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Smog Mitigation and Climate Resilience in Pakistan: A Policy-Centric Review of Strategies and Challenges

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Abstract

Smog is a severe environmental and public health problem in major cities in Pakistan, particularly Lahore and Faisalabad. This review looks into the structure and content of smog policies and frameworks on climate resilience, drawing out the enhanced and the insignificant. Sources of significant smog are industrial emissions, traffic problems, and crop burning, all heightened by climate change. However, programs like the Pakistan Clean Air Program have been launched to control these emissions, yet they still need the enforcement mechanism and public awareness. Finally, regarding future work, the review advises that increased integration across disciplines, mainly through collaboration with international organizations such as the World Economic Forum, could enhance policy coordination. They get specific by stating that public engagement and community involvement are crucial, calling for better organizational practices. Recommendations for policy improvement include practical actions against smog and improving Pakistan's protection against climate change.

Keywords: Smog mitigation, Climate resilience, Pakistan air quality, Emission control policies, Public awareness.



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1. Introduction

1.1 Contextual Background

Air pollution in the form of smog has redefined an environmental and health disaster in Pakistan, particularly in the urban cities of Lahore, Faisalabad, and Gujranwala. Winter discharges are the most polluted days, and Lahore has been in the hazardous category since 2013 because of industrial and vehicular emissions and crop burning. Such activities emit large quantities of nitrogen oxides, sulfur oxides, ozone, and particulate matter that cause respiratory disorders, cardiovascular diseases, and skin diseases (Raza et al., 2021; Mirza, 2022). The spatial mapping of the corresponding region proves that domestic emissions are more responsible for smog formation than external factors (Mirza, 2022). There are policies such as current regulatory frameworks like the Pakistan Clean Air Program and the National Environment Action Plan. The problem, though, is that their effectiveness continues to be an area of concern, with more pervasive environmental degradation (Mukhtar, 2023). Increased and better intervention from the public and policy body is required to reduce this increasing concern (Ashraf et al., 2022; Colbeck et al., 2010).

In Pakistan, rapid urbanization, population growth, and industrialization have been identified as the leading causes of poor air quality, with PM and NO₂ exceeding WHO standards most of the time (Colbeck et al., 2010). While some government programs exist to monitor and control emissions, there needs to be more enforcement and no fixed standards for ambient air quality (Aziz, 2006; Mukhtar, 2023). Measures to enhance air quality have to be systemic, whereby such measures entail the modernization of monitoring facilities, emission source estimation, fine-tuning of traffic and fuel quality control, as well as enhancement of isolation standards of ambient air (Qadir, 2002). Further, claims for reducing emissions even in the transport segment through better engine maintenance and cleaner fuel might be highly effective (Taimoor, 2023).

Another essential function is educating the public and encouraging people to change their behavior, as many rate-limiting steps in Pakistan are linked with social behaviorism, such as transportation systems and waste disposal. Ghaffar (2023) and Ullah et al. (2022) identified that people need better knowledge about particular pollutants and health effects. Therefore, initiatives should be necessary to create awareness among people about sustainable practices, adopting approaches through different web platforms. Several hurdles have been provided by the community's lack of enough use of sustainable transport and minimal use of energy-efficient technologies. Pollution control, therefore, requires that the public acquire enhanced information on pollutants and promote environmentally friendly practices (Ghaffar, 2023).

The formation of smog in Pakistan is closely related to climate change, making air quality issues more complex in the nation. Global warming causes increased temperatures, changes in precipitation, and relative humidity, all of which affect the level of air pollutants (Naseem et al., 2018). However, in addressing climate change, the policy aims only at lowering carbon emissions while remaining vague on the steps to reduce air pollution in Pakistan (Butt et al., 2024). Research shows that sustainable development measures may significantly decrease PM_{2.5} mortality rates by 2050 and slash greenhouse gas emissions by 50% (Mir et al., 2022). Since the energy sector is one of the most significant contributors to climate and air quality effects, policies must focus on achieving two pollutant control goals. The formation of interdisciplinary research teams might also help eliminate gaps in current monitoring and assessment capacities and enhance Pakistan's preparedness to tackle such matters in a more comprehensive and comprehensive manner (Naseem et al., 2018; Mir et al., 2022).

