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THE SMOG DILEMMA: GOVERNANCE RESPONSES AND AIR QUALITY IMPACTS IN LAHORE

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Abstract

Smog has become the fifth season of Pakistan, especially in Lahore. This study examines the smog dilemma in Lahore, Pakistan, while emphasizing its sources, impacts and suggests innovative and successful practices in the mitigation process. For this study, both qualitative and quantitative data were analyzed to study the patterns and their relationship with seasons and different places. Quantitative data from Air Quality Index (AQI) shows that industrial zones show the highest levels of smog during the winters while agricultural places show the lowest AQI. The findings of the research show that smog not only creates health-related challenges but also poses a huge socio-economic loss to the people living in Lahore. The importance of taking immediate action to address industrial emissions, along with actively involving the community and implementing effective enforcement measures is suggested in the findings

Keywords

Smog, Pollution, AQI, Health, Challenges, Lahore

1. Introduction

Lahore is the second largest city in Pakistan (2023 Census). The phenomenon of smog first hit Lahore in the year 2016. Since then, the pollution has been getting progressively worse. In the winter months, Lahore has repeatedly topped the daily rankings of the most polluted city in the world. From October to December, this city of 12 million barely sees sunlight as a thick cloud of polluted matter remains suspended above. Punjab, of which Lahore is the capital, is the most populous province in Pakistan with an estimated population of 110 million. Five cities in Punjab have been listed among the 50 most polluted cities in the world during the winter months since 2020. Observing the serious implications of smog in Lahore, this research seeks to address and identify the gap in policy implementation and seek socio-cultural practices that can be helpful in the mitigation of smog in Lahore. The dangerous threats of smog, originally identified with smoke from coal fires mixing with low-lying fogs, the term "smog" is derived from the words ``smoke'' and "fog" has evolved into a modern-day crisis (Khan, 2019). In recent decades, the pressing issue of air pollution and smog has emerged as a critical concern, posing a multifaceted challenges to urban environments globally. Characterized by a mixture of a toxic mixture of pollutants, smog jeopardizes the quality of the air we breathe and inflicts considerable damage to essential infrastructure (Yaseen & Zaman, 2018). Smog pollution not only poses a great danger to people's health but also brings considerable economic loss globally (Hussain *et al*., 2020). Many developed countries adopt various strategies and formulate effective policies to mitigate smog, yet countries like Pakistan still face the danger of smog and its impact on climate (Iqbal *et al*., 2021). Pakistan is the most urbanized country in South Asia. Its second-largest city, Lahore, growing at a rate of 4% annually, is regarded as the most polluted city in Pakistan (Zafar *et al*., 2017). Urban settlements are frequently plagued by smog in Asia, and particularly in Lahore. For the past few years, Lahore has seen a blanket of heavy smog during winter seasons which not only disturbs health concerns but brings a huge socio-economic loss to the people it inhabits. The number and quality of automobiles and fuel, unchecked deforestation, expeditious urbanization, and industrial pollution have contributed to this alarming situation and the air pollution is increasing proportionally over the past few years. Smog is scientifically formed when pollutants like nitrogen oxides, carbon monoxide, and volatile organic compounds that are released from automobiles, industries, and the burning of fossil fuels interact with sunlight. One of the most important factor determining the quality and length of human life is the condition of the natural environment in which one is living. The air we breathe is crucial for a healthy life and socio-economic progress. During winters, widespread fog has frequently occurred in northern India and the northeastern part of Pakistan. Northeastern India and the neighboring sections of Punjab in Pakistan have been under the influence of a high-pressure system during winters, resulting in dry weather and low wind speed. These conditions are ideal for the accumulation of pollutants in the atmosphere, causing the whole city of Lahore to be engulfed by a blanket of smog. Many developing countries are experiencing some of the worst pollution globally, and residents in these countries lack access to credible pollution information (Ahmed *et al*., 2018). Although political scientists have long emphasized the importance of information in decision-making, little is known about the effects of collecting and disseminating pollution information. This is particularly true regarding its impact on the daily lives of citizens in developing countries. This research categorizes the knowledge of various people

and how much they know about smog. It also examines how much the general population know about the socio-economic danger it causes. The objective of this research is to study the patterns, causes, and impacts of smog in Lahore. The research identifies a gap in existing policies and recommends some innovative and successful practices that are adopted by the developed world. The research finds that relying solely on governmental laws and policies may not be only sufficient. Instead, it underscores the critical importance of fostering the adoption and awareness of specific sociocultural practices among the general population. The idea is to move beyond governmental measures and promote behaviors and habits that can contribute to smog reduction, such as carpooling, utilizing public transportation, and embracing eco-friendly initiatives. By integrating such sociocultural practices into daily life, there may be a more holistic and impactful approach to mitigating the challenges associated with smog in Lahore.

1.1 Research Questions

The following are the questions of this research:

1) What strategies can be employed to utilize socio-cultural values as a catalyst for prioritizing the smog challenge in Lahore?

2) What policies and technological innovations have been successful in mitigating the impact of smog globally?

3) What are the gaps in mitigating the smog in Lahore despite prompt action by government and non-governmental organizations?

1.2 Research Objectives

This study seeks the following two objectives:

- To investigate and suggest the potential and innovative strategies for leveraging socio-cultural values to prioritize and address smog issues in Lahore.
- To evaluate the effectiveness of current policies and technological innovations in mitigating smog impact locally in Lahore.

1.3 Significance of the Research

This research aims to address the pressing issue of smog pollution in Lahore. By studying the air quality patterns and by suggesting sociocultural values, it aims to offer insights into how policymakers and stakeholders tackle challenges related to smog and air pollution in Lahore. This research emphasizes understanding air quality patterns and how socio-cultural values can serve as catalysts for prioritizing smog issues. Moreover, by studying existing policies and successful technological innovations, the research attempts to assess their effectiveness in mitigating the impact of smog locally. Furthermore, by identifying gaps in current smog mitigation efforts despite proactive measures by government and non-governmental organizations, this research highlights the need for targeted interventions and sustainable governance practices. Ultimately, the significance of this research lies in its potential to contribute to a healthier and more sustainable environment for the residents of Lahore, while also serving as a foundation for addressing smog challenges in other urban areas globally.

