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Analysis of Particulate Matter Fraction in Residential Area of Lahore, Pakistan

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Competing interests
The authors have declared that no competing interests exist.

Abstract

Background: *Air pollution have reached to an alarming level from the past few decades in Pakistan. An increasing trend in particulate matter (PM) pollution in the urban areas have been observed contributing to different health concerns to human like cardiovascular arrest, blood pressure, asthma, pulmonary dysfunction, many eye problems such as cataracts.*

Materials and Methods: *To analyze the levels of air quality index in the urban areas at a residential site, in Pakistan, PM fractions PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ were analyzed from 1st October 2022 to 31st March 2023 in provincial capital city Lahore by using a PurpleAir sensor located at Gulberg Town Lahore.*

Results: *The average PM_{10} concentration of PM sustained at 200.96 $\mu g/m^3$ ±138.37 $\mu g/m^3$ for 6 months with maximum level in December 2022 (851.64 $\mu g/m^3$ ± 160.58 $\mu g/m^3$) with an average value of 287.96 $\mu g/m^3$, and minimum level in March 2023 (10.12 $\mu g/m^3$ ± 10.10 $\mu g/m^3$) with an average 30.56 $\mu g/m^3$. The average $PM_{2.5}$ concentrations was recorded to 164.59 $\mu g/m^3$ ± 110.16 $\mu g/m^3$. for 6 months with maximum level in December 2022 (622.28 $\mu g/m^3$± 119.06 $\mu g/m^3$) with an average value of 229.93 $\mu g/m^3$ and minimum level in March 2023 (9.16 $\mu g/m^3$ ± 7.94 $\mu g/m^3$) with an average of 25.24 $\mu g/m^3$. The average $PM_{1.0}$ concentration was recorded to 86.19 $\mu g/m^3$± 51.50 $\mu g/m^3$ for 6 months with maximum level in November 2022 (252.42 $\mu g/m^3$ ± 47.54 $\mu g/m^3$) with an average of 147.94 $\mu g/m^3$ ± 47.54 $\mu g/m^3$ and minimum level in March 2023 (5.89 $\mu g/m^3$ ± 5.15 $\mu g/m^3$) with an average value 15.89 $\mu g/m^3$.*

Conclusion: *Taken into consideration these findings it can be concluded that the high PM levels during November and December were due to the environmental factors including smog, burning of residual crops, brick kilns and excessive vehicle emission.*

Key words: *Particulate matter (PM), PurpleAir sensor, Pollution; Residential site*

Introduction

Natural and anthropogenic environmental conditions by their compound cooperation are the major contributing factors in the deterioration of air quality causing adverse effects on human health (Kampa & Castanas, 2008). Air quality is a major emerging issue in urban residential areas as well as it is greatly concerning for people's health when pollutant levels are high in the atmosphere (Ali et al., 2015) . PM is categorized into coarse particles (PM_{10}), fine particles ($PM_{2.5}$), and ultrafine particles ($PM_{1.0}$) with diameter <10µm, <2.5 µm, and < 1.0µm, respectively. Metropolitan areas have already been reported to be heavily concentrated with $PM_{2.5}$ due to rapid industrial growth (Ji et al., 2021). It is reported that $PM_{2.5}$ being the most hazardous toxic pollutant pose serious health threats to human and cause climatic crisis (Li et al., 2016). The elevated level of particulate air pollution is strongly associated with SIDS (Sudden Infant Death Syndrome) with enhanced babies and perinatal mortality (Woodruff et al., 2006). $PM_{2.5}$ is reported as leading indoor air pollutant, its exposure rate for people living indoor is much higher than ambient air because of cooking activities, unventilated homes, smoke, use of various seasonings resulting in pulmonary dysfunction and congestive heart failure (O'Leary et al., 2019). About 25% of $PM_{2.5}$ is released into the environment due to fire and burning activities (Kulkarni et al., 2020). The ambient PM_{10} pollution level is elevated about 40% more near crowded and vibrant area and 55% of the further pollution is due to the toxic metals and carbon-containing materials such as petroleum, and coal. Another source of PM_{10} air pollution is combustion in large power plants as well as in heating stoves at homes. $PM_{1.0}$ being the ultrafine particles are formed by gas nucleation and can grow up to the size of 1 µm by condensation with other particles.

