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Assessing the Status of Air Pollution in the selected Cities of Pakistan

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ABSTRACT

This study was conducted to assess air quality status in the selected cities of Pakistan through Air Quality Index (AQI) and Multi Pollutant Index (MPI) and their correlation. Secondary data on air pollutants' concentrations for the year 2021 were used from the literature. For this investigation, major air pollutants including carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter were used and compared with Punjab Environmental Quality Standards. Air quality indices, Multi Pollutant Index (MPI) and the Air Quality Index (AQI) were used in the study. Overall condition of the air pollutants in the particular location was described using the Air Quality Index. For this formula, the average concentration of each pollutant across a range of time periods was first calculated. The concentration of each pollutant was then divided by the relevant standard value, which was then cumulatively averaged and represented as a percentage. Results showed that Lahore and Karachi are two of the cities with unhealthy to hazardous AQI values and poor air quality according to MPI values. Air quality is deteriorating in industrial and traffic-congested cities where pollution levels significantly exceeded the threshold values. Using the linear regression, the results confirmed the strong association between the AQI and MPI. There is a need for immediate action to be taken to lower pollutants' concentrations and improve air quality in urban areas.

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INTRODUCTION

Air is one of the key elements required to sustain life. On a global scale, the general public, the government, and the scientific community begin to worry about it (Fan, 2022). Air pollution is the emission of harmful pollutants into the atmosphere that may have adverse consequences on not only human health but also on the quality of the planet as a whole (Irshad et al., 2020). The ambient air quality has gradually deteriorated as a result of urbanization, industrialization, increased number of vehicles, and awful road conditions (Uddin, 2022). The two main contributors to air pollution are motor vehicles and industrial emissions. The contaminant could be anything from the sneeze-induced particles to the cancer-causing compounds released by industry (Karimi, 2021).

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Particulate matter (PM_{10} and $PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxides (NO_2), carbon monoxide (CO), and ozone (O_3) are the most dangerous air pollutants. Scientific research has been done on how air pollution affects human health. Long-term exposure to pollutants can result in a variety of health issues, including early death, respiratory ailments, eye irritation, and cardiac issues (Jyothi, 2019). Zhao et al. (2019) found that air emissions in China have very negative effects. Numerous studies have shown that those who breathe dirty air are more likely to develop respiratory and cardiovascular conditions (Fan, 2020). According to the World Health Organization (WHO), SO_2 and particles smaller than micron can lead to respiratory and cardiovascular conditions like asthma, bronchitis, heart attacks, impaired lung function, and death. Additionally, with a concentration of 10 g/m^3 for particles smaller than 10 um, there has been a 6% rise in mortality in various European towns. The size of particles in the air has been one of the key health problems of cities in recent years, along with changes in the distribution and number of secondary pollutants like ozone. According to statistics, epidemiological research conducted over the past 20 years has demonstrated a correlation between outdoor air pollution and an increase in respiratory failure, cardiovascular illness, chronic bronchitis, and even mortality, which is linked to worldwide mortality. Roughly 1.3 million people died from air pollution in 2010, compared to nearly one million in 2000, with the Asian continent accounting for more than half of these fatalities (Taghizadeh, 2019).

For the general public to easily understand how good or bad the air quality is for their health and to help in the data interpretation for decision-making processes related to pollution mitigation measures and environmental management, AQI and MPI are important indicators of the health effects of air pollutants (Kumar, 2022). An AQI is a generalized method that divides each concentration of specific parameters related to air pollution (SOx, NOx, CO, PM_{10}, and $PM_{2.5}$) into sub-indices, which are then compared to a predetermined scale to assess the quality of the air. MPI, developed by Gurjar et al. (2008) and Du et al. (2012) can be used to assess the combined pollution levels of many pollutants and to compare the levels of air pollution in various cities or urban regions.

Trend analysis on air pollution in most cities is very constrained due to a lack of reliable data. This study used Lahore, Faisalabad, Karachi, Peshawar, Quetta, and Islamabad as the case cities and conducted a thorough review of the situation of urban air pollution for better understanding of air pollution in Pakistan's cities. Through the use of AQI, the MPI, and their correlation, this study sought to ascertain the status of ambient air quality in the chosen cities of Pakistan. CO, SO_2, NO_2, and $PM_{2.5}$ and PM_{10} were chosen as the primary pollutants, and the alterations in pollution patterns were examined. This study develops a new statistical approach to selected data for 2021 to evaluate and compare pollution concentrations by using two air quality indices in different selected cities to assess their air quality. This research focuses on the most commonly used guideline-based air quality indices, such as the "Air Quality Index" (Tabinda, 2020) and the "Multi Pollutant Index" (Gurjar et al., 2008). This study will be useful for policymakers in order to improve air quality and advance sustainable development because they are based on the same criteria to address air quality and its effects on health by using different methodologies.

