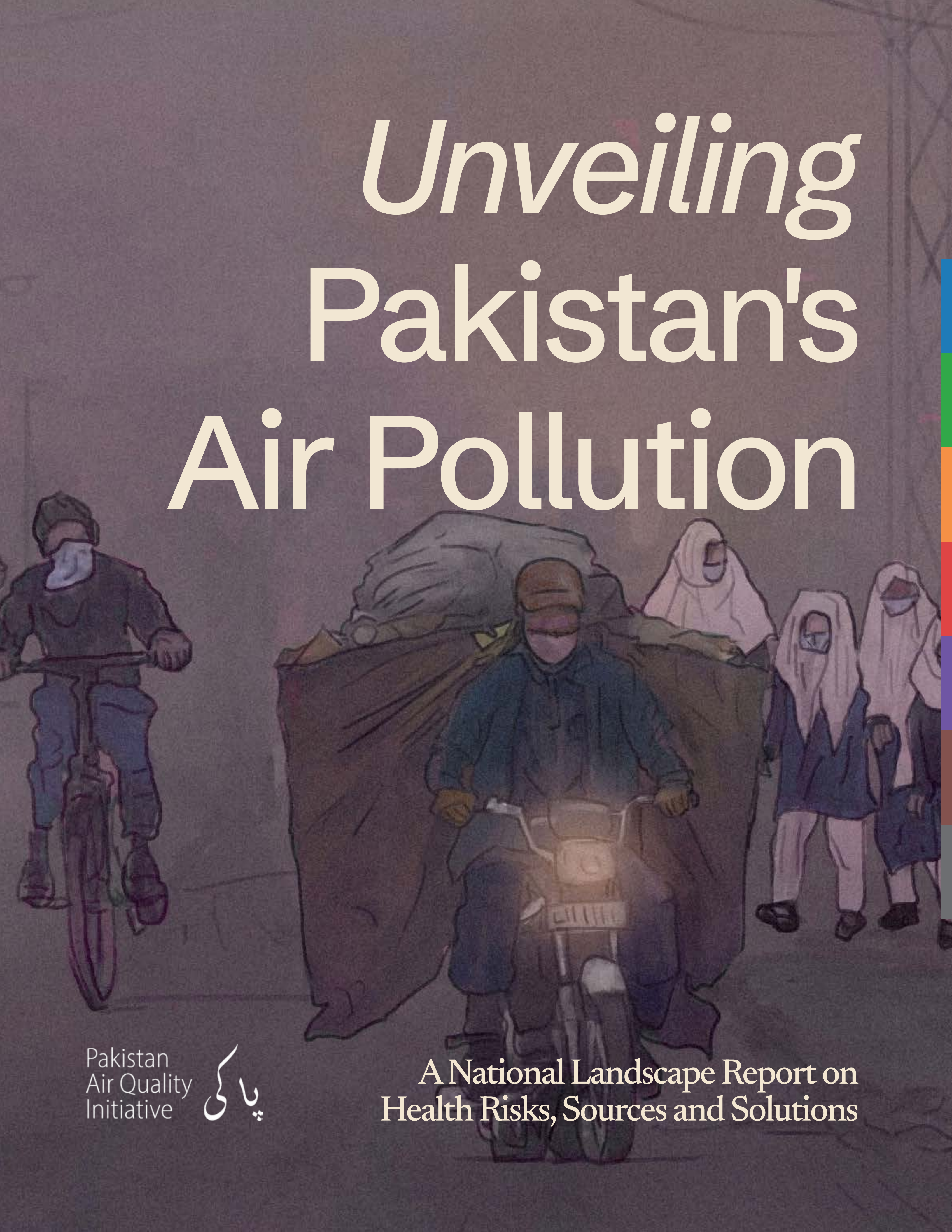


Unveiling Pakistan's Air Pollution

A National Landscape Report on Health Risks, Sources and Solutions

Pakistan Air Quality Initiative پاکی

Watercolor artist Fasih Ud Din Toor invokes the aesthetic of Kashi Kari, the intricate, fading glazed tilework of the Mughal era, to frame Hawanama (The Story of Air) in Urdu calligraphy. Just as Toor's art is a loving restoration of Lahore's eroding heritage, this report seeks to tell that story, situating the right to breathe as a timeless and sacred trust.

