BTEX Emissions, Seasonal Variability and its Associated Health Risks on Human Health in Outdoor Air of Delhi

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Abstract. Benzene, toluene, ethylbenzene and xylene (BTEX) are classified as hazardous compounds and their toxic effects on human health are well documented. These compounds are volatile in nature and play an important role in atmospheric chemistry as they react with nitrogen dioxide to form secondary air pollutants like ozone. These compounds are emitted into the atmosphere by various anthropogenic sources including motorized transport run on gasoline and diesel, fuel wood combustion, furniture materials and many other consumerism processes also contribute. In this study, we have selected a major connectivity hub location for the sampling of BTEX. The BTEX samples were obtained through activated charcoal tube using passive method of sampling and were subjected for analysis using GC-FID from November, 2017 to June 2018. It has been observed that the levels of BTEX were found higher for winter season followed by autumn, spring and least during summer season. The associated cancer and non-cancer risks were calculated using the USEPA methodology for health risk assessment. The levels of toluene were higher than xylene followed by ethylbenzene and benzene. The standard for benzene proposed by Central Pollution Control Board is 5 µg/m³ but in this work the levels were observed higher than the standard value. It has been found that the levels of toluene were 3-4 times higher during the traffic period in comparison with non-traffic period. The estimated cancer risks of benzene were observed to be higher than the prescribed standard value by World Health Organization. These high levels of emissions and their associated health risks is a matter of concern for the public health.

Keyword: Health risks, air quality, BTEX, ambient air, Delhi

1. Introduction

With increase in urbanization and modernization, the vehicular growth in metropolitan cities is a major problem of air pollution [1-2]. Increase in the vehicular growth leads to the emission of various harmful chemicals including oxides of sulphur, oxides of nitrogen, carbon dioxide, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), particulate matter (PM), and heavy metals [3-4]. Delhi, the capital and one of the largest metropolitan cities of India is facing a havoc problem of air pollution nowadays [5]. Mostly of the studies in India were carried out on particulate matter and correlate the effects with human health [6-8]. Nowadays, other compounds like benzene, toluene, ethylbenzene and xylene (BTEX) are also gaining attention as its higher concentration in urban air causes serious threats to human health [9]. Benzene is one of the most hazardous organic
compounds which can be easily vaporised [10]. These compounds have been released from burning fuel such as gasoline, wood, and coal. These compounds are also released from many consumer products such as cigarettes, solvents, paint and thinners, building materials and furnishings, and pesticides [11-12]. The short-term adverse effects include nose and throat discomfort, sleeplessness, impaired short-term memory, tremors, headache, skin problems, fatigue, and dizziness [13]. While the long-term exposure to benzene can lead to more adverse effects like genotoxicity, haematotoxicity, reproductive effects with various cancer, loss of coordination, lung cancer, anemia, leukemia, and damage to the liver, kidney and central nervous system [14-16]. These compounds also has a tendency to form secondary aerosol including ozone hence possessing the ozone formation potential [17-18]. After looking at the both carcinogenic and non-carcinogenic chronic effects of BTEX, the present study has been designed at a highly traffic and vehicular dense area of Delhi. The study was carried out to identify the levels during rush and non-rush hours, variability of BTEX during different seasons and examine the health threats of benzene on human health.

2. Material and methods

2.1. Study Area

Kashmere Gate (KG), which is a major connectivity hub of Central Delhi, located at 28.665° N and 77.233° E was selected for this study (Figure 1). The area is highly vehicular dense with traffic congestion and is connected to different metro lines, railway terminal and also Inter State Bus Terminal (ISBT). The ISBT situated at KG is one of the biggest and oldest bus terminals in India, operating bus services between seven states of India.

![Figure 1. Study area map showing Kashmere Gate as sampling location](image)

2.2. Sampling design

The sampling of BTEX was carried out at this location from November, 2017 to June 2018. These months were classified into four different seasons depending upon climatic condition as November (Autumn), December-January (Winter), March (Spring), May-June (Summer). The sampling was designed in a manner to identify the variation in benzene level during rush and non-rush hours of the day i.e. to identify the diurnal variations. The morning hours (09:00-11:00 am) and afternoon hours (02:00-04:00 pm) were considered as rush and non-rush hours for the study. The methodology adopted for sampling and analysis was based on corrigendum method 1501 prepared by National Institute for Occupational Safety and Health (NIOSH) [19]. The ambient air was sucked through the activated charcoal tube using a portable low flow and constant volume sampler known as benzene handy sampler (with a flow rate of about 30-35 ml/min. and sampling duration 120-150
minutes). As the sampling time completed, the sampling charcoal tube was then remove off from sampling train. Tubes were wrapped with aluminium foil and placed in an opaque, clean and air tight container which will immediately sent back to laboratory and placed in a refrigerator (< 4°C). Samples collected were desorbed by 1 ml conventional solvent (carbon disulfide) in an ultrasonic bath for 30 minutes. Carbon disulphide desorbed samples were get analyzed using GC fitted with capillary column and Flame ionization detector (FID). Since, Benzene possesses both cancer and non-cancer risks therefore for the estimation of these risks the USEPA methodology was adopted by considering inhalation pathways [20-21]. In this method, the cancer risks were calculated as incremental lifetime cancer risk (ILTCR) whereas non-cancer risks were calculated in terms of hazard quotient (HQ).