MATERIAL AND METHODS

In this study, six selected cities of Pakistan including Lahore, Faisalabad, Quetta, Peshawar, Karachi, and Islamabad were selected as study areas. Lahore is second largest city of Pakistan and capital of Punjab Province with a population of 6.31 million. Faisalabad is the third largest city of Pakistan with a population of 2.51 million. Quetta is capital city of Balochistan province with a population of 0.73 million. Peshawar is capital city of Khyber Pakhtunkhwa (KPK) with a pollution of 1.22 million. Karachi is the largest city of the country and capital of Sindh province with a population of 11.62 million. Islamabad is the capital of Pakistan with a population of 6.02

million (World Population Review, 2022).

Secondary data on the ambient air pollutant concentrations in six selected cities in Pakistan for the year 2021 was collected from research papers, Pak-EPA website, Punjab EPD air quality reports, etc. For this investigation, the five ambient air pollutants (CO, NO_2, SO_2, $PM_{2.5}$, and PM_{10}) were used and compared with National Environmental Quality Standards (NEQS) as shown in **Table 1**.

There are currently six air quality monitoring stations in Pakistan that measure the levels of key pollutants such as carbon monoxide, nitrogen dioxide, sulphur dioxide, and particulate matter ($PM_{2.5}$ and PM_{10}) on hourly basis. These air quality monitoring facilities were constructed to continually gather, measure, and monitor all the specified ambient air quality information. Each air quality monitoring station has a set of tools that are used to measure the principal pollutants.

The data was analyzed through two air quality indices i.e. Air Quality Index and Multi Pollutant Index. The overall state of the gaseous air pollutants in the specific location was described using the Air Quality Index. The AQI is helpful in assessing the level of pollution in a certain location. Environmental Protection Agency (Pak-EPA), is the provider of the AQI colour coding. According to Eq. 1, the AQI was determined.

$$AQI = \left(CO/5\right) + \left(NO_2/40\right) + \left(SO_2/80\right) + \left(PM_{2.5}/15\right) + \left(\left(PM_{10}/120\right)\right)/5 \times 100 \quad (1)$$

This formula was used first by calculating the pollutants' average over various time periods, then turning each pollutant's concentration into its index by dividing it by the appropriate standard value, which was then cumulatively averaged and expressed in percentage (Tabinda, 2020). **Table 2** depicts the Air Quality Index (AQI) and health effects of selected pollutants.

Secondly, Multi Pollutant Index was used to lessen the potential influence of subjective assessments on the amount of emissions in selected cities based on levels of pollution with one or even more contaminants in a specific megacity, the MPI was chosen. The following equation represents the MPI (Gurjar, 2008; Lokys, 2015):

$$MPI = \left(1/n\right)\left[\sum\{(ACi - GCi/GCi\}\right] \quad (2)$$

Where, *i* is the pollutant under consideration (for example, CO, SO_2, NO_2, $PM_{2.5}$, or PM_{10}), *n* is the number of pollution taken into account, *ACi* is pollutant's atmospheric concentration in a megacity's background air and *GCi* the pollutants recommended concentration.

To evaluate the significant relationship between AQI and MPI, one-way ANOVA testing and linear regression (R^2) for correlation were deemed to be the most acceptable methods.

Table 1. Standard Guideline Values of National Environmental Quality Standards (NEQS)

Sr. No	Pollutants	Standards
1.	Carbon Monoxide (CO)	5 mg/m^3
2.	Sulphur Dioxide (SO_2)	80 µg/m^3
3.	Nitrogen Dioxide (NO_2)	40 µg/m^3
4.	Respirable particulate matter. $PM_{2.5}$	15 µg/m^3
5	Respirable particulate matter. PM_{10}	120 µg/m^3

(Source: Pak-EPA, 2010)

Table 2. Air Quality Index and its Health Impacts

Sr. No.	Range	AQI Category	Health Impacts
1	0 -50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk.
2	51 -100	Moderate	Air Quality is acceptable, however for some pollutants there may be more moderate health concerns for a small number of people .
3	101 - 150	Unhealthy for Sensitive People	Members of sensitive groups may experience health effects. The General Public is not likely to be affected.
4	151 - 200	Unhealthy	Everyone may begin to experience health effects, members of sensitive groups may experience more serious health effects.
5	201 - 299	Very Unhealthy	Health Alert: Everyone may experience more serious health effects .
6	300 - 500	Hazardous	Health warnings of emergency conditions. The entire population is more likely to be affected.