Unveiling Pakistan's Air Pollution: A National Landscape Report on Health Risks, Sources and Solutions

Editor: **Abid Omar**

Design and Layout: **Halima Sadia**

Contributors: **Kulsum Ahmed, Ahmad Rafay Alam, Sunil Dahiya, Gemma Dipoppa, Saad Gulzar, Sara Hayat, Haneea Isaad, Imran Saqib Khalid, Manoj Kumar, Rimmel Mohydin, Sanval Nasim, Pallavi Pant, Muhammad Huzaifa Qasmi, Chengcheng Qiu, Sherry Rehman, Saima Saeed, Syed Mansoor Ali Shah, Abid Qaiyum Suleri, Khizr Imran Tajammul**

ISBN 978-627-7928-03-2 (print)
ISBN 978-627-7928-02-5 (electronic)
DOI 10.5281/zenodo.17629179

Suggested Citation: Omar, A. (Ed.). (2025). Unveiling Pakistan's Air Pollution: A National Landscape Report on Health Risks, Sources and Solutions. Pakistan Air Quality Initiative.

The Pakistan Air Quality Initiative (PAQI) is an independent research and advocacy organisation dedicated towards a breathable and healthy Pakistan, with robust scientific insights and data-driven solutions to overcome the air pollution crisis. Our vision is a future where every Pakistani breathes clean air, supported by informed policies and an engaged society.

Email: hello@pakairquality.com

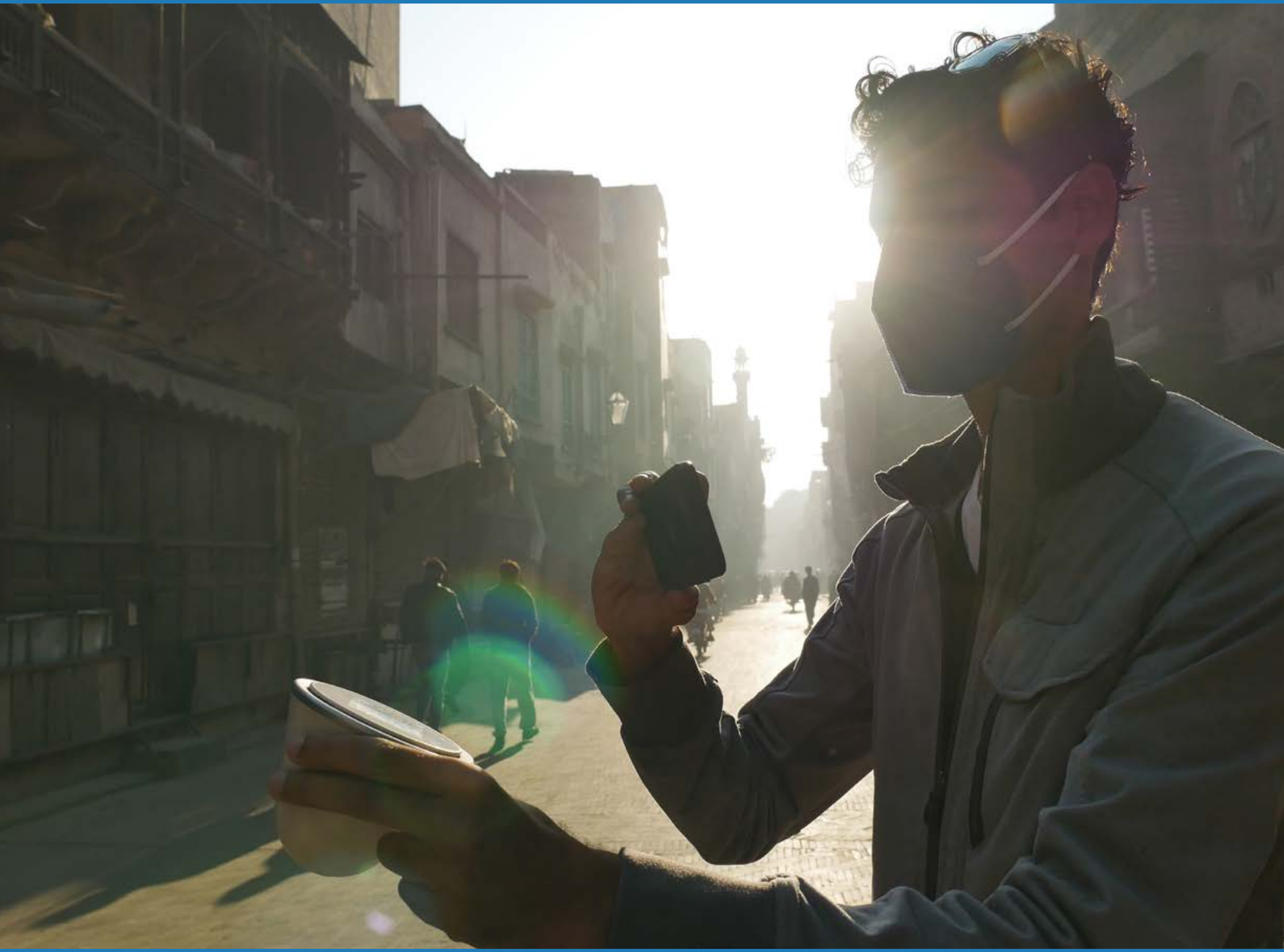
Published with the support of:

