Agricultural Sciences Journal
Available online at http://asj.mnsuam.edu.pk/index.php
ISSN 2707-9716 Print
ISSN 2707-9724 Online
https://doi.org/10.56520/asj.v7i1.451

Review Article

A REVIEW OF STUBBLE BURNING INDUCED SMOG: RIPPLE EFFECTS ON SOIL ECOSYSTEMS AND HUMAN HEALTH

Diyan Rashid[1], Muhammad Aakash Ather[1], Adnan Fareed[1*], Marina Qayyum[1], Muhammad Shan Latif[2], Moazzam Riaz[1], Zoraiz Amjad[1], Khawaja Muhammad Shoaib[1], Rabbia Khalid[3], Muhammad Affaq Ather[4]

[1] *Department of Soil and Environmental Sciences, MNS University of Agriculture Multan, Pakistan*
[2] *Institute of Plant Protection, MNS University of Agriculture Multan, Pakistan*
[3]*Department of Environmental Sciences, MNS University of Agriculture Multan, Pakistan*
[4]*Department of Agriculture, MNS University of Agriculture Multan, Pakistan*
**Corresponding Authors: adnan.fareed@mnsuam.edu.pk*

Abstract

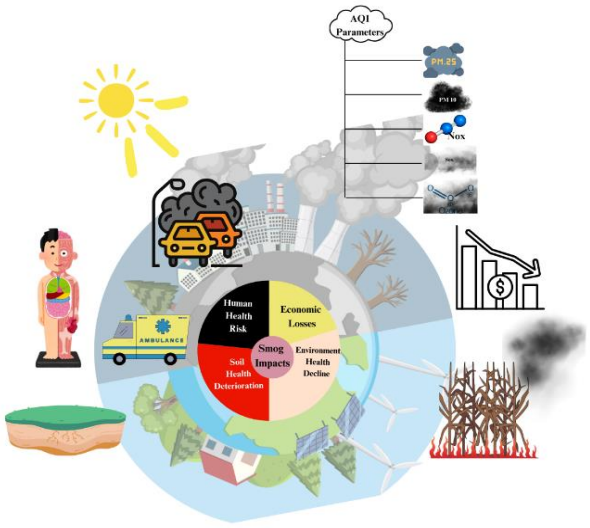
Smog pollution poses a significant threat to the environment, public health, agriculture, and economy of Pakistan. This paper elucidates the mechanisms involved in the generation of smog, impact on the environment and key recommendations to address this pressing issue. It accords much attention to crucial sources which include industrial emissions, vehicular exhaust, burning of crop residue, and unfavorable meteorological conditions with a major focus on urban centers especially Lahore, Multan, and Islamabad. The detrimental adverse effects on agriculture include reduction of photosynthetic rate and a decrease in crop yield, soil health deterioration, and high economic losses to the farming community. Concurrently, smog poses a severe public health risk exacerbating diseases such as respiratory and cardiovascular ailments. Socioeconomic repercussions include escalating healthcare costs, loss of labor productivity, and environmental degradation. Addressing these challenges necessitates integrated approaches combining strict environmental protection policy measures, developments and advancements in clean technologies, and effective large-scale public awareness campaigns. By synthesizing currently available data and identifying critical knowledge gaps, this review aims to recommend sustainable development policies and strategies to mitigate the pervasive impacts of smog on Pakistan's environment and society.

Keywords: *Smog, Air pollution, Environmental health, Agricultural productivity, Public health, Socioeconomic impact, Soil Health.*

Highlights

- Smog, which arises from vehicular emissions, industrial pollution, power generation, and crop residue burning, has severe environmental and health impacts.
- It causes respiratory and cardiovascular diseases, worsens air quality, and increases healthcare burdens, affecting vulnerable populations the most.
- Smog hampers photosynthesis, reduces crop yields, deteriorates soil health, and threatens food security through lower nutritional quality.
- Economic losses include higher healthcare costs, reduced labor productivity, agricultural decline, and disruption to tourism and transportation sectors.
- Strategies to mitigate involve enforcing emission standards, promoting clean energy, sustainable farming practices, public awareness, and innovative technologies like smog-eating towers.

Graphical abstract



(Received: 20-Nov-2024 Accepted: 24- April-2025) Cite as: Diyan. R., Ather. M. A., Fareed. A., Qayyum. M., Latif. M., S., Riaz. M., Amjad. Z. Shoaib. K. M. Khalid. R., Ather. M. A., 2025. A review of stubble burning-induced smog; ripple effects on soil, ecosystems, and human health. Agric. Sci. J. 7(1): 44-65

1. Introduction

The climate of our planet is undergoing continuous and dynamic changes due to anthropogenic and natural factors, significant change was observed throughout the twentieth century as human activities contributed to a rise in the Earth's average temperature of around 0.6° to 0.9° Celsius between 1906 and 2005 (Mondal and Samanta). Human-induced activities are the primary source of pollution that affects Human health, but climate change threatens our future. This is all happening to owe to the excessive and unnecessary usage of an enormous quantity of oil, gasoline, coal, and natural gas in our daily lives to meet household requirements, utilization motor vehicles, manufacture of different products, and generating electricity (Karl and Trenberth, 2003). Scientists determined that ozone pollution will exacerbate global warming and harm plants and trees that help absorb carbon emissions (Harmens and Mills 2012). It is suspected that humans have ignored a significant aspect of the climate-change equation. Ozone is causing trees and plants to lose their well-known ability to absorb carbon dioxide (CO_2), the primary greenhouse gas. As a result, more CO_2 will accumulate in the atmosphere, instead of being taken up by the land, which may ignite global warming and thus aggravate climate change, generating smoggy skies, black carbon, or soot as a secondary contributor to the major issue of global warming. The agriculture sector also contributes to environmental pollution and climate change.

Smog is a significant environmental challenge in contemporary times. Smog is defined as a toxic cocktail of air contaminants formed by complex photochemical reactions including, NOx, SO_2, PM2.5 and PM10, and ground-level ozone (Sokhi, 2008). Smog, an ominous amalgamation of pollutants affecting the ecosystem worldwide, and in the case of Pakistan, most of Punjab and majorly the cities residing next to Indian Punjab, presents a tremendous challenge to environmental well-being. This atmospheric blanket, primarily composed of particulate matter and ground-level ozone, demands urgent and comprehensive solutions. Rice residues are burned due to their limited utility. Similar to Wheat straw, it is not used as livestock feed, reason unlike wheat rice residue has lower nutritional value and high silica content (up to 15%) which makes it difficult for animals to chew and digest, also it is economically ineffective to have it incorporated in the soil, so farmers take the shortest route of burning the rice straw. Agriculture is the primary contributor to Pakistan's economy, with major crops such as wheat, rice, and cotton playing a pivotal role, as per the reports agriculture contributed 24% to the national GDP and also provided 37.4% employment. The productivity of these crops is intricately tied to a complex interplay of factors, including climate conditions, soil health, and agronomic practices. The number of toxic substances that create smog in the air comes mostly from farming operations.

Previous research reveals that crop development depends on farm management methods particularly nitrogen use and water supply systems (Ahmed *et al*., 2023).The effects of sulfur and organic compost on plant photosynthesis and yields highlight the importance of sustainable agricultural practices to reduce environmental degradation (Haq *et al*., 2021). The current review Focuses on exploring the impact of smog in Pakistan, especially south Punjab exploring its origin and contributing sectors. Due to climate change, Pakistan has become one of the most polluted regions of the world, Lahore, Multan usually tops the list of most affected cities with hazardous AQI readings,

the emphasis laid here is on its trend throughout the winter season. Multan was reported as the world's most polluted city in the First 2 weeks of November 2024 by IQAir (An international air quality technology company) when on 8 November 2024, 21:00hrs the AQI was reported at 2266 Points with PM 2.5 values being 242.2 times the normal permissible limit, exposing >5.3 million residences to air quality categorized as "Hazardous". This Exposure caused the appearance of an estimated more than 1000 daily health issues, the culprit being smog. As of 20th November 2024, Multan has an AQI of 156 categorizing it as "unhealthy", with Lahore at 224 AQI Points and currently 3rd most polluted city, Delhi being the most polluted at 285 AQI points and Cairo being 2nd most polluted world city with 254 points with air categorized as "very unhealthy" in all 3 mentioned cities. Smog is an ever-recurring nightmare to humanity, agriculture, and general health complications including respiratory and cardiovascular diseases, soil health, crop yield, and photosynthesis (De Jouvenel, 1999). On the Parallel side, it had the same negative impacts on the economy it has raised the costs of health care and has impaired the productivity of employees, transport, and the industrial areas.

The review aims towards the severity and complexity of the smog problem in Pakistan. The review suggests how these problems can be solved as well as in various collaborations for these problems which include strict environmental policies, the use of clean energy, awareness among people, and the right techniques of farming. This also speaks about the application of innovations, the towers that supposedly purify the air, and the case studies born out of the samples of the best practices, represented as applicable to the Pakistan environment. The smog crises present a multifaceted challenge that requires collaborative action from government, environmental organizations, and research centers. By offering insights into the causes, consequences, and potential solutions for smog this review aspires to guide future research and inform policy strategies to alleviate the environmental and societal impact of this pressing problem. The study highlights the necessity of interdisciplinary approaches to successfully address the pollution challenge, aims to identify knowledge gaps, causes, impacts of smog, and possible solutions. and highlight more focus on Pakistan with a special reference to most polluted cities (Lahore, Multan).

Understanding this nexus is crucial for devising strategies to enhance crop yields and ensure the food security of all plants, which relies on the fundamentals process of photosynthesis for growth and grain development (Smith *et al.*, 2023). However, smog, acts as a veil, obstructing the sunlight crucial for photosynthesis in Punjab Pakistan (Figure 1).

