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RESEARCH ARTICLE

RISK ASSESSMENT OF BENZENE IN AMBIENT AIR OF DELHI

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ABSTRACT

Globally different countries in the world use environmental risk assessment as a tool to evaluate the toxicity of a pollutant in the environment. Health risk assessment is done to evaluate the possible adverse health effects of benzene on human health. The concentration of benzene was measured at two locations in Delhi, a global city, during 2011-2015.The cancer risk in ambient air of Delhi was calculated at C_{EXPavg}, C_{EXP50}, and C_{EX90}. From the year 2011 to 2015 at C_{EXPavg} and C_{EXP50} cancer risk varies from 1.71 to 9.26 per 10^6 and at C_{EXP90} cancer risk varies from 3.9 to 24.12 per 10^6 which were higher in comparison with mean and median concentrations. The cancer risk calculated in this study is comparable with the studies conducted in Kolkata, India and few other European countries. The annual average exposure concentration of benzene ranges from 3.02 µg/m^3 in 2015 to 16.3 µg/m^3 in 2011.The mean value found in 2015 was less than National Ambient Air Quality Standards (NAAQS) of benzene i.e. 5µg/m^3.Our study revealed that there is a decrease in the level of benzene from 2011 to 2015 at two locations in Delhi which may be attributed to the implementation of Auto Fuel Policy 2003, by the Government in reducing benzene contents in the gasoline from the source and subsequent environmental measures in Delhi.

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INTRODUCTION

Benzene- a molecule with six carbon and six hydrogen atoms (C_6H_6) is the first member of a series of aromatic hydrocarbons that are usually recovered from refinery streams during the catalytic reformation and processing of petrol. Physically it is a clear, colourless and highly flammable liquid at room temperature (Benzene Toxicity, 2003). It has been classified as Group A and Class 1 carcinogen by the International Agency for Research Cancer (IARC) and United States Environmental Protection Agency (USEPA) respectively (World Health Organization, 2010). It is a well-known human carcinogen, which may disseminate throughout the entire hematologic system and results in depression of the bone marrow (Atlanta, 2007). It has highest emission factor than other volatile organic compounds (Dewangan *et al*., 2013).Usually it enters into the body through the lungs, skin and gastrointestinal tract. Headaches, dizziness, impaired short-term memory, inability to concentrate and tremors are the adverse health effects associated with short-term human exposure to benzene at high concentration (Navasumrit *et al*., 2005). The long-term exposure to benzene can lead to more complex health effects, counting genotoxicity, haematotoxicity, and reproductive effects with various cancers (Keretetse *et al*., 2008; Cooper *et al*., 2007; Badjagbo *et al*., 2010). Gasoline exhaust systems have been found to be themajor cause of benzene emission in Delhi (Hoque *et al*., 2008). Exposure to benzene is caused mainly through the emissions of the motor-vehicles Different countries in the world use risk assessment as a tool to assess the toxicity of a pollutant (Eikmann *et al*., 1992). Health risk assessment is done to evaluate the possible adverse effects of benzene on human health (Guidelines for carcinogen risk assessment, 2005). Generally, the concentrations of airborne benzene associated with an excess lifetime risk of leukaemia of 10^{-4}, 10^{-5} and 10^{-6} are 17, 1.7, and 0.17µg/m^3 respectively (WHO, 2000). The World Health Organisation estimated that the lifetime risk of chronic leukaemia from the exposure of 1 µg/m^{3}benzene is 4.4 – 7.6 people per million populations (WHO, 2000). A recent study conducted in 2013 (Sehgal *et al*., 2016) on the air quality of Delhi showed that the level of benzene has exceeded the maximum permissible restrictions

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laid down by the National Ambient Air Quality Standards (NAAQS).

MATERIALS AND METHODS

The strategy used in this research involved collation of benzene exposure data from two locations: NSIT, Dwarka, and DMS, Shadipur. The Central Pollution Control Board (CPCB) laid down the national guidelines for the monitoring and chemical analysis of benzene found in the outdoor air by using Gas Chromatography (CPCB, 2003). Ambient air was sampled at DMS and NSIT for 2011-2015 and ambient air concentration of benzene was determined by using an online continuous monitoring system (CPCB, 2012–13). Cumulative Probability Distribution (CPD) plots were constructed (Figure 1).

