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TOWARDS MORE EFFECTIVE AIR POLLUTION GOVERNANCE STRATEGIES IN PAKISTAN: A SYSTEMATIC REVIEW OF THE LITERATURE

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Abstract

Pakistan consistently faces challenges of poor air quality, ranking third globally in mortality linked to air pollution. This review critically evaluates the current policy landscape, identifying gaps in political commitment and regulatory enforcement, and suggests the way forward for reducing the severity of air pollution in Pakistan. It begins with identifying the sources and uncovers the wide-ranging impacts of air pollution to human health and the broader economy. It examines the failure of policy interventions in Pakistan as has been exemplified by some policies notably the Punjab Smog Policy of 2017, which is largely attributed to the lack of an effective feedback mechanism, inadequate institutional cooperation, and insufficient information. The study emphasizes the responsibility of developed nations in global air pollution and advocates for their financial support to assist developing countries in transitioning to cleaner air. Additional recommendations propose strengthening policy frameworks, raising public awareness, and implementing targeted interventions in the transportation and industrial sectors. Conclusively, the findings underscore collaborative efforts to bridge the implementation gap and provide a roadmap for sustainable development amid persistent air pollution challenges in Pakistan.

1 Introduction

Air pollution, as defined by the World Health Organization (WHO), refers to the contamination of indoor or outdoor environments by various agents altering the natural atmosphere. Its implications extend far beyond environmental degradation, posing a substantial threat to human health and well-being. According to the WHO, air pollution stands as the fifth-largest risk factor for mortality globally (HEI, 2019). A staggering statistic reveals that over 90% of the world's population resides in areas where the WHO's recommended guidelines for healthy air are exceeded, underlining the

[1] WWF-Pakistan

pervasive nature of this issue (HEI, 2019). The consequences of air pollution reverberate across diverse populations, transcending income brackets and geographical boundaries (WHO, 2018).

To report the daily air quality status, different agencies rely on the use of Air Quality Index (AQI), an indicator designed to inform the public about the current and forecasted pollution levels. The AQI operates on a scale from 0 to 500, indicating the level of air quality and amount of suspended particulate matter in the atmosphere. Higher values of the AQI represent low air quality while the lower values of AQI represent better quality of air (IQAir, 2022).

The rapid deterioration of global air quality presents an imminent threat to health, and the economy, with staggering economic charges. For instance, according to Greenpeace, the world incurs an estimated cost of around 8 billion dollars per day due to air pollution (Farrow et al.,

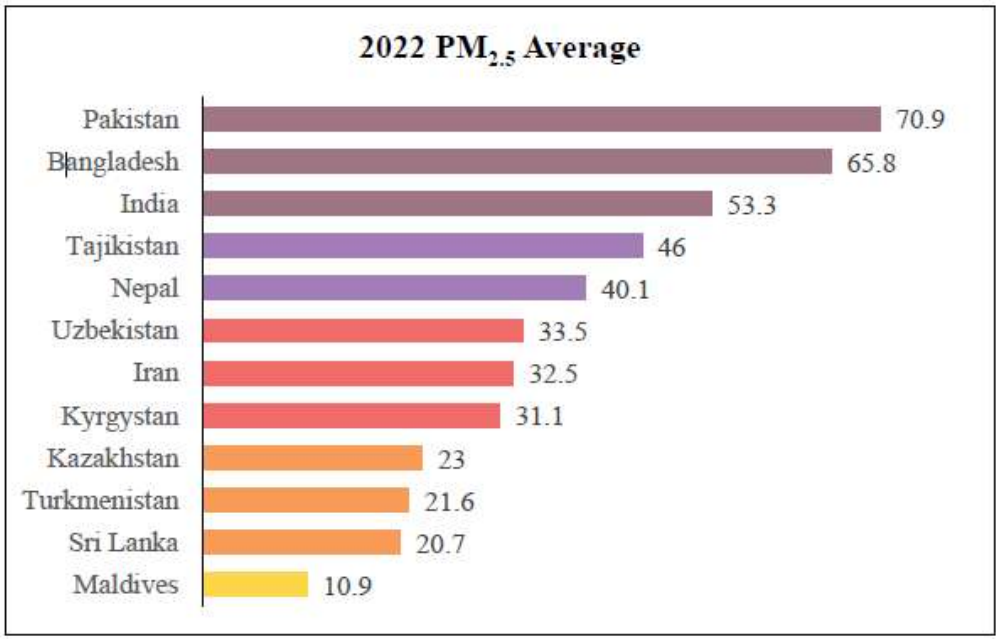
2020). The Asian continent, particularly South Asia, bears a significant burden of air pollution, with notably high concentrations of particulate matter reported in countries like India, Bangladesh, and Pakistan. South Asian cities consistently rank among the world's most polluted, primarily due to emissions from various sources including transportation, industrial activities, agricultural burnings, and coal combustion (IQAir, 2019). Furthermore, recent reports from 2019 indicate that nearly 100% of populations in countries such as China, India, Pakistan, and Bangladesh inhabit areas where pollutant concentrations surpass WHO guidelines (Institute of Health Metrics and Evaluation, 2019).