2. Smog and Key contributors

Smog is not a new disaster that human beings are facing today due to climate change. The history of Smog is old as more than half a century ago (Atafar *et al.*, 2025). Great London Smog is the historical example about how severe air pollution can be, that is an environmental disaster that occurred in London in December 1952 had a major impact on the subsequent international regulation of environmental and public health. For five days, from December 5 to December 9, the Great London Smog caused a great deal of chaos and left between 4,000 and 12,000 people dead. Several factors realized the haze, several variables in other words. During winter, people in London use a lot of volumes of cheap and high-sulfur coal as a source of warmth. Consequently, Thick black smoke was choked into the atmosphere. A layer of warm air over the cold air hinders the spreading of pollutants and holds them down to the ground. This led to the phenomenon known as temperature

inversion. This was made worse when the city recently replaced the electric trams with diesel buses, which further emitted pollutants. The smog of a thick yellow-black "pea-souper" cut visibility to less than 10 meters in the worst areas. Daily life was severely disrupted, with transport systems shutting down, increased accidents, and overwhelmed healthcare facilities. In addition to immediate health hazards, the situation highlighted deeper environmental issues, e.g., the effect of pesticides on fruits and vegetables demonstrates the long-term impacts of environmental contamination. These problems need for stringent environmental monitoring and the adoption of sustainable management practices for the protection of ecosystem as well as human wellbeing (Mehar *et al*., 2023). This noxious substance attacked the respiratory, skin, and mucous membranes, resulting in a completely overwhelmed hospital and mortuary system. Undertakers ran short of coffins, while florists could not meet the demand for funeral flowers (Polivka, 2018). A sobering effect of uncontrolled industrial pollution is provided by the Great London smog, which emphasizes the value of strict environmental laws.

A combination of agricultural waste burning and automobile pollution and industrial operations generates smog formation. Oxidative degradation techniques in studies established that pesticide breakdown from agricultural soil and their environmental longevity play vital roles in smog formation (Fareed *et al.*, 2021). If we talk about Pakistan which is one of the most affected countries by climate change the first-ever smog in the country was reported in the 1990s in Lahore. According to (Khan and Rashid, 2019), Lahore capital of Punjab is the country's most populated and dense industrialized city that experiences visible smog during the winter months. However, it was not identified as a distinct environmental issue at that time. Afterwards it gained attention in early 2000s when the haze became more frequent and severe (Pakistan Meteorological Department, 2020; Air Pollution Trends and Seasonal Smog in Pakistan, 2020). As per the information given by Raina, 2021, Lahore's first smog event was recorded in November 2015, then in November 2016 there was a second smog event and the Lahore High Court took notice. Then in 2017, a smog policy came out but no significant action has been taken and Air Quality Index levels in Lahore still cross 300 which is hazardous to human health. According to her, there were 20,000 brick clines in the country that burn all kinds of fuel and release cancer-causing dioxins into the air. (Figure 2) showing the formation of photochemical smog. According to (Nasar-u-Minallah *et al.*, 2024) public awareness and preventive measures are vital to contests against smog's health effect. According to him by engaging communities through digital tools, targeted campaigns, and participatory initiatives like citizen sciences, people become more informed, responsible, and motivated to support smog-reduction practices and support for policy change.

Several factors are responsible for air pollution, but the following are some key factors that have significant contributions to the production of smog (Figure 3 & 4).

2.1. Transport or vehicular emission

This is the largest source of pollution with more than half (45%) of the total pollutant contribution. Probably included are the emissions from automobiles, trucks, airlines, and other forms of transportation (Van fan *et al*., 2018). Since most roads transportation are based on fossil fuels such as gasoline and diesel it highly depends on all fossil vehicles like automobiles, trucks, buses, and motorcycles. Some of the main contaminants emitted by these automobiles include PM, carbon monoxide, nitrogen oxides, and carbon dioxide. Another important source is

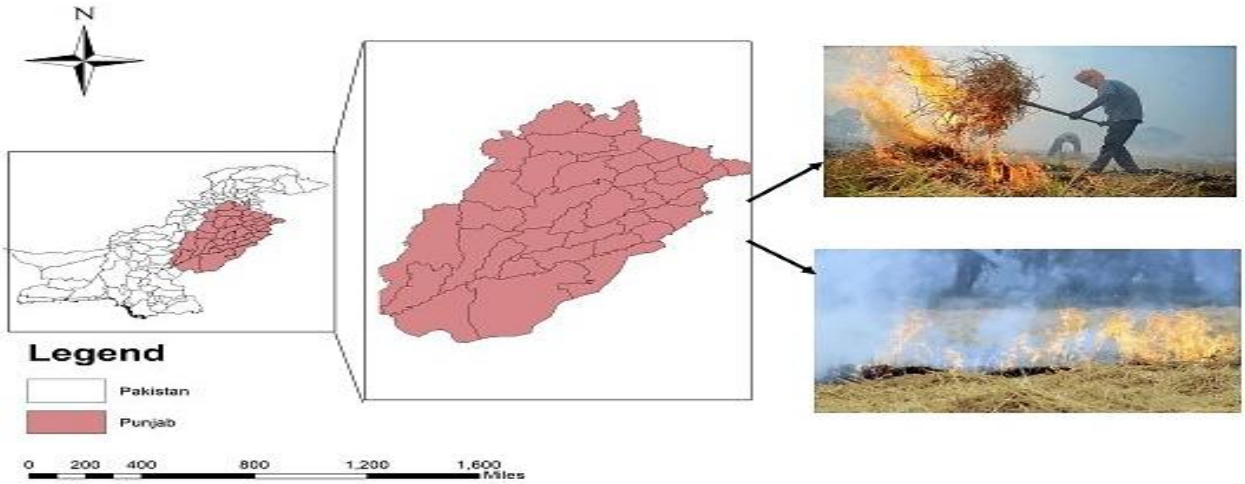


Figure 1: stubble burning a major source of smog in Punjab, Pakistan.

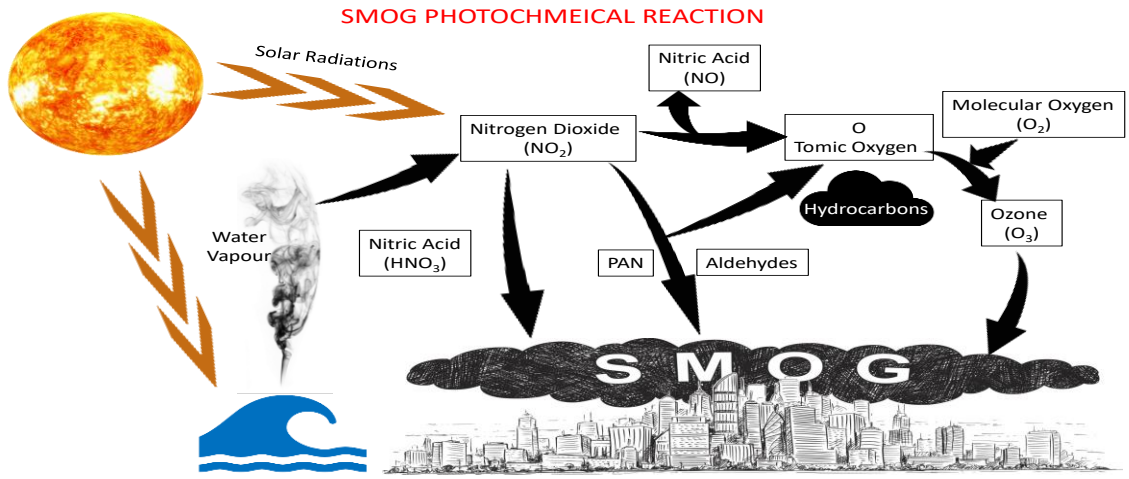


Figure 2: Formation of photochemical smog through interaction gases with atmospheric components.

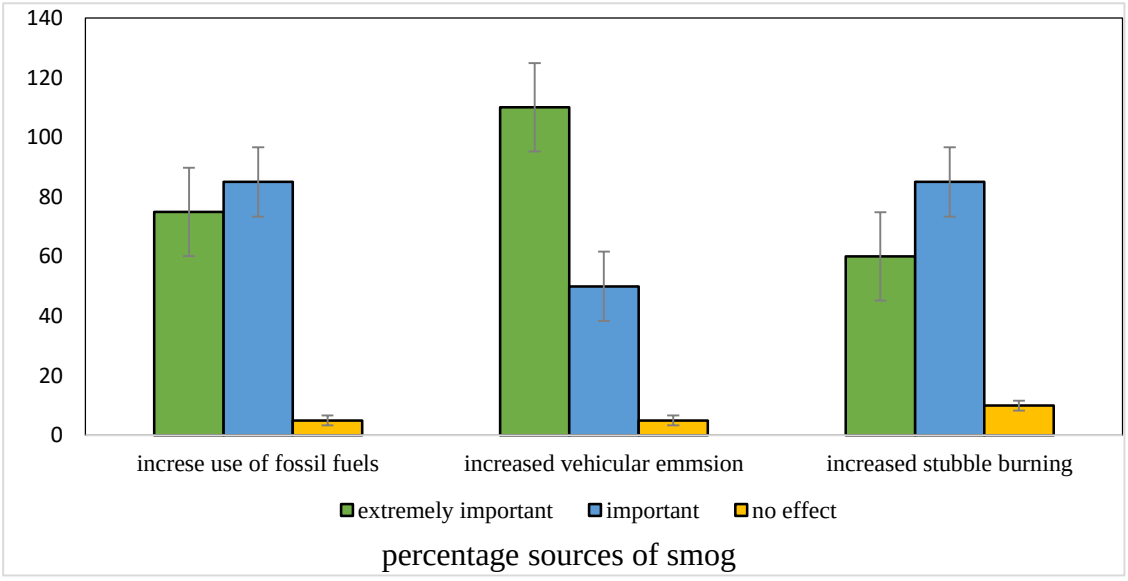


Figure 3: contribution of different factors in Smog

aviation because planes emit quite a lot of COS_2, and high-altitude emissions contribute to climatic effects like aviation-related clouds and contrails. NOx and SOx are emitted by ships that use heavy fuels for maritime transport, affecting port and coastal communities (Mark, 2014). Although electric trains are cleaner, rail transportation also plays a role, mostly through diesel-powered locomotives in areas with insufficient electrification.

