Asian Journal of Chemistry; Vol. 24, No. 12 (2012), 5463-5465

ASIAN JOURNAL OF CHEMISTRY

www.asianjournalofchemistry.co.in

Concentrations of Polycyclic Aromatic Hydrocarbons in Indian Atmosphere During 1999-2011†

LAKSHMI NARAYANA SUVARAPU*, YOUNG-KYO SEO and SUNG-OK BAEK

Department of Environmental Engineering, Yeungnam University, Gyeongsan-si 712 749, Republic of Korea

*Corresponding author: E-mail: suvarapu@gmail.com

AJC-11668

India is the seventh largest country by geographical area and the second highest populous country with over 1.2 billion people in the world. India is one of the fastest growing major economies in the world, because of the economic reforms introduced in 1991. In this paper, we reviewed and discussed the concentration of PAHs have been reported in India during 1999-2011.

Key Words: India, Polycyclic aromatic hydrocarbons, Hazardous air pollutants, 1999-2011.

INTRODUCTION

In developing countries, the high influx of population towards the urban areas, leads to more consumption of energy sources and may cause air pollution. Most of the world's larger populous cities are placed in developing countries; like China, India and Indonesia. The annual polycyclic aromatic hydrocarbon emissions from Asian countries were 290 Gg year^{-1}, with China and India contributing 114 and 90 Gg year^{-1}, respectively[1]. This indicates the seriousness of the polycyclic aromatic hydrocarbon pollution in China and India. In India, we found that most of the data was published after 2000. Because of the severity of air pollution in India, we want to review the concentration of polycyclic aromatic hydrocarbons in the atmosphere reported during 1999-2011, which in terms gives a clear idea about the air quality of the Indian cities.

Atmospheric concentration of polycyclic aromatic hydrocarbons in India: The atmospheric concentration of particulate polycyclic aromatic hydrocarbons in Delhi during different seasons of 2003 was reported by Sharma *et al.*[2]. For this study they collected the ambient air samples at three sites in Delhi, namely Okhla (industrial), Dhaulakuan (commercial and residential) and Daryaganj (commercial and residential). The suspended particulate matter samples were collected on glass fibre filters (8" × 10") with a high volume sampler in four seasons *i.e.*, winter December, January, February), summer (March, April, May), monsoon (June, July, August) and post monsoon (September, October, November) of 2003. Their result shows that the polycyclic aromatic hydrocarbons concentration at Daryaganj site was higher than the other two sites. They found the average BaP concentration during winter season in the range of 86.50-90.32 ng/m^3 at three sites. Their principle component analysis study predicts the major reason for high concentration of polycyclic aromatic hydrocarbons in Delhi city was vehicular emission. Masih *et al.*[3] have reported the concentration of polycyclic aromatic hydrocarbons at indoor and outdoor environment of ten homes at urban and roadside sites of Agra city, during the winter season (November 2006-February 2007). According to their studies they predicted the major source for high concentration of polycyclic aromatic hydrocarbons at roadside site was vehicular emissions where as in indoor environments it was attributed to gas utilities, cooking (frying and oil combustion), smoking and incense burning. Chemical speciation of respirable suspended particulate matter during a major firework festival, Diwali in Delhi was reported by Sarkar *et al.*[4]. They have reported the high concentration of PM_{10} and heavy metals during the Diwali day in Delhi (three different sites), than the pre Diwali and post Diwali days. Interestingly, the concentration of polycyclic aromatic hydrocarbons was decreased during Diwali day than pre and post sessions. Regarding the concentration of polycyclic aromatic hydrocarbons at their study sites, BbF was dominated by others which contribution was up to 22 %, followed by BaP (13.9 %), DahA (11.8 %), BghiP (9.8 %) and BkF (9.3 %). The major sources for the atmospheric polycyclic aromatic hydrocarbons in their study sites may be coal combustion (their study sites are inclusive of two thermal power plants) and vehicular emissions. In these sites, the carcinogenic (IARC

