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Chemical characteristics and mutagenic activity of $PM_{2.5}$ at a site in the Indo-Gangetic plain, India

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ABSTRACT

Airborne fine particulate matter $PM_{2.5}$ was collected from May 2010 to December 2012 at Agra, a semi-urban site in north-central India. $PM_{2.5}$ samples were chemically characterized for 16 polycyclic aromatic hydrocarbons by gas chromatography. $PM_{2.5}$ values varied between 8.4 and 300 μg m^{-3} with 55% of the values exceeding the 24 h average NAAQ (National Ambient Air Quality) standard of 65 μg m^{-3}. Particle associated total PAHs ranged between 8.9 and 2065 ng m^{-3} with a mean value of 880.8 ng m^{-3} during the sampling period, indicated an alarming level of pollution in Agra. Strong relationship was observed between $PM_{2.5}$ and total PAHs (r=0.88), suggesting an increasing PAHs concentration with increasing $PM_{2.5}$ mass. On a mass basis 3-ring and 4-ring compounds were dominant. Seasonal variation in mass concentration of PAHs was observed with high concentration in winter followed by post monsoon, summer and monsoon. This seasonal pattern could be attributed to differences in source strength and climatic conditions. PAHs concentration were also observed to be negatively correlated with the meteorological parameters i.e. temperature, solar radiation, relative humidity and wind speed. Molecular diagnostic ratios revealed vehicular emissions and combustion of wood and coal as the probable sources. The estimated carcinogenicity of PAHs in terms of benzo(a)pyrene toxic equivalency ($B[a]P_{TEQ}$) was assessed and confirmed that benzo[a]pyrene was the dominant PAH contributor (3.64%). Health risk of adults and children by way of PAHs was assessed by estimating the lifetime average daily dose (LADD) and corresponding incremental lifetime cancer risk (ILCR) using USEPA guidelines. The assessed cancer risk (ILCR) was found to be within the acceptable range (10^{-6}–10^{-4}). The particulate samples indicated the presence of both base pair and frame shift mutagens using TA98 and TA100 strains of *Salmonella typhimurium*. Enhanced mutagenic response was observed in the presence of enzyme activation.

1. Introduction

The analysis of atmospheric particles with an aerodynamic diameter <10 μm (PM_{10}) and <2.5 μm ($PM_{2.5}$) from urban regions has become important, considering the biological effects and potential health hazards they can impose (DeVizcaya-Ruiz et al., 2006). These health hazards are essentially exerted due to the size and chemical composition of the particulate matter (PM) involved. These particles can enter the organism through the respiratory tract, may get deposited and induce diverse biological effects. Particulate matter comprises several compounds including PAHs and their derivatives which display mutagenic and carcinogenic properties (Villalobos-Pietrini et al., 2007).

PAHs are formed during the incomplete combustion of fossil fuels, biomass or other organic substances like tobacco or food. In urban areas, A large amount of PAHs are derived from incomplete combustion in motor vehicle engines, especially heavy-duty trucks and diesel engines (Barakat, 2002). PAHs exist in the atmosphere in both vapor and particulate-phase (Bidleman et al., 1986). Low molecular weight PAHs tend to be more concentrated in the vapor-phase while the ones with higher molecular weight are mostly associated with fine particulate matter. Thus, it is important to understand the abundance, speciation, distribution and potential sources of PAHs in aerosols. There are more than 100 different PAHs. PAHs that draw health concerns include acenaphthene, acenaphthylene, anthracene, benz[a]anthracene, benzo[a]pyrene, etc. Nine PAHs including phenanthrene, pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, and dibenz[a,h]anthracene were identified as TA98 mutagens showing mutagenic potency (Maertens et al., 2008), and seven PAHs benzo[a]anthracene (B[a]A), benzo[a]pyrene (B[a]P), benzo[b]fluoranthene (B[b]F), benzo[k]

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Table 1
Average concentration of ΣPAH and BaP in $PM_{2.5}$ at various countries and areas.