3. Results and discussions
The descriptive statistics in terms of mean, standard deviation, minimum, and maximum concentration of BTEX at Kashmere gate location has been summarized in Table 1. It has been cleared from Figure 2(a) that the levels of benzene during rush hours (12.32±6.69 µg/m³) are greater than during non-rush hours (8.50±5.83 µg/m³). Similarly, the levels of toluene and xylene were also reported higher during morning rush hours. The higher levels of these compounds during the rush hours in comparison with non-rush hours at study site which is a highly vehicular dense area and a major connectivity hub, indicating that morning hours have more vehicular density due to commuting activities including offices, school, and organizations etc.

Figure 2. Distribution of BTEX levels at Kashmere Gate: (a) BTEX levels during rush and non-rush hours, (b) Cumulative probability distribution of ILTCR, (c) ILTCR at 50% and 95% probability, (d)
Non-cancer risks in terms of Hazard Quotient

Surprisingly, the levels of xylene during non-rush hours were found to be greater than rush-hours indicating that xylene may have some other emission sources (industrial processes, commercial activities, painting and printing activities) other than traffic. Overall results (Figure 3) shows that BTEX exhibit seasonal variability with maximum concentration during winter season followed by autumn, spring and least during the summer season. These seasonal variations could be attributed to the meteorology of Delhi, as in summer temperature rises to 48°C and in winter it decreases to 3°C. In winter, temperature inversion, low mixing height, and more stable atmospheric condition slow down the dilution process of these pollutants and results in more accumulation of these compounds. Whereas, in summer, atmospheric conditions are stable, which increases dilution and dispersion process and results in the reduction of the pollutant concentration [22-23].

| Parameter | Benzene (µg/m³) | Toluene (µg/m³) | Ethylbenzene (µg/m³) | Xylene (µg/m³) |
|-----------|----------------|-----------------|---------------------|----------------|
|           | Rush | Non-rush | Rush | Non-rush | Rush | Non-rush | Rush | Non-rush |
| Mean      | 12.32 | 8.50 | 35.97 | 27.05 | 9.68 | 8.44 | 21.64 | 24.83 |
| SD        | 6.69  | 5.83 | 26.79 | 27.11 | 7.75 | 6.20 | 16.98 | 21.91 |
| Min       | 4.42  | 2.53 | 6.75  | 4.63 | 2.34 | 1.99 | 3.99  | 2.29  |
| Max       | 23.35 | 21.56 | 112.68 | 98.48 | 32.45 | 20.23 | 62.32 | 67.89 |

The cumulative probability distribution of ILTCR by benzene has been shown in Figure 2(b). Cancer risks were calculated for exposure to benzene at the median level (CR50) which represents the main group of exposed individuals. Whereas, the cancer risks were calculated for exposure to benzene at the 95% level (CR95) representing the highest exposed group in the population. The estimated ILTCR at 50% and 95% go much higher than the threshold value of $1 \times 10^{-6}$ is the indication of considerable risks of having cancer due to benzene exposure in study site (Figure 2(c)). Reference concentration value of benzene was taken as 30 µg/m³ (Masih et al., 2016). The hazard quotient (HQ) was calculated in terms for identifying the non-carcinogenic effects on human health by the BTEX exposure at this particular location. The high value of HQ (figure 2(d)) was observed for benzene followed by xylene which may be attributed for the high non-cancer risks of these compounds in the urban air of Delhi. But the value of HQ was observed less than unity which signifies that there is no chronic health effects will be observed on the population residing near these areas for the specific level of such pollutants.
The harmful effects of benzene include both carcinogenic and non-carcinogenic effects on human health. BTEX not only affects the human health but also affects environmental components by the formation of secondary aerosols. In this study, the levels of benzene were found to be 2-3 times higher in compare with the national air quality standards proposed by Indian regulatory bodies. The study also reports that these levels were higher during rush-hours as compared to non-rush hours. The levels were reported higher during winter seasons particularly due to effect of meteorological parameters and more biomass burning practices. The high significant cancerous risks were observed at traffic area is the indication of traffic as the major emission source of Benzene at such areas. These high levels of benzene not only affect the health of nearby residents, roadside vendors but also affect the health of the daily commuters.

