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# *Monitoring of Ambient Air Pollution in Lahore City*

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**ABSTRACT:** Lahore is facing different environmental issues, including air pollution. The present study was conducted to measure the level of different air pollutants in the ambient air of Lahore city. Six ambient air pollutants ($PM_{2.5}$, $PM_{10}$, NO, $NO_2$, $SO_2$, and $O_3$) were measured with the standard method. Different instruments were used for measuring target pollutants. These instruments include CO analyzer, NOx analyzer, $SO_2$ analyzer, ozone analyzer and BAM analyzer. Results were compared with Punjab Environmental Quality Standards (PEQS). The level of fine particulate matter ($PM_{2.5}$) was found as 55.99 µg/m$^3$, higher than PEQS i.e. 15µg/m$^3$. The mean concentration of course particulate matter throughout the year was found as 105.08 µg/m$^3$, which was lower than PEQS i.e. 120 µg/m$^3$. The mean level of NO was 54.56 µg/m$^3$, which was higher than the PEQS (40 µg/m$^3$). The annual average level of $SO_2$ was 23.56µg /m$^3$, which is lower than PEQS (80µg /m$^3$). Higher levels of air pollutants can cause health issues among the city's residents. Regular monitoring and necessary mitigation measures should be implemented to control the level of pollutants in the city.

**Keywords:** Urbanization, Air pollution, Ambient air, Particulate matter, Gaseous pollutants

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## Introduction:

Pakistan is facing different environmental problems such as climatic changes, air pollution, winter smog, water pollution, soil contamination and land degradation. There is huge change in temperature and rainfall anomalies in different cities of Punjab province, including Lahore. Problems of land use changes and decreased forest areas have also been found in different cities of the province [1]–[4]. Different chemicals are being introduced to the environment due to different anthropogenic and natural activities. It causes different environmental impacts. Reliance on fossil fuels and natural resource depletion are important factors that cause change in atmospheric composition [5], [6].

Urban air pollution poses a significant environmental challenge in developing countries across the globe. The primary sources of this issue stem from the release of gaseous pollutants during urban transportation and industrial activities, which include heavy metals, $SO_x$, $NO_x$, CO, and particulate matter [7]. The emission of harmful pollutants into the atmosphere, collectively known as air pollution, affects human health and degrades the overall environmental quality [8]. The expansion of urbanization, industrialization,

the escalating number of vehicles, and substandard road conditions have gradually deteriorated ambient air quality [9].

Among the most hazardous air pollutants are particulate matter ($PM_{10}$ and $PM_{2.5}$), sulphur dioxide ($SO_2$), nitrogen dioxides ($NO_2$), carbon monoxide (CO), and ozone ($O_3$). Prolonged exposure to these pollutants can lead to a range of health issues, including premature death, respiratory ailments, eye irritation, and cardiovascular problems [10]. Lahore's air quality is measured by an air-quality index of 161, with $PM_{2.5}$ being the prominent pollutant, classifying the air as poor according to the US AQI standards. There is increase in built-up area by 57%, decrease in green cover by 21%, decrease in open area by 42% and decrease in 58% in water bodies [11]. The city's air pollution primarily arises from a combination of emissions from vehicles, industrial sources, and smoking. Lahore, being a rapidly growing city with a significant population, features a network of forty-two major and busy roads throughout its expanse [12]. Present study was conducted to analyze levels of different gaseous and particulate pollutants in the ambient air of Lahore city.

**Methodology:**

**Study area:** The current study was carried out in Lahore, the capital of the Punjab province and the second-largest metropolis in Pakistan after Karachi. The average annual temperature in Lahore is 30 °C, with June being the hottest month, recording an average temperature of 37 °C. Conversely, January is typically the coldest month, with an average temperature of 21 °C. This results in a temperature difference of 16 °C between the warmest and coldest months. With an average annual precipitation of 838.8 mm, Lahore exhibits a semi-dry climate.

**Study time:** Secondary data on the ambient air pollutant concentrations of Lahore was collected from Environmental Protection Department (EPD) for a period of one year on daily basis. Average level (monthly) data was estimated for the twelve months.

**Target parameters:** The six ambient air pollutants ($PM_{2.5}$, $PM_{10}$, NO, $NO_2$, $SO_2$ and $O_3$) were target varibales and their levels were compared with Punjab Environmental Quality Standards (PEQS).

