

EXPOSURE TO NO₂ IN OCCUPATIONAL BUILT ENVIRONMENTS IN URBAN CENTRE IN LAHORE

S. Andleeb¹, Z. Ali^{2*}, F. Afzal¹, A. A. Razzaq¹, T. Mehmood², N. Noor², F. Rasheed³, Z. A. Nasir^{4,5} and I. Colbeck⁵

¹Government Islamia College for Women, Cooper Road Lahore, Pakistan

²Environmental Health and Wildlife, Department of Zoology, University of the Punjab, Lahore- Pakistan

³Department of Zoology, Lahore College of Women University, Lahore- Pakistan

⁴School of Energy, Environment and Agrifood, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK

⁵School of Biological Sciences, University of Essex, Colchester, CO4 3SQ, UK

*Corresponding Author's Email: zali.zool@pu.edu.pk

ABSTRACT

Increased economic growth, urbanisation and substantial rise in automobile vehicles has contributed towards the elevated levels of air pollution in major cities in Pakistan. A one week study was conducted by using passive samplers to assess NO₂ concentration in occupational built environments at two most congested and populated sites of Lahore. Both sites were located on the busy roads of Lahore. At Site-I the highest concentration was in outdoors followed by corridor and indoor. While at Site II all the sampling locations were indoors and levels were comparable to that of outdoor levels at Site I. The results suggest the likely contribution of ambient sources in exposure to indoor NO₂ in educational and other occupational built environments in urban centres.

Keywords: Lahore, NO₂, passive samplers.

INTRODUCTION

In the developing countries, like Pakistan, industrialization is the key factor for economic growth. Along with industrialization, number of automobiles and population has also increased in these countries in last two decades. These factors have deteriorated environmental quality, especially, in urban areas. With growing pollution as well as population little attention is paid towards the environmental safety. Environmental policies are inappropriate and pollution control strategies are not yet fully developed. Among range of environmental issues air pollution has emerged as major threat to public health. Different studies have demonstrated adverse effect of air pollution on cardiopulmonary health. Susceptible population (children, elderly, immunocompromised) are at increased risk of adverse health outcome (Chen *et al.*, 2015; Kaushik *et al.*, 2006). According to the WHO report, air pollution in 2012 caused premature deaths of around 3.7 million people worldwide (WHO, 2014).

Pakistan is the 6th major country with respect to its population, comprising 2.62% of the world's population (World Population Prospects, 2012). Due to increased urbanisation (34% of population live in urban areas), substantial rise in automobile vehicles, industrialization and poor compliance with environmental quality control standards the country is facing severe air pollution (Sanchez-Triana *et al.*, 2014). Available literature on state of air quality in Pakistan clearly shows the gravity of situation and this may have public health

implications, particularly, in urban areas. Among different air pollutants NO₂ is of major concern, following particulate matter, in the country (Colbeck *et al.* 2010a). It is hazardous to human health and also one of the main precursor to form secondary pollutant (ozone, fine particles). According to US EPA short term exposure (30 minutes to 24 hours) to NO₂ is associated with range of respiratory illness - airway inflammation, asthma (USEPA, 2014).

The available literature on NO₂ levels in Pakistan is scattered and is mostly on ambient concentration. The knowledge base on indoor levels of NO₂ is limited (Colbeck *et al.*, 2010b). Nonetheless, people both in rural and urban areas may be exposed to excessive levels of NO₂ in different built environments due to specific indoor sources (solid fuel use) or contribution from outdoors combustion sources (especially in urban areas).

There is a need to carry out studies to evaluate NO₂ in different built environments. The present study was carried out to examine the level of NO₂ at two different higher education institutes in Lahore in order to demonstrate the level of indoor NO₂ exposure in different occupational settings in urban centres.

MATERIALS AND METHODS

Sampling sites: NO₂ samples were collected from two higher education institutes of Lahore. Lahore is the capital city of the Pakistani province of Punjab, the second largest metropolis in the country with a

population of more than 10 million (Demographia, 2015). Available studies on air pollution in Lahore indicate that state of air quality in the city is poor (Jafar and Faridi, 2006; Colbeck *et al.*, 2011; Ashraf *et al.*, 2013; Abrar *et al.*, 2014). Two sites were selected to measure NO₂: Site I -University of the Punjab, New Campus and Site II: Islamia College for Women Cooper road. Both the selected sites were located along heavy traffic roads in populated urban areas.

