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Insights into the Current Smog Episode in Punjab: Air Pollution and Health Crisis

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ABSTRACT

Background: Smog is a critical environmental issue, posing a significant threat to public health, air quality and urban sustainability. Punjab, the largest province of Pakistan by population, is facing severe environmental challenges due to smog and all major divisions of Punjab are affected by smog.
Objective: To assess the impact of smog on the air quality parameters, and health and behavior of people in Punjab
Methods: The cross-sectional analytical study covered a one-year period encompassing pre-smog and peak smog season in Punjab. Total 2000 residents of major cities of Punjab exposed to smog-related air pollution selected. Air quality and health outcomes assessed using a combination of Environmental Monitoring Points and Health Assessments. Bivariate regression employed to explore association between air quality indicators and health outcomes.
Results: The concentrations of air quality indicators including particulate matter (PM2.5 and PM10), carbon monoxide, Sulfur dioxide, and nitrogen dioxide significantly increased in peak smog season ($p<0.05$), while a reduction was observed in Ozone concentration. Multan faced the highest problem of smog followed by Lahore and then other cities. The number of hospital admissions, cardiovascular incidents, respiratory symptoms score, and respiratory problems (asthma, bronchitis and COPD) elevated significantly ($p<0.05$). Moreover, public awareness to smog and use of masks significantly increased ($p<0.05$), while average time spent outdoors reduced markedly ($p<0.05$).
Conclusions: Smog had a severe health impact in Punjab. Increased concentrations of air quality indicators has been linked with worsening of cardiovascular and respiratory conditions. Although public awareness about smog is increased, but more effective and sustainable methods to address the effects are still required.

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Introduction

Punjab, the largest province of Pakistan by population, is facing severe environmental pollution challenges, particularly smog. This kind of pollution is generally present from October to December and is brought on by industry, motor vehicle emissions, crop burning in neighboring provinces, and unfavorable weather patterns including low wind speed and temperature inversion. The air pollution index of air in all the major cities of Punjab is above dangerous level and exceeds the WHO acceptable guideline for both PM 2.5 and PM 10 concentrations [1]. The main feature of this smog phenomenon is an increase in particulate matter, especially PM2.5, which poses serious health hazards

since it can penetrate the respiratory system of humans and animals [2][3][4]. In Punjab, aerosol pollution and other associated pollutants, including PM2.5, PM1, CO, NO2, and SO2, rise sharply during the smog season [5][6][7]. Since these pollutants are linked to cardiovascular [8] and respiratory disorders [9] and exacerbate preexisting problems including bronchitis, asthma, and chronic obstructive pulmonary disease (COPD), they have both short-term and long-term negative effects on health [10][11][12]. There are a number of detrimental public health problems linked with prolonged pollution exposure in the major cities. According to research, air pollution increases the risks of cardiovascular and respiratory conditions and raises the number of premature deaths [13]. The aforementioned health conditions brought on by pollution increase the demand for healthcare on the decreasing health facilities of the Punjab against air-borne diseases.

Air pollution has further social and economic repercussions in addition to its effects on physical health. Reduced Medical care, missed work and school days, and decreased productivity increase the financial losses in the residents [14]. Nonetheless, akin to the poll conducted in Pakistan, the public has yet to adequately address the undeniably serious smog danger [15], and there have been noticeable but modest behavioral adjustments, such as wearing masks and staying inside during smog. Given that the issue of smog in Punjab and its major divisions have gotten to a critical point during the recent episode of smog during October and November 2024, it is indispensable to examine the changing patterns of air quality and their negative effects on human health. Therefore, the current research was performed to assess the impact of smog on the air quality parameters, and health and behavior of people in Punjab.

Methods

The current study employed a cross-sectional analytical design to analyze air quality trend during the smog season in Punjab and to estimate its impacts on public health. These parameters were assessed in the major divisions of Punjab province including, Lahore, Multan, Sahiwal, Rawalpindi, Faisalabad, Bahawalpur, Dera Ghazi Khan, Sargodha and Gujranwala. The research was focused on air quality parameters and their effects on individuals with respiratory and cardiovascular conditions. The data was collected using a combination of Environmental Monitoring Points (EMPs) for air quality assessment and Health Assessments (HAs) for evaluating health outcomes. The current study covered a one-year period, encompassing both the pre-smog phase and the peak smog season.