**Monitoring of air pollutants:** Data for ambient air pollutants (carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone, and particulate matter) was collected in the collaboartion with Environmental Protection Department (EPD) on an hourly basis at Pakistan Meterological Department, near Shadman, Jail Road, Lahore. Table 1 presents the specific tools and instruments used at each air quality monitoring station to measure the primary pollutants.

Table 1. Ambient Air Quality Pollutants and its Instruments with range and detection limit

| Pollutant | Instrument | Range | Method | Detection Limit |
|---|---|---|---|---|
| CO | CO Analyzer | 0~50 ppm | non-dispersive infrared ray method (ISO4224) | 0.1ppm |
| NO/ $NO_2$ /NOx | NOx Analyzer | 0~1 ppm | Chemiluminescence (ISO7996) method | 0.5 ppb |
| $SO_2$ | $SO_2$ Analyzer | 0~0.5 ppm | U.V. fluorescence method (ISO10498) | 1 ppb |
| $O_3$ | Ozone Analyzer | 0~1ppm | UV photometry method | 0.5 ppb |
| $PM_{2.5}$/$PM_{10}$ | BAM Analyzer | 0~5 mg $m^{-3}$ | Gravimetric Method/Beta attenuation Method | - |

**Statistical analysis:** Mean values of monthly air pollutants were estimated using MS-excel and are represented in graphs. Statistical analysis was performed in terms of correlation which includes standard deviation, Kurtosis and Skewness among concentration of pollutants.

**Results and Discussion:**

**Particulate Pollutants:** The fluctuation in pollutant levels is associated with various anthropogenic sources as well as seasonal variations. All pollutants showed variation in concentration during different months. Figure 1 shows monthly average concentration of pollutants during the study period. The concentration of $PM_{2.5}$ showed substantial changes during the monitoring period. August had the lowest $PM_{2.5}$ concentration, measuring 23.3 μg/$m^3$, which was probably caused by higher precipitation. On the other hand, December showed the greatest level of $PM_{2.5}$, reaching 117.6 μg/$m^3$. It is important to note that the mean $PM_{2.5}$ concentration for the year of 2019 was estimated as 55.99 μg/$m^3$, which was much higher than the PEQS i.e. 15 μg/$m^3$. This suggests that the measured location had consistently high levels of $PM_{2.5}$, indicating poor air quality and potential health concerns from fine particulate matter. Previous studies showed that the concentration of $PM_{2.5}$ was 70 μg/$m^3$ in November 2017 in Gulberg area of Lahore and this mean value was lower than other areas such as Jail Road and Ravi Road where $PM_{2.5}$ levels were 147 and 170 μg /$m^3$, respectively [13]. The previous five-year data from 2007 to 2011 showed that the mean $PM_{2.5}$ level during winter remained 157 and 171 μg/$m^3$ at Town Hall and Township sites, respectively and 99 and 115 μg/$m^3$ during summer and 66 and 97 μg/$m^3$ during rainy season [14]. The mean concentration of $PM_{10}$ throughout the year was 105.08 μg/$m^3$ which was within safe limits of 120 μg/$m^3$ (PEQS). But $PM_{10}$ concentration was five times higher than the guidelines given by World Health Organization (20μg/$m^3$).

$PM_{2.5}$ and $PM_{10}$ have significant negative effects on human health. These microscopic particles can readily go into the respiratory system, which can have a number of negative

health effects. Respiratory conditions such asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) have been linked to exposure to $PM_{2.5}$ and $PM_{10}$ [15]. Additionally, these pollutants can exacerbate cardiovascular issues including hypertension, heart attacks, and strokes [16]. Lung cancer risk is also elevated with prolonged exposure to these contaminants. In conclusion, exposure to $PM_{2.5}$ and $PM_{10}$ can have negative effects on human health, especially on the cardiovascular and respiratory systems [17].

