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Atmospheric Volatile Organic Compounds (VOCs) at a farming area of Gorakhpur – A terai region

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ABSTRACT

Volatile organic compounds (VOCs) are chemicals that both vaporize into air and dissolve in water. VOCs are pervasive in daily life, because they're used in industry, agriculture, transportation, and day-to-day activities around the home. The interest in determining ambient concentrations of VOCs due to their significant adverse effects on human health has increased in the past few years. Thus, an investigation of ambient VOCs (benzene, toluene and xylene) was conducted at agricultural area in Gorakhpur for a span of one year in order to ascertain the contamination levels. The levels of BTX were measured with the help of low volume sampler. The samples were extracted with carbon disulphide by occasional agitation and the aromatic fraction was subjected to GC-FID. The average concentration of total BTX in all samples was 11.5 µg/m3 and the total range was from 1.03 µg/m3 to 23.9 µg/m3 with the median of 7.8 µg/m3. The maximum concentration of total BTX was found to be 14.2 µg/m3 in winter season, followed by 10.6 µg/m3 in summer and 9.6 µg/m3 in monsoon season. Toluene contributed maximum (63%) followed by benzene (33%) and xylene (4%) and residential site (14%). The concentration of BTX decreased in the order toluene > benzene > xylene. The hazard quotient of benzene, toluene and xylene were 3.8E-01, 4.3E-03 and 1.3E-02 respectively. Integrated lifetime cancer risk for benzene was 7.6E-06.

KEYWORDS: BTEX, Carcinogenic/Non-carcinogenic risk, Terai zone,

1. INTRODUCTION

With the rapid urbanization and industrialization in the region, more and more chemicals are introduced into the environment, and environmental pollution, including air pollution, has attracted increasing public and regulatory concerns. Volatile organic compounds (VOCs) are important tropospheric pollutants. VOCs are carbon-based compounds that have vapor pressure (0.01 kPa or higher at 20 °C) to significantly vaporize and enter the atmosphere [1]. The estimated worldwide average emissions of VOCs are about 1,347 million tons/year from biogenic sources and 462 million tons/year from anthropogenic sources. Ambient total concentrations of airborne VOCs (155 species) in urban and suburban areas have been reported to be in the range of 16.2–1,033 µg/m^3 [2]. During the recent decades volatile organic compounds (VOCs) such as benzene, toluene and xylene (BTX) have gained interest in the field of indoor and outdoor air quality [3]. These monoaromatic hydrocarbons are the sources of a variety of adverse health effects such as asthma, dizziness, fatigue, and eye, nose, and throat irritation. Moreover, nausea and similar nonspecific symptoms have been also associated with BTX [4]. Among BTX compounds, xylenes are highly reactive and contribute to ozone formation and hence to climate change [5].

BTX have been extensively measured worldwide in the last decade [6]. Benzene ambient concentration is regulated by guidelines and is limited to 5 mg/m3 as an annual average. Levels of toluene and xylenes, although still not regulated, are suspected to have synergic effects to benzene and their concentrations are usually indicated in the air-monitoring reports [3].

Humans are exposed to benzene mainly through breathing polluted air [7]. Therefore, great efforts have been devoted to identifying the sources of benzene in both indoor and outdoor air [8]. Benzene is emitted by vegetation and petroleum reservoirs [9]. However, because it is present in crude oil, natural gas, and unleaded gasoline, anthropogenic sources are the main contributors. Emissions from vehicle exhaust, evaporative loss, and incomplete fuel combustion processes are considered the main sources of benzene in outdoor air. Toluene and xylene are more abundant in gasoline than benzene and are also widely used in solvents. Therefore, outdoor levels of these compounds were expected to be higher than that of benzene. Despite the fact that their toxicity is lower than that of benzene, they have the same environmental fate and, when exposed to photochemical reactions in the atmosphere, produce compounds which can provoke adverse effects on human health. Therefore, the analysis of benzene, toluene, and xylene (BTX) concentrations in air is necessary [2].