In 2019, outdoor air pollution was associated with an estimated 4.2 million premature deaths annually, primarily linked to exposure to fine particulate matter (HEI, 2019). Throughout the 21st century, air pollution has emerged as a pressing environmental menace, responsible for approximately 6.5 million annual deaths globally, with more than 5.5 million of these being premature fatalities attributed to air pollution-related illnesses (World Bank, 2016). In urban areas, particularly, respiratory ailments are a major concern, contributing to 80% of chronic diseases, as noted by the World Health Organization (Jahanzaib, 2023; Sharma, 2022; Asif, 2018).

The rapid industrial and urban growth in developing nations exacerbates these risks due to inadequate health awareness, rapid industrialization, vehicular emissions, lax air quality standards, outdated technology, and densely populated regions (Kermani, 2023; Butt, 2018). The effects of air pollution, particularly fine particulate matter (PM2.5), have a substantial impact on human health and the environment. PM2.5, particles smaller than

2.5 mm, poses severe health risks by deeply penetrating the human respiratory system, leading to various health issues (Raaschou-Nielsen et al., 2016). These particles originate from diverse sources like agriculture, road dust, vehicle emissions, power generation, combustion, construction, and industries (Matus et al., 2012).

The impact goes beyond respiratory issues, contributing to cardiovascular diseases, decreased lung function, premature mortality, cancer, diabetes, and obesity (Kim, 2015; Farrow, 2020; and PAQI, 2018). Research highlights its impact on human physiology, from inflammation and hormonal disruption to behavioral changes, especially in children (Furlong, 2020; Wang, 2021; and Bloemsma, 2019). Pollutants like PM10, CO, NOx, SO2, VOCs, and PM2.5 worsen health conditions in densely populated areas, especially concerning asthma (De Bont, 2019; Pant, 2019).



Source: https://www.iqair.com/world-most-polluted-cities

Pakistan, in particular, struggles with persistently poor air quality, exceeding WHO interim targets since 1990 due several reasons with lack of robust political action as the most prominent reason (IQAir, 2019). The provided chart displays the rankings of Central and South Asian countries based on air quality. Notably, Pakistan, Bangladesh, and India exhibit the poorest air quality, with Pakistan recording the highest PM2.5 average at 70.9µg/m³. These nations, with their substantial populations, experience heightened industrial activity, leading to increased emissions and subsequently poorer air quality. Conversely, Sri Lanka and Maldives, situated by the sea and

smaller in size, exhibit comparatively better air quality, as reflected by the lowest values in the chart (IQAir, 2022).

2 Severity of Air Pollution in Pakistan – A background

Pakistan ranks third in the world in terms of mortality attributable to air pollution, with an annual loss of 128,000 lives (Government of Pakistan, F.D, 2019). The nation also holds the third rank globally in terms of countries with most hazardous air quality index (IQAir, 2022). This has led to a high level of harmful pollutants in the air, posing serious health risks to the population. The situation is exacerbated by the lack of political commitment, limited resources, and weak enforcement of air quality standards, with developing countries like Pakistan being particularly vulnerable to air pollution due to factors such as rapid urbanization, industrialization, open burning, geographical location, increased vehicular traffic, and limited resources for pollution control (Bilal, 2021).

There is a consistent failure to meet WHO air quality guidelines in Pakistan, particularly during the winter and autumn seasons in cities like Lahore (highest polluted city), Peshawar, Karachi, and Islamabad. Air Quality Index (AQI) levels in Lahore frequently surpass "Hazardous" thresholds,

70.9 65.8 53.3 46 40.1 33.5 32.5 31.1 23 21.6 20.7 10.9 Pakistan Bangladesh India Tajikistan Nepal Uzbekistan Iran Kyrgystan Kazakhstan Turkmenistan Sri Lanka Maldives **2022 PM2.5 Average**

primarily due to anthropogenic sources like transportation, brick kilns and power plants, contributing to smog formation (Omer, 2018; Bilal, 2021).

Moreover, in Pakistan, this smog is responsible for many serious health issues including respiratory problems such as asthma exacerbation, coughing, burning throat and chest irritation and chronic bronchitis. Besides these breathing problems, smog also causes eye, cardiac and skin manifestations (Ali, 2019). Particular Matter 2.5 (PM 2.5) is a component in smog which is considered to be the major health hazard. It can pass through the airways and settle down in the lungs causing many pulmonary pathologies. It is the same component which reduces visibility and causes “haziness” seen in smog (Ashraf, 2022). Also, countries like Pakistan bear a higher burden of these health impacts due to ill-equipped healthcare systems, facing substantial economic costs including healthcare expenditures, lost labor productivity, and damage to agricultural and natural resources. Thus, air pollution is a severe health risk, impacting mortality rates and imposing significant economic burdens, especially in developing countries like Pakistan (Riaz, 2022). To highlight the gravity of the problem, this study examines the smog situation in Lahore to provide a closer look:

