



A Preliminary Assessment and Control Strategy of Size Segregated Pollutants in Urban and Peri-urban Areas of Metropolitan Faisalabad, Pakistan

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Abstract

In recent years, Pakistan has experienced severe and persistent air pollution associated with urbanization and industrialization and it has substantial effects on ecosystem and air quality. In urban and peri-urban areas, maximum TSP concentrations were observed at Satiana Road ($987 \mu\text{m}^{-3}$) and Chak 215 RB ($1123 \mu\text{g m}^{-3}$). Similarly, maximum PM_{10} concentrations were recorded at Gutte Wala ($782 \mu\text{g m}^{-3}$) and Chak 215 RB ($893 \mu\text{g m}^{-3}$), while maximum $\text{PM}_{2.5}$ concentrations were observed at Madina Food Mill ($621 \mu\text{g m}^{-3}$) and Chak 215 RB ($654 \mu\text{g m}^{-3}$). The statistical results suggested that there were significant difference between urban and peri-urban areas. Majority of size segregated pollutants including TSP, PM_{10} and $\text{PM}_{2.5}$ were found with higher values than the United States Environmental Protection Agency (US-EPA), World Health Organization (WHO) and National Environmental Quality Standards for Pakistan (NEQS-Pak) limits for both urban and peri-urban areas. However, only 4%, 8% and 4% for TSP, PM_{10} and $\text{PM}_{2.5}$, respectively in urban and in peri-urban samples for TSP (40%) PM_{10} (60%) and $\text{PM}_{2.5}$ (44%) were found under prescribed guidelines. Furthermore, we have also compared metropolitan size segregated pollutant (PM_{10}) with other Pakistan and Asian metropolitan's cities and purposed a control strategy to improve air quality in Faisalabad.

Keywords: Size segregated pollutants; PM_{10} ; $\text{PM}_{2.5}$; Vehicular emissions; Urban; Peri-urban

Introduction

Atmospheric degradation has become a severe threat to human health and welfare in developing countries like Pakistan, where urbanization, motorization, and industrialization coupled with concomitant growth of energy use are growing rapidly. This threat is severe especially where technologies and strategies for controlling emissions are limited due to lax legislative standards and enforcement of regulations [1-5].

Size segregated pollutants levels are escalating swiftly in urban and peri-urban areas of numerous metropolitan cities especially in

developing world [6]. Worldwide, around 3.7 million deaths were reported particularly due to ambient air pollution during 2012 [7], 88% of these were in low and middle-income countries and this hefty burden of disease was related to size segregated pollutants. Developing countries like Pakistan, there is no exclusion and all metropolitan cities are under severe threats. Approximately, all major cities of Pakistan (Karachi, Lahore and Faisalabad) are facing the menace of air pollution due to expansion of urban land and escalation of traffic emissions [1]. The menace of size segregated pollutants becomes worst at some sites

where signalized traffic junctions with high pollutants loads, which are further defined as “hot spot” [7]. Globally, Shanghai, Mumbai, Kolkata, Beijing are under great influence of air pollution [8]. It has been well documented that the average PM₁₀ concentration was elevated by more than 5% in 720 cities annually across the world [8].

Pakistan Environment Protection Agency (Pak-EPA) and Japan International Cooperation Agency (JICA) jointly estimated that the concentration of particulate matter (PM) in large cities of Pakistan are 4.4 to 7.5 times greater than WHO Guidelines [9]. In another finding by Pak-EPA/JICA analyzed the quality of ambient air in Gujranwala and Faisalabad [9]. In Gujranwala, TSP concentration (24 h avg.) increased up to 5190 $\mu\text{g m}^{-3}$, which is 30 times greater than WHO guidelines. The environmental assessment report established that PM severe as an environmental and health issue in Pakistan and responsible for 22,000 premature deaths among adults and 700 deaths among children [10,11]. Residents closer to main roads, industrial units and in dense settlements are more susceptible to health problems [12,13, 38]. Rapid increase in population and industries have enhanced pollution to manifold for the residents of big dense population city like Faisalabad. Despite of the fact, it is a third largest city in Pakistan on population basis, but there is no scientific data available regarding air quality status. Considerable researches on rapid increasing levels of size segregated pollutants in urban and industrial areas of developing countries have been well explained, but the peri-urban have scarcely been explored.