(Source: Jyothi, 2019)

Table 3. Average Ambient Air Pollutant Concentrations in Selected Cities of Pakistan

Sr. No.	City	CO (mg/m^3)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	References
1.	Karachi	0.00105	63.43	89.19	95	384.4	(Ahmad et al, 2022)
2.	Lahore	1.68	20.84	19.21	175	310	(IQ Air, 2021) (EPD, 2021)
3.	Faisalabad	0.00195	25.7	19.81	36.5	172	(Aslam, 2021) (Master Plan Report, 2021)
4.	Peshawar	0.0064	15.64	29.58	35.88	434.62	(EPD, 2021) (IQ Air, 2021)
5.	Islamabad	3.5	14	20.83	29.2	75.1	(EPD, 2021)
6.	Quetta	0.0011865	37	68	35.2	181.5	(Hussain, 2021) (IQ Air, 2021)

RESULTS AND DISCUSSION

Table 3 shows ambient pollutant concentration of the target pollutants (CO, NO_2, SO_2, $PM_{2.5,}$ and PM_{10}) and sources of relevant research studies.

Among all the selected areas, the lowest average concentration of CO was in Peshawar (0.0064 mg/m^3) and the highest concentration was in Islamabad (3.5 mg/m^3) which indicates that all values are below than NEQS (5 mg/m^3). The highest average concentration of NO_2 was in Karachi (63.435 $\mu g/m^3$) and the lowest concentration was in Islamabad (14 $\mu g/m^3$). NO_2 levels were below than the guidelines (40 $\mu g/m^3$) except in Karachi. The highest average concentration of SO_2 in Karachi was 89.19$\mu g/m^3$ and the lowest concentration was 19.21$\mu g/m^3$ in Lahore. SO_2 levels were below than the guidelines (80 $\mu g/m^3$) except Karachi. The highest average concentration of $PM_{2.5}$ was in Lahore (175$\mu g/m^3$) and the lowest one was in Islamabad (29.2 $\mu g/m^3$). Levels of $PM_{2.5}$ were above the recommended values by NEQS (15 $\mu g/m^3$). The highest average concentration of pollutant PM_{10} was in Peshawar (434.62$\mu g/m^3$) and the lowest concentration was in Islamabad (75.1 $\mu g/m^3$). Levels of PM_{10} exceeded the permissible limit (120

μg/m^3) in all cities except Islamabad, as shown in Fig. 1.

Previous studies also showed that the concentration of NO_2 and SO_2 exceeded the WHO permissible limits as described by Ahmed et al., (2021). Similarly, the literature showed that Lahore was among the most polluted cities with high levels of atmospheric particulate matter exceeding the baseline values suggested by WHO, which leads to serious health impacts (Naveed, 2022; Aslam, 2022). The study found that children who lived and went to school in Lahore's areas with high $PM_{2.5}$ exposures had considerably higher blood pressure than kids who were exposed to less of the particle. According to a study, urban pollution from traffic can increase children's blood pressure and increase their chance of developing hypertension and cardiovascular problems later in life (Bhatti, 2021). According to Riaz (2018), increased $PM_{2.5}$ combined with increased pollution has a negative influence on health.

Air Quality Indexes for selected six cities were estimated using pollutants' concentration as well as their standard values, using the corresponding colour codes. The most polluted city in all six of them was Lahore, which had an average AQI of 307 (hazardous), while Islamabad and Faisalabad had relatively lower average AQIs of 78 and 95, respectively (moderate). Compared to other cities, Karachi, which has an average AQI of 245, is considered to be a highly unhealthy city. Quetta and Peshawar both fall under the category of being unhealthy for sensitive people, with average AQIs of 113 and 136, respectively shown in Fig.2.

The findings revealed that situation in Lahore and Karachi are going to get worse due to unplanned development, urbanization and increased vehicles. The air quality is severely affected by different sources such as vehicles, industrial emissions, and fossil fuel burning, which has led to considerable health issues (Sarmadi, 2021; Ahmed et al., 2021). As previously mentioned, various colour coding was used to show the air quality severity at specific places. The Pak-EPA is the one that provides the colour code. The start of the industrial revolution and other human activities have significantly worsened the air quality. Similarly, fast urbanization and economic development had a negative impact on the quality of the air in cities and have caused other environmental harms that have a negative impact on people's health (Wang, 2018). Furthermore, some studies predicted that the prevalence of lung disorders may increase with the level of air pollution. Children's respiratory illnesses are more common because of their underdeveloped respiratory systems, and suspended particles in the air with sizes between 10 and 2.5 μm can increase newborn mortality. Air pollution affects children and elder people and major health