Smog Crisis in Lahore: A Growing Environmental Challenge

Lahore, Pakistan, once known as "The City of Gardens," is facing a severe environmental crisis due to smog (Shahid, 2020). The average $PM_{2.5}$ concentration in Lahore in 2010 was 121.8 µg/m3 and has been on the rise each year (Government of Punjab; Lahore AQI, 2021). Notably, the city experienced a severe smog episode in 2015, which raised public awareness and forced the government to acknowledge the problem. The air pollution problem in Lahore is closely linked to industrial activities, vehicular congestion, the use of polluting fuels for power generation, and the lack of effective air quality standards and monitoring facilities. This situation poses a significant health risk that requires urgent attention and action. In 2020, Lahore was ranked as the 18th most polluted city in the world and the second most polluted mega-city, primarily due to high $PM_{2.5}$ levels (Ali, 2022). Presently, the city has escalated to being among the top 5 most polluted cities worldwide. Thus, in light of these alarming statistics, thorough measures are essential to address the root causes of poor air quality not only in Lahore but Pakistan.

3 Significance of the study

This systematic review aims to thoroughly analyze existing literature concerning air pollution governance in the country, highlighting critical areas that demand immediate attention.

1. The review emphasizes on the proactive measures needed to address the critical issue of air pollution in Pakistan.
2. It analyses that the current strategies have gaps and require immediate control interventions, including policy adjustments, their stringent enforcement and enhancing international collaborations.
3. Further it presents the idea that developed countries have a responsibility to provide financial support to Pakistan in resolving air pollution issues.

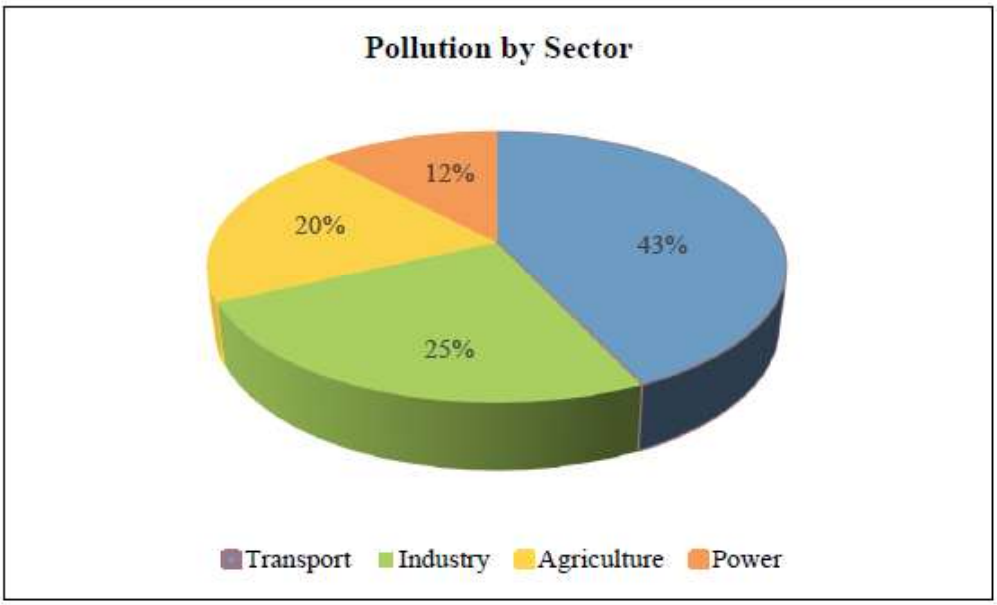
4 Problem Identification

To effectively tackle the air pollution crisis, it is crucial to get a thorough understanding of the sources of air pollution (its trend over the past years) and the current policies to address the problems arising due to lack of stringent policies to manage the air quality effected as a result of the pollution. Additionally, the gaps in these policies are underscored to pave the way for the formulation of effective policies that can address the root causes of air pollution.

4.1 Sources of air pollution in Pakistan

The reviewed literature highlights vehicular emissions as the primary source of air pollution in Pakistan, closely trailed by thermal power generation, industrial activities, biomass burning, and transboundary factors. The

significant contributors to air pollution encompass the consistent burning of fossil fuels in vehicles, power production, and industrial processes, often lacking pollution control technologies. Other notable sources involve the combustion of municipal and industrial waste, as well as brick kilns utilizing unclean fuels like rubber tires. Additional pollution arises from burning crop residue and the dust produced at construction sites for new infrastructure development (Niaz, 2016).



The provided chart illustrates how each sector contributes to pollution, resulting in a rise in greenhouse gas emissions in Pakistan. The transport sector is the primary contributor, accounting for nearly half of the emissions (43%), followed by substantial contributions from industries (25%) and the agriculture sector (20%). Additionally, the power sector in Pakistan contributes 12% to the total emissions (Habib, 2021). To effectively decrease emissions, the country should prioritize efforts to address pollution from the transport sector.

The dependence on fossil fuels, including coal and biomass, for energy generation and household cooking within many developing nations results in a dual impact of both outdoor and indoor air pollution (Perera, 2018). Particularly vulnerable groups, such as women and children, face heightened exposure to harmful particulate matter and gases indoors. Air pollution

43% 25% 20% 12% **Pollution by Sector** Transport Industry Agriculture Power

disproportionately affects lower-income communities in these nations due to limited access to healthcare and living in areas subjected to higher pollution levels, often situated near industrial zones or major roadways (Rentschler, 2023).