Table 1: *Climate Variables Influencing Smog Formation in Pakistan*

Climate Variable	Impact on Smog Levels	Description
Temperature	Increases pollutant concentrations in warmer seasons	Hotter temperatures increase chemical reactions in smog (Naseem et al., 2018)
Humidity	Affects pollutant dispersion, can intensify or alleviate smog	Higher humidity can increase haze formation (Ahmed et al., 2020)
Precipitation	Helps wash out pollutants, reducing smog	Rain events reduce particulate matter in the air (Ali et al., 2019)
Wind Speed	Disperses pollutants over larger areas, reducing concentration	Higher wind speeds help break down pollution levels (Mir et al., 2022)

Following the preceding review, this section explores the critical problem of smog in Lahore, Pakistan, including its chief components, adverse health consequences, and effects on agricultural produce. Winter smog is worst in Lahore due to emissions from industries, vehicles, and burning of crop residue, while weather conditions also make the pollution worse during winters (Razzaq et al., 2024). This air quality crisis thus impacts respiratory and cardiovascular health, and soil deterioration and agricultural labor wellness and efficiency are affected (Shahid & Sabir, 2024).

As a result, these issues require a multi-sectorial approach involving policy measures, information, and technologies (Arif & Hassan, 2023). This is particularly so given the growing evidence that there is a need to improve intersectoral policy coherence regarding climate change in the water, agriculture, and energy sectors (Waheed et al., 2021). It emerged from the empirical analyses that alignment at the federal level is more efficient than provincial-level alignment, especially when energy policies need high alignment for better climate change response. It is recommended that structures for consultation between central and sub-central levels of government for integrated cross-sectoral policymaking are urged for coherent climate action (Waheed et al., 2021). This review focuses on sustainable measures, standard and ambitious policies, and solution-oriented approaches for addressing the smog pollution in Lahore, along with enhancing climate change resilience meant for Pakistan by Masud and Khan (2024).

In conclusion, smog poses a problem in Pakistan that can be attributed to a combination of industrial emissions, vehicle pollution, and lack of policy compliance. Policy-driven emission controls, spreading awareness sessions, and climate hardening best solve this policy crisis. While the government's current policies and actions towards smog are well-meaning, it means there is a need to step up the level of implementation, increase the clarity of standards to be met, and even increase public participation.

1.2. Purpose and Relevance

This review paper will focus on synchronous with the national policies of Pakistan for addressing smog and climate change. It will also look at the effectiveness of current policies and practices and potential enhancements to reach the set goals. There is a symbiotic relationship between smog and climate change since smog sources release greenhouse gases, which cause climate change. Reducing smog is an air quality concern and a climate debate.

1.3. Scope and Objectives

This review concerns Pakistan's policy-centric measures toward tackling smog, shifting energies, and raising awareness. Key objectives include:

1. Explaining the causes of smog in the zones of Pakistan's big and small cities.
2. Analyzing current state government policies related to emission regulation, shift in energy sources, and people involvement.
3. Assessing the contribution of climatic change in increasing smog formation and associated health effects in Pakistan.
4. The major issues in policy implementation and the viable recommendations.

2. Materials and Methods

This review paper adopts a policy analysis type to investigate best practices in smog moderation and climate change adaptation policies in Pakistan, emphasizing the government's policies. The methodology involves three main stages:

2.1. Literature Collection and Screening:

In order to ensure the validity of the datasets, a multi-database search was carried out in Google Scholar, Science Direct, PubMed, and JSTOR using the following search terms: 'smog mitigation Pakistan,' 'climate resilience policies,' 'emission control strategies,' 'public awareness regarding air.' Criteria used in selecting these articles included the availability of the studies from the year 2000 onward to capture the relevant changes in Pakistan's policies and environmental conditions. Official documents, including government reports, official policies, and publications by environmental agencies, were also considered to get a picture of official thinking and actions. The AND and OR Boolean operators were employed to enhance the search process and ensure the accrual of a rich list of material sources.