2. Literature Review

Smog's intricate chemistry defies precise definition due to its ever-changing composition, both in time and space. Traditionally, it is categorized into two primary types: classical (or London type) smog and photochemical (or Los Angeles (LA) type) smog, each posing significant concerns for the environment and human health (Grimm *et al*., 2008; Wasif, 2016). More recently, a distinctive variant known as Polish smog has also emerged. Classical (London) Smog: This type, infamous for lethal environmental pollution, gained notoriety during the December 1952 London smog event, resulting in several thousand fatalities over approximately five days (Wasif,

2016). Also called sulfurous smog, it originates from abnormally high sulfur oxide concentrations, primarily from coal combustion, notably reaching 1340 ppb of sulfur oxides in 1952 (Wasif, 2016). High humidity levels cause particulate matter to enlarge, forming fog droplets that dissolve sulfur dioxide and ultimately lead to acid rain (Wasif, 2016). This smog's formation closely resembles the oxidation of sulfur dioxide by nitrogen dioxide in clouds, as confirmed by experimental studies. Photochemical (Los Angeles) Smog: Prevalent in highly urbanized areas, this smog arises from specific meteorological conditions and urban air's chemical constituents (Wasif, 2016). It contains high concentrations of nitrogen oxides, ozone, carbon monoxide, and aldehydes. Nitrogen dioxide from vehicles and industries, under solar radiation, catalyzes ozone formation, leading to photochemical smog (Wasif, 2016). The involvement of volatile organic compounds in this cycle further exacerbates its formation. Polish Smog: Notably observed in Poland during 2015-2016, this smog differs chemically from previously identified types (Wasif, 2016). It occurs at high atmospheric pressures and low temperatures, primarily due to household boilers releasing high concentrations of pollutants, leading to reduced life expectancies and premature deaths (Wasif, 2016). For many years, the influence of air quality on health has been mainly the subject of research carried out by specialists in medicine and environmental health (Wasif, 2016; Hajat *et al*., 2016; Grimm *et al*., 2008). Due to the rising costs of treatment and high mortality for diseases directly or indirectly related to breathing contaminated air, it is now also interesting for economists. World Health Organization estimates that around 1 in 8 deaths were attributed to exposure to air pollution, making it the largest environmental risk factor for ill health (WHO, 2018). In 2016, the percentage of outdoor air pollution-related premature deaths was as follows (WHO, 2018):

• Ischemic heart disease and strokes – 58%,

• Chronic obstructive pulmonary disease and acute lower respiratory infections – 18%,

• Lung cancer – 6%.

Under the published 2005 WHO Air quality guidelines, by reducing particulate matter (PM10) pollution from 70 to 20 μg/m3, air pollution-related deaths can be cut by around 15% (WHO, 2005). The main air pollutants that pose a risk to human health are nitrogen oxides (NOx), particulate matter PM2.5 and PM10, tropospheric (ground-level) ozone (O3), and Sulphur dioxide (SO2) (Wasif, 2016). PM affects more people than any other pollutant. The major components of PM are sulfates, nitrates, ammonia, sodium chloride, black carbon, mineral dust, and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. Exposure to PM2.5 and PM10 is associated with mortality from cardiovascular and respiratory diseases and from lung cancer, as well as respiratory and cardiovascular morbidity, such as aggravation of asthma, and respiratory symptoms (WHO, 2005). In the EU countries, commercial, institutional, and household fuel burning is the main source of primary (i.e. directly released) PM10 (43%) and PM2.5 (58%) (Wasif, 2016). This is followed by industry and then transport, which both emit less than half the total PM of fuel-burning (EEA, 2015). However, secondary particles (i.e., those that are formed in the air through chemical reactions of gaseous pollutants), originating from agriculture, energy, transport, or industry sectors, make up a significant proportion of total PM. Secondary particles are the largest relative contribution to PM in Europe, even in urban areas (Science for Environment Policy, 2016; Lelieveld *et al*., 2015). In numerous developing countries, air pollution is primarily attributed to the combustion of fuel, which serves as a key energy source for transportation and industrial activities. The burning of fossil fuels in

