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Distribution of Gaseous pollutants SO_2 and NO_2, in the urban roadside schools in Imphal City

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Abstract

Investigations were carried out during the winter season to assess the air quality by assessing gaseous pollutants in the urban roadside schools in Imphal City. Concentrations of SO_2 and NO_2 were measured simultaneously inside and outside the classroom using handy air samplers. Statistical analysis of the relationship between indoor and outdoor concentration levels was carried out. The highest concentrations of SO_2 and NO_2 were found in the school located at the city center surrounded by busy streets and commercial activities, with an average indoor concentration of 5.73±0.69 µg/m^3 and 6.76±0.17µg/m^3, respectively. The overall average levels of SO_2 (4.66±0.85 µg/m^3) and NO_2 (6.37±0.42µg/m^3) were below the permissible limits laid by the NAAQs and WHO. The relationships between indoor and outdoor air quality were investigated using linear regression analysis. The calculated I/O concentration ratios were found to be less than 1. There was a positive correlation between the indoor and outdoor concentrations of SO_2 ($r = 0.91$, *at* $p < 0.001$) and NO_2 ($r = 0.96$, *at* $p < 0.001$) in the schools establishing the influence of outdoor sources on the indoor concentration levels.

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Introduction

Deterioration in classroom indoor air quality (IAQ) has become an essential concern for maintaining a safe, educational environment. Children in urban schools located close to busy urban streets are exposed to various roadside pollutants and are vulnerable to hazardous health impacts (Khoiyangbam, 2010). Children are more susceptible to air pollutants compared to adults because of their lower body mass index and breathing pattern (Faustman *et al.,* 2000). The IAQ factors such as pollution levels, humidity and temperature may significantly impact the health and comfort levels of students, teachers and staff (Torresin *et al.,* 2018). Every day, almost 1.8 billion (93%) children under the age of 15 are subjected to severe urban air pollution, putting their health and development at serious risk (WHO, 2018). Furthermore, people exposed to indoor air pollutants for extended periods are more vulnerable to acute lower respiratory infections. The young, the elderly, and the physically ill, especially those suffering from respiratory or cardiovascular disorders are more prone to such health issues (Ramesh *et al.,* 2012, USEPA, 1995).

Urban air pollution is largely attributed to the combustion of fossil fuel in the transportation sector. Air pollutants consist primarily of gaseous pollutants and particulates (Dandotiya *et al.,* 2018). The burning of sulfur-containing fossil fuels or smelting of sulfur-containing ores produces SO_2 (Kampa & Castanas, 2008). NO_2 and SO_2 emitted through combustion processes may subsequently transform into HNO_3 and H_2SO_4 as aerosols in the atmosphere (Sutton *et al.,* 1993). Such acidic pollutants can cause adverse health effects and environmental damages (Lee *et al.,* 1999). Many indoor air pollutants may be from outside sources (Habre *et al.,* 2013). The health risk due to indoor air pollution may sometimes be higher than that of outdoor pollution (Misra *et al.,* 2012). The quality of outdoor air may affect the indoor air quality in roadside schools in urban areas (Achour *et al.,* 2011). Building structures, design, ventilation rates, building materials influences the levels of indoor air pollution. Investigations on IAQ in the schools in general, revolves around the premises of health issues of students and employees. The primary objective of the present study is to evaluate whether the concentrations of SO_2 and NO_2 inside the classrooms and the campus of the roadside schools in Imphal city are within the safe limits.

Material and methods

Imphal city and Sampling schools

Imphal city (24.721ºN & 24.883ºN and 93.887ºE & 93.982ºE) is located in the central part of the state at an elevation of 786 m *amsl.* As per the 2011 Census, the city housed 42.13% of the urban population of the state. The city experiences five distinct seasons, ranging from a humid subtropical climate with mild, dry winter and a hot monsoon season. The annual average relative humidity ranges between 36% and 100% (Mastec, 2020). The current investigations were carried out in five roadside schools in Imphal city of Manipur state, India. The schools are either surrounded by roads, commercial areas, government offices, residential areas, or a combination of the above. Most of the buildings in the schools are single-storey concrete structures. The classrooms of the schools are natural ventilated through doors, windows and ventilators.

Measurement of pollutants

Measurements of gaseous concentrations were carried out inside and outside the classroom in the schools. Air sampling was carried out for eight hours (8 am to 4 pm) on fortnightly intervals for four months (November 2018 to February 2019). For outdoor measurements, the sampler was placed far away from any obstructions and at the height of 1.5 m above the ground level. The concentration of gaseous pollutants was measured by using handy air samplers (Envirotech APM 433). The content of SO_2 in the air was measured by absorbing it in tetrachloromercurate (TCM) solution and then analyzed it using the Improved West and Gaeke method (CPCB, 2013). The NO_2 was measured by absorbing it in sodium hydroxide and sodium arsenate solution and then analyzed it using Modified Jacob and Hochheiser method (CPCB, 2013).