Inclusion and Exclusion Criteria: In this case, only sources freely accessible to the general public were considered. We excluded articles that did not advance the policy aspects or had nothing to do with smog or climate in Pakistan.

2.2. Policy Analysis Framework:

The selected literature was analyzed through a policy analysis framework, focusing on four key dimensions: The question includes: (a) types and causes of smog and air pollution in both urban and rural Pakistan; (b) the present policies governing emission reductions, energy transition, and public awareness; (c) the role of climate change in the exacerbation of smog and adverse effects on health; and (d) prospects and limitations to policy measures. For this reason, the approach was guided and structured to facilitate the comparison of the policy intentions and the results against the policy in as much as it awakened us to possible gaps and limitations of modern conceptual frameworks.

2.3. Data Synthesis and Thematic Coding:

Based on the same, findings were put into significant themes, including emission sources, health consequences, effects on agriculture, and awareness. The literature pointed out policy efforts, challenges, and policy gaps that need attention and noted down systematically and documented narratively for easy understanding of Pakistan.

Using such a research method allows for a rigorous critical consideration of existing and formulated smog and climate resilience policies in Pakistan, with an added emphasis on suggesting

recommendations on how the country can enhance its policy implementation in environmental governance.

3. Primary Sources of Smog in Pakistan

3.1. Industrial Emissions

The most recent articles emphasize that industrial areas in Pakistan, such as Karachi and Faisalabad, bear a critical level of air pollution. PM, SO₂, NO_x, and CO regularly surpass national environmental quality standards. This problem originates from industrial emissions, vehicular exhaust, and rapid rates of urbanization (Idress et al., 2021; Idrees et al., 2023; Nawazish et al., 2021). Pollutant concentrations are also seasonal; pre-monsoon periods are higher than post-monsoon, as Idress et al. (2021) and Idrees et al. (2023) reported. Air quality is also a big issue in Lahore, with PM_{2.5} forecasted to rise above 100 µg/m³ in the coming years (Bhatti et al., 2021). High traffic emissions are a significant concern not only for human well-being but also for plant health and soil quality, stressing the importance of the implementation of legal acts on the environment and efficient pollution control measures (Idrees et al., 2023; Nawazish et al., 2021).

3.2. Agricultural Burning and Crop Residue Management

Crop residue burning in the region, especially in Pakistan and Northwest India, highly influences air pollution, smog generation, and greenhouse gases, particularly in the post-harvest seasons, as highlighted by Singh and Kaskaoutis (2014) and Ahmed et al. (2019). This practice has extreme implications for health and traffic problems, with high chances of an accident occurring in low visibility. There is still awareness of the effects of burning crop residue among farmers, and many of them continue with the practice, attributing to a lack of better options. New approaches have been developed, known as sustainable crop residue management practices (SCRMPs), which have been identified to lower or contain the cost of health and its adverse environmental effects (Raza et al., 2022). However, implementing the alternatives provides specific unavoidable challenges that need farmers' preference and externality of market factors. Policymakers are encouraged to formulate integrated strategies to ensure the efficient use of crop residues and effective adoption of the SCRMPs on both the environment and farmers' prospects (Ahmed et al., 2019; Raza et al., 2022).

3.3. Vehicle Emissions

Air pollution in Pakistani cities is relatively high, and transport remains one of the main culprits. Motor vehicles contribute high amounts of NO_x, CO, and hydrocarbons, and with the currently growing vehicle population and the dated technology, pollution is continuing to rise. According to different works, the proportion of vehicular-related air pollution contribution is as low as 5% and as high as over 80% (Bajwa & Sheikh, 2023). Cues like non-renewable energy consumption and population density expand environmental deterioration beyond tolerable levels (Koçak et al., 2024). High levels of motor vehicle activity in Pakistan have considerably increased urban air pollution, affecting health, climate, and economy (Ilyas, 2007). To resolve this problem, coordinated measures are required

- Attaining higher efficiency in traffic management,
- Transitioning to cleaner fuels,
- Increasing the efficacy of emission standards and
- Increasing the efficiency of inspection and maintenance programs.

