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Assessment of Environmental Pollutants and their Relationship with Chronic Respiratory Disease Exacerbations in Jamshoro: A Cross-Sectional Study

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ABSTRACT

Background: COPD and Asthma are a burden to our society and in a city like Jamshoro having industries and power plants in close vicinity, this becomes a greater concern. The objective of this cross-sectional study was to evaluate the relationship between air quality indices (AQIs) and exacerbations in chronic obstructive respiratory diseases such as asthma and COPD, prevalent among the general population in Jamshoro.

Methods: This cross-sectional study, conducted from August 2023 to February 2024 at LUMHS, Jamshoro (ERC approval: 14287/23/081), used purposive sampling to recruit 300 adults with asthma or COPD. Air quality data (PM10, PM2.5, NO2, SO2) were collected, and respiratory outcomes were measured via spirometry and a validated questionnaire. Pearson's correlation and multiple regression analyzed the association between air quality and exacerbations. Ethical approval and informed consent were obtained.

Results: There was a significant inverse relationship between PM10, NO2, and FEV1 ($r = -0.45$, $p < 0.01$; $r = -0.40$, $p < 0.01$). Chi-square analysis indicated a strong association between AQI categories and exacerbation rates ($\chi^2 = 25.6$, df = 3, $p < 0.001$). Multiple regression showed that PM10 and NO2 were significant independent predictors of respiratory exacerbation ($\beta = 0.049$, $p < 0.01$; $\beta = 0.038$, $p < 0.01$).

Conclusion: The study underscores the adverse respiratory health consequences of poor air quality in Jamshoro and recommends the implementation of effective air quality management policies.

Keywords: Air Quality Index (AQI), Chronic Obstructive Pulmonary Disease (COPD), Asthma, Particulate Matter (PM10, PM2.5), Nitrogen Dioxide (NO2), Spirometry, Exacerbation, Environmental Health.

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INTRODUCTION

Air contamination is a crucial public health issue, specifically in crowded urban cores with significant industrial activities and vehicle emissions[1,2,3]. Past research consistently shows that atmospheric pollution can lead to numerous health issues, especially respiratory diseases like asthma and chronic obstructive pulmonary disease [4,5,6]. This investigation aims to analyze the relationship between air quality indices and exacerbations of asthma and COPD among residents of Jamshoro, a region known for its high pollution levels from industrial and vehicular sources [7,8].

Jamshoro faces similar air quality challenges as other urban centers due to its industrial and geopolitical factors[9]. Locals are exposed to toxins such as particulate matter, nitrogen dioxide, and sulfur dioxide, all of which negatively impact respiratory health [10,11]. Few studies have explored the relationship between these pollutants and respiratory disease outbreaks, making this investigation critical for understanding the public health outcomes in Jamshoro[12]. The connection between air quality and respiratory health is a longstanding concern in environmental health research [13]. Atmospheric pollution remains a significant public health concern, particularly in densely populated industrial areas like Jamshoro, where the prevalence of chronic respiratory diseases is rising [14].

This investigation provides evidence that pollutants, such as particulate matter, nitrogen dioxide, and sulfur dioxide, can exacerbate asthma and chronic obstructive pulmonary disease by triggering an irritative response in lung tissue, reducing pulmonary function, and worsening symptoms [6,12]. Persistent exposure to these pollutants not only worsens respiratory diseases but also affects mortality and morbidity[15,16]. Recent research highlights the direct toxicity of nearby pollution, including fine particulate matter and nitrogen dioxide, even at concentrations below standard air quality thresholds [1,3,7].

In Jamshoro, industrial emissions, traffic congestion, and seasonal atmospheric variations further degrade the pollution profile[8]. Different population groups, such as industrial workers and the elderly, face varying levels of risk, emphasizing the need for comprehensive air quality management strategies[14]. Tailored strategies are essential for managing air quality and protecting vulnerable populations in specific societal and environmental contexts[12].

