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Spatial and temporal variation of BTEX in the urban atmosphere of Delhi, India

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ABSTRACT

Benzene, toluene, ethylbenzene and xylene (BTEX) form an important group of aromatic Volatile Organic Compounds (VOCs) because of their role in the tropospheric chemistry and the risk posed by them to human health. Concentrations of BTEX were determined at different sampling points in the ambient air of Delhi in order to investigate their temporal and spatial distributions. Significant positive correlation coefficient ($p<0.01$) was found between inter-species concentrations at all the sampling locations. Inter-species ratio and Pearson's correlations indicate that gasoline vehicular exhaust could be the major source of BTEX in Delhi. The inter-species ratios exhibit clear seasonal variations indicating differential reactivity of the VOC species in different seasons. Xylenes were found the largest contributor to the ozone formation followed by toluene.

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1. Introduction

Volatile Organic Compounds (VOCs) have grasped much attention over the last two decades because of their significant contribution in the formation of oxidants like ozone and PAN in the troposphere besides their health implications to human beings (Haagen-Smit and Fox, 1956; Atkinson, 1994, 2000; Atkinson et al., 1997, 1999; DeMore et al., 1997). In urban areas, a group of aromatic VOCs, benzene, toluene, ethylbenzene and xylene collectively called as BTEX constitute up to 60% of non-methane VOCs (Lee et al., 2002) and can be considered as an efficient indicator of organic compound pollution from road traffic. The use of unleaded gasoline, which is rich in aromatic hydrocarbons, has increased worldwide and the monitoring of these hydrocarbons in urban regions has become a priority. Benzene, an important representative of aromatic hydrocarbons has been a prime target for assessment in the urban atmosphere (Brocco et al., 1997; Coursimault et al., 1995; Pfeffer et al., 1995) as it is considered to be a genotoxic carcinogen (WHO, 2000; Hellén et al., 2002).

The reaction of the BTEX with hydroxyl radicals (OH) and/or nitrate (NO_3) radicals serves as the dominant degradation processes for aromatic VOCs in the atmosphere (Brocco et. al., 1997). The resulting products contribute to secondary organic aerosol (SOA) formation by nucleation and condensation. It was reported by Odum et al. (1997) that the reaction of toluene with NO_x in the presence of a light source formed SOA with a significant aerosol yield. Thus, aromatic VOCs influence gas-phase pollutants directly and particle-phase pollutants indirectly. In the presence of NO_x, they react with OH radicals to form ozone (Atkinson, 2000) thus modifying the oxidizing capacity of the atmosphere. It is well established that ozone is generated in situ from the sunlight-initiated oxidation of VOCs, in the presence of NO_x. Consequently, the reduction of

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ozone levels during photochemical pollution episodes may be achieved by control of the emissions of the precursor VOC and NO_x. There are two conditions in the atmosphere, which are usually referred to as the low and high NO_x regimes. In the low NO_x regime the production of ozone is mainly governed by the amount of NO_x, while in the high NO_x regime the amount of ozone is controlled both by NO_x and VOC levels (Sillman et al., 1990; Chameides et al., 1992).

Ozone formation potential of VOCs can vary by virtue of differences in their reactivity and structure. This has led to the development of scales of so called 'reactivity' or 'ozone formation potential' for VOC, of which the most widely applied are the 'Maximum Incremental Reactivity' scale (MIR), developed by Carter and co-workers (Carter, 1994, 1995; Carter et al., 1995), and the 'Photochemical Ozone Creation Potential' (POCP) scale, developed by Derwent et al. (1998).

Inspite of the well known toxic effects of VOCs, data available on VOC levels in India is very limited. Moreover, there is no legislation for VOC in ambient air in India. Few studies have reported VOC levels in Indian metro-cities (Srivastava et al., 2006; Srivastava et al., 2005; Chattopadhyay et al., 1997; MohanRao et al., 1997 and Padhy and Varshney, 2000). The present study is an attempt to envisage the source characteristics of BTEX in terms of their inter-species correlations and concentration ratios in the ambient air of Delhi. Significance of the present study is in terms of its sampling protocol. A week-long passive sampling method adopted in the present study implies the average concentration of VOCs over a period of 1 week rather than projecting short-term concentration—few hours—as reported in other studies. Ozone formation potential of BTEX was also calculated to workout the contribution of different species to ozone formation.

