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Review

A review of assessment of benzene, toluene, ethylbenzene and xylene (BTEX) concentration in urban atmosphere of Delhi

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The most universal atmospheric pollutants present in the atmosphere are one of the representatives of volatile organic compounds (VOCs), popularly known as benzene, toluene, ethylbenzene and xylene (BTEX) which have their origin from both natural and anthropogenic sources. These compounds make an important contribution in the formation of photochemical smog. In spite of the well known toxic effects of BTEX, data available on them in India is very limited and very less study have reported their levels in Indian metro-cities. This paper reviews the status of BTEX concentrations at different sampling points in the ambient air of Delhi in order to investigate their temporal and spatial distributions.

Key words: Atmosphere, benzene, toluene, ethylbenzene and xylene (BTEX), sampling points.

INTRODUCTION

Volatile organic compounds (VOCs) have a significant role in the formation of photochemical pollution. Many hundreds of VOCs have been found in urban atmospheres. Some of the classified compounds such as benzene, toluene, ethylbenzene, xylene, formaldehyde and polynuclear aromatic hydrocarbons (PAHs) are grouped in the category of potential carcinogens which pose a high risk to public health. There are more than one lakh different types of VOCs which directly or indirectly affect our whole ecosystems and these group of compounds undergo complex photochemical reactions giving rise to a number of highly toxic and carcinogenic secondary pollutants, such as tropospheric ozone (Aikin et al., 1982) and peroxyacyl nitrate (PAN) (Crutzen, 1979), which are not only injurious to human health but also to vegetation (Majumdar et al., 2011). Being precursor of ozone, they are tightly regulated in United States under the criteria pollutant programme. About 189 hazardous air pollutants (HAPs) have been identified by United States Environmental Protection Agency (USEPA, 1990) out of which 97 are VOCs (US Clean Air Act Amendment, 1990; Ruddy and Carroll, 1993). VOCs can be emitted from anthropogenic as well as natural sources (Carlton et al., 2010). For maintaining healthy air quality, knowledge of ambient levels of VOCs is necessary but miserably the information on VOCs level for Indian cities is lacking. In urban atmosphere, benzene, toluene, ethylbenzene and xylene (BTEX), group of aromatic VOCs constitute up to 60% of non-methane VOCs (Lee et al., 2002), group act as one of the major polluter, proving it to be an efficient indicator of pollution arising from road traffic (because of increased global consumption of gasoline). Among all the aromatic hydrocarbons which are constituted in the class of BTEX, benzene has been chosen a prime target for assessment of pollution levels 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 which have fatal effect, mutagenicity (WHO, 2000; Hellén et al., 2002; Chowdhary and Macleod, 2011). According to Brocco et al. (1997), “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 and the resulting products contribute to secondary organic aerosol (SOA) formation by nucleation and condensation” (Brocco et al., 1997). It was reported

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by Odum et al. (1997) that "the reaction of toluene with NOx in the presence of a light source formed SOA with a significant aerosol yield and therefore, aromatic VOCs influence gas phase pollutants directly and particle-phase pollutants indirectly". According to Atkinson (2000), in the presence of NOx, they react with OH radicals to form ozone and thus modifying the oxidizing capacity of the atmosphere". Despite the fact that VOCs are grouped under HAPs, data available on VOC levels in India is very limited. Moreover, there are no proper norms and standards for VOCs (except benzene) in ambient air in India as reported by studies on VOC levels in Indian metro-cities (Srivastava et al., 2006; Srivastava et al., 2005; Chattopadhyay et al., 1997; MohanRao et al., 1997; Padhy and Varshney, 2000; Talapatra and Srivastava, 2011). This paper is an attempt to review some of the standard methods used for monitoring BTEX and the source characteristics of BTEX in the ambient air of Delhi at different locations to determine the status of BTEX concentrations in the city.

FOCUS OF AREA, DELHI

The capital city of India, Delhi, is one of its largest cities which lies at an altitude between 700 and 1000 ft with an area of approximately 1500 km^2 situated on the banks of Yamuna River. Delhi is a major centre of trade, commerce and industry especially in the northern part of India and it also gives employment to the people living outside Delhi since all the headquarters of major industries/offices are located there only. In spite of the fact that there have been restrictions on the establish-ment of large industries, a number of industrial units have been increased on a large scale (Srivastava et al., 2005). Delhi's eastwest length is approximately 51.9 km and the northwest width approximately 48.48 km. The cover of Delhi is to some extent circular. The major activities involve in this city are mainly engineering, clothing and commercial, although electrical goods are gaining importance. As we have been told earlier that Delhi is a major centre for set-up of major industries; these industries are one of main source of high pollution in this city. Moreover, the pollution level can also be increased as northwesterly winds often drag pollution from western industrial areas across the city. The population of this city has so much increased that two major thermal power plants could not support the total power need, therefore, generator sets are used in commercial, residential and industrial areas as backup power. Due to the increased use of generator sets, cooking, various internal combustion engines, burning of organic wastes landfill, sewage treatment plants, slums and open defecation, the air quality has been deterio-rated especially the concent-rations of VOCs has been increased. Delhi has a tropical steppe climate; continental air leads to relatively dry condition with extremely hot summers. Monthly mean temperature ranges from 14.3°C in January (minimum 3°C) to 34.5°C in June (maximum 47°C) and the annual mean temperature is 25.3°C. There are three main seasons in Delhi viz. monsoon, winter and summer. The main seasonal climatic influence is that of monsoon, typically from July to September. The mean annual rainfall total is 71.5 mm. The heavy rains of the monsoon act as a cleansing agent which washout the high concentration of pollutants in atmosphere. Wind speeds are typically higher in summer and monsoon periods; in winter they are generally calm. Delhi is in top ten cities in terms of pollution in the world. Delhi has the highest number of vehicles (~ 9.4 millions as on 31.10.11) among the Indian cities (Department of Transport, 2011). Delhi has witnessed an exponential growth in the number of vehicles, which increased from 28.48 lakh in 1996 to 1997 to 52.32 lakh in 2006 to 2007 at an annual compound growth rate of 60.6% (Department of Transport, 2010). Decennial growth rate is substantially higher in case of private vehicles (91.13%) as compared to commercial vehicles (8.65%). In the category of private vehicles, cars and jeeps have registered a decennial growth rate of 126.49%, which is highest among all the categories of vehicles followed by two wheelers with 77.82% (Hoque et al., 2008). Among the motor vehicles in Delhi, 2-wheelers (motorcycles and motor scooters) which are mainly 2-stroke and gasoline-driven, account for 63%; private 4-wheelers (cars, jeeps and wagons) account for 30% and the rest is represented by public vehicles (3-wheeled auto-rickshaws, taxis, buses and goods vehicles). Delhi adopted unleaded gasoline regime (lead content 0.013 g/l) in December, 1998 to meet the octane requirement, BTEX was added and thus, the aromatic content of the vehicular fuel has gone up. Public transport in Delhi constitutes mostly buses, auto rickshaws and a metro rail system. Buses are the most popular means of transport catering to about 60% of the total demand. The state-owned Delhi Transport Corporation (DTC) is a major bus service provider for the city. The DTC operates the world's largest fleet of environment-friendly compressed natural gas (CNG) buses. Even after the amendments made for the improvement of traffic volume, the pollution level in this city doesn't have remarkable change; therefore, it is a matter of study for the scientists to assess and to control the pollution level in this city especially in case of BTEX.

