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AIR QUALITY IN SCHOOLS LOCATED ALONG THE NATIONAL HIGHWAY IN JHANSI CITY

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Abstract

The outdoor and indoor SO_2 and NO_2 concentrations were measured in seven schools located along the section of National Highway passing through Jhansi city. The results showed both spatial and temporal variation of these gases in the schools. The levels of pollution were recorded higher in the morning compared to afternoon. Outdoor concentrations were found to be consistently higher compared to the indoor concentrations. However, the concentrations of the two gases were well within the prescribed safe limits. A positive and significant (SO_2, R_2 = 0.607; NO_2, R_2 = 0.612) correlations between outdoor and indoor concentrations were established for both the gases. There was a significant (R_2 = 0.697) positive correlation between the concentration of SO_2 and NO_2 in the air.

Keywords: Air pollution, Sulfur dioxide, Nitrogen dioxide, School, Jhansi city

Introduction

Respiratory health is increasingly recognized as an important public health problem worldwide (Dong, *et al.*, 2007). Many estimates indicate that current levels of air pollution cause significant effects on health in major cities of the world (Brunekreef and Holgate, 2002). In India, air pollution has been aggravated by the growth in the size of cities, rapid economic development, industrialization and increasing traffics (Gupta, *et al.,* 2007). Transportation is the major source of air pollution in urban environment, the other potential sources being industrial operations, combustion of wastes, construction activities and natural contaminants. The vehicle fleets in our country are old and poorly maintained, roads are narrow and the number of two stroke engines is high, thus increasing the significance of motor vehicles as a pollutant source (Pandey, *et al.,* 1998). The population residing in the vicinity, daily commuters, and business people are always exposed to the traffic air containing various toxic pollutants such as nitrogen oxides (NOx), hydrocarbons, carbon monoxide, respirable particles, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and volatile organic compounds (Dockery, *et al.,* 1993; Maynard and Howard, 1999; Samet *et al.,* 2000). Of the 3 million premature deaths in the world that occurs each year due to outdoor and indoor air pollution, the highest numbers are assessed to occur in India (Kumar *et al.,* 2003). The Indian national ambient air quality data demonstrate the increasing emissions of a range of air pollutants (Agarwal, *et al*., 2006). Annual average SO_2 concentrations range between 4 and 15 ppb in majority of the regions where measurements have been made and the concentrations range between 23 and 32 ppb in industrial belts and metropolitan cities. The annual average NO_2 concentrations ranged between 5 and 47 ppb, with high levels in metropolitan cities (Agarwal, *et al*., 1999).

School going children are one of the most sensitive population subgroups to air pollution since they may received an increased dose of pollutants to their lungs compared to adults (Diapouli, *et al.,* 2008). Environmental problems often encountered in roadside schools include health risks associated with accident and continuous exposure to high intensity noises. Faulty design of the school building due to lack of fund and space often led to poor ventilation and improper access to pure air and natural light. As classrooms have a larger number of occupants, large amounts of outdoor air must move freely through the building to assure proper aeration. Roadside schools faced double disadvantages in circulation of air. While, well ventilated rooms are prone to noxious gases seepage, poor ventilation may result into built up of indoor air pollutants exceeding the permissible levels. Considering the fact that a child spends at least 4-6 h a day on all working day in the school, it becomes important to assess the air quality in and around the school, particularly for those located near heavy traffic roads. The current study aims to estimate the outdoor and indoor concentrations of SO_2 and NO_2, in seven schools in Jhansi city located along the National Highway.