This research will contribute to the current literature by exploring the link between air quality indices and respiratory disease outbreaks in Jamshoro. By combining laboratory tests and demographic surveys, this study aims to provide objective evidence of the impact of air pollution on asthma and chronic obstructive pulmonary disease patients[10]. The findings will inform public health policies and interventions aimed at reducing the respiratory health impacts of air pollution[13]. The rationale for this study stems from the increasing prevalence of respiratory illnesses in regions with poor air quality, such as Jamshoro, where industrial emissions and vehicle traffic contribute significantly to pollution levels. Understanding the link between air contamination and respiratory disease exacerbations will provide valuable insights for public health interventions. By identifying key pollutants and their health impacts, this research will inform policy measures aimed at improving air quality and reducing the burden of asthma and COPD on the local population[14,16].

METHODS

This cross-sectional study was conducted, from August 2023 to February 2024 at Liaquat University of Medical and Health Sciences, Jamshoro. The study was approved by the Institutional Review Committee ERC letter no 14287/23/081. The study methodology consists of four major components: (a) selecting the participants, (b) collecting air quality data, (c) measuring health outcomes, and followed by statistical analysis.

Participants were recruited from outpatient clinics of Liaquat University Hospital in Jamshoro specializing in respiratory diseases. The sample size was calculated using OpenEpi software, considering a prevalence of asthma and COPD in Pakistan of approximately 10% and 8%, respectively. Previous epidemiological data were used to determine a sample size of 300 subjects, ensuring adequate power to test associations with significant effects. A purposive sampling technique was employed to select subjects based on specific criteria related to the study objectives. The sample size was calculated with a 95% confidence interval and a 5% margin of error, ensuring the reliability and precision of the study findings[4]. Adults (aged over 18 years) with a confirmed diagnosis of asthma, made clinically based on a comprehensive medical history and physical examination, were eligible for inclusion. Asthma diagnosis was confirmed by a clinician using established criteria, while the Global Initiative for Asthma (GINA) guidelines were followed for subsequent management and categorization of asthma severity [19]. For COPD, the diagnosis followed the GOLD criteria eligibility. Exclusion criteria included current smokers, individuals with other severe lung diseases such as lung cancer or pulmonary fibrosis, those with significant co-morbid conditions that could affect respiratory health, such as severe cardiovascular diseases, individuals unable to perform spirometry due to physical or cognitive limitations, and those with a recent acute respiratory infection within the last 4 weeks. Smokers and subjects with other severe lung diseases besides COPD (e.g., lung cancer or pulmonary fibrosis) were excluded, as they might function as confounders.

The daily air quality data for Jamshoro was obtained from the Local Environmental Protection Agency. They were most interested in the following pollutants that they measured: particulate matter (PM10 and PM2. 5): nitrogen dioxide (NO2), Sulphur dioxide, anion-sulfide, and ozone. These pollutants were chosen because of their established connections to respiratory health outcomes as well as for being common urban air contaminants. Concentrations were averaged and the number of days with air pollution higher than guideline values set by the World Health Organization (WHO) was identified.

PM10 (Particulate Matter ≤ 10 micrometers): These coarse airborne particles, found in dust, pollen, and through combustion, easily slip into our lungs and can lead to respiratory issues or deteriorate health if levels get too high.

PM2.5 (Particulate Matter ≤ 2.5 micrometers): Termed as "fine" particulate matter for its tiny size, it penetrates deepest into our respiratory tract and is implicated in serious illnesses like heart and lung disease. Vehicles burning gas and diesel, industrial processes producing goods, and home heating generate much of this pervasive pollution.

NO2 (Nitrogen Dioxide): A gaseous pollutant chiefly from traffic and other processes involving combustion, it can irritate and inflame lung tissue, weaken our immune defenses against infection, and exacerbate existing respiratory problems like asthma.

SO2 (Sulfur Dioxide): Principally emitted by power plants and industrial operations fueled by fossil fuels, this airborne gas has been shown to cause breathing problems, especially in asthma sufferers, while also worsening overall air quality through contributions to fine particle formation and acid rain."

Study endpoints were health outcomes measured by spirometry and a validated, structured questionnaire for respiratory symptom exacerbations. Spirometry testing was performed according to the standards of the American Thoracic Society/European Respiratory Society (ATS/ERS), measuring Forced Expiratory Volume at one second (FEV1) in liters, Total Lung Capacity on Body Plethysmograph Technique and Residue Functional Capacity Trough Helium method. Exacerbations were defined as an increase in required action from the medical team (e. g new medication, hospital, or visits to the emergency department) within 12 months preceding diagnosis. Moreover, age and sex as well as occupational exposure to pollutants were separately recorded to account for possible confounding effects.