2. Materials and Methods

Site description, sampling and analysis

Air sampling was set up for a span of one year (Nov. 2014 to Oct. 2015) at an agricultural area '*haiderganj*'. Monitoring was performed for 20-24 hrs once a week in a scheduled manner and a number of forty eight samples were collected. BTX were sampled and analyzed using a methodology based on National Institute for Occupational Safety and Health (NIOSH) method 1501 [10]. BTX were sampled by drawing air through activated coconut shell charcoal tubes (CSC, 8 mm x 110 mm, 600mg) containing two sections of (main section 400 mg, second section 200 mg) separated by a 2 mm urethane foam (SKC Inc.), using a low-flow SKC Model 220 sampling pump (SKC, USA) at the flow rate of 250 ml/min for 20-24 hrs. The air suction rate was verified every week using calibrated rotameters with an accuracy of ±1%. Sampled air was then analyzed with an HP 6890 gas chromatography/mass spectrometer and gas chromatography/ flame ionization detector [11].

3. RESULTS & DISCUSSION

The seasonal BTX concentrations measured at agricultural sites of Gorakhpur is presented in Figure 1. The concentration of benzene ranges from 3.5 µg/m^3 to 34.1 µg/m^3 with the mean value of 11.4 µg/m^3.

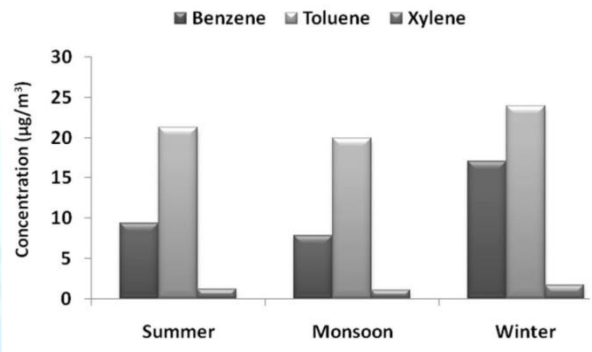

Figure1: Seasonal BTX concentrations (µg m^{-3})

Toluene ranges from 9.4 µg/m^3 to 47.1 µg/m^3 having an average of 21.7 µg/m^3. Xylene has a mean concentration of 1.3 µg/m^3 with the range of 0.5 µg/m^3 to 3.4 µg/m^3. The total mean concentration of BTX was 11.5 µg/m^3 at agricultural area of Gorakhpur. Figure 2 depicts that toluene (63%) had the highest contribution followed by benzene (33%) and xylene (4%) of the total BTX at agricultural area.

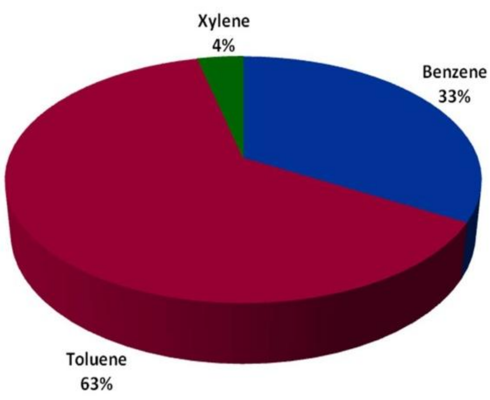

Figure 2: Individual Contribution (%) of BTX

The interspecies ratios of VOCs with varying reaction rates against OH provide information about the characteristics of air at the sampling site. Average VOC relative ratios at Gorakhpur region with respect to benzene, toluene and xylene (BTX) were studied. Benzene and Toluene are chief constituents of gasoline emitted into the environment by vehicular exhausts. Table 1 illustrates that the maximum B/T ratio was found during winter season (0.71) followed by summer (0.43) and monsoon seasons (0.39) indicating that increase in concentration from monsoon to winter and summer to winter is maximum for benzene as compared to toluene and xylene.

Table 1: Average interspecies ratios (B/T & X/B)

	B/T Ratio	X/B Ratio
Summer	0.438498	0.122056
Monsoon	0.39598	0.130711
Winter	0.715481	0.095906

This fact is also supported by the X/B ratio which was found to be lowest in winter season (0.09) and increased during summer (0.12) and monsoon season (0.13). This may be explained on the account of prevalent usage of cow-dung cakes, charcoal, wood etc. for cooking throughout the year. Additionally, in winter season stubble, brushwood and straw are also used for heating purpose. The weather of Gorakhpur can be generally classified into three seasons, winter (November-February), summer (March-June) and monsoon (July-October). Figure 3 depicts the seasonal pattern of measured BTX in ambient air at agricultural area of Gorakhpur. The concentration of benzene in during winter, summer and monsoon seasons are in the order of 17.1, 9.3 and 7.9 μg/m^3 respectively, whereas toluene (23.9, 21.3 and 19.9 μg/m^3), and xylene (1.6, 1.1 and 1.0 μg/m^3).

