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Keywords: *TVOC, indoor, outdoor, residential, roadside, terai region.*

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Total Volatile Organic Compounds (TVOCs) in Indoor and Outdoor Urban Atmospheres at a Terai Region of Northern India

Amit Masih [α] & Anurag S. Lall [σ]

Abstract- Volatile organic compounds (VOCs) are an important class of air pollutants and even at a trace amounts; these compounds have a high potential hazard to human health due to their carcinogenic nature. In particular, highly reactive VOCs, which are reported to be toxic and also may participate in numerous reactions in the atmosphere to form secondary air pollutants including ground level ozone and secondary organic fine particles. Thus, an investigation of indoor/outdoor TVOC was conducted at selected locations in Gorakhpur in order to ascertain the contamination levels. The concentrations of TVOC were measured at two locations in the city of Gorakhpur, which covers residential and roadside areas. The samples were collected for the period of three consecutive days for indoors and outdoors, at each microenvironment. TVOC levels were measured using a portable data logging Ion Science PhoCheck^{+} photo-ionization detector (PID). TVOC concentration for combined indoor/outdoor air was 65.03 ppb and 161.08 ppb at residential and roadside site respectively. At residential site, the indoor and outdoor mean concentration of TVOC was 90.45 ppb and 39.62 ppb respectively. The average indoor concentration at roadside site was 173.52 ppb whereas at outdoor it was 148.68 ppb. At both the sites, the indoor TVOC levels were higher than that at outdoors.

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I. Introduction

A dramatic impact on air quality world-wide was created by the rapid urbanization and industrialization over the past decades. Recently, Asia alone has more than 10 megacities, including Delhi, and Mumbai, India. The impact of air pollution on human health has stimulated much interest for both public and scientific communities. A wide range of organic and inorganic pollutants have been recognised. Amongst these, the volatile organic compounds (VOCs) have gained special attention because they not only deteriorate human health, but also contribute significantly to major environmental problems such as global warming, stratospheric ozone depletion as well as ground level ozone formation. VOCs are carbon-compounds that have boiling point lower than or equal to 250°C at an atmospheric pressure of 1atm. (EU, 2004). The reaction of VOCs with hydroxyl radicals (OH) and/or nitrate (NO_3) radicals serves as the dominant degradation processes for aromatic VOCs in the atmosphere and the resulting products contribute to secondary organic aerosol (SOA) formation by nucleation and condensation (Brocco et al., 1997). The major sources of VOCs in ambient air include vehicular and industrial emissions, petrol refineries and usages of solvents. (de Blas et al., 2012). However, in indoor air, the sources of VOCs are diverse. Major sources include the combustion processes like cooking, heating and smoking. In addition, several domestic products such as cleansers, stain removers, paints, varnishes, furnishings and certain building materials also have a significant contribution. (de Blas et al., 2012). Exposure to elevated levels of VOCs may cause several adverse health effects such as irritation in mucous membrane, weakness, difficulty in concentrating, nausea, discomfort and headache. It may also cause some serious health effects such as lung cancer and leukemia. Although large number of individual VOCs has been identified in air, our knowledge regarding the health effects caused by some of these individual VOCs is very limited. (WHO, 1989). Hence, in order to illustrate the pollutant load in terms of VOCs, the individual VOC concentrations should be added together to obtain an entity called Total Volatile Organic Compounds (TVOC). (Molhave, 1990; Andersson et al., 1997). In India, the monitoring of TVOC has become more important because this country is in developing phase & in urban area there is very close proximity of residence and busy road with high traffic is quite often. People residing in an urban area especially in India spend more time while commuting for their work and residence. Thus, it becomes more important to get the actual air quality parameters for Indian cities. To our knowledge, there has been a shortage of TVOC studies especially in this particular part of northern India. Therefore, this paper describes a monitoring study conducted at Gorakhpur in which the indoor and outdoor TVOC levels were measured along with seasonal variation in residential and roadside atmospheres of a terai region of northern India.