The data was analysed through SPSS version 26.0 software. Descriptive Statistics Participant characteristics, air quality data, and health outcomes were summarized using descriptive statistics. The association of air quality indices with lung function measurements was examined by using Pearson's correlation coefficients. Independent predictors of respiratory exacerbations were identified using multiple regression analysis that controlled demographic and clinical variables. Significantly different values $p < 0.05$

Ethical issues involved getting informed consent from participants before participating in this study and that the data collection was treated confidentially, which all took place anonymously.

RESULTS

In this section, we report the results found after correlating air quality indices and chronic respiratory disease exacerbation, specifically asthma & COPD, works done in Jamshoro only. Using data from three hundred participants, the study explores long-term exposure to particulate matter (PM10 and PM2. Sulphur dioxide (SO2) and respiratory health outcomes.

Three hundred participants, including 150 patients diagnosed with asthma and an equal number of those suffering from COPD. The baseline demographic and clinical characteristics of the sample are shown in Table 1.

Table 1: Basic Characteristics of Participants

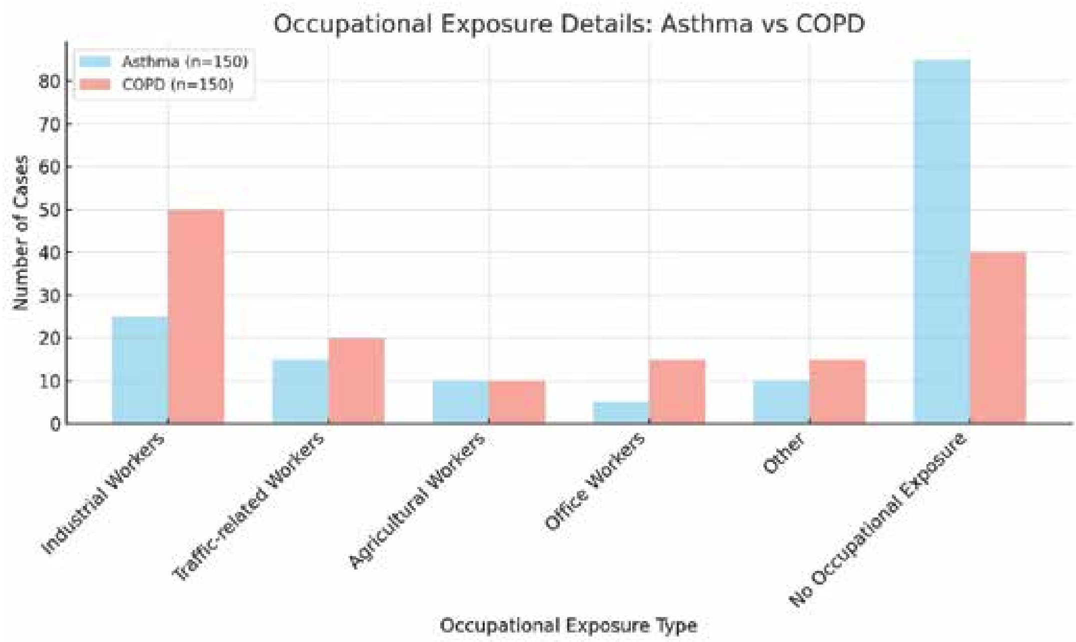
Characteristic	Asthma (n=150)	COPD (n=150)	Total (n=300)
Mean Age (years)	45.2 ± 12.5	62.8 ± 10.4	54.0 ± 13.5
Gender (Male/Female)	70/80	100/50	170/130
Mean BMI (kg/m²)	25.3 ± 4.2	26.1 ± 5.1	25.7 ± 4.7
Co-Morbidities (%)	40 (26.7%)	60 (40.0%)	100 (33.3%)

Table 1 presents the basic characteristics of participants in the study, divided into two groups: those with asthma (n=150) and those with COPD (n=150), with a total of 300 participants. The mean age for the asthma group is 45.2 years, while for the COPD group, it is 62.8 years, with an overall mean age of 54.0 years. Gender distribution shows a higher percentage of males in the COPD group (100 males vs. 50 females) compared to the asthma group (70 males vs. 80 females). The mean BMI is slightly higher in the COPD group at 26.1 kg/m² compared to 25.3 kg/m² in the asthma group, with an overall mean of 25.7 kg/m². Co-morbidities are more common in the COPD group, with 40.0% affected, compared to 26.7% in the asthma group, resulting in an overall co-morbidity rate of 33.3%.