The target population for this study consisted of residents of the major cities of Punjab, encompassing both adults (aged 18 to 65 years) and children who are regularly exposed to smog-related air pollution. Participants were selected based on their residential locations, with an emphasis on areas experiencing varying levels of air pollution during the smog season. The sample size for this study was determined through power analysis, ensuring a statistical power of over 80% and a 95% confidence level. A total of 2,000 participants were recruited, with equal representation during the pre-smog and peak smog seasons. This sample size was considered adequate for comparisons across air pollution parameters (APPs) and associated public health outcomes.

Participants were included if they had resided in the above-mentioned divisions of Punjab for at least three years and were familiar with the environmental and weather patterns. Exclusion criteria included individuals with chronic illnesses unrelated to air pollution (e.g., ischemic heart disease) or conditions that could obscure the specific health impacts of smog exposure. Pregnant women were also excluded to avoid confounding factors related to their heightened vulnerability to air pollution and distinct respiratory health profiles.

Informed consent was obtained from all participants prior to their inclusion in the study. Participants were fully briefed on the study's objectives, procedures, and potential risks. They were also informed about their right to withdraw from the study at any time without consequence. To protect participant privacy, personal identifiers were removed and strict measures were taken to ensure confidentiality and anonymity throughout data collection and analysis.

Efforts were made to ensure diversity in gender, age, and geographical representation among participants across Punjab. This approach aimed to capture a comprehensive spectrum of smog exposure, which varies by location and the degree of urbanization. To achieve this, residential areas were categorized into high-exposure,

moderate-exposure, and low-exposure zones based on air quality index (AQI) data provided by the Pakistan Environmental Protection Agency and Environmental Protection Department of Lahore. This stratification enabled the inclusion of participants from areas with varying levels of air pollution, thereby enhancing the study's representativeness and relevance.

Air Quality Indicators data were obtained through daily real-time monitoring at multiple established air quality monitoring stations across Punjab. The monitoring focused on key pollutants during both the pre-smog and peak smog seasons, including:

- PM2.5: Fine particulate matter with a diameter of less than 2.5µm.
- PM10: Particulate matter with a diameter of 10µm or less.
- CO (Carbon Monoxide)
- NO_2 (Nitrogen Dioxide)
- SO_2 (Sulfur Dioxide)
- O_3 (Ozone)

Measurements were conducted daily over a one-year period, spanning both pre-smog and peak smog phases. Seasonal averages were calculated to capture variations and provide a comprehensive assessment of air quality during these periods.

Health-related data were collected through structured questionnaires and clinical examinations. The questionnaires were specifically designed to address respiratory symptoms (e.g., cough, difficulty breathing, wheezing), cardiovascular complaints (e.g., chest pain, palpitations), and hospitalizations. Outcomes were assessed using a combination of clinical evaluations and standardized questionnaires targeting respiratory conditions such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). To quantify health impacts, two composite indices were developed i.e., a Respiratory Symptoms Score and a Cardiovascular Incidents Score to assess the frequency and severity of respiratory and cardiovascular complications linked to smog.

To evaluate public awareness of air quality alerts and behavioral responses to smog exposure, a survey was conducted among participants. The survey included questions designed to assess the population's understanding of AQI levels and the extent to which individuals adjusted their routines during the smog crisis. The level of awareness of air quality alerts and their significance along with behavioral modifications, such as the use of protective measures (e.g., mask-wearing) and changes in outdoor activities (e.g., reducing time spent outdoors).

Statistical Analysis: The data were analyzed using SPSS 26 software and presented as mean ± standard deviation. Descriptive quantitative analysis was performed to summarize air quality parameters and health outcomes. Comparisons between pre-smog and peak smog season values were conducted using paired t-tests. Statistical significance was determined at a $p < 0.05$. Additionally, bivariate regression analysis was employed to explore potential correlations between air quality indicators and health outcomes. This analysis controlled for confounding factors such as age, sex, and pre-existing chronic conditions, ensuring robust and reliable results.