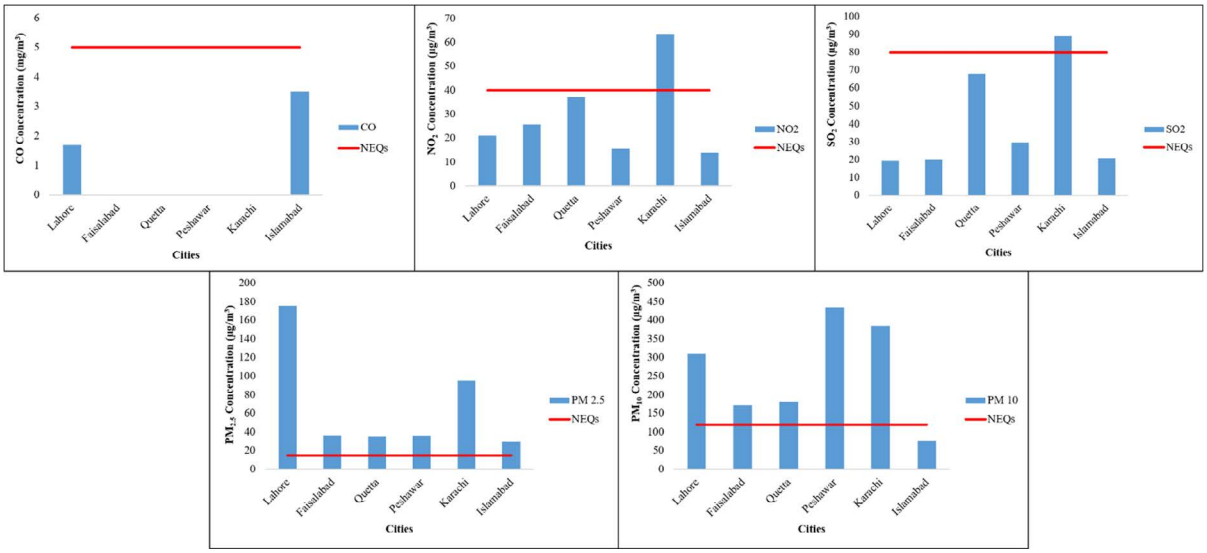

Fig. 1. Comparison of average ambient air pollutant concentration with NEQS

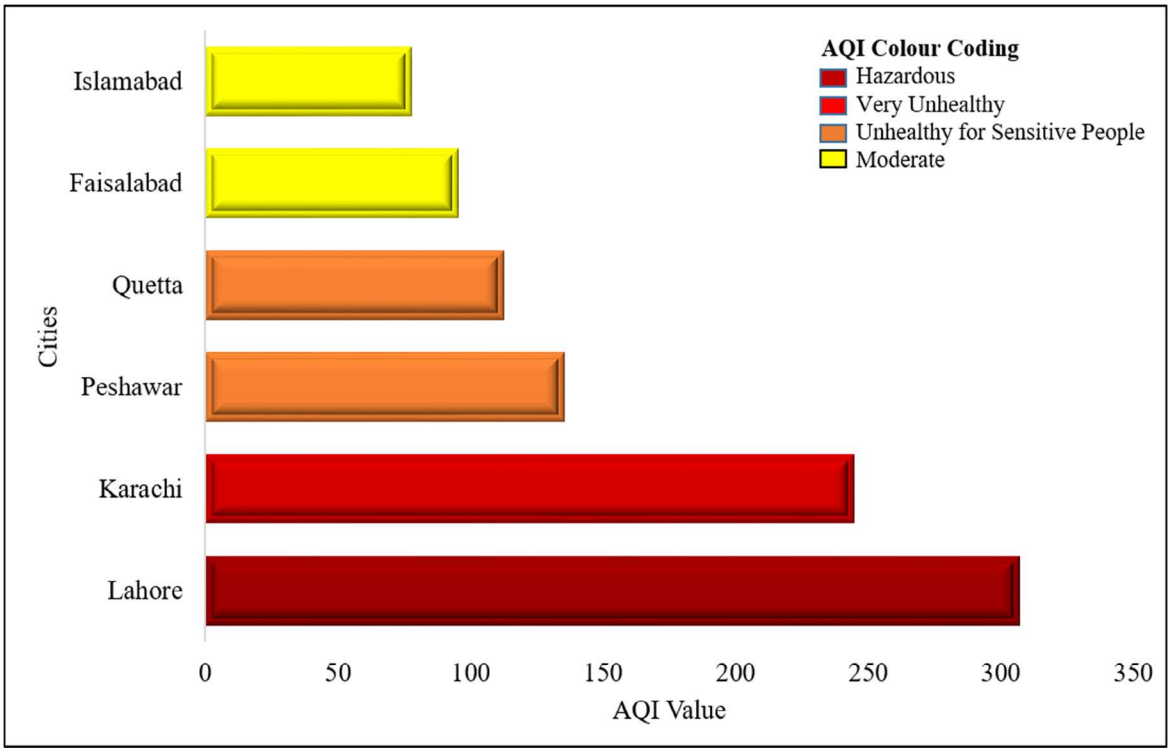

Fig. 2. Air Quality Index of selected cities of Pakistan

Table 4. Multi Pollutant Index of Ambient Air Pollutant Concentrations in Selected Cities of Pakistan

Sr. No	City	CO (mg/m^3)	NO_2 (µg/m^3)	SO_2 (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)
1.	Karachi	-0.16	0.12	0.02	1.07	0.44
2.	Lahore	-0.13	-0.10	-0.15	2.13	0.32
3.	Faisalabad	-0.20	-0.07	-0.15	0.29	0.09
4.	Peshawar	-0.20	-0.12	-0.13	0.28	0.52
5.	Islamabad	-0.06	-0.13	-0.15	0.19	-0.07
6.	Quetta	-0.20	-0.02	-0.03	0.27	0.10

problems include chronic and acute respiratory and cardiovascular disorders (Mehmood et al., 2021; Anwar et al., 2021; Mehmood et al., 2020).

Heavy traffic, the dust created during the development of numerous infrastructure projects, and smoke emissions from many other sources are some of the main emission sources in these chosen cities. The bulk of the selected cities has relatively poor air quality, as indicated by the AQI's black colour coding, as urban regions are increasingly affected by ambient air pollution. Since a few years ago, increased traffic and the number of vehicles on the road have made the existing air quality worse. If appropriate practices are not adopted, it is anticipated that additional pollutants, such as CO, SO_2, and NOx, would also exceed NEQS. So, there is need to pay close attention towards this issue and come up with effective ways to deal with it (Tabinda, 2020).