Source of air pollution	Situation in Pakistan
Vehicular congestion/Transportation	Transportation is a major source of air pollution in Pakistan, accounting for around 43.2% of NOx emissions and 39.6% of CO emissions (Shahid, 2015). The number of vehicles in Pakistan has increased dramatically in recent decades, from 5,633,353 in 2006 to 23,588,268 in 2018 (ESP, 2019). This increase, along with the use of old, poorly maintained, and smoky vehicles, has led to a significant deterioration in air quality.
Industrial Emissions	The industrial sector is another major source of air pollution in Pakistan, accounting for around 39.6% of NO_x emissions, 75.6% of SO_2 and CO emissions. The industrial sector in Pakistan consumes around 16% of the total oil in the country and releases around 162 tonnes of NO_x, 378 tonnes of Sulphur products, 285 tonnes of CO, and nearly 4400 tonnes of particulate matter. These emissions are likely to increase in the future with the increasing use of oil and petroleum by the industrial sector (Anjum, 2021).
Construction	Construction activities are a major source of dust and particulate pollution, which can significantly deteriorate air

Source of air pollution	Situation in Pakistan
	quality. These activities can increase the values of total suspended particles, PM10, and PM2.5 by 42%, 20%, and 16%, respectively (Yan, 2019). The construction sector in Pakistan has a large impact on the overall air quality of the region, from the production of bricks and raw materials to the use of heavy machinery (Khan, 2019).
Open burning	Open burning of solid and agricultural waste is a widespread practice in Pakistan, with various contributing economic and social factors. This practice significantly impacts air quality, as it is considered a major source of air pollutants, including black carbon and greenhouse gases. Studies have shown that open burning of biomass waste contributes to over 90% of the total gaseous pollutants emitted, with rice straw and bagasse being the primary contributors. The emission of these pollutants, especially CO, has been increasing dramatically over the past 15 years, with the highest emissions occurring in districts of Punjab and Sindh due to their intensive agricultural activities. While agricultural residue burning accounts for the majority of open burning in Pakistan, the impact of open solid waste burning on health cannot be overlooked. Solid waste collected in

Source of air pollution	Situation in Pakistan
	communal bins is often set on fire to reduce its volume, leading to the release of hazardous compounds, including particulate matter, greenhouse gases, persistent organic pollutants, and solid residues, all of which have severe documented health impacts (Abdurrahman, 2020).
	House and forest fires contributed to Pakistan's poor air quality in 2022. The Dadu village fire in April, the Haripur and Sherani District wildfires in May, and the Shangla District and Karachi fires in June each contributed to Pakistan's 12% increase in annual PM2.5 concentrations (IQAir, 2022). Crop burning and winter weather patterns resulting in temperature inversions that promote air stagnation keep air pollution trapped close to the ground are other main contributors to this country's poor air quality.

5 Current Policies in Pakistan

The legal landscape governing environmental and vehicular matters in Pakistan is shaped by a series of laws, policies, standards, and guidelines. The table presented below represents an overview of key laws, policies, standards, and guidelines that govern the realms of motor vehicles and environmental protection in Pakistan. Each entry provides a snapshot of significant legal instruments, detailing their historical background, amendments, and specific provisions. Together, these legal frameworks reflect Pakistan's current commitment to air quality regulation and reduction of vehicular emissions.

Laws, Policies, Standard, and Guidelines	Description
Pakistan Environmental Protection Act, 1997 (Amended, 2012)	The Pakistan Environmental Protection Act, 1997 is the primary environmental legislation in Pakistan. The Act provides a framework for the protection of the environment, including the prevention of air pollution.
NEQS (revised 2000)	National Environmental Quality Standards (NEQS) are a set of regulations established by the Pakistan Environmental Protection Agency (Pak-EPA) to protect the country's environment and human health. These standards cover a wide range of environmental parameters, including air quality, water quality, noise pollution, and industrial emissions. The NEQS are designed to set limits on the levels of pollutants that can be released into the environment to ensure that they do not pose a risk to human health or the environment.
National Environment Policy (NEP) 2005	The National Environment Policy aims to protect, conserve and restore Pakistan's environment in order to improve the quality of life of the citizens through sustainable development. The policy aims to set regulations for ambient and indoor air quality, vehicle and industrial emissions, fuel quality, and energy conservation.
Punjab Environmental Quality Standards (PEQS) for Ambient Air 2016	The PEQS were established in 2016 and set limits on the concentration of specific pollutants in the air. The PEQS are based on the WHO air quality guidelines and are designed to protect human health and the environment.