Table 2: Occupational Exposure Details

Occupational Exposure Type	Asthma (n=150)	COPD (n=150)	Total (n=300)
Industrial Workers	25 (16.7%)	50 (33.3%)	75 (25.0%)
Traffic-related Workers	15 (10.0%)	20 (13.3%)	35 (11.7%)
Agricultural Workers	10 (6.7%)	10 (6.7%)	20 (6.7%)
Office Workers	5 (3.3%)	15 (10.0%)	20 (6.7%)
Other	10 (6.7%)	15 (10.0%)	25 (8.3%)
No Occupational Exposure	85 (56.7%)	40 (26.7%)	125 (41.7%)

Table 2 shows the occupational exposure details of asthma (n=150) and COPD (n=150) participants. A higher proportion of COPD patients (33.3%) are industrial workers compared to asthma patients (16.7%). Traffic-related, agricultural, and office workers show smaller percentages, while 56.7% of asthma patients have no occupational exposure, compared to 26.7% in the COPD group.



The accompanying bar graph visualizes these trends, highlighting the higher prevalence of COPD among industrial workers and the greater number of asthma cases with no occupational exposure. This comparison illustrates the differing occupational risk profiles between the two groups.

Table 3: Frequency of Hospital Visits for Exacerbations

Number of Hospital Visits	Asthma (n=150)	COPD (n=150)	Total (n=300)
0-1 Visits	80 (53.3%)	50 (33.3%)	130 (43.3%)
2-3 Visits	40 (26.7%)	60 (40.0%)	100 (33.3%)
4-5 Visits	20 (13.3%)	25 (16.7%)	45 (15.0%)
>5 Visits	10 (6.7%)	15 (10.0%)	25 (8.3%)

Table 3 summarizes the frequency of hospital visits for exacerbations among asthma and COPD patients. In the asthma group, 53.3% reported 0-1 visits, compared to 33.3% in the COPD group. Conversely, a higher percentage of COPD patients (40.0%) reported 2-3 visits compared to 26.7% in the asthma group. For 4-5 visits, the percentages are relatively close, with 16.7% of COPD patients and 13.3% of asthma patients. A small proportion of participants in both groups reported more than 5 visits, with 6.7% in the asthma group and 10.0% in the COPD group.

Table 4: Average Concentrations of Air Pollutants

Pollutant	Mean Concentration (µg/m³) ± S.D.
PM10	85.4 ± 12.5
PM2.5	45.2 ± 8.3
NO2	32.8 ± 5.9
SO2	14.7 ± 2.4

Table 4 presents the average concentrations of key air pollutants measured in µg/m³, along with their standard deviations (S.D.). The mean concentration of PM10 is 85.4 ± 12.5 µg/m³, while PM2.5 averages 45.2 ± 8.3 µg/m³. The concentration of nitrogen dioxide (NO2) is 32.8 ± 5.9 µg/m³, and sulfur dioxide (SO2) is recorded at 14.7 ± 2.4 µg/m³. These values highlight the levels of pollutants present in the area and their potential impact on respiratory health.

Table 5: Spirometry Results

Spirometry Parameter	Asthma (Mean ± SD)	COPD (Mean ± SD)
FEV1 (L)	2.5 ± 0.8	1.4 ± 0.6
FVC (L)	3.0 ± 0.9	2.0 ± 0.7
FEV1/FVC Ratio	0.83 ± 0.05	0.70 ± 0.08

Table 5 presents the spirometry results for participants with asthma and COPD. The mean Forced Expiratory Volume in 1 second (FEV1) for asthma patients is 2.5 ± 0.8 litters, while COPD patients have a significantly lower mean of 1.4 ± 0.6 litters. The Forced Vital Capacity (FVC) is higher in asthma patients at 3.0 ± 0.9 litters, compared to 2.0 ± 0.7 litters in COPD patients. The FEV1/FVC ratio is also higher in asthma patients (0.83 ± 0.05) than in those with COPD (0.70 ± 0.08), reflecting the more severe obstruction in COPD.