The objective of this study was to evaluate the size segregated pollutants in peri-urban and rural locations of Faisalabad, and also to evaluate the preliminary status of urban size segregated pollutants, while considering the US-EPA, WHO, NEQS-Pak guidelines and propose a control strategy. This study could be used as a preliminary assessment in urban and peri-urban to instigate other studies related to source contribution, identification and risk involved to human health. It is also expected that the present work will be useful for controlling and instituting future abatement techniques regarding emission regulations.

Material and Methods

Site selection for urban and peri-urban areas

Faisalabad is located at 73-74° E, 30-31.15° N in geographical map of Pakistan and is the major industrial zone of Pakistan. Therefore, its air quality is an eminent apprehension. The sampling sites for urban areas were selected based on the existing anthropogenic activities such as food processing units, marble factories, flour mills, engineering complexes, chemical and soap factories engineering complexes, busy intersection and commercial centers. It is noted that these areas are the main source of size segregated pollutants. We assumed that potential stationary and mobile sources described by [13] in metropolitan Faisalabad. The sampling sites for peri-urban areas were based on the outskirts areas near clusters of brick kilns, unpaved roads, and heavy traffic load with poorly maintained vehicles. Further, this study was carried out based on the hypothesis that size segregated pollutants changes spatially and temporally largely in terms of concentration, chemical composition and sizes attributes to different types of local sources in Faisalabad areas. In this one month study we were assumed that size segregated pollutants have higher mass concentration on the basis of large anthropogenic activities and favorable meteorological condition (for the deposition of particles with high residence time, relative humidity and low temperature) to elevate mass concentration [14-16].

Monitoring procedures

Ambient PMs of varying size fraction include TSP, PM₁₀, and PM_{2.5} were examined with Micro Dust Pro Real Time Particulate Monitor (model HB3275-07, Casella CEL, UK) for 6 hours at each sampling point at height of 2.5 meters above the ground to monitor air quality status in both urban and peri-urban areas during December 02 to 30 December, 2013. Total fifty samples (TSP, PM₁₀ and PM_{2.5}) were collected from both urban and peri-urban areas. Micro Dust Pro Real Time Particulate Monitor instrument uses a modulated beam of infra-red light projected to estimate the size segregated pollutants. It includes infra-red emitter, sample volume, infra-red detector and light stop. The detection range of instrument is 0.001 to 2500 μm^{-3} with a resolution

0.001 $\mu\text{g m}^{-3}$. This apparatus analyzes PM concentration using a near forward angle (12-20°) infrared light (880 nm) scattering method. A polyurethane foam (PUF) filter adapter (flow rate of 3.5 L min^{-1}) was applied for size-selective monitoring of airborne size segregated pollutants. The PUF filter encumbered into the adapter that determines the size of PMs being quantify. Filters were available for PM₁₀ and PM_{2.5} size fractions.

Calibration / standardization

Micro Dust Pro Real Time Particulate Monitor is individually factory calibrated through gravimetric technique. It can be revert to factory calibration setting using non-degradable calibration insert at any time during its life. We have performed an individual gravimetric (filtered) calibration through possible simultaneous assortment of a gravimetric (filtered) sample of the size segregated PM mass concentration sample. Like this, we have collected two averages (one is from the filter of every size segregated pollutants and second by the mean function within the instrument) sample readings over the exposure duration. In this way, we have derived the possible difference between these two readings and corrected accordingly. In order to ensure high quality and control procedures were followed.

Sampling frequency and statistical analysis

Monitoring of size segregated pollutants (TSP, PM₁₀ and PM_{2.5}) were spread from December 2 to 30, 2013. On sample days, two 6 hours samples were gathered from around 7:30 am to 1:30 pm and again started from 1:30 pm to 7:30 pm. Please note that samplings were not performed during dust storms and rainy days. Box whisker plot were using IBM SPSS statistics version 23 to assess the difference in urban and peri-urban areas.