Continuous air quality management and tracking programs to curb pollution are essential for policy development in Bajwa and Sheikh (2023) to achieve the strategic goals of effectively monitoring and investigating the origins of air pollution.

3.4. Fossil Fuel Combustion

Underlying environmental implications due to Pakistan's heavy use of coal and oil involve smog proximal pollutants such as delicate particulate matter and sulfur compounds. Thermal power plants employing heavy residual oil have a high propensity to emit SO₂, NO_x, and particulate matter. They are typically higher than the national and international permissible limits set for them (Ali et al., 2011). Significant linkages with pollution, urbanization activity, the use of fossil fuels, inadequate control of polluting industries, and the excessive use of cars thus remained contributory factors for smog becoming a significant public health issue, especially in cities in Lahore (Akbar, 2018). The situation has been deteriorating since 2013, leading to several diseases like pulmonary, respiratory, and skin diseases (Raza et al., 2021). To overcome these challenges, Pakistan should institutionalize ecological concerns in energy policies and budgets and dramatically enhance energy research and development spending. The energy sector is also a significant source of press rendering environmental effects. Global costs related to classic pollutants are significantly higher than in Europe or the US (Husain, 2010).

Table 2: Primary Sources of Smog and Associated Pollutants in Pakistan

Source of Smog	Primary Pollutants	Health Effects	Environmental Impact
Industrial Emissions	PM _{2.5} , SO ₂ , NO _x	Respiratory diseases, lung cancer (Raza et al., 2021)	Soil and water contamination (Idrees et al., 2023)
Vehicular Emissions	CO, NO _x , hydrocarbons	Cardiovascular and respiratory issues (Akbar, 2018)	Urban air quality degradation (Bajwa & Sheikh, 2023)
Crop Residue Burning	PM ₁₀ , CO ₂ , methane	Eye irritation, respiratory issues (Ahmed et al., 2019)	Soil degradation, low visibility (Singh & Kaskaoutis, 2014)
Fossil Fuel Combustion	SO ₂ , CO ₂ , particulate matter	Pulmonary diseases, cardiovascular issues (Ali et al., 2011)	Greenhouse gas emissions, acid rain (Husain, 2010)

4. Government Policies for Smog Mitigation

4.1. Emission Control Regulations

Air quality in Pakistan is threatened by rapid urbanization, industrialization, and growth in motorization (Colbeck et al., 2010). These pollutions stem from households, transportation, industries, agriculture, and waste. The government has measures to address this problem through the 2023 Clean Air Policy, which sets out suitable ambient air quality standards and defines strategic action plans within high emissions sectors. They silently could reduce primary PM_{2.5} emissions by 36.4% by 2030 and 80% by 2050 compared to the business-as-usual projections (Slater et al., 2024). Besides, the policy seeks to enhance the quality of fuel and transport equipment and advance the technologies that control emissions in the transportation industry (Taimoor, 2023). Sitansu Purohit et al. (2013) reviewed earlier literature on measures for managing air pollution: cleaner fuel and end-of-pipe control measures. However, some issues, especially concentrations of particulate matter and nitrogen dioxide emissions, remain above WHO standards (Colbeck et al., 2010).