2.2. Industrial source

Industry is the second largest pollution source, accounting for 25% of the overall tally. This could be the discharge from manufacturing facilities, factories, and other industrial activities that emit poisonous chemicals into air (Holman, 1999)

2.3. Power sector

Twenty-two percent of all pollution comes from power generation. This includes emissions from power plants that produce electricity by burning fossil fuels like coal, oil, and gas (Cropper *et al*., 2019).

2.4. Agriculture sector

The crop residue burning of the agriculture industry contributes to 20% of the pollution in the table. Crop residue burning is the burning of crop waste, including stalks and leaves, after crops such as rice, wheat, and sugarcane have been harvested. This is often in practice with the farmers since it is comparatively quick and cheaper to prepare fields for the next planting season, especially in regions where mechanized alternatives are either not available are too expensive (Borghi *et al*., 2023). This activity emits a great deal of various pollutants into the atmosphere such and Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), particulate matter (PM2.5 and PM10), carbon monoxide (CO), and black carbon. Methane and nitrous oxide are particularly worrying because they are strong greenhouse gasses that contribute enormously to global warming but particulate matter and black carbon degrade air quality and have effects on respiratory health (Harizanova-Bartos and Stoyanova, 2018).

3. Key Indicators of Smog

Smog is an atmospheric complex phenomenon associated with the mixing of a variety of pollutants degrading air quality, visibility, and public health. It primarily involves smog contributors like PM2.5 and PM 10 and O3, NOx, SO2, CO, and VOCs, which often form as emission products of vehicles, industrial activities, and biomass burning. Meteorological factors such as the high temperature, photic strength, humidity, winds, and temperature inversion all contribute to the formation and dissipation of smog. Indices of the existence of smog, which may include invariably lowered visibility by haze and light scattering, also exhibit seasonal and diurnal variations. Environmental impacts of smog range from damage to vegetation to acid precipitation and climate changes, while health effects from smog include an increase in respiratory and cardiovascular diseases. These comprise the Air Quality Index (AQI), satellite imaging, and ground monitoring stations through which it is possible to analyze smog-connected trends of influence. Knowledge of these measurements is very critical to developing strategies that could potentially solve smog and its extensive consequences (Haq, 2022).

3.1. Air Quality Index

The AQI is a standardized measure communicating the quality of air in a specific area, making it easier for the public to interpret complicated information about pollution. The concentration of pollutants is translated into an understandable scale ranging from "Good" to "Hazardous" and provides health advisories based on the same levels. The five primary air contaminants emphasized by AQI are particulate matter PM 2.5 and PM 10. ground-level ozone (O3), nitrogen dioxide (NOx) Sulphur dioxide

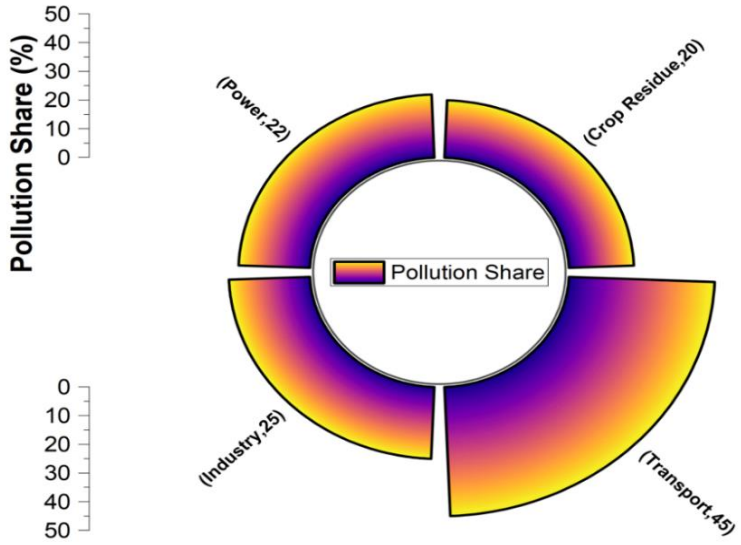


Figure 4: contribution of different sectors

Table 1. The AQI scale typically ranges from 0 to 500, with higher values indicating poorer air quality and greater health concerns. It is divided into several categories:

AQI	Pollution level	Health implications	Cautionary Statement (2.5,2.10)
0 - 50	Good	Air pollution poses no risk, and the quality of air is considered satisfactory	None
51 -100	Moderate	The quality of air is acceptable but some people have little health concerns from air pollutants and are usually sensitive to air pollution	People with respiratory conditions like asthma, as well as active adults and children, should avoid extended outdoor exercise.
101-150	Unhealthy for Sensitive Groups	General public may not be affected but sensitive people may experience health effects.	People with respiratory conditions like asthma and active children and adults should avoid extended outdoor exercise.
151-200	Unhealthy	Every individual experience health effect but sensitive people experience serious health issues.	Active children, adults, and persons with respiratory diseases, such as asthma, should avoid extended outdoor exercise; everyone else, especially youngsters, should restrict prolonged outdoor exertion.
201-300	Very Unhealthy	Health emergency condition, the entire population likely to be affected	Everyone else, especially youngsters, should minimize their outside exercise, but active children and adults and those suffering from respiratory conditions like asthma should avoid all outdoor activity.
300+	Hazardous	Dangerous to health and everyone experiences serious effects	Prevent outdoor exertion

The AQI is accessible to public both in tabular and graphically interpreted through the free apps like IQAir that are available for both Android and IOS

(SO2), and carbon monoxide (CO). All these pollutants differ in their health effects and source of emission which makes them indicators of air quality (Table 1).

3.1.1. Particulate matter 2.5 and 10

Particulate matter 2.5 and PM 10 represents fine and coarse particles present in the air. PM 2.5 small enough to be transported by the blood vessels, is mainly released by vehicles, industries and associated with diseases like respiratory and cardiovascular. PM 10 is slightly larger in size. It mainly affects the upper portion of the respiratory system, thus causing irritation. For particulate matter permissible limits for PM 2.5 5 is set at 5 µg/m³ for the mean annual and at 15 µg/m³ for the mean over 24 hours. For PM 10, the limit is set at an annual mean of 15 µg/m³ and at a 24-hour mean of 45 µg/m³. These sizes are easy to penetrate even through the lung and bloodstream, potentially leading to respiratory and cardiovascular problems (Brook and Rajagopalan, 2009).

3.1.2. Ground-level Ozone (O_3)

Ground-level ozone is a secondary pollutant that is formed by photochemical reactions between NOx and VOCs in the presence of sunlight. Ozone can cause respiratory problems, besides damaging the vegetation as it suppresses photosynthesis. The allowed concentration for O_3 is 60 µg/m³ for the 8-hour average during peak season. However, though it is considered a non-primary pollutant, which is produced through photochemical processes, it still contributes to formation of smog and irritates human respiration (Sicard, 2021).

3.1.3. Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2) & Carbon mono-oxide (CO)

Nitrogen dioxide, NO_2, is a reddish-brown gas formed from combustion processes, including engines in vehicles and industrial processes (Patel *et al*., 2014). It aggravates asthma, contributes to the formation of smog, and causes acid rain. In the same way, sulfur dioxide, SO_2, is a gas emitted once its combined fossil fuel with high sulfur contents undergoes combustion, which irritates the respiratory system and creates acid rain and particulate matter. Carbon monoxide (CO), an invisible, odorless gas, is a product of incomplete combustion that competes with oxygen in the body and, at higher concentrations, can cause dizziness and confusion, or even death. There is a permissible limit for nitrogen dioxide (NO_2) set annually at 10 µg/m³ and 24-hour at 25 µg/m³; it is another bad actor often emitted from car exhaust systems and industrial operations but blamed for contributing to respiratory disease and forming smog. These permissible limits are set at 40 µg/m³ for the 24-hour mean and 500 µg/m³ for the 10-minute mean. It is highly produced as a byproduct from burning sulfur-rich fossil fuels. SO_2 is capable of causing respiratory irritation and contributes to acid rain. The set standards of carbon monoxide (CO) articulate several threshold levels including: 4 mg/m³ for a 24-hour average; 10 mg/m³ for an 8-hour average; 35 mg/m³ for a 1-hour average; and 100 mg/m³ for a 15-minute average. A high exposure level of CO interferes with the transport of oxygen in the body and causes heavy health impacts (Ogbiye *et al*., 2019).

3.2. AQI data for Major Cities of Pakistan

The AQI act as indicator developed by the government agencies to communicate the public that how polluted air is. Talking about Pakistan, it has faced some of the world's worst AQI in recent years. Lahore, a major city of Pakistan and Provincial capital of Punjab has been the most polluted country of the world. Following is the AQI data of some major local cities. Following is the AQI data of some major local cities

3.2.1. Lahore: Capital of Punjab, Pakistan

Lahore has been the most polluted country of the world in recent years. Several causes of this pollution lead to the increase in the AQI of Lahore to a harmful level for the community. Following is a graph that shows

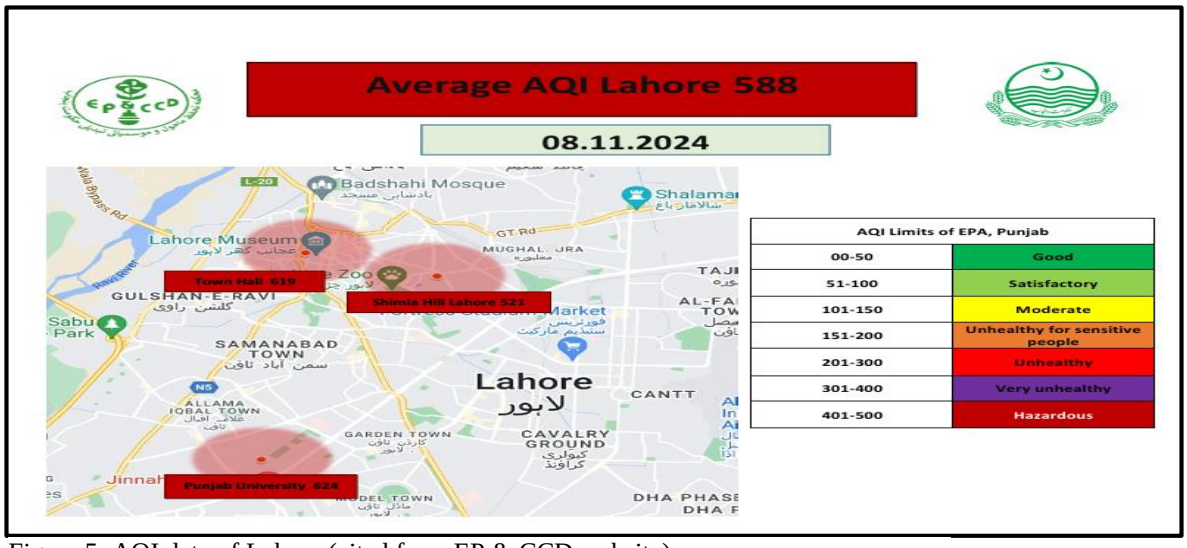


Figure 5: AQI data of Lahore (cited form EP & CCD website)

