Smog, Stress, and Society

Aqsa Shabbir[1], Sahar Zia[2], Ali Hussain Kazim[3], Naveed Iqbal[4], Ayesha Mubeen Puri[5], Amina Muazzam[6]*

[1]Lahore College for Women University, Department of Electrical Engineering, Lahore, 54000, Pakistan

[2]Lahore College for Women University, Department of Geography, Lahore, 54000, Pakistan

[3]University of Engineering and Technology, Automotive Engineering Centre, Lahore, 54000, Pakistan

[4]Lahore College for Women University, Department of Mass Communication, Lahore, 54000, Pakistan

[5] Lahore College for Women University, Department of STEM Education, Lahore, 54000, Pakistan

[6]Lahore College for Women University, Department of Applied Psychology, Lahore, 54000, Pakistan

*__Correspondence__: amina.muazzam@lcwu.edu.pk

Citation | Shabbir. A, Zia. S, Kazim. A. H, Iqbal. N, Puri. A. M, Muazzam. A, "Smog, Stress and Society", IJIST, Vol. 07 Special Issue pp 245-257, August 2025

Received| July 27, 2025 **Revised|** August 14, 2025 **Accepted|** August 15, 2025 **Published|** August 16, 2025.

Smog, an escalating byproduct of climate change and rapid urbanization, poses a significant risk to public health and resilience, especially in megacities like Lahore. This study examines the psychological, biological, and social impacts of smog on young adults, situating these findings within the broader discourse on climate-induced hazards and disaster risk reduction (DRR). Employing a mixed-method approach, the research involved focus group discussions, scale development with expert validation, and large-scale public perception analysis using digital text analytics (Voyant Tools) on responses from 800 participants. Results revealed eleven major themes ranging from anxiety, mood disturbances, and impaired concentration to respiratory ailments, skin conditions, and reduced social interactions, capturing the multidimensional burden of smog exposure. Traffic emissions, loss of green spaces, and industrial pollution emerged as the most cited contributors, reflecting gaps in urban environmental management. The study's Bio-Psychosocial (BPS) Scale (CVI = 0.93) offers a validated tool for assessing smog's multifaceted impacts, enabling targeted policy and anticipatory interventions. These insights highlight the need to integrate air quality monitoring, green infrastructure, and public awareness into climate change adaptation and DRR strategies to safeguard both health and societal cohesion in vulnerable urban populations.

Keywords: Smog, Climate Change, Disaster Risk Reduction, Young Adults, Psychological Health, Social Well-Being, Urban Pollution

Introduction:

Climate change has intensified the frequency and severity of environmental hazards, with air pollution–induced smog emerging as a recurrent and pressing threat in urban South Asia. Smog, a dense haze formed from particulate matter, ground-level ozone, and other pollutants, has become a seasonal hazard in Lahore, Pakistan's second-largest metropolitan city and one of the most polluted globally. Its persistence is exacerbated by anthropogenic drivers such as unchecked traffic emissions, industrial discharges, loss of green spaces, waste burning, and agricultural residue combustion—factors compounded by climatic variations and weak regulatory enforcement [1][2][3].

The events of smog have occurred from time to time in major cities of the world in the past century [4][5]. It was first noticed in Los Angeles in 1943 [6]. Some other major episodes occurred in Donora in 1948, London in 1952 [7], and New York in 1962. The London smog was the first to be identified as photochemical smog, which then led to the Clean Air Act in 1953 [8].

According to the World Health Organization, Pakistan, India, Bangladesh, Saudi Arabia, and Egypt are among the top ten countries with the most polluted air quality based on PM 2.5 (World Health Organization, 2016). The ever-worsening air pollution in Pakistan has resulted in heavy smog events in recent years. This is due to the increase in the aerosol load and the precursor gases over the city, which contribute to air pollution and have recently resulted in events of smog. Furthermore, in winter, due to shortages of natural gas, the use of biofuels such as dung cake, coal, and charwood adds to the emissions of smoke, gases (especially NO2, CO, and SO2), black carbon, and most importantly, aerosols. [9].