From the CPD plots, lifetime average daily dose, hazard quotient, and cancer risk were calculated at an average annual exposure concentration (C_{EXPavg}), median exposure concentration (C_{EXP50}) and 90% exposure concentration (C_{EXP90}) by cumulative probability of benzene exposure levels. Data of benzene concentration is collected from CPCB and all the standards values were taken from US EPA methodology (Benjamin *et al.*, 2015; US Environmental Protection Agency, 1996; US Environmental Protection Agency, 1992). Some assumptions were taken into consideration while performing cancer risk analysis to conform to the US EPA methodology.

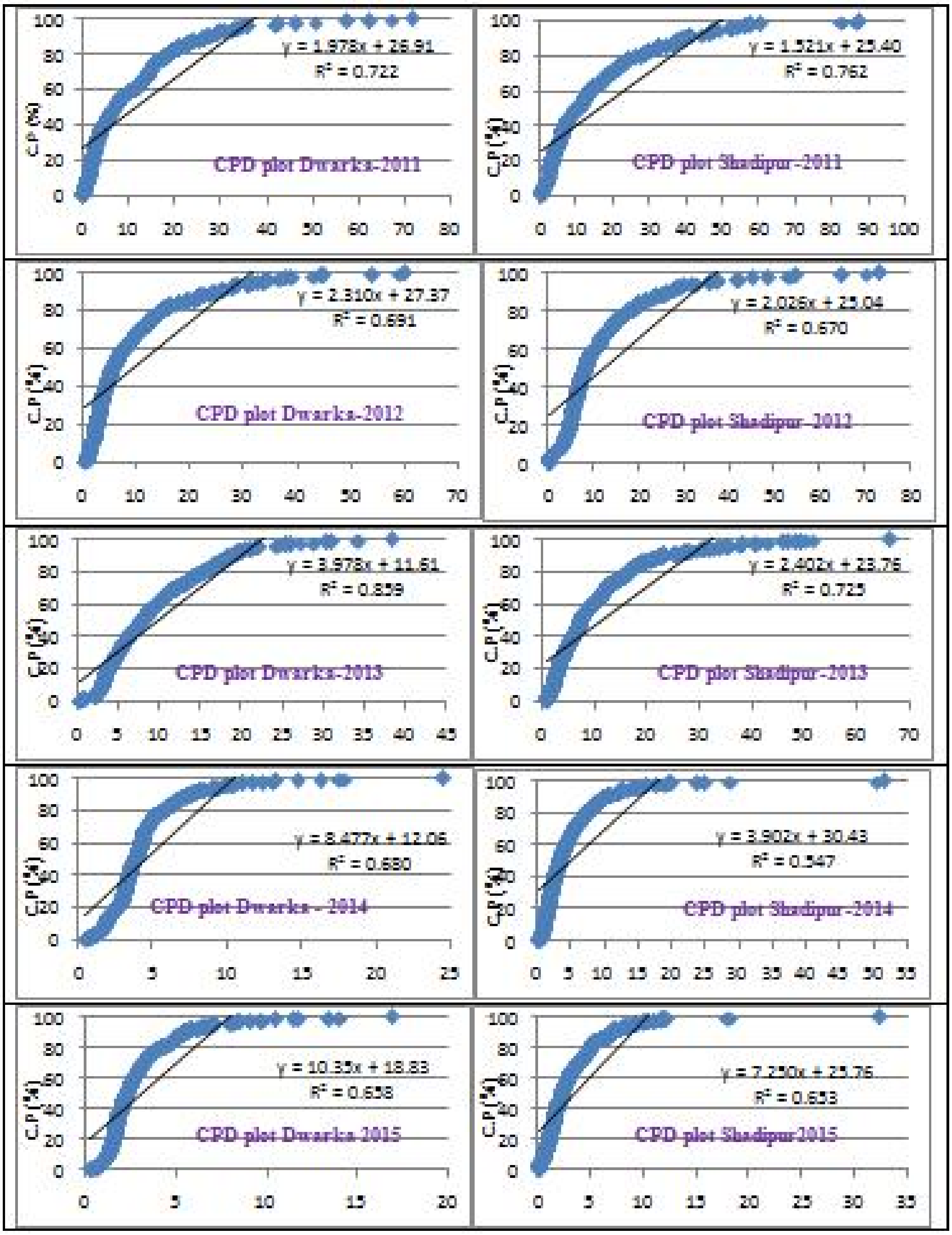

Figure 1. Represents the CPD plots for Dwarka and Shadipur. From these plots exposure concentration at cumulative probability of 50% and 90% is calculated from years 2011-2015 by using regression line by equation; (y=mx+c); here 'y' represents cumulative probability; 'x' represents exposure concentration C_{EXP} and 'm' represents slope of the equation