Laws, Policies, Standard, and Guidelines	Description
Punjab Smog Policy	The Punjab Smog Policy was established in 2017 and aimed to address the intensifying smog crisis in the region. The policy includes a number of measures to reduce air pollution, such as the introduction of low-sulfur diesel, the promotion of public transportation, and the control of industrial emissions.
Pakistan Clean Air Plan (PCAP)	In June of 2021, Pakistan announced a revised Pakistan Clean Air Plan (PCAP) to perform national and local air pollution assessments. Implementation of this plan continued in 2022 via the development of a National Clean Air Plan, a joint effort with contributions from the Pakistan Ministry of the Environment and support from the Climate and Clean Air Coalition (CCAC), the Stockholm Environment Institute (SEI), and Clean Air Asia. This plan sets targets for air pollution concentrations, identifies air pollution mitigation strategies, and outlines a plan for coordinating action on air quality management. Development of the plan has also resulted in the country's first national air pollutant inventory, which includes the first-ever quantification of black carbon and other air pollutants at both the national and the provincial scale.
Punjab Environment Policy 2015	The Punjab Environment Policy 2015 is a detailed plan to address environmental issues in Punjab, Pakistan. The policy includes a number of measures to reduce air pollution, such as urging industries to contribute to the clean development mechanism (CDM),

Laws, Policies, Standard, and Guidelines	Description
	reducing emissions from transport, and reducing emissions from open burning of agricultural/municipal waste.

6 Gaps and Challenges in effective air pollution governance

In light of the inadequacies and limitations in the current legal and policy framework to address air pollution in Pakistan, the country faces persistent challenges with severe air quality issues. This highlights the pressing need for a revision of existing policies and standards to tackle the complexities of air pollution. The following gaps and challenges underscore the necessity for more robust and effective regulatory approaches:

6.1 Increasing Energy Demands

The country's air quality deterioration in the past two decades can be attributed to growing energy demands and a shift to more polluting fuels like coal and oil. Pakistan relies heavily on imported oil and coal, which raises concerns about energy security and environmental quality. The energy sector's substantial use of imported oil and coal and the lack of indigenous reserves for energy needs contribute to increased energy intensity. Inefficient energy use in various sectors, especially in transportation and power, exacerbates air pollution challenges, making effective management more complex (Anjum, 2021).

6.2 Lack of Political Will and Priority

The lack of consistent political instability, support and commitment to environmental and health issues in Pakistan remains a major obstacle. Ongoing political instability in the country has resulted in unsatisfactory enforcement of key environmental policies and standards. Many well-devised policy solutions remain largely ignored or poorly implemented, reflecting a lack of sustained political commitment to address air pollution issues. The failure to enforce policies like the Prohibition of Smoking and Protection of Non-Smokers Health Ordinance exemplifies this challenge (Anjum, 2021).

Despite the severity of air pollution and its impact on public health, air quality issues often fail to receive the necessary political attention and priority. This lack of political will hinders the implementation of effective air quality management strategies. Air pollution is often not considered a top priority

by government officials, who may prioritize economic growth over environmental protection (Anjum, 2021).

6.3 Ineffective Policies and Non-stringent Implementation

The effective implementation of existing air quality policies and regulations in Pakistan faces substantial challenges due to a lack of political will, resources, and capacity at the government level. Political inefficiencies and corruption further impede the enforcement of air quality control measures, with the Pakistan Environmental Protection Agency (EPA) frequently understaffed and underfunded, hindering its ability to fulfill its mandate (Anjum, 2021).

The absence of a proper feedback mechanism, coupled with inadequate institutional cooperation and insufficient information, significantly contributes to the failure of policy interventions in Pakistan. Illustrated by the Punjab Smog Policy of 2017, the policy's ambition to address the smog crisis fell short due to poor strategy, bureaucratic inertia, and interdepartmental politics. Factors such as the lack of robust air quality monitoring data, diverse pollution sources, and ineffective short-term measures implementation all played roles in the policy's ultimate failure. The proposed

privatization of vehicle fitness inspections and the involvement of reputable international companies also failed to materialize, further obstructing policy implementation.

In the absence of appropriate standards and policies, developing economies, especially in South Asia, are prone to extracting indigenous resources in unsustainable and polluting ways. The inadequacy of health, industrial, and monitoring policies in the region is particularly evident. While stringent air quality standards have been introduced in several countries, their effectiveness is undermined without proper enforcement mechanisms. The lack of a policy feedback mechanism at regulatory authorities, despite occasional revisions of Pak-NEQS (National Environment Quality Standards), exacerbates the issue. Regular air quality monitoring can play a crucial role in providing feedback. The unsatisfactory and ineffective nature of government policies related to air pollution and human health in Pakistan is largely attributed to insufficient government support and a lack of awareness among the public and legislative members. The emission standards for vehicles and industries in Pakistan are often outdated and less stringent compared to international standards. This allows for continued emissions of harmful pollutants into the air (Anjum, 2021).

6.4 Lack of Coordination Between Relevant Stakeholders

Addressing the challenge of air pollution control requires seamless coordination among various stakeholders, spanning government departments such as environmental protection agencies, transportation authorities, urban planning departments, and energy ministries. Beyond governmental entities, collaboration with academia, industries, communities, regulators, analysts, landowners, and local users of natural resources is essential. Unfortunately, a prevailing lack of effective coordination has led to fragmented and ineffective approaches in managing air quality in Pakistan. This coordination gap poses a significant hurdle, hindering the implementation of effective and impactful air pollution control measures. Bridging this divide and fostering collaboration among diverse stakeholders is imperative for achieving sustainable and meaningful improvements in air quality management (Anjum, 2021).