The respective absorbing solutions (30mL) were taken in midget impinger. The rate of air sampling was kept at 1 LPM for both the gases. The concentration of SO_2 and NO_2 was analyzed colorimetric ally using a spectrophotometer (Genesys 180, Thermo-scientific) at 560nm and 540 nm wavelength.

Results and discussion

The concentrations of SO_2 and NO_2 in the air, observed in the five schools, are presented in Table 1. The concentration of indoor SO_2 during the study ranged from 2.93 to 6.94µg/m^3, with an average value of 4.49±0.87µg/m^3 whereas, the corresponding outdoor concentration ranged from 3.36 to 6.94µg/m^3, with an average value of 4.82±0.82µg/m^3. The concentration of indoor NO_2 ranged from 5.53 to 7.04µg/m^3, with an average value of 6.26±0.39µg/m^3, while the corresponding outdoor concentration ranged from 5.76 to 7.29µg/m^3, with an average value of 6.48±0.43µg/m^3. The overall mean concentrations of SO_2 and NO_2 for the five schools were 4.66±0.85µg/m^3 and 6.37±0.42µg/m^3, respectively.

The recorded concentrations of both the gaseous pollutants were well within the permissible limits prescribed by the National Ambient Air Quality Standards (50µg/m^3 annually and 80 µg/m^3 daily for SO_2 and 40µg/m^3 annually and 80 µg/m^3 daily for NO_2) (NAAQS, 2009) and the World Health Organization (WHO, 2005) standards (20µg/m^3 daily and 500µg/m^{3}10-minute mean for SO_2 and 40µg/m^3 annually and 200µg/m^{3}1-hr mean for NO_2). Vehicular emissions are the primary source of air pollutants in Imphal. Other sources include small-scale industries, diesel-based power backup generators in commercial areas, mobile towers, urban households, *etc*.

Table 1. Indoor and outdoor levels of SO_2 and NO_2 in the schools.

SO_2 (µg/m^3)	Outdoor		NO_2 (µg/m^3)	Outdoor
	Indoor	Indoor		
	X ± sdev. min-med-max	X ± sdev min-med-max	X ± sdev min-med-max	X ± sdev. min-med-max
Urban schools	5.73±0.69	5.88±0.81	6.76±0.17	7.01±0.19
(UR)	4.87–5.73–6.94	4.44–6.01–6.94	6.58–6.69–7.04	6.83–6.97–7.29
UR-1	3.99±0.80	4.62±0.68	6.11±0.28	6.40±0.41
UR-2	2.93–4.01–5.51	3.86–4.54–5.80	5.78–6.07–6.56	5.97–6.29–7.23
UR-3	4.21±0.53	4.51±0.55	6.11±0.34	6.29±0.38
	3.44–4.29–4.87	3.72–4.58–5.15	5.63–6.13–6.56	5.78–6.34–6.81
UR-4	4.19±0.27	4.46±0.26	5.95±0.32	6.11±0.29
	3.79–4.15–4.65	4.08–4.47–4.87	5.53–5.87–6.49	5.76–6.08–6.58
UR-5	4.35±0.68	4.64±0.81	6.39±0.29	6.58±0.26
	3.29–4.47–5.37	3.36–4.76–5.58	5.90–6.41–6.79	6.18–6.57–6.98
All schools	4.49±0.87	4.82±0.82	6.26±0.39	6.48±0.43
	2.93–4.37–6.94	3.36–4.65–6.94	5.53–6.30–7.04	5.76–6.47–7.29

UR-1: Johnstone Higher Secondary School UR-2: Lamlong Higher Secondary School; UR-3: Ananada Singh Higher Secondary Academy; UR-4: Churachand Higher Secondary School; and UR-5: Ibotonsana Girls Higher Secondary School

The data obtained in the study revealed that the air in the school, UR-1 (Johnstone Hr. Sec. School), was comparatively more polluted with SO_2 and NO_2. The average concentrations of SO_2 in the school UR-1 was 5.73±0.69µg/m^3 (indoor) and 5.88±0.81µg/m^3 (outdoor) and the corresponding average values of NO_2 were 6.76±0.17µg/m^3 (indoor) and 7.01±0.19µg/m^3 (outdoor). The UR-1 is in the city center, surrounded by heavy traffic streets, highways, and commercial centers. It is suspected that the rush-hour traffic congestions plus idling of vehicles in traffic light near the school have contributed significantly to the pollution. The lowest values of indoor SO_2 (3.99±0.80µg/m^3) was observed in the school UR-2, while the lowest concentration of the outdoor SO_2 (4.46±0.26µg/m^3) was observed in the school UR-4. In the case of the NO_2 both the lowest concentration of the indoor (5.95±0.32µg/m^3) and outdoor (6.11±0.29µg/m^3) was observed in the school UR-4. The lower values of gaseous concentrations in these schools may be explained by the larger distance of the sampling classrooms from the nearby roads. Lee and Chang (2000) concluded that low sulphur content fuels lowers the ambient SO_2 levels. Olufemi, *et al.* (2018) reported that the concentration of SO_2 and NO_2 within the classroom ranged from 3 to 38µg/m³ and 19 to 28µg/m³ in schools located near coal mines. The average concentrations of SO_2 and NO_2 in the current study were comparatively lower than those observed by the above researchers. Chithra and Nagendra (2018) explained that the increased concentrations of NO_2 in urban areas (schools) were related to increasing conversion of nitric oxide (NO) to NO_2 in the presence of O_3, VOCs, and sunlight.