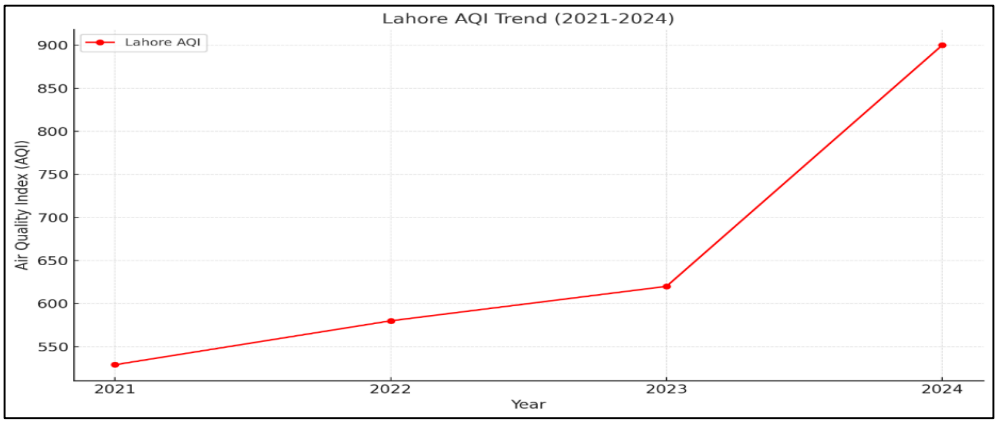


Figure 6: AQI trend of Lahore of last four years

Following is the AQI calendar of Lahore of the last 2021 cited from IQ air website

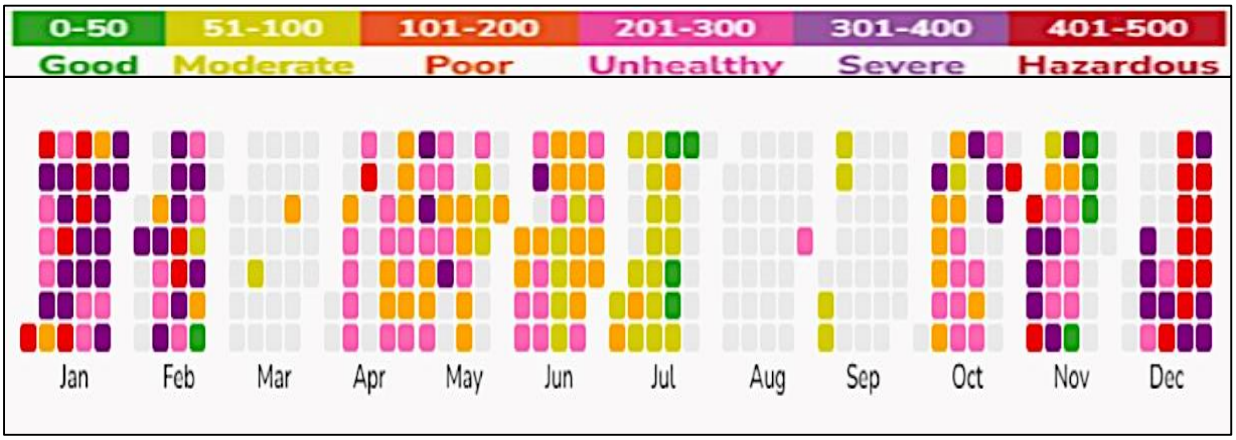


Figure 7: AQI calendar of Lahore 2021

The following graph show the daily basis PM 2.5 level of Lahore of year 2024, from October to so on.