6.5 Lack of International Collaboration

The lack of international collaboration in addressing air pollution poses a critical challenge, particularly in developing countries like Pakistan, underlining the urgency of climate justice. While developed nations bear significant responsibility for global air pollution, they also share accountability for Pakistan's current situation. Securing immediate financial assistance, possibly through mechanisms like carbon credits, is imperative for Pakistan to undertake a just transition towards cleaner air. However, a primary stumbling block to international collaboration is the misconception that air pollution is solely a domestic concern, disregarding the principles of just transition. Though domestic policies, technological interventions, and high national emissions in Pakistan contribute, it remains an international issue intertwined with global climate justice. Despite Pakistan's less than 1% contribution to global emissions, its populace bears substantial impacts, emphasizing the necessity for collective efforts to address cross-border air pollution challenges and uphold climate justice principles (Anjum, 2021).

Governments often prioritize internal challenges, overlooking the transboundary nature of air pollution where emissions from one country significantly affect air quality in another. Economic

and political complexities further hinder international collaboration, as developed nations may be hesitant to commit to agreements that impose additional costs or restrictions on their industries. Political considerations, such as ongoing trade negotiations and diplomatic relations, can influence a country's willingness to engage in international environmental cooperation. Thus, insufficient funding limits the implementation of effective

mitigation, constraining environmental agencies and worsening the global struggle against air pollution (Anjum, 2021).

7 Recommendations and Way Forward

7.1 Policy Framework and Implementation

- Strengthen policy frameworks and government actions for effective air pollution control.
- Develop and enforce strong policies to regulate and reduce the use of highly polluting plastic and coal-based fuels.
- Implement policies that advocate the use of better technological standards in the transportation and industrial sectors, including the use of catalytic converters, scrubbers, and cleaner fuels.
- Implement a car changing policy mandating the replacement of vehicles after a certain period to curb emissions and promote cleaner transport alternatives.
- Revise national and provincial air quality standards, expanding the number of outdoor and industrial pollutants while developing indoor air quality standards.
- Establish a policy feedback mechanism to ensure effective implementation and identify areas for improvement.
- Strengthen enforcement mechanisms by allocating more resources to the Environmental Protection Agency (EPA) and other environmental protection agencies.
- Implement regular penalties for non-compliance with environmental laws and regulations.
- Emphasize the importance of equitable distribution of carbon credits and other environmental incentives to support sustainable initiatives in developing countries.
- Advocate for the inclusion of climate justice policies in international agreements, ensuring that developed nations bear a fair share of the responsibility for mitigating air pollution's global effects.
- Foster collaboration amongst a spectrum of stakeholders to unite disparate entities towards a shared goal of environmental sustainability and improved public health.

- Prioritize a phased transition towards cleaner and more renewable energy sources, emphasizing the development and utilization of indigenous resources by implementing incentives for the renewable energy sector, such as tax breaks and subsidies.

7.2 Public Awareness and Stakeholder Involvement

- Promote active anti-smog awareness campaigns to educate the public about the sources, types and health risks of air pollution through different mediums of communication.
- Promote appropriate public discourse and disclosure schemes, requiring industries to report emissions and policymakers to accept feedback during the policy process.
- Enhance institutional cooperation between different government agencies involved in air quality management.
- Provide more information and support to the public and legislative members about air pollution issues.

7.3 Transportation and Industrial Sector

- Advocate for public transportation, discourage/potentially ban poorly maintained and polluting vehicles.
- Implement policies to reduce and promote efficient fuel use in industry and power generation.
- Strengthen controls on non-industrial pollution sources, including burning waste and vehicular emissions.
- Enforce policies incentivizing industries to adopt cleaner technologies, like scrubbers and zig-zag technology in brick kilns.

The presented scenarios indicate substantial reductions in PM2.5 emissions by two-thirds in 2030, demonstrating the potential impact of well-designed policy portfolios. To bridge the implementation gap, legislation and legal parameters pertaining to air quality must be effectively enforced, accompanied by institutional capacity building. Sector-specific policies, incorporating targeted rules and regulations, are essential for effective air pollution mitigation. Regular monitoring of ambient air pollution and its associated health impacts is crucial to offset future environmental costs. Overall, systematic implementation is required to achieve significant health and environmental improvements without compromising economic development.

8 Conclusion

In conclusion, this review provides insights into the complex landscape of air pollution governance in Pakistan, highlighting the various challenges and consequences associated with this critical issue. The analysis emphasizes the immediate need for robust policies and their effective implementation to tackle the intricate dynamics contributing to poor air quality. Noteworthy hurdles such as political will, insufficient regulatory enforcement, and global collaboration gaps impede progress in mitigating the impact of air pollution. Recognizing the responsibility of developed nations in supporting efforts of developing countries, like Pakistan, to combat air pollution emerges as a vital aspect. The study advocates for collaborative efforts, underscoring the significance of targeted interventions in key sectors. Moving ahead, addressing the identified gaps and challenges demands a collective commitment to instigate change at local, national, and international levels. Acknowledging the shared responsibility in tackling air pollution, concrete actions must be taken to ensure a healthier and sustainable future for everyone.

