Spatio-temporal Variations in Automotive Exhaust Pollution across Lucknow (U.P) India

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ABSTRACT:

The present study deals with the monitoring of automotive exhaust pollution at Lucknow across five traffic sites during the different seasons. Traffic density was recorded across the sites (during peak traffic hours) fortnightly during the different seasons (*i.e.*, winter, summer and rainy). Simultaneously, monitoring of SO_2, NO_2, RSPM and SPM was also carried out. During these entire three seasons site V recorded maximum concentration of SO_2, NO_2, RSPM and SPM, decreasing significantly down the sites with site I recording the minimum concentrations. Seasonal variations in the concentrations of SO_2, NO_2, RSPM and SPM were observed at all the five sites. The results showed that concentrations of gaseous compounds were highly dynamic with significant seasonal variations characterized by high winter and low monsoon levels. The concentration of all the pollutants was in general more during winter followed by summer and least during the rainy season.

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INTRODUCTION

Use of automobiles is growing fast globally at large and with much greater pace in developing countries and India being no exception, has also experienced marked increase in the automobile sale trends during the last few years. Currently, in India, air pollution is wide spread in urban areas where automobiles are the major contributors and a few other areas with a high concentration of industries and thermal power plants. Motor vehicles have been closely identified with increasing air pollution levels in urban centers of the world **[1,2].** As reported by

National Environmental Engineering Research Institute (NEERI) the level of pollution due to round the clock automobile emissions in Indian cities is on the rise, if compared to other cities of the world. Vehicles contribute significantly to the air pollution load and are responsible for 60 to 70% of the pollution found in an urban environment **[3].** Like many other parts of the globe, air pollution from motor vehicles is one of the most serious and rapidly growing problems in urban centers in India **[4,5].** In some of the major metropolitan cities of India, the problem of air pollution has assumed serious proportions and vehicular exhausts have been identified as one of the major contributors responsible for the deterioration of air quality in these urban centers **[6,7]**. The problem has been further compounded by the concentration of large number of vehicles and comparatively high motor vehicles to population ratios in these cities **[8,9]**. It is estimated that in all the big cities in the country about a million tons of pollutants are being released into the atmosphere every day and out of which 75% contribution is from automobiles **[10]**. Depending upon the fuel type, the main exhaust emissions are oxides of nitrogen (NOx), oxides of carbon, oxides of Sulphur (SOx), carbon particles, heavy metals, water vapor and hydrocarbons including aldehydes, single and poly aromatic hydrocarbons, alcohols, olefins, alkyl nitrites besides a number of secondary pollutants such as ozone *etc*. causing serious environmental and health impacts **[11,12].** It is estimated that, vehicles account for 70% CO, 50% of HC, 30-40% of NO_X , 30% of SPM and 10% of SO_2 of the total pollution load in the major metros of India, of which two third is contributed by two wheelers alone. These high levels of pollutants are mainly responsible for respiratory and other air pollution related ailments including lung cancer, asthma *etc.* **[13,14]**.

In Lucknow city alone, the vehicle number has frighteningly augmented many folds (presently over 0.6 million) during past one decade, which has compounded the health problems of the citizens. The reasons for high incidence of mortality and morbidity associated with auto-pollution are many; firstly, the city has more population of two wheelers than 3- and 4-wheelers, which being largely 2-stroke, belch out more pollutants due to incomplete internal combustion, as compared to 4-wheelers; secondly, the pollutants from the auto-exhaust are released at very low height from the ground and hence not diffused into the larger sphere of the environment; thirdly, the dilution of auto-emission is impended by the high-rise buildings along the roads. In such situations, the pollution level increases alarmingly, particularly in the winter season, in morning or evening hours, due to atmospheric inversion and hence, the city dwellers have to

suffer from chronic diseases like asthma, lung cancer, bronchitis, kidney failure *etc.* Keeping in view all this, the present study was designed to work out the seasonal and spatial variations of this menace (especially SO_2, NO_2, RSPM and SPM) at different traffic sites across Lucknow.