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Materials and Methods

Jhansi city and the study schools

Jhansi, the walled city is an important historic city in central India where, once the heroic young Rani Lakshmi Bai, had reigned and led her force into battle against the British imperialism. The city was founded by Raja Bir Singh Deo in 1613 AD. Jhansi city (255m a.m.s.l.) covers an area of 152 km^2 and supports a total population of around 5 lakhs. Climatically Jhansi falls under a semi-arid climate, with two main seasons: monsoon and dry. The monsoon (June-September) brings over 90 % of the annual rainfall. Peak summer (May-June) brings excessively high temperatures, often exceeding 40^0 C, as the hot dry loo winds sweep in. Indeed, the area is notorious for experiencing droughts in summer. During the winter months (December-February) daytime temperatures are quite pleasant reaching highs between 16.5 and 21^0 C. Nighttime brings much cooler temperatures and frost has been known to occur on the coldest evenings. Vegetation growth in the area is very sparse. The normal slope of the region is from southwest to northeast direction. For the present study, seven schools in Jhansi city along the National Highway–25 (NH–25) were selected randomly taking care to represent schools located at varying distances from the Highway and also thereby, representing schools with students of different age groups (Fig. 1 & Table 1). Information regarding the size of the classrooms, number of doors, windows and ventilators per room, schooling hours, *etc.*, were gathered from the school office.

Fig. 1. Map showing the sampling sites

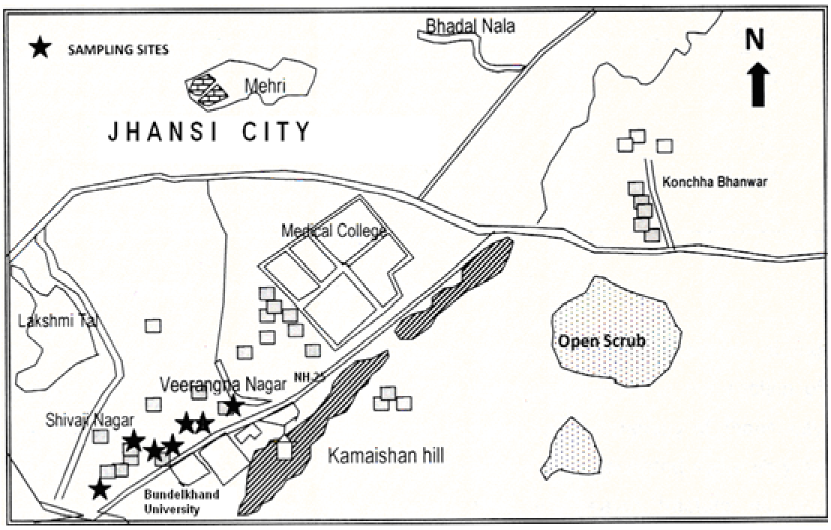


Table 1. Characteristics of the sampling sites

Name of school	Description of sampling site			Major air pollution sources within 200m
	Indoor		Outdoor	
	site	ventilation	site	
Sarswati G Mandir School	CR	W – 01; D – 01	Lawn	National Highway – 25, small scale industries
Sun International School	CR	W – 02; D – 01	Lawn	National Highway – 25, small scale industries
Gyan Sthali P School (Jnr.)	CR	W – 01; D – 01	Lawn	National Highway– 25, diesel powered electric generator in bank, small scale industries
Gyan Sthali P School (Snr.)	CR	W – 02; D – 01	Lawn	National Highway– 25, diesel powered electric generator in school, small scale industries
Kid's Kingdom School	CR	W – 03; D – 01	Main entrance	NH– 25, diesel powered electric generator in hospitals, sugarcane juice stall, telephone tower
Sahaj Public School	CR	W – 03; D – 01	Near gate	NH –25, diesel powered flour mill
BR Memorial Jnr. H School	CR	W – 03; D – 01	Lawn	National Highway – 25

CR – classroom; W – window; D – door; NH – National Highway

Assessment of air quality (SO_2 and NO_2)

The air pollution sampling was carried out at fortnightly intervals during the months of March to May. The measurements were carried out 4 h a day in two 2 h shifts covering morning (10–12 h) and afternoon (14–16 h). On the first day of each sampling session in a school, outdoor gas measurement was carried out followed by indoor air sampling in classroom at similar timing on the subsequent day. The air samplings were carried out by using a Handy Air Sampler (PEM–HAS 1B, Polytech Instrument). The flow rate of the gas sampler was adjusted at 0.5 L min^{-1}. The SO_2 and NO_2 in the air were collected in the respective absorbents (30 mL) placed in the impingers. Sodium arsenite was used as absorbing media of SO_2 and tetrachloromercurate for NO_2. The impingers were placed in ice cubes during sampling, transportation and storage before analyzing the samples. The samples were analyzed spectrophotometrically using spectrophotometer (Simadzu, Model UV–265). West and Gaeke method was used for analysis of SO_2 (West and Gaeke, 1956) and Jackob and Hochheiser (1958) modified method for analysis of NO_2. The Handy Air Sampler was operated at desk-height around 1 m above ground.