Unveiling Pakistan's Air Pollution

A National Landscape Report on Health Risks, Sources and Solutions

Pakistan
Air Quality
Initiative
پاکی

Acknowledgments



In February 2015, Abid Omar explored Lahore's Walled City with a handheld monitor, seeking to determine if the city's winter haze was fog or toxic smog. This act of curiosity laid the foundation for the Pakistan Air Quality Initiative in 2016, igniting a community-driven movement to build a nationwide air quality monitoring network.

This report was prepared by the Pakistan Air Quality Initiative (PAQI). The team members include Abid Omar, Dawar H. Butt, Mahad Naveed, Mariam Shah, Adeel Mirza and Rehan Ahmed. The foundational emissions modelling and analysis was led by Dawar H. Butt with Mahad Naveed, supported by Raza Ashfaq and Tanzeel Ur Rehman. The report was edited by Abid Omar.

The team greatly benefitted from insightful comments and guidance from peer reviewers from the Pakistan Air Quality Experts Group (PAQx), including Dr. Nazish Afraz, Zulfiqar Ahmad, Dr. Rabia Akhtar, Ahmad Rafay Alam, Dr. Nausheen H. Anwar, Sohaib Anwar, Dr. Zaeem Babar, Dawar H. Butt, Dr. Ahmad Ali Gul, Dr. Saad Gulzar, Abdul Waris Hameed, Sara Hayat, Dr. Mahwish Hayee, Maha Hussain, Dr. Imran Khalid, Dr. Aazir Khan, Dr. Kaleem Anwar Mir, Dr. Zulfiqar Mir, Dr. Sanval Nasim, Abid Omar, Dr. Rabia Qaiser, Muhammad Huzaifa Qasmi, Shazia Rafi, Dr. Muhammad Rafiq, Raja Rehan, Dr. Saima Saeed, Dr. Hassan Aftab Sheikh, Momin Imran Sheikh, Khizr Imran Tajammul, Dr. Misha Tanveer, and Dr. Adil Zareef. Their expertise and rigorous feedback were invaluable in strengthening this analysis.