†Presented at International Conference on Global Trends in Pure and Applied Chemical Sciences, 3-4 March, 2012; Udaipur, India

group 1, 2A and 2B) polycyclic aromatic hydrocarbons contribution was ranged from 41-88 %, which clearly indicates that the population expose to most of the carcinogenic polycyclic aromatic hydrocarbons in these sites. Concentration, sources and exposure profiles of polycyclic aromatic hydrocarbons associated with PM_{10} in the city of Agra was reported by Masih *et al.*[5]. They measured the concentration of 17 polycyclic aromatic hydrocarbons (Nap, Ace, Acp, Flu, Phe, Ant, Carbazole, Flt, Pyr, BaA, Chry, BbF, BkF, BeP, BaP, IcdP, DahA and BghiP) at four different sites representing industrial, residential, roadside and agricultural areas during the winter season (November 2005-February 2006). The total 17 polycyclic aromatic hydrocarbons concentration in four different sites is follows the order industrial > residential > roadside > agricultural. The concentration of polycyclic aromatic hydrocarbons associated with $PM_{2.5}$ in ambient atmosphere of Chennai city was reported by Mohanraj *et al.*[1]. They found and measured the concentration of 11 polycyclic aromatic hydrocarbons (Phe, Ant, Flt, Pyr, BaA, Chry, BbF, BkF, BaP, IcdP and BghiP) at four different sites representing urban commercial, urban-residential and industrial regions of Chennai during March 2009-February 2010. They found highest mean concentration of 11 polycyclic aromatic hydrocarbons at urban commercial area (Egmore) followed by industrial site. Their studies reveals the highest concentration of BaP in Chennai city which ranged form 6.8-16.4 ng/m^3, it is much more exceeding the national ambient air quality standards. The principle component analysis predicts that the major sources for polycyclic aromatic hydrocarbons in the prescribed sites are vehicular emissions followed by off-road combustion sources such as wood and solid waste. Khillare *et al.*[6] have reported the comparative assessment of the concentration of polycyclic aromatic hydrocarbons in Delhi before and after the implementation of compressed natural gas (CNG). The authors have reported the concentration of polycyclic aromatic hydrocarbons associated with PM_{10} in Delhi at all seasons 1998 and 2004, before and after implementation of CNG policy, respectively. It is clear from their study that, the concentration of total polycyclic aromatic hydrocarbons was reduced up to 51-74 % compare to the pre-CNG data. They measured ambient air concentration of polycyclic aromatic hydrocarbons at three different sites in Delhi. Before the implementation of CNG policy the BaP concentration at three different sites were ranged from 0.95-29.82 ng/m^3, while the implementation of CNG policy it was in the range of 0.53-7.24 ng/m^3, which clearly indicates the sharp decrease. But still it is higher than the national ambient air quality standards of India. Ravindra *et al.*[7] also have reported the similar results that the decrease in the concentration of polycyclic aromatic hydrocarbons in Delhi atmosphere after the implementation of CNG to the public transport system. They measured the concentration of polycyclic aromatic hydrocarbons in two different sites in Delhi during January to December 2003. In the urban atmosphere of Tiruchirappalli, of Tamil Nadu state the concentration of polycyclic aromatic hydrocarbons associated with $PM_{2.5}$ was measured by Mohanraj *et al.*[8] during March 2009-February 2010. They found and measured 9 polycyclic aromatic hydrocarbons (Phe, Ant, BaA, Chry, BbF, BkF, BaP, BghiP and IcdP) in four seasons at four different sites representing urban, commercial, sub-urban residential and mixed commercial and residential atmospheres, which were in the range of 136-487.5 ng/m^3. Based on principle component analysis they found that the major source of polycyclic aromatic hydrocarbons in this city was diesel engine emissions.

Pandey *et al.*[9] have reported the ambient concentration of 12 polycyclic aromatic hydrocarbons (Phe, Ant, Flu, Pyr, BaA, Chry, BbF, BkF, BaP, DahA, BghiP and IcdP) during May 1995-April 1996, at Bhilai steel industry, one of the major steel industries in India. They claimed that it was the first report on the concentration of polycyclic aromatic hydrocarbons at this area. They measured the polycyclic aromatic hydrocarbons concentration at two different sites in Bhilai, namely CISF site and MPEB site. The yearly mean BaP concentration at CISF site and MPEB site were recorded as 6.27 ng/m^3 and 3.81 ng/m^3, respectively. They did not observe any seasonal variation about the concentration of polycyclic aromatic hydrocarbons at these two sites, which indicates that the emission sources were consistent. Size distribution and source apportionment of polycyclic aromatic hydrocarbons in ambient atmosphere of Delhi was reported by Gupta *et al.*[10] They collected the ambient aerosol particles with a five-stage cascade particle separator at five different sites (Jawaharlal Nehru University, Uttam Nagar, Nizamuddin, ITO, Okhla and Connaught place) representing residential, industrial and commercial regions during January to December 2006. Based on size distribution studies, the smallest size particles (< 0.7 μm) comprized the major portion of polycyclic aromatic hydrocarbons. In most cases, they found that the polycyclic aromatic hydrocarbons concentrations decrease with the increase in particle size. With principle component analysis studies, it was concluded that the major sources for polycyclic aromatic hydrocarbons at their studied sites were fossil fuel, wood and leaf burnings.