4.2. Quality of Air Standards and Monitoring

Given the current increases in urbanization, industrialization, and motor vehicle usage in Pakistan, this country is greatly threatened by air quality. The government of Pakistan formally recognized air pollution as a local chronic disease in Pakistan and has initiated some measures, including the Pakistan Clean Air Program and some continuous monitoring stations; however, ambient air quality standards still need to be effectively implemented. PM and NO₂ are the most severe pollutants; their concentration often exceeds the WHO standard (Colbeck et al., 2010; Aziz, 2006). The level of temperature, relative humidity, and precipitation impact the levels of air pollutants (Naseem et al., 2018). Scholars have suggested formulating general guidelines on air quality, expanding the monitoring systems, developing emission strategies, and adopting vehicular emission standards. Further, developing multidisciplinary research and expertise integration is essential to eradicate restrictions on air quality control and enforcement in Pakistan (Colbeck et al., 2010; Aziz, 2006; Naseem et al., 2018).

4.3. Vehicle Emissions Standards

Active attempts are being made worldwide to enhance vehicle emissions standards with instruments like fuel economy standards, vehicle emission standards, and fuel quality standards. Although developed countries have implemented strategies including emission standards, clean fuels, and maintenance programs, developing countries need help with enforcement since the required resources and regulatory mechanisms are weak (Timilsina & Dulal, 2009). Enforcing stricter vehicle emissions standards could be expensive and futile in developed countries. This has led to the need to target high-emitting vehicles and evaluate the use of economic incentives. Remote sensing technology has become practical for on-road surveys for high-emitting vehicles for urban air quality improvement through better enforcement programs. However, some issues still need to be addressed: restrictive cut-points and a lack of practical experience with diesel automobiles (Huang et al., 2022).

Table 3: *Summary of Smog Mitigation Policies and Their Effectiveness in Pakistan*

Policy/Program	Objectives	Key Measures	Challenges	Outcomes
Pakistan Clean Air Program	Reduce ambient air pollution (Mukhtar, 2023)	Emission control, air monitoring	Weak enforcement, limited funding (Aziz, 2006)	Minimal improvement in air quality (Qadir, 2002)
National Environment Action Plan	Sustainable environmental management (Ashraf et al., 2022)	Industrial regulations, public awareness	Inconsistent implementation (Mukhtar, 2023)	Limited impact due to weak execution (Colbeck et al., 2010)
Provincial Smog Control Policies	Reduce local sources of pollution (Butt et al., 2024)	Vehicle inspection, crop burning bans	Limited provincial resources, lack of public support (Raza et al., 2021)	Improvements in compliance in urban centers (Taimoor et al., 2023)
Climate Change Policy 2012	Address climate impacts on air quality (Waheed et al., 2023)	Shift to clean energy, afforestation	Limited coherence with air quality measures (Naseem et al., 2018)	Some progress in energy sector, limited air quality impact (Mir et al., 2022)
Policy/Program	Objectives	Key Measures	Challenges	Outcomes

4.4. Health and Agricultural Impacts of Smog in Pakistan

Pollution in Pakistan has dangerous implications for human health and crop production. It reduces grain size and weight, thus hurting wheat productivity. To solve this crisis, investigators encourage stricter environmental measures, better farmer education, better credit incentives, and cleaner technologies (Safdar et al., 2022). Smog is associated with pulmonary, respiratory, and skin illnesses; Lahore has had deteriorating air quality since 2013 (Raza et al., 2021). The haze of smog carries gross elements like little particles and toxic gases, which result in acute respiratory sickness, eyesores, seasons of allergy, and even malignant lung growth (Naveed, 2023). PM2.5 carries the potential risks of cardiovascular diseases and a shorter life span when a human being is exposed to such pollutants for an extended period (Naveed, 2023). In this case, smog also impacts the transportation and education sectors. Fuzzy VIKOR, as a multi-criteria decision-making tool, can be helpful when it comes to defining the choice of the best environmental and health-promoting policies (Ali et al., 2019).

