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Survey of ecological environmental conditions and influential factors for public parks in Shanghai

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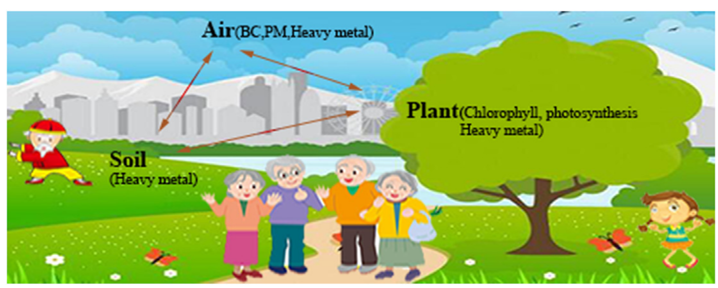
HIGHLIGHTS

- The ecological environment inside parks is important for residents.
- Experimental data were investigated in 10 parks.
- Geographical locations were major reasons for heavy metals concentration.
- Heavy metals mainly came from vehicle emissions.
- Chlorophyll and stomatal conductance can be regarded as an indicator for assessing air quality.

GRAPHICAL ABSTRACT



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ABSTRACT

Urban public parks provide a recreational environment for residents, hence more and more citizens would spend time in parks, especially elderly and kids. Therefore, it is important to evaluate the quality of ecological environment inside parks. Therefore, this study conducted the first measurements in ten public parks of Shanghai to investigate heavy metals in air, soil and leaf, growth parameters of leaf, and ambient $PM_{2.5}$ and black carbon (BC) concentrations. Results showed Al and Mg appeared the highest in air. Cr, Cu, Mn and Zn were dominating in soil. Ca and Mg were much greater in leaves. It was concluded geographical locations were major reasons to explain the level of heavy metals, which mainly came from vehicle emissions. A small portion was attributing to chemical industries nearby. $PM_{2.5}$ concentrations ranged from 0.01 mg/m^3 to 0.10 mg/m^3, which met up level I and level II of air quality standard in China. BC concentrations ranged from 1000 ng/m^3 to 6000 ng/m^3. Via comparing the correlation between photosynthesis and $PM_{2.5}$, as well as chlorophyll content and $PM_{2.5}$, it was concluded that chlorophyll can be regarded as an indicator for assessing air quality, but not photosynthesis. Unexpectedly, a positive correlation was observed between the stomatal conductance and $PM_{2.5}$ as well as BC, which might be attributed to plants resisting the ambient stress. The results of this study can be used for assessments of air quality and health exposure inside parks, and also could provide urban policy maker with scientific evidences for urban park planning.

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1. Introduction

Rapid urbanization and strengthened human activities have caused a variety of environmental problems to cities. Urban residents are eager to spend a portion of daily life at a green land to escape the all-around pollution. Urban public parks have the comprehensive ecological characteristics of interface exchange among plant, soil and air, which not only provide a recreational environment, but also improve the urban ecological environment. Therefore, residents are willing to enjoy recreation and entertainment in parks, especially for elderly and kids. For this reason, more studies have been conducted to evaluate the ecological environment inside parks.

Heavy metal is one of the major indicators for evaluation of environmental pollution, which have already attracted great attention due to their toxicity and complex geochemical properties (Luo et al., 2012). Du et al. (2013) claimed that the health risk of Cu, Zn, Cd and Pb for children were magnitudes higher than those for adults (Du et al., 2013). The environment risk was also considered (Yang et al., 2014a). It was found Cd was the highest risk factor for environment and followed by Zn, and only low or non-risk was from Cu and Pb. Scientist have investigated heavy metals in soil inside parks, and they found the concentration ranges of Cd, Cu, Pb, Zn, As, Cr, Mn and Ni were 0.4–4, 30–200, 30–200, 90–300, 11–26, 20–60, 200–500 and 20–80 mg/kg dw (dry weight) (Du et al., 2013; En et al., 2015; Gu et al., 2016; Khan et al., 2016; Li et al., 2012, 2015; Marinho et al., 2013; Wang et al., 2016; Yang et al., 2014a, 2014b). These studies were completed in Beijing (Du et al., 2013; Li et al., 2012, 2015), Guangzhou (Gu et al., 2016), Shanghai (Yang et al., 2014a, 2014b) and some European and American National Parks (Khan et al., 2016; Marinho et al., 2013). Concentrations of heavy metals in soil of parks and the surrounding geographical environment were closely related (Li et al., 2012; Yang et al., 2014a). Yang et al. (2014a) measured the concentrations of Co, Cr, and Ni from sediments of lakes in parks, and found they were similar to the background, but the levels of Cd, Cu, Pb, and Zn were elevated.