Table 6: Distribution of Respiratory Exacerbations by Air Quality Index (AQI) Categories and Associated PM10 and NO2 Levels

Air Quality Index Category	Number of Exacerbations	PM10 Level (µg/m³)	NO2 Level (µg/m³)	F-value	p-value
Low	30	40.2	20.5	5.2	**0.030**
Moderate	45	60.3	25.7	6.8	**0.020**
High	75	85.4	32.8	8.3	**0.010**
Very High	90	110.5	45.0	9.1	**0.005**

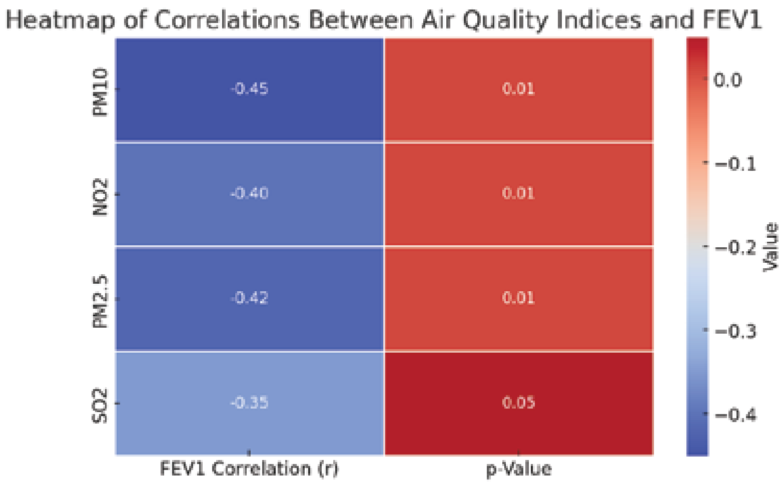
ANOVA (Analysis of Variance) was applied to assess the differences in COPD or asthma exacerbations across Air Quality Index categories

Table 6 highlights the distribution of exacerbations by Air Quality Index (AQI) categories. As AQI worsens, exacerbations rise from 30 in the low category to 90 in the very high category. PM10 and NO2 levels also increase, with the highest levels (110.5 µg/m³ and 45.0 µg/m³) in the very high AQI category. Statistical analysis shows a significant correlation between worsening air quality and exacerbations (F-value = 9.1, p-value = 0.005).

Pearson's correlation coefficient was applied to analyze the association of air quality indices with lung function measurements. FEV1 values were negatively correlated with PM10 levels ($r = -0.45$, $p < 0.01$) and NO2 concentration measurements ($r =-40$, $p < 0.01$).

Table 7: Correlation Between Air Quality Indices and Lung Function Measurements

Variable	FEV1 Correlation (r)	p-Value
PM10	-0.45	<0.01
NO2	-0.40	<0.01
PM2.5	-0.42	<0.01
SO2	-0.35	<0.05



Heatmap comparing the correlations between various **Air Quality Indices** (PM10, NO2, PM2.5, SO2) and **FEV1**. The color intensity represents the strength of the correlation (r values), with annotations displaying the exact values and p-values to indicate statistical significance.

Multiple regression analysis, controlling demographic and clinical variables, identified PM10 and NO2 as independent predictors of respiratory exacerbations.

Table 8: Regression Analysis Results for PM10 and NO2 Impact Exacerbations

Variable	Beta Coefficient	Standard Error	t-Statistic	p-Value
PM10	0.049	0.015	3.27	<0.01
NO2	0.038	0.012	3.17	<0.01

Table 8 presents the regression analysis results for the impact of PM10 and NO2 on COPD exacerbations. The Beta coefficient for PM10 is 0.049 with a standard error of 0.015, resulting in a t-statistic of 3.27 and a p-value of less than 0.01, indicating a significant effect. Similarly, NO2 has a Beta coefficient of 0.038, a standard error of 0.012, a t-statistic of 3.17, and a p-value also less than 0.01, showing its significant impact on COPD exacerbations.