Table 4: *Health and Agricultural Impacts of Smog in Pakistan*

Impact Category	Specific Effects	Affected Population/Region
Health Impacts	Increased respiratory diseases, cardiovascular issues, eye irritation (Raza et al., 2021; Mirza et al., 2022)	Urban centers (Lahore, Faisalabad)
	Higher incidence of lung cancer and asthma (Akbar, 2018)	Vulnerable populations (elderly, children)
Agricultural Impacts	Reduced crop yields, soil acidification (Ahmed et al., 2019)	Farming communities, especially Punjab
	Adverse effects on livestock and food security (Raza et al., 2022)	Rural agricultural areas

5. Public Awareness and Community Engagement

5.1. Education Campaigns

Thus, public awareness measures bear essential responsibility for increasing citizens' awareness of smog threats to their health and encouraging them to change their behavior in a more environmentally friendly way. Siddiqui et al. (2023), sampling across urban and rural areas, noted that social media campaigns help create awareness of smog and embrace pro-environmental practices. Research confirms that people learn about smog through television; most employ mitigation measures during smog episodes (Hussain et al., 2024). Mobile phone alert systems have been used to show that people's awareness and preventive actions concerning smog developments have enhanced outcomes (Mehiriz & Gosselin, 2019). However, there are barriers to air quality communication: ignorance about who is in charge of it, lack of information on how to deal with the risks and its long-term health consequences, and ineffective ways of getting to social groups that are sensitive to polluted air (Ramírez et al., 2019). Based on these findings, therefore, there is a need to assess ways of supplementing community-level environmental health literacy about sources, effects, and risk mitigation of air pollution.

5.2 Community-Centric Programs

Recent programs aimed at cutting smog levels have been effective in different communities. Measures of population increase and vehicle utilization in Southern California from 1994 to 2011

showed growth, but both NO₂ and PM_{2.5} levels were reduced due to comprehensive compliance approaches for controlling emissions (Lurmann et al., 2015). Early interventions prevent individual baseline cardiovascular risk and embed air pollution into land use planning (Giles et al., 2011). As for Dieng in Indonesia, the countermeasures against factory-generated air pollution included organizing local environment groups, launching awareness-raising actions, and demanding a higher level of monitoring. Thus, information disclosure strategies are identified as a “third wave” in pollution control policy alongside legal and market mechanisms. These strategies have been applied in developed and developing countries, using public information to change polluter behavior (Ma’rifah, 2023). One positive that has been illustrated from these multiple approaches is the possibility of solving challenges relating to air pollution through community engagement.

5.3. Role of NGOs and Private Sector

More than 40,000 NGOs and transnational corporations’ impact international environmental governance rather than supplementing the government’s efforts and pushing for cleaner technologies. In China, state actors continue to dominate this domain, and “public service units” and “social associations” perform roles that could be seen as more familiar in the Western liberal NGO (Guttman et al., 2018). The latter is, however, often discovered by private firms and NGOs, though the government plays an important role, especially in the energy sector (Norberg-Bohm, 2000). These indirect regulatory instruments, forged by governments, companies, and NGOs, are reorganizing global environmental governance, especially in tropical agriculture and forestry (Lambin & Thorlakson, 2018). It is essential to understand that these private governance mechanisms have a complex relationship with public policy, where they often can work in parallel to or in support of state-based governance, instead of which can be viewed as being in direct conflict, as assumed by some scholars (Falkner, 2003). Knowledge of these interactions is critical to developing intervention strategies and capturing the shifts in the global politics of the environment (Lambin & Thorlakson, 2018; Falkner, 2003).

6. Impact of Climate Change on Pakistan’s Smog Levels

6.1. Interrelation Between Smog and Climate

Air pollution and smog problems worsen in Pakistan due to climate change by increasing temperatures and changing weather conditions. The literature review confirmed that temperature, humidity, and precipitation play a vital role in shaping air pollutant concentration levels (Naseem et al., 2018). Since 2013, smog has emerged as a critical source of socioeconomic and health issues in major Pakistani cities, with matters getting worse every year (Raza et al., 2021). Punjab faces immense challenges; hence, challenges such as population density, rapid expansion of cities, elevated levels of emissions, and dependence on fossil fuels have led to long smog seasons (Aslam et al., 2020). Some of the concentrations of TSP and lead violate the threshold standard, thus resulting in considerable health hazards. In order to solve these problems, the scholars propose an integrated multi-pollutant control policy, enhancing the governmental policy, increasing the people's awareness, and strengthening regional cooperation (Niaz & Zhou, 2013; Naseem et al., 2018).