II. Methods and Materials

a) Sampling site description

Gorakhpur (26°45′32″N 83°22′11″E) is located in the terai region of eastern Uttar Pradesh in northern

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India, near the border of Nepal, in the foothills of the Shiwalik Himalayas. Situated on the basin of rivers Rapti and Rohini, the geographical shape of the Gorakhpur city is of bowl, surrounded by the river and other small streams from three sides. River Rapti is interconnected through many other small rivers. The present district of Gorakhpur, 265Kms east of capital Lucknow, on National Highway (NH-28), covers geographical area of 3483.8 Sq. km having total population of about 4,440,895 (Masih and Lall., 2016). In winter season, the temperature ranges from 3.5°C to 29.5°C with an average of 18.6°C and humidity is 71%. During summer season, average temperature was 35.5°C with the range from 20.5°C to 48.5°C having 82% humidity, whereas in monsoon season the temperature ranges from 18.2°C to 43.8°C with an average of 30.8°C and humidity is 89% as represented in Table 2. Figure 1 illustrates that the prevailing summer and monsoon winds are east-northeast (ENE-30.1% & 26.3%) and west-southwest (WSW-14.1% & 19.4%) with wind speeds of 0.1 to 12.2 and 0.1 to 14.1 meters per second respectively, while during winters, the wind direction are towards east-southeast (ESE-21.9%) and west (W-20.1%) with wind speeds of 0.1 to 10.1 meters per second. Air sampling was accomplished at two sites of Gorakhpur city namely, 'Taramandal' which is exclusively a residential area, and 'Golghar' which is representative of a roadside area, since it is situated by the side of a road which carries high traffic density resulting in emission of smoke and total suspended particulate matter from engine exhausts (Masih et al., 2016).

a) BTEX sampling

Samples were collected for the period of three consecutive days for indoors and outdoors, at each microenvironment. Sampling duration was for 8 h from 10:00 am to 6:00 pm during all the seasons. TVOC levels were measured using a portable data logging Ion Science PhoCheck^{+} photo-ionization detector (PID) equipped with 10.6eV ultra-violet lamp (NIOSH, 2003). The sampling instrument was placed above 1.5 m (breathing zone) from floor level at indoor and outdoor locations. The instrument uses ultra-violet light to break down VOCs in the air into positive and negative ions. Then, it measures the flow of electric current, which is proportional to the concentration of contaminants. The concentration is displayed on the monitor. About 220 ml/min of air was drawn through the instrument's internal pump. The PID data logger was set for 1-sec measurement interval. Before each sampling, the instrument was calibrated by 100 ppm isobutylene according to manufacturer's instructions (Henderson, 1999; ASSE, 2000).

III. Results and Discussion

The indoor-outdoor combined average TVOC concentration was 65.03 ppb and 161.08 ppb at residential and roadside site respectively.