Lahore, Pakistan's second-largest metropolitan city, is most affected by air pollution and the smog episodes, is also among the world's topmost polluted cities. The average level of PM2.5 is 68 μg/m3/year, according to which the Air Quality Index of Lahore corresponds to 155, which is unhealthy as defined in the Air Quality Index Scale by the US-EPA 2016 standard (AQICN, 2018). The PM2.5 concentrations in Lahore were observed to be 2-14 times higher than the limits prescribed in the USEPA standard. Different studies show that Lahore has been witnessing periods of smog/ haze from 2008 to 2015. However, the episodes in November 2016 and then in October 2017 highlighted the issue, as this time, the smog experienced was heavier and much more hazardous than in previous years. The Pakistan Environment Protection Act (1997) and the National Environmental Quality Standards were quite obsolete until the 2016 smog event, after which the government has more actively started to devise new action plans, projects, and policies. The Environment Protection Department, Government of Punjab, has developed a policy and action plan, "Policy on Controlling Smog 2017," to control, mitigate, advise, and provide protective measures in smog conditions (Environment Protection Department, 2017). The Punjab Government has started a project, "Establishment of Environmental Monitoring System in Pakistan," to strengthen air quality monitoring (Environment Protection Department, 2018).

Since the major smog event of 2016 in Lahore, many studies have been done in this regard. Although some literature is available, the number is still lacking, and the work and contribution to the literature are still in progress. The researchers have contributed to the literature, providing information and knowledge of the causes and impacts (both environmental and health impacts) of smog on people living in Lahore. Furthermore, work has been done on the prevention of smog [10]. Much work has been done on air pollution/smog and its effect on the physical health of human beings**,** either directly inflicting diseases due to air pollution or playing a factor in aggravating others. The air pollutants are significant contributors to the total number of illnesses and deaths (World Bank, 2006). Major air pollutants include NO2, PM2.5, PM10, O3, SO2, and CO, which cause cardiovascular diseases and many respiratory and lung problems such as emphysema,

bronchitis, and asthma [11]. During a smog episode, high concentrations of pollutants such as O3, NO2, and SO2 are seen to play a major role in enhancing and increasing the cases of allergic diseases in the airway, such as asthma [12]. Furthermore, an investigation in Lahore concluded that the city observed haze and reduced visibility due to the contribution of sulfate particles (secondary aerosol), which are responsible for cases of respiratory problems [13].

However, there was not much work done on the relationship between air pollution and mental health and cognitive abilities. In the past decade, some researchers have contributed related work to the literature. For instance, a study conducted in Korea among a group of elderly people showed an increase in depressive symptoms with an increase in air pollutants, mainly PM10, NO2, and O3. It was a 3-year follow-up study using the Geriatric Depression Scale to evaluate the association of these air pollutants with depression. The factor analysis showed that air pollution was more strongly causing emotional symptoms than somatic and affective symptoms. PM10, NO2, and O3 are known to induce oxidative stress, which can potentially cause depression [14]. The issues identified in this study, such as disturbances and uncertainty about situations, align with these cognitive challenges. Another study was conducted on 958 adults residing in Barcelona to analyze the relationship between the history of anxiety and depression disorders and the use of antidepressants and benzodiazepines with long-term exposure to air pollution. They concluded that the self-reported history of depression was statistically significant for air pollutants, i.e., NOx, NO2, PM2.5, and PM10 [15].

Beyond its well-documented respiratory and cardiovascular impacts, smog poses a multidimensional challenge to human well-being, disrupting psychological health, impairing cognitive functioning, and constraining social interactions. These effects are particularly acute for young adults, a demographic essential to societal resilience yet underrepresented in smog-related research. In the context of the climate change–disaster risk reduction (DRR) nexus, smog represents both a slow-onset hazard and a trigger for acute public health crises, demanding anticipatory actions.

The present study aims to investigate the psychological, biological, and social effects of smog on young adults in Lahore, and to develop a validated instrument for assessing its multidimensional impact.

Objectives of the Study were to:

Explore the psychological, biological, and social effects of smog through qualitative focus group discussions.

Develop and validate the Bio-Psychosocial (BPS) Scale using the Content Validity Index (CVI).

Examine public perceptions of the causes of smog using large-scale survey data and digital text analysis.