Results

Table 1 reveals the effects of smog on the air quality parameters. During peak smog season the concentrations of particulate matter 10 (PM10) were significantly ($p<0.05$) increased from 82.87±15.44µg/m³ to 233.73±19.31µg/m³, as compared to the pre smog season. Similar trend was observed in the concentrations of particulate matter 2.5 (PM2.5) that increased substantially ($p<0.05$) from 66.20±8.65µg/m³ to 177.33±16.73µg/m³.

Table 1: AQI assessment before and during smog season

Indicators	Smog season (n=2000)		p-value
	Before	During	
PM10 (µg/m³)	82.87±15.44	233.73±19.31	0.000
PM2.5 (µg/m³)	66.20±8.65	177.33±16.73	0.000
CO (mg/m³)	0.59±0.12	2.52±0.47	0.001
NO_2 (ppb)	27.64±6.59	58.66±9.62	0.003
SO_2 (ppb)	10.22±2.24	30.30±4.67	0.000
O_3 (ppb)	44.35±9.94	24.21±4.95	0.007

Moreover, the concentrations of CO, NO_2, and SO_2 also increased significantly ($p<0.05$) in peak smog season, rising from 0.59±0.12mg/m³, 27.64±6.59 ppb and 10.22±2.24 ppb to 2.52±0.47mg/m³, 58.66±9.62 ppb and 30.30±4.67 ppb, respectively. However, the concentration of O_3 reduced significantly ($p<0.05$) from 44.35±9.94 ppb to 24.21±4.95 ppb.

Table 2 and Table 3 show the effects of smog on the health of people. The number of hospital admissions per 1000 individuals in peak smog season increased significantly ($p<0.05$), rising from 28.29±7.58 to 59.60±9.00, as compared to pre-smog season. Furthermore, cardiovascular incidents (from 5.50±1.29 to 12.75±2.50) and respiratory symptoms score (from 29.75±3.30 to 88.50±3.42) also elevated significantly ($p<0.05$) in peak smog season. The prevalence of respiratory problems is escalated markedly ($p<0.05$) in peak smog season, as compared to pre-smog season. The percentage of asthma rose from 17.75±4.57 to 40.83±3.18. Moreover, the ascertainment of bronchitis and Chronic Obstructive Pulmonary Disease (COPD) also increased from 13.50±3.51 and 8.47±0.88 to 31.52±2.71 and 20.99±2.56, respectively.

Table 2: Health issues associated with smog exposure

Health issues	Smog season (n=2000)		p-value
	Before	During	
Hospital admissions	28.29±7.58	59.60±9.00	0.000
Cardiovascular incidents	5.50±1.29	12.75±2.50	0.002
Respiratory symptoms	29.75±3.30	88.50±3.42	0.000

Table 3: Prevalence of respiratory problems

Problems	Smog season (n=2000)		p-value
	Before	During	
Asthma	17.75±4.57	40.83±3.18	0.003
Bronchitis	13.50±3.51	31.52±2.71	0.007
COPD	8.47±0.88	20.99±2.56	0.002

Table 4 shows the impact of smog on the behavior of people and public awareness. Our results demonstrated that public awareness to smog was increased notably ($p<0.05$). The knowledge of air quality alerts to people increased from 40.50±3.11 to 90.19±4.48.

Table 4: Public awareness and behavioral changes

Problems	Smog season (n=2000)		p-value
	Before	During	
Knowledge of air quality alerts	40.50±3.11	90.19±4.48	0.000
Use of masks	19.50±4.72	87.47±7.82	0.002
Time spent outdoor (hrs/day)	3.73±0.36	1.25±0.18	0.001

Moreover, the behavior of people was also altered which was validated by an escalation in the use of masks (from 19.50±4.72 to 87.47±7.82) and reduction in the number of hours per day spent outside (from 3.73±0.36 h to 1.25±0.18 h).