Site I: Site-I was surrounded from all sides by the roads with continuous flow of heavy traffic. (Figure 1). Three sampling locations in site-I were selected in zoology department and named as outdoor (roof), semi ambient (corridor) and indoor (Wildlife and Ecology laboratory).

There were traffic within the university mainly buses run by university and private student/staff cars, composing and printing shops, cafeterias and laboratories in surroundings of sampling locations.



Figure 1. Location of site-I and site-II in the Lahore (source google maps)

Site II: Site II was located on the road in a populated area with high traffic density and nearby fuel filling stations. A number of different shops and hotels were located in the nearby vicinity that used natural gas and LPG gas as fuel for the purpose of cooking and heating the food (Figure 1). Three sampling locations were selected and named as (A) Zoology laboratory, (B) Physics laboratory and (C) Chemistry laboratory. A few lab activities were performed as students only visited these laboratories twice a week for practical. Most of the time, laboratories were used as class rooms for lectures. Ventilation in all the laboratories was natural and occurred through the windows, doors and ventilators.

Preparation and analysis of Passive samplers: Passive sampler (Plumes diffusion tube) comprises of an acrylic tube of 7cm long and 1cm diameter capped at both ends. At one end, two stainless steel grids coated with 50% triethanolamine TEA/acetone solution were placed. These samplers were mounted on the sites approximately 2m above the ground. Three samplers were mounted at each sampling location. After one week, samplers were subjected to spectrophotometric analysis. The NO₂ reacted TEA as nitrite. Mixture of sulphanilamide in orthophosphoric acid and N-1-naphthylethylenediamine

dihydrochloride (NEDD) was used as colour reagent. The nitrite diazotised the sulphanilamide and diazonium salt reacted with the NEDD. This formed a purple azo dye and intensity of which was determined at 540 nm. By using standard solutions of nitrites spectrophotometer was calibrated to determine the total NO₂ collected by sampler as nitrite. Mean, maximum, minimum and standard deviation values were derived.

RESULTS AND DISCUSSION

Site-I: Average NO₂ concentration in outdoor environment was observed to be 79µg/m³ that was greater than the semi-ambient and indoor (Table 1). The key factors elevating the outdoor levels were most probably emissions from vehicular exhaust (in and outside of university). Whereas the levels in corridor (average - 69µg/m³) were likely to be influenced by activities in adjacent departments labs as well as outdoors. The NO₂ level in indoor environment (laboratory) were lowest and ranged from 35 to 50µg/m³ with an average concentration of 44µg/m³. The lower concentrations were very likely due the less usage of lab and low ventilation rates.

Table 1: Summary of NO₂(µg/m³)at Site I.

Location	Ave	Max	Min	SD*
Outdoor (Roof)	79	93	54	21.7
Semi-ambient (Corridor)	69	91	30	34.12
Indoor (Lab)	44	50	35	8.14

Ave. Average, Max. Maximum, Min. Minimum, *SD. Standard deviation

Site-II: The weekly average concentration in Zoology, Chemistry and Physics laboratory were 77, 79 and 67µg/m³ respectively (Table 2). These levels most probably reflect the contribution from both outdoors and indoors activities. The site was surrounded by heavy traffic and contribution from outdoors via ventilation or infiltration is might be the dominant source of indoor NO₂.