Novelty of the study: Unlike previous research that focused primarily on the physical health impacts of smog, this study introduces a culturally validated Bio-Psychosocial (BPS) Scale, integrates psychological, biological, and social dimensions, and combines qualitative, quantitative, and digital text analysis methods. This multidisciplinary approach offers a more comprehensive understanding of smog's impact in the Pakistani context and provides a practical tool for policymakers and public health practitioners.

Method:

A mixed-method approach was used to explore the effects of smog/air pollution on the psychological, biological, and social aspects of young adults. This study was conducted in two phases. In the first phase, the effects of smog on young adults were explored qualitatively by conducting focus groups and applying thematic analysis to analyze the qualitative data. The next phase was the development of an integrated scale by applying the Content Validation Index (CVI).

Phase I:

Participants:

A convenience sampling technique was used to draw a sample for this study. Twenty students were selected from different departments of a Public Sector University. The number of participants was gender balanced. Students belonged to the Bachelor's, Master's, and PhD programs and had been attending university on the days when the smog events in Lahore had occurred. The age group of these young adults was 20 to 25 years.

Instrument:

The focus group method was used to obtain data for the study. The structure of the interview was open-ended questions. This process required encouragement from the researcher to the participants to describe the relevant themes. Although the focus group interviews were mainly unstructured**, ** a few key questions were asked to generate in-depth information. For example, "What are the effects of smog on biological health?", "What do you think are the psychological effects of smog?", "How does smog affect our social life?".

Procedure:

In the first step, permission from the concerned university authorities was obtained. The initial screening was done for the selection of students who had enough awareness and information about the smog episodes that had been taking place in Lahore, especially since 2016. Also, the students were interviewed by taking their consent to participate. The participants were individually met at the time of their convenience. Two focus groups were conducted, including 10 participants in each group, with equal distribution of gender. Each interview lasted for 10 to 15 minutes, which involved rich and free discussion on smog and its effects. The participants were asked what they perceived or had observed to be the effects of smog on the psychological, biological, and social health of young adults during the time it prevails. The participants were very cooperative, energetic, and enthusiastic, which helped hold healthy discussions. The points of the discussion were written to keep a record. An audio recording was done for these interviews after seeking permission. Later, transcription was done using notes and audio tapes of interviews.

Date Analysis:

The data obtained by the focus group discussions were analyzed by the method of Thematic Analysis. The data was familiarized by reading it multiple times. Significant features were identified from the data by using labels. The data was then searched using the identified labels to find the potential major themes that signify "the broader pattern of meaning". The data was then reviewed again, and keeping in view the major themes, sub-themes were identified. Many of the major themes and sub-themes were then split, combined, or discarded. Each theme was then identified in detail, and the focus and scope of each were determined. The final step was to write together the 'analytical narrative', 'data extracts', and 'contextualizing the analysis with reference to the existing literature.

Phase II: Development of the scale (using content validation index):

Step I:

To develop the integrated scale for the analysis of the psychological, biological, and social effects of smog on young adults, the sources used were (1) a review of literature from relevant sources to gather information about possible effects of smog on human beings**,** and (2) focus group interviews with 20 students were carried out face-to-face. They were interviewed about the possible effects of smog on biological, psychological, and social aspects of young adults. Items were generated on the basis of a literature review and themes generated through thematic analysis.

Step II:

Content validation was used to check whether the data collected from the interviews were in accordance with the concept (Haynes et al., 1995). For assessing the content validation

of the scale, the number of judges needed to be at least three and at most ten [16]. The number of judges selected to analyze the items of this study was six (3 environmentalists and 3 psychologists). The experts were asked to rate the items according to the following categories: 1= not relevant, 2= somewhat relevant, 3= quite relevant, and 4= completely relevant [17]. The experts were asked to suggest any further items related to any aspect of the study. The ratings received from all six experts were then used for the calculation of the Content Validation Index (CVI) scale. Item Content Validation Index (I-CVI) was then calculated by dividing the number in agreement of each item by the total number of experts [18]. The literature shows the item CVI to be 1 when five or fewer experts rated the items, but with six or more experts, I-CVI should not be less than 0.78 [16]. After the ratings by the experts, the items retained were the ones with ratings of five or more.