Results and Discussion

Size segregated pollutants concentration in urban areas

Maximum TSP concentrations were observed at Satiana road (987 $\mu\text{g m}^{-3}$) followed by Gutt wala (972 $\mu\text{g m}^{-3}$), Railway station (954 $\mu\text{g m}^{-3}$) (Table 1). Minimum TSP concentration was observed at Al-Noor Home Colony area (154

$\mu\text{g m}^{-3}$) (Table 1). Similarly, maximum PM₁₀ concentrations were recorded at Gutte Wala (782 $\mu\text{g m}^{-3}$) followed by Madina Food Mill (754 $\mu\text{g m}^{-3}$), Tariqbad area (735 $\mu\text{g m}^{-3}$). Minimum PM₁₀ concentrations were observed at Alnoor Home Colony area (110 $\mu\text{g m}^{-3}$). Meanwhile, the maximum PM_{2.5} concentrations were monitored at Madina Food Mill (621 $\mu\text{g m}^{-3}$), Satina road (458 $\mu\text{g m}^{-3}$) and Makonwala road (361 $\mu\text{g m}^{-3}$). Size segregated pollutants in urban areas were found highly significant and all of the monitoring points were significantly different from each other. In general, the 6 hours average size segregated pollutant concentrations were higher in urban areas due to high traffic load. Box and whisker plot suggested (TSP, PM₁₀, and PM_{2.5}) distributions in urban areas (Fig. 1). The 6 hours TSP concentration in urban areas were varied from 154 to 987 $\mu\text{g m}^{-3}$ with average of 662 $\mu\text{g m}^{-3}$. Our findings showed that 6 hours PM₁₀ concentrations were assorted from 110 to 782 $\mu\text{g m}^{-3}$ with average concentration of 419 $\mu\text{g m}^{-3}$. Meanwhile, 6 hours PM_{2.5} concentrations were ranged from 103 to 621 $\mu\text{g m}^{-3}$ with mean concentration of 254 $\mu\text{g m}^{-3}$. In comparison with Karachi, the average mean concentration of PM was observed to be 239 $\mu\text{g m}^{-3}$ in 1985 and increased to 265, 275, and 328 $\mu\text{g m}^{-3}$ in 1986, 1987 and 1988, respectively, and the annual average PM concentration during 1987 and 1988 in Karachi at the Sindh Industrial Trading Estate and Sadar sites were recorded 254, 459 and 333, 397 $\mu\text{g m}^{-3}$ respectively [1]. Majority size segregated pollutants in current study (TSP, PM₁₀, PM_{2.5}) were higher than the US-EPA, WHO and NEQS-Pak [17-19], only 4%, 8% and 4% for TSP, PM₁₀ and PM_{2.5} samples were found under prescribed guidelines. The highest average concentration of segregated pollutants (TSP, PM₁₀, and PM_{2.5}) were observed at Satiana road followed by Gutewala and Railway Station.

We have also estimated cumulative percentage (%) distribution of all segregated pollutants to each site having more 50% contribution to total size segregated pollutants. The highest average concentrations of segregated pollutants (TSP, PM₁₀, and PM_{2.5}) were observed at Satiana road followed by Gutewala and Railway Station. These three sites are industrial areas and situated in industrial clusters and further size

segregated pollutants concentrations were increased due to the major road intersections that are heavily dense by traffic load and busy business commercial centers round the clock. Similarly, increased level of size segregated pollutants at Madina Food Mills and Tariqabad were likely due to emissions from brick kilns and industrial emissions situated upwind and proximal to these monitoring points. Moreover, higher level of size segregated pollutants at these sampling sites were mainly due to re-suspended road dust and emissions from public and commercial transportation (i.e. two wheelers trucks, auto-rickshaws vans, and buses) which are in line with the findings of [20-22]. Overall, sampling locations exhibited poor air quality due to high traffic density which mainly consists of heavy duty vehicles such as trucks, local buses, trailers, vans, and tractors moving along the roads. Most of the vehicles are usually old, poorly maintained, overloaded, and smoky and use inefficient engines that consume bad quality fuel which were increased PM concentrations [1, 21-22]. The air born pollutants originated from exhaust and non-exhaust sources in the urban environments. Plying vehicles are a main source of such type of particle emissions and these could share up to 90% in polluted urban environments [23-24]. The measured size segregated PMs in urban areas were found higher during some periods of the year and this situation may become more worse in coming year due to the increased population and heavy traffic load in big cities like Faisalabad. While, at typical urban sites (Al-Noor Colony and Kekshian Colony), the size segregated concentrations were significantly low because these areas have relatively low vehicular and industrial activities in the surroundings.