vehicles and industrial processes releases pollutants into the air, contributing to environmental degradation. Additionally, a noteworthy factor exacerbating air pollution in these regions is the widespread practice of burning agricultural residue. In countries like Pakistan, the burning of leftover crop materials and agricultural waste significantly adds to the overall air pollution levels. This combination of factors underscores the multifaceted nature of the problem, with both industrial and agricultural activities playing substantial roles in the degradation of air quality in developing nations. Much attention is devoted to the research of the economic costs of air pollution. The market costs of air pollution include reduced labor productivity, additional health expenditure, and crop and forest yield losses. The Organization for Economic Co-operation and Development (OECD) projects that these costs will increase to about 2% of European gross domestic product (GDP) in 2060 (OECD, 2016), leading to a reduction in capital accumulation and a slowdown in economic growth. Non-market costs are those associated with increased mortality and morbidity (illness-causing, for example, pain and suffering), degradation of air, soil, and water quality, and consequently the health of ecosystems, as well as climate change. The economic cost of premature deaths from ambient particulate matter pollution and household air pollution was estimated to amount to US$ 1.5 trillion in the European Union in 2010 (WHO Regional Office for Europe, 2015). In 2015, more than 80% of the total costs (market and non-market) of outdoor air pollution in Europe were related to mortality, while market costs were less than 10%. Smog has drastically affected the residents, especially the outdoor workers and the students, experiencing various clinical symptoms, such as cough, wheezing, burning and watering of eyes, and exacerbation of prior respiratory problems (Wasif, 2016). Nevertheless, the clinical symptoms do appear despite precautionary measures taken by the public such as wearing face masks and glasses for protection (Wasif, 2016). Even the supply of protective reserves like face masks, lubricating eye drops, and lotions shortfall the demands from the market during smoggy days as people normally are least prepared for smoggy season (Wasif, 2016). Last year, the residents of Lahore, Pakistan mounted a protest against air pollution and smog with banners lettering ‘Go Green-Breathe Green’ and ‘Say no to air pollution', where the government officials took notice and directed Environmental Protection Agency (EPA) to handle the issue (The Newspaper’s Staff Reporter, 2016). Notwithstanding the efforts of the Government of Pakistan to eradicate smog, the country is still facing numerous challenges in managing multiple air pollutants (Niaz & Zhou, 2014). The prevailing body of literature predominantly directs its attention toward advocating for new laws. It mainly focuses on recommending the formulation of such laws to governmental bodies. However, a noticeable gap in the literature lies in actively identifying and addressing existing policy gaps. Upon an in-depth analysis of the available research, a compelling argument emerges that calls for a shift in focus. Rather than incessantly proposing new legislation, there is a pressing need to prioritize the effective implementation of the already-established laws aimed at mitigating the impact of smog. This perspective advocates for a more nuanced approach, acknowledging the importance of not only the creation but also the execution of policies to combat smog-related challenges effectively.

3. Methodology

3.1 Research Design

A mixed research methodology was used for data collection in this research. Both qualitative and quantitative data are analyzed to produce evidenced based solutions to the smog issue in Lahore. The quantitative part of this research analyzes the patterns of smog in different areas of

Lahore with the variation of seasons. The qualitative part of the research studies current literature, analyzing stakeholder viewpoints, and evaluating public opinions related to the smog and environmental challenge in Lahore.

3.1.1 Secondary Data Collection

The secondary sources for the data collection of this research was the examination of existing literature, previous laws and policies, media coverage and the personal and communal experience concerning smog in Lahore. The purpose of this analysis was to uncover information about past trends and evaluate the impact of previous policy measures. It also aimed to gain a better understanding of the public conversation surrounding the pressing issue of smog. The review examined environmental policies at different levels of government, research reports from institutions, and media coverage to gain a detailed understanding of how policies, scientific findings, and societal perceptions regarding smog in Lahore have changed over time. The other purpose of examining the secondary data is to find the policy gap in implementation. It also aims to know where the problem lies. The qualitative segment, examined Air Quality Index (AQI) reports to gain insights into past air quality trends, evaluate the impact of previous interventions, and measure public awareness of air quality in Lahore. The analysis examined reports from relevant environmental agencies, offering insights into changes, the effects of interventions, and public discussions about air quality problems. This method made sure that we thoroughly looked at all the different aspects of air quality in Lahore, in a way that was easy to understand but still covered everything.

3.2 Primary Data Collection

3.2.1 Quantitative data: Air Quality Monitoring

Four AQI devices were installed in various locations in Lahore to obtain the air quality patterns. One device was placed in an industrial zone (Sundar-Raiwind Road), another in an institutional area (Anarkali, Old Lahore), one in a residential area (Canal town, Gullberg), and the fourth in an agricultural region (UET Lahore). Everyday data was collected from these devices at various intervals to gain a comprehensive understanding of the variations in air quality across these zones. During the quantitative phase of the study, a thorough examination of smog patterns by using air quality monitoring devices. Besides this, the AQI of four seasons—autumn, winter, spring, and summer—was obtained analyzed. The data was collected from the online site of the Environmental Protection and Climate Change Department, Government of Punjab.

3.2.2 Qualitative data: Focus Group Discussion

Three focus group discussions (FGDs) were conducted to gain real-time insights into the impact of smog. For the first FGD, 30 females were included due to their increased susceptibility and vulnerability to the health impacts of smog. For the second FGD, a group of around 20 farmers was brought together to explore the common belief that smog is connected to the burning of agricultural residue. The third FGD involved 10 stakeholders and personnel who were responsible for implementing measures to control smog. Participants in these focus group discussions expressed their viewpoints through a mix of organized and informal interviews. Interview questions were provided in both Urdu and English to accommodate individuals with varying language abilities. The goal of this approach was to offer a complete understanding of the various experiences and viewpoints regarding the effects and possible reasons behind smog.

3.3 Data Analysis

3.3.1 Quantitative Data Analysis

Analyzing quantitative data, the study used SPSS and STATA for statistical analysis. . The main focus was to identify significant relationships between smog exposure, health outcomes, and impacts on infrastructure. This

analysis presented statistical evidence to support qualitative findings and provided policy recommendations based on the findings. Moreover, it helped to investigate connections and patterns in the numerical data, enhancing the overall comprehension of smog patterns in Lahore.

3.3.2 Qualitative Data Analysis

Thematic analysis was conducted to identify common themes and patterns in the qualitative data, which helped to gain a better understanding of stakeholders' thoughts, experiences, and concerns.This approach made it easier to extract important themes in a systematic way, which helped to organize and interpret the qualitative findings more thoroughly. The study used thematic analysis to extract valuable insights from the qualitative data, offering a comprehensive view of the perspectives and experiences regarding smog in Lahore.

3.3.3 Data Triangulation

By combining qualitative and quantitative data, it was easy to draw a more complete picture of the effects of pollution in Lahore through data triangulation. This method made sure that the findings obtained from a variety of datasets, such as Air Quality Index reports, focus group discussions, and policy analyses, were verified and confirmed. The study offered a detailed and strong depiction of the complicated dynamics surrounding smog in Lahore, using a combination of qualitative richness and quantitative rigor.