6.2. Adaptation and Resilience Building

Regarding air pollution and climate change, there are severe problems in Pakistan that require integrated approaches toward prevention and preparedness. Studies show that integrating sustainable development approaches in developing countries could prevent premature deaths from PM_{2.5} by 24 percent by mid-century and cut carbon emissions in half (Mir et al., 2022). Although

Pakistan has clean energy and climate change policies consistent with global CO₂ emission goals, there is little focus on air pollution (Butt et al., 2024). Nevertheless, the country has progressed in climate adaptation policies and standards, but there are still existing knowledge gaps, a lack of involvement of stakeholders, and a need for more awareness among the public (Ali et al., 2019). A study conducted in Khyber Pakhtunkhwa revealed several green aspects that were deemed to be as vital in the pursuit of impacting favorably on UGI indications; there is a possibility that the government's most valued development model, green growth development model, should help in changing the existing Khyber Pakhtunkhwa province culture to minimize its vulnerability to urban flooding and ecosystem impacts (Rayan et al., 2022).

7. Challenges and Barriers to Policy Implementation

7.1. Financial Constraints

There are always hurdles in policy implementation and enforcement, especially in Pakistan; when it comes to environmental laws and air quality standards, several challenges are on the housing radar (Asghar et al., 2024). Lack of physical and financial capital and scarce concerns from the government hinder the efficiency of monitoring and controlling pollution. Volunteer-based monitoring systems, for example, have been tried due to resource constraints (Ikram & Akram, 2007). Lack of funds also has vital input, showcasing green finance schemes, FDI, financial development, and sustainability (Kanwal et al., 2023). Although there are some measures of success with the Pakistan Environmental Protection Program, existing air pollution management projects need to improve the national air quality standards. However, it is mandatory to formulate sustainable development policies and international cooperation to improve air quality, public health, and minimization of greenhouse gases in Pakistan. Such actions can contribute to shifting the emission control cost to a level of one-quarter of GDP by 2050 (Mujeeb et al., 2023).

7.2 The enforcement and regulation of FCPA is quite complex.

There are challenges in implementing climate change and environmental policies in Pakistan's rural and industrial regions. Some of the challenges are a centralized management system, exclusion of stakeholders, and inadequate knowledge among policy executors (Masud & Khan, 2023). These problems are compounded by a need for more solid regulations and reforms and a lack of enforcement actions (Asghar et al., 2024). The present chapter has identified that the National Climate Change Policy of 2012 has experienced various barriers to implementation in both conceptual and practical dimensions (Hussain et al., 2020). In this case, the elitist model of policymaking has acted as a barrier to the implementation of actual policies, meaning that the country needs to move towards more people-centered means. To solve these problems, the researchers suggest increasing care-based communities, increased public involvement, and cooperation between civil society organizations and related media, research institutions, and the public (Ittefaq & Kamboh, 2023). Enhancing the capacity to engage stakeholders in policy formulation and planning stages is critical to designing and implementing adaptation measures under decentralized governance (Masud & Khan, 2023).

8. Future Directions and Recommendations

8.1. Policy Recommendations

Pakistan suffers from terrible urban air quality based on the infrastructure specifics of the transport and energy industries, with visible health and economic repercussions. Suggested measures include vocational measures, such as improving traffic control, the promotion of environmentally friendly fuels such as CNG, and CPI measures like mobility checks. A “Green Cities” policy for

Pakistan can establish benchmarks for air quality and energy use among Pakistan’s urban centers, technologies and management solutions, and financial rewards (Qadir, 2002). In response to this problem, some scholars proposed that emissions should be increased, air quality standards should be tightened, and funds for developing renewable energy sources should be introduced (Purohit et al., 2013). It is now postulated that future air pollution control technology with sustainable development approaches and desirable reductions in PM2.5-related mortalities, health damage, and greenhouse emissions will be cut in half and an optimized approach to emission control cuts of 2050 (Mir et al., 2022). This integrated approach is significantly beneficial in terms of air quality, public health, and economic saving for Pakistan.

