans (Remy et al., 2011; Chen et al., 2013). Air pollution induced by PM is therefore gaining wide attention around the world. Many studies have demonstrated that plants can effectively retain dust due to their large leaf surface areas and sophisticated leaf microstructures (Yin et al., 2011; Nowak et al., 2013; Wang et al., 2015d; Chen et al., 2017). Consequently, mitigating and controlling the PM pollution by using urban trees and forest has attracted more and more attention around the world in recent years (Yang et al., 2005; Przybysz et al., 2014; Chen et al., 2015; Zhang et al., 2015; Chen et al., 2016).

A quantitatively comprehensive assessment of the amount of PM retained on the plant leaves is very important for accurately assessing the air purification abilities of the urban forests at different scales (leaf, individual tree, and stand) and for screening tree species with a higher PM retention capability. Thus, several relative studies have been carried out in recent years (Dzierżanowski and Gawroński, 2011; Song et al., 2015; Wang et al., 2015a; Wang et al., 2015b). In these studies, the mass subtraction method (Baidurela et al., 2015; Fan et al., 2015), the membrane filter method (Dzierżanowski and Gawroński, 2011; Przybysz et al., 2014; Sgrigna et al., 2015; Chen et al., 2016), the elution weighing method coupled with a particle size analysis (EWPA) (Zhang et al., 2014), and other direct determination methods are often used to quantitatively estimate the total quantities of the different-sized particles retained on a unit of leaf area. The key to the successful application of these methods is to collect the PM retained on the leaf surfaces completely. To achieve this purpose, researchers often clean the sampled leaves by conventional cleaning methods, such as a single water washing (soak and rinse leaves using deionized water) (Dzierżanowski and Gawroński, 2011; Zhang, 2013), followed by scrubbing the leaves (Beckett et al., 2000; Wang et al., 2006; Yao et al., 2014; Wang et al., 2015b; Chen et al., 2016). However, the research results of Wang and Li (2006) demonstrated that these conventional cleaning methods could not elute the PM on the leaf surfaces completely. In contrast, Liu et al. (2016a) found that if these conventional cleaning methods are augmented by an appropriate ultrasonic leaf cleaning procedure, the cleanliness of a *Ginkgo biloba* leaf surface could be improved markedly (i.e., increasing the efficiency in eluting the PM on the leaf surfaces) without destroying the leaf microstructure. However, this effect of the ultrasonic leaf cleaning still needed to be tested for different tree species under different dust retention durations.

The particle size distribution is a very important parameter to estimate the PM mitigation ability of the trees (Cao et al., 2012) because many physical and chemical properties of particles are related to the particle diameters (Yu, 2008). Investigating the size distribution of the PM not only can help to determine the precise amounts of different-sized particles retained on the leaf surfaces but can also help to understand the ability of the leaves to get rid of the toxic pollutants (heavy metals, acidic oxides, microorganisms, etc.) in air (Meng et al., 2015; Pooltawee et al., 2017). Therefore, many studies have investigated the size distribution of the particles on leaves. However, in these studies, the entire particle size range was often divided into limited fractions [such as three (0.2–2.5, 2.5–10 and 10–100 μm) (Przybysz et al., 2014) and four (≤1, 1–2.5, 2.5–10 and 10–100 μm) (Fan et al., 2017) fractions], so more detailed information (continuous and very small diameter variation characteristics) about particle size distribution was not shown. Subsequently, the total mass of the $PM_{2.5}$ ($d \le 2.5$ μm), PM_{10} ($d \le 10$ μm) or TSP retained on a unit of leaf area has been commonly used to estimate the ability of the urban trees to absorb and retain PM (Nguyen et al., 2015; Wang et al., 2015a; Fan et al., 2017). Besides, at present, the relevant research has mainly focused on the difference in the size distribution of the PM on the leaves among different tree species (Wang, 2007; Yu, 2008; Sæbø et al., 2012; Liu et al., 2013) and under different air pollution levels (Ottelé et al., 2010; Wang et al., 2012; Przybysz et al., 2014). However, little research has paid attention to the variation of the particle size distribution on the leaves experiencing different dust retention durations. In addition, there is poor comparability among the different research results when using the retained PM mass to assess the air purification ability of the urban trees (Liu et al., 2016b), since the dust retention durations of the trees used in the research might be different. Thus, as an alternative, some researchers used the PM retention efficiency (the number of particles retained on a unit of leaf area per unit time) to assess the ability of the urban trees to retain PM (Yao et al., 2014; Chen et al., 2016), but similar studies are still scarce.

In this study, we used three broadleaf tree species (*G. biloba*, *Sophora japonica* and *Salix babylonica*) and two needleleaf tree species (*Pinus tabuliformis* and *Sabina chinensis*), all of which are widely planted urban greening tree species in Beijing. We collected the leaves of these trees while they were experiencing two different dust retention periods to use as the test materials to carry out comparative research. The objectives of this study were 1) to evaluate the elution characteristics of the PM retained on the leaves cleaned successively with three different methods (single water washing, brush cleaning, and ultrasonic cleaning) and to assess the effect of the ultrasonic cleaning on eluting the PM; 2) to compare and analyse the size distribution of the particles retained on the leaves of the different tree species; and 3) to estimate the efficiency of the different tree species in retaining particles at both the leaf and individual tree scales.

2. Material and methods

2.1. Experimental materials and sample collection

The study area was in Xitucheng Park, Beijing, China (39.97° N, 116.36° E, and elevation 55 m). Two needleleaf (*P. tabuliformis*, *S. chinensis*) and three broadleaf urban tree species (*G. biloba*, *S. japonica*, *S. babylonica*) with a similar diameter at breast height (DBH) were selected in this park for leaf sampling. All sampling trees were located closely in a greening strip, with length and width of about 250 and 60 m, respectively. The distances between sampling trees and the road were about 10–20 m. Thus, the environmental conditions of these sampling trees were similar. The leaves were collected on October 15th [4 days after last rainfall (>15 mm), hereinafter referred to as the short dust retention (SDR) period] and October 25th, 2014 [14 days after rainfall, hereinafter referred to as the long dust retention (LDR) period]. For each tree species, five healthy individual trees (i.e., five

Download English Version:

https://daneshyari.com/en/article/8862370

Download Persian Version:

https://daneshyari.com/article/8862370

Daneshyari.com