Table 1. Descriptive statistical analysis of urban and peri-urban areas in metropolitan Faisalabad.

	Size segregated PM urban areas*			Size segregated PM Peri-urban areas**		
	TSP	PM ₁₀	PM _{2.5}	TSP	PM ₁₀	PM _{2.5}
Minimum	154	110	21	77	40	9
Maximum	987	782	621	1123	893	654
Mean ([†] n=25)	662	419	246	323	191	120
SD ^a	243	207	134	250	188	130

[†]n=Number of samples ; SD^a Standard deviation

Size segregated pollutants concentration in peri-urban areas

Maximum 6 hours TSP concentrations were recorded at Chak 215 RB (1123 $\mu\text{g m}^{-3}$) followed by Chak 238 (785 $\mu\text{g m}^{-3}$), Chak 237 (614 $\mu\text{g m}^{-3}$) (Table 1). Minimum 6 hours TSP concentration was monitored at Chak 226 RB (77 $\mu\text{g m}^{-3}$). Similarly, maximum 6 hours PM₁₀ concentrations were recorded at Chak 215 (893 $\mu\text{g m}^{-3}$) followed by Chak 238 (542 $\mu\text{g m}^{-3}$), and Chak 237 (419 $\mu\text{g m}^{-3}$). Minimum 6 hours PM₁₀ concentration was observed at Chak 255 RB (40 $\mu\text{g m}^{-3}$), while the maximum 6 hours PM_{2.5} concentrations were observed at Chak 215RB (654 $\mu\text{g m}^{-3}$), Chak 238 (254 $\mu\text{g m}^{-3}$) and Chak 237 (267 $\mu\text{g m}^{-3}$). Meanwhile the minimum concentration was recorded at Chak 244 (9 $\mu\text{g m}^{-3}$).

The variations of all size segregated pollutants in peri-urban areas were also highly significant and different from each other at all monitoring points. The 6 hours TSP concentration in peri-urban areas were ranged from 77 to 1123 $\mu\text{g m}^{-3}$ with average mean 654 $\mu\text{g m}^{-3}$. The highest concentration of size segregated pollutants (TSP, PM₁₀, and PM_{2.5}) were observed at Chak 215, Chak 238 and Chak 237. We have also estimated cumulative percentage (%) distribution of all segregated pollutants to each site having more 50% contribution to total size segregated pollutants. Box and whisker plot suggested (TSP, PM₁₀, and PM_{2.5}) distribution in peri-urban areas (Fig. 1). Increased concentration was attributed to clusters of brick kilns which were found near the monitoring sites (Chak 215 and Chak 238). Moreover, poor and unpaved roads were found at Chak 238.

In our finding, 6 hours PM₁₀ concentrations were varied from 40 to 893 $\mu\text{g m}^{-3}$ with an average concentration of 191 $\mu\text{g m}^{-3}$. Urban cities depicted different pattern for PM₁₀ concentrations decreasing from Lahore (368 $\mu\text{g m}^{-3}$), Peshawar (350 $\mu\text{g m}^{-3}$), Quetta (331 $\mu\text{g m}^{-3}$), Karachi (302 $\mu\text{g m}^{-3}$), Islamabad (280 $\mu\text{g m}^{-3}$), to Rawalpindi (276 $\mu\text{g m}^{-3}$) [9]. Meanwhile, current 6 hours PM_{2.5} concentrations were assorted from 9 to 654 $\mu\text{g m}^{-3}$ with mean concentration 120 $\mu\text{g m}^{-3}$. Majority of size segregated PMs (TSP, PM₁₀, PM_{2.5}) were found higher than US-EPA, WHO and