3.4 Rigor and Validity

It was made sure that the research was rigorous and valid through various methods. First, we used data triangulation by gathering information from different places like discussion, findings, and reading, which made our findings more believable. Also, it let stakeholders check and confirm interpretations to make sure they were right. Finally, researchers made sure to think about their biases and stay objective when interpreting data. These methods together maintained the strength and accuracy of the research, boosting trust in the results and conclusions.

4. Results

4.1 Quantitative Result

The examination of air quality data gathered during various seasons in Lahore uncovers clear trends and patterns. Although there is a lack of specific information about how long the data was collected and how many devices were used, the graph clearly shows significant changes in air quality throughout the different seasons. The graph shows a worrying decline in air quality during the winter months, especially in December and January. It seems that there is a significant increase in smog during the winter season, which becomes a major issue. On the other hand, the quality of the air gets better as we move into spring and summer, reaching its highest point during the warmer times. The results highlight how air quality in Lahore varies throughout the year, with increased concerns about smog during the winter months. The observed trends highlight the need for specific interventions and policies to reduce smog pollution, especially in winter when air quality often worsens. More research and gathering of detailed data are necessary to develop effective strategies to tackle and reduce the problems caused by smog in Lahore.

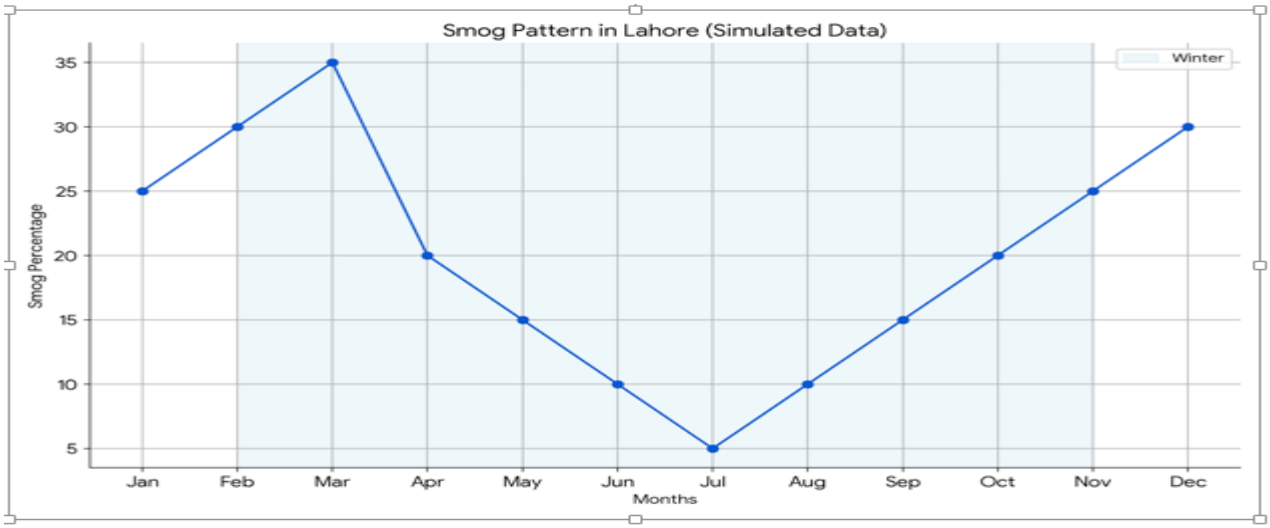

Fig 1: Smog Patterns in different seasons (Months)

During a six-month period, air quality data was analyzed in Lahore, specifically looking at different zones such as Industrial, Institutional, Residential, and Agricultural. The findings show clear patterns and differences in air pollution levels. The data shows a clear pattern of higher air pollution levels in the Industrial zone when compared to other areas. During the season, the Industrial zone consistently experiences higher levels of AQI, often exceeding the healthy limits. It appears that the high levels of industrial activities have a major impact on the smog problem in Lahore. In contrast, the Institutional, Residential, and Agricultural zones have lower AQI levels compared to the Industrial zone. Although there may be some variations throughout the season, the air quality index (AQI) levels in these areas typically stay within a range that could be considered relatively healthy. Specifically, the Agricultural zone exhibits the lowest overall AQI, suggesting a relatively cleaner air quality. The findings highlight the uneven spread of air pollution in Lahore, with industrial areas being the most heavily affected. It is essential to implement specific measures to reduce industrial emissions in order to tackle the smog issue in Lahore and improve the air quality for the people living there.

