

## STATE OF AIR QUALITY IN AND OUTSIDE OF HOSPITAL WARDS IN URBAN CENTRES – A CASE STUDY IN LAHORE, PAKISTAN

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### ABSTRACT

Particulate pollution in healthcare facilities is a potential threat to healthcare workers, patients and visitors. A study was carried out to monitor particulate levels in and outside of five wards of Sheikh Zayed Hospital, a tertiary healthcare facility of Lahore. Measurements indicated that the hourly mean concentrations of PM<sub>2.5</sub> in a medical, pulmonology (chest), surgical, pediatric and nephrology ward were  $78 \pm 37$ ,  $86 \pm 46$ ,  $94 \pm 48$ ,  $169 \pm 122$  and  $488 \pm 314 \mu\text{g m}^{-3}$  respectively. The outside levels of PM<sub>2.5</sub> of the same wards were  $69 \pm 27$ ,  $81 \pm 49$ ,  $178 \pm 85$ ,  $282 \pm 164$  and  $421 \pm 240 \mu\text{g m}^{-3}$ . Indoor levels were higher than outdoors in all the wards except surgical and pediatric ward. Such elevated levels of PM can result in aggravation of the poor health status of the patients as well as affecting the hospital staff and visitors.

**Keywords:** Particulate matter, hospital, wards, outdoor, Pakistan.

### INTRODUCTION

Nosocomial outbreaks have been associated with airborne transmission and role of microorganisms in aerosolized form in hospital acquired infection is thought to be much greater than is up to now recognized. Immuno-compromised patients have also higher risk of becoming infected. Furthermore, epidemiological studies demonstrate associations between particulate matter (PM) concentrations and increased morbidity and mortality; while toxicological studies have begun to provide potential biological explanations for these observed associations. Previous studies have revealed the significance of indoor air quality and of the contribution of indoor sources to particle concentrations. The quality of air in the indoor hospital environment is of increasing concern both for patients and healthcare personnel who are exposed to infectious microorganisms and particulate matter. Additionally, healthcare staff are also prone to healthcare associated infections (HCAIs) due to their interaction and proximity to infectious sources. The problem regards not only medical equipment and the cleanliness of the staff but also surfaces in rooms and indoor air. (Charkowska, 2008).

In general, HCAIs are spread by contact, however, there is growing evidence that an airborne route has played a major role in nosocomial outbreaks of many pathogens e.g. *Staphylococcus aureus*, *Acinetobacter* spp and *Serratia marcescens* (Uduman *et al.* 2002; Kumari *et al.* 1998; Bernards *et al.* 1998). Additionally, infection transmission by deposition and/or resuspension is also an important pathways. It can be argued that the state of air

quality in hospitals, particularly with reference to particulate matter, is likely to impact on HCAIs.

Many air pollutants are present in the air but most important is particulate matter which is responsible for cardio-vascular ailments (Pope *et al.* 1995). Concentrations of particulate matter indoors depend upon the various indoor sources/activities (e.g. cleaning, dusting and sweeping and poor ventilation) and also on outdoor sources and seasonal variations (Nitta *et al.* 1994; Abt *et al.* 2000). Air borne particles in hospitals are of vital concern for infection control to protect hospital workforces and patients. Infectious agents in aerosols may be spread by droplet nuclei, aerial and unclean surfaces. Prospective health effects of particulate matter in hospital air are many including toxic, allergenic and infectious. In fact, every hospital has an inherent risk of HCAIs, however, the burden is higher in developing countries in comparison to developed with a prevalence of 10% (WHO 2011). Furthermore, developing countries are facing excessive levels of particulate matter, especially, in urban centres and these are very likely to contribute to indoor level of particulate matter in hospitals in these areas. Additionally, administrative, engineering and personal control measures to reduce the risk of exposure to airborne hazards in hospitals are often minimal in these countries.

The current research was undertaken to monitor ambient and indoor PM<sub>2.5</sub> levels, simultaneously, in five different wards of Sheikh Zayed Hospital in Lahore, Pakistan as a case study to comprehend the impact of ambient PM on indoors as well as to gauge the effectiveness of existing protection measures.

## MATERIALS AND METHODS

**Study site:** Sheikh Zayed Hospital is a tertiary care hospital located in Lahore (31° 30'N and 74° 18'E), Punjab Pakistan (Figure 1). It was established in 1986

and is consisting of 99 wards and 713 beds. About 50,000 patients visit the hospital annually. Table 1 provides a summary of the selected wards in the Sheikh Zayed Hospital.