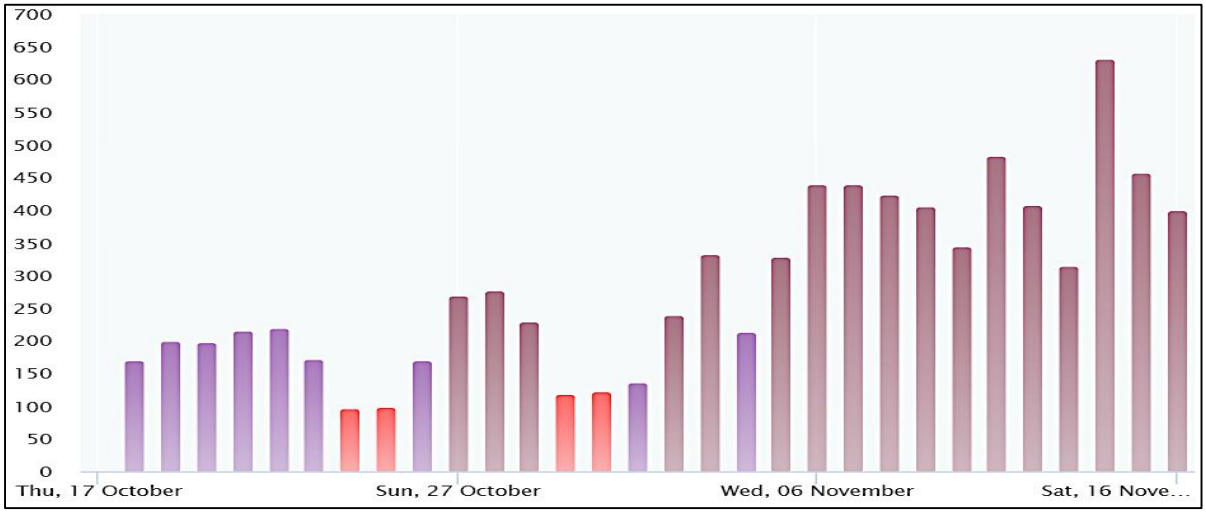


Figure 8: Daily basis PM 2.5 level of Lahore

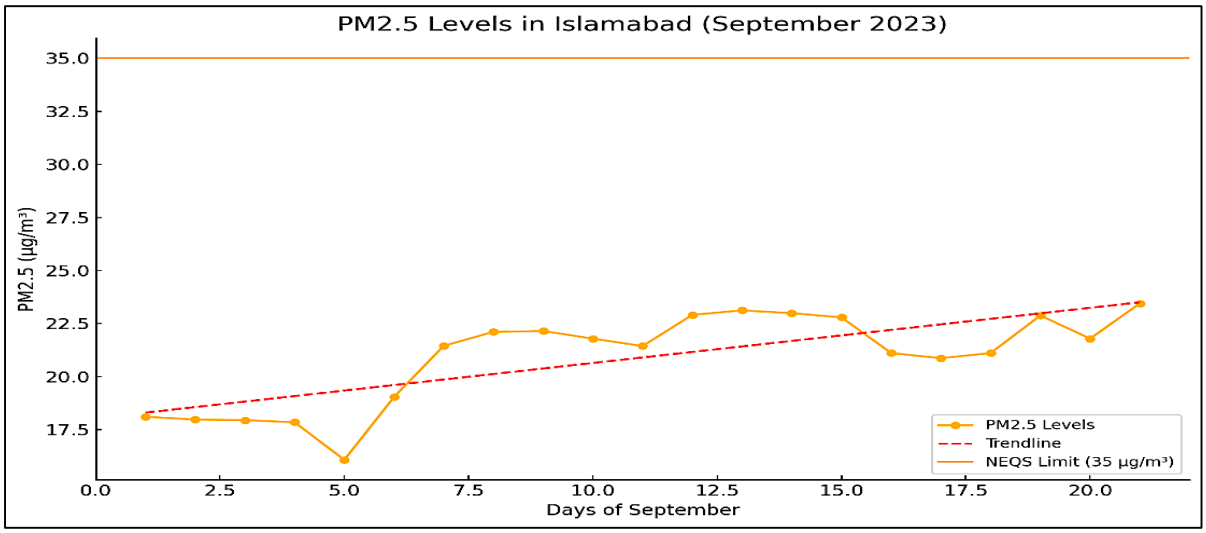


Figure 9: PM 2.5 level in Islamabad

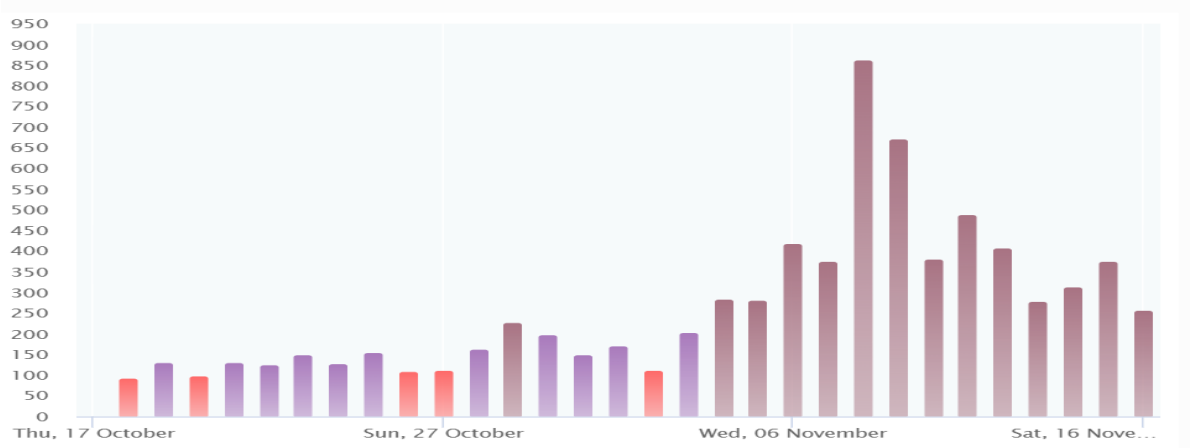


Figure 10: Daily basis PM 2.5 data Multan

Table 2. The trend of PM 2.5 and 10 among various countries

WHO Region	Country Name	City or Locality	Measurement Year	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	Reference
Eastern Mediterranean Region	Pakistan	Faisalabad	2013	36.5	148.17	Niaz Y. *et al*., (2016), Pak. J. Agri. Sci., Vol. 53(1), 97-106; DOI: 10.21162/PAKJAS/16.3623
Eastern Mediterranean Region	Pakistan	Islamabad	2019	39.78	78	Pakistan Environmental Protection Agency
Eastern Mediterranean Region	Pakistan	Lahore	2010	121.8	198	Alam K, *et al*., Aerosol size distribution and mass concentration measurements in various cities of Pakistan, J. Environ. Monit., 2011, 13, 1944
Eastern Mediterranean Region	Pakistan	Peshawar	2010	95	540	Alam K, *et al*., Aerosol size distribution and mass concentration measurements in various cities of Pakistan, J. Environ. Monit., 2011, 13, 1944

how AQI of Lahore contaminates each year from 2021 to 2024. This trend shows us the alarming situation of Lahore which is very dangerous for both ecosystems as well as humans. Starting from already hazardous level 529 which is the average value of AQI of 2021 to this ongoing year it has reached to extreme spike of Almost an average of 900 till November 2024 we see that there is an extreme level of increase in the pollution of Lahore. If we see the 2024 catastrophe, suggest that the environment is heavily saturated with PM and toxic gases making the air virtually unbreathable. The immediate effect causes respiratory disorders, increases the number of lung patients in hospitals and causes a significant impact on the Economy and community.

3.2.2. Islamabad: Capital of Pakistan

Islamabad has been famous for its fresh and healthy air. Unfortunately, due to carelessness and lack of interest towards the environment the natural beauty of. Islamabad IF we see the Average PM 2.5 data of September 2023 that is approximately 20.90 $\mu g/m^3$ that is greater than the 2022 and previous years AQ index. Red line in the graph showing that how gradually the AQI increasing on daily basis.

The chronic exposure to this PM 2.5 may leads to the premature death and lungs cancer like issue. So, to maintain the air quality of Islamabad government must have to take some steps for crucially monitoring the pollution spike. And make awareness in public about the harmful impacts to protect them from poisonous air.

3.2.3. Multan: Most Affected City in 2024

Multan AQI ha increased surprisingly in 2024, here till the Multan becomes the most polluted city of the Pakistan, there are multiple factors that leads to this situation. Multan has recently been Pakistan's most polluted city, with its Air Quality Index (AQI) reaching apocalyptic levels during the September days because of industrial emissions, traffic pollution, crop burning,

and irresponsible development. The issue has thus worsened due to the lack of strong environmental laws and general awareness. This pollution disaster not only creates respiratory diseases, cardiovascular diseases, and immunity but also seriously harms public health and disturbs the pattern of everyday life by reducing visibility, delaying transportation, and shortening outdoor activities. The city is also facing a sharp decline in agricultural yields, productivity of workers, increased healthcare costs, and tourists visiting the city. The situation become too critical that government decides to impose Health emergency in the city and lock down for some times.

In the early days of 2021 as well as the very tail end of 2020, Multan was coming in consistently with some elevated readings of PM2.5, indicating that it does indeed have a problem with pollution, a problem that is unfortunately shared by many other cities in Pakistan. In late December 2020, PM2.5 readings varying from as low as 40.3 μg/m³ were recorded, going all the way up to readings as high as 136.3 μg/m³(Figure 10). The implications of smog-induced challenges are not confined to the crops alone. Reduced visibility, altered climatic conditions, and uncertainties about the growing environment disrupt routine farming activities. Timely planting, irrigation, and harvesting become challenging, adding a layer of stress for farmers who are already grappling with numerous uncertainties (Table 2).

4. Impact of smog on soil indicator

A study reported rapid acidification of forest soils in the San Bernardino Mountains of southern California. The pH of soil down to 25 cm has dropped from 4.8 to 3.1 after 30 years. It is now pH 4.2 instead of 4.8 at the 50-cm depth. Very high rates of anthropogenic atmospheric nitrogen (N) (A key component of Photo chemical compound) delivered to the soil surface (72 kg ha–1 year–1) from wet, dry, and fog deposition under a Mediterranean climate were blamed for this quick change in soil reactivity (Wood *et al*., 2007).

4.1. The Impact of Smog on Chemical Indicators

A polluted environment can greatly influence the chemical indicators of soils by falling gaseous pollutants such as NOx and SO_2 (Gaffney *et al.*, 2009). These pollutants lead to acid rain, thus reducing soil pH. Acid rain can thus reduce the pH from a neutral range of 6.0-7.5 below 5.5 in highly affected regions with the high potential to limit the availability of precious nutrients. Therefore, soil acidity is one of the nutrient imbalances associated with smog and hence leads to leaching up to 50% in water-soluble forms of calcium (Ca) and magnesium (Mg). But availability of toxic metals like aluminum (Al) may increase by as much as 70% under these acidic conditions and lead to toxicity that depresses plant growth and productivity (Raza *et al.*, 2021).

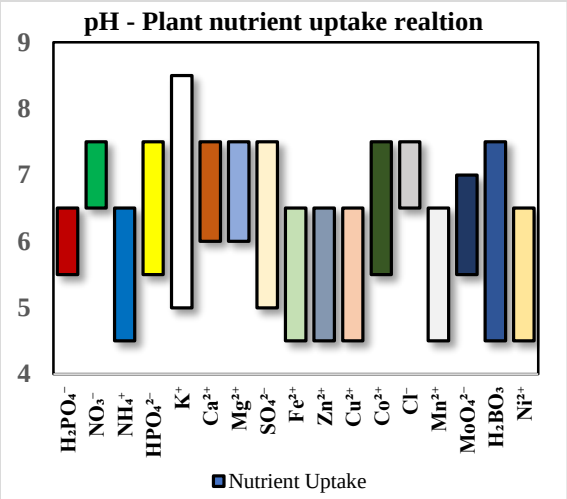


Figure 11: Effect of stubble burning on the pH and plant nutrition interaction

Impact of Smog on Biological Indicators

In turn, smog adversely affects the biological soil health markers including microbial activity and organic matter content in soil (Arif and Hassan, 2023). For those residing in highly exposed areas, the pollutants through smog may decrease microbial biomass by as much as 30%. Low pH and

deposition of harmful compounds can reduce respiration rates that indicate microbial activity by 25–40%. Acid rain accelerates soil organic matter decomposition. Losses are seen to be 20–30% in carbon on analyses conducted in the affected regions. Water retention may be decreased to as much as 15% and this reduces the vigor of soil and its capacity for agriculture (Nizhelskiy *et al.*, 2025).

4.2. Smog Effect on Physical Properties of Soil

The physical properties (Figure 12 a & b) such as soil structure and bulk density, are indirectly affected by smog. Acid precipitation weakens soil aggregates through an amount of 35% reduction of the stability in very badly affected areas (Ali *et al.*, 2024). Soils were compacted and values of bulk density exceeded the optimal ranges of 1.1–1.3 g/cm³ to as high as 1.6 g/cm³, thus limiting root penetration and water infiltration. Destabilized soil aggregates linked to erosion doubled in the smog-affected areas than in the control areas. Loss of nutrient-rich topsoil can decrease crop yields between 20–50% (Gaffney *et al.*, 2009).

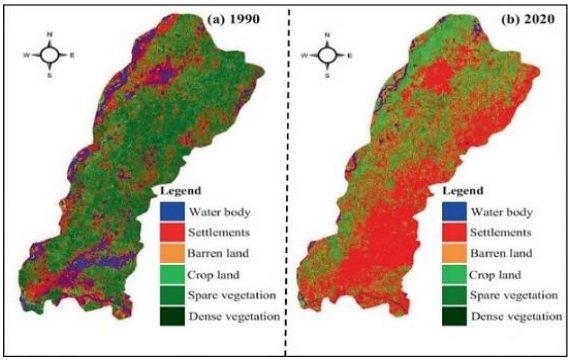


Figure 12: (a) Smog impact on the physical properties in 1990, (b) Smog impact on physical properties in 2020. Cited from: (Naeem *et al.*, 2022)

4.3. Effects of Smog on Soil Ecological Indicators

Among all other ecological indicators, soil biodiversity and erosion rates are most easily affected by smog. The pollutants resulting from smog lowered populations of all soil organisms-from earthworms to mites and fungi-by 40-60%. Such disruptions impair vital ecosystem services, including decomposition and nutrient cycling. Acidification and changed soil structure add to erosion, with an annual loss rate of up to 30 tons per hectare of sediment in areas with high levels of smog (Gaffney *et al.*, 2009). Urbanization, which is often caused by smog-producing industries, causes soil sealing, affecting between 20–30% of agricultural land in urbanized regions, thereby reducing the available land with threats to soil sustainability (Razzaq *et al.*, 2024). Smog is a long-standing problem in Pakistan, and in the winter months of October till February, contaminates in the air in Punjab province shoot up, especially due to the burning of post-harvest rice stalks (Safdar *et al.*, 2022). The lethal fog has also harmed Pakistan's winter crops. While field laborers are unable to operate in the fields as previously, crops and yields are also harmed by this type of air pollution.

