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Characteristics of carbonaceous aerosols: Impact of biomass burning and secondary formation in summertime in a rural area of the North China Plain

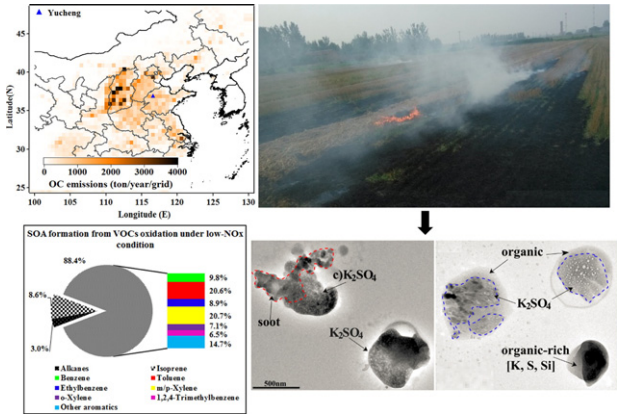
Lan Yao [a], Lingxiao Yang [a,b,*], Jianmin Chen [a,b,c], Xinfeng Wang [a], Likun Xue [a], Weijun Li [a], Xiao Sui [a], Liang Wen [a], Jianwei Chi [a], Yanhong Zhu [a], Junmei Zhang [a], Caihong Xu [a], Tong Zhu [d], Wenxing Wang [a]

[a] Environment Research Institute, Shandong University, Jinan 250100, China
[b] School of Environmental Science and Engineering, Shandong University, Jinan 250100, China
[c] Key Laboratory of Atmospheric Particle Pollution and Prevention (LAP3), Fudan Tyndall Centre, Department of Environmental Science and Engineering, Fudan University, Shanghai 200433, China
[d] State Key Laboratory for Environment Simulation and Pollution Control, College of Environmental Sciences and Engineering, Peking University, Beijing 100871, China

HIGHLIGHTS

- OM/OC ratio (2.07) was calculated to estimate organics at rural areas in NCP.
- Biomass burning contribution to carbonaceous aerosols was quantified.
- SOA formation was investigated based on VOCs evolution.

GRAPHICAL ABSTRACT



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ABSTRACT

To determine the characteristics of carbonaceous aerosols in rural areas of the North China Plain, field measurements were conducted at Yucheng (YC) in the summers of 2013 and 2014. The concentrations of carbonaceous aerosols at YC exhibited clear diurnal variation, with higher concentrations in the early morning and at night and lower concentrations during the afternoon hours. The mass-balance method designed for particulate matter smaller than 2.5 μm ($PM_{2.5}$) was used to calculate the organic matter (OM)/organic carbon (OC) ratio. The value obtained, 2.07 ± 0.05, was suggested as a reference to estimate organics in $PM_{2.5}$ in rural areas of the North China Plain. Biomass burning was identified to be a significant source of carbonaceous aerosols; approximately half of the samples obtained at YC were affected by biomass burning during summer 2013. Case studies revealed that biomass burning accounted for up to 52.6% of the OC and 51.1% of the elemental carbon in $PM_{2.5}$ samples. The organic coatings observed on sulphur-rich and potassium-rich particles indicated the formation of secondary organic aerosols (SOA) from the oxidation of precursor volatile organic compounds (VOCs) during the aging of smoke released from biomass burning. Based on the evolution of the VOCs, the contribution of VOCs

* Corresponding author.
E-mail address: yanglingxiao@sdu.edu.cn (L. Yang).

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oxidation to SOA concentration was 3.21 and 1.07 μg m^{-3} ppm^{-1} CO under conditions of low nitrogen oxide (NOx) and high NOx, respectively. Aromatics (e.g. benzene, toluene, xylene and ethylbenzene) made the greatest contribution to SOA concentration (88.4% in low-NOx conditions and 80.6% in high-NOx conditions). The results of the study offer novel insights into the effects of biomass burning on the carbonaceous aerosols and SOA formation in polluted rural areas.