NEQS-Pak guidelines. On the other hand, size segregated pollutants include TSP (40%) PM₁₀ (60%) and PM_{2.5} (44%) samples in peri-urban were observed under the permissible limits of US-EPA, WHO, and NEQS-Pak. In order to analyze PM_{2.5} and PM₁₀ concentrations in Islamabad during 2002-2005, Hopke et al. [25] found that the average concentrations were 15 and 68 $\mu\text{g m}^{-3}$, respectively, which is close to the present study. However, low levels of size segregated pollutants in peri-urban areas were attributed to the low emissions and paved roads around the sampling sites.

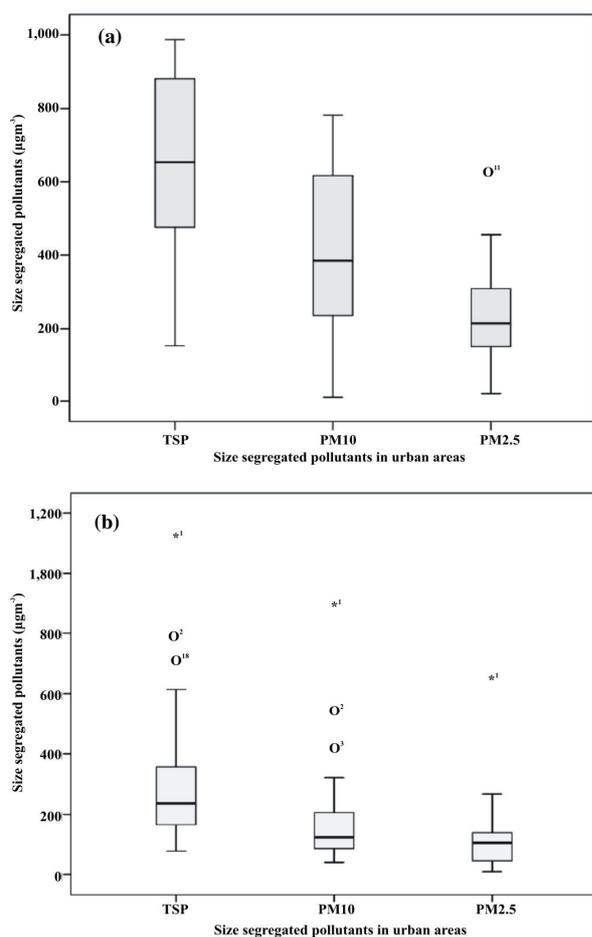


Figure 1. Box and whisker plot of size segregated PMs distribution in (a) urban and (b) peri-urban areas of metropolitan Faisalabad

Comparison with other Asian countries

As indicated in (Fig. 2), comparisons of average 6 hours size segregated pollutant (PM₁₀) level in current study with other metropolitan's

cities of Pakistan and Asian cities illustrate that the mass concentration was highest in Faisalabad metropolitan than all others cities of the world. In 2008, Gurjar et al. [26] suggested that the Karachi was the highest polluted cities in world regarding TSP concentration. However, World Bank highlighted that PM₁₀ concentration was decreased from 165 $\mu\text{g m}^{-3}$ to 226 $\mu\text{g m}^{-3}$ during 1990 in Pakistan. Keeping in view the sporadic investigations, an increasing pattern of size segregated pollutants level will prevail in Faisalabad metropolitan Pakistan and other Asian metropolitans in future.

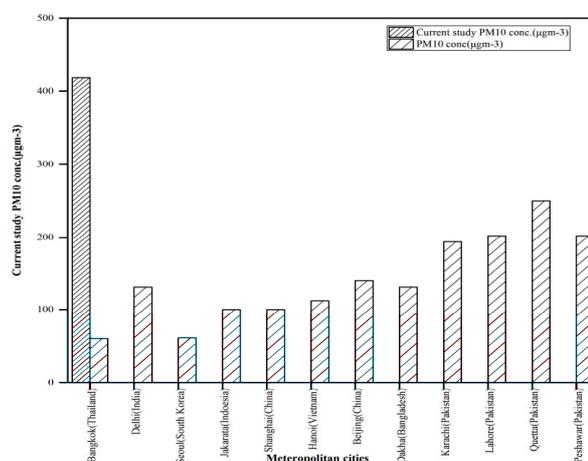


Figure 2. Comparison of size segregated pollutant (PM₁₀) with Pakistan metropolitans and other Asian cities with current study [31-37,7]