9 References

1. Abdurrahman, M.I., Chaki, S. and Saini, G., 2020. Stubble burning: Effects on health & environment, regulations and management practices. *Environmental Advances*, *2*, p.100011.

2. Ali, M., Siddique, I. and Abbas, S., 2022. Characterizing Air Pollution and Its Association with Emission Sources in Lahore: A Guide to Adaptation Action Plans to Control Pollution and Smog. *Applied Sciences*, *12*(10), p.5102.

3. Ali, Y., Razi, M., De Felice, F., Sabir, M. and Petrillo, A., 2019. A VIKOR based approach for assessing the social, environmental and economic effects of “smog” on human health. *Science of the Total Environment*, *650*, pp.2897-2905.

4. Anjum, M.S., Ali, S.M., Subhani, M.A., Anwar, M.N., Nizami, A.S., Ashraf, U. and Khokhar, M.F., 2021. An emerged challenge of air pollution and ever-increasing particulate matter in Pakistan; a critical review. *Journal of Hazardous Materials*, *402*, p.123943.

5. Ashraf, M.F., Ahmad, R.U. and Tareen, H.K., 2022. Worsening situation of smog in Pakistan: A tale of three cities. *Annals of Medicine and Surgery*, *79*, p.103947.

6. Asif, A., Zeeshan, M. and Jahanzaib, M., 2018. Indoor temperature, relative humidity and CO2 levels assessment in academic buildings with

different heating, ventilation and air-conditioning systems. *Building and Environment*, *133*, pp.83-90.

7. Bilal, M., Mhawish, A., Nichol, J.E., Qiu, Z., Nazeer, M., Ali, M.A., de Leeuw, G., Levy, R.C., Wang, Y., Chen, Y. and Wang, L., 2021. Air pollution scenario over Pakistan: Characterization and ranking of extremely polluted cities using long-term concentrations of aerosols and trace gases. *Remote Sensing of Environment*, *264*, p.112617.

8. Bloemsma, L.D., Wijga, A.H., Klompmaker, J.O., Janssen, N.A., Smit, H.A., Koppelman, G.H., Brunekreef, B., Lebret, E., Hoek, G. and Gehring, U., 2019. The associations of air pollution, traffic noise and green space with overweight throughout childhood: The PIAMA birth cohort study. *Environmental research*, *169*, pp.348-356.

9. Butt, M.U., Waseef, R.F. and Ahmed, H., 2018. Perception about the factors associated with smog among medical students. *Biomedica*, *34*(4), p.264.

10. De Bont, J., Casas, M., Barrera-Gómez, J., Cirach, M., Rivas, I., Valvi, D., Álvarez, M., Dadvand, P., Sunyer, J. and Vrijheid, M., 2019. Ambient air pollution and overweight and obesity in school-aged children in Barcelona, Spain. *Environment international*, *125*, pp.58-64.

11. ESP Economic Survey of Pakistan 2018-2019. (2019. Retrieved from: http://finance.gov.pk/survey/chapters_19/Economic_Survey_2018_19.pdf.

12. Farrow, A., Miller, K.A. and Myllyvirta, L., 2020. Toxic air: the price of fossil fuels.

13. Farrow, A., Miller, K.A. and Myllyvirta, L., 2020. Toxic air: the price of fossil fuels.

14. Furlong, M.A. and Klimentidis, Y.C., 2020. Associations of air pollution with obesity and body fat percentage, and modification by polygenic risk score for BMI in the UK Biobank. *Environmental research*, *185*, p.109364.

15. Government of Pakistan, 2019. Pakistan Economic Survey 2018–19.

16. Government of Pakistan, Ministry of Communications. Traffic Study Report Peshawar to Torkham Section. Available online: http://nha.gov.pk/uploads/topics/16244486166661.pdf

17. Habib, A., Nasim, S. and Shahab, A., 2021. Charting Pakistan's air quality policy landscape. *International Growth Centre: London, UK*.

18. HEI: Health Effects Institute, 2019. State of Global Air 2019. A special report on global exposure to air Pollution and its Disease Burden. Health

Effects Institute. Available at: https://www.stateofglobalair.org/sites/default/files/soga_2019_report.pdf

19. Institute of Health Metrics and Evaluation, 2019. State of global air 2019. Special report. Health Effects Institute Boston, MA. Available at: https://www.stateofglobalair.org/sites/default/files/soga_2019_report.pdf

20. IQAir, 2019. WORLD AIR QUALITY REPORT 2019. Retrieved from: http://www.iqair.com/world-most-polluted-cities/world-air-quality-report-2019-en.pdf

21. IQAir, 2022. World Air Quality Report 2022. Retrieved from: https://www.iqair.com/world-most-polluted-cities

22. *IQAir, First in Air Quality*, 2022. Available at: https://www.iqair.com/newsroom/what-is-aqi (Accessed: 19 November 2023).

23. Jahanzaib, M., Sharma, S., Bakht, A., Heo, J. and Park, D., 2023. Analyzing the effectiveness of air curtain in reducing particulate matter generated by human-induced slipstream. *Process Safety and Environmental Protection*, *170*, pp.834-841.