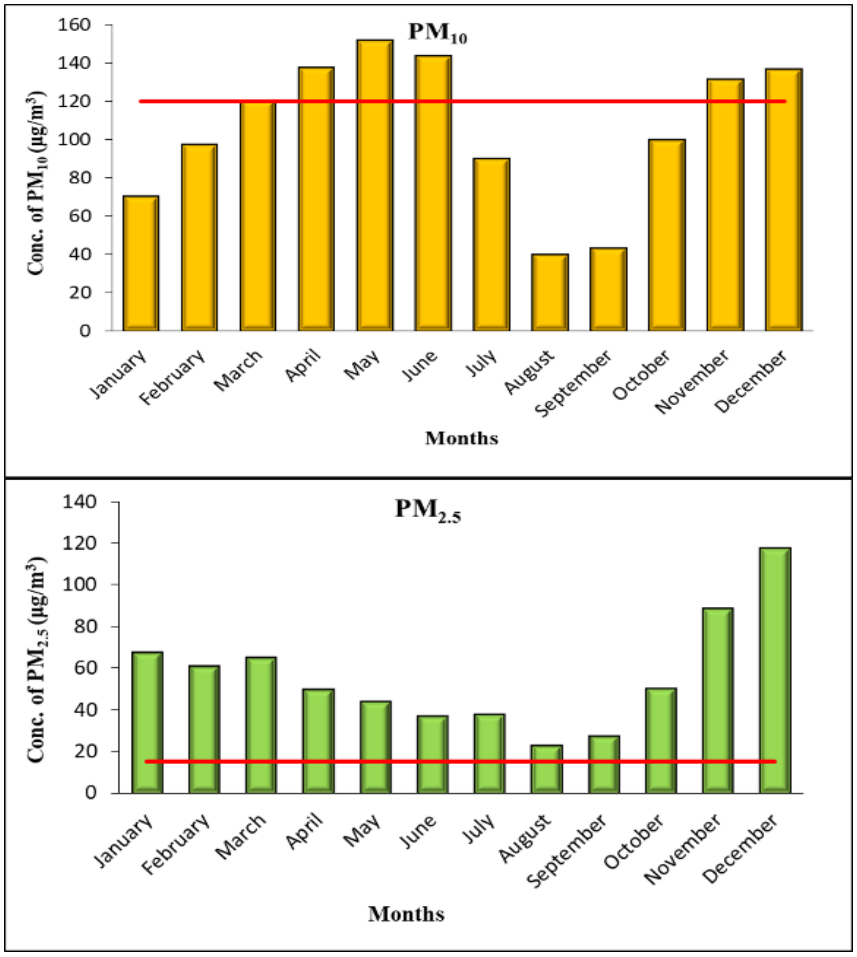



Figure 1. Levels of $PM_{2.5}$ and $PM_{10}$ in different months of Lahore. Means values are given in the graphs. Horizontal line shows standard value of PEQS for the parameter.

**Gaseous Pollutants:** Level of nitric oxide (NO) concentration varied greatly throughout the monitoring period, with August having the lowest recorded concentration of 7.3 µg/m$^3$. In contrast, December recorded the greatest NO content, measuring 160.1 µg/m$^3$. The average concentration of NO during the observation period was determined to be 54.56 µg/m$^3$. It is significant to note that the average NO level was higher than the PEQS of 40 µg/m$^3$, suggesting that the monitored area's air quality was below than acceptable levels. According to previous study, maximum concentration of NO during winter is due to stable atmospheric condition and temperature inversion [18]. The level of $NO_2$

(nitrogen dioxide) varied noticeably over the duration of the observation period. The lowest $NO_2$ content, 20.1 μg/m³, was found in September, while the highest, 95.7 μg/m³, was found in November. The average annual $NO_2$ concentration was found to be 66.04 g/m³. It is noteworthy that the monitored area did not fulfil the necessary air quality criteria because the annual mean $NO_2$ concentration was higher than the PEQS (40 g/m³). Sulphur dioxide is considered as a toxic gas released during industrial process, diesel fueled vehicles and power generation plants [6]. The level of $SO_2$ (sulphur dioxide) varied noticeably throughout the observation period. The lowest $SO_2$ level of 11.1 μg/m³ was recorded in July, while the highest level of 41.5 μg/m³ was recorded in January. It was found that the yearly average $SO_2$ concentration was 23.56 μg/m³. Importantly, the annual average $SO_2$ concentration remained substantially below than PEQS. The monitored region had excellent air quality criteria for $SO_2$, as indicated by the reported average value of 23.56 μg/m³, which is below the PEQS of 80 μg/m³. $SO_x$ is one of the major pollutants that deteriorate the environment and human health [19]. The annual mean concentration of ozone ($O_3$) remained 47.7μg/m3 which was well within one hour standard for $O_3$, but no annual standard level is set for $O_3$. According to WHO standards, $O_3$ level should be 100μg /m³ per 8-hour mean whereas according to PEQS, it must be 130 μg/m³ per 1-hour mean. Recent studies have revealed that $PM_{2.5}$, $PM_{10}$, NO and $NO_2$ exceeded PEQS in the smog season [20]. Use of public transport should be promoted in urban areas of Lahore which reduces emission of air pollutants [12].