Indoor and outdoor relationship

The relationships between indoor and outdoor air quality were investigated using linear regression analysis (Fig. 1 A&B). A significant positive correlation between the indoor and outdoor concentrations of the SO_2 ($r = 0.91$, at $p < 0.001$) and the NO_2 ($r = 0.96$, at $p < 0.001$) were observed indicating the influence of outdoor sources on the indoor concentration levels. In general, gas appliances, heaters and cigarette smoking represent the primary sources of NO_2 pollution in the indoor environment while oxidation of sulfur found in coal and other fuel combustion produces SO_2. In the absence of indoor pollution sources, levels of SO_2 and NO_2 in classrooms generally correlate well with those observed outdoors (Lee and Chang, 2000). The correlation coefficient between the SO_2 and NO_2 concentration in the schools for the study period was 0.43. The outdoor concentrations of SO_2 and NO_2 were consistently higher than those of indoor concentrations. The average indoor to outdoor (I/O) ratio of two gaseous pollutants was 0.93±0.08 for SO_2 and 0.97±0.02 for NO_2. Overall, the calculated I/O ratio for both the gaseous parameters was found to be less than 1 (one) in all the sampling incidents, except in three incidents. These I/O ratios indicated the presence of outdoor pollutants inside the classroom. Outdoor pollutants may contribute significantly to indoor pollution, particularly in schools located near highly trafficked roads (Rivas *et al.*, 2014).

Since, there were no prominent sources of SO_2 and NO_2 in the classrooms and within the campus of the five schools, the source of the pollutants in the classrooms could only be traced beyond, the campus and among the potential sources, vehicular pollution represents the prime one.

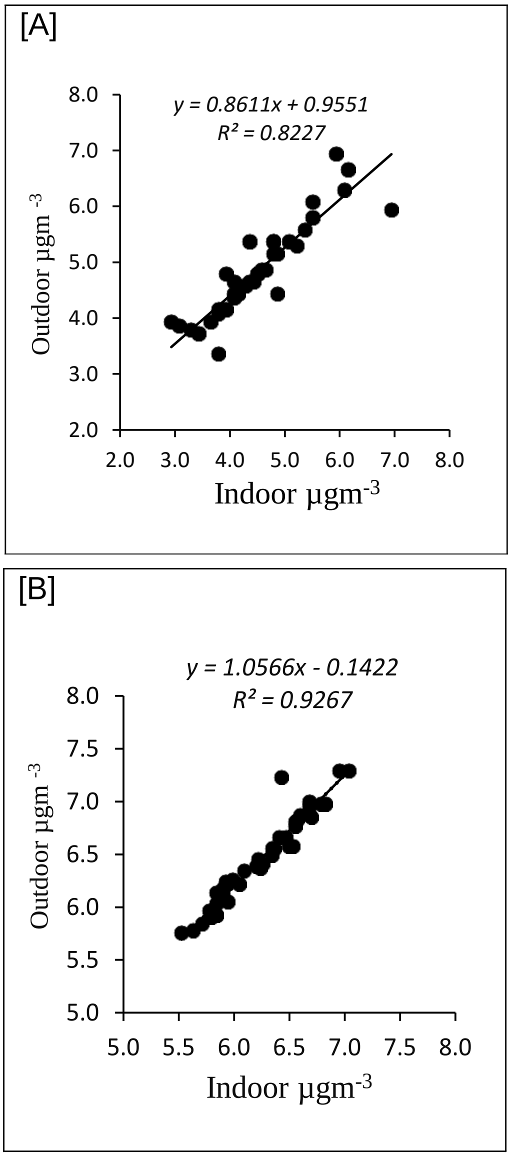

Fig. 1. Indoor and Outdoor relationship of: [A] SO_2 and [B] NO_2 concentrations.

Conclusion

Air quality-related investigations in urban schools become essential, considering the intensified daytime traffic volume in the city streets, the time school-going children spent on roads and classrooms, plus the sensitive nature of children to the pollutants. The aim of the present study is to investigate the status of air pollution in the schools situated adjacent to urban streets in Imphal city. Like many of the cities in the country, the public transport system in Imphal is inadequate, and thus, the resident increasingly relied on personalized vehicles, mainly two and four-wheelers. The primary source of air pollutants in the city originates from transport sectors, the others being small-scale industries and intermittently operated fossil fuel-based power generators in households and commercial areas. The concentrations of SO_2 and NO_2 were recorded comparatively higher in a school located at the city center, compared to the rest of schools located away from the center. A strong positive corelation between the indoor and outdoor concentration of the gaseous was observed. However, the recorded SO_2 and NO_2 levels in the schools were well below the permissible limits prescribed by WHO and NAAQs Standards.

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