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Significance of wet deposition to removal of atmospheric particulate matter and polycyclic aromatic hydrocarbons: A case study in Guangzhou, China

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HIGHLIGHTS

- Increased use of cleaner energy lowers the PAH levels in rain from 2005 to 2010.
- Washout ratio of organic pollutants decreases with increasing rainfall intensity within 0–6 mm h^{-1}.
- Wet deposition is significant for removing PM and PAHs, especially when rainfalls are scarce.

GRAPHICAL ABSTRACT

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ABSTRACT

Rainwater samples were simultaneously collected from three locations in Guangzhou, a mega metropolitan center in South China, during the entire year of 2010, and analyzed for particulate matter (PM), total organic carbon and polycyclic aromatic hydrocarbons (PAHs), with the objectives of assessing the seasonality of washout effects and efficiency for removal of pollutants from the atmosphere by wet deposition. The contents of PM, particulate organic carbon, and dissolved organic carbon were in the ranges of 0.74–420 (average: 8.1 mg L^{-1}), 0.16–40 (average: 1.3 mg L^{-1}), and 0.34–6.9 mg L^{-1} (average: 1.4 mg L^{-1}), respectively. Concentrations of Σ_{15}PAH (sum of the 16 priority PAH compounds defined by the United States Environmental Protection Agency minus naphthalene) in wet deposition samples ranged from 39 to 1580 ng L^{-1} with an average of 170 ng L^{-1}. The PAH concentration levels were slightly abated compared to those acquired previously in Guangzhou during the year of 2005, probably indicating a favorable change of energy consumption patterns in the region. There were moderately significant negative correlations between washout ratios and rainfall intensities (0–4.3 mm h^{-1}). The total annual fluxes of wet and dry depositions combined for PM and PAHs in the urban area of Guangzhou were 34 g m^{-2} yr^{-1} and 6.0 × 10^2 μg m^{-2} yr^{-1} with 50 and 57% being contributed from wet deposition, respectively. The monthly capacity for removal (CR) of PM and PAHs (calculated as the wet deposition flux dividing the total flux) varied widely with different months, and was lower during the dry weather season (January–March and October–December) than during the wet weather season (April–September). Finally, the air quality index related to PM_{10} was negatively correlated to CR values of PM and PAHs, indicating the need to control the emissions of anthropogenically derived pollutants during the dry weather season.