Results and Discussion

The rapid population growth, economic development and efforts to impart universal elementary education have resulted into mushrooming of schools in and around Jhansi city, maximum being located in the crowded urban setup. All the seven schools taken up for the present study are located in crowded areas of the city. For want of sufficient space, the health and environmental conditions are often grossly neglected in such schools. The size, shape and number of rooms vary in the individual schools but in most cases the rooms were found congested. Pollution sources affecting air quality in these schools could be identified as point, area and line sources. Point sources within 200m from the sampling sites are largely attributed to diesel engines for power supply or motive force required for telephone towers, banks, hospitals, small scale industries and educational institutions (Table 1). These point sources are significant taking in account the unreliable nature and erratic supply of electric power in the area, thereby making it virtually dependent on diesel engines for any meaningful productive work. The line sources are due to the vehicular emissions in the Highway.

Table 2. Concentrations of sulphur dioxide in the outdoor and indoor air

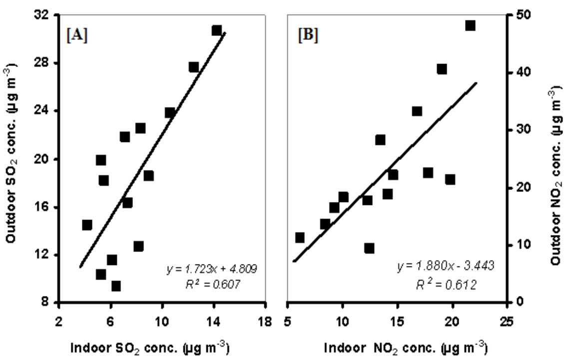
Name of school	Morning (10–12 h)				Afternoon (14–16 h)			
	Indoor		Outdoor		Indoor		Outdoor	
	Ranges	Mean	Ranges	Mean	Ranges	Mean	Ranges	Mean
Sarswati G M S	3 – 7	5.3 ± 0.67	15 – 28	19.8 ± 2.02	2 – 8	4.2 ± 0.87	8 – 22	14.5 ± 2.09
Sun Intl. S	9 – 18	12.5 ± 1.38	22 – 36	27.7 ± 2.01	5 – 14	8.3 ± 1.26	15 – 29	22.5 ± 2.08
Gyan S P (Jnr.) S	6– 12	9.0 ± 0.97	13 – 25	18.5 ± 1.75	4 – 13	7.3 ± 1.33	9 – 23	16.3 ± 1.99
Gyan S P (Snr.) S	4 – 11	7.2 ± 0.95	17 – 31	21.8 ± 2.10	4 – 10	5.5 ± 0.96	12 – 25	18.2 ± 2.06
Kid's Kingdom S	9 – 18	14.3 ± 1.58	26 – 39	30.7 ± 1.98	7 – 19	10.7 ± 1.76	15 – 33	23.8 ± 2.46
Sahaj Public S	5 – 14	8.2 ± 1.30	8 – 19	12.7 ± 1.65	3 – 11	6.5 ± 1.12	5 – 17	9.3 ± 1.84
BR Memorial Jnr.S	3 – 9	6.2 ± 0.91	7 – 18	11.5 ± 1.61	3 – 9	5.3 ± 0.92	7 – 15	10.3 ± 1.31