Assumptions include a 70 years human life expectancy, 70 kg body weight and $20m^3$/day inhalation rate.

2.1. Calculation of Cumulative Probability (CP)

CP (%) = (i/n+1) ×100 ------------eq-1,

Where, CP = cumulative probability (%); i = i^{th} point and n = the total number of data points.

The linear regression equations of the CPD (Cumulative Probability Distribution) plots were usually calculated between 10%–90% of the cumulative probability distribution because it represents almost the linear part of the CPD plots (figure 1) when a normal distribution occurs.

Calculation of Lifetime Average Daily Dose (LADD) (µg/kg/day) –

LADD= (C_{EXP} ×IR ×EL× ED)/ (BW ×LT) ------- eq 2

Where C_{EXP} = exposure concentration (µg/m^3); IR= Inhalation Rate (m^3/day); EL= Exposure Length (day/day); ED=Exposure Duration (days); BW= Body Weight (kg); LT= Lifetime (days).

Calculation of Hazard Quotient (HQ)

Non-cancerous risks were expressed as the Hazard Quotient (HQ), which is defined as the ratio between the lifetime average daily dose (LADD), and the reference dose (RfD) (a level below which adverse health effects are not likely to occur). This algorithm was used to calculate the chronic non-cancerous risk (*i.e.*, the risk associated with long-term exposures), using chronic RfDs. The HQ method of risk characterization was used to estimate the adverse health effects of exposure to benzene.

The RfD value derived for benzene was used to estimate the benzene exposure at average level (C_{EXPavg}), the median level (C_{EXP50}) representing the main group of individuals, and the 90% level (C_{EXP90}) representing the highest exposed group in the population. Such highly exposed group occurs at a level of 10% in the population and the median group represents over 50% in the population.

HQ = LADD/RfD --------eq 3

Where HQ = Hazard Quotient; LADD= lifetime average daily dose (µg/kg/day); RfD = USEPA reference dose (µg/kg/day)

Calculation of Cancer Risk (CR)

Cancer risk is expressed as an excess risk of developing cancer over a lifetime of exposure (70 years). The USEPA inhalation slope factor derived from benzene was used to quantitatively estimate the excess cancer risk at C_{EXPavg}, C_{EXP50} and C_{EXP90} in terms of LADD.

CR = LADD (µg/kg/day) × SF $(\mu g/kg/day)^{-1}$ --------eq 4

Where SF = slope factor for benzene.

EPA Exposure Factors Recommended for Risk Assessment

Hence ambient air exposure for people, if they exposed to 4h/day - (LT = 7 days/week × 52 weeks/year × 70 years = 25,480 days; ED = 7 days/week × 52 weeks/year × 30 years = 10,920 days; EL = 0.17 day/day)

RESULTS

Risk analysis at average exposure concentration (C_{EXPavg})

Cancer risks were calculated at C_{EXPavg} and the values of average exposure concentration, lifetime average daily dose, hazard quotient, and cancer risk aregiven in Table 2. At C_{EXPavg}, the cancer risks in the terms of lifetime exposure to benzene were 6.69 per 10^6 for Dwarka and 9.26 per 10^6 for Shadipur in 2011. The cancer risk has been decreased from 2011 to 2015 (Figure 2). In 2015, cancer risks were 1.72 and 1.91 per 10^6 for Dwarka and Shadipur respectively. From 2011-2014 average annual concentration of benzene ranges from 4.49 to 16.3 µg/m^3 which is higher than National Ambient Air Quality Standards (NAAQS) for benzene (i.e. 5 µg/m^3) **(**Central Pollution Control Board, 2009**).** Also, at this concentration from 2011 to 2014 cancer risk varies from 2.557 to 9.26 per 10^6. In 2015, concentration is below the NAAQS and ranges from 3.0-3.36µg/m^3. Comparatively there is a lesser cancer risk in 2015 i.e. ranges from 1.72 to 1.91 per 10^6. Also, HQ has been found as less than 1 for the period of 2011-2015, representing that there is very less chronic non-cancerous effect on human health. The value of HQ which was 0.029 in 2011 was reduced to 0.007 in 2015 in Dwarka and similarly in Shadipur also this value was 0.04 in 2011 but now reduced to 0.008 in 2015.