DISCUSSION

The results of this study determined that people living in Jamshoro are at much higher risk than the rest of the world with regard to all types of respiratory illnesses, mainly due to high levels of air pollution in the area, and chronic ailments such as asthma and COPD in particular. This corresponds to previous studies demonstrating that the outside air pollution level, in particular for cities or industrial regions, aggravates respiratory conditions [16,17]. Jamshoro faces its own set of challenges, similar to those observed in the United States, as noted by Collins, who identified comparable patterns in the environmental issues affecting Jamshoro[18]. A similar situation is present here about the causes of environmental pollution in cities such as Lahore, Karachi, and Multan. Increasing industrial waste discharge, and urban traffic together with factory pollution, especially smoke and noise from generators, have made the area unhealthy for the people.

In our study, it was found that in the patients suffering from chronic obstructive pulmonary disease (COPD) or asthma, high concentrations of PM10 and NO_2 were a significant risk factor for lung function impairment and decreased quality of life (Table 3). Quite similarly, earlier investigations have also brought out a detrimental effect of particulate matter on the health of the population[19,20]. Pertaining to the above conditions, the present data also shows that these pollutants, namely PM10 and NO_2 in higher concentrations, are associated with deteriorated lung status as demonstrated by the decline of FEV1. This adds to the establishment of the fact that these pollutants are related to respiratory diseases, especially pulmonary emphysema[21]. The alveolar particulate matter (PM10 and PM2.5) goes to the lung's gas-exchanging part, thus inducing inflammation and prostaglandin release, worsening already existing inflammation and causing damage in the long run. These finding patterns of study have fairly reported similar findings[22,23]. Moreover, these internal and external inflammation factors have increased the discomfort at that time, but have also had detrimental effects on the prognosis of diseases such as asthma and COPD in the long term.

As an additional point, the research mentions that people who have been chronically exposed to air pollution lower their immune response, and this is greater in people predisposed genetically. This aggravates chronic inflammation and immune system dysregulation as pointed out in other studies [24]. Increases in these factors make the risk of presenting with more severe symptoms and high inflammation much greater in susceptible populations. The results of the chi-squared test (Table 2) show that, amongst other things, the evaluation of air pollution contributes towards the persistence of chronic symptoms such as respiratory infections and pneumonia. This is supported by evidence indicating that pollution is one of the determinants of increasing numbers of disease exacerbations[25]. In our study, we found that study subjects residing in high pollution zones were nearly three times more likely to experience asthma or COPD exacerbations than those residing in low pollution zones, consistent with other studies[26].

As seen in previous research on respiratory exacerbations, PM10 was found to be a predictor of future severe respiratory symptoms in the multivariate regression analysis. Unfortunately, nitrogen dioxide (NO_2) was not found anywhere in the study, which implies that NO_2 may not be the main cause of respiratory illnesses, as is the case with particulate matter[27]. This accumulation of evidence for restrictive lung disease should compel authorities to implement air quality policies and measures, especially in cities like Jamshoro, with potential air pollution from both factories and motor vehicles[28].

CONCLUSIONS

Our research concludes that air pollution, especially high levels of PM10 and NO_2, can significantly aggravate chronic respiratory diseases such as asthma or COPD in Jamshoro. The results reveal a direct link between bad air quality and diminished lung function. Population with diseases of the airways have lower forced expiratory volume in one second (FEV1) levels. Especially those with pre-existing conditions who form a vulnerable group. The findings further underscore the need for public health campaigns focused on specific groups, continuous monitoring of air quality, and rigorous implementation of policy to control pollution sources.

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CONFLICTS OF INTEREST

There is no conflict of interest in the publication of this article.

ETHICAL APPROVAL

All ethical standards were met, and approval was obtained from the Review Committee ER letter no 14287/23/081 of LUMHS, Jamshoro.

AUTHORS CONTRIBUTIONS

AAU led the study design and data analysis. **TS, SNS**, **UA**, and **SS** contributed to data collection, manu-script drafting, and final revisions.

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