**Figure 1: Location of Sheikh Zayed Hospital, Lahore**

**Table 1. Characteristics of the selected wards**

| Parameters             | Medical ward                                                                                 | Pulmonary ward                                                                               | Surgical ward                                                                                                                | Pediatrics ward                                                                        | Nephrology ward                                                                        |
|------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Ward size              | 39m <sup>2</sup>                                                                             | 39m <sup>2</sup>                                                                             | 39m <sup>2</sup>                                                                                                             | 39m <sup>2</sup>                                                                       | 39m <sup>2</sup>                                                                       |
| Number of beds         | 6                                                                                            | 6                                                                                            | 6                                                                                                                            | 8                                                                                      | 8                                                                                      |
| Beds occupied          | 4                                                                                            | 6                                                                                            | 5                                                                                                                            | 8                                                                                      | 7                                                                                      |
| Number of windows      | 2                                                                                            | 2                                                                                            | 2                                                                                                                            | 2                                                                                      | 3                                                                                      |
| Windows closed/open    | Closed                                                                                       | Closed                                                                                       | Closed                                                                                                                       | Closed                                                                                 | Closed                                                                                 |
| Number of visitors     | 9                                                                                            | 10                                                                                           | 9                                                                                                                            | 14                                                                                     | 17                                                                                     |
| Activities in the ward | Monitoring of vitals, running medication, people movement, dinning practices, doctor's visit | Monitoring of vitals, running medication, people movement, dinning practices, doctor's visit | Preoperative and post-operative care, Administering medication by nurses, people movement, dinning practices, doctor's visit | Administering medication by nurses, people movement, dinning practices, doctor's visit | Administering medication by nurses, people movement, dinning practices, doctor's visit |
| Ventilation            | By door                                                                                      | By door                                                                                      | By door                                                                                                                      | By door                                                                                | By door                                                                                |

**Monitoring of ambient and indoor PM<sub>2.5</sub> levels:** PM<sub>2.5</sub> was sampled by using a real time aerosol monitoring instrument, DustTrak (TSI Model 8520). Two DustTrak monitors were run in parallel, one inside the ward and the other running simultaneously just outside the hospital.

The sampling duration for each ward (indoor and ambient) was 24 hours. Ambient air was sampled relative to each ward and the sampler was placed on the roof of the ward. Average concentrations of all the sampling sites were obtained. Different activities in the wards were also noted. The association between indoor (ward) air and ambient air was statistically tested by

applying correlation bivariate analysis using SPSS version (17) with a significance level of 0.01.

## RESULTS AND DISCUSSION

The latitude of this work was to characterize PM<sub>2.5</sub> in different wards (Medical, Pulmonology, Surgical, Pediatrics and Nephrology) of patients in hospital microenvironment and to examine the relative contribution of indoor and outdoor sources to PM<sub>2.5</sub> in different wards (Table -2).

**Table 2. Summary of PM<sub>2.5</sub> concentration in different wards**

| PM <sub>2.5</sub> hourly mean and standard deviation at the study site |             |      |           |
|------------------------------------------------------------------------|-------------|------|-----------|
| Wards                                                                  | Hourly Mean | SD   | I/O ratio |
| Medical ward                                                           | 78          | ±37  | 1.130     |
| Medical ward outdoor                                                   | 69          | ±27  |           |
| Pulmonary ward                                                         | 86          | ±46  | 1.061     |
| Pulmonary ward outdoor                                                 | 81          | ±49  |           |
| Surgical ward                                                          | 94          | ±48  | 0.528     |
| Surgical ward out door                                                 | 178         | ±85  |           |
| Pediatrics ward                                                        | 169         | ±122 | 0.600     |
| Pediatrics ward outdoor                                                | 282         | ±164 |           |
| Nephrology ward                                                        | 488         | ±314 | 1.159     |
| Nephrology ward outdoor                                                | 421         | ±240 |           |

The indoor to outdoor PM ratio of five different wards i.e. medical, pulmonology, surgical, pediatrics and nephrology was observed to be 1.13, 1.06, 0.53, 0.60 and 1.16 respectively. The highest I/O ratio was found in the nephrology ward. This has the largest number of visitors, along with varied activities. The differences among the wards results from the geometry of the cracks in buildings, indoor particle sources, outdoor environments and ventilation patterns. Different indoor activities largely influence the levels of indoor PM. It was noted that although peaks were recorded in the ambient air during high vehicular activity, in most cases the levels were generally lower than those recorded in the indoor environment. The impact of ambient PM<sub>2.5</sub> levels on the indoor air quality is also clearly indicated in the comparative graphs given. It is evident that although the hospital is centrally air conditioned, the wards are not air-tight thereby allowing infiltration from the outside mainly by doors. Such infiltration is an important contributing

factor in defining the indoor air quality and this situation can cause multiple health effects.