MONITORING METHODS USED FOR BTEX

BTEX are one of the commonly observed traffic-related air pollutants found in urban centres. In recent years, epidemiological studies have shown that among BTEX, benzene is a far more serious pollutant than previously thought. Benzene is a carcinogenic compound, likely responsible for myeloid leukaemia. Recently, WHO (2008) has estimated that for

Table 1. Summary of monitoring methods for the determination of BTEX in ambient air.

Method	Average time	Detection limit (µg/m³)	Sample flow/uptake rate (ml/min)	Advantage	Disadvantage
BTEX monitors (Eisenberger, 1996; Godet, 1997a, b, c; Muckler, 1996; Rudolf and Medem, 1998; Hun et al., 2011).	15 - 30 min	0.16	10 to 30 min	Flexible time resolution, real-time datam analysis of BTEX simultaneously	High cost, need of monitoring hut with air condition, need of carrier gas supply
On-line GC instruments (Guillard and Godet, 2000; Krol et al., 2010)	½ to 1 h	0.1	10 to 30 min	High time resolution, real time data, analysis of C2-12 simulteanously	High cost, need of monitoring hut with air condition, need of carrier gas supply, some instruments need supply of liquid nitrogen
Canister thermal desorption (EMEP,1996; Ramirez et al., 2011)	Grab sampling	0.3	Grab samples (51)	No electrical power is needed, same comments as in 1 and 2 depending upon analysis technique	Only grab samples have to be taken, difficult to clean
Pumped sampling on tubes with thermal desorption – GC (Woolfenden, 1997; Harper, 2000)	15 min - 24 h	0.14 to 4	50 to 150	Low cost, many sampling sites with one analytical instrument, work with toxic species is minimized, flexible time resolution	Expensive thermal desorption system is needed, strongly labour demanded
Pumped sampling on tubes with solvent extraction-GC (Coursimault et al., 1995; Heinrich, 1997; Krol et al., 2011)	3 - 24 h	0.14-4	50-750	Low cost, many sampling sites with one analytical instrument, analysis is made on cheap GC, flexible time resolution	Toxic solvents are needed, strongly labour demanded
Diffusive sampling with thermal desorption-GC (Cocheo et al., 1996; Heinrich,1997;Brown et al., 1981; Brown, 1999)	1 - 4 weeks	0.5	~1	No electrical power is needed, long sampling time possible, same comments as in no. 2	Long sampling time needed, expensive thermal desorption system is needed

a lifetime exposure of urban populations to benzene concentrations of 2.7 µg/m^3, 10 cases of leukaemia per million inhabitants should be expected. For the monitoring of BTEX, various methods which are used for their determination are as follows (Table 1):

Monitoring sites covered in Delhi

As per the literature survey, the sites which are selected for determining the variation of BTEX in Delhi are on the basis of four different sectors, that is, residential, commercial, industrial, traffic intersection and petrol pump locations (refuelling stations). In each sector and petrol pump areas, different sites were also selected:

Residential sector

The different locations which are selected in this sector are typically residential and air quality is influenced mainly by domestic activities, vehicular movement, roadside eatouts and open burning of leaves and solid waste. The sites are as follows:

1) Janakpuri (Srivastava et al., 2005)
2) Kalkaji (Srivastava et al., 2005)
3) Mayur Vihar Phase II (Srivastava et al., 2005)
4) Jawaharlal Nehru University (JNU) (Hoque et al., 2008)

Commercial sector

There are three sites which are selected for monitoring of BTEX with different criteria of their selection:

1) Karol Bagh: It is a very busy market place with vehicular traffic consisting of heavy duty trucks, buses, two wheelers, three wheelers and cars (Srivastava et al., 2005)
2) Cannaught Place (CP): This is a posh market place and traffic consists of three wheelers, two wheelers, buses and cars. Cinema halls, restaurants, roadside eatouts and markets are in plenty (Srivastava et al., 2005).
3) Lajpat Nagar: It is a crowded market place in

South Delhi. Air quality is mainly influenced by generator sets, vehicular movement, roadside eatouts and markets (Srivastava et al., 2005).

Industrial sector

All the three sites are purely industrial with no mixing of residential or commercial areas. The sites are as follows:

1) Jhilmil: The location of monitoring carried out in this area was opposite to Para Sheild Cables manufacturing industry. The area is surrounded by other cable and tyre manufacturing industries (Srivastava et al., 2005).
2) Okhla: Monitoring in Okhla Phase I was carried out at the open terrace of Enviro Tech Pvt Ltd. This industry is also surrounded by other industries (Srivastava et al., 2005).
3) Mayapuri: The sampling was conducted in an industry behind Car Service Centre near the DTC bus stand and metal forging company (Srivastava et al., 2005).