Risk Analysis at 50% exposure concentration (C_{EXP50})

Cancer risks were calculated for exposure to benzene at the median level (C_{EXP50}) which represents the main group of exposed individuals. The values of exposed concentration, lifetime average daily dose, hazard quotient, and cancer risk are given in Table 3. At C_{EXP50}, the excess cancer risks in the terms of lifetime exposure to benzene were 6.63 per 10^6 for Dwarka and 9.18 per 10^6 for Shadipur in 2011. The cancer risk has been decreased from 2011 to 2015 (Figure 3). In 2015, Cancer risks were 1.7 and 1.9 per 10^6 for Dwarka and Shadipur respectively. From 2011 to 2014 C_{EXP50} ranges from 4.475 to 16.16µg/m^3. In 2015, the concentration is below NAAQS i.e. ranges from 3.01 to 3.343 µg/m^3) and there is comparatively lesser cancer risks in 2015 i.e. ranges from 1.71 to 1.9 per 10^6. Also HQ has been found as less than 1 for the period of 2011-2015, representing that there is very less chronic non-cancerous effect on human health. The value of HQ which was 0.028 in 2011 was reduced to 0.007 in 2015 in Dwarka and similarly in Shadipur also this value was 0.04 at 2011 was reduced to 0.008 in 2015.

Risk Analysis at 90% exposure concentration (C_{EXP90})

Cancer risks were calculated for exposure to benzene at the 90% level (C_{EXP90}) representing the highest exposed group in the population.

Table 1. EPA exposure factor for benzene (18)

Parameters	Unit	Default Value
Lifetime (LT)	Years	70
Body Weight (BW)	Kg	70
Exposure Length (EL)	day/day	0.17 (4 h/day) (outdoor)
Exposure Duration (ED)	Years	30 (residential)
Inhalation Rate (IR)	m^3/day	20
Inhalation Reference Dose (RfD)	µg/kg/day	8.5
Slope Factor	$(\mu g/kg/day)^{-1}$	27.3

Table 2. Cancer risk estimation at C_{EXPavg}

year	C_{EXPavg} (µg/m^3)		LADD (µg/kg/day)		HQ		CR (in1 million)	
	Dwarka	Shadipur	Dwarka	Shadipur	Dwarka	Shadipur	Dwarka	Shadipur
2011	11.78	16.3	0.245	0.34	0.029	0.04	6.69	9.26
2012	9.89	12.04	0.206	0.25	0.024	0.03	5.62	6.84
2013	9.69	10.97	0.202	0.23	0.024	0.027	5.51	6.23
2014	4.49	5.05	0.093	0.105	0.011	0.012	2.557	2.87
2015	3.023	3.36	0.063	0.07	0.007	0.008	1.72	1.91