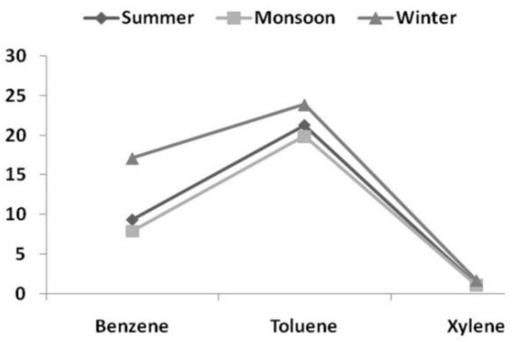

Figure 3: Seasonal BTX pattern at agricultural area

Although the trend of seasonal variation of BTX at agricultural area is similar with nature *i.e.* maximum concentration of BTX were found to be in winter followed by summer and monsoon seasons. The total BTX ratios for winter to summer (W/S) and winter to monsoon (W/M) were 1.3 and 1.5 at agricultural area indicating significant seasonal variations of BTX. Figure 4 shows the plot of toluene against benzene with R^2 value 0.91, which suggests a linear relationship between toluene and benzene. Moreover it also specifies that the source for benzene and toluene may be same *i.e.* the use of biomass fuel [12].

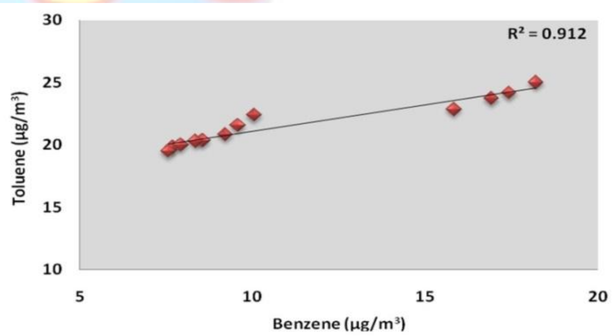

Figure 4: Correlation between Benzene and Toluene

Benzene is classified as carcinogenic substance, while toluene, m,p-xylene and o-xylene are classified as non-carcinogenic but hazardous to health substances. Thus, risk assessment has been performed in regard to estimate the brunt of hazards on human health by these mono-aromatic pollutants [13]. In the current study, the non-cancer hazard and integrated lifetime cancer risk (ILTCR) due to the exposure to BTX at their prevailing levels were estimated [14]. The integrated life time cancer risk (ILTCR) was calculated from the equation:

$$\textbf{ILTCR} = \textbf{E}_L \text{ (mg kg}^{-1}\text{day}^{-1}) \times \textbf{CPF} \text{ (mg kg}^{-1}\text{day}^{-1})$$

Where, E_L is the effective lifetime exposure and CPF is the carcinogenic potency factor or cancer slope factor. The inhalation cancer slope factor of carcinogenic compounds for benzene was obtained from Risk Assessment Information System (RAIS) as 2.73 x 10^{-2} mg $kg^{-1}day^{-1}$[15]. A cancer risk of > 10^{-6} was considered "carcinogenic effect of concern;" a value ≤10^{-6} was considered an "acceptable level" [13]. Risk assessment for non-malignant conditions was expressed by hazard quotient (HQ) defined as the ratio of yearly average daily concentration received (E_Y) and the reference concentration (RfC) calculated according to equation:

HQ = E_Y/RfC

Where RfC - the inhalation reference concentration of the non carcinogenic compounds toluene and xylene was obtained from the Integrated Risk Information System (IRIS) as 5 and 0.1 mg/m^3, respectively [16,17]. The RfC of benzene for non-cancer risk is 0.03 [18]. Summation of HQs for individual contaminants gave Hazard Index (HI).

Table 2: Estimate of non-cancer and cancer risk

	HQ	ILTCR
Benzene	3.8E-01	**7.6E-06**
Toluene	4.3E-03	
Xylene	1.3E-02	

HQ: Hazard Quotient

ILTCR: Integrated Life Time Cancer Risk

Table 2 represents ILTCR and non-cancer (HQ) risks (for 15 years residing time for and individual). The estimated cancer risk for benzene exceeded the threshold value of 1E-06 indicating more cancer risk from benzene due its high carcinogenicity. Toluene gives the highest non-cancer HQ followed by benzene and xylene. The individual HQs for BTX did not exceed unity anywhere indicating no serious threat of chronic non- cancer health effect in pollutant specific target organs for the city population [19].

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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