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# Volatile organic compounds in stormwater from a community of Beijing, China☆

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Stormwater samples were collected from six different land use sites with three time-intervals during a precipitation event on August 12, 2016, from a community of Beijing, China. A total of 46 species volatile organic compounds (VOCs) were detected in these stormwater samples, including methyl tertiary-butyl ether (MTBE), aromatic hydrocarbons, halogenated aromatics, Halogenated alkanes, and alkenes. The total VOC concentrations varied in the six sites following order: highway junction > city road > gas station > park > campus > residential area, except for MTBE, which was much higher at gas station compared to other land use sites. ANOVA results indicated both land use and precipitation time intervals could significantly affect the VOC concentrations even in the small area. The Beijing atmospheric VOC concentrations were too low to explain the high concentrations in stormwater, suggesting that land surfaces may be the main sources of VOC other than the ambient atmosphere. MTBE and other VOCs correlation analysis indicated that MTBE mostly came from gasoline emissions, spills or vehicle exhausts, whereas the BTEX (benzene, toluene, ethylbenzene, Xylenes) and the halogenated aromatics were transferred from chemical plants through land surfaces accumulating and the wind blowing atmospheric VOCs. Xylenes/ethylbenzene (X/E) ratios variations indicated that stormwater incorporated larger amount of fresh emitted air during the precipitation event than prior to it. Information of these stormwater VOCs in this study could be used in the community pollution reduction strategies.



## 1. Introduction

Volatile organic compound (VOC) pollutants have been reported in the atmosphere (Field et al., 1992; Lopes and Bender, 1998; Lee et al., 2002; Okochi et al., 2004; Hsieh et al., 2006; Li et al., 2016), precipitation (Lopes et al., 2000; Okochi et al., 2004; Mullaugh et al., 2015), stormwater and groundwater (Delzer et al., 1996; Lopes and Bender, 1998; Yu et al., 2017). Anthropogenic emissions of VOCs are associated with the utilization of fossil fuels, paints and coatings, pesticide, solvents, adhesives, deodorants, and other industrial products (Field et al., 1992; Delzer et al., 1996; Zogorski et al., 2006). However, fossil fuel use has been identified as the major VOC anthropogenic emissions source (Lopes and Bender, 1998; Okochi et al., 2004; Li et al., 2016).

Precipitation could bring VOC pollution to water systems and even groundwater, which may cause contaminants in the waters (Lopes et al., 2000; Okochi et al., 2004; Mullaugh et al., 2015; Yu et al., 2017). The VOC pollution in water systems may be a concern to human health because VOCs have potential carcinogenicity and could adversely affect the liver, kidney, spleen, stomach, and heart, as well as the nervous, circulatory, reproductive, and respiratory systems (Zogorski et al., 2006). In the United States, long-term aquifer studies (1985–2011) detected VOC pollutants in approximately 20% of the 3500 groundwater and drinking water samples (Zogorski et al., 2006). VOC pollutants in groundwater have also been reported in the United Kingdom, Switzerland, and

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Italy (Ellis and Rivett, 2007; Aeppli et al., 2008; Di Lorenzo et al., 2015). In China, VOC pollutants have been found in 80% of the 130 groundwater samples from five alluvial plains (Bi et al., 2012). Recently, VOC pollutants have been found in the Yangtze River and some water-source reservoirs in China (Han et al., 2013).

Studies have shown that VOCs in stormwater could be reflective of atmospheric VOCs of certain areas (Lopes and Bender, 1998; Lopes et al., 2000; Borden et al., 2002; Okochi et al., 2004; Yu et al., 2017). Urban communities include many different functional zones such as residential areas, schools, parks, gas stations, roads, etc. For examples, Lopes and Bender (1998) suggested the urban land surfaces were the primary nonpoint source of most stormwater VOCs. Borden et al. (2002) studied different land use affecting stormwater VOCs in a large scale (the state of North Carolina, US), which included large watersheds (drainage area varied between 4095 acres and 57,712 acres) and small areas (gas stations, and open space with 9 acres), they found that high-intensity urban land uses had relatively high VOC contaminant concentrations, median stormwater aromatic hydrocarbons (BTEX) concentrations in commercial, industrial, mixed-small watersheds, methyl tertiary-butyl ether (MTBE) in stormwater from gas stations (point source of VOCs) were about an order of magnitude higher than other land uses. Lopes et al. (2000) and Okochi et al. (2004) revealed there were no significant relations between stormwater VOC concentrations and rain intensities. Yu et al. (2017) compared the VOC differences between stormwater and groundwater in the city of Seoul (South Korea). However, the stormwater VOC pollution in different functional zones (point, nonpoint, and other sources) in a single community, which may bring different VOC pollution pressures to the community water systems (Lopes and Bender, 1998; Lopes et al., 2000; Yu et al., 2017), were few studied so far. In this study, we sampled stormwater from six different zones with three time-intervals of a precipitation in a single community from Daxing District (suburban area) of Beijing and analyzed the stormwater VOC concentrations variations. The objectives of this study were: (1) to determine stormwater VOC characteristics and their possible sources; (2) to test if different land uses have an effect on stormwater VOC concentrations in a small area; (3) to explore how these VOC concentrations temporally change in a certain precipitation event.