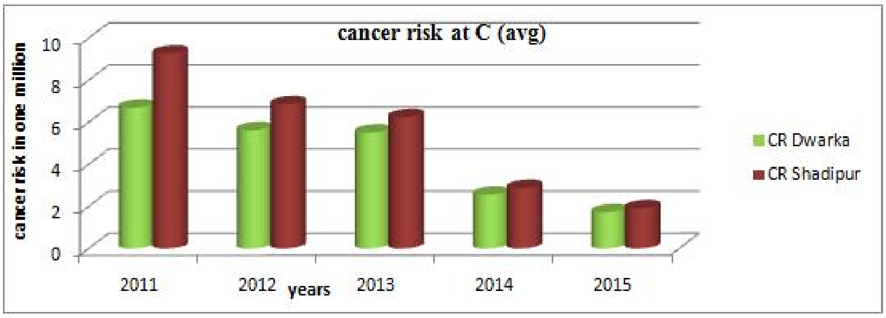

Figure 2. Cancer risk at average exposure concentration

Table 3. Cancer risk estimation at C_{EXP50}

year	C_{EXP50} (µg/m^3)		LADD (µg/kg/day)		HQ		CR (in1 million)	
	Dwarka	Shadipur	Dwarka	Shadipur	Dwarka	Shadipur	Dwarka	Shadipur
2011	11.67	16.16	0.243	0.33	0.028	0.04	6.63	9.18
2012	9.79	12.31	0.204	0.256	0.024	0.03	5.56	6.99
2013	9.65	10.92	0.2	0.227	0.023	0.026	5.48	6.2
2014	4.475	2.013	0.09	0.104	0.01	0.0123	2.54	2.849
2015	3.01	3.343	0.06	0.069	0.007	0.008	1.71	1.9

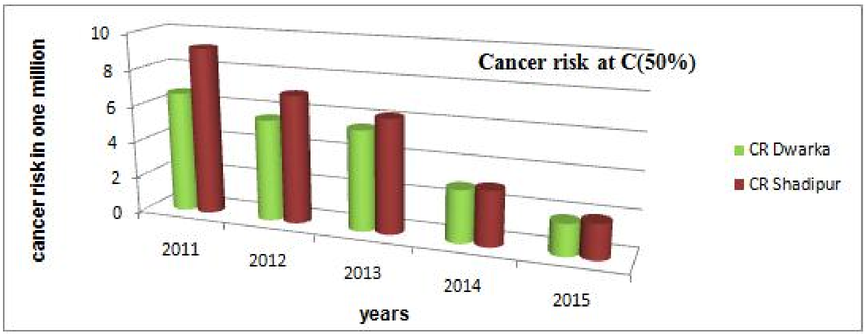

Figure 3. Cancer risk at 50% cumulative probability

Table 4. Cancer risk estimation at C_{EXP90}

year	C_{EXP90} (µg/m^3)		LADD (µg/kg/day)		HQ		CR (in1 million)	
	Dwarka	Shadipur	Dwarka	Shadipur	Dwarka	Shadipur	Dwarka	Shadipur
2011	31.89	42.44	0.664	0.88	0.078	0.1	18.12	24.12
2012	27.12	32.05	0.56	0.667	0.067	0.08	15.41	18.2
2013	19.7	27.56	0.41	0.57	0.048	0.067	11.19	15.66
2014	9.2	15.26	0.19	0.3	0.022	0.037	5.23	8.67
2015	6.87	8.86	0.14	0.18	0.017	0.02	3.9	5.035