This study has taken the MPI as a quantitative measure of pollution in a selected cities expressing the combined pollution levels of five criteria pollutants (i.e., CO, SO_2, NO_2, $PM_{2.5}$ and PM_{10}) relative to the guidelines for air quality (Pak-EPA, 2010). As an illustration, **Table 4**

shows ambient atmospheric concentrations of CO, SO_2, NO_2, $PM_{2.5}$, and PM_{10} in terms of their MPI index. The MPI of pollutant CO was found to be fair air quality among all selected cities of Pakistan i.e., Lahore (-0.13), Faisalabad (-0.20), Quetta (-0.20), and Peshawar (-0.20), Karachi (-0.16), Islamabad (-0.06). The MPI for NO_2 was highest in Karachi and lowest in Quetta. According to the MPI of the pollutant SO_2, Quetta had fair air quality while Karachi had poor air quality. All major cities had low MPIs for $PM_{2.5}$, while Lahore had the highest levels. The MPI of PM_{10} was fair in Islamabad and the other five selected cities were poor in air quality.

Air pollution levels are based on MPI for selected cities. It is intriguing to note that, all selected cities in Pakistan show negative values in terms of CO pollutants, which indicates that there is no problem of this pollutant in selected cities in Pakistan. As a result of NO_2, the most polluted megacity was Karachi, while other selected cities show negative values. In Pakistan, SO_2 levels were also high in Karachi, according to the results of MPI. It was found that all major cities were polluted with $PM_{2.5}$ concentrations and, among all, Lahore was found to be the most polluted city. Similarly, PM_{10} was also found to be the cause of air pollution in study area of Pakistan except Islamabad, where issue was not found for PM_{10}, as shown in Fig. 3.