Traffic intersection sector

All the three sites are very busy traffic intersections. Monitoring was carried out at the kerbsides near traffic intersections. During peak hours, traffic jams are frequent in these locations. The average vehicular speed is at most 20 to 25 km/h at these locations. The sites are as follows:

1) Raja Garden (Srivastava et al., 2005)
2) ITO (Srivastava et al., 2005)
3) Shakarpur Crossing (Srivastava et al., 2005)
4) AIIMS (Hoque et al., 2008)

Petrol pump stations

Sampling was carried out in the center of petrol pump where vehicles halt for refuelling. The sites are selected:

1) C.P. (Srivastava et al., 2005)
2) IIT Crossing (Srivastava et al., 2005)
3) Race Course (Srivastava et al., 2005)

STATUS OF BTEX VARIATION IN DELHI

In Delhi, the summarization of all the studies regarding to BTEX variation are reported in this review paper. According to Srivastava et al. (2005) study about BTEX, the monitoring was performed at fifteen locations in five categories namely residential, commercial, industrial, traffic junctions and petrol pumps. The method used for monitoring was TO-17 method which involves adsorbing ambient air at a uniform flow rate on specially fabricated activated-charcoal cartridge followed by thermal desorption and detection on gas chromatography with mass spectrometry (GC–MS) for the determination of toxic organic compounds (USEPA, 1999). The residential areas selected were Janakpuri, Kalkaji and Mayur Vihar Phase II, locations in the commercial area include Karol Bagh, CP and Lajpat Nagar, industrial areas include Jhilmil, Okhla Phase I and Mayapuri, traffic intersections include ITO, Raja Garden and Shakarpur Crossing and petrol pumps include CP, IIT Crossing and Racecourse.

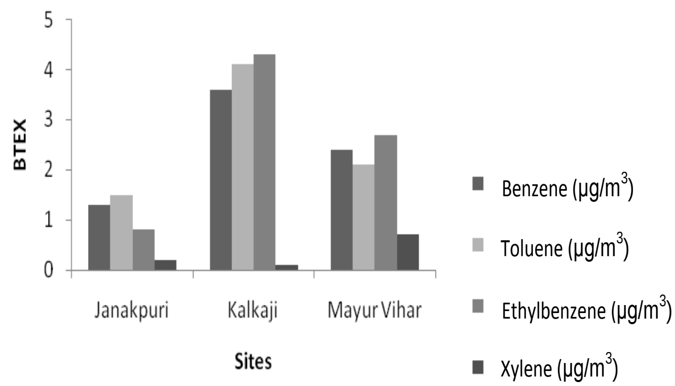

Figure 1. Variation of BTEX at residential sector in Delhi (2001 to 2002). Source: Srivastava et al. (2005).

At residential sector of Janakpuri, Kalkaji and Mayur Vihar Phase II, benzene was found in the range 1.3 to 3.6 μg/m^3, toluene with 1.5 to 4.1 μg/m^3, ethylbenzene from 0.8 to 4.3 μg/m^3 and xylene from 0.1 to 0.7 μg/m^3 (Figure 1). As per seasonal profile, it was found that at Kalkaji, higher concentrations of BTEX were found during winter than summer than other two selected sites (Figure 2a to c). This may be due to open defecation, garbage rotting and sewage main hole breathing, use of generator sets was indicated by pollutants associated with diesel internal combustion engines. At commercial sector of Karol Bagh, CP and Lajpat Nagar, benzene was found in the range of 1.3 to 6 μg/m^3, toluene from 0.5 to 1.6 μg/m^3, ethylbenzene from 0.6 to 3.5 μg/m^3 and xylene from 0.1 to 1.4 μg/m^3 (Figure 3). Moreover, it has been found that Cannought Place higher concentrations of BTEX were found than other two selected sites (Figure 4a to c). This may be due to the reason that VOCs associated with emissions due to diesel internal combustion engines as Cannought Place is an area of heavy road vehicles. At industrial sector of Jhilmil, Okhla Phase I and Mayapuri, benzene was found in the range of 1.2 to 2.7 μg/m^3, toluene from 0.3 to 0.7 μg/m^3, ethylbenzene from 0.6 to2.3 μg/m^3 and xylene from 0.2 to 4.1 μg/m^3 (Figure 5). Higher concentrations were found at Mayapuri during winter than monsoon and summer as compared to other two sites (Figure 6a to c). This was due to the reason that opens defecation in slums around Mayapuri industrial area contributes to emissions, which are classically