Table 1: Summary of NO₂ at site-II (µg/m³)

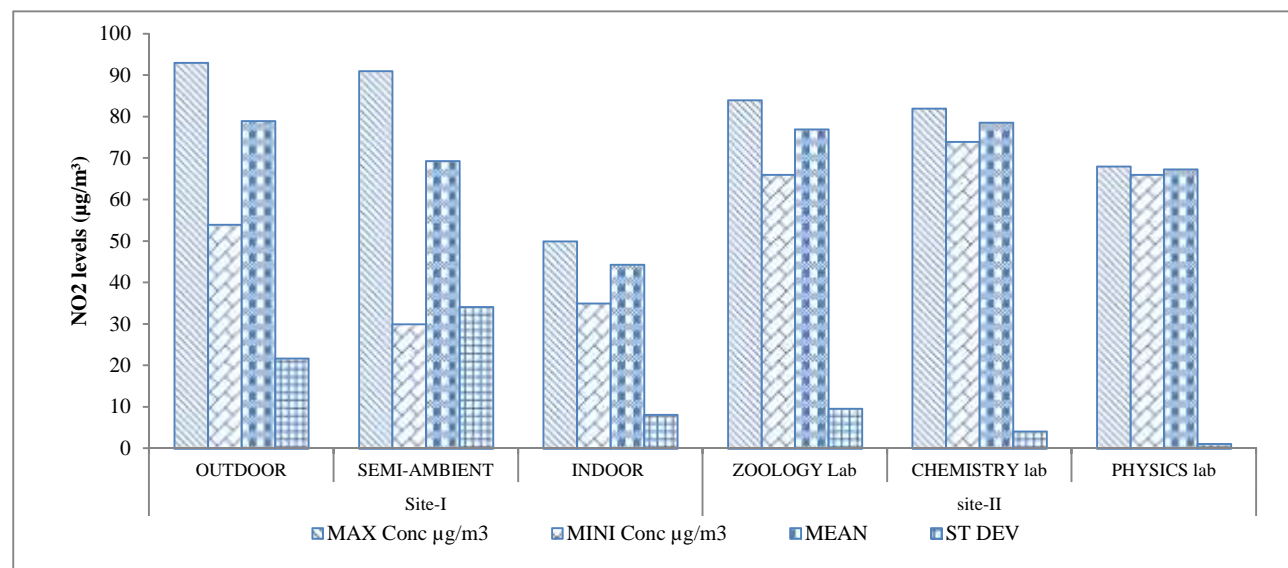
Location	Ave	Max	Min	SD*
(A) Zoology lab	77	84	66	9.64
(B) Chemistry lab	79	82	74	4.16
(C) Physics lab	67	68	66	1.15

Ave. Average, Max. Maximum, Min. Minimum, *SD. Standard deviation

There was less variation in meanlevels at different locations at Site II in comparison to site I. It is of note that all the sampling locations at site II could be classified as indoor and levels in these settings were considerably higher than indoor at Site I. In fact indoor levels at site II were comparable to outdoor levels at Site I. This trend can elucidate the dynamic contribution of various activities/sources to NO₂ levels. The vehicular emission within and nearby locality and road proximity seemed to play a considerable role in enhancement of indoor NO₂ level at site-II as compared to site-I.

Mirza *et al.*, (2013) measured the concentrations of NO₂ using passive samplers biweekly in three phases (pre-monsoon, monsoon and post-monsoon). The mean values were observed to be 74.09, 79.87 and 86.09 µg/m³, respectively. Despite of difference in total exposure time (two weeks) than present study (one week), the average outdoor value is comparable and in close relation to the values of all the three phases. During winter and summer of 2010, Colbeck and his colleagues measured the NO₂ concentration at different household in Lahore. The mean concentrations during winter sampling campaigns in kitchen, living room and courtyard were 218,136 and 64µg/m³, respectively whilst in summers the subsequent levels were recorded to be 234, 103 and 138 µg/m³. These levels are higher than our study and the observed differences could be due the differences in sources specific to built environment types.

Our sampling sites were educational /occupational, had no direct burning of any type of fossil fuel very close to the sampling location, spacious and well ventilated as compared to kitchens and living rooms in households.