The particle size complicacy is basically playing important role in determining the impacts on the health and atmosphere (Whitworth, 2003). Indoor and outdoor air pollution affect the level of atmospheric pollution in residential areas. Globally, indoor, and atmospheric pollution accounts for 8 million early deaths every year (Cincinelli & Martellini, 2017). In 2018, the air pollution level in Germany exceeded EPA limits in 57 German cities (Wettengel, 2019). 90% of deaths due to pollution mainly occur in underdeveloped countries. One of largest community hazards all over the world is anthropogenic air pollution which accounts for 9 million deaths per year (Fuller et al., 2022).

The increase in PM concentration is due to key energy resources like carbon and burning fossil fuels in conjunction with weather conditions in monitoring production of secondary $PM_{2.5}$ (Rasheed et al., 2015). The highest level of PM is found in Lahore, the second major contaminated cities in Pakistan. It has been reported that $PM_{2.5}$ contains 47% of organic carbon and ionic species like ammonium ions, chloride ions and nitrate ions (Ahmad et al., 2020). According to the air quality index (AQI) of Lahore, $PM_{2.5}$ concentrations exceeded the guidelines of WHO and is 11.5 times than the recommended air quality value. The smog season made Lahore the second most polluted city after Delhi in November 2019. Increasing industrial development, lack of public transportation, insufficiency of regulatory control are considered the contributing factors for poor air quality of Lahore.

Materials and Methods

Lahore, the capital city of Province of Punjab with geographical coordinates (latitude, longitude) 31°34' N, 74°18' E (Figure 1) is the second-largest city of Pakistan (Bukhari & Ali, 2021). The sampling location was an urban residential area in Gulberg III, Lahore with geographical location of latitude 31.505355 and longitude 74.34995. This area is highly populated due to which there is always a lot of traffic on roads with indoor human activities that elevates the level of particulate matter.

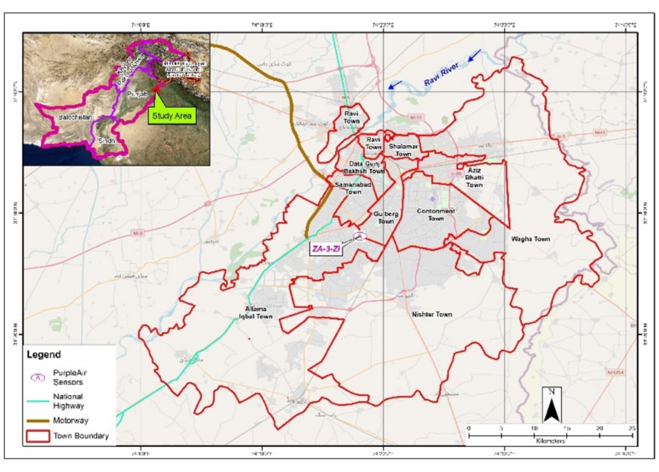

Figure 1. Location of PA-II Sensor ZA-3-AB on Map

The study was conducted to characterize and measure PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ at selected sites. The concentration of PM was measured for six months October 2022 to March 2023 comprising of three seasons Autumn (October and November), Winter (December to February) and Spring (March and April). The data was recorded with an interval of 10 minutes. PurpleAir PA-II sensor was used to monitor and record the PM levels. The estimation of fraction of particulate matter was recorded based on the light-scattering principle. All the data about the PA-II units and its measurements were downloaded from PurpleAir site. PM fraction was evaluated by using this data.

Result

The variation of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ ($\mu g/m^3$) levels are presented in Figure 2 for the study period of six months. The mean value of PM_{10} was recorded at 200.96±138.37 $\mu g/m^3$. The highest level of PM_{10} was recorded in the month of December at 851.64±160.58 $\mu g/m^3$ with an average value of 287.96 $\mu g/m^3$ (Figure 2A), while the minimum concentration of PM_{10} was recorded in the month of March at 10.12±10.10 $\mu g/m^3$ with an average 30.56 $\mu g/m^3$ (Figure 2B).