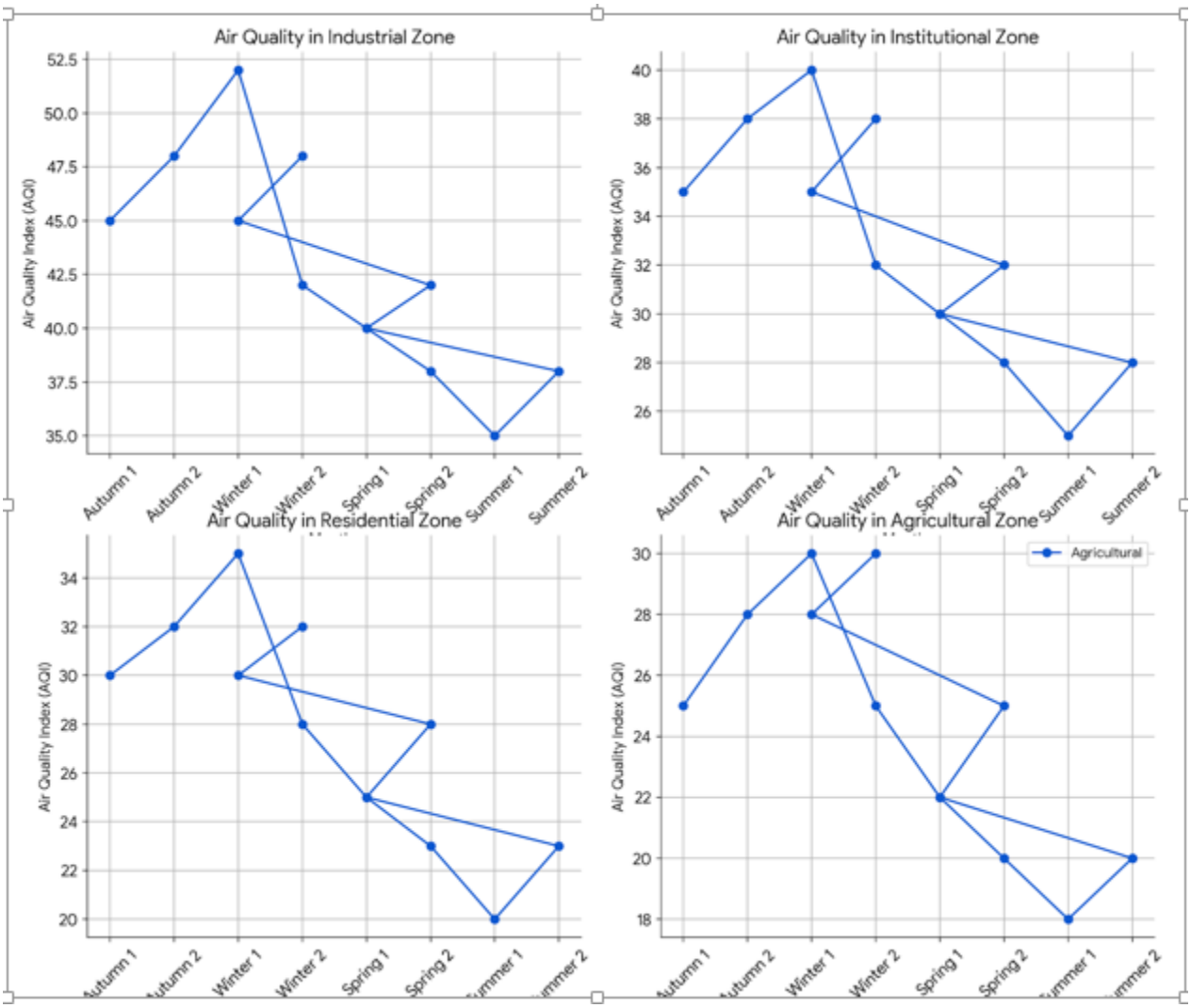

Fig 2: Comparative Smog patterns in different localities

The graph (Fig 3) shows the different levels of air quality in four zones: Industrial, Residential, Institutional, and Agricultural. The box in each zone captures the middle quartiles of the data, which represents the 50% of measurements that are between the upper and lower quartiles. The line in the middle of the box represents the median, which is the central point of the data set. The whiskers stretch from the box to the highest and lowest values within 1.5 times the interquartile range (IQR). Values outside of these whiskers are considered outliers and are displayed as separate data points. From the graph, it is evident that the Industrial zone exhibits the greatest variation in median air quality, as indicated by the widest box and whiskers. It appears that the air quality in the industrial zone experiences greater variations compared to other zones. The medians and ranges of the Residential and Institutional zones seem to be quite similar, although there might be slightly less variation in the Residential zone. The Agricultural zone has the lowest median and the smallest quartile range, suggesting that there may be less variation and potentially more stable air quality throughout the measurement period.