Table 5 demonstrates the comparative effect of smog on the different cities of Punjab. Multan had the highest AQI, 392.96±48.72, followed by Lahore, 244.31±40.85. Similarly, Multan had the highest concentrations of PM2.5 (180.02±35.94 μg/m³), PM10 (307.42±39.58 μg/m³), CO (1419.54±301.62 ppb), NO_2 (42.78±10.49 ppb) and SO_2 (11.96±3.69 ppb). While the concentrations of aforementioned parameters in other cities were less as compared to Multan. However, the values of all AQI in all the cities were far more than normal, non-hazardous concentrations of these parameters, showing that smog has affected the whole Punjab province during its peak season.

Discussion

The smog problem in Punjab and its major cities including Lahore and Multan, is a serious environmental and public health issue that requires prompt and coordinated solution. One may describe the present smog difficulties in these cities, which are indicating elevation in air pollution throughout the season of its activity, as a serious public health risk. These findings highlight the dramatic rise in air pollutants, such as PM2.5, PM10, CO, NO_2, and SO_2. These pollutants are one of the major causes of respiratory and cardiovascular diseases [16][17]. The results of the current study are in line with the research of Awez et al. [18], who reported the effects of air pollution in South Asia. According to Khan et al. [12], the level of air pollution in South Asian cities is rising, particularly in Lahore, which is recognized as one of the most polluted metropolitan areas in the region. Our study has revealed that PM2.5 and PM10 concentrations were significantly greater during the peak smog season than they were in the pre smog season [19].

Particularly, PM2.5 levels have significantly increased. Several studies have explained that these fine particles are harmful because they can enter in the lungs and are linked to a number of health risks, including cardiovascular disorders, respiratory illnesses, and premature death.

Since CO, NO_2, and SO_2 concentrations increase during the peak smog period, this exacerbates the public health demands [7][20]. When the smog season is taken into account, the primary sources of these pollutants are automobiles, factories, and biomass burning, and their emissions rise in the winter months [21]. According to recent studies, the incidence of cardiovascular diseases, bronchitis, and asthma is positively correlated with increased NO_2 and CO emissions [22][23].

The findings of our study revealed significantly ($p<0.05$) increased levels of NO_2 and SO_2 which support the concerns about elevated levels of these pollutants during the period of increased smog. These findings highlight the necessity of more stringent regulations to control industrial and vehicle emissions during this time.

Table 5: Air quality index (AQI) of different cities of Punjab

City	AQI (Overall)	PM2.5 (µg/m³)	PM10 (µg/m³)	CO (ppb)	NO_2 (ppb)	SO_2 (ppb)
Lahore	244.31±40.85	131.16±22.09	221.18±25.52	1157.16±325.38	20.96±8.67	8.50±2.37
Multan	392.96±48.72	180.02±35.94	307.42±39.58	1419.54±301.62	42.78±10.49	11.96±3.69
Faisalabad	209.19±25.63	126.35±24.74	209.12±21.37	968.72±286.26	21.85±7.54	6.19±2.14
Gujranwala	193.40±28.62	113.04±20.37	177.94±18.02	932.18±267.13	17.62±4.31	5.61±1.96
Bahawalpur	204.32±30.89	118.83±21.41	182.57±20.86	1034.54±292.15	19.95±5.16	6.04±1.84
Dera Ghazi Khan	176.54±21.25	109.42±22.61	149.67±16.72	874.76±210.06	16.25±3.09	5.90±1.99
Sargodha	183.94±27.67	114.63±17.59	158.34±19.60	898.23±243.73	18.70±3.73	5.78±2.03
Rawalpindi	196.72±29.41	115.19±19.32	176.04±22.49	919.65±238.85	20.13±6.22	5.91±1.75
Sahiwal	218.59±31.94	129.97±20.84	191.56±25.16	1076.36±250.92	23.5±7.18	6.30±2.34

According to our research, hospital admissions, respiratory symptoms, and cardiovascular events increased markedly throughout the studied time, demonstrating the negative health effects of smog exposure. Previous studies reported that, smog vulnerable cities have reported startlingly high rates of emergency department visits and admissions due to pulmonary and cardiovascular conditions during the episodes of high air pollution [24][25]. Our findings were also consistent with these studies due to a significant ($p<0.05$) increase in hospital patient admissions during the smog period.