The mean value of $PM_{2.5}$ was recorded at 164.59±110.16 $\mu g/m^3$. The highest level was recorded in the month of December at 622.28±119.06 $\mu g/m^3$ with an average value of 229.93 $\mu g/m^3$ while the minimum value was 9.16±7.94 $\mu g/m^3$ with an average value 25.24 $\mu g/m^3$ (Figure 2C) record in March 2023. The highest levels of $PM_{2.5}$ were recorded in November 2022, that remained at their peak till December 2022 (Figure 2D).

The mean value of $PM_{1.0}$ was recorded at 86.19 ± 51.50 $\mu g/m^3$. The highest level was recorded in the month of November 2022 at 252.42 ± 47.53 $\mu g/m^3$ with an average value of 147.94 $\mu g/m^3$ while the minimum value was 5.89 ± 5.15 $\mu g/m^3$ with an average value 15.89 $\mu g/m^3$ (Figure 2E). Early November was the period of intense smog which continued in December comparatively high and alarming levels of $PM_{1.0}$ were recorded in both months. The highest levels of $PM_{1.0}$ were recorded in November 2022, to 162.81 ± 34.78 $\mu g/m^3$, that remained at their peak till December 2022 (Figure 2F). The daily values of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ along with their mean values are depicted in Figure 3.

Discussion

World air quality report 2021, reported that states and territories in East Asia, Southeast Asia, and South Asia was experiencing highest annual average of particulate matter (IQAir, 2021). Worldwide $PM_{2.5}$ is claimed to be responsible for 3.2 million deaths in year 2010 with significant rise in mortality rate to 6.4 million in 2015 and 6.7 million in 2019.

It is reported that $PM_{2.5}$ being the most hazardous PM pose serious health threats to human. In 2021, the average $PM_{2.5}$ concentration was reported 13.4 times higher than the World Health Organization atmosphere quality index in Pakistan. According to 2021 AQI country ranking Pakistan was ranked 3rd in air pollution and low air quality out of 118 countries with average US AQI of 156. Lahore was reported to be 18th most polluted city and second polluted megacity in 2020.

Different factors like industrial emissions, transportation construction dust, road dust, cooking fuels, combustion of biomass and fossil fuels are held responsible for worst air quality of the Lahore throughout the year with worst situation during fall and early winters. Since the onset of October 2022, a heavy smog has enveloped the Northern India and Pakistan. Autumn, farmers burned barren stalks of the harvest to purge land for the next season farming. As these farm fields burn, local air contamination barbs to "extremely unhealthy" and "hazardous" levels. From mid-November 2022, as many as 4,000 agrarian