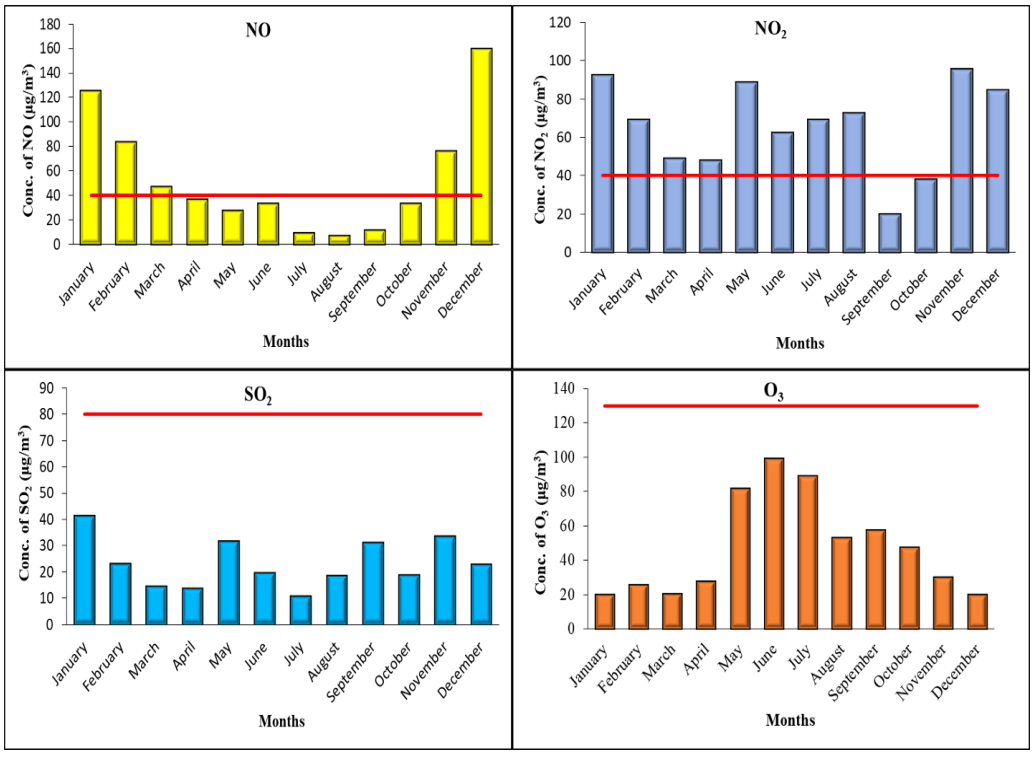



Figure 2: Levels of NO, $NO_2$, $SO_2$ and $O_3$ in different months of Lahore. Means values are given in the graphs. Horizontal line shows standard value of PEQS for the parameter

**Statistical Analysis:** Positive correlation was observed between $PM_{10}$, $PM_{2.5}$, NO, $NO_2$ while negative correlation was observed between $PM_{10}$ and $SO_2$. Skewness and Kurtosis of the concentration curve was also measured to show the mode of distribution of the data. Results showed that distribution curve of $PM_{10}$ and $NO_2$ were negatively skewed -0.6093 and -0.54, respectively showing that respective mean level is less than median. Kurtosis of $PM_{10}$, $NO_2$, $SO_2$ and $O_3$ was also negative and found that the data has flatter peak as compared to normal distribution. The data of $SO_2$ and $O_3$ was positively skewed but kurtosis was negative. The low level of $SO_2$ showed less contribution from industrial (diesel and coal) sources. Less use of diesel engines in vehicles leads to lower level of $SO_2$ in the city area. It showed that minimum level of $PM_{2.5}$ is still greater than the annual WHO guidelines for $PM_{2.5}$.