Place/location	Type of aerosols	Site description	ΣPAH		BaP		Reference
			Range	Average	Range	Average	
Agra, India	$PM_{2.5}$	Residential and agricultural		880.8 ± 2.7		32.1	Present study
Hongkong	$PM_{2.5}$	Road Side	3–330	41.7	0.2–18.6	3.24	Guo et al. (2003)
		Residential, Industrial, commercial	0.5–122	27.9	0.3–8.2	2.06	
Xiamen, China	$PM_{2.5}$		5.2–28.0		0.16–1.3		Wang et al. (2007)
Chennai, India	$PM_{2.5}$	Industrial and populated	121.1–1370.5	517.1	6.8-16.4		Mohanraj et al. (2011a)
Tiruchirapalli, India	$PM_{2.5}$	Urban and Residential	202.6–333.7		8.5–2.5		Mohanraj et al. (2011b)
Shanghai, China	$PM_{2.5}$	Industrial and populated		167	2.6–3.2		Chen et al. (2011)
Coimbatore, India	$PM_{2.5}$	Urban and industrial	4.1–1632.3		5.7–12		Mohanraj et al., (2012)
Agra, India	$PM_{2.5}$		13.6–112.5		18.2 ± 1.1		Singla et al. (2012)
Guangzhou	$PM_{2.5}$			18.7		0.54	Wang et al. (2013)
Hongkong				2.6		0.16	
Urumqui, China	$PM_{2.5}$	University		54.1(In Winter)		2.21	Limu et al. (2013)
				11.9 (In autumn)		0.53	
Nanjing, China	$PM_{2.5}$	Sub-urban and Industrial	30.7–102.2		1.09–12.5	3.73	He et al. (2014)
	$PM_{2.5}$	Urban and Industrial	25.9–90.8				
Gipuzkoa, Spain	$PM_{2.5}$	Peri urban environment and industrial	0.3–8.2		0.05–0.8	0.15	Villar-Vidal et al. (2014)
Taiyuan, China	$PM_{2.5}$		0.18–17.9	119.8		13.8	Li et al. (2014)

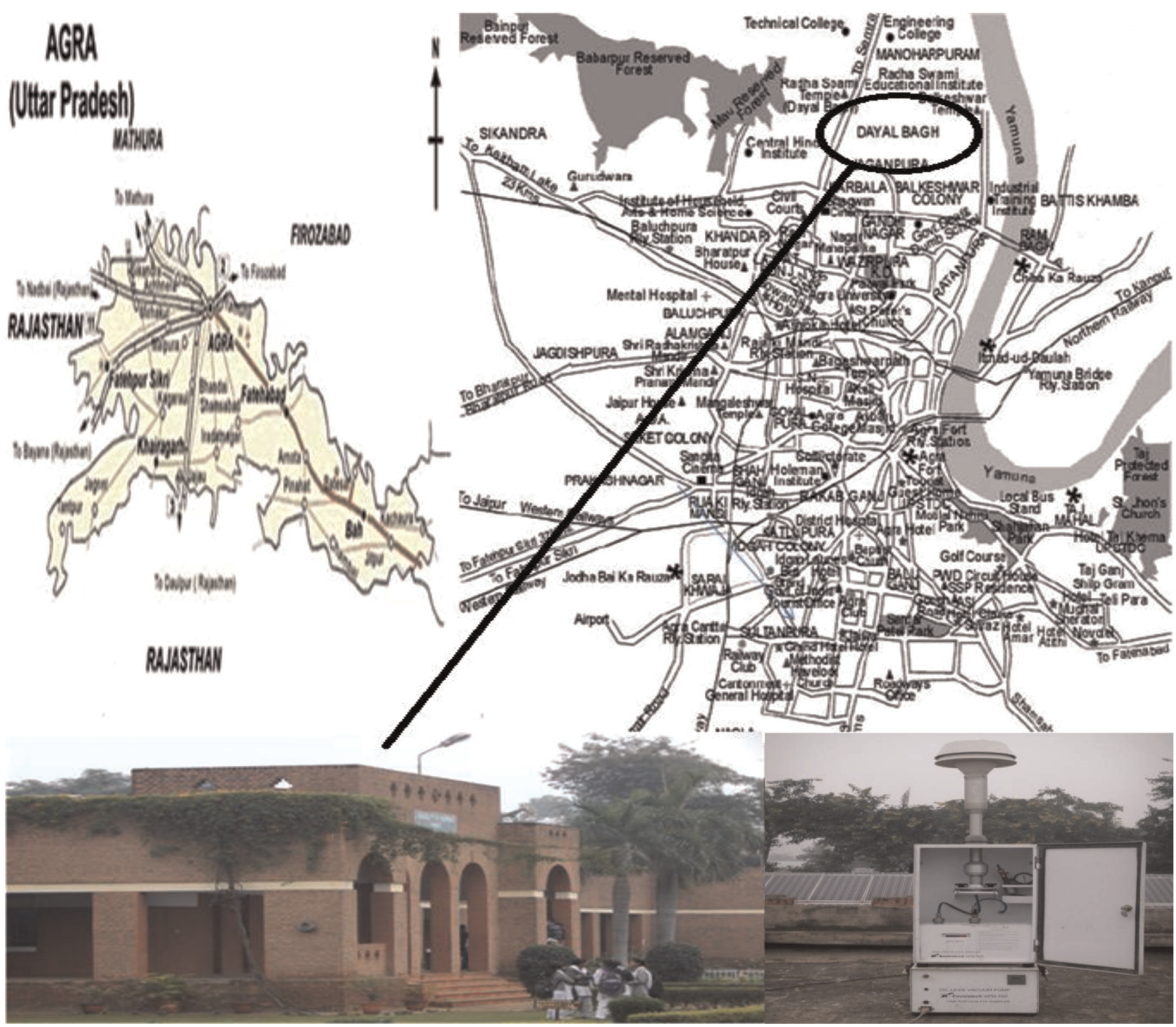

Fig. 1. Location of sampling site.