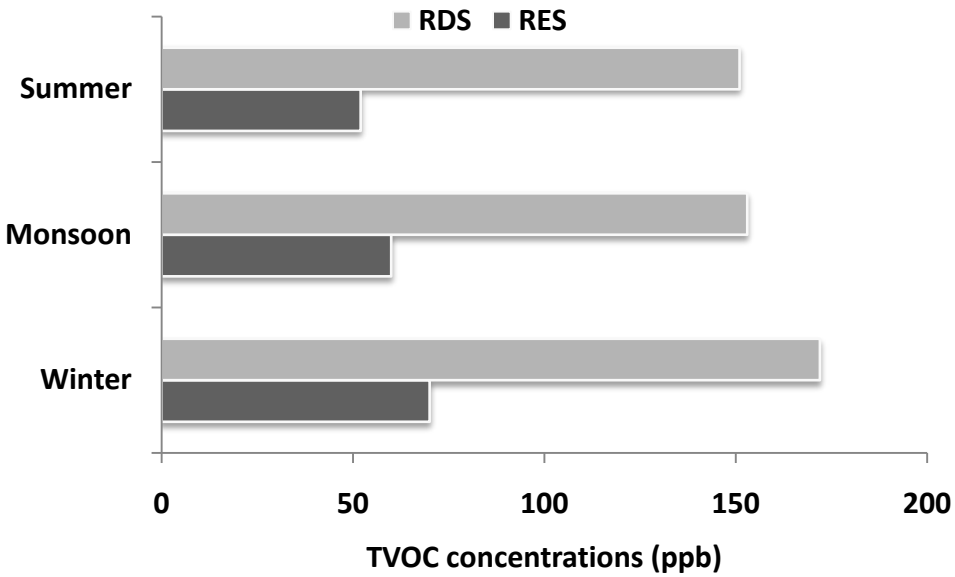

Figure 1 : TVOC levels at residential and roadside sites during different seasons

Figure 1 shows the pattern of average TVOC levels during different seasons. From the figure, it is evident that in each season the TVOC levels at roadside site were higher than that at residential site. Higher concentrations at roadside site may result from the proximity of intense automobile traffic.

a) Spatial Variation

At residential site, the indoor concentration of TVOC ranged from 66.07 ppb to 116.06 ppb with a mean value of 90.45 ppb, while for outdoor air the mean concentration was 39.62 ppb with a range of 34.3 ppb to 46.89 ppb. The average indoor concentration at

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roadside site was 173.52 ppb with a range of 145.66 ppb to 206.10 ppb; however the ambient TVOC concentration ranged from 134.94 ppb to 163.88 ppb with a mean value of 148.68 ppb. At both the sites, the indoor TVOC levels were higher than that at outdoors. This may be probably due to indoor combustion activities like cooking, smoking and heating as well as diverse indoor sources of emission like fabrications and furnishings used within the house. The indoor TVOC concentration at roadside site was higher than that at residential site, which suggests that roadside indoors were under combined influence of indoor emissions and outdoor vehicular emissions. This is supported by the fact that VOCs from outdoor air may also enter the indoor air through various vents present in the building (Batterman et al., 2007). This is also evident from the indoor-outdoor (I/O) ratios which show that at roadside site I/O ratios were lower than that observed at residential site. Mean I/O ratio at residential site was 2.3 with a range of 1.7 to 2.7 while at roadside site I/O ranges from 0.9 to 1.3 with a mean value of 1.1.

b) Seasonal Variation

During winters the TVOC concentration at residential and roadside were 44.13 ppb and 157.14 ppb for outdoors while it was 106.46 ppb and 192.66 ppb for indoors respectively.