Table 5: Recommendations for Enhancing Smog Mitigation Policies in Pakistan

Recommendation	Proposed Actions	Responsible Parties	Expected Outcome
Strengthen emission standards	Update and enforce strict standards for industrial emissions	Ministry of Climate Change, EPA	Improved air quality, reduced smog levels (Ashraf et al., 2022)
Enhance public awareness	Run campaigns on smog risks and preventive actions	Local governments, NGOs	Increased public engagement, behavior change (Siddiqui et al., 2023)
Integrate climate resilience into policies	Align energy, water, and agriculture policies with climate goals	National and provincial governments	Greater resilience to climate-induced smog (Waheed et al., 2023)
Promote cleaner technologies	Provide subsidies for green tech in transport and industry	Government, private sector	Reduction in emissions, cleaner production (Purohit et al., 2013)

8.2. Technology Adoption

Pakistan has a grim environmental situation mainly marked by air pollution and climate change effects. To solve these problems, the country is searching for different solutions. Extending cleaner production technologies and CE practices in industries is essential for reducing pollution and improving resource use (Amanullah, 2024). PM 2.5 mortalities could be lowered to 24% by 2050 if sustainable development strategies were practiced while advanced control measures in consonance with the strategies could cut greenhouse gas emissions in half besides saving on the cost of emissions control (Mir et al., 2022). Encouraging GETs is essential, although consumer acceptance must catch up. Drivers to adopt GET include environmental concerns, awareness, and perceived benefits, while costs and discomfort are the barriers to adoption (Zeng et al., 2022). So, in the context of the manufacturing sector, green innovation (GIA) is vital for sustainable development. This study shows that performance expectancy, effort expectancy, and facilitating conditions determine green behavioral intention and further GIA (Shahzad et al., 2022).

8.3. International Collaboration

The Pakistan Climate Change Act 2021 recognizes that the country is vulnerable to climate change and air pollution, for most of which it has contributed little (Adnan et al., 2024). The country suffers extensive effects such as floods, glacier melt, and low urban air quality, which negatively impact the health of the inhabitants and the economy. To cope with such problems, there is a need to integrate Transitions Climate Change Mitigation Strategies – Air Pollution Control in Pakistan. Such approaches can, in principle, cut greenhouse gas emissions in half and decrease mortality from PM2.5 by 24% by 2050 (Mir et al., 2022). Altogether, the country experiences a deficiency of knowledge, scarcity of resources, and coordination problems in climate change research among

institutions. There is a need to strengthen substantive international cooperation at the level of funding, the exchange of knowledge and experience, and capacity building. This involves enhancing access to large data sets, knowledge of freshly developed methodologies, and climate change education in universities to foster effective change adaptation and mitigation measures (Rasul, 2010).

9. Conclusion

Pakistan's ongoing smog crisis, primarily driven by industrial activity, vehicle emissions, and crop residue burning, demands immediate, coordinated action. Current policies, including emission control regulations and clean air initiatives, provide a foundational framework, yet gaps in enforcement, inadequate public engagement, and climate-related challenges hinder their success. Climate change exacerbates smog issues by altering atmospheric conditions, intensifying pollutant concentrations, and extending smog seasons. This review emphasizes the need for strengthened intersectoral policy coherence across energy, water, and agriculture sectors to support effective climate resilience strategies. Increasing public awareness and community engagement is equally critical, as behavioral changes are essential to achieving long-term improvements in air quality. For sustainable progress, Pakistan must invest in cleaner technologies, foster public-private partnerships, and prioritize research to fill knowledge gaps. These efforts will alleviate immediate health risks and contribute to building a resilient, environmentally conscious society.

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