± denotes the SE of means

The results of the measurement of SO_2 concentrations in the seven schools along the NH – 25 in Jhansi are presented in Table 2. The data reflected both spatial and temporal variation of SO_2 concentrations in the schools. The outdoor SO_2 concentrations were found to be consistently higher compared to the indoor concentrations on all sampling sites and sessions. The respective mean outdoor and indoor SO_2 concentrations (in $\mu g\ m^{-3}$) recorded during morning hours (10–12 h) in the schools were: Sarswati Gyan Mandir (19.8 ± 2.02 and 5.3 ± 0.67), Sun International (27.7 ± 2.01 and 12.5 ± 1.38), Gyan Sthali Public Jnr. (18.5 ± 1.75 and 9.0 ± 0.97), Gyan Sthali Public Snr. (21.8 ± 2.10 and 7.2 ± 0.95), Kid's Kingdom (30.7 ± 1.98 and 14.3 ± 1.58), Sahaj Public (12.7 ± 1.65 and 8.2 ± 1.30) and BR Memorial Jnr. (11.5 ± 1.61 and 6.2 ± 0.91). Similar pattern of higher concentrations of SO_2 in the outdoor air was observed during the afternoon (14–16 h) sampling session. For instance, the outdoor and indoor SO_2 concentrations in Sarswati Gyan Mandir, Sun International and BR Memorial Jnr. schools were 14.5 ± 2.09 and 4.2 ± 0.87 $\mu g\ m^{-3}$, 22.5 ± 2.08 and 8.3 ± 1.26 $\mu g\ m^{-3}$ and 10.3 ± 1.31 and 5.3 ± 0.92 $\mu g\ m^{-3}$, respectively. There was a significant (R^2 = 0.607) positive correlation between outdoor and indoor SO_2 concentrations in the schools

(Fig. 2A). It was found that the SO_2 concentrations recorded in all the schools were well below the threshold limit for causing any harmful human health problem.

Fig. 2. Relationship between outdoor and indoor concentrations: [A] Sulphur dioxide and [B] Nitrogen dioxide



Levels of NO_2 concentrations in the outdoor and indoor air in the seven schools under investigation are shown in Table 3. The data revealed that the concentrations of NO_2 in the school vary with space (outdoor and indoor) and time (morning and afternoon). The levels of outdoor NO_2 concentrations ranged between 4 and 60 $\mu g\ m^{-3}$ and were higher than that of indoor concentration levels that ranged between 3 and 32 $\mu g\ m^{-3}$. For instance, the mean indoor NO_2 concentration during the morning hours in Sarswati Gyan Mandir, Sun International and BR Memorial Jnr. schools were 16.83 ± 2.44 $\mu g\ m^{-3}$; 19.17 ± 2.82 $\mu g\ m^{-3}$ and 10.17 ± 0.98 $\mu g\ m^{-3}$, respectively. Corresponding outdoor concentrations of NO_2 were 33.17 ± 3.67 $\mu g\ m^{-3}$; 40.50 ± 4.13 $\mu g\ m^{-3}$ and 18.33 ± 2.12 $\mu g\ m^{-3}$. There was a significant ($R^2 = 0.612$) positive correlation between outdoor and indoor NO_2 concentrations in the schools (Fig. 2B). The levels of NO_2 concentrations in the morning hours (10–12 h) were found to be higher compared to the afternoon hours (14–16 h). For instance, the recorded mean indoor NO_2 concentrations during morning hours in Sarswati Gyan Mandir, Sun International and BR Memorial Jnr. schools were 16.83 ± 2.44 $\mu g\ m^{-3}$; 19.17 ± 2.82 $\mu g\ m^{-3}$ and 10.17 ± 0.98 $\mu g\ m^{-3}$ respectively, against the corresponding concentrations of 12.5 ± 1.28 $\mu g\ m^{-3}$; 14.7 ± 1.82 $\mu g\ m^{-3}$ and 8.5 ± 1.38 $\mu g\ m^{-3}$ during the afternoon hours. It was found that the NO_2 concentrations recorded in all the schools were well below the threshold limit for causing any harmful human health problem.