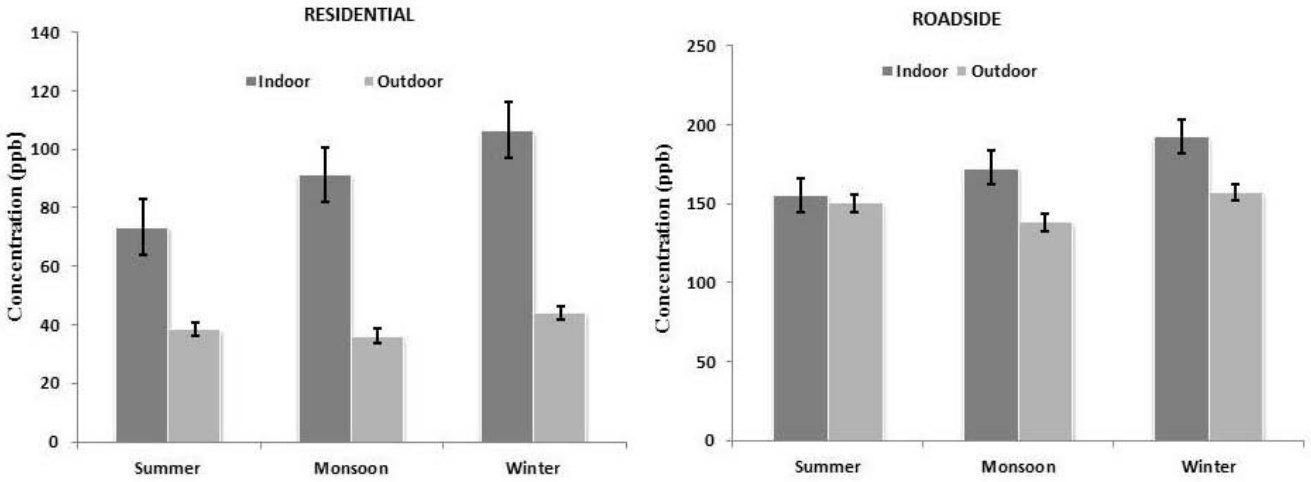

Figure 2 : Indoor and outdoor TVOC seasonal variation at both sites

In summer season, the TVOC levels were 38.43 ppb (residential) and 150.48 ppb (roadside) for outdoors whereas 73.57 ppb and 155.26 ppb at indoors respectively. During monsoons, the TVOC for residential and roadside were 36.29 ppb and 138.38 ppb at outdoors, while 91.33 ppb and 172.68 ppb at indoors respectively. Seasonal variation of indoor and outdoor TVOC levels at both sites is depicted in Figure 2(a) and (b). Seasonal trend for TVOC at outdoors was in the order of winter > summer > monsoon whereas for indoors it was winter > monsoon > summer at both the sites. In winters, high TVOC levels at outdoors might be due to the decrease in the rate of photochemical degradation due to OH radicals, whereas at indoors it may be explained on account of relatively higher emissions in winters (Na et al., 2005) due to frequent combustion activities like room heating. (Masih and Lall., 2016). The wash out effect due to frequent rain showers may be the probable reason for lowest outdoor TVOC levels in monsoon season at both the sites. Seasonal variation of I/O ratios at both sites is shown in Figure 3(a) and (b). It is evident from the figure, that at both the sites, the I/O ratios were highest in monsoon season followed by winter and summers. Highest I/O ratios in monsoon season may also be explained due to the wash out effect on outdoor VOCs.

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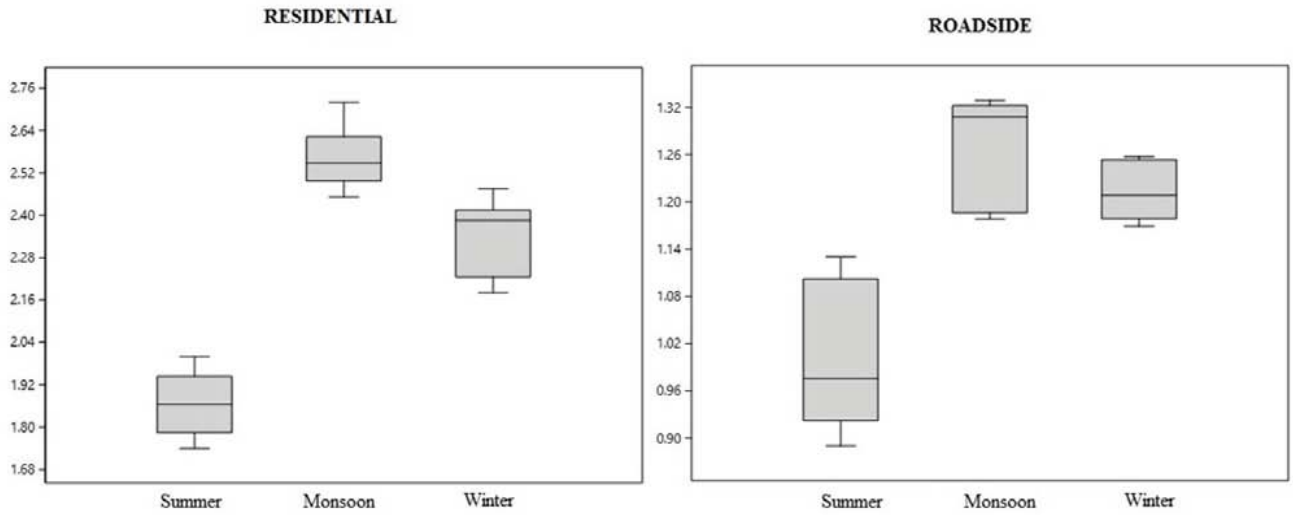

