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Levels, characteristics and health risk assessment of VOCs in different functional zones of Hefei

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A R T I C L E I N F O

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A B S T R A C T

In order to study the characteristics and health risk of VOCs in the ambient air in the typical developing cities in China, the research was conducted in five functional zones in Hefei from September 2016 to January 2017. The average concentrations of total measured VOCs in traffic zone was the largest (85.94 μg m^{-3}), followed by industrial zone (64.84 μg m^{-3}), development zone (58.92 μg m^{-3}), resident zone (57.31 μg m^{-3}), and background zone (54.94 μg m^{-3}). Cl-VOCs were most abundant species in chlorinated VOCs (85.06%), which showed much higher level in industrial zone. the mean value of BTEX found in presented study was 65.19 μg m^{-3}. Based on the specific VOC ratio method (B/T), the observed sites were greatly affected by the traffic emissions. The ratios of T/B, E/B and X/B were 1.15, 1.35 and 0.47, respectively, possibly due to the aging air mass. Carcinogenic risks for benzene, carbon tetrachloride, trichloroethylene, 1, 2-dichloroethane and chloroform were higher than the general acceptable risk level of 1.00×10^{-6}. Potential non-carcinogenic risk assessment showed that hazard quotient (HQ) of 10 VOCs not exceeded unity, but the hazard risk index (HI) at site ED, LY, YH and HD were both higher than 1.

1. Introduction

The volatile organic compounds (VOCs) are among the major organic pollutants in urban air, which of great concern due to their adverse effects on human health, they can induce cancer directly and associated with increased long term health risks due to their carcinogenic and toxic (Dewulf and Van Langenhove, 1999; EPA, 2008). Moreover, they play an important role in the photochemical process, for the production of photochemical ozone and some secondary organic aerosols, may affect the air quality and chemistry of atmosphere (Carter, 1994; Dumanoglu et al., 2014; Sawyer, 1997).

VOCs represent a large variety of species such as non-methane hydrocarbons (NMHCs), Cl-VOCs (chlorinated VOCs) and BTEX (benzene, toluene, ethylbenzene and meta-, para- and ortho-, xylenes), which are emitted from a wide variety of natural and anthropogenic sources. The main anthropogenic sources of VOCs are transport related, fuel related and industrial related. Including automobile exhausts, combustion processes utilizing fossil fuels, petroleum refining, storage and distribution of petroleum products, industrial emissions and using of solvents (Ilgen et al., 2001; Zhao et al., 2004). Some of biogenic compounds among VOCs are mainly emitted by natural sources, such as vegetation, oceans and soils (Öztürk et al., 2015; Sahu et al., 2016), compared to anthropogenic emissions this contribution is usually minor in urban atmospheres (Barletta et al., 2005). Consequently, anthropogenic sources of VOCs, especially traffic emissions and industrial procedure have been an increasing concern.

Ambient concentrations of VOCs showed large variations between different regions, which were complex due to the different surrounding and existence of a variety of anthropogenic sources. Among large amount of VOCs, Cl-VOCs and BTEX were the dominant species in nearly all studies of urban area, their ambient pollution levels, concentrations and variation patterns reflected different sources, and determined the potential health risk. Cl-VOCs are a group of ubiquitous contaminants that have been widely detected in ambient air environment in recent years (Huang et al., 2014). These halocarbons mainly comes from anthropogenic sources and are considered probable human carcinogens (Humans, 2007). Cl-VOCs have be widely used as solvents for many industrial process, such as the production of pesticides, refrigerants and pharmaceuticals, they also used for dry cleaning and metal degreasing, thus playing an essential role in our daily life and industrial development (Doherty, 2000; Huang et al., 2014). The most abundant BTEX was xylene, followed by toluene, benzene and

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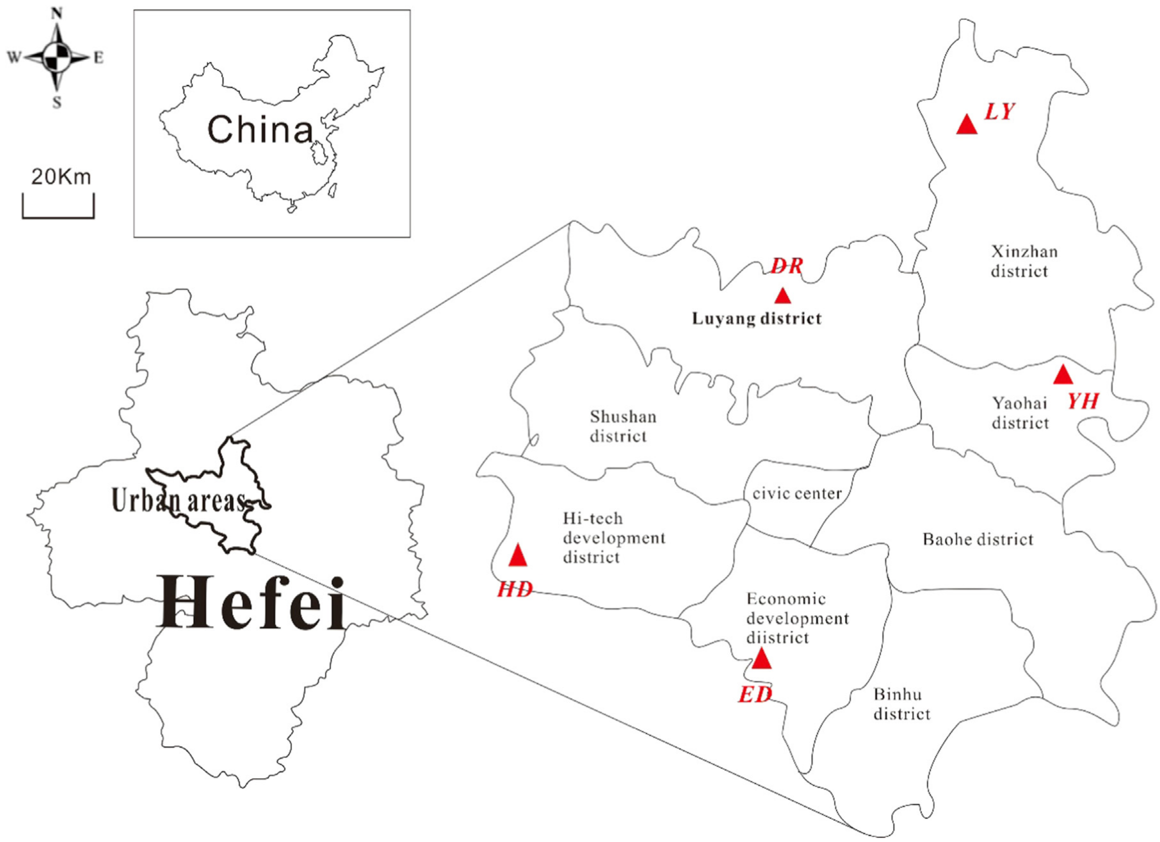