MONITORING SITES

Lucknow, the Capital of Uttar Pradesh (26°52′N latitude, 80°56′E longitude, 128 m above the sea level), is spread over an area of 310 sq. km in the central plain of the Indian subcontinent, supporting a population of 36.48 lakh **[15]**. It has distinct tropical climate with a marked monsoonal effect. The year is divided into three distinct seasons *i.e.*, Summer (March to June), Rainy (July to October) and Winter (November to February). The temperature ranges from a minimum of 5°C in winter to a maximum of 47°C in summer. The mean average relative humidity is 60%, with a rainfall of 1006.8mm.

To conduct the aforesaid study, an extensive survey of Lucknow city was under taken to select the sites based on the number and type of vehicles plying over there. During the survey, five sites, which differ significantly in the number and type of the automobiles, were selected as:

Site I	Babasaheb Bhimrao Ambedkar University Campus (Vidya Vihar) Lucknow
Site II	Sardar Patel Institute of Dental and Medical Sciences, Lucknow (Lucknow - Raebarelly Road)
Site III	Banthara Field Station of NBRI, Lucknow (Lucknow-Kanpur Road)
Site IV	Central Institute of Unani Medicine (Lucknow -Kursi Road)
Site V	Sikandar Bagh Crossing (NBRI Genetic Block), Ashok Marg, Lucknow (one of the busiest roads of Lucknow)

All the sites are quite different from each other as far as the number and type of vehicles plying through these sites are concerned. The Babasaheb Bhimrao Ambedkar University Campus, Vidya Vihar (Site: I), an area of 250 acres, which is not open for the thorough passes and has not developed the connecting roads, as it is a newly established campus of the university, has been marked as the ‘control site’ as the expected pollution levels were negligible, much below the threshold values (almost an healthy environment).

SAMPLING AND ANALYSIS

At all the three sites traffic density was recorded (between 9.00 AM to11.00 AM) between the peak traffic hours. Air monitoring was also carried out at all these sites and the parameters studied were SO_2, NO_2, RSPM and SPM. Monitoring of RSPM and SPM was carried out with the help of a high volume air sampler (Envirotech make-APM 460) and an attachment device (APM 411) with the high volume air sampler was used for the monitoring of gaseous pollutants. Air was allowed to bubble at a flow rate of 1.2 l/min in glass impingers with 30 ml of absorbing solutions *i.e.*, potassium tetrachloromercurate for SO_2 and basic sodium arsenate for NO_2. The sampler was run for six hours (between 9.00 AM to3.00 PM) and the samples were brought to the laboratory for analysis as per the standard methods of West and Gaeke, (1956) **[16]** and Jacobson and Hochheiser, (1958) **[17]** respectively for SO_2 and NO_2.

STATISTICAL ANALYSIS

Data was statistically analyzed by two-way ANOVA to check the authenticity of the results using STATISTICA-7.1 (Stat Soft) USA.

RESULTS AND DISCUSSION

Growing population and increasing urbanization has resulted in sudden increase in number of vehicles. It is now a known fact that 60% of air pollution in cities is caused by automobiles only. The use of automobiles is growing very fast in both the developed and developing nations. These automobiles have been closely identified to increase air pollution levels in the urban areas all over the world. In India, like most other parts of the globe, air pollution from motor vehicles is one of the most serious and alarmingly growing problems and it is estimated that in all the big cities in the country about a million tons of pollutants are being released into the atmosphere every day and out of which 75% contribution is from automobiles **[10]**. The problem posed by vehicles is due to discharge of pollutants like CO, SOx, NOx, and PM *etc*. Gaseous and particulate emissions react under the influence of sunlight and diverse meteorological conditions generating a variety of toxic products such as PAN, O_3 *etc.* which are hazardous to animal, plant and human life. In particular atmospheric pollutants produce negative effects on vegetation even at low concentrations as plants absorb, accumulate and integrate pollutants impinging on their surfaces showing diverse responses in terms of morphological, physiological and biochemical characteristics.