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References

[1] Mohan, M., Pathan, S. K., Narendrareddy, K., Kandya, A.., & Pandey, S. (2011). Dynamics of urbanization and its impact on land-use/land-cover: a case study of megacity Delhi. Journal of Environmental Protection, 2(09), 1274.
[2] Kathuria, V. (2002). Vehicular pollution control in Delhi. Transportation Research Part D: Transport and Environment, 7(5), 373-387.
[3] Goyal, S. K., Ghatge, S. V., Nema, P. S. M. T., & Tamhane, S. M. (2006). Understanding urban vehicular pollution problem vis-a-vis ambient air quality–case study of a megacity (Delhi, India). Environmental Monitoring and Assessment, 119(1-3), 557-569.
[4] Sehgal, M., Tyagi, S. K., & Gautam, S. K. (2016). Air quality in Delhi: status and concerns. International Journal of Environmental Studies, 73(6), 905-916.
[5] Rizwan, S. A., Nongkynrih, B., & Gupta, S. K. (2013). Air pollution in Delhi: its magnitude and effects on health. Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine, 38(1), 4.
[6] Guttikunda, S. K., & Gurjar, B. R. (2012). Role of meteorology in seasonality of air pollution in megacity Delhi, India. Environmental Monitoring and Assessment, 184(5), 3199-3211.
[7] Kumar, R., & Joseph, A. E. (2006). Air Pollution Concentrations of PM 2.5, PM 10 and NO 2 at Ambient and Kerbsite and their Correlation in Metro City–Mumbai. Environmental Monitoring and Assessment, 119(1-3), 191-199.

[8] Pandey, P., Khan, A. H., Verma, A. K., Singh, K. A., Mathur, N., Kisku, G. C., & Barman, S. C. (2012). Seasonal trends of PM2.5 and PM10 in ambient air and their correlation in ambient air of Lucknow City, India. Bulletin of Environmental Contamination and Toxicology, 88(2), 265-270.

[9] Aleksic, N., Boynton, G., Sistla, G., & Perry, J. (2005). Concentrations and trends of benzene in ambient air over New York State during 1990–2003. Atmospheric Environment, 39(40), 7894-7905.

[10] Zhu, L., & Su, Y. (2002). Benzene vapor sorption by organobentonites from ambient air. Clays and Clay Minerals, 50(4), 421-427.

[11] Wallace, L. (1990). Major Sources of Exposure to Benzene and Other Volatile Organic Chemicals 1, 2. Risk Analysis, 10(1), 59-64.

[12] Truc, V. T. Q., & Oanh, N. T. K. (2007). Roadside BTEX and other gaseous air pollutants in relation to emission sources. Atmospheric Environment, 41(36), 7685-7697.

[13] Bahadar, H., Mostafalou, S., & Abdollahi, M. (2014). Current understandings and perspectives on non-cancer health effects of benzene: a global concern. Toxicology and Applied Pharmacology, 276(2), 83-94.

[14] Smith, M. T. (2010). Advances in understanding benzene health effects and susceptibility. Annual Review of Public Health, 31, 133-148.

[15] Zhang, Y., Mu, Y., Liu, J., Mellouki, A., 2012. Levels, sources and health risks of carbonyls and BTEX in the ambient air of Beijing, China. J. Environ. Sci. 24, 124–130.

[16] Kerbach, R., Boughedadoui, M., Bounoua, L., & Keddam, M. (2006). Ambient air pollution by aromatic hydrocarbons in Algiers. Atmospheric Environment, 40(21), 3995-4003.

[17] Carter, W.P., 2010. Updated maximum incremental reactivity scale and hydrocarbon bin reactivities for regulatory applications. California Air Resources Board Contract, 07-339.

[18] Garg, A., & Gupta, N. C. (2019). A comprehensive study on spatio-temporal distribution, health risk assessment and ozone formation potential of BTEX emissions in ambient air of Delhi, India. Science of the Total Environment, 659, 1090-1099.

[19] Bureau of Indian Standard (BIS), 2006. 5182 (Part 6). Methods for Measurement of Air Pollution. Bureau of Indian Standard, New Delhi, India.

[20] USEPA, 1998. Integrated Risk Information System (IRIS), Available at: www.epa.gov. Washington, DC, US Environmental Protection Agency.

[21] USEPA, 2010. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment, EPA-540-r-070-002). Office of Superfund Remediation and Technology Innovation Environmental Protection Agency, Washington, D.C.

[22] Garg, A., Gupta, N., & Tyagi, S. (2019). Study of seasonal and spatial variability among Benzene, Toluene, and p-Xylene (BTP-X) in ambient air of Delhi, India. Pollution, 5(1), 135-146. doi: 10.22059/poll.2018.260934.469

[23] Hoque, R. R., Khillare, P. S., Agarwal, T., Shridhar, V. and Balachandran, S. (2008). Spatial and temporal variation of BTEX in the urban atmosphere of Delhi, India. Sci. Total Environ., 392(1); 30-40.

[24] Masih, A., Lall, A. S., Taneja, A., & Singhvi, R. (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.