Phase III: Public perception (using Voyant tool):

Step I: Survey Development:

A structured questionnaire was developed to gather information on respondents' perceptions of the causes of smog in Lahore. The survey included multiple-choice questions to capture a comprehensive range of responses.

Step II: Sampling:

A random sampling technique was employed to select 800 adult participants from diverse demographic backgrounds residing in different areas of Lahore (Figure 1). The sample was aimed to be representative to ensure the generalizability of findings.

Step III: Data Collection:

Data were collected through face-to-face interviews and online surveys, allowing for a mix of responses from both urban and suburban populations. Trained interviewers ensured consistency in the administration of the survey, and participants were assured of the confidentiality of their responses.

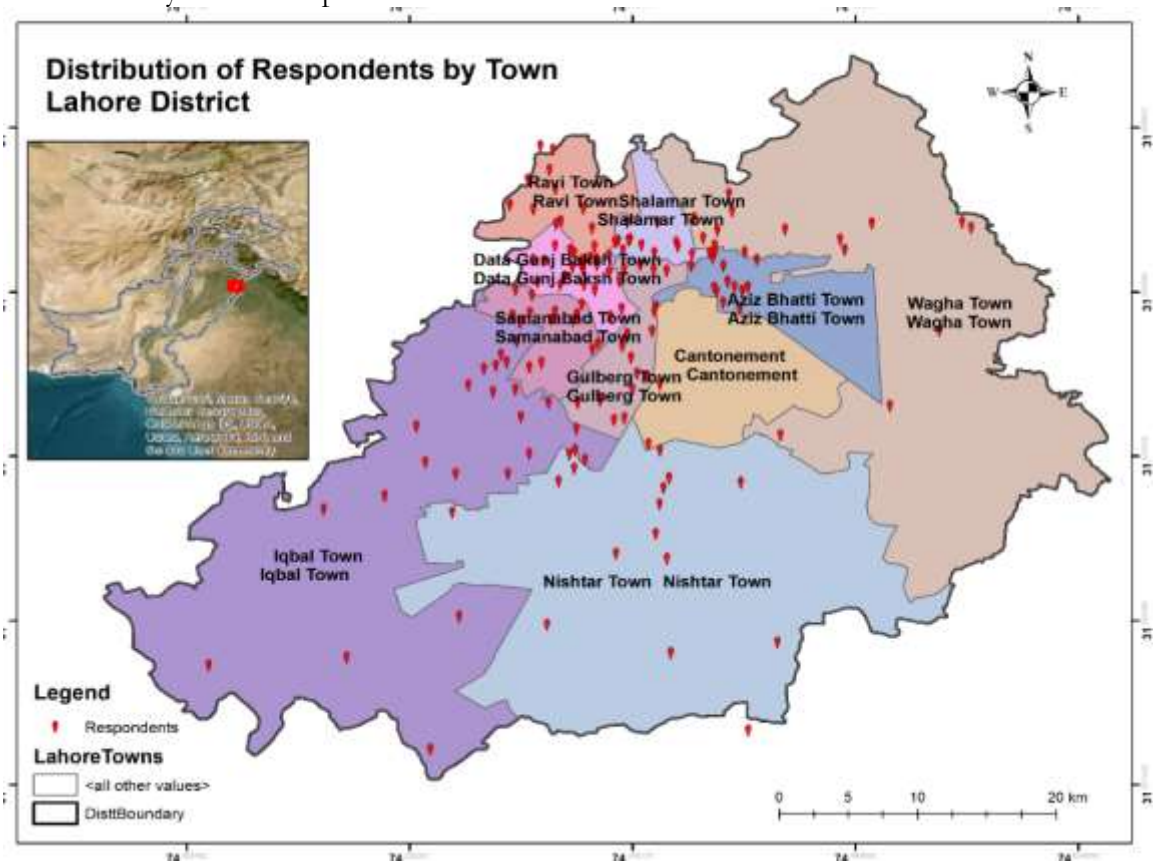

Figure 1. Showing the location of respondents by town in District Lahore.

Step IV: Voyant Tools Analysis:

Pre-processing:

Textual data collected from the survey were pre-processed to eliminate irrelevant information, correct spelling errors, and standardize the format. The cleaned dataset was then uploaded to Voyant Tools for analysis.