A considerable reduction in the quality of agricultural output is also projected. Standing crops are also poorly affected by foggy conditions. Wheat, a major crop of the winter season and a food staple in Pakistan, is also severely affected by it. Wheat production remained almost stagnant in the last decade as its production fluctuated between 23295 to 24946 thousand metric tons from 2007 to 2020 Overall yield loss is estimated between 10% to 30% due to smog (Safdar *et al.*, 2022). This study shows the significant negative result of air pollution and NO_2 on crops in developing countries. Air pollution has a negative result on food security since it affects plant expansion and is also dangerous for agricultural products or plants. Hence, air pollution significantly reduces vegetable prices and effects on consumer actions in the short run. The detrimental effects of smog on wheat extend beyond quantitative losses. The

pollutants infiltrate the grains, compromising their quality and nutritional content. In a nation where wheat is not merely a commodity but a dietary cornerstone, the potential health risks associated with diminished nutritional quality pose an additional layer of concern to national food security (Ehrlich *et al.*, 1993). A weakened crop becomes an open invitation to pests and diseases. The stress induced by smog compromises the natural defense mechanisms of wheat plants, making them more susceptible to infestations (Cerdeira and Duke, 2006).

Increased pesticide use may follow, exacerbating environmental concerns and further destabilizing the delicate ecological balance within agricultural ecosystems. In Pakistan, the menacing presence of smog emerges as a dire threat to the nation's food security, exacerbating the vulnerability of its agricultural sector. The adverse impact of smog on crops, particularly staple foods like wheat and rice, disrupts the delicate balance required for sustained agricultural productivity. The reduction of sunlight penetration due to smog impedes the process of photosynthesis, compromising the energy production vital for robust crop yields. This hindrance not only leads to diminished quantities but also jeopardizes the nutritional quality of the food produced, directly impacting the health and well-being of the population. Furthermore, the infiltration of smog's components, including sulfur dioxide and nitrogen oxides, weakens the respiratory systems of crops, rendering them more susceptible to diseases and pests. This increased vulnerability threatens the resilience of crops, contributing to yield losses and exacerbating food security concerns. Climate instability, influenced by smog-induced alterations in local weather patterns, introduces unpredictability into agricultural practices. This unpredictability, manifesting as irregular growing seasons and unanticipated weather events, compounds the challenges faced by farmers striving to ensure stable yields (Gupta, 2014).

5. Impact of Smog On Agricultural System

5.1. Changes in Crop Composition

Air pollution exposure modifies crop composition. The excess amount (for instance, a high level of SO_2) can cause the plants to accumulate sulfur and consequently decrease the nutritive value obtained from such harvested crops. Such alterations also have an effect on human as well as animal nutrition (Yadav *et al.*, 2022).

5.2. Soil Contamination

Pollutant smog may also be found on some soils thus contaminating them. It can also impact the supply of nutrients for plants and might lead to severe degradation of soil fertility. The quality and safety of foods produced can also be adversely affected by the contamination of soils (Razzaq *et al.*, 2024). The smog-contaminated environment produces adverse effects on soil health that diminish both soil fertility and microbial action while decreasing crop productivity (Akhtar *et al.*, 2022).

5.3. Water Contamination

Smog deposition of pollutants can also cause the pollution of freshwater sources affecting the quality of irrigation water. Farmers may also encounter problems associated with the use of water that is polluted (Rani *et al.*, 2011). Such contamination may render crops unhealthy, making it difficult for them to be productive.

5.4. Impact of Smog on Livestock

Livestock may suffer from health problems due to air pollution such as smog. Pollution especially of ambient air can cause diseases such as respiratory tract complications in stock. It affects livestock productivity, including the production of milk and meat. Smog has substantial health repercussions, including asthma, respiratory tract damage, air canal and tracheal complications, heart

disorders, and many Pathogenic and allergic infections. Numerous remedies to the smog problem have been presented by numerous writers in recent years. Investing in renewable energy technology is the most effective strategy to minimize air pollution caused by fossil fuels and coal power plants. To reduce wasteful waste, enterprises must prioritize the usage of renewable energy. In other words, we must reduce our industrial wastes by enacting legislation and policies that require industries to transition to renewable energy sources, as it will guarantee a much more livable and sustainable future but also reduce Nitrogen dioxide, Nitrous Oxide, Sulphur Oxide, semi-volatile organic compounds and volatile organic compounds emissions. Pollution detectors can come in handy while determining the extent of pollutants in the atmosphere, notifying authorities well in advance to take all necessary precautions to prevent it. Extensive usage of renewable green energy will address the difficulties of expanding energy consumption in densely populated places, reducing greenhouse gas emissions, and preserving environmental production efficiency and sustainability integrity (AmuzuSefordzi *et al.*, 2018).

6. Impact of smog on Human Health

Smog not only reduces people's quality of life by introducing illnesses into their lives, but it also exacerbates health conditions such as asthma, emphysema, chronic bronchitis, and other respiratory ailments (Figure 13a, b). In addition, eye irritation, decreased flu resistance, changes in climatic conditions, an increase in lung infections, and numerous skin problems (Naureen *et al.*, 2022). When questioned about various health conditions caused by pollution, 87% reported coughing and throat infections, 31.7% had asthma worsening, and 41% had difficulties breathing. Similarly, 11.2%, 24.2%, and 30.4% of respondents reported chronic bronchitis, irritated breathing passages, and skin illnesses, respectively. Furthermore, 83% of participants said that pollution made their illness worse (Yang *et al.*, 2017).

Through the production of reactive oxygen species, smog can either directly or indirectly cause oxidative stress in humans. A vast network of bacteria linked with humans covers the outermost layer of human skin and mucous layers. These microbial communities have primarily mutualistic relationships with

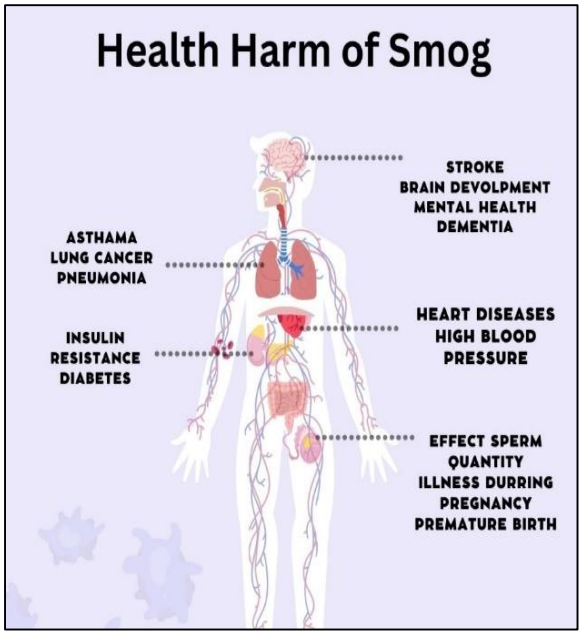


Figure 13.a: Impact of smog on the human health and ailment

their human hosts. These microorganisms affect human physical, immunological, nutritional, and mental development and offer vitamins, nutrients, and defense against other infections (Wong, 2017). These bacteria may experience oxidative stress due to smog-related factors, which could result in the collapse of the community. Unexpected health hazards could arise if these mutualistic microbiotas are disturbed, particularly in neonates and young children. Advanced techniques that use a variety of physical, chemical, and biological approaches to reduce the sulfur and nitrogen contained in fossil fuels could also minimize smog formation, lowering the burning of fossil fuels as the ultimate answer. The risk

evaluation of long-term smog exposure to human populations should also incorporate knowledge of microbiota disturbance, which is based on functional genomics, culturomics, and general ecological concepts (Wong, 2017). As per (Hussain *et al.*, 2025) their also exist a strong co relation between Smog and COVID. He said that people having long exposure to the PM 2.5 particles have increased the risk of lungs diseases, heart issues and stroke similar to the issues observed in severe COVID cases. In below cited diagram he illustrated the relationship between smog and COVID.

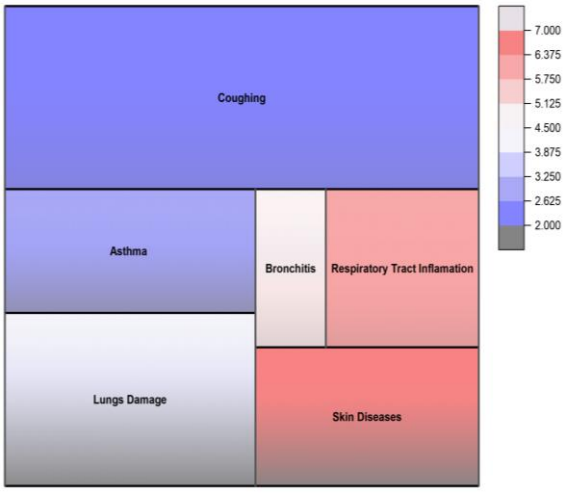


Figure 13.b: Frequency of smog on the human ailment

7. Impact of smog on the Economic sector

Economically, the impacts of smog are multiple and range from health to agriculture, to the industrial sector, and to long-term economic development. Resolution of these will require an integrated effort from governments, business, and community levels. This can only be achieved through investments in clean technologies, powerful policies, and public education (Shi *et al.*, 2016). Its impacts are extensive with considerable economic implications in several ways. Its effects affect public health, productivity, infrastructure, and even wider social costs. Here is a holistic review of its economic impact through perspectives on different perspectives. Smog holds harmful pollutants that include PM2.5, nitrogen oxides, and sulfur dioxide, which bring severe health impacts (Ali *et al.*, 2019). A higher rate of respiratory and cardiovascular diseases leads to increased medical costs to the individuals and governments. More patients flood hospitals, straining healthcare facilities as chronic illnesses and illnesses attributed to smog reduce the productivity of the labor force. The reduction comes from absenteeism plus long term health issues.