Cardiovascular occurrences and respiratory symptoms also increased substantially ($p<0.05$) in peak smog season, which is especially concerning due to its impacts on the health of population. Moreover, there is an upward trend in respiratory problems during periods of high pollution, as validated by increased instances of COPD, bronchitis, and asthma. In particular, as particulate matter aggravates the respiratory system, pollution has been linked to asthma. According to epidemiological research, elevated air pollution worsens asthma and COPD conditions [26].

Since our findings show that the percentage of patients suffering from COPD, bronchitis, and asthma increased significantly during the smog season. Therefore, pollution presents a major health risk, particularly to those who are exposed to high levels of pollutants for extended periods of time. Public awareness and opinions about the pollution season and behavior during it were also compared in this research. A growing knowledge of the problem posed by air pollution and the efforts made by people to mitigate its negative consequences are clear from the significantly ($p<0.05$) increased percentage of knowledge of air quality alerts and mask wearing [7][27]. Considering that these behavioral changes are to adjust yourself against the harsh environment, it is encouraging to witness them. Moreover, the numbers of hour spent outside per day were also reduced markedly ($p<0.05$) in the peak smog season, showing a notable change in the life style of the people. Similar circumstances have been seen in other places with polluted air when individuals restrict their outside activities to reduce negative health impacts during periods of increased air pollution [18][21][28].

For all of these reasons, safe transportation options, stricter vehicle emissions regulations, and the encouragement of health awareness initiatives are long-term solutions that are far more suitable in this situation in order to combat the two evils of smog and its effects on the residents of Punjab. The data above reflect shocking air quality outcomes in the major cities of Punjab including Lahore, Multan, Sahiwal, Rawalpindi, Faisalabad, Bahawalpur, Dera Ghazi Khan, Sargodha and Gujranwala. The air quality index was dramatically higher than the normal and bearable levels of these parameters. In the current study, Multan had the highest air quality index (392.96±48.72) and concentrations of SO_2 (11.96±3.69 ppb), NO_2 (42.78±10.49 ppb), CO (1419.54±301.62 ppb), PM2.5 (180.02±35.94 µg/m^3), and PM10 (307.42±39.58 µg/m^3). Lahore stood second in the level of AQI, 244.31±40.85, followed by Sahiwal (218.59±31.94), Faisalabad (209.19±25.63), Bahawalpur (204.32±30.89), Rawalpindi (196.72±29.41),

Gujranwala (193.40±28.62), Sargodha (183.94±27.67), and Dera Ghazi Khan (176.54±21.25), This indicates that the air quality of Punjab has been far below the healthy air quality, which calls on the government to take immediate action to alleviate the air pollution problems in the province, especially in all the larger cities.

Conclusion

In conclusion, this research adds to our understanding of the severe health impacts of smog in Punjab. The worsening of cardiovascular and respiratory conditions has been linked to the increased AQI and concentrations of PM2.5, PM10, CO, NO_2, as well as SO_2. Although public awareness on the effects of air pollution has increased and they are improving their behavior, more effective and sustainable methods to address these effects are still required. More rigorous emission rules, more contemporary human transportation networks, and public health campaigns aimed at preventing exposure to airborne contaminants are a few examples of the changes that may be made to reduce the impacts of air pollution. Moreover, resolving the smog problem in the whole province is crucial to handle the environmental problems and to improve the lifestyle of the public.

Authors' contributions

ICMJE criteria	Details	Author(s)
1. Substantial contributions	Conception, OR Design of the work, OR Data acquisition, analysis, or interpretation	1,2 1,2,3 4,5,6
2. Drafting or reviewing	Draft the work, OR Review critically for important intellectual content	1,2,3 4,5,6
3. Final approval	Approve the version to be published	1,2,3,4,5,6
4. Accountable	Agree to be accountable for all aspects of the work	1,2,3,4,5,6

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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