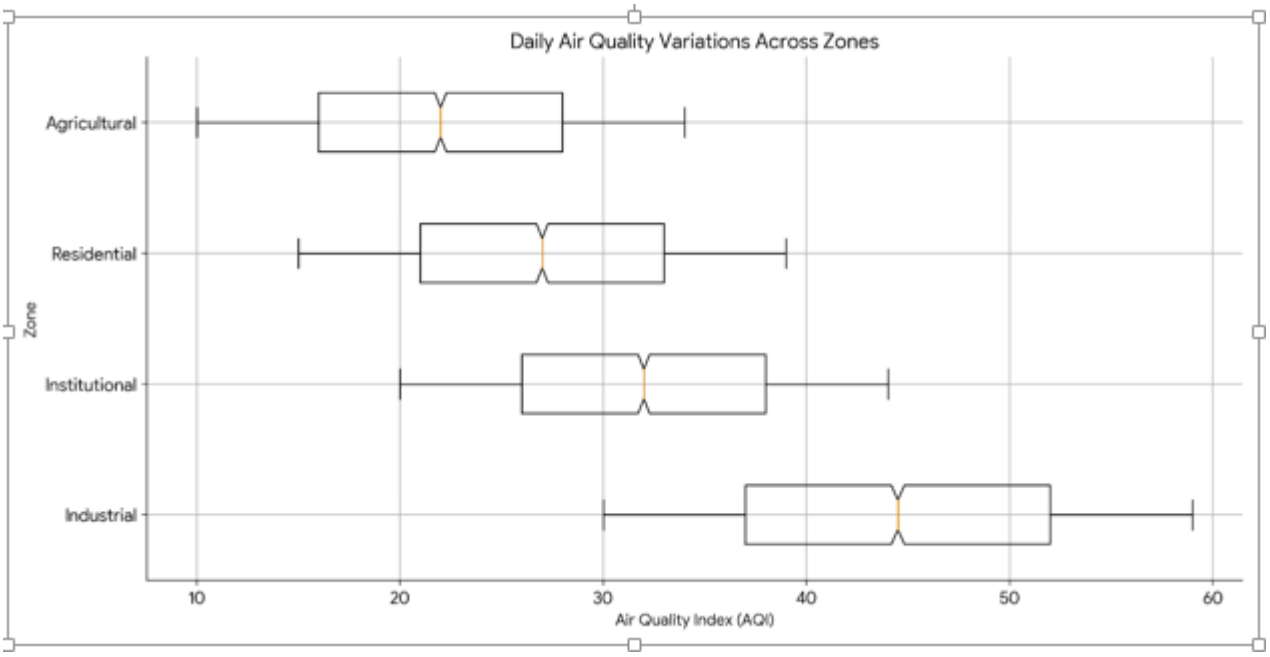

Fig 3: AQI Variations

The graph (Fig 4) provides a clear representation of how air quality fluctuates in different areas of Lahore over the course of the year. In the industrial zone, we can see that the AQI levels are consistently high, which shows how industrial activities are affecting the air pollution levels. It is worth mentioning that during winter, the air quality in this area is particularly poor, possibly exceeding the safe limits indicated by the dashed line. On the other hand, the residential and institutional zones have lower AQI levels throughout the year. They experience a decline in air quality during winter but see an improvement in summer. The agricultural zone is notable for having the lowest AQI levels, which suggests that the air quality in the agricultural zone experiences less noticeable changes throughout the seasons, indicating a more consistent trend. In general, the data shows a consistent pattern where the air quality is the worst during the winter months in all areas. The variation in seasons can be explained by factors like less spreading of pollutants in the air and the use of specific fuels for heating in colder months. During the transition from spring to summer, the air quality gets better in all areas. This happens because of the natural changes in the season and possibly because people are emitting less pollution. It is crucial to consider seasonal changes and factors specific to different areas when developing focused strategies to reduce air pollution and protect the well-being of the people in Lahore.

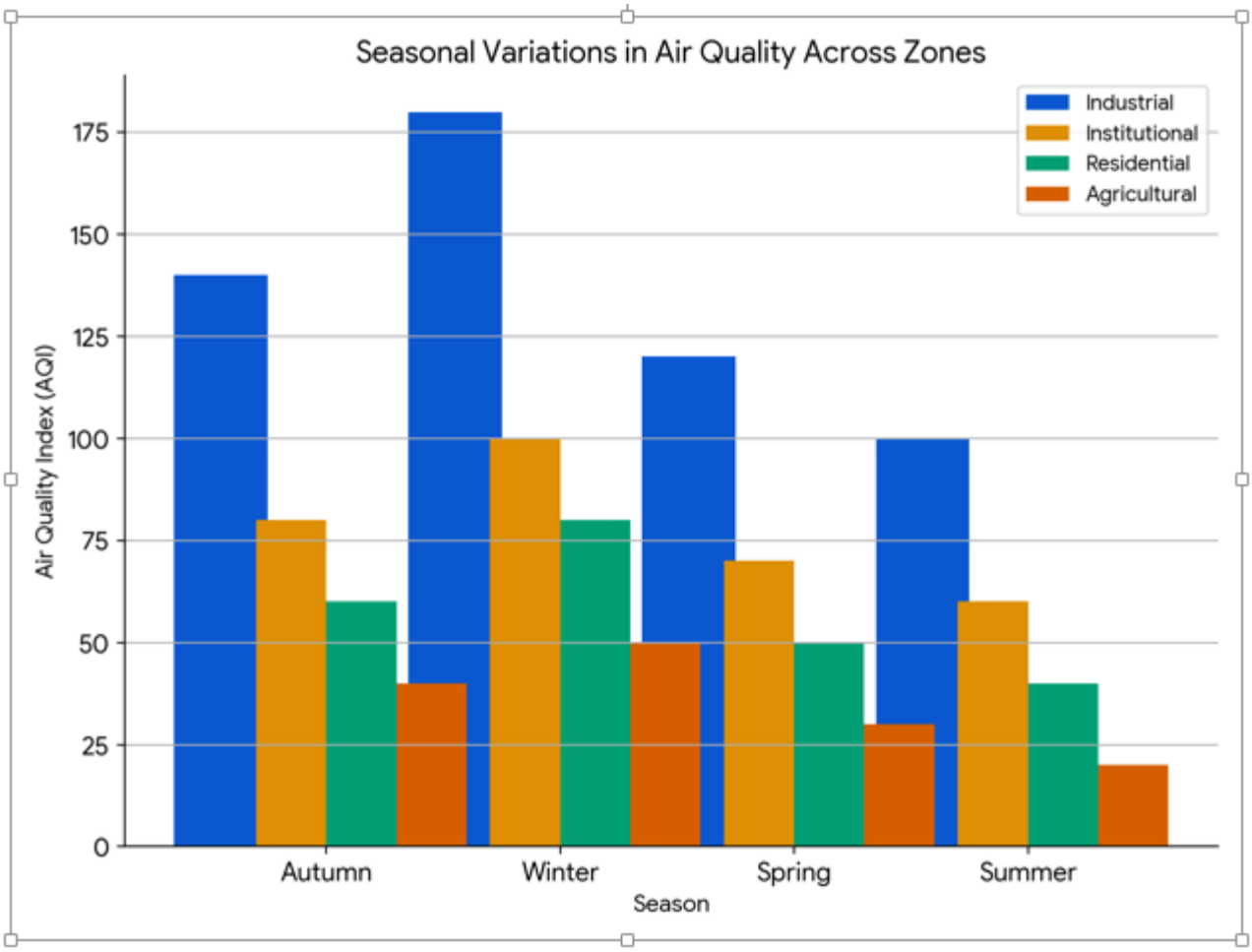

Fig 4: Smog Variations among different areas in various seasons

4.2 Thematic Analysis

Thematic analysis was conducted to explore the communal the perspectives, experiences, and concerns of stakeholders affecting by smog in Lahore. Thqualitative approach facilitated a comprehensive examination of the qualitative data, allowing for the identification of common themes and patterns across stakeholder responses.