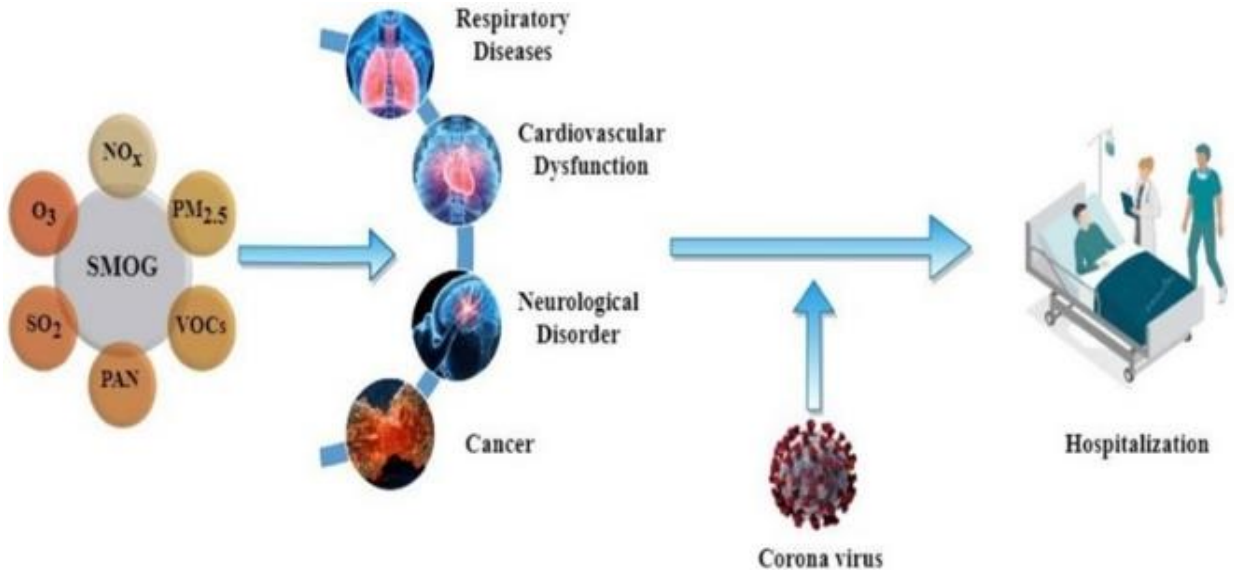


Figure 14: Relationship between Smog and COVID (Hussain *et al.*, 2025)

In addition, high number of deaths caused by smog-borne illnesses erodes the economy through the loss of productive manpower in addition to loss of labor force. Smog blocks sunlight, reducing photosynthesis, which lowers crop yields (Borgschulte *et al.*, 2024). It causes lower production of major crops like wheat, rice, and vegetables are the crops that are highly affected by reducing yield. The supply deficit increases the price which include lower yields entail lower revenues for farmers in agriculture-intensive areas as well as rippling effect on supply chain also lower yields may have other effects further down the line to affect food processing industries, export earnings, and international trade. Smog slows down present-day economic activities, primarily in urban and industrial hubs. It caused the reduction in visibility impacts road, rail, as well as air modes of transport. It means that goods and people are delayed as the fuel becomes costlier.

Moreover, smog-related issues involve more energy for some forms of air filter and cooling systems, and thus, the costs of electricity in business and residential areas. However, poor quality of air discourages outdoor activities and affects businesses like tourism, retail, and hospitality (Rosenzweig *et al.*, 2018). Smog causes environmental degradation and incurs clean-up and restoration costs. Acid rain produced by smog is lethal to forests, rivers, and soil, thereby reducing biodiversity and ecosystem services. Smog mitigation measures, such as the better quality of air and restoration of damaged infrastructure, are costly to governments and private organizations. Continuing smog reduces attraction to certain sites, with a consequent decline in property values and municipal tax income (Fadenipo, 2021). The psychological and social impacts of smog become economic costs. Smog triggers a new wave of urban migration by pushing people away from highly polluted areas, thus hurting the regional economy (Sun *et al.*, 2016). Popular discontent with pollution manifests in protests that may bring about policy changes and lead to political instability, disrupting economic planning and investments. Accumulated effects of smog slow long-run economic growth. Exposure to smog, particularly in children, affects cognitive development and future workforce productivity (Tang *et al.*, 2019). Poor air quality perception deters foreign firms and investments Governments spend to combat the problem of smog, through stricter regulations, subsidies on clean energy, as well as healthcare (Al-Thani and Isaifan, 2024).

8. Impact of smog on the environment

Smog has a wide-ranging impact on the environment, including effects on crop growth, plant, and agricultural output, as well as the relocation and migration of birds and animals. Furthermore, pollution endangers animals by disrupting mating and migratory cycles. Furthermore, it causes a rise in respiratory disorders in birds and mammals, resulting in a considerable population decline (Zhang *et al.*, 2018). The influence of smog on wildlife has been examined and proven using data obtained from respondents (shown in Fig. 5), with 61% believing that smog has a substantial impact on wildlife and 36% not seeing any relationship between the two. Similarly, the dangerous effects of pollution on the local environment have been investigated and shown in this study. Using the data obtained, it becomes obvious that 62% of individuals believe that smog has severely harmed the locality's ecology, while 38% believe that pollution leaves no visible damaging impacts on the environment.

9. Recommendation and Awareness

The recommendations to address the smog pollution involve implementation and enforcing vehicle emission standards, and regularly inspecting and maintaining vehicles to ensure compliance. It is also recommended to promote the use of electric vehicles and

invest in charging infrastructure. Moreover, afforestation and green Spaces increase green cover through afforestation initiatives to absorb pollutants and improve air quality. Government organizations should prioritize the creation of more parks and green spaces in urban areas to act as lungs for the city and enhance overall air quality. In addition, public awareness efforts should be raised to educate people on the causes and impacts of pollution. Encourage behavioral changes such as carpooling, decreasing vehicle idle, and taking public transit. Educational programs are critical in improving public understanding of smog's health and environmental consequences, allowing people to help reduce pollution. Furthermore, crop residue should be managed by implementing and promoting proper crop residue management practices in agriculture to reduce open burning, a significant contributor to smog (Kumar and Singh, 2021). Provide farmers with incentives and alternatives for managing crop residues sustainably. In Pakistan recent activities such as the development of Housing societies that cut down large numbers of trees to established societies influence the climate change process and disturb many natural cycles to control pollution thus, they have also played their role in air pollution in Pakistan. So, the government must have to make some strategies to mitigate the pollution caused by these activities. Since car emissions are a major contributor to the accumulation of smog, it is imperative that the public be made more aware of the benefits of using public transit rather than driving a personal vehicle. Second, since car emissions are a primary cause of smog, it is imperative to increase public awareness of the advantages of using public transit over private vehicles. Our farmer community also needs to be taught the risks associated with burning stubble and how to use the remaining stems as fertilizer rather than burning them. There are also some modern solutions to deal with pollution, such as smog-eating towers, which are a completely new and effective technology being deployed in China right now. Smog-eating towers work much like large vacuum cleaners, vacuuming up dangerous airborne pollutants and then reintroducing cleaned and refined air into the surrounding area. Up to 30,000 cubic meters of air can be cleaned by it in an hour (Hamza *et al.,* 2025).

There’s no information on whether China's bizarre smog-sucking suction tower is actually in use. Another innovative device that removes dangerous pollutants from the air while you paddle is a smog-free bicycle. It works by sucking up dirty air. (Mellina et al., 2017; Morby, 2017). Although these technologies are still very new and would be highly expensive to implement in Pakistan, we can keep them in mind as a potential future option. Invest in and encourage the use of renewable energy sources such as solar and wind power, to minimize reliance on fossil fuels. Provide incentives for the use of renewable energy technology in both the industrial and residential sectors. According to (Ali *et al.,*2019*)* we should have to encourage the mixed use of development to reduce the need for long-term effects.

10. Conclusion

As smog is produced by industrial pollutants, vehicles, and agriculture, it is one of the most severe environmental issues in Pakistan and many other countries. This research engages with the poor effects of pollution on agriculture, economy, health, and the environment because the AQI values in cities like Lahore, Multan, and Islamabad are not satisfactory. Smog is also known to affect the cardiovascular and respiratory systems and impede normal functioning, affect crop production and overwhelm health care facilities. Other than the health implications, it has social implications in that it's a major causative agent of soil erosion, climate

change, as well as loss of bio diversities and food security which leads to the destabilization of the environment for any given country. With sources of smog such as automotive outputs, burning of agricultural residues, and industry related products, the issues demand more comprehensive solutions. This paper gives special importance to the cause of clean energy, proper practice of farming, and strict adherence to rules related to the environment. Since the improvement in air quality objectively needs long-term attention, smog-eating towers and other innovations in urban planning also fall within the category of green technologies. In addition, as the main reasons behind making a change inevitable become highlighted, compulsion, awareness drives and information play a central role in driving such attitudes like opting for public transport and proper waste management by farmers for agricultural residues. The costs involved in this include increased healthcare costs, decreased levels of worker production, and losses in agriculture to emphasize the magnitude of the need for pollution reduction. Pollution is a significant challenge that calls for the involvement of several errands of government, firms, and societies. Pollution regulation and control, using clean energy, increasing the green area to act as a filter for cleaner air are some of the good steps which can be observed. This research ensures that the removal of the smog requires this coordinated effort which only depends on public involvement, politics, and academic scholarships. Criticisms and problems encountered by pollution and sustainability in Pakistan can be minimized, and the development that guarantees a bright future for the people of the country as well as ecosystems through maintaining the environment should focus on developmental sustainability and environmental management.

Credit authorship Contribution statement

Diyan Rashid: Data curation, Investigation, Visualization, Writing – original draft, **Muhammad Aakash Ather**: Visualization, Data curation, Investigation, Visualization, Writing – original draft, **Adnan Fareed**: Conceptualization, Visualization, Writing – original draft, review & editing, **Marina Qayyum**: Writing – review & editing, **Muhammad Shan Latif**: Writing – review & editing, **Moazzam Riaz**: Visualization, Writing–review & editing**, Zoriaz Amjad:** Writing–review & editing **Khawaja Muhammad Shoaib**: Visualization.

Acknowledgment

The authors acknowledge the guidance and constructive feedback provided by the mentors which greatly enhanced the quality of this review.