1. Introduction

Carbonaceous aerosols, composed mainly of organic carbon (OC) and elemental carbon (EC), play important roles in human health, radiative forcing and climate change, as they make up a significant proportion of particulate matter smaller than 2.5 μm ($PM_{2.5}$) (Jacobson, 2001; Mauderly and Chow, 2008). OC, a complex mixture of hundreds of organic compounds (e.g. polycyclic aromatic hydrocarbons, PAHs), is associated with respiratory and cardiovascular disease, and may even cause cancer (Mauderly and Chow, 2008). EC is a major absorber of visible solar radiation in the atmosphere, and has been identified as the second greatest contributor to global warming in the troposphere, after carbon dioxide (CO_2) (Ramanathan and Carmichael, 2008). Of the numerous anthropogenic sources of carbonaceous-aerosol emissions, such as power plants, industrial production, residential and transportation, biomass burning has been reported to be the largest global source of OC and EC (Cheng et al., 2013). OC is either emitted directly from combustion sources, which is primary OC (POC), or formed as secondary OC (SOC) from the photochemical reactions of precursor volatile organic compounds (VOCs) with either hydroxyl (OH) radicals and ozone (O_3) (predominantly during the daytime) or nitrate (NO_3) radicals (during the night) (Lambe et al., 2015; Rollins et al., 2012).

North China Plain (NCP) suffered from serious air pollution. Zhang et al modeled the emission of carbonaceous aerosols over China (Zhang et al., 2009) and proposed far more OC is emitted in the NCP region than in other areas of China (Fig. 1). Thus, intensive studies on carbonaceous compounds, including seasonal variation, spatial distribution, sources and biomass burning impact, have been conducted in the NCP region (Cheng et al., 2013; Fu et al., 2012b; Li and Bai, 2009; Pathak et al., 2011; Yang et al., 2011; Zhao et al., 2013). Biomass burning has an influence on carbonaceous aerosols level in NCP (Cheng et al., 2013; Fu et al., 2012b), however, quantitative data on the contribution

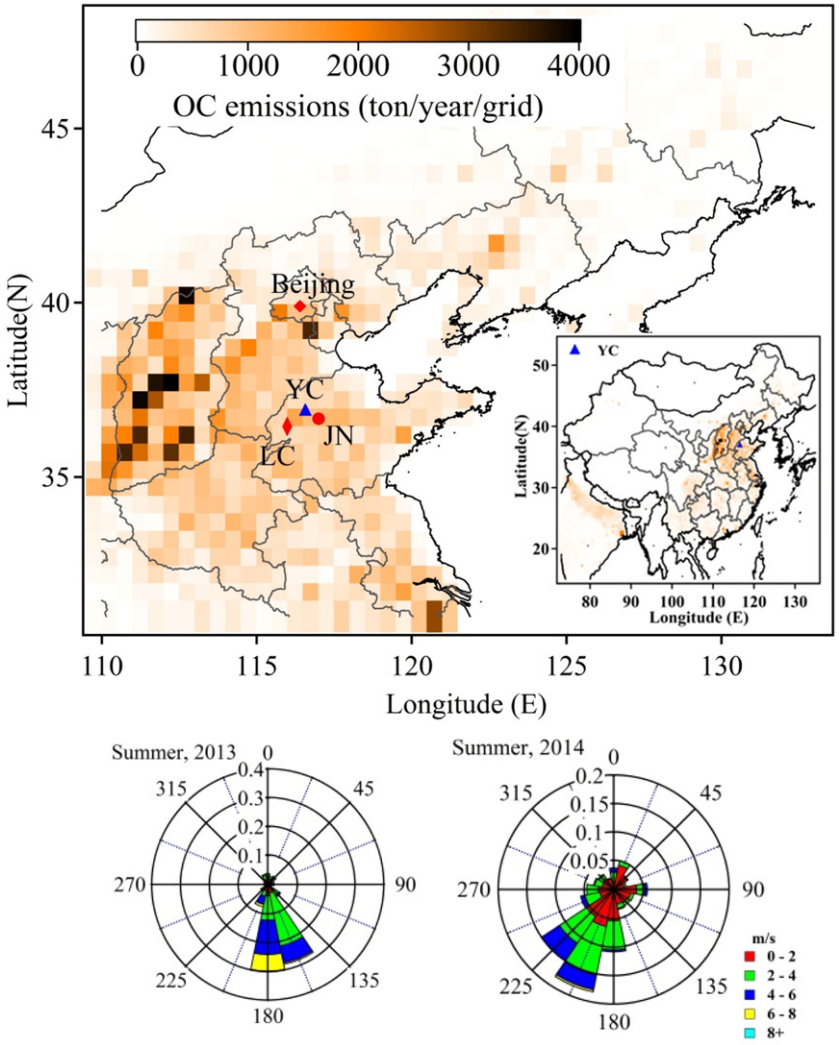

Fig. 1. OC emissions over China (Zhang et al., 2009). The blue marker is the sampling site, YC. LC: Liaocheng; JN: Jinan; Winds at YC during summer in 2013 and 2014 are also shown.