**Figure 2 Comparison of mean concentration of NO₂ along with maximum, minimum and standard deviation at two sites.**

Conclusion: The present study found high concentration of NO₂ at different sampling locations in higher education institutes located in city centre. Due to limited sampling sites and duration no firm conclusions can be made. However, the results suggest that outdoor sources are a major contributor to indoor exposure to NO₂ in heavy traffic urban areas (Site II) and ventilation and infiltration play a major role in NO₂ level in urban built environments. Direct comparison of observed levels of NO₂ cannot be made with WHO guideline or Pakistan National Environmental Quality Standards (NEQS) for ambient air due to differences in the averaging period. However, it is likely that levels of NO₂ probably exceeded WHO guideline value of 200 µg/m³ (1 hour mean) and NEQS value of 80 µg/m³ (24 hour mean) especially at site II and outdoors and corridor at site I. There is urgent need to put in place stringent emission control strategies to improve air quality in urban areas. Further long term studies are required to assess the actual exposure to air pollutants in different built environments in urban as well as rural areas in the country.

Acknowledgment: We are very thankful to students and staff of Zoology department, University of the Punjab Lahore and Islamia college copper road for their cooperation and assistance in sample collection.

REFERENCES

- Abrar, A., W. Sundas, F. Perveen, M. Habib (2014). Air Quality Monitoring of some Gaseous Pollutants at selected points in Gulberg II, Lahore, Pakistan. *Int. Res. J. Env. Sci.* 3(6):38-47
- Ashraf, N., M. Mushtaq, B. Sultana, M. Iqbal, I. Ullah, S.A. Shahid (2013). Preliminary monitoring of tropospheric air quality of Lahore City in Pakistan. *Sustainable Development*. 3: 1.
- Colbeck, I., Z.A. Nasir, Z. Ali (2010a). The State of Ambient Air Quality in Pakistan-A Review. *Environ. Sci. Pollut. Res.* 17: 49-63.
- Colbeck, I., Z. A. Nasir, Z. Ali, and S. Ahmad (2010b). Nitrogen dioxide and household fuel use in the Pakistan, *Sci. Total Environ.* 409(2): 357-363.
- Colbeck, I., Z. A. Nasir, S. Ahmad, and Z. Ali (2011). Exposure to PM₁₀, PM_{2.5}, PM₁ and carbon monoxide on roads in Lahore, Pakistan. *Aerosol Air Qual. Res.* 11: 689-695.
- Chen, Z., M. T. Salam, S. P. Eckel, C. V. Breton, and F. D. Gilliland. (2015). Chronic effects of air pollution on respiratory health in Southern California children: findings from the Southern California Children's Health Study, *J. Thorac. Dis.* 7 (1): 46-58.
- Demographia (2015). World Urban Areas. (Built-Up Urban Areas or World Agglomerations). 11th Annual Edition. Available at: <http://www.demographia.com/db-worldua.pdf>
- Jafary, Z. A. and I. A. Faridi (2006). Air pollution by roadside dust and automobile exhaust at busy road crossings of Lahore. *Pakistan J. Physiol.* 2:31-34.
- Kaushik C.P., K. Ravindra, K. Yadav, S. Mehta and A.K. Haritash (2006). Assessment of ambient air quality in urban centres of Haryana (India) in relation to different anthropogenic activities and health risks. *Environ. Monit. Assess.* 122(1-3): 27-40
- Mirza, A. I., S. M. Mayo, A. Aziz, M. B. Sharif (2013). Spatial-Temporal Variations of Nitrogen Dioxide in and Around Lahore Metropolitan Areas Using "GIS" Techniques. *Pakistan Journal of Science.* 65(3).
- Sanchez-Triana, E., S. Enriquez, J. Afzal, A. Nakagawa, and A. S. Khan. (2014): Cleaning Pakistan's Air: Policy Options to Address the Cost of Outdoor Air Pollution. World Bank. Washington, DC. Doi: 10.1596/978-1-4648-0235-5.
- USEPA (2014). United States Environmental Protection Agency. Nitrogen Dioxide, Health. Available at: <http://www.epa.gov/oaqps001/nitrogenoxides/health.html>
- WHO. (2014). Ambient (outdoor) air quality and health. Fact sheet N 313. Updated March 2014. WHO media Centre. Available at: <http://www.who.int/mediacentre/factsheets/fs313/en/>
- World Population Prospects. (2012). The (2012) Revision: Highlights and Advance Tables" (XLS). The Department of Economic and Social Affairs of the United Nations. pp. 51-55. Retrieved 2013-08-11.