Sharma *et al.*[11] have reported the concentration of polycyclic aromatic hydrocarbons associated with PM_{10} at a residential site in New Delhi during December 2001- March 2002. They found and measured 9 polycyclic aromatic hydrocarbons (BbF, BjF, BkF, BaP, BeP, IcdP, BghiP, DahA and Cor) at this site. Along with polycyclic aromatic hydrocarbons they measured other organic pollutant present at the prescribed site. They suggested that the biomass burnings and motor vehicle exhaust emissions were significant contributors to the organic fraction of PM_{10} in this area.

Precipitation scavenging of polycyclic aromatic hydrocarbons in Mumbai has been reported by Sahu *et al.*[12]. They collected the rain water and air samples simultaneously during thirteen rain events between last week of May and to the end of June 2001. Based on their studies, they concluded that the gas phase scavenging ration was increases with the increase of molecular weight of polycyclic aromatic hydrocarbon. The particle phase scavenging ratio values are higher for more volatile polycyclic aromatic hydrocarbons than the less volatile polycyclic aromatic hydrocarbons. Sharma *et al.*[13] have reported the characterization and source identification of polycyclic aromatic hydrocarbons in the urban environment of Delhi during January 2002-December 2003. They found the annual average concentration of total 12 polycyclic aromatic hydrocarbons (Phe, Ant, Flt, Pyr, BaA, Chry, BbF, BkF, BaP, IcdP, DahA and BghiP) as 668 ± 399 and 672 ± 388 ng/m^3, in the years 2002 and 2003, respectively. They found higher concentration of polycyclic aromatic hydrocarbons during winter season than the other seasons. Based on their source identification studies, they concluded that the diesel vehicles, coal combustion, gasoline vehicles and wood were the principle sources of polycyclic aromatic hydrocarbons in winter season (December-February); vehicular emissions and wood combustion were the principle sources in premonsoon season (March-May); diesel vehicles, gasoline vehicles and wood combustion was the major sources in monsoon season(June-August); and vehicular emissions and coal combustion were the major sources in post monsoon season(September-November). The concentration of EPA 16 prior polycyclic aromatic hydrocarbons associated with both PM_{10} and $PM_{2.5}$ in eastern part of Delhi during winter and summer period of 2007-2008 was reported by Singh *et al.*[14]. In their studies, they found that the higher concentration of polycyclic aromatic hydrocarbons in winter than the summer period. Low molecular weight polycyclic aromatic hydrocarbons (2-3 ring) contribute lower fraction in total polycyclic aromatic hydrocarbons, while high molecular weighted polycyclic aromatic hydrocarbons have higher fraction, ranging from 80.1 % to 95.2 %. The reason for this may be attributed to the combustion of petroleum fuels. They observed high concentration of IcdP in both in PM_{10} and $PM_{2.5}$ in winter but BkF was found in higher concentration in summer. Another important and alarming issue in their studies is they found seven carcinogenic polycyclic aromatic hydrocarbons (IARC, group1, 2A and 2B) were almost two-third in the total polycyclic aromatic hydrocarbons. Based on the comparison of these results with the other major cities in the world they concluded that the concentration of polycyclic aromatic hydrocarbons in their specified site was higher than the others. Karar and Gupta[15] have reported the seasonal variations and chemical characterization of ambient PM_{10} at residential and industrial sites of an urban region of Kolkata during November 2003-November 2004. They found and measured the concentration of Flt, Pyr, BaA, BbF and BaP at the specified sites. The major polycyclic aromatic hydrocarbon compound at their monitoring sites was BbF, which was found 30 ng/m^3, 20 ng/m^3 at residential and industrial sites, respectively. Regarding the seasonal variation in the concentration of polycyclic aromatic hydrocarbons, they found higher in winter than the summer due to temperature inversion, leading to an accumulation of pollutants over the city.