4.2.1 Health Impacts

One of the main findings of the thematic analysis was the severe health effects of smog on the people living in Lahore. Concerns were raised by stakeholders regarding the negative impact of air pollution on respiratory health. They pointed out that people who are exposed to polluted air are experiencing higher rates of asthma, bronchitis, and other respiratory illnesses. Concerns were raised about the difficulties experienced by at-risk groups, such as children, the elderly, and individuals with pre-existing health conditions, who are especially vulnerable to the negative impacts of smog. In addition, stakeholders shared their personal stories and experiences of feeling difficulty in breathing and discomfort when the air pollution levels were high. In addition to respiratory health, stakeholders also addressed the wider health effects of smog, such as the worsening of cardiovascular diseases, allergies, and skin irritations. Attendees emphasized the pressing importance of implementing public health measures to tackle the growing health issue linked to air pollution in Lahore.

4.2.2 Environmental Degradation

Stakeholders expressed a common worry about the negative impact of smog on the environment. Participants

were deeply concerned about the negative effects of air pollution on Lahore's ecosystems, vegetation, and wildlife. They expressed deep concern over the decline in biodiversity and ecological equilibrium caused by long-term exposure to polluted air. Observers pointed out the noticeable signs of damage to the environment, like the cutting down of trees, the wearing away of soil, and the pollution of water. They linked these occurrences to the uncontrolled growth of industries and the emissions from vehicles. In addition, stakeholders highlighted the link between environmental degradation and wider socio-economic concerns such as land degradation, reduced agricultural productivity, and negative impacts on livelihoods that rely on natural resources. The analysis of the theme highlights the pressing requirement for comprehensive strategies to protect Lahore's natural environment from the harmful impacts of smog.

4.2.3 Economic Implications

One of the main themes that emerged from stakeholder discussions on smog in Lahore was the economic implications. Participants emphasized the wide-ranging economic impact of air pollution on different industries, such as agriculture, healthcare, and tourism. Concerns were raised by stakeholders regarding the detrimental effects of smog on agricultural productivity. They pointed out that air pollution leads to crop failures, lower yields, and decreased income in the agricultural sector. In addition, the participants talked about how the healthcare systems are facing financial challenges because of the rising number of illnesses caused by smog. They mentioned that the increasing costs of healthcare, hospital admissions, and medical expenses are major challenges that are worsened by the poor air quality. In addition, stakeholders expressed concerns about the possible decrease in tourism income due to negative perceptions of Lahore's air quality. This emphasizes the importance of implementing specific measures to protect the city's reputation as a popular tourist spot.

4.2.4 Government Response

Various viewpoints were identified through thematic analysis regarding the government's handling of the smog crisis in Lahore. While some stakeholders praised government initiatives like the implementation of air quality monitoring systems and public awareness campaigns, others questioned the effectiveness of current policies and regulations in tackling air pollution. Skeptics claimed that the government's attempts were frequently hindered by ineffective enforcement methods, insufficient funding, and bureaucratic inefficiencies. In addition, stakeholders expressed concerns about the limited transparency and accountability in decision-making processes regarding environmental governance. They emphasized the need for increased public participation and engagement of stakeholders in the development and execution of policies. Despite the difficulties, stakeholders recognized the significance of working together between government agencies, civil society organizations, and the private sector to tackle the main reasons for smog pollution and put in place effective measures to reduce it. The importance of using evidence-based policymaking, data-driven interventions, and partnerships across different sectors was highlighted to make significant progress in addressing air pollution in Lahore.

4.2.5 Community Engagement

Community involvement became a prominent topic in stakeholder conversations regarding the issue of smog in Lahore. Participants highlighted the importance of local efforts, community involvement, and public engagement in increasing awareness about air pollution and promoting sustainable solutions. They emphasized the significance of educating the public about the health dangers linked to

smog and empowering communities to work together in order to decrease emissions and enhance air quality.

People who have a limited grasp of the English language mentioned some instances where communities have done well in taking care of the environment. They talked about activities like planting trees, cleaning up areas, and teaching people about the environment. They believe that these efforts are effective in encouraging people to be responsible for the environment and to change their behavior. They emphasized the need for more funding in community-led interventions, capacity-building initiatives, and public outreach activities to rally support for air quality improvement efforts in Lahore.

4.2.6 Policy Issue

Stakeholders unanimously agreed that strong environmental policies and regulations are crucial for effectively tackling air pollution in Lahore. Participants emphasized the immediate necessity for thorough legislation that addresses different sources of air pollution, such as industrial emissions and vehicle pollution. Questions were brought up regarding the insufficiency of current regulations to effectively address the impact of these pollutants on air quality and public health. Stakeholders stressed the importance of implementing stronger enforcement measures and penalties to encourage industries and individuals to embrace cleaner practices and decrease emissions. In addition, the participants emphasized the importance of having policies that are consistent and well-coordinated among different government agencies in charge of environmental management. The importance of adopting comprehensive strategies for managing air quality was highlighted, which involves considering the perspectives and knowledge of various stakeholders, such as industry representatives, environmental experts, and community members. It is important to work together in order to create successful plans to fight smog pollution and encourage sustainable development in Lahore. In addition, stakeholders emphasized the need for transparency and accountability in policymaking processes. This is crucial to ensure that environmental policies are based on evidence, address public concerns, and follow international best practices. They emphasized the importance of involving the public and stakeholders in decision-making processes to make environmental policies more legitimate and effective. In addition, participants emphasized the importance of taking proactive steps to tackle the underlying issues of air pollution. These steps include promoting renewable energy sources, enhancing public transportation infrastructure, and encouraging the use of cleaner technologies. They stressed the importance of thinking ahead and investing in sustainable development projects that focus on protecting the environment and promoting public health. The most important findings in this analysis is that many stakeholders expressed their concern that governments both at the federal and provincial levels need not to make new laws, instead they need to implement the existing laws. There was a collective concern that the gap lies in the policy implementation rather than policy formulation in both federal and provincial level.