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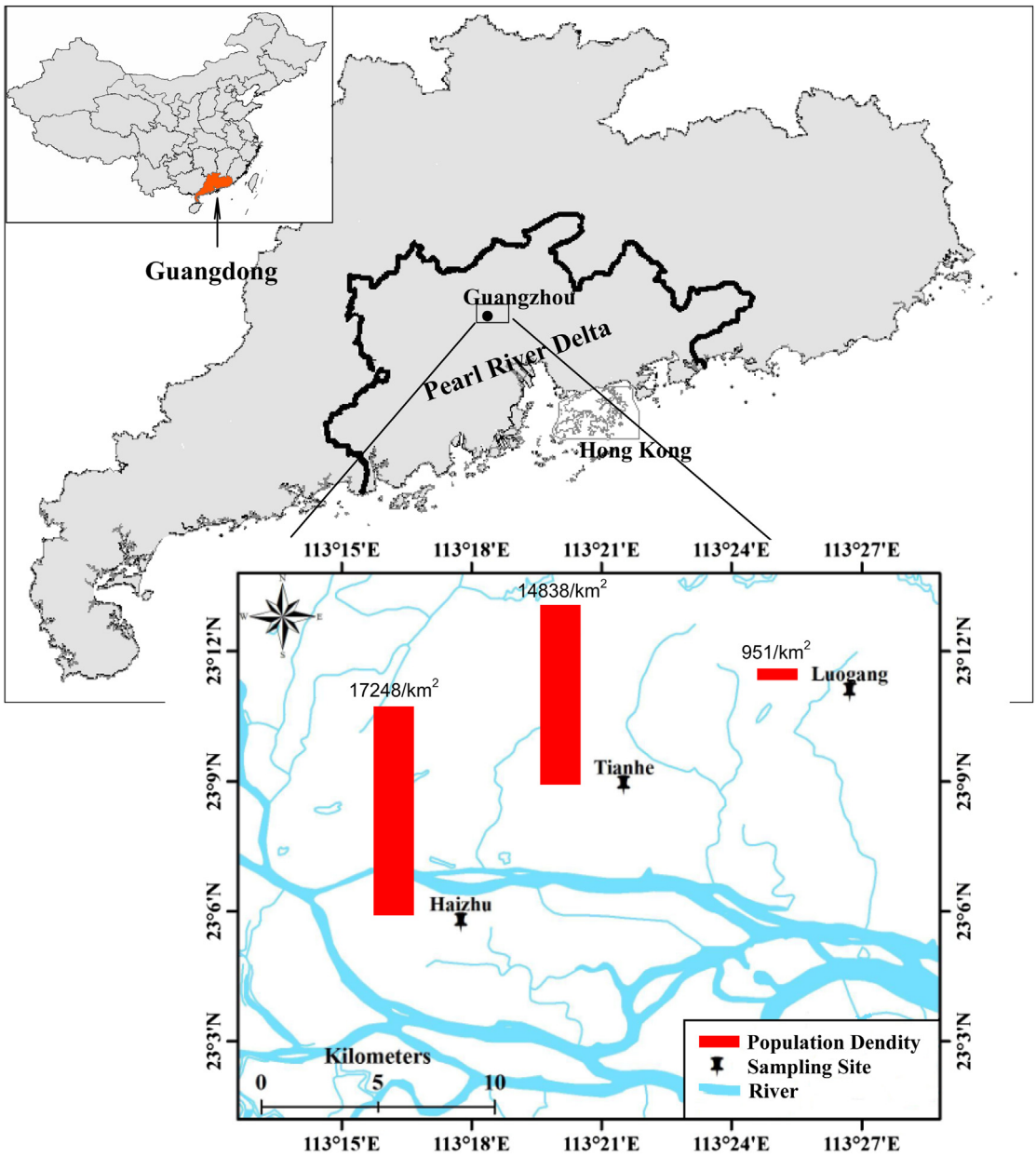

Fig. 1. Map showing the sampling sites (Tianhe, Haizhu and Luogang) in Guangzhou, China. The red bars indicate the population densities in these three sampling areas (Statistical Bureau of Guangzhou City, 2011). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

1. Introduction

Worsening air pollution in urban areas, a global environmental problem, is often associated with accelerated urbanization processes, and may adversely affect human health (WHO, 2011). To evaluate the magnitude of air pollution, indicative pollutants are often monitored and their trends are tracked. For example, among the six common air pollutants and 187 toxic air pollutants listed by the United States Environmental Protection Agency (USEPA), particulate matter (PM) and organic pollutants are the priority contaminants (USEPA, 2010). The USEPA in 1997 revised its air quality standards and proposed a standard for airborne PM less than 2.5 μm diameter ($PM_{2.5}$) to address potential health issues posed by these respirable particles, which are in a size range small enough to penetrate deeply into human lungs and therefore have direct and deleterious health effects (USEPA, 1997). Due to the adoption and implementation of the air quality standards and regulations, levels of atmospheric PM and organic pollutants decreased, and at the same time air pollution was eased in the last 10 years (USEPA, 2010).

One of the main mechanisms for removal of PM and organic pollutants from the atmosphere is wet deposition. In addition, total organic carbon (TOC) in wet deposition, comprised of particulate organic carbon (POC) and dissolved organic carbon (DOC), can be used to evaluate the magnitude of organic pollution in precipitations. Similarly, levels of polycyclic aromatic hydrocarbons (PAHs) in rainwater may also be used to reflect air pollution by total hydrocarbons and investigate their removal patterns during wet deposition. Therefore, PM, TOC, and PAHs were selected as the target analytes in the present study to examine any possible link between the characteristics (e.g., amount and intensity) of wet deposition and its efficacy for removal of PM and organic pollutants from the atmosphere.