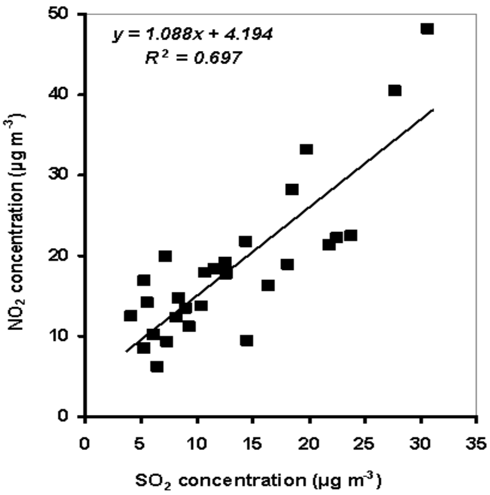
Table 3. Concentrations of nitrogen dioxide in the outdoor and indoor air

Name of school	Morning (10–12 h)				Afternoon (14–16 h)			
	Indoor		Outdoor		Indoor		Outdoor	
	Ranges	Mean	Ranges	Mean	Ranges	Mean	Ranges	Mean
Sarswati G M S	12 – 28	16.83 ± 2.44	25 – 49	33.17 ± 3.67	9 – 18	12.5 ± 1.28	4 – 18	9.5 ± 2.06
Sun Intl. S	12 – 32	19.17 ± 2.82	28 – 58	40.50 ± 4.13	11 – 23	14.7 ± 1.82	14 – 33	22.2 ± 2.98
Gyan S P (Jnr.) S	6 – 22	13.50 ± 2.47	20 – 39	28.17 ± 2.98	7 – 14	9.3 ± 1.12	10 – 23	16.3 ± 1.82
Gyan S P (Snr.) S	14 – 32	19.83 ± 2.91	17 – 28	21.33 ± 1.84	10 – 22	14.2 ± 1.74	16 – 28	18.8 ± 1.85
Kid's Kingdom S	17 – 32	21.67 ± 2.38	32 – 60	48.17 ± 4.54	12 – 26	17.8 ± 2.07	14 – 28	22.5 ± 2.17
Sahaj Public S	6 – 20	12.33 ± 2.04	14 – 26	17.67 ± 1.82	3 – 14	6.2 ± 1.64	7 – 15	11.2 ±1.22
BR Memorial jnr. S	8 – 14	10.17 ± 0.98	13 – 27	18.33 ± 2.12	5 – 14	8.5 ± 1.38	6 – 25	13.7 ± 2.80

± denotes the SE of means

Of the seven schools under investigation, the concentration of SO_2 was recorded highest in Kid's Kingdom (morning outdoor – 30.7 ± 1.98 $\mu g\ m^{-3}$), followed consecutively by Sun International (morning outdoor – 27.7 ± 2.01 $\mu g\ m^{-3}$), Gyan Sthali Public (Snr.) (morning outdoor – 21.8 ± 2.10 $\mu g\ m^{-3}$), Sarswati Gyan Mandir (morning outdoor – 19.8 ± 2.02 $\mu g\ m^{-3}$) and others. The lowest level of SO_2 pollution was recorded in BR Memorial with a mean outdoor concentration of 11.5 ± 1.61 $\mu g\ m^{-3}$ in the morning. The levels of NO_2 pollution in the schools showed similar pattern of rise and fall with SO_2. A linear correlation was obtained between the levels of SO_2 and NO_2 in the air: $y = 1.088x + 4.194$ ($R^2 = 0.397$) (Fig. 3). Correspondingly, the highest level of NO_2 concentration was recorded in Kid's kingdom and the least in BR Memorial. The variation in the pollution levels among the schools might be largely determined by virtue of its location from the highway coupled with the type of point sources nearby. Schools such as Kid's Kingdom, Sun International, Gyan Sthali Public (Jnr. and Snr.) located comparatively nearer to the highway records higher concentration of SO_2 and NO_2, as expected. Ashmore, *et al.,* (2000) opined that pollutant levels show an exponential decay with distance from the road reaching background levels within 10 to 100 m. This reflects that the actual concentrations of SO_2 and NO_2 in the road might be considerably higher but falls rapidly towards the school. Kid's Kingdom though located somewhat away from the highway compared to Sun International was more polluted with SO_2 and NO_2. The obvious reason for higher concentrations in Kid's Kingdom might be the operation of a diesel engine in a sugarcane juice stall near the school gate through out the study period. It is also noteworthy to mention that schools with younger subgroup of children but having comparatively higher gaseous concentrations like Kid's Kingdom and Sun International needs special attention.