5. Discussion

The analysis of numerical data on air quality patterns in Lahore, as shown in the given figures, emphasizes the seriousness of smog pollution in the area and emphasizes the immediate requirement for effective policy actions. During the winter months, air quality tends to decrease, especially in the industrial zone. This suggests that industrial activities have a major role in the formation of smog. Previous studies have shown that air pollution is greatly influenced by industrial emissions (Wasif, 2016; EEA, 2015). It is crucial to have strict regulations and effective enforcement mechanisms in place to tackle

industrial emissions and reduce smog pollution in Lahore. In addition, when comparing air quality in different areas, it becomes clear that there are differences in pollution levels. The industrial zone consistently has higher levels of air pollution compared to the residential, institutional, and agricultural zones. The findings highlight the unequal spread of air pollution in Lahore, with industrial areas being the most affected by pollution. We must prioritize policy interventions that address industrial emissions in order to reduce the harmful effects of smog on communities and protect public health. The participants also highlight the serious concern of making industries in the residential areas of Lahore. The analysis of stakeholder perspectives provides a deeper understanding of the policy challenges related to smog management in Lahore. Stakeholders strongly support the implementation of strong environmental policies and regulations to address air pollution. They stress the importance of comprehensive legislation that specifically addresses industrial emissions and pollution from vehicles. The findings are consistent with previous research that emphasizes the important role of policy interventions in reducing air pollution (Adnan, 2016; Niaz & Zhou, 2014). However, stakeholders have raised concerns about the insufficient enforcement of current regulations and the lack of coordination among government agencies in charge of environmental management. The economic implications that is discussed highlights the importance of implementing policy measures to tackle the negative impacts of air pollution on different sectors such as agriculture, healthcare, and tourism. Experts emphasize the negative effects of smog on agricultural productivity and healthcare costs, pointing out the economic burden that comes with poor air quality. Implementing effective policies to reduce smog pollution in Lahore can help alleviate the economic consequences and promote sustainable development. Moreover, the focus on community engagement highlights the significance of involving the communities in developing and carrying out policies. Involving communities in decision-making processes and increasing awareness about the risks of air pollution can help garner public support for policy initiatives and encourage people to change their behavior (Grimm *et al*., 2008; Hajat *et al*., 2016). It is crucial for policymakers to focus on engaging the community and mobilizing grassroots efforts in order to effectively implement smog control measures. To sum up, combining quantitative data and input from various stakeholders highlights the complex nature of the smog problem in Lahore and emphasizes the importance of policy measures in tackling air pollution. Policies that effectively address industrial emissions, along with stronger enforcement measures and strategies to involve the community, are crucial in reducing smog pollution and protecting the health and economic prosperity of the public by focusing on policy coherence and fostering collaboration among stakeholders, policymakers can create holistic strategies to address smog pollution. Making decisions based on evidence further supports driving sustainable development in Lahore.

6. Policy Recommendation

Based on the extensive exploration of smog-related challenges in Pakistan, several key recommendations emerge to combat and alleviate the detrimental impacts of this environmental issue. First and foremost, robust policy enforcement and the introduction of stringent regulations are imperative, particularly focusing on reducing vehicular emissions in urban centers like Lahore through the promotion of public transportation and incentivizing eco-friendly vehicles. Concurrently, targeting industrial emissions, especially from sectors like brick kilns, demands the implementation of green industrial policies and cleaner technologies to curb pollution output.

Encouraging the adoption of renewable energy sources within industrial and domestic sectors could significantly diminish smog-causing emissions. Public awareness campaigns and educational programs must be intensified to inform and engage citizens about smog hazards and encourage behavioral changes. Also leveraging digital solutions and technological innovations to combat smog in Lahore will require a multifaceted approach in the foreseeable future. Advancements in technologies like Artificial Intelligence, Big Data Analytics, and Machine Learning will refine air quality monitoring, enhancing predictive capabilities and data accessibility. Establishing a comprehensive network of monitoring stations and electric vehicle charging points across the city will be pivotal in expanding smart infrastructure. Innovative public engagement strategies, such as gamification and augmented reality applications, must be emphasized to disseminate accessible and engaging smog-related information across diverse communities. Simultaneously, robust policy frameworks developed through collaborative efforts among governmental bodies, tech industries, and research institutions will guide sustainable interventions. Prioritizing educational programs, research initiatives, and global partnerships will foster knowledge exchange, nurturing a culture of innovation and informed decision-making for a cleaner and healthier Lahore environment.

7. Future Research Direction and Conclusion

Future research could be directed by studying and exploring the long-term health outcomes and economic impacts of smog exposure on vulnerable populations in Lahore, such as children, the elderly, and low-income communities. Additionally, further studies into the effectiveness and scalability of innovative mitigation practices, including community-based interventions and technological solutions, would provide valuable insights. The climate change and air pollution need to be studied interdisciplinary. Comparative studies across other major urban centers in Pakistan could also help identify region-specific challenges and policy responses, contributing to a more comprehensive national strategy for smog reduction. Finally, integrating climate change projections with air quality models may offer a deeper understanding of how smog patterns might evolve, informing proactive and adaptive policy-making. To conclude a strong policy interventions are urgently required to resolve the pollution situation in Lahore based on the thorough examination of quantitative data and stakeholder viewpoints. The findings highlight the significant effect of industrial emissions on air quality and emphasize the importance of implementing strict regulations and enforcement measures to address industrial pollution. In addition, it is important to recognize the economic consequences and take policy actions to reduce the negative impact of air pollution on different industries and promote sustainable growth. Engaging with the community becomes a vital part of developing and carrying out policies, highlighting the significance of involving people in order to encourage changes in behavior and gain public backing for efforts to combat smog. In order to address the issue of smog pollution and protect the health and economy of Lahore, it is crucial to implement effective policies that target industrial emissions. These policies should be accompanied by stronger enforcement measures and strategies to engage the community. By giving importance to policy coherence, working together with stakeholders, and making decisions based on evidence, policymakers can create thorough strategies to address smog pollution and encourage sustainable development.

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