## 2. Materials and methods

### 2.1. Sample collection

The sampling community is located in the Daxin District, a southwestern suburb of Beijing (Fig. 1), which had a population density of 1650 per km$^2$ in 2016 (DXSB, 2017). The six functional zones included highway junction (hereafter Highway), gas station (GS), city road (Road), university campus (Campus), park and residential. The gas station represented a point source of VOCs, the highway junction and city road represented non-point sources, and other four sites (campus, park, and residential) appeared as intermediate sources of VOC pollution. One specific sampling site was selected for each functional zone, and each sampling site (rainwater pit) covers a contributing drainage area between 60 m$^2$ and 100 m$^2$ land surface, the slopes (gradients) of those sampling areas grounds were less than 0.1%, except the highway junction with a slope of 3.4%. There were no large (or specific) buildings in the six sampling drainage areas, which could avoid drastic VOC differences from various buildings (Wilson et al., 2017).

The sampling was completed by a group of six people. All samples in the present study were collected during a precipitation event occurred on August 12, 2016, following five preceding dry days. The air temperature averaged at 24.9 °C (between 24.7 °C and 26.1 °C) during the sampling period. The precipitation started at 1:17 p.m. on the sampling date. Our sampling started at 1:18 p.m. since the first stormwater drop formed and ended at 2:37 p.m., which lasted approximately 48 min. Data on rain intensity changes (Fig. 2) was obtained from the Daxin Meteorological Office (city of Beijing). A total 17.6 mm precipitation were recorded in the sampling area during our sampling period, the average wind speed and atmospheric pressures were 3.3 m/s (0 m/s to 7.8 m/s) and 0.987 atm (0.983 atm–0.990 atm) during the sampling period, respectively. Wind direction changed from western to southern to eastern during our sampling period (Daxin Meteorological Office).

The sampling period of the present study (between 1:17 p.m. and 2:37 p.m., Friday, Aug 12th, 2016) was out of heavy traffic hours (after 4 p.m.). Besides, most people had known the upcoming precipitation information (through weather forecast) prior to the rain, consequently, there were fewer human activities (i.e. running cars, walking people) than those in normal daytime hours during our sampling period. The stormwater samples were collected in


**Fig. 1.** Locations of the six sampling sites in this study. All sites are located in Daxin (yellow oval with red outline in the top-right plot), a suburb district of Beijing.

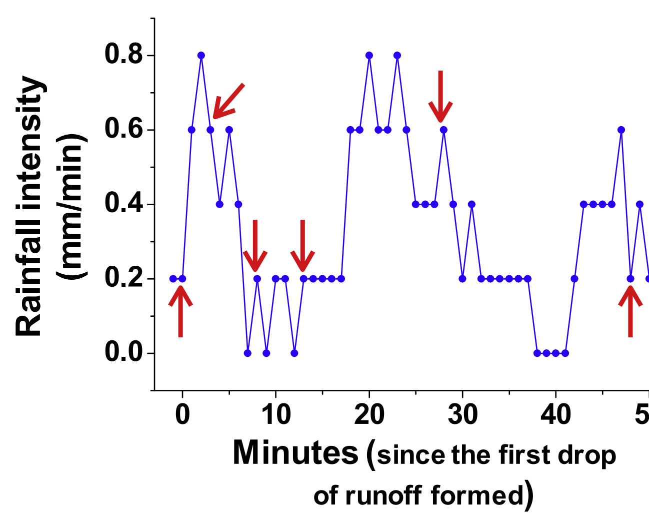


**Fig. 2.** Rain intensity changes during the sampling periods on August 12th, 2016 (data source: Daxin Meteorological Office, City of Beijing). The red arrows represent the sampling time points ("0" min, 3rd min, 8th min, 13th min, 28th min, and 48th min).