With reference to medical ward the highest levels of PM<sub>2.5</sub> occurred during the hours when there was a doctor's visit, dinner time and prayer time as shown in Figure 2. For the pulmonology ward (Figure 3) the highest levels of PM<sub>2.5</sub> occurred during the hours when there was heavy traffic load. As the hospital is situated in an urban area on a busy road, traffic emission are major source of PM<sub>2.5</sub>. Other activities including a doctor's visit and dining times show increases in PM concentrations. Peak concentrations of PM<sub>2.5</sub> were seen during heavy traffic which indicates the infiltration of particulate matter from outside. Different indoor activities and outdoor sources were main contributor to increased PM concentrations in the surgical wards as well (Figure 4).

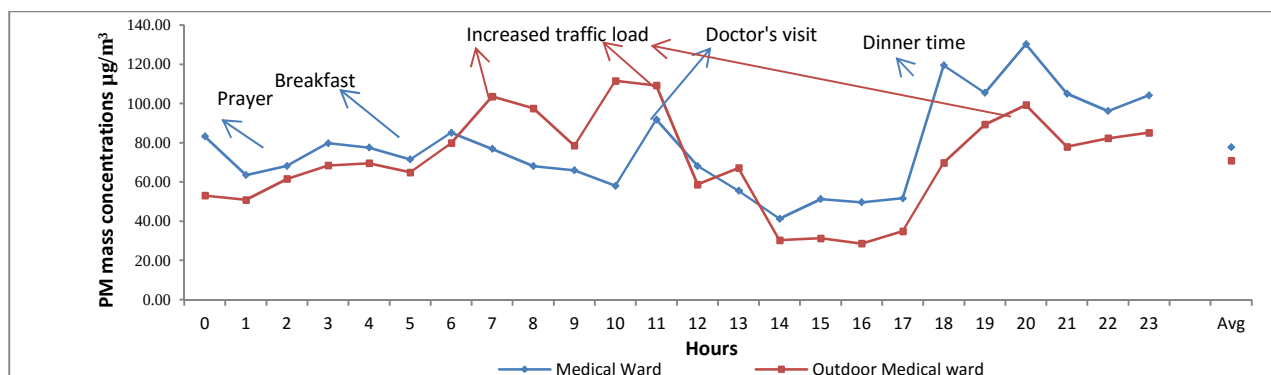


Figure 2: PM<sub>2.5</sub> levels in Medical ward and outdoor resulting from various activities

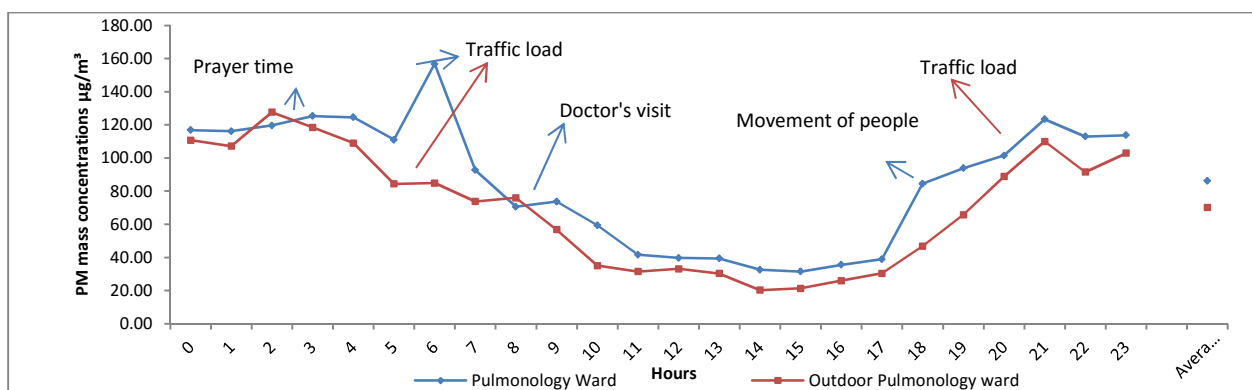


Figure: 3 PM<sub>2.5</sub> levels in pulmonary ward and outdoor resulting from various activities