2. Methodology

2.1. The Study Area

Delhi, the National Capital Territory of India, has a geographic area of 1483 km^2 stretched in east–west width approximately 51.9 km and northwest width approximately 48.48 km with a population 13.79 million. Delhi is situated at latitude of 28°24′ 17″ to 28°53 and the longitude of 76°20′37″ to 77°20′37″ with an altitude of 216 m above mean sea level in the semi-arid zone of India. To the north the Himalayas are at a distance of just 160 km and to the south are the central hot plains. To the west of Delhi is the Great Indian Desert (The Thar) of Rajasthan and cooler hilly regions to the northeast.

The climate of Delhi is mainly influenced by its inland position and the prevalence of continental air during the major part of the year. Extreme dryness with an intensively hot summer and cold winter are the main characteristics of the climate. The mean annual rainfall in Delhi is 71.5 mm. About 81% of the annual rainfall is received during the monsoon months. January is the coldest month with the mean daily maximum temperature at 21.3 °C and mean daily minimum at 7.3 °C. May and June are the hottest months with temperatures touching 46–47 °C. The average annual temperature ranges between 22 °C and 25 °C. The air in Delhi is dry for most of the year, with very low relative humidity from April to June and markedly higher humidity in July and August, when weather conditions are oppressive. Temperature inversions are common in winter. Meteorological data taken from Indian Meteorological Department (IMD) was used to obtain general wind pattern of Delhi during the sampling period which is illustrated as windrose in Fig. 1. In Fig. 1 values 0–10 represent wind speed (in Knots) while the percentages given at the axis

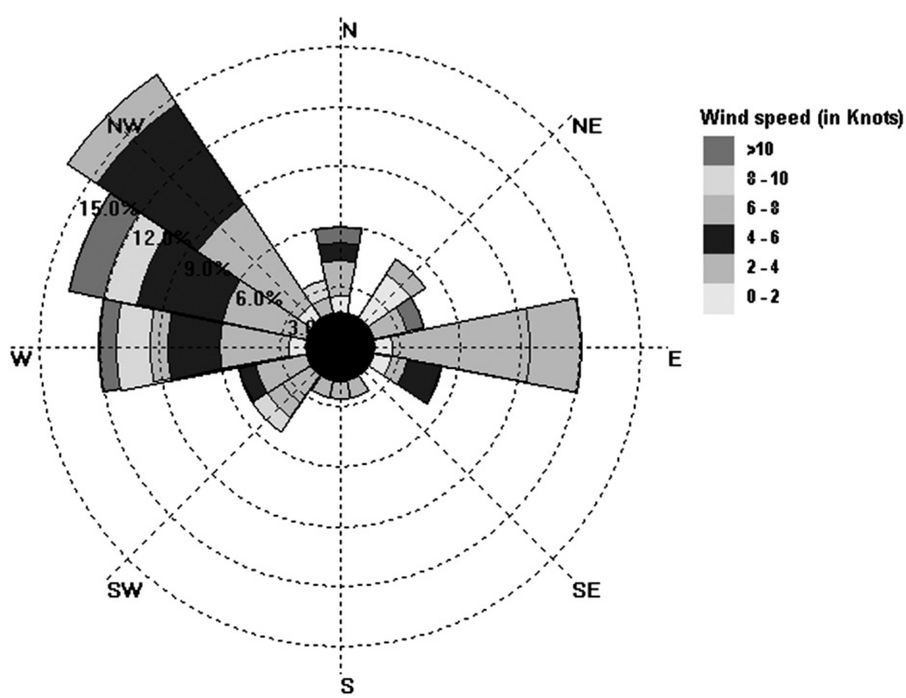

Fig. 1 – Windrose showing general wind pattern for the sampling period (October 2001–September 2002) in Delhi.

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