Ethical Declaration

The authors declare no human participants, data and issues

Consent to Publish

All authors have a consensus regarding the publication of review article

Competing Interests

The authors declare no known competing interest

References

Ahmed, S., A. Hussain, M. A. Tariq, U. Riaz, A. Fareed, Z. U. R. Farooqi, N.A. Ikram, Z. Khan, M.I. Ahmad and J. Imam. 2023. Effect of Irrigation Regimes and Nitrogen Levels on Growth and Yield of Cotton Genotypes Under Climate of Multan. Plant Bull. 2:69–81.

Akhtar, M. N., A. Hussain, M. Nawaz, A. Fareed, S. Ullah and S. Ahmad. 2022. Effect of Mulching and Drip Irrigation on Water Use Efficiency and Vegetative Growth of Mango under Small Tree System. Plant Bull. 1:101–120.

Ali, S., A. Zahid, M.U. Ahmed, I. Liaqat and M.N. Aftab. 2024. Properties of aerosol particles in the air and their effects on greenhouse gases dispersion. Advances and Technology Development in Greenhouse Gases: Emission, Capture and Conversion. Elsevier. pp.71–102.

Ali, Y., M. Razi, F. De Felice, M. Sabir and A. Petrillo. 2019. A VIKOR based approach for assessing the social, environmental and economic effects of "smog" on human health. Sci. Total Environ. 650:2897–2905.

Al-Thani, H. G. and R. J. Isaifan. 2024. Policies and Regulations for Sustainable Clean Air: An Overview. Springer Berlin Heidelberg, Berlin, Heidelberg.

Amuzu-Sefordzi, B., K. Martinus, P. Tschakert and R. Wills. 2018. Disruptive innovations and decentralized renewable energy systems in Africa: A socio-technical review. Energy Res. Soc. Sci. 46:140–154.

Arif, M. and E.A. Hassan. 2023. Beyond the Haze: A Study of Smog, Its Types, and Mitigation.

Atafar, Z., M. M. Sarkhoshkalat and M.B. Manesh. 2025. 1 - Overview of air pollution: history, sources and effects. In: A. Basile, D. Saloglu, and A. Cassano (eds.), Air Pollution, Air Quality, and Climate Change. Elsevier. pp.1–21.

Borgschulte, M., D. Molitor and E.Y. Zou. 2024. Air pollution and the labor market: Evidence from wildfire smoke. Rev. Econ. Stat. 106:1558–1575.

Brook, R.D. and S. Rajagopalan. 2009. Particulate matter, air pollution, and blood pressure. J. Am. Soc. Hypertens. 3:332–350.

Cerdeira, A.L. and S.O. Duke. 2006. The Current Status and Environmental Impacts of Glyphosate-Resistant Crops: A Review. J. Environ. Qual. 35:1633–1658.

Cropper, M.L., S. Guttikunda, P. Jawahar, Z. Lazri, K. Malik, X.-P. Song and X. Yao. 2019. Applying benefit-cost analysis to air pollution control in the Indian power sector. J. Benefit-Cost Anal. 10:185–205.

De Jouvenel, B. 1999. Economics and the Good Life: Essays on Political Economy. Transaction Publishers.

Ehrlich, P. R., A. H. Ehrlich and G. C. Daily. 1993. Food security, population and environment. Popul. Dev. Rev. 1–32.

Fadenipo, A. A. 2021. Environmental Smog Control Costs and proceeds of Oil and Gas Conglomerates. PhD Thesis, University of Shanghai for Science and Technology.

Fareed, A., A. Hussain, M. Nawaz, M. Imran, Z. Ali and S. U. Haq. 2021. The impact of prolonged use and oxidative degradation of Atrazine by Fenton and photo-Fenton processes. Environ. Technol. Innov. 24:101840.

Gaffney, J.S., N.A. Marley and J.E. Frederick. 2009. Formation and effects of smog. Environ. Ecol. Chem. Sabljic Ed Eolss Publ. Co Ltd Oxf. UK 2:25–51.

Gupta, A.K. 2014. Darkening Air: The Invisible Threat. Lulu. com.

Hamza, M., S. Yaqub, M. Ali, M. Anwar, A. Bokhari, M. Murtaza, A.A. Ansari and Q.S. Ali. 2025. Parametric analysis and prototype development of smog-free tower for sustainable urban environment. Sep. Purif. Technol. 362:131776.

Haq, M.A. 2022. SMOTEDNN: A novel model for air pollution forecasting and AQI classification. Comput. Mater. Contin. 71.

Haq, S.U., A. Hussain, U. Riaz, M.B. Hussain, A. Fareed, N.A. Ikram and F. Nawaz. 2021. Combined Sulfur and Organic Compost Treatment Influences Nutrient Uptake and Photosynthetic Activity to Improve Growth and Yield of Sunflower. Pak. J. Agric. Res. 34.

Harizanova-Bartos, H. and Z. Stoyanova. 2018. Impact of agriculture on air pollution. CBU International Conference Proceedings. pp.1071–1076.

Hussain, A., M. Abbas and M. Kabir. 2025. Smog Pollution in Lahore, Pakistan: A Review of the Causes, Effects, and Mitigation Strategies.

Karl, T. R. and K. E. Trenberth. 2003. Modern Global Climate Change. Science 302:1719–1723.

Kumar, P. and R. K. Singh. 2021. Selection of sustainable solutions for crop residue burning: an environmental issue in northwestern states of India. Environ. Dev. Sustain. 23:3696–3730.

Mehar, M.A., A. Hussain, T. ul-Haq, N. Faried, A. Fareed and U. Riaz. 2023. Detection of Pesticide Residues in Fruits and Vegetables from Multan, Punjab Pakistan. Plant Bull. 2:01–10.

Merk, O. 2014. Shipping emissions in ports.

Nasar-u-Minallah, M., M. Zainab and M. Jabbar. 2024. Exploring mitigation strategies for smog crisis in Lahore: a review for environmental health, and policy implications. Environ. Monit. Assess. 196:1269.

Naureen, I., A. Saleem, S. Aslam, L. Zakir, A. Mukhtar, R. Nazir and S. Zulqarnain. 2022. Potential Impact of Smog on Human Health. Haya Saudi J Life Sci 7:78–84.

Nizhelskiy, M., K. Kazeev, V. Vilkova, A. Fedorenko and S. Kolesnikov. 2025. Impact of gaseous smoke pollutants from modelled fires on air and soil quality. Carbon Res. 4:17.

Ogbiye, A., K.A. Kenneth and A.A.B. Ayobami. 2019. Assessment of Air Pollution in A Semi-Urban Industrial Cluster. Journal of Physics: Conference Series. IOP Publishing. pp.022103.

Patel, A. K., H. H. Chaudhary, K. S. Patel and D. J. Sen. 2014. Air pollutants all are chemical compounds hazardous to ecosystem. World J. Pharm. Sci. 729–744.

Rani, B., U. Singh, A.K. Chuhan, D. Sharma and R. Maheshwari. 2011. Photochemical smog pollution and its mitigation measures. J. Adv. Sci. Res. 2:28–33.

Raza, W., S. Saeed, H. Saulat, H. Gul, M. Sarfraz, C. Sonne, Z.-H. Sohn, R. J. Brown and K.-H. Kim. 2021. A review on the deteriorating situation of smog and its preventive measures in Pakistan. J. Clean. Prod. 279:123676.

Razzaq, A., M. M. Zafar, L. T. Zahra, F. Qadir, F. Qiao and X. Jiang. 2024. Smog: Lahore needs global attention to fix it. Environ. Chall. 100999.

Rosenzweig, C., W. D. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal and S.A. Ibrahim. 2018. Climate change and cities: Second assessment report of the urban climate change research network. Cambridge University Press.

Safdar, S., I. U. H. Padda, Z. Andlib, A. Khan and K. Javed. 2022. Impact of Smog on Wheat Productivity and Determinants of Smog Adaptation Options: A Case Study of Layyah and Lodhran. NUST J. Soc. Sci. Humanit. 8:209–233.

Shi, H., Y. Wang, J. Chen and D. Huisingh. 2016. Preventing smog crises in

China and globally. J. Clean. Prod. 112:1261–1271.

Sicard, P. 2021. Ground-level ozone over time: an observation-based global overview. Curr. Opin. Environ. Sci. Health 19:100226.

Smith, E. N., M. van Aalst, T. Tosens, Ü. Niinemets, B. Stich, T. Morosinotto, A. Alboresi, T.J. Erb, P.A. Gómez-Coronado and D. Tolleter. 2023. Improving photosynthetic efficiency toward food security: Strategies, advances, and perspectives. Mol. Plant 16:1547–1563.

Sokhi, R. S. 2008. World atlas of atmospheric pollution. Anthem Press.

Sun, C., X. Yuan and M. Xu. 2016. The public perceptions and willingness to pay: from the perspective of the smog crisis in China. J. Clean. Prod. 112:1635–1644.

Tang, J., X. Yuan, V. Ramos and S. Sriboonchitta. 2019. Does air pollution decrease inbound tourist arrivals? The case of Beijing. Asia Pac. J. Tour. Res. 24:597–605.

Wong, T.-Y. 2017. Smog induces oxidative stress and microbiota disruption. J. Food Drug Anal. 25:235–244.

Wood, Y. A., M. Fenn, T. Meixner, P.J. Shouse, J. Breiner, E. Allen and L. Wu. 2007. Smog Nitrogen and the Rapid Acidification of Forest Soil, San Bernardino Mountains, Southern California. Sci. World J. 7:784903.

Yadav, P., K. Usha and B. Singh. 2022. Air pollution mitigation and global dimming: a challenge to agriculture under changing climate. Climate change and crop stress. Elsevier. pp.271–298.

Yang, L. E., P. Hoffmann and J. Scheffran. 2017. Health impacts of smog pollution: the human dimensions of exposure. Lancet Planet. Health 1:132–133.

Zhang, S., Y. Li, Y. Hao and Y. Zhang. 2018. Does public opinion affect air quality? Evidence based on the monthly data of 109 prefecture-level cities in China. Energy Policy 116:299–311.