In addition, ambient pollutants were also measured, such as black carbon of 3.7–4.25 $\mu g/m^3$ in Beijing (Liu et al., 2011; Wang et al., 2009) and $PM_{2.5}$ concentrations of 6.4–31.4 $\mu g\ m^{-3}$ in American (Lewandowski et al., 2007). Scientists have proved plant leave in the park have certain adsorption capacities for airborne particles and gaseous pollutants. In shanghai, Yin et al. (2011) conducted measurements inside six parks in Shanghai and found plants was capable of removing 9.1% of TSP, 5.3% of SO_2 and 2.6% of NO_2. The major depositing pollutant on leaf surface was $PM_{2.5}$, reaching up to 75.2%. Fu et al. (2016) found that the concentration of particulate matter in parks varies greatly with time, which is due to the physiological conditions of the plant, also related to meteorological parameters (Fu et al., 2016).

Shanghai, one of the largest cities in China, has experienced rapid urban expansion over the last decades. Meantime, serious environmental pollution occurred. On the other side, Shanghai has a population of over 241,970,000, and covers an area of 6340 square kilometers (Zhang and Xia, 2001). The number of public parks in Shanghai was over one hundred till the year of 2016, which occupied a total area of 1473.4 ha. Public parks have been regarded as important recreational and leisure sites for Shanghai residents. Therefore, this study conducted measurements in ten public parks in Shanghai mainly to assess the levels of heavy metals in air, soil and leaf. The ambient $PM_{2.5}$ and BC concentrations were also discussed. The results of this study can be used for evaluation of air quality and health exposure inside parks, and also could provide urban policy maker with scientific evidences for urban park planning.

2. Experimental methods

2.1. Park descriptions

According to Shanghai green space distribution and building time, 10 representative public parks built up during different time periods were chosen. The total area was about 412 ha. The information of parks and the corresponding adjacent EPA monitoring stations is shown in Fig. 1 and Table 1.

2.2. Instrumentations

LCi-SD portable photosynthesis instrument was used to measure the photosynthetic phenomenon, transpiration rate, stomatal conductance and parameters related to the plant photosynthesis inside parks. LCi-SD is based on the theory of IRGA (infrared gas analysis) principle to measure the CO_2 concentration and water change above the leaf surface, and then to assess the process of plant photosynthesis. The chlorophyll content was measured using CCM-300 chlorophyll meter based on the fluorescence ratio of red emissions measured at 700 nm and 735 nm, respectively. Compared with other traditional methodologies, CCM-300 is capable of conducting nondestructive monitoring chlorophyll of tiny leaves and samples difficult to measure (Bussotti and Pollastrini, 2015). The entire process is rapid and reliable. TSI9565-P Anemometer was applied to record the real-time wind speed, temperature and relative humidity. DustTrak™ DRX 8534 can was used to monitor $PM_{2.5}$ concentrations with a time resolution of 20 s. Aethlabs AE-51 mini black carbon meter (Costa-Surós and Markowicz, 2015) was adopted to measure the black carbon concentration according to its absorption characteristics with a time resolution of 60 s. The heavy metals existing in leaf, soil and air were tested using an inductively coupled plasma tandem mass spectrometer (Agilent 8800 ICP-MS/MS). Acid decomposition of material was conducted in TFM™-PTFE digestion vessels using a

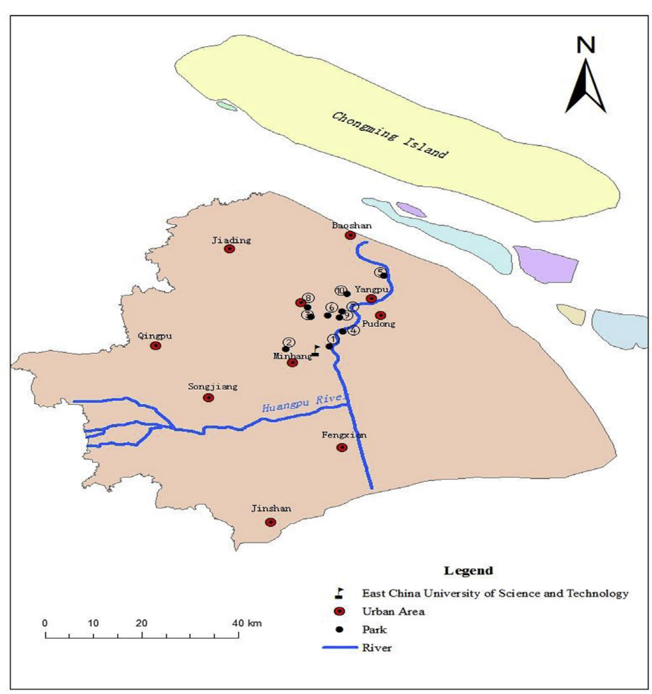

Fig. 1. Geographical locations for ten parks.