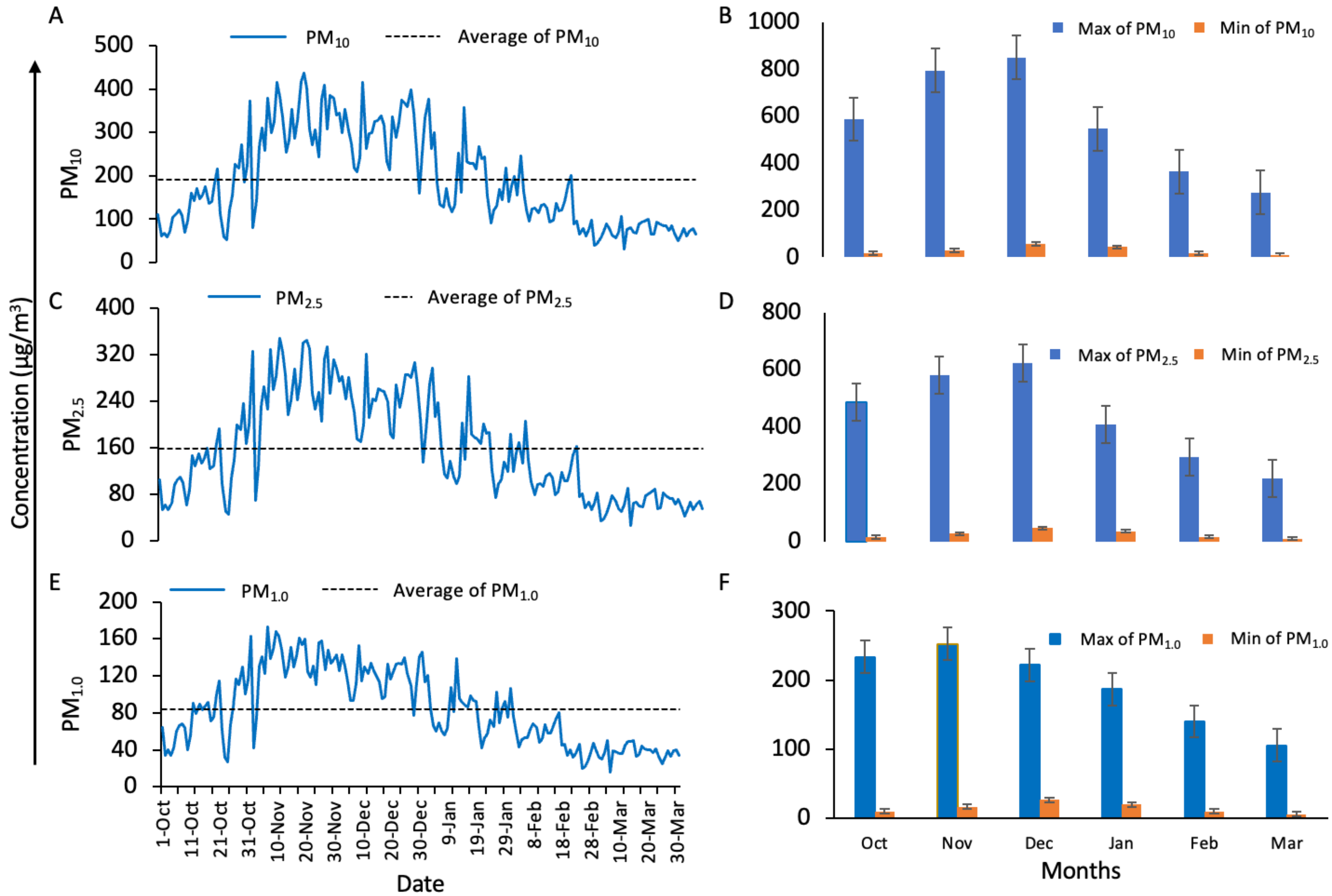

Figure 2. Average values of PM_{10} (A), $PM_{2.5}$ (C), PM_{10} (E)in µg/m^3. Maximum and minimum values of PM_{10} (B), $PM_{2.5}$(D) and $PM_{1.0}$(F) in µg/m^3 in Gulberg III residential study area of Lahore during the study period from October 2022 to March 2023.