PAQI gratefully acknowledges the generous financial support from Open Philanthropy. Their commitment to this issue was instrumental in making this comprehensive national assessment possible.

Artworks, Illustrations & Photography

PAQI extends its sincere gratitude to all the talented individuals whose visual contributions have given this report its unique power and voice. This report features the work of Maria Adil, Hazem Asif, Dryden Goodwin, Sehar Salman Haider, Itrat Jabeen, Maaz Jan, Maheen Azam Khan and Abdullah Khalid, Rohama Malik, Shehzil Malik, Sotirios Papathanasiou, Maryam Rahman, Fatima Shah, and Fasih Ud Din Toor.

PAQI would also like to give a special mention and thanks to Itrat Jabeen for the front cover artwork.

The infographic in Chapter 8 is adapted from the work of Adolfo Arranz for the *South China Morning Post.* Photographs were contributed by Abid Omar, Mahera Omar and the Pakistan Air Quality Initiative.

Table of Contents

Section One

Scale, Science, and Human Impact

Section Two

Addressing Key Pollution Sources

Section Three

Governance, Policy, and Public Engagement

Acronyms & Abbreviations

AQI	Air Quality Index
AQLI	Air Quality Life Index
AQM	Air Quality Management
BAM	Beta Attenuation Monitor
Balochistan EPA	Balochistan Environmental Protection Agency
BRT	Bus Rapid Transit
CEMS	Continuous Emissions Monitoring Systems
CFI	Commercial Financial Institutions
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
DFI	Development Financial Institutions
DHS	Demographic and Health Survey
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency (Federal)
EPC	Environment Protection Council
EPD	Environmental Protection and Climate Change Department (Punjab)
ESP	Electrostatic Precipitator
EV	Electric Vehicle
FAO	Food and Agriculture Organization
FCBTK	Fixed Chimney Bull's Trench Kiln
FEM	Federal Equivalent Method
FRM	Federal Reference Method
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographic Information System

GRAP	Graded Response Action Plan
HAS-CAPEs	Health Advisory System for Critical Air Pollution Events
HEPA	High-Efficiency Particulate Air
ICT	Islamabad Capital Territory
IGCEP	Integrated Generation Capacity Expansion Plan
IPP	Independent Power Plant
JICA	Japanese International Cooperation Agency
KPK EPA	Khyber Pakhtunkhwa Environmental Protection Agency
LEEP	Lead Exposure Elimination Project
LEZ	Low Emission Zone
LHC	Lahore High Court
LMIC	Low- and Middle-Income Country
LPG	Liquefied Petroleum Gas
LSEV	Low-Speed Electric Vehicle
MAF	Mitigation Action Facility
NCAP	National Clean Air Policy
NDC	Nationally Determined Contributions
NEPRA	National Electric Power Regulatory Authority
NEQS	National Environmental Quality Standards
NOx	Nitrogen Oxides
NO2	Nitrogen Dioxide
NTDC	National Transmission and Despatch Company
O3	Ozone
PAH	Polycyclic Aromatic Hydrocarbons
PAQI	Pakistan Air Quality Initiative
PbCAP	Punjab Clean Air Policy
PCAP	Pakistan Clean Air Programme
PCB	Polychlorinated Biphenyls

PEPA	Pakistan Environmental Protection Act
PEPO	Pakistan Environmental Protection Ordinance
PEQS	Punjab Environmental Quality Standards
PLAC	Partial Load Adjustment Charges
PM	Particulate Matter
PM2.5	Particulate Matter 2.5 micrometres or smaller
PM10	Particulate Matter 10 micrometres or smaller
RCT	Randomised Controlled Trial
RLNG	Regasified Liquefied Natural Gas
SEPA	Sindh Environmental Protection Agency
SEQS	Sindh Environmental Quality Standards
SLCP	Short-Lived Climate Pollutants
SOE	State-Owned Entities
SOx	Sulfur Oxides
SO2	Sulfur Dioxide
TCO	Total Cost of Ownership
TEOM	Tapered Element Oscillating Microbalance
ULEZ	Ultra Low Emission Zone
US-EPA	United States Environmental Protection Agency
UV	Ultraviolet
VOC	Volatile Organic Compounds
WHO	World Health Organization
WRI	World Resources Institute