Text Analysis:

Voyant Tools' functionalities, including word frequency analysis, keyword extraction, and topic modeling, were employed to identify patterns and trends within the textual data. The analysis aimed to uncover prevalent themes, sentiments, and associations related to the perceived causes of smog in Lahore.

Figure 2. Flow Diagram of Methodology

Results:

The data generated from the focus group interviews resulted in three labels after conducting thematic analysis. The major identified themes were eleven, and the sub-themes were fifty-five. The three identified labels were psychological effects, biological effects, and social effects of smog.

Table 1 outlines the psychological effects identified through a survey, categorizing them into major and minor themes. Under the label of "Psychological Effects," five major themes have been extracted, each shedding light on distinct aspects of individuals' mental well-being. The five themes are: (i) Behavior problems that explore issues such as reduced tolerance, frustration, rude behavior, stubbornness, easy irritability, avoidance, unhelpful behavior, insensitivity towards others, and aggressive behavior; (ii) Mood problems that include the spectrum of mood-related challenges**, and it** encompasses feelings of unhappiness, a dull or glum sensation, worry, sadness, despair, mood swings, and disturbances leading to mental discomfort; (iii) Concentration problems that include challenges associated with focus and productivity**,** including issues like reduced concentration on studies, procrastination, disturbances, decreased productivity, and uncertainty about situations; (iv) Isolation that explores the psychological impact of smog on social connections, investigating feelings of confinement and loneliness experienced by individuals**,** and; (v) Anxiety/Stress that includes feelings of tension, stress, anxiety, depression, and a heightened fear of breathing, illuminating the diverse psychological responses to smog exposure.

Table 1. Themes related to psychological effects

Label	Major themes	Minor themes
Psychological effects	Behavior problems	Reduced tolerance
		Frustration
		Rude behavior
		Stubbornness
		Easily irritated
		Avoidance

		Unhelpful behavior
		Insensitive towards others
		Aggressive behavior
	Mood problems	Unhappy
		Dull/glum feeling
		Worry
		Sad feeling
		Despair
		Mood swings
		Mentally disturbed
	Concentration problems	Concentration on study reduces
		Procrastination
		Disturbance
		Productivity reduces
		Unsure about situations
	Isolation	Feeling of confinement
		Loneliness
	Anxiety/ Stress	Tension
		Stress
		Anxiety
		Depression
		Afraid of breathing

Similarly, Table 2 illustrates three major themes that capture the diverse physiological impacts of smog on individuals under the label of biological effects. The following three include: (i) Eye Problems: This major theme highlights the various issues related to eyesight. Minor themes within this category encompass eye irritation, reduced visibility, and redness in the eyes, shedding light on the range of ocular challenges posed by smog exposure. (ii) Respiratory Problems: Focusing on the impact on the respiratory system, this major theme includes minor themes such as difficulty in breathing, sore throat, coughing, the development of asthma, respiratory diseases, and the perception of odors related to smog. (iii) Skin Problems: Exploring the effects on the skin, this major theme encompasses minor themes like acne/eruptions and skin allergies, offering insights into the varied dermatological challenges arising from exposure to smog. (iv) Headache: This major theme delves into the physiological impact on the head. The minor themes include general headache, migraines, and dizziness, revealing the diverse ways in which smog contributes to discomfort and health issues.

Table 2. Themes related to biological effects

Label	Major themes	Minor themes
Biological effects	Eye problems	Eye irritation
		Reduced visibility
		Redness in the eyes
	Respiratory problems	Difficulty in breathing
		Sour throat
		Cough
		Asthma develops
		Respiratory diseases
		Odour
	Skin problems	Acne/ eruptions
		Skin allergy

	Headache	Headache
		Migraine
		Dizziness

Furthermore, Table 3 outlines the social effects identified. Two major themes shed light on the various ways in which smog influences individuals' social interactions and activities under social problems. This section's major theme encompasses the broad impact of smog on individuals' social engagements. Minor themes within this category include the reduction of social interactions, fewer social gatherings, limited activities, increased isolation, restrictions on activities in confined areas, altered daily routines such as leaving home late and returning early to avoid smog exposure, and a noticeable increase in traffic jams. Likewise, the minor themes include avoiding driving, refraining from going out, avoiding long-distance travel, steering clear of vacations, and an observable rise in absenteeism.