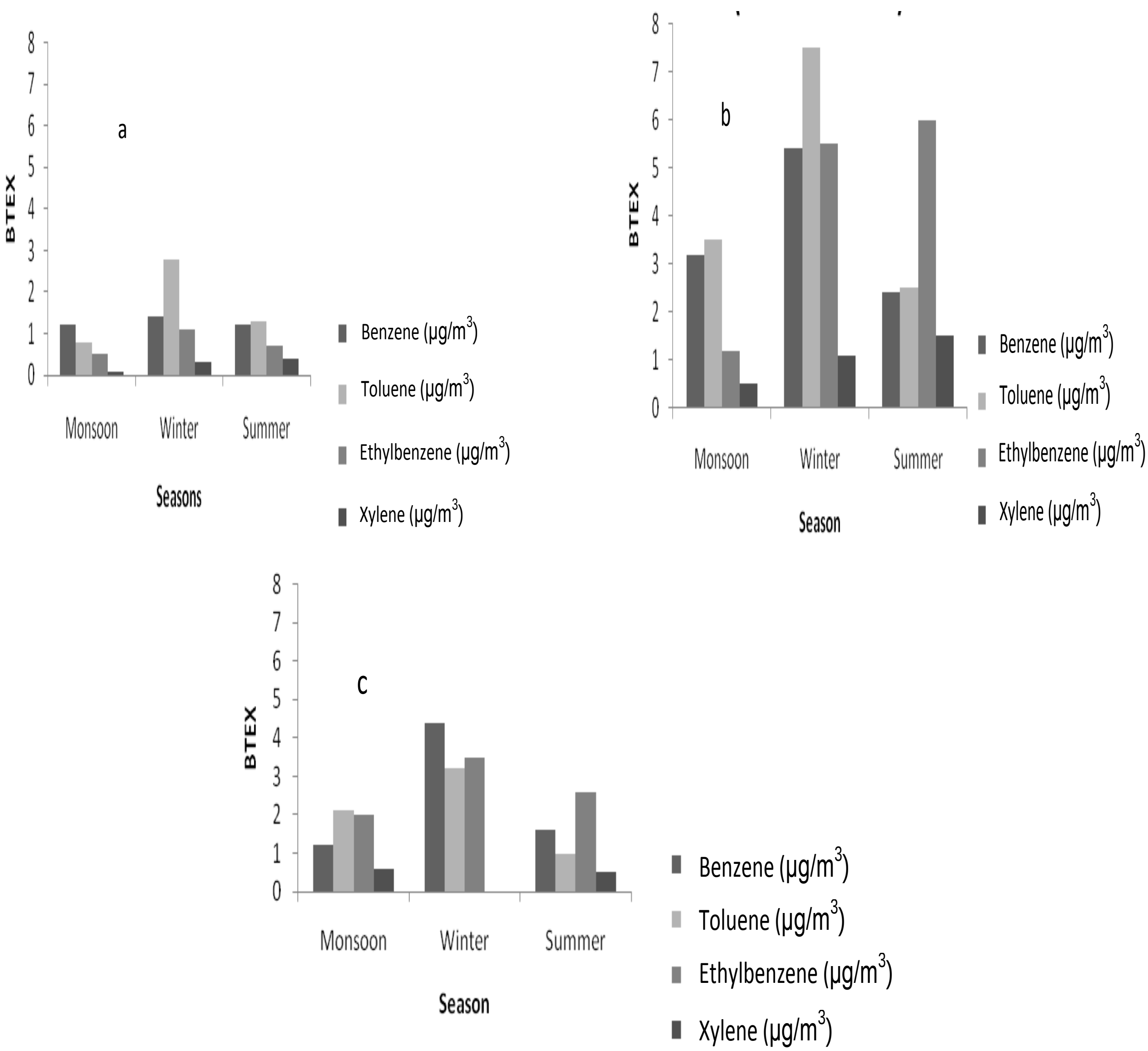

Figure 2. Seasonal Variation of BTEX at residential sector in Delhi (2001 to 2002): a, BTEX at Janakpuri; b, BTEX at Kalkaji; c, BTEX at Mayur Vihar. Source: Srivastava et al. (2005).

considered to originate from sewage sludge. Large use of generators results in VOCs associated with diesel internal combustion engines. At traffic intersection sector of ITO, Raja Garden and Shakarpur Crossing, benzene was found in the range of 1.7 to 3.7 µg/m^3, toluene from 2.6 to 3.6 µg/m^3, ethylbenzene from 2 to 4.5 µg/m^3 and xylene from 1.5 to 3.4 µg/m^3 (Figure 7). Higher concentrations were found at Raja Garden during winter and monsoon season except in summer season at ITO (Figure 8a to c). This is because, at Raja Garden site, the emissions associated with road asphalts and also diesel internal combustion engine. At petrol pumps of Cannaught Place, IIT Crossing and Racecourse, benzene was found in the range of 3.1 to 4.8 µg/m^3, toluene from 3 to 5 µg/m^3, ethylbenzene from 1.5 to 2.8 µg/m^3 and xylene from 2.5 to 4.5 µg/m^3 (Figure 9). Higher concentrations were found at CP during winter and monsoon season except in summer season at IIT crossing (Figure 10a to c). This was due to the reason that at CP site, VOCs can be associated with evaporative emissions of petrol, combustion of natural gas and diesel internal combustion engines. According to Hoque et al. (2008) study about BTEX, the monitoring was performed at four sites, representative of different categories with varied traffic density and local activities were selected. The sites selected were namely, JNU is an Institutional

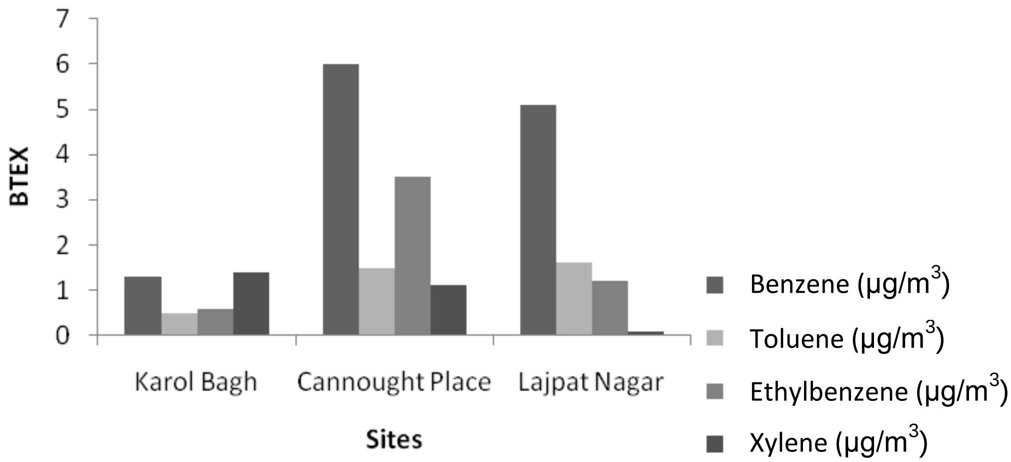

Figure 3. Variation of BTEX at commercial sector in Delhi (2001 to 2002). Source: Srivastava et al. (2005).