Figure 3 : Seasonal variation of I/O ratios at both sites

The results of the present study have been compared with other studies on TVOC in Table 1 showing that most of the countries have higher TVOC levels than India.

Table 1 : Average TVOC (ppb) levels compared from literature

Country	TVOC* (ppb)
USA	195.23
Brazil	195.15
India	150.75
This Study	**113.04**
Sweden	86.13
Greece	67.33

**Average TVOC*

IV. Acknowledgements

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References Références Referencias

1. Andersson K., Bakke J.V., Bornehag C.G., Clausen G., Skerfving S., Sundell J. (1997). TVOC and Health in Non-Industrial Indoor Environments. *Indoor Air* 7, 78-91.
2. American Society of Safety Engineers (ASSE) (2000). Use of a Portable Photo-Ionization Detector (PID) in Determining Occupational Exposure to Volatile Organic Compounds (VOCs) in a Print Shop. Proceeding of the ASSE Professional Development Conference and Exposition, June 25 - 28, Orlando, Florida, USA.
3. Batterman S, Jia C, Hatzioasilis G. (2007). Migration of volatile organic compounds from attached garages to residences: A major exposure source. *Environmental Research* 104(2), 224-240.
4. de Blas M, Navazo M, Alonso L, Durana N, Gomez MC, Iza J. (2012). Simultaneous indoor and outdoor on-line hourly monitoring of atmospheric volatile organic compounds in an urban building. The role of inside and outside sources. *Science of the Total Environment* 426, 327-335.
5. EU. (2004). " Directive 2004/42/CE of the European Parliament and of the Council of 21 April 2004 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC."
6. Henderson R. E. (1999). Portable Gas Detectors used in Confined Space and Other Industrial Atmospheric Monitoring Programs. Safety and Health in Confined Spaces, McManus, Neil, Lewis Publishers, Boca Raton, FL.
7. Masih A., Lall Anurag S., Singhvi R., Taneja A. (2016) Inhalation exposure and related health risks of BTEX in ambient air at different microenvironments of a terai zone in north India. *Atmospheric Environment* 147, 55-66.
8. Masih A. & Lall A.S. (2016). Measurements of BTEX in the Vicinity of Roadside at Gorakhpur, India. *Proceedings of the International Conference on Sciences, Engineering and Technical Innovations*, Jalandhar, Punjab, India, Vol.2, 195-197.
9. Molhave L., (1990). Volatile organic compounds, indoor air quality and health. In: Walkinshaw, D.S.(ed.) *Proceedings of Indoor Air* '90, Ottawa, Canada Mortgage and Housing Corporation, Vol. 1, 15-33.

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10. Na K, Moon KC and Kim YP. (2005). Source contribution to aromatic VOC concentration and ozone formation potential in the atmosphere of Seoul. *Atmospheric Environment*. 39, 5517-5524.
11. NIOSH. (2003). Hydrocarbons, aromatic: method 1501. NIOSH Manual of Analytical Methods (NMAM).
12. World Health Organization (1989). Indoor Air Quality: Organic Pollutants, Copenhagen, WHO Regional Office for Europe (EURO Reports and Studies No. 111).

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