Fig. 3. Mean NO_2 concentration in the air plotted against SO_2 concentration



Vehicle composition and the speed of traffic flow are known to affect the proportions of air pollutants in roads (Ashmore, 2000). Carbon monoxide and particulates are released in higher amounts at low speeds whereas, NOx increase at high speeds. In Jhansi, three wheelers (*Tempo*) are the major means of public transport. These vehicles are two-stroked, poorly maintained and often overloaded, emitting large quantities of soot and gaseous pollutants. The concentrations of pollutants in the air are affected by traffic volume, rate of emission, dispersion, deposition and chemical transformation (Ball *et al*., 1991). Prevailing winds and other climatic conditions affects pollutant levels and the pattern of dispersal. As far as the two gaseous pollutants under investigation are concerned, the level of NO_2 concentrations was higher in the schools. Radojevic (1998) claimed that nearly half of all man-made NOx emissions come from transport. Simpson *et al.* (1990) estimate that traffic emissions account for about 70 % of ground-level NO_2 in a study at Britain. The main NOx emitted by vehicles is NO, which is readily oxidized to yield NO_2. Rates of conversion of NO to NO_2 are reduced at lower temperatures or when O_3 levels are low (Wellburn, 1990). Thus, the ratio of NO: NO_2 will decrease with distance from the roadside, and will be dependent on meteorological factors and the time of day. Sulfur oxides, mainly in the form of SO_2 enter the atmosphere when sulfur-containing fuel is burned (Tereshin and Klimenko, 1999). Oxides of sulfur have a strong incidence on public health and are known to be an irritant for eyes, throat, and respiratory tract (Pope *et al*., 1995). Their effects could be enhanced as a result of combination with other contaminants.

Air pollution levels at the roadside and its possible health impacts may be minimized up to some extent by adopting proper management framework and well planned mitigation strategies. Some of the mitigation measures that can be attempted to reduce the impacts of vehicular pollution on roadside schools are: (a) *Zoning of land* – Zoning of land for educational purpose will be of great importance taking in account the health perspectives of young children. The ideal procedure would be to make an assessment of the overall land capability of the area and allocate appropriate lands for schools maintaining distances from heavy transportation roads. (b) *Development of shelter belts* – Shelterbelts alter pollutant dispersion characteristics and take up or capture certain pollutants from the atmosphere. (c) *Buffer zone* - buffer zones create a physical distance between the road and the protected site. The nature of the vegetation in the buffer zone will affect uptake of pollutants and hence size of the buffer zone is important in order to be effective. Dry deposition of many pollutant gases and aerosol particulates is greater to wooded areas than to shorter vegetation (Fowler *et al*., 1989). (d) *Emission reduction* - Phasing out of old vehicles, enforcement of strict emission norms, reduction in the volume of traffic flow in congested streets, encouraging clean and alternative fuel for power generation and transportation, *etc.*

Conclusion

There is an increasing concern over the deterioration in ambient air quality in urban environments because of its associated potential health effects. Children in schools located close to busy streets are exposed to various roadside pollutants and are prone to hazardous health impacts. Air quality monitoring at roadside schools becomes important taking into consideration the escalated daytime traffic volume in urban streets, the average time spent on roads and classroom by school going children and the sensitive nature of young children to pollutants. Overall, on environmental and health point of view the schools under study were not encouraging, except for two schools. From air quality view point, the results obtained from the current study convincingly revealed that the air in the schools was quite safe with respect to SO_2 and NO_2, as their concentrations were well below the prescribed harmful thresholds. However, the current study falls short to represent a complete analysis of the air quality in the schools because of certain limitations. Some of the limitations are: (i) limited coverage of schools, (ii) very short study period, failing to cover different seasons and (iii) total neglect of other important roadside primary and secondary pollutants. Despite some of these limitations, the current study stands important as it is the first of its kind in India that attempts to document air quality status in context of SO_2 and NO_2 in schools located close to a busy urban street.

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