Table 3. Themes related to Social Problems effect

Label	Major themes	Minor themes
Social problems	Social life	Social interactions reduce
		Reduced social gatherings
		Limited activities
		Isolation
		Activities are restricted in confined areas.
		Leave late in the morning to avoid exposure to smog.
		Rush back in the evening to avoid exposure to smog.
		Traffic jams increase
	Outings avoided	Avoid driving
		Avoid going out
		Avoid travelling long distances.
		Avoid going on vacations.
		Absenteeism increases

Content Validity Index:

After the ratings from the experts, 52 items were retained by following the criteria of [16] to make the final scale (see Appendix). The scale (PBS) Content Validity Index is calculated as follows:

Scale CVI = Total item CVIs/ Total no. of items

$$=52/55 = 0.94$$

According to the criteria of the S-CVI, 0.80 is acceptable, and 0.90 and higher is excellent [19].

Response format of the Bio Psychosocial (BPS) Scale:

The response format of the psychological, biological, and social effects of smog inventory was decided to be a Likert-type 5-point scale (1 = never, 2 = sometimes, 3 = often, 4 = most often, and 5 = always) that allows for clear ratings. This format is regarded as being balanced as both sides are neutral options. The format gives the respondents sufficient choice to choose the most appropriate option. Furthermore, a higher score represents a higher effect, while a lower score represents a lower effect on the psychological, biological, and social aspects of young adults due to smog.

Perceptions based on Textual Analysis:

From the textual analysis, traffic emissions are mentioned the most frequently (91 times), followed by fewer green spaces (81 times) and factories and industries (78 times). Moreover, power plants and agricultural practices are mentioned the least frequently, as shown in Table 4 and Figure 2.

Table 4. Textual frequency of selected factors contributing to environmental pollution

Sr. No	Factors	Textual Frequency of selected causes
1	Weather Conditions	23
2	Fewer Green Spaces	81
3	Factories and Industries	78
4	Construction Activities	48
5	Traffic Emissions	91
6	Agricultural Practices	16
7	Street Dumping Blaze (Waste Burning in streets)	29
8	Waste Burning	68
9	Power Plants	15

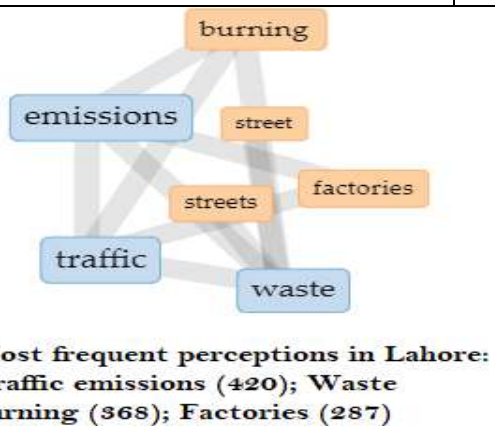

Figure 2. Perception-based word occurrences linked to smog causes in Lahore

Table 5 provides a comprehensive summary of the prevailing combinations of factors contributing to smog, as perceived by the public, along with their respective frequencies. Among all combinations, fewer green spaces with traffic emissions is the most frequent combination selected by respondents in Lahore.

Table 5. Frequency of Public Perception Contributing to Smog

Factors	Textual Frequency of combination
Fewer green Spaces, Traffic emissions	**75**
Less Green Spaces, Factories and Industries, Traffic Emissions	63
Less Green Spaces, Factories and Industries, Construction Activities, Traffic Emissions	52
Less Green Spaces, Factories and Industries, Traffic Emissions, Waste Burning	47
Less Green Spaces, Construction Activities, Traffic Emissions, Waste Burning	42
Factories and Industries, Street Dumping Blaze (Waste Burning in streets), Traffic Emissions	40
Less Green Spaces, Factories and Industries, Traffic Emissions, Weather Conditions	38
Traffic Emissions, Weather Conditions	34
Less Green Spaces, Factories and Industries, Construction Activities, Street Dumping Blaze (Waste Burning in streets), Traffic Emissions, Weather Conditions, Power Plants, Waste Burning	31