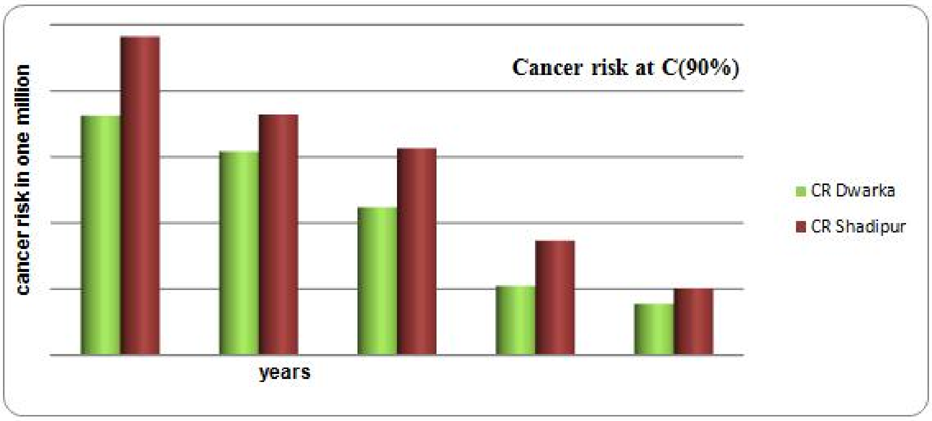

Figure 4. Cancer risk at 90% cumulative probability

Table 5. Comparison of estimated cancer risk with other cities

S.NO	City and year of the city	Prevalent benzene concentration and matrix		Cancer risk (in one million)	Reference
1	Data including (France, Spain, Mexico, Brazil, Finland, Taiwan, U.K), 1993-2013	Inside service station , at $LADD_{50}$ (0.069 µg/kg/day)		2	(26)
		Inside service station , at $LADD_{95}$ (0.72µg/kg/day)		21	
		Outside service station, $LADD_{50}$ (0.35µg/kg/day)		10	
		Outside service station , $LADD_{95}$ (2.2µg/kg/day)		61	
2	Beijing, China 2008-2012	Exposure at mean concentration		131*	(27)
		Exposure at 50%		107*	
		Exposure at 95%		304*	
3	Kolkata, India (Dec 2003- Feb 2005)	North, South and Central Kolkata- in seasonal variation		8.9-30	(28)
4	In present study (in ambient air of Delhi, 2011-2015)	At C_{EXPavg}	2011	6.69-9.26	
			2012	5.62-6.89	
			2013	5.51-6.23	
			2014	2.56-2.87	
			2015	1.72-1.91	
		At C_{EXP50}	2011	6.63-9.18	
			2012	5.56-6.69	
			2013	5.48-6.2	
			2014	2.54-2.85	
			2015	1.71-1.9	
		At C_{EXP90}	2011	18.12-24.12	
			2012	15.41-18.2	
			2013	11.19-15.66	
			2014	5.23-8.67	
			2015	3.9-5.035	

The values of exposed concentration, lifetime average daily dose, hazard quotient, and cancer risk are given in Table 4. At C_{EXP90}, the excess cancer risks in the terms of lifetime exposure to benzene were 18 per 10^6 for Dwarka and 24 per 10^6 for Shadipur in 2011. The cancer risk has been decreased from 2011 to 2015 (Figure 4). In 2015, cancer risks were 4 and 5 per 10^6 for Dwarka and Shadipur respectively. From 2011-2015 C_{EXP90} ranges from 6.87 to 42.44µg/m^3, and the cancer risk varies from 3.9 to 24.12 per 10^6. Also, HQ has been found as less than 1 for the period of 2011-2015, representing that there is very less chronic non-cancerous effect on human health.

DISCUSSION

It is calculated that from 2011 to 2015 at C_{EXPavg} and C_{EXP50} cancer risk varies from 1.71 to 9.26 per 10^6 whereasat C_{EXP90} cancer risk varies from 3.9 to 24.12 per 10^6, which is higher in comparison with mean and median concentration.

The cancer risk calculated in the present study is comparable with the studies done in Kolkata, India and few European countries (Table 5). The average annual concentration of benzene ranges from 3.02 µg/m^3 in 2015 to 16.3 µg/m^3 in 2011.The mean value found in 2015 is also less than NAAQS of benzene i.e. 5µg/m^3. In this study, it has been found that the Hazard Quotient during 2011-2015 at all concentrations (annual average concentration, C_{EXP50},and C_{EXP90}) varies from 0.007-0.1 µg/m^3, which is always less than one. Hence, there is no significant non-cancerous risk at such concentration in the outdoor environment. According to Auto Fuel Policy in India 2003, Indian petrol standard requires that the benzene levels should not exceed 1% for Bharat Stage IV (equivalent to Euro 4) norms and this standard is mandatory for 13 cities of India having a population greater than 2 million which includes Delhi. Further it should not exceed 5% for Bharat Stage III (equivalent to Euro 3) norms for rest of the India (http://www.siamindia.com/technical-regulation.aspx?mpgid=31&pgidtrail=33 (accessed 08/02/2016)).

It is observed that gasoline standard was implemented on April 1, 2010, in India by which benzene limits were reduced to 3% in Bharat III cities (1% in Delhi and Mumbai) and 5% elsewhere to nationwide (http:// transportpolicy.net/index.php?title=India:_Fuels:_Diesel_and_Gasoline#cite_note-3 (accessed on 09/02/2016)). The other significant reasons for decrease in benzene concentration were related to increase in green cover from 6% in 1999 to 20.8% in 2013. mainly due to plantation activity carried out in non-forest urban areas in Delhi by the State Government agencies like New Delhi Municipal Corporation (NDMC), Delhi Development Authority(DDA), MCD (Municipal corporation of Delhi), Forest Department (FD), Public Works Department(PWC), several NGOs, and academic institutions (http://articles.economictimes.indiatimes.com/2015-08-22/news/65739637_1_delhi-high-court-green-cover-national-forest-policy (accessed 01/05/2016); Bhalla and Bhattacharya, 2015).