Control strategy in urban and peri-urban areas

Better air quality becomes more effective if it includes the assessment of how to rationalize the necessary outlays. Several studies have reported to investigate air pollution in Faisalabad areas [27-30]. None of them have suggested about improving the air quality of Faisalabad. In our point of view, the strategy to reduce size segregated pollutant reduction is depicted in (Fig. 3). In order to improve air quality in Faisalabad, limiting both industrial and vehicular emissions in urban areas will be obligatory. From the obtained results in urban areas we suggest that at an industrial level environmental engineering techniques should be introduced such as thrust for cleaner techniques (flu gas desulfurization, combustion adjustment for NO_x mitigation gravity (gravitational chamber), centrifugation (cyclone

separator), filtration (fabric filter system), scrubbing (dry & wet scrubber), electrostatic precipitators (electrostatic force to separate dust particles from exhaust gases), combustion systems (thermal oxidizers), condensers, absorbers, absorbers). Incentives should be given for those industries who adopt air quality control measures. For the effectiveness of these measures, database about air cleaner performance should be maintained and updated regularly. Faisalabad has developed exponentially through a logistic and economic nightmare. High loads of vehicles on roads require extension transport infrastructure, and mass rapid transport system should be in place to reduce the vehicular emissions loads especially at intersection or chowks in Faisalabad [31]. In addition, strict monitoring and compliance of NEQS-Pak quality standard are needed to improve air quality.

Highest size segregated pollutant concentrations in peri-urban areas were observed and call for immediate attention for government and researchers. Keeping in view the upward increasing trend in peri-urban areas demand for paved roads should be constructed to avoid coarse particles originated from roads dust. Additionally, brick kilns should be situated far away from peri-urban areas to limit the exposure of human from pollutants emissions.

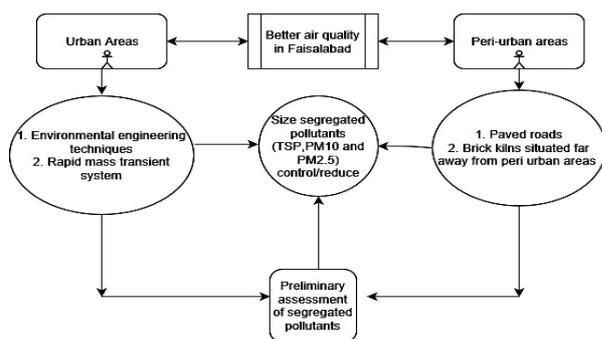


Figure 3. Schematic diagram about strategy to improve air quality in urban and peri-urban areas of metropolitan Faisalabad

Conclusion

The current study indicated a significant variation of mass concentrations of different size segregated pollutants in urban and peri-urban areas of the Faisalabad metropolitan. Size segregated

pollutant concentrations were higher in urban area attributed to industrial emissions and high traffic loads, while in peri-urban brick kilns emissions, unpaved roads were contributing to higher level of size segregated pollutant. Majority of size segregated pollutant (TSP, PM₁₀, PM_{2.5}) were higher than the US-EPA, WHO and NEQS-Pak limits for both urban and peri-urban areas. We concluded that both urban and peri-urban areas were highly polluted and posing potential threats to inhabitants. It is suggested that size segregated pollutant could be controlled by using environmental engineering techniques. Furthermore, complete restrict emissions related to transportations are required to control size segregated polluted. In peri-urban areas, paved roads should be constructed and brick kilns should be situated far away from outskirts areas to avoid minimal exposure. Urgent mitigation measures and strategy should be adopted to control the size segregated pollutant for better air quality in metropolitan Faisalabad and thus improving the air quality for ecosystems sustainability and mars the serenity of the real estate environment at large for habitation.

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