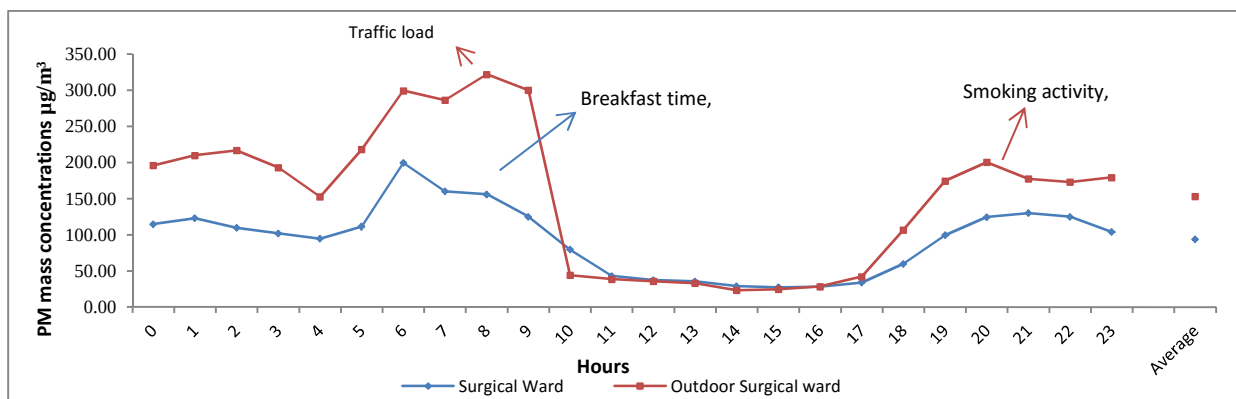


Figure 4: PM<sub>2.5</sub> levels in surgical ward and outdoor resulting from various activities

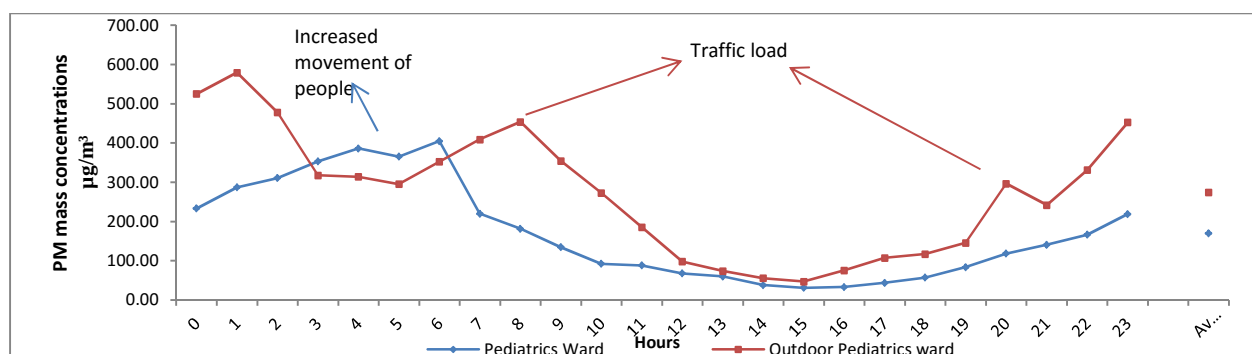


Figure 5: PM<sub>2.5</sub> levels in Pediatric ward and outdoor resulting from various activities

Increased levels of PM<sub>2.5</sub> were observed in the pediatrics ward during visiting hours where the movement of people causes re-suspension of the pollutant

as shown in Figure 5. In addition this ward is not air conditioned and is equipped with 8 fans which, when on, cause high rates of particulate matter re-suspension.