Table 2. Statistical Correlation among the air pollutants

| | $PM_{10}$ | $PM_{2.5}$ | NO | $NO_2$ | $SO_2$ | $O_3$ |
|---|---|---|---|---|---|---|
| $PM_{10}$ | 1 | | | | | |
| $PM_{2.5}$ | 0.46349 | 1 | | | | |
| NO | 0.245718 | 0.889341 | 1 | | | |
| $NO_2$ | 0.304713 | 0.488146 | 0.531932 | 1 | | |
| $SO_2$ | -0.13952 | 0.234662 | 0.424477 | 0.415566 | 1 | |
| $O_3$ | 0.060131 | -0.64044 | -0.64762 | -0.09604 | 0.20357 | 1 |

Table 3. Descriptive statistics analysis of the air pollutants in Lahore

| Parameters | Mean | Median | Standard error | Standard deviation | Kurtosis | Skewness | Range | Mini. | Max. |
|---|---|---|---|---|---|---|---|---|---|
| $PM_{10}$ | 105.08 | 109.9 | 11.05 | 38.30 | -0.885 | -0.609 | 111.66 | 40.01 | 151.67 |
| $PM_{2.5}$ | 55.99 | 50.25 | 7.72 | 26.77 | 1.38 | 1.14 | 94.26 | 23.34 | 117.61 |
| NO | 54.56 | 35.29 | 13.93 | 48.27 | 0.74 | 1.22 | 152.79 | 7.34 | 160.14 |
| $NO_2$ | 66.04 | 69.39 | 6.76 | 23.44 | -0.42 | -0.54 | 75.61 | 20.18 | 95.79 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $SO_2$ | 23.56 | 21.48 | 2.65 | 9.21 | -0.46 | 0.58 | 30.40 | 11.16 | 41.56 |
| $O_3$ | 47.76 | 38.88 | 8.34 | 28.91 | -0.92 | 0.74 | 79..60 | 19.89 | 99.50 |

## Conclusion

Human activities are primarily responsible for the release of gaseous emissions into the atmosphere in urban areas. Winter seasons exhibit the highest pollution levels due to factors such as reduced precipitation, low wind speeds, and increased inversion caused by lower temperatures. Conversely, pollution levels are comparatively lower during summers due to abundant rainfall, higher wind speeds, and enhanced dispersion facilitated by higher temperatures. However, ozone levels remain high during summers due to increased solar radiation. The results indicated that level of air pollutants were higher than standards. Particulate pollutants ($PM_{2.5}$ and $PM_{10}$) had higher levels than Punjab Environmental Quality Standards (PEQS). Similary, gaseous polluatnts including NO and $NO_2$ showed higher levels as compared to PEQS, but $SO_2$ and $O_3$ shows lower concentration as compared to permissible limit of PEQS. There is a strong positive correlation among pollutants such as $PM_{10}$, $PM_{2.5}$, NO, and $NO_2$, suggesting a common source of pollution for these substances. On the other hand, $SO_2$ does not exhibit a high correlation with these pollutants, likely due to reduced usage of diesel and coal in the studied area. Ozone demonstrated a negative correlation with most pollutants due to lower levels at night and during winters when solar radiation is absent or minimal. Daily analysis revealed that pollution levels tend to be higher during night time due to reduced dispersion caused by lower temperatures. In order to decrease pollutants' emissions in urban areas, it is imperative to shift towards clean energy sources such as natural gas, hydropower, wind power, nuclear power, solar power, and reduce the reliance on fossil fuels such as coal and heavy oil as energy sources. It is essential to prioritize the development of public transportation systems, aiming to decrease traffic congestion and recrease emission from vehicles.

**Author's Contribution:** H.M.M. & I.A., Conceptulization; H.M.M., & R.H., Data Collection; I.K. & R.N. Supervision; H.M.M. & R.H., Data Analysis; I.K. & I.N., Draft Preparation; I.N., M.A.I. A.A.A.K. & S.I.H.S., Draft Revision.

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