From this study, it is also estimated that the concentration of benzene is more at DMS, Shadipur than NSIT, Dwarka. The reason for these changes are the difference in the population size, the pattern of land use, vehicular and traffic density and presence of factories. As Dwarka is comparatively newly settled area predominated by residential sector and it is reported that the total built-up area had increased by nearly 17% between 1997 and 2008 in Delhi. The similar pattern was also reported due to increase in the number of motor vehicles **(**Mohan *et al*., 2011**).** Hence, from our study, it is clear that implementation of Auto Fuel Policy and increase in green cover helped in reduction of benzene.

Conclusion

It is estimated that at present there is comparatively lesser cancer risk, due to benzene exposure in ambient air of Delhi. Such studies are important to understand the impact of policy intervention by the Government in controlling the pollution and ultimately protecting the public health of Delhi. Benzene levels were measured from 2011 to 2015 in selected parts of Delhi.

A decrease in the cancer risk has been estimated. It was observed that there is a decrease in the concentration of benzene due to the strong implementation of Auto Fuel Policy in India (2003). Special efforts were made to lower down the concentration of benzene in gasoline, in order to make our fuel quality better. Other than the policy intervention, some subsequent measures like massive plantation in Delhi and increase in tree cover were also helpful in reducing the concentration of benzene. Forest Survey of India also reported that during this time, due to plantation, green cover was also increased in Delhi. While formulating infrastructure related policies, improving urban forestry status through periodic monitoring of the health of urban trees and effective green space planning can further improve the air quality of Delhi **(**Bhalla and Bhattacharya, 2015**).** Promotion of cleaner technologies to reduce vehicular pollution and to ensure better fuel quality may be panacea and which will support the transition to healthier air in Indian cities.

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Disclosure statement

No potential conflict of interest was reported by the authors.

REFERENCES

Atlanta, 2007. Toxicological profile for Benzene, Toxic substance portal benzene, United States Department of Health and Human Services Public Health Service, Agency for Toxic Substances and Disease Registry.

Badjagbo, K., Loranger, S., Moore, S., Tardif, R., Sauvé, S. 2010. BTEX exposures among automobile mechanics and painters and their associated health risks. *Human and Ecological Risk Assessment*, 16, 301–316, Doi: 10.1080/10807031003670071.

Benjamin, Edokpolo., Qiming, JimmyYu and Des, Connell., 2015. Health Risk Assessment for Exposure to Benzene in Petroleum Refinery Environments.595–610. Doi:10.3390/ijerph120100595

Benzene Toxicity, Case study in environmental medicine, 2003. Agency for toxic substances and disease registry. Available online at; http://www.bvsde.paho.org/tutorial3/fulltex/benzene.pdf (last accessed on-22/02/2015)

Bhalla, P. and Bhattacharya, P. 2015, Urban Biodiversity and Green Spaces in Delhi: A Case Study of New Settlement and Lutyens' Delhi, *Journal of Human Ecology*, 51(1, 2), 83-96.

Central Pollution Control Board; 2009, Revised National Ambient Air Quality Standards; NAAQS Notification dated 18th November 2009.

Cooper, K., Noller, B., Connell, D., Yu, J., Sadler, R., Olszowy, H., Golding, G., Tinggi, U., Moore, M.R., Myers, S., 2007. Public health risks from heavy metals and metalloids present in traditional Chinese medicines. *Journal of Toxicology and Environmental Health Part: A.*; 70(19), 1694-1699. Doi: 10.1080/152873 90701434885.

CPCB, 2003. Guidelines for ambient air quality monitoring, National Ambient Air Quality Monitoring Series (NAAQMS).

CPCB, 2012–13. Guidelines for the measurement of ambient air pollutants, Volume-II: guidelines for real time sampling & analyses CPCB. National Ambient Air Quality Series: NAAQMS/37/2012-13.

Majumdar, D., A, Mukherjeea., and S, Sen., 2011, BTEX in Ambient Air of a Metropolitan City, *Journal of Environmental Protection,* 2(1), 11-20. Doi: 10.4236/jep.2011.21002

Dewangan, S., Chakrabarty, R., Zielinska, B., Pervez, S. 2013, Emission of volatile organic compounds from religious and ritual activities in India, *Environmental Monitoring and Assessment*; 185(11), 9279-86. doi: 10.1007/s10661-013-3250-z.