Fig. 1. Location of sampling sites in different functional zones in Hefei.

ethylbenzene. Xylene is refined from crude oil; toluene is a major constituent used as solvents in industrial production; benzene in ambient air as a result of burning fuels (coal, petrol and wood) (Anderson et al., 1974; Lee et al., 2002).

Exposure to VOCs can induce a wide range of acute and chronic health effects from asthma, sensory irritation and nervous system impairment (Otto et al., 1992; Tang et al., 2005). Some VOCs such as dichloromethane, trichloroethylene and BTEX are classified as hazardous air pollutants (HAPs), which are mutagens or carcinogens (EPA, 1990, 2003; Finlayson-Pitts and Pitts, 1999). Risk assessments is effectively tools to evaluate the hazardous impact of the VOCs on human health, which are usually classified as carcinogenic and non-carcinogenic for estimating their human health risks (Asante-Duah, 1993; EPA, 2005). In recent study, Zhang et al. (2012) investigated the levels, sources, and health risk of BTEX at a same sampling site in Beijing, they found that integrated life time cancer risks in Beijing exceeded the value of 1E-06, and the hazard quotient (HQ) of non-cancer risk of exposure to formaldehyde exceeded unity. Huang et al. (2014) used three different remediation approaches to explore the sources and potential human health impacts of Cl-VOCs from contaminated sites. In Tianjin, Zhou et al. (2011) found that the mean value of specific VOC concentrations in outdoor were 0.18–3.89 $\mu g\, m^{-3}$, and the cancer risk analysis of benzene, chloroform, carbon tetrachloride and 1,3-butadiene exceeded the U.S. EPA benchmark. Fifty-eight VOCs were detected in Aliaga, Turkey. The concentrations ranged between 0.1 and 1770 $\mu g\, m^{-3}$ (avg ± SD, 67 ± 193 $\mu g\, m^{-3}$), and the carcinogenic risks reach high levels in this study area (Dumanoglu et al., 2014).

Hefei (31°52′N 117°17′E) is the capital city of Anhui province, a developing city in eastern China. It is located in the central portion of Anhui province, with a population of 7,800,000 and covering an area of ~11000 km^2 (Hu et al., 2017; PRC, 2014; Zhang et al., 2013a). Hefei has faced increased resource consumption and environmental degradation, with their accelerated development of economy, industrial facilities, urban construction and public transportation (Huang et al., 2012; Li et al., 2010; Ni et al., 2008).

Measurements in different functional zone in same city would better understood the role of VOCs, but majority of the studies focusing on the one sites in same area or different sites in different cities. Therefore, this study aims to augment this lack of important information. In the present study, airborne VOCs were measured at five sampling sites in different functional zones. The variation of some groups of VOCs including Cl-VOCs and BTEX between different functional zones were examined. By the utilization of specific VOC ratios, source profiles of VOCs and assessment of the age of the air mass were examined. This would provide a reference for future studied and atmospheric pollution control in Hefei. Health risks due to inhalation exposure to specific VOCs were performed through health risk assessment approaches, including carcinogenic risk and non-carcinogenic risk assessment. To our knowledge, this is one of the first detailed studies investigating the VOCs in different functional zones of Hefei.

2. Materials and methods

2.1. Sites description and field sampling

The study were performed in the urban area of Hefei, which is located in the central portion of Anhui province. In order to investigate the characteristics of VOCs in different functional zones, five sites were selected including ED (industrial area), LY (traffic zone), YH (residential zone), HD (development zone) and DR (background zone) for VOCs monitoring. Site ED situated in the west section of Fanhua Avenue, economic development district. This district is a main industrial area in Hefei, so that this site was used to represent the industrial area in this study. LY is in the intersection of Fuyang north road and Jiqiao road, Luyang district, which surrounded by viaduct and highway. It is about 10 km to Hefei railway station and bus terminal,