According to the study by Du et al. (2012), the MPI value in Zhengzhou ranged from 0.17 to 2.23, indicating that the air pollution was extremely severe and far worse than it was in Tokyo, Sao Paulo, Los Angeles, and New York, where the MPI ranged from 0.3 to 0. High air pollution in Zhengzhou is a result of the city's low-quality industrial structure, ineffective energy conversion and use, and inefficient air pollution treatment methods. These factors create a strong link between pollution levels and human health. Numerous research and epidemiological studies have revealed a clear link between ambient air quality and human health. People may face health consequences at this level of pollution, but sensitive groups may have severe health issues. Children, adults, and those with respiratory problems like asthma should avoid extended

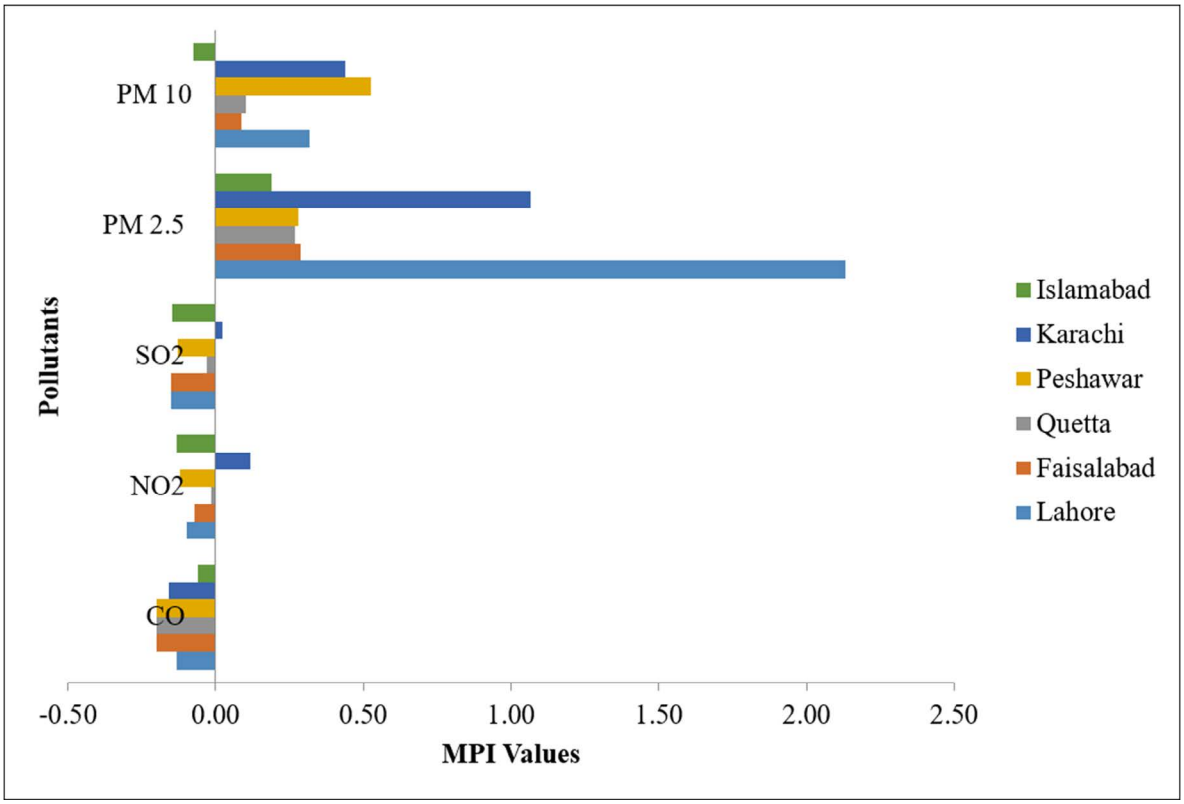

Fig. 3. Multi Pollutant Index of selected air pollutants of selected cities of Pakistan