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Traffic densities recorded along the sites during the different seasons are presented in Fig.1.

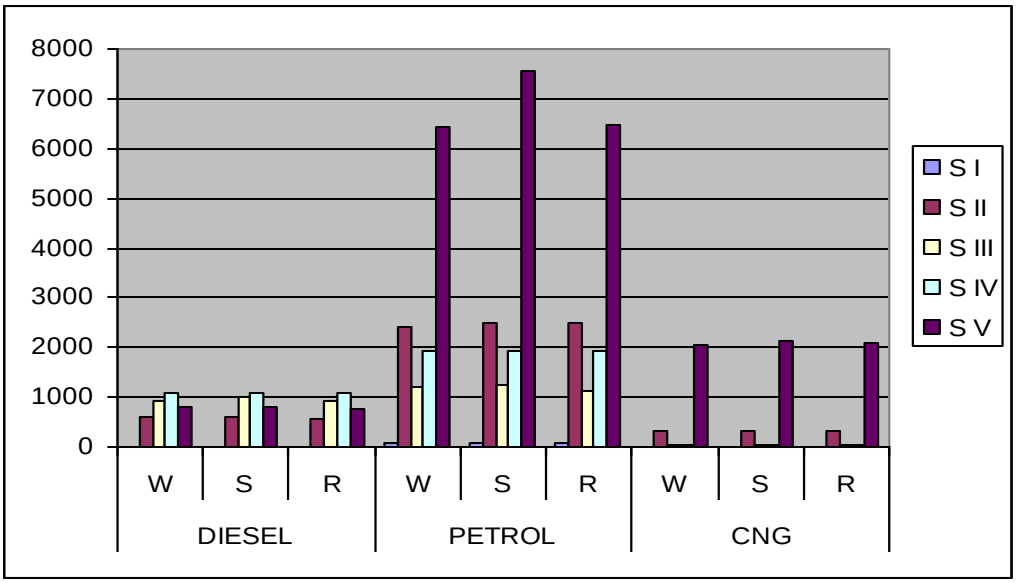

Fig.1. Season wise traffic density at the study sites during the peak traffic hours (between 9.00 AM to 11.00 AM)

During all the three seasons, maximum traffic density was registered at site V (4,634, 5,261 and 4,657 vehicles per hr. during the peak traffic hours in winter, summer and rainy seasons respectively), while low traffic density was recorded at site I (84, 41 and 39 vehicles per hr. during the peak traffic hours in winter, summer and rainy seasons respectively). However, the vehicular density at the other sites *i.e.* site II, III and IV was intermediate between these two sites.

During all the three seasons site V recorded maximum concentration of SO_2, NO_2, RSPM and SPM, decreasing significantly down the sites with site I (Table 1&2), registering minimum values, which may be attributed to varying vehicular frequency. Jafary and Faridi, 2006 **[18]**; Verma and Singh, 2006 **[19]**; Gupta *et al*., 2007 **[20]** and Joshi and Swami (2007) **[21]** too have reported similar relation between pollution level and vehicular frequency. In addition to the different meteorological conditions and traffic volumes at the different sites, the concentration of the gaseous and particulate pollutants are associated with some other conditions as a high rate of abrasion in vehicular engines and greater emission of particulates including dust by slow running vehicles over the fast ones, addition pollution produced by vehicles halting at traffic signals and less favorable conditions of ventilation and dispersion of pollutants in areas

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surrounded by high buildings. Mandavilli *et al*., 2007, **[22]** and Verma and Singh, 2006 **[19]** also have attributed the increase in pollution levels to these factors.