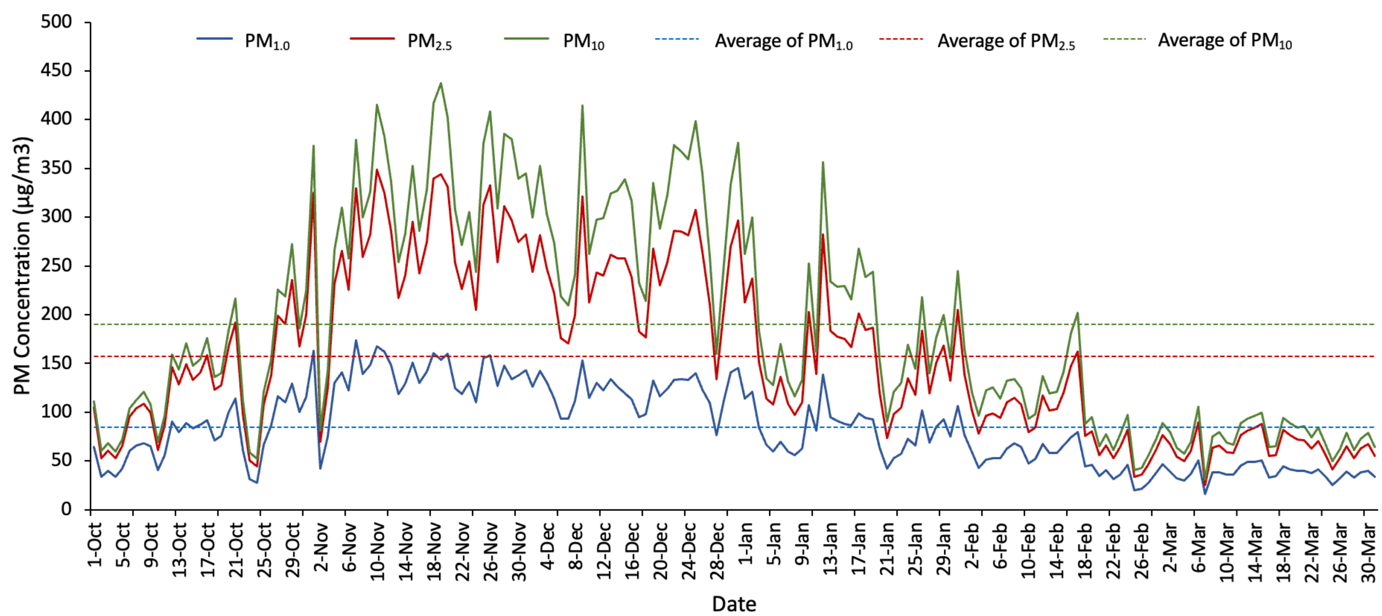

Figure 3. Average Values of $PM_{1.0}$, $PM_{2.5}$, PM_{10} (µg/m^3) from October 2022 to March 2023.

fires burned anytime in the 409 km stretch between Delhi, India and Lahore, Pakistan. Since that time, air pollution levels across the region remained “very harmful”. This air quality means that all 50 million residents unprotected are likely to encounter some harmful effects as a result. The maximum open-air $PM_{2.5}$ concentrations has earlier been reported in winters 14 ± 12 μg/m^3 (Connolly et al., 2022). The peak of PM_{10} concentration was noted over winter (November), while maximum $PM_{2.5}$ concentrations was recorded in the winter (November). The concentration of $PM_{2.5}$ was noticeably high 28.7 μg/m^3 to 149.5 μg/m^3, by an average of 63.1 ± 22.6 μg/m^3 than the guidelines of WHO (35 μg/m^3) (Yin et al. 2022). From January to March the 24-hr. daily concentration of $PM_{2.5}$ and PM_{10} were measured at four different sites in Delhi. The results indicated that $PM_{2.5}$ and PM_{10} for the levels exceeded the standard guidelines of NAAQS that were 26.4 μg/m^3 to 217.8 μg/m^3 and 29.4 μg/m^3 to 496.1 μg/m^3 respectively (Shanmuga et al., 2022). The combustion of biomass source accounts for 8% of the average PM_{10} at a residential sea urban site (Galindo et al., 2021). The concentrations of $PM_{2.5}$ and PM_{10} in outdoor air exceeded the acceptable range of 35 μg/m^3 and 150 μg/m^3 respectively by PAK-EPA (Asghar et al., 2024).

Conclusion

Taken together these observations it can be concluded that the peaked levels of PM impacted the air quality of the study site. Besides the urban factors, other contributors to this worst air quality are the farm fires, fossil fuel burning, and other environmental abuses carried out by the public at large. Serious efforts at community, urban as well as national levels are required to improve the air quality of the urban areas for health community.

Author contributions

SSIB; perceived the idea, designed the study, analyzed the data, corrected and approved the manuscript, AN and SM executed the study, compiled the data, and prepared the manuscript draft.

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