Edokpolo, B., Yu, Q J., Connell, D. 2014. Health Risk Assessment of Ambient Air Concentrations of Benzene, Toluene and Xylene (BTX) in Service Station Environments., *International journal of environmental research and public health*, 11(6), 6354-6374. Doi: 10.3390/ijerph110606354

Eikmann, T., Kramer, M., Goebel, H., 1992. The exposure of the population to toxic substances in the interior of motor vehicles--the example of benzene,*ZentralblHygUmweltmed.*; 193(1):41-52.

Guidelines for carcinogen risk assessment, 2005, Risk Assessment Forum U.S. Environmental Protection Agency Washington, DC; EPA/630/P-03/001B.

Hoque, R.R., Khillare, P.S., Agarwal, T., Shridhar, V., Balachandran, S. 2008. Spatial and temporal variation of BTEX in the urban atmosphere of Delhi, India, *Science of the Total Environment*; 15, 30-40.

Huang, L., Mo, J., Sundell, J., Fan, Z., Zhang, Y., 2013. Health Risk Assessment of Inhalation Exposure to Formaldehyde and Benzene in Newly Re-modelled Buildings, Beijing. *PLOS ONE* 8 (11). Doi:10.1371/journal.pone.0079553.

Keretetse, G.S., Laubscher, P.J., du Plessis, J.L., Pretorius, P.J., van der Weshuizen, F.H., van Dyk, E., Eloff ,F.C., Aarde, M.N., du Plessis, L.H., 2008. DNA damage and repair detected by the comet assay in lymphocytes of African petrol attendants: A pilot study, *An Occupational Hygiene*,. 52(7), 653-662. Doi: 10.1093/annhyg/men047.

Mohan, M., Pathan, S., Narendrareddy, K., Kandya, A. and Pandey, S. 2011. "Dynamics of Urbanization and Its Impact on Land-Use/Land-Cover: A Case Study of Megacity Delhi," *Journal of Environmental Protection*, 09, 1274-1283.

Navasumrit, P., Chanvaivit, S., Intarasunanont, P., Arayasiri, M., 2005. Environmental and occupational exposure to benzene in Thailand, *Chemico Biological Interaction,* 153, 75-83.

Sehgal, M., Tyagi, S.K., and Gautam, S.K. 2016. Air quality in Delhi: status and concerns, *International Journal of Environmental Studies,* DOI:10.1080/00207233.2016.1144378

SIAM (Society of Indian Automobile Manufacturers), 2005, Available online at: http://www.siamindia.com/technical-regulation.aspx?mpgid=31&pgidtrail=33 (accessed 08/02/2016)

The Economic Times, August 22, 2015, 20.8 per cent green cover in Delhi due to plantation: Government to High Court, Available online on- http://articles.economictimes.indiatimes.com/2015-08-22/news/65739637_1_delhi-high-court-green-cover-national-forest-policy (accessed 01/05/2016)

Transport policy.net, India: Fuels: Diesel and Gasoline. Available on- http://transportpolicy.net/index.php?title=India:_Fuels:_Diesel_and_Gasoline#cite_note-3 (accessed on 09/02/2016)

US Environmental Protection Agency, 1992, Guidelines for exposure assessment, Risk Assessment Forum U.S. Environmental Protection Agency Washington, DC, EPA/600/Z-92/001.

US Environmental Protection Agency, 1996, Exposure factors handbook, volume-1 General factors, Update to Exposure Factors Handbook, EPA/600/8-89/043.

US Environmental Protection Agency. Risk Assessment Guidance for Superfund: Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors".

WHO, 2000. Air Quality Guidelines for Europe, 2nd ed., World Health Organization, Regional Office for Europe, Copenhagen, WHO Regional Publications, European Series No. 91.

WHO, 2000. Benzene. In: Air quality guidelines for Europe, 2nd ed. Copenhagen, World Health Organization Regional Office for Europe.

World Health Organization, 2010. Guidelines for Indoor Air Quality: Selected Pollutants; WHO Regional Office for Europe: Copenhagen, Denmark.

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