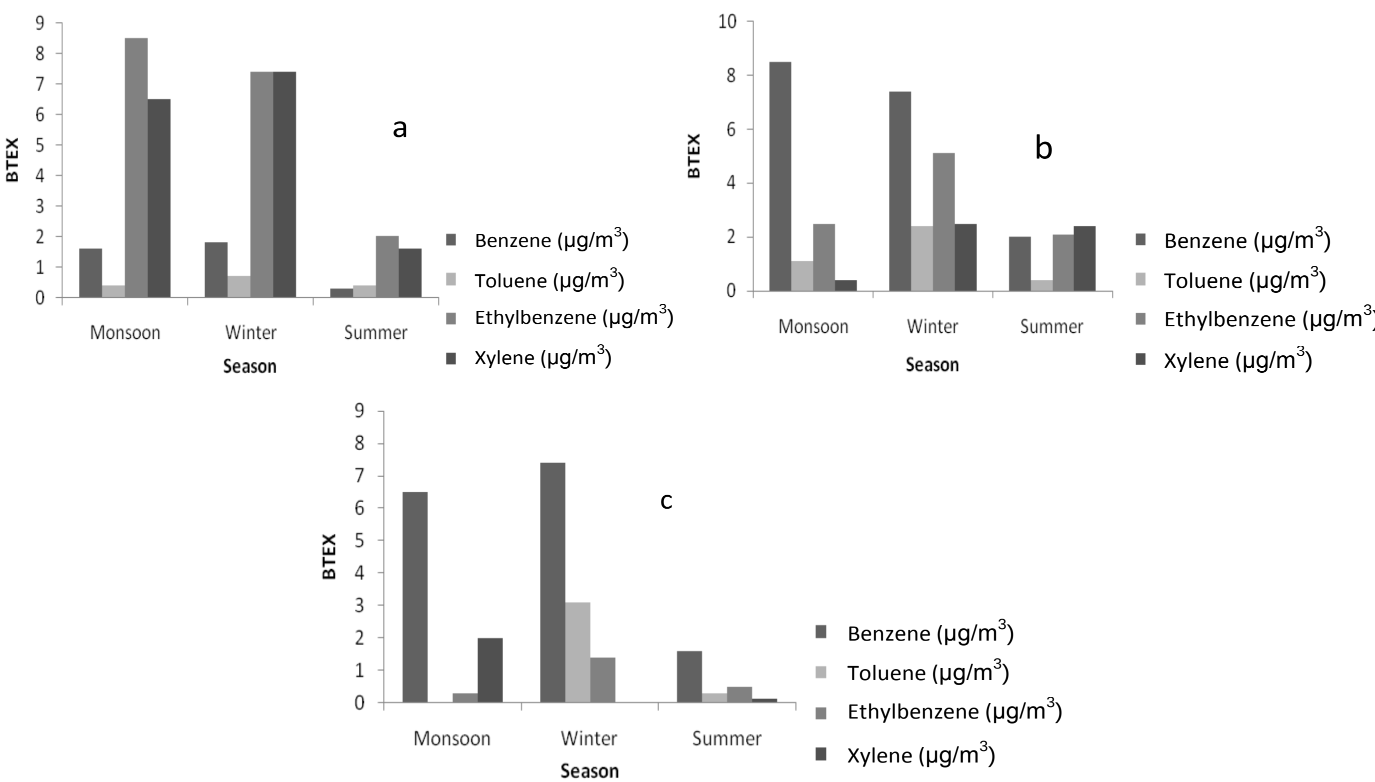

Figure 4. Seasonal Variation of BTEX at commercial sector in Delhi (2001 to 2002): a, BTEX at Karol Bagh; b, BTEX at Cannought Place; c, BTEX at Lajpat Nagar. Source: Srivastava et al. (2005).

cum residential area with good vegetation cover and low traffic density, CP comes under the category of commercial area with plenty of shopping malls and corporate offices with high traffic density. Okhla is an industrial area with large traffic density of two wheelers and cars during office hours with waste dumping areas around and All India Institute of Medical Sciences (AIIMS) was selected near a traffic intersection. This site is a matter of great concern with respect to air pollution as two of the biggest hospitals - AIIMS and Safdarjung Hospital are located just adjacent to the monitoring site with high traffic density. The method used for monitoring by activated charcoal method followed by identification of compounds in GC-FID. Annual average concentrations of

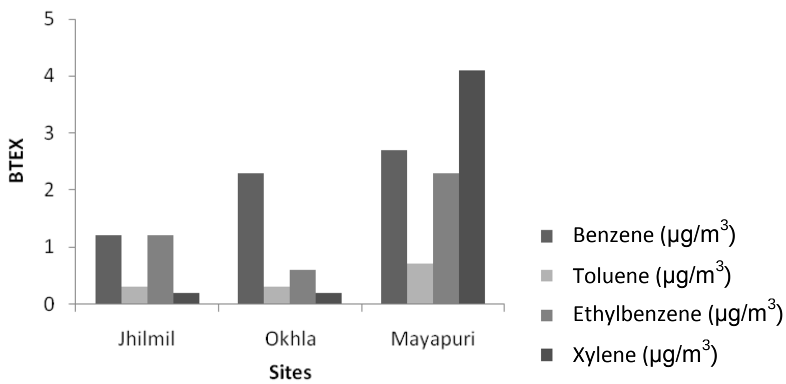

Figure 5. Variation of BTEX at industrial sector in Delhi (2001 to 2002).
Source: Srivastava et al. (2005).