Table 1. Concentrations of (µg m^{-3}) of NO_2 and SO2 at the five sites during different seasons

Parameter	Season	Site				
		I	II	III	IV	V
NO_2	W	9.50 ± 6.51^{d}	23.34 ± 2.76^{c}	32.73 ± 2.69^{b}	36.59 ± 9.56^{b}	55.86 ± 2.76^{a}
	S	7.09 ± 4.55^{c}	13.71 ± 2.76b^{c}	18.53 ± 6.51b^{c}	22.14 ± 3.13^{b}	39.18 ± 6.10^{a}
	R	0.76 ± 1.31^{b}	8.29 ± 4.17b^{a}	12.51 ± 3.76^{a}	14.91 ± 4.78^{a}	19.13 ± 2.09^{a}
SO_2	W	8.57 ± 3.22^{c}	20.14 ± 4.28^{b}	22.35 ± 4.35^{b}	26.24 ± 3.59^{b}	39.28 ± 3.51^{a}
	S	6.36 ± 3.16^{c}	16.67 ± 1.74^{b}	17.62 ± 1.49^{b}	19.93 ± 4.78^{b}	30.34 ± 3.18^{a}
	R	4.47 ± 2.10^{d}	10.67 ± 3.46^{bcd}	13.41 ± 1.38^{ac}	13.72 ± 6.98^{ab}	22.24 ± 3.01^{a}

Values in rows followed by same superscript are not significantly different at p≤0.05 according to Newman Kuels test.

Seasonal variations in the concentrations of SO_2, NO_2, RSPM and SPM were observed at all the five sites. The results showed that concentrations of gaseous compounds were highly dynamic with significant seasonal variations characterized by high winter and low monsoon levels. The concentration of all the pollutants was in general more during winter followed by summer and least during the rainy season. During the winter months, increased atmospheric stability and less atmospheric circulation makes the air mass more stagnant. As a result, minimum atmospheric dispersion throughout the planetary boundary layer is observed. Moreover, the lack of precipitation during winter months reduces the potential for wet deposition and associated cleansing mechanisms. Conversely, during monsoons, low pollutant concentrations can be ascribed to precipitation driven washout (especially for SO_2 and NO_2).

Monsoon rains have the most dramatic effect in lowering the gaseous pollutant levels in the atmosphere. Despite low solubility of oxides of nitrogen in water, rains in the monsoon season effectively reduce their concentrations in the air. Gupta *et al*. (2007) have observed similar situation under Kolkata conditions **[20]**.

Table 2. Concentrations of RSPM and SPM (µg m^{-3}) at the five sites during different seasons

Parameter	Season	Site				
		I	II	III	IV	V
RSPM	W	89.96 ± 10.34^{c}	213.08 ± 27.99^{b}	291.35 ± 71.86^{b}	292.85 ± 13.77^{b}	401.22 ± 76.84^{a}
	S	86.87 ± 7.36^{c}	222.27 ± 43.53^{b}	246.38 ± 32.26^{b}	253.05 ± 42.67^{b}	369.49 ± 40.04^{a}
	R	77.73 ± 11.61^{b}	251.48 ± 52.47^{a}	254.94 ± 44.11^{a}	247.35 ±63.50^{a}	332.80 ±39.06^{a}
SPM	W	153.45 ± 11.83^{d}	439.23 ± 38.90^{c}	498.80 ± 35.81^{c}	572.91 ± 30.48^{b}	744.98 ± 49.09^{a}
	S	115.26 ± 17.85^{c}	313.59 ± 28.10^{b}	319.26 ± 23.60^{b}	342.86 ± 29.64^{b}	564.98 ± 19.43^{a}
	R	135.53 ± 22.95^{c}	370.56 ± 34.78^{b}	345.91 ± 72.23^{b}	340.35 ± 34.14^{b}	454.22 ± 52.41^{a}

Values in rows followed by same superscript are not significantly different at $p \leq 0.05$ according to Newman Kuels test.

CONCLUSION

It was concluded from the results that concentrations of gaseous compounds were highly dynamic with significant seasonal variations characterized by high winter and low monsoon levels. The concentration of all the pollutants was in general more during winter followed by summer and least during the rainy season.

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