Discussion:

The findings of this study demonstrate that smog, driven by both climatic conditions and human-induced emissions, is not merely an environmental nuisance but a multidimensional hazard affecting psychological, biological, and social well-being. The identified behavioral changes, mood disturbances, concentration issues, and heightened anxiety reflect a clear mental health burden associated with recurrent smog episodes. Physiological impacts such as respiratory ailments, eye irritation, headaches, and skin problems underscore the acute biological vulnerabilities, while reduced social interactions and restricted mobility reveal broader societal disruptions. For instance, a study by [20] found a positive association between air pollution exposure and increased aggressive behavior in children. The observed behaviors, such as reduced tolerance and irritability, correspond to the findings in our study, emphasizing the broader implications of smog on individuals' behavior. Likewise, our findings indicate that fluctuations in short-term ambient air pollution levels may be linked to an increased likelihood of engaging in violent behavior, irrespective of the community setting [21]. The current study reinforces these findings, illustrating the wide spectrum of mood-related challenges individuals face due to smog exposure. The findings of the current study on behavioral problems also find support in studies investigating the cognitive effects of air pollution. A longitudinal study was conducted in China to see the relationship between short-term happiness and mental health with air quality. It was found that as the air pollution index increased, short-term happiness significantly reduced, and the rate of depressive symptoms increased. [22].

Furthermore, this study also highlights the diverse physiological impacts of smog on individuals, categorizing them into three major themes: eye problems, respiratory problems, and skin problems, with an additional focus on headaches. These themes collectively underscore the multifaceted nature of biological effects associated with smog exposure. The theme of eye problems draws attention to several issues related to eyesight, supported by the existing literature. Studies have demonstrated that exposure to smog can lead to eye irritation, reduced visibility, and redness in the eyes [2][23][24]. Likewise, an indigenous study was conducted using the Pak-IEM (Pakistan Integrated Energy Model) and GAINS (Greenhouse gas and Air pollution Interactions and Synergies) model for the assessment of overall health effects in Pakistan due to air pollution. Particulate matter, sulfur dioxide, and nitrogen oxides were found in the air in large concentrations. The increase in these pollutant concentrations was associated with a decrease in life expectancy [25].

The physiological and biological effects, including respiratory problems, align with numerous studies highlighting the impact of smog on the respiratory system. Research has shown that individuals exposed to high levels of smog experience difficulty in breathing [26][27], sore throat, coughing, and an increased risk of developing asthma and respiratory diseases [28]. Likewise, major air pollutants of concern in Lahore are particulate matter, sulfur dioxide, and nitrogen oxides that have given rise to respiratory diseases such as cough, asthma, wheezing, chest congestion, and chronic bronchitis [10]. Exposure to particulate matter has shown high blood pressure (systolic and diastolic) in school children (8-12 years) in high air pollution areas of Lahore [29], as well as in older age groups, reported in a study conducted in London [30]. The increase in CO_2 emissions into the air has increased the number of cases of malaria, pneumonia, dengue fever, cholera, heat strokes, and heart attacks in the residents of Pakistan [31].

This study further presents an exploration of the social effects of smog, revealing two major themes that illuminate the various ways in which smog influences individuals' social interactions and activities, falling under the category of social problems. Supporting this, studies have shown a reduction in social interactions and fewer social gatherings in areas with high smog levels. Additionally, individuals exposed to smog often face limited activities and

increased isolation, contributing to the social challenges posed by environmental pollution [32]. Another study revealed that air pollution also has a profound impact on daily hospitalizations and associated costs in Italy, utilizing public transportation strikes as an exogenous shock [33].

Besides, the effects of perceptions are also being recorded with the help of a questionnaire during the study to figure out the real cause of smog in Lahore. The frequency of mention served as an indicator of the perceived impact or importance attributed to each factor. The findings of the study revealed that the prominence of traffic emissions, fewer green spaces, and factories and industries are the most significant factors as perceived by the adults. Traffic emissions emerge as the most frequently discussed contributor, underscoring the pervasive concern regarding vehicular pollution. This aligns with the existing research emphasizing the substantial role of traffic-related pollutants in air quality deterioration, specifically in Lahore district.

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