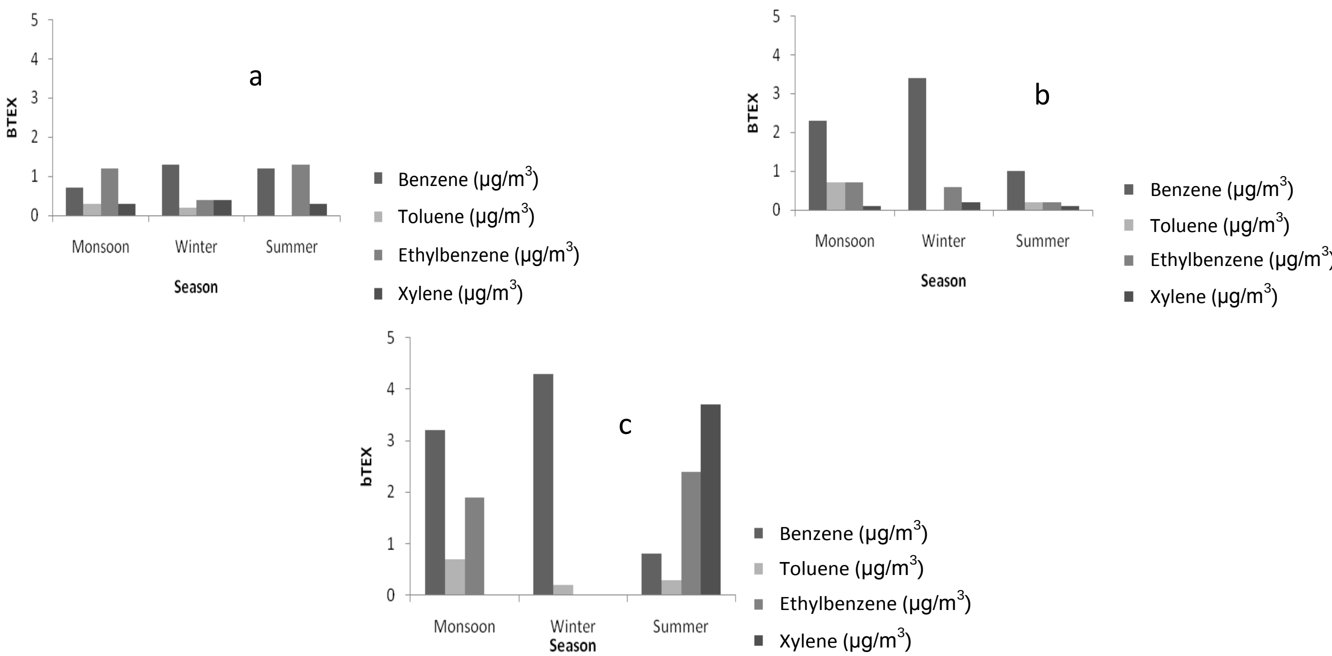

Figure 6. Seasonal variation of BTEX at industrial sector in Delhi (2001 to 2002): a, BTEX at Jhilmil; b, BTEX at Okhla; c, BTEX at Mayapuri. Source: Srivastava et al. (2005).

BTEX at different sampling sites are given in Table 2. Maximum average concentration of BTEX (456±224 μg/m^3) was found at site AIIMS while minimum at site JNU (186±107 μg/m^3). High levels of VOCs at AIIMS could be attributed to very high automobile traffic density (ATD), slow movement of the traffic and more frequent idling of the vehicles as during the sampling period a major flyover was under the process of construction at this site. Among BTEX, toluene was found to be the most abundant species varying from 42 to 50% of the total BTEX at different sites followed by benzene (26 to 30%).

Average concentration (204±70 μg/m^3) of toluene was recorded to be maximum at site Okhla which could be justified as this sampling site is surrounded all around by industries mostly of paints and varnishes, motor vehicle serving stations and electric motor winding. Average concentration of benzene was found to be maximum at site AIIMS which is a site with highest ATD as compared to other sites.

CONTROL OF BTEX POLLUTION IN DELHI

There are various control steps required for the

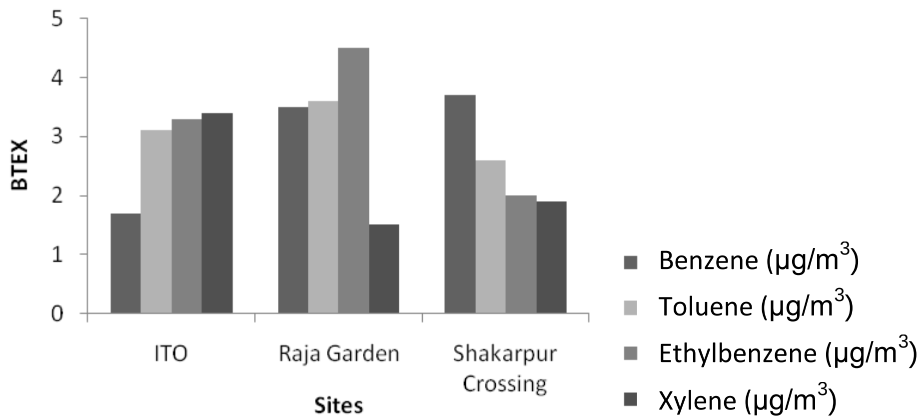

Figure 7. Variation of BTEX at traffic intersection sector in Delhi (2001 to 2002). Source: Srivastava et al. (2005).