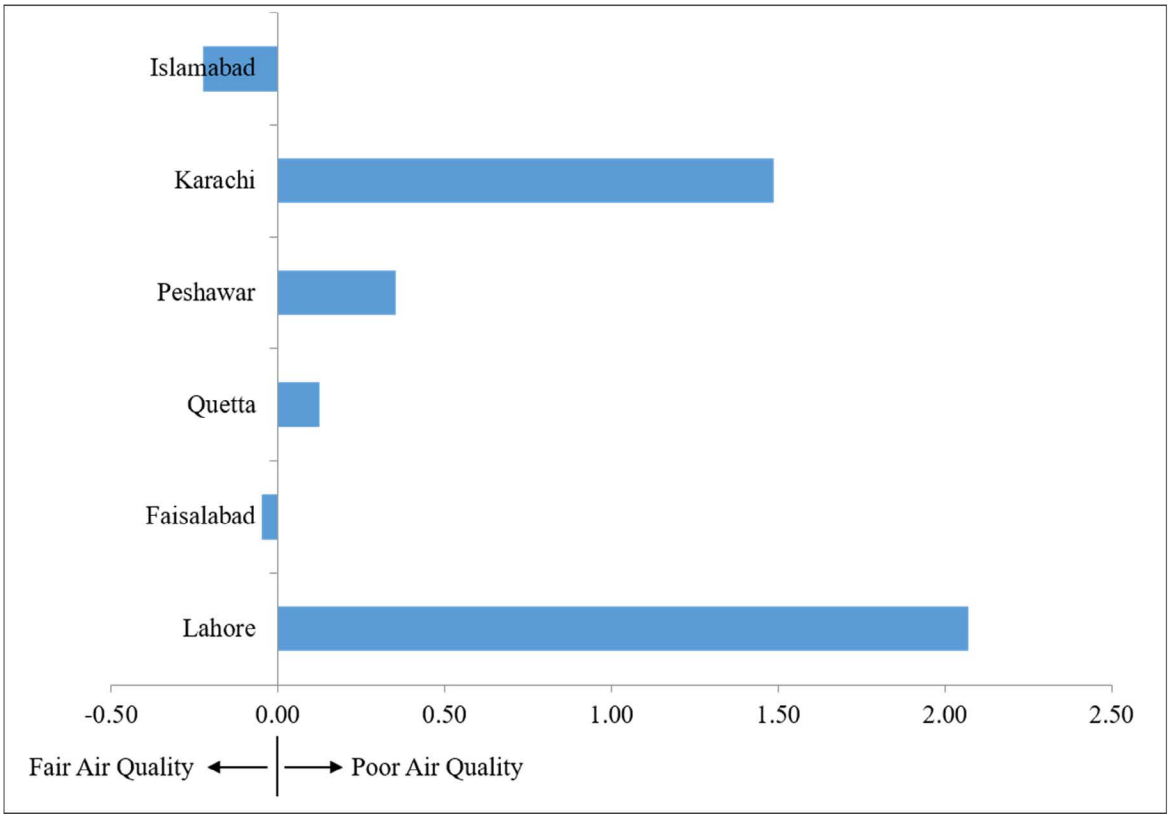

Fig. 4. Multi Pollutant Index based ranking of selected cities of Pakistan

outdoor activity (Verma, 2021; Abel, 2018; Gu, 2016).

The most polluted megacity in 2021 was Lahore, according to the MPI ranking of Pakistan's major cities (Fig 4). Karachi is Pakistan's second-most polluted megacity. This is due to the increasing population, urbanization, and no implementation of relevant policies. Peshawar ranks 3rd polluted city according to the MPI ranking. This is because it is the capital of KPK and the resource burden is expected to be higher in upcoming years if we don't take action to prevent air pollution. Quetta was in the 4th ranked number in Pakistan in terms of the multipollutant index. It can be prevented by taking minor actions to control air pollution. Faisalabad was in the 5th ranked number but it shows negative relation with a borderline value (-0.05). Islamabad was found to have lesser problems of air pollution. Due to the variety of plantations, the air quality is suitable for human settlement. A study revealed Karachi to be the 10th most polluted megacity in the world (Gurjar, 2008). According to previous studies, Islamabad was rated as Pakistan's cleanest city, whereas Lahore and Karachi were among the most polluted cities in the world (Saleemi, 2022; Ali, 2022, Naveed, 2022).

Linear regressions of the relationship of AQI and MPI are shown in Fig. 5. It was shown that AQI and MPI were more highly correlated ($R^2 = 0.9998$). Since all pollutants have an impact on the MPI and AQI, the term "Responsible pollutant" in the index refers to the pollutant that has the most impact on the final index value. According to the calculation method of the MPI and AQI, the responsible pollutant was $PM_{2.5}$ and PM_{10}, which always have the highest percentage of the guideline value because these cities (Lahore and Karachi) are highly-populated which were considered the main reason behind the high concentration of $PM_{2.5}$ and $PM_{10.}$ Industrialization and arid climatic conditions are also important factors responsible for higher PM levels.

Human activities including motor vehicles, industries, and wind-blown dust are causes of PM generation. Air quality issues in Lahore and Karachi have been exacerbated by the high