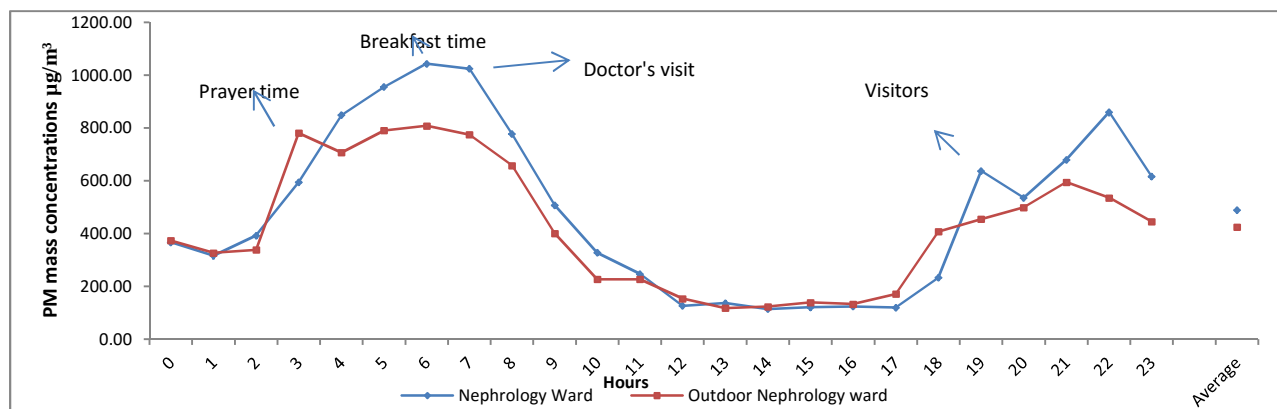


Figure 6: PM<sub>2.5</sub> levels in and out of Nephrology ward resulting from various activities

Similar results were obtained in the nephrology ward as shown in Figure 6. A statistically significant positive correlation was observed between the wards (indoor air) and ambient air with an alpha value of 0.01 being used. The obtained p values were 0.00, 0.001, 0.00, 0.006, 0.000 for medical, pulmonary, surgical, and paediatric and nephrology ward respectively.

Apart from outdoor air influencing the indoor air, multiple indoor sources are also important to consider. Movement of people re-suspends the dust settled on the surface and thereby increases the PM levels. In our case, it has to be mentioned that due to strike of janitorial staff, cleaning activities were quite irregular and not up to the normal standards. A visible impact of the strike was recorded in our results as the average levels of PM<sub>2.5</sub> are observed to increase from ward to ward. The medical ward was monitored first and the PM levels are lower as compared to the nephrology ward (78 vs 488 µg/m³). Although cleaning activities re-suspend the settled particles, it is a temporary process as most of the particles are swept away in the cleaning activity. On the other hand, irregular cleaning and floor sweeping results in more deposition of particles than are cleared. As observed in this research, as the cleaning activities decreased over time, PM levels increased considerably. The deposited dust was re-suspended again and again due to movement of people as there was no removal process.

In addition the results show that outdoor concentrations of PM<sub>2.5</sub> were above accepted air quality standards and indicate that site is highly affected by heavy traffic. Indoor levels were generally higher than the corresponding outdoor, bar surgical and paediatric wards. This is most probably due to presence of indoor aerosol sources such as people movement/activities, sweeping, and poor ventilation. In the urban environment there are many sources for particulate matter such as

traffic and industry (Wehner *et al.* 2002, Hussein *et al.* 2005, and Arnold *et al.* 2006). These may lead to elevated indoor concentrations by ambient air penetration in the indoor microenvironments (Diapouli *et al.* 2011).

**Conclusion:** The study demonstrated that aerosol particles are frequently liberated within the wards. The high I/O ratios observed in the wards and ambient air reveals greater contribution from indoor sources to PM. Pakistan, being a developing country, is confronting serious problems in the health sector and lacks strategies to maintain air quality in the healthcare environments. The outcomes of the study illustrates that the particulate matter levels imparted by various indoor activities and infiltration from outdoor can be used as a tool in determining air quality of the healthcare environments.

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## **State of air quality in and outside of hospital wards in urban centres – a case study in Lahore, Pakistan**

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**2015-06-30**

Pakistan Agricultural Scientists Forum

<http://www.thejaps.org.pk/docs/Supplementary/v-25-sup-2/59.pdf>

Gulshan T, Ali Z, Zona Z, et al. State of air quality in and outside of hospital wards in urban centres – a case study in Lahore, Pakistan, The Journal of Animal and Plant Sciences, Volume 25, Issue 3 Supp. 2, 2015, pp. 666-671