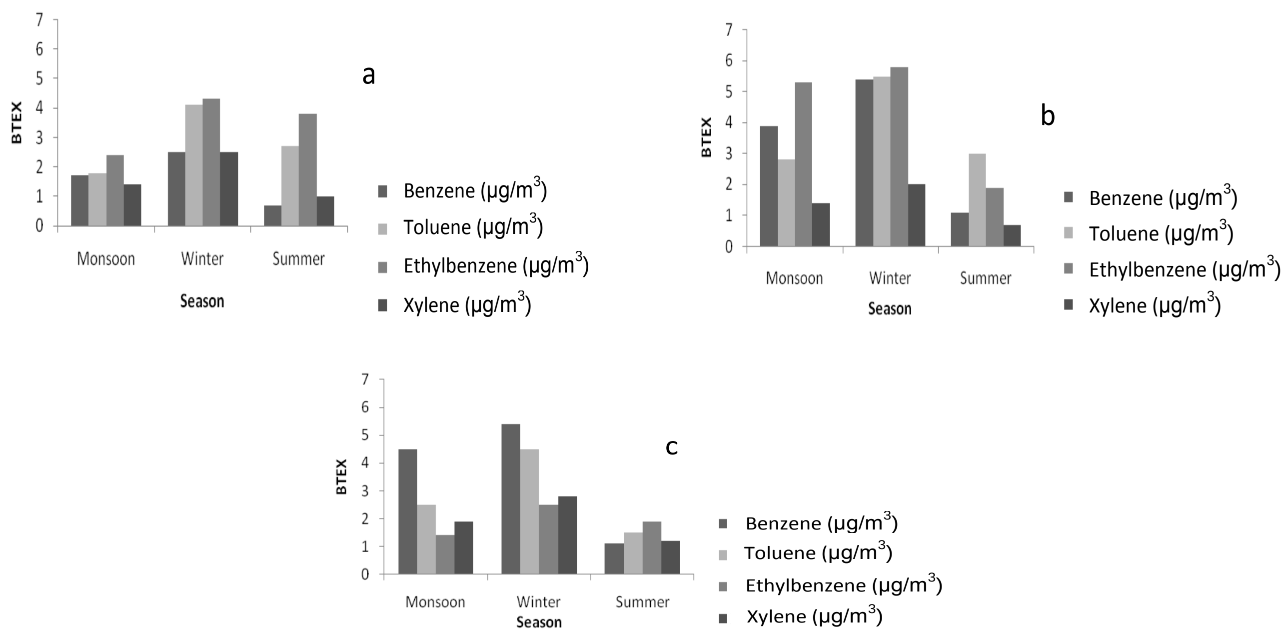

Figure 8. Seasonal Variation of BTEX at traffic intersec sector in Delhi (2001 to 2002): a, BTEX at ITO; b, BTEX at Raja Garden; c, BTEX at Shakarpur Crossing. Source: Srivastava et al. (2005).

minimization of BTEX pollution by various adopted techniques such as adsorption/condensation of VOC in air medium, PV of VOC in aqueous medium, biodegradation of VOC in aqueous medium, biofilters, catalytic combustion and by implementing various policies and standards. Adsorption/condensation of VOC in air medium involves condensation using N_2 at cryogenic temperatures was recognized as the most effective and commercially suitable technique. Adsorption is considered as the state-of-art technology having immense potential for VOC control. The keyword of an adsorption process is a porous solid medium having high adsorptive capacity (Talapatra and Srivastava, 2011). Recently, there have been a series of studies in this area focusing on: theoretically establishing condensation followed by adsorption to be more effective in controlling VOCs than the condensation or adsorption alone. If the VOC concentrations varied over a large range (Gupta and Verma, 2002), experimental analysis to confirm adsorption is an effective means for controlling VOC if the concentration levels are typically lower than 1%, which is mostly the case with air bound VOCs in parts per million (ppm) level,

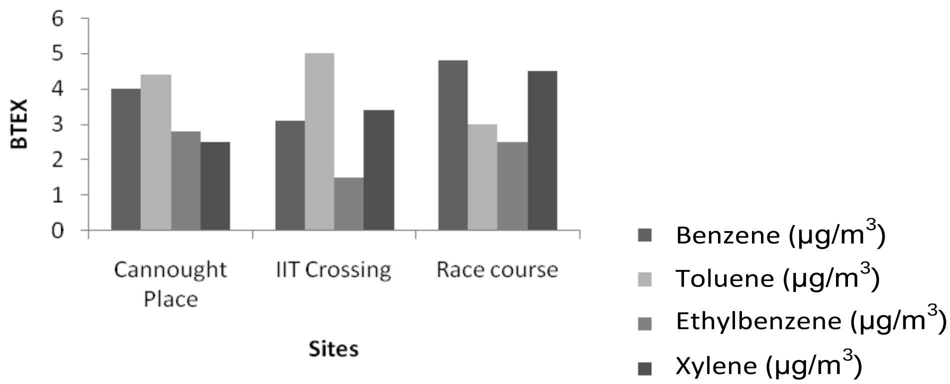

Figure 9. Variation of BTEX at petrol pump area in Delhi (2001 to 2002). Source: Srivastava et al. (2005).