24. Kermani, M., Jonidi Jafari, A., Gholami, M., Taghizadeh, F., Masroor, K., Abdolahnejad, A., Shahsavani, A. and Fanaei, F., 2023. Characterisation of PM2. 5–bound PAHs in outdoor air of Karaj megacity: the effect of meteorological factors. *International Journal of Environmental Analytical Chemistry*, *103*(14), pp.3290-3308.

25. Khan, M.W., Ali, Y., De Felice, F., Salman, A. and Petrillo, A., 2019. Impact of brick kilns industry on environment and human health in Pakistan. *Science of the Total Environment*, *678*, pp.383-389.

26. Kim, K.H., Kabir, E. and Kabir, S., 2015. A review on the human health impact of airborne particulate matter. *Environment international*, *74*, pp.136-143.

27. Lahore US Embassy Air Pollution: Real-Time Air Quality Index (AQI). 2021. Available online: https://aqicn.org/city/pakistan/lahore/us-embassy/

28. Matus, K., Nam, K.M., Selin, N.E., Lamsal, L.N., Reilly, J.M. and Paltsev, S., 2012. Health damages from air pollution in China. *Global environmental change*, *22*(1), pp.55-66.

29. Niaz, Y., Zhou, J., Nasir, A., Iqbal, M. and Dong, B., 2016. COMPARITIVE STUDY OF PARTICULATE MATTER (PM 10 AND PM 2.5)

IN DALIAN-CHINA AND FAISALABAD-PAKISTAN. *Pakistan Journal of Agricultural Sciences*, *53*(1).

30. Omer, A., 2018. LahoreSmog, Just How Bad Is it?

31. Pant, P., Lal, R.M., Guttikunda, S.K., Russell, A.G., Nagpure, A.S., Ramaswami, A. and Peltier, R.E., 2019. Monitoring particulate matter in India: recent trends and future outlook. *Air Quality, Atmosphere & Health*, *12*, pp.45-58.

32. PAQI. Lahore Smog, Just How Bad Is It? Pakistan Air Quality Initiative. 2018. Available online: https://www.iqair.com/profile/pakistan-air-quality-initiative

33. Perera, F., 2018. Pollution from fossil-fuel combustion is the leading environmental threat to global pediatric health and equity: Solutions exist. *International journal of environmental research and public health*, *15*(1), p.16.

34. Raaschou-Nielsen, O., Beelen, R., Wang, M., Hoek, G., Andersen, Z.J., Hoffmann, B., Stafoggia, M., Samoli, E., Weinmayr, G., Dimakopoulou, K. and Nieuwenhuijsen, M., 2016. Particulate matter air pollution components and risk for lung cancer. *Environment international*, *87*, pp.66-73.

35. Rasheed, A., Aneja, V.P., Aiyyer, A. and Rafique, U., 2015. Measurement and analysis of fine particulate matter (PM2. 5) in urban areas of Pakistan. Aerosol Air Qual. Res. 15, 426–439.

36. Rentschler, J. and Leonova, N., 2023. Global air pollution exposure and poverty. *Nature Communications*, *14*(1), p.4432.

37. Riaz, K., Ahmad, M., Gul, S., Malik, M.H.B.A. and Rehman, M.E.U., 2022. Climate change and its implications on health and the healthcare system: A perspective from Pakistan. *Annals of Medicine and Surgery*, *81*.

38. Shahid, A., Ansub, M., Hafeez, A., Saleem, H. and Basharat, A., 2020. Socio-Economic Impacts of Transit Projects (A Case Study of Orange Line Lahore). *Saudi J. Civ. Eng*, *4*, pp.161-169.

39. Shahid, M.Z., Liao, H., Li, J., Shahid, I., Lodhi, A. and Mansha, M., 2015. Seasonal variations of aerosols in Pakistan: Contributions of domestic anthropogenic emissions and transboundary transport. *Aerosol Air Qual. Res*, *15*(1), pp.1580-1600.

40. Sharma, S., Bakht, A., Jahanzaib, M., Lee, H. and Park, D., 2022. Evaluation of the effectiveness of common indoor plants in improving the indoor air quality of studio apartments. *Atmosphere*, *13*(11), p.1863.

41. Wang, Z., Zhao, L., Huang, Q., Hong, A., Yu, C., Xiao, Q., Zou, B., Ji, S., Zhang, L., Zou, K. and Ning, Y., 2021. Traffic-related environmental factors and childhood obesity: a systematic review and meta-analysis. *Obesity reviews*, *22*, p.e12995.

42. WHO, 2018. Ambient (outdoor) air pollution. Available at: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

43. World Bank, 2016. Air Pollution Deaths Cost Global Economy US$225 Billion (Press Release). Retrieved from: https://www.worldbank.org/en/news/press-release/2016/09/08/air-pollution-deaths-cost-global-economy-225-billion

44. World Health Organization. Air Pollution. World Health Organization. Retrieved from: https://www.who.int/health-topics/air-pollution#tab=tab_1

45. Yan, H., Ding, G., Li, H., Wang, Y., Zhang, L., Shen, Q. and Feng, K., 2019. Field evaluation of the dust impacts from construction sites on surrounding areas: a city case study in China. *Sustainability*, *11*(7), p.1906.