In India, the economic reforms were introduced in 1991; it makes a big change in Indian economic growth. After the year 2000, India has registered a very high GDP (gross domestic product)[16] due to the renewal of economic reforms. With the economic development and high population, energy consumption also increased. Because of the shortage or unaffordable prices of commercial fuels forces the Indian rural people towards the traditional biomass fuel consumption including coal, coke and waste burnings[17]. The incomplete combustion of the above said biomass fuels, produces so many pollutants into the ambient air among them polycyclic aromatic hydrocarbons are major concern because of carcinogenic properties. These biomass fuels consumption usage in rural Indian villages causes health damage to the local people. The proportion of biomass in India's energy demand will decrease in future, its proportion, 27 % in 2007 and expected as 15 % in 2030, is considerably higher than the world's average, 9.8 % in 2007 and 9.5 % in 2030[18]. The world energy outlook expected that 436 million Indian people of rural areas will still depend on biomass; it was 597 millions in 2005. But in urban areas it will be 36 millions in 2030, which was 71 million in 2005[19]. The more economic growth and efficient technology in rural areas to maintain the biomass burning will reduce the pollution due to biomass fuel consumption and improves the quality of air. Another major contribution of atmospheric polycyclic aromatic hydrocarbons in India is from vehicular emissions. In India, the vehicles number increases in a rapid way it is confirmed from the statistics of the ministry of road transport. The number of vehicles (all types) registered in 2001 was 55 millions but its number in 2009 was 114.95 million[4]. It clearly indicates that the number of vehicles became doubled in just 8 years, but at the same period the population growth was just 17.6 % only. In India, to regulate the vehicle emissions Euro standards were implemented since 2000. In the year 2000, Euro 1 standards for four wheeler vehicles in nationwide, later Euro 2, Euro 3 and Euro 4 standards were implemented in 2001, 2005 and 2010, respectively[20]. But it was limited to for few metropolitan cities only. In case of two wheelers standards still Bharat Stage III (equal to Euro 3) is applicable in India. In case of vehicle emission standards India is far away when compare to the European or Western countries.

REFERENCES

1. R. Mohanraj, G. Solaraj and S. Dhanakumar, *Environ. Sci. Pollut. Res.*, **18**, 764 (2011).
2. H. Sharma, V.K. Jain and Z.H. Khan, *Environ. Monit. Assessm.*, **147**, 43 (2008).
3. J. Masih, A. Masih, A. Kulshrestha, R. Singhvi and A. Taneja, *J. Hazard. Mater.*, **177**, 190 (2010).
4. S. Sarkar, P.S. Khillare, D.S. Jyethi, A. Hasan and M. Parween, *J. Hazard. Mater.*, **184**, 321 (2010).
5. A. Masih, R. Saini, R. Singhvi and A. Taneja, *Environ. Monit. Assessm.*, **163**, 421 (2010).
6. P.S. Khillare, T. Agarwal and V. Shridhar, *Environ. Monit. Assessm.*, **147**, 223 (2008).
7. K. Ravindra, E. Wauters, S.K. Tyagi, S. Mor and R.V. Grienken, *Environ. Monit. Assessm.*, **115**, 405 (2006).
8. R. Mohanraj, G. Solaraj and S. Dhanakumar, *Bull. Environ. Contaminat. Toxicol.*, **87**, 330 (2011).
9. P.K. Pandey, K.S. Patel and J. Lenicek, *Environ. Monit. Assessm.*, **59**, 287 (1999).
10. S. Gupta, K. Kumar, A. Srivastava, A. Srivastava and V.K. Jain, *Sci. Total Environ.*, **409**, 4674 (2011).
11. D.N. Sharma, A.A. Sawant, R. Uma and D.R. Cocker, *Atmosph. Environ.*, **37**, 4317 (2003).
12. S.K. Sahu, G.G. Pandit and S. Sadasivan, *Sci. Total Environ.*, **318**, 245 (2004).
13. H. Sharma, V.K. Jain and Z.H. Khan, *Chemosphere*, **66**, 302 (2007).
14. D.P. Singh, R. Gadi and T.K. Mandal, *Atmosph. Environ.*, **45**, 7653 (2011).
15. K. Karar and A.K. Gupta, *Atmosph. Res.*, **81**, 36 (2006).
16. http://en.wikipedia.org/wiki/Economic_development_in_ India
17. http://www.decisioncraft. com/energy/papers/ecc/re/biomass/bti.pdf
18. http://www.iea.org/country/Poverty_India/Biomass2.pdf
19. http://www.worldenergyoutlook.org/docs/weo2007. WEO_ 2007_ English.pdf
20. http://www.dieselnet.com/standards/in/