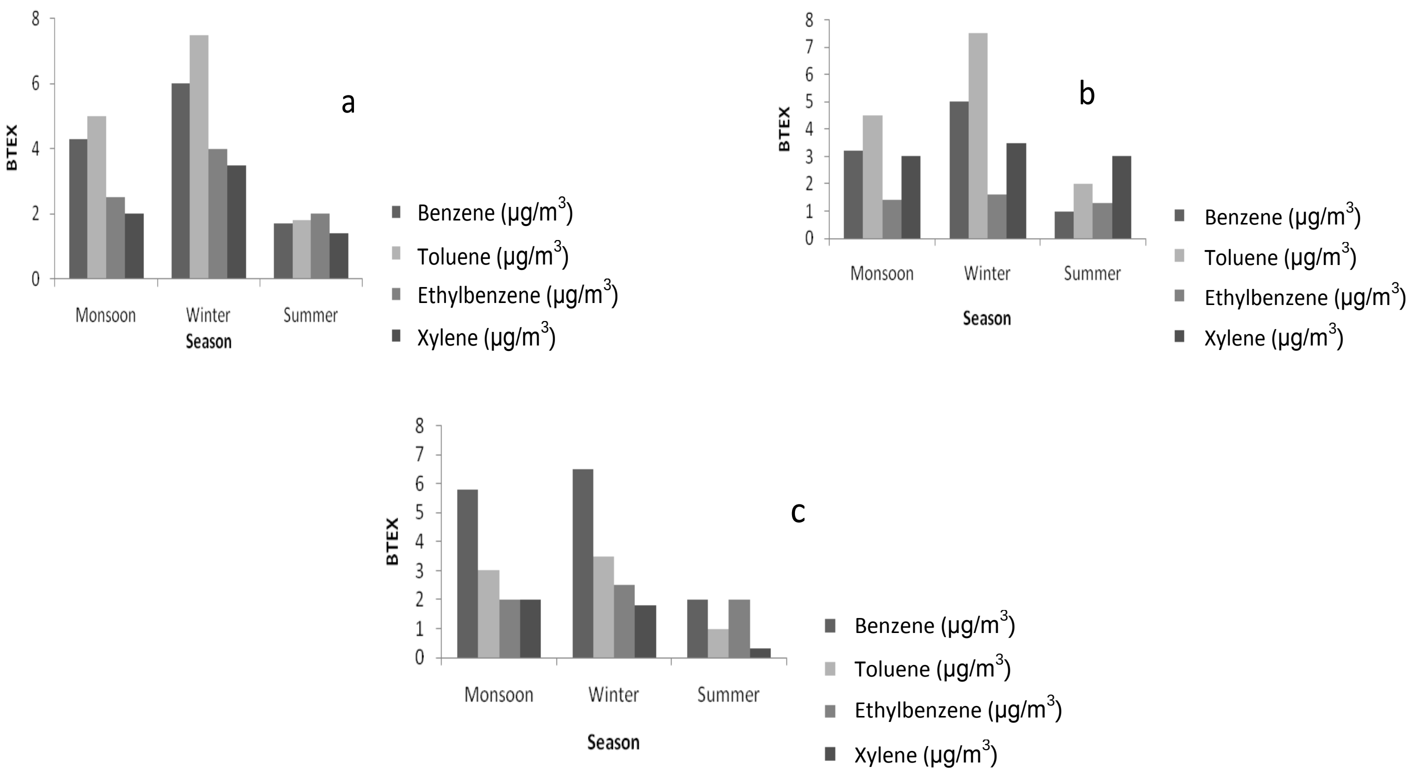

Figure 10. Seasonal variation of BTEX at petrol pump area in Delhi (2001 to 2002): a, BTEX at Cannought Place; b, BTEX at IIT Crossing; c, BTEX at Race Course. Source: Srivastava et al. (2005).

while the condensation is suited for higher concentration levels (Dwivedi et al., 2004) and experimentally demonstrating the suitability of activated carbon fiber in effectively adsorbing VOCs from inert gaseous stream under varying operating conditions (Das and Verma, 2004; Mohan et al., 2009). The next technique is PV of VOC in aqueous medium. PV is a membrane process involving separation of liquid mixtures through a dense membrane. In PV, separation of the desired component is achieved by its preferential sorption and diffusion through the membrane under reduced pressure which creates a chemical potential gradient in the liquid phase. The selectivity of the membrane is the determining factor in the relative flow of the different components (Talapatra and Srivastava, 2011). Another technique is biodegradation of VOC in aqueous medium. Aerobic biological processes such as the activated sludge process are very effective in removing VOCs from wastewaters. To come out with a balance between too high concentration of hazardous waste causing inhibition of microorganism and

Table 2. BTEX concentration at different sampling sites.

Site		Benzene	Toluene	Ethylbenzene	m,p-xylene	o-xylene	BTEX
JNU (N=36)	Mean	48	85	7	30	15	186
	SD	26	48	5	23	11	107
	Max	91	181	21	78	46	405
	Min	6	23	1	3	2	52
CP (N=39)	Mean	97	180	21	83	40	421
	SD	53	86	14	50	26	222
	Max	203	323	52	193	95	836
	Min	21	36	4	13	9	84
Okhla (N=41)	Mean	89	204	16	61	41	411
	SD	41	70	10	29	21	152
	Max	180	373	39	140	105	826
	Min	30	58	3	13	7	148
AIIMS (N=42)	Mean	110	191	24	90	41	456
	SD	53	80	15	57	23	224
	Max	249	381	62	238	115	1037
	Min	41	77	7	28	15	177

Source: Hoque et al. (2008).

too low rate of addition heading towards starvation of microbial cell, two phase partitioning bioreactor (TPPB) using water immiscible and biocompatible organic solvent has been well studied by a series of experiments by Singh and Fulekar (2010). In TPPB, 5000 mg/l benzene was biodegraded up to 50.17% over a period of 168 h (Maliyekkal et al., 2004; Singh and Fulekar, 2010). Next is catalytic combustion which involves oxidative destruction at low temperature in presence of a catalyst and this energy efficient process can operate with very dilute pollutants (Mishra et al., 2008). Manganese nodule and TiO_2-SiO_2 have been studied for decomposition of VOCs (Parida and Samal, 1999; Samantaray and Parida, 2005). High temperature stable iron and manganese mixed pillared clay having high manganese content shows acetone decomposition reaction whereas material with high iron contents acts as a better catalyst for trichloroethylene decomposition (Mishra et al., 2008). The next is implementing certain policies like the use of CNG which up to some extent reduce the pollution level in the city, restriction over sale of old vintage vehicles, introduction of only 1% v/v benzene (since November 2000) in gasoline in Delhi (Sengupta, 2004).

CONCLUSION AND RECOMMENDATION

As previously discussed, it has been reported that there are major issues regarding VOCs in India particularly, BTEX. They are also responsible for the production of tropospheric ozone and further help in the formation of photochemical smog. Delhi is one of the most polluted cities in the world; therefore, more attention should be given to improve the quality of air. It has been found that the concentration of BTEX was high in commercial sectors because of large office complexes and big shopping malls traffic volume was increased and therefore, that becomes a good source for BTEX. Moreover, the main source of BTEX was found to be gasoline exhaust from vehicular fleet and areas with heavy crowd. Among the seasons, it has also been observed that the concentration of BTEX was highest during winter season followed by monsoon and then in summer. Moreover, the values of BTEX were crossing the permissible limit; hence, it shows that in Delhi, the people are in unsafe zone. As we know that according to USEPA, benzene was regarded as most carcinogenic compound and it causes deleterious effects on human beings, therefore, it is a matter of concern that government should take immediate action to control VOCs especially BTEX in Delhi city.

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