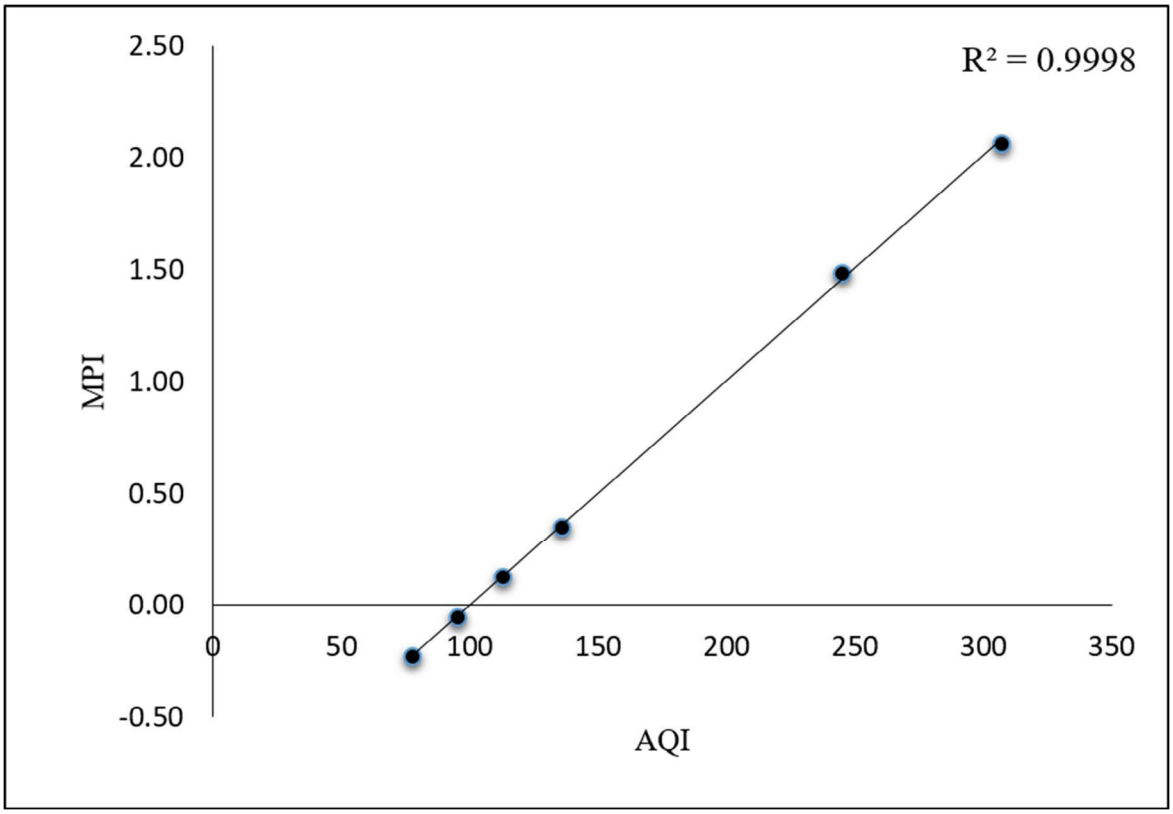

Fig. 5. Linear regression of Air Quality Index and Multi Pollutant Index of selected pollutants of selected cities

Table 5. One-way ANOVA Test Analysis

Source of Variation	df	SS	MS	F	P-value
Between Groups	2	102492.6	51246.3	18.04681	0.000102
Within Groups	15	42594.48	2839.632	--	--
Total	17	145087.1	--	--	--

density of primary industrial sources, the absence of effective pollution controls, and a lack of mass transportation. Statistically, it was also verified that AQI and MPI were highly significant ($p < 0.01$) tested by One-way ANOVA. The results proved that the AQI and MPI value of p was 0.0001 which is less than 0.01 which shows the significant positive trends in the air quality indices (**Table 5**). This suggests that studies of air quality indices might provide a comprehensive picture of air quality and its potential health impacts.

CONCLUSION

Most of the urban areas in Pakistan are facing problem of air pollution and there is a need for a monitoring strategy to evaluate the air pollution. The concentration of pollutants is increasing day by day and exceeding national standards. Except for Karachi, the average CO, NO_2, and SO_2 concentrations were slightly below the permissible limit. However, due to heavy traffic and commercial areas, $PM_{2.5}$ and PM_{10} concentrations were found to be over the permissible limit throughout in all selected cities. It is projected that additional pollutants including CO, SO_2, and NO_2 would also exceed permissible limits if planned countermeasures are not put

into place. According to the AQI category among the selected cities, Lahore and Karachi were revealed to have very unhealthy to hazardous air quality and MPI categories as well as poor air quality. The levels of AQI and MPI in Lahore and Karachi have significantly increased due to the poor ambient air quality, which is largely attributable to $PM_{2.5}$ and PM_{10}. The findings show a strong correlation between the AQI and MPI. The results demonstrate a substantial association between the AQI and MPI values. There is need of careful consideration when making suggestions to policymakers in the future to preserve healthy air quality in metropolitan regions. The development of more environmentally friendly and alternative energy sources, careful traffic planning, advancements in vehicle technology, increased plantation, and the support of concerned authorities are required to control air pollution for sustainable urban management.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors. Proper citations and acknowledgements are made for use of published information.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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