Looking out from the historic Delhi Gate, a motorcyclist rides into a suffocating gray haze.
Photo by Maheen Azam Khan and Abdullah Khalid


Walled City of Lahore Authority

Foreword

For three decades, the Supreme Court of Pakistan has recognised the right to a clean and healthy environment as a **fundamental right** to life under Article 9 of the Constitution of the Islamic Republic of Pakistan, 1973. This judicial recognition began in 1994 with the landmark Shehla Zia case,[1] which was to become a cause célèbre for future generations. This legal principle is more critical than ever, as Pakistan now confronts one of the greatest environmental threats to human health: air pollution causes an estimated one in every nine deaths worldwide.[2] The threat is particularly acute in South Asia,[3] home to the four most polluted countries in the world and 22.9% of the global population.

[1] Shehla Zia v. WAPDA, PLD 1994 SC 693.

[2] Greenstone, M., & Hasenkopf, C. (2023). Annual update. Air Quality Life Index.

[3] Bangladesh, India, Nepal and Pakistan

Constitutional Courts in Pakistan have played a significant role in combating environmental crises and climate change. Three decades after Shehla Zia, the same Court in the Amer Ishaq case[4] coined the term ‘environmental constitutionalism’ to embody the fusion of fundamental rights and the environment. This principle establishes the environment as a proper subject for protection in constitutional texts, to be vindicated by constitutional courts worldwide. The Court also noted that this concept has its ideological roots within Islamic environmentalism. It is this triple-planetary crisis; climate change, biodiversity loss, and widespread pollution; that calls for entrenching environmental concerns as supreme constitutional norms.[5]

In the past three decades, the Courts realised that they required skills in environmental science, technology, health, natural science and economics to adjudicate upon environmental issues. This led to the idea of Commissions—a mere fact-finding body and its evolution to a broad-based forum comprising technical experts, government, academia and members of the civil society to propose sustainable solutions to environmental issues. What the commissions do, the courts cannot. The constitution of a Clean Air Commission in 2003 by the Lahore High Court in the Lahore Air Pollution case was not only a significant step towards actualising the issue of air pollution in Lahore but it also paved the way for the constitution of more commissions to address issues of environmental and climate justice.

Moving forward, it is time to humanise the environment and give it a voice of its own.

‘Unveiling Pakistan’s Air Pollution: A National Landscape Report on Health Risks, Sources and Solutions’ provides a comprehensive framework for addressing the issues of air pollution that Pakistan faces and will face in the future due to climate change. It should serve as a ‘living document’ to address emerging concepts and issues in the ever-evolving science of climate change.

Justice Syed Mansoor Ali Shah
Senior Puisne Judge, Supreme Court of Pakistan

[4] Amer Ishaq v. Province of Khyber Pakhtunkhwa (Constitutional Petition No. 04/2021).

[5] Bookman, S. (n.d.). Demystifying environmental constitutionalism. Environmental Law Review, Lewis & Clark Law School, 54(1).

About

Pakistan Air Quality Initiative

The Pakistan Air Quality Initiative (PAQI) is an independent research and advocacy organisation committed to addressing the complex and pressing challenge of air pollution in Pakistan. Founded in 2016 by Abid Omar, PAQI was born out of a citizen-led concern for the deteriorating air quality in Pakistan's urban centres and the lack of accessible, reliable data and informed public discourse on this critical issue. In a nation where air pollution is recognised as a public health emergency with profound impacts on life expectancy and well-being, PAQI is dedicated to scientific understanding and promoting effective, evidence-based solutions to Pakistan's air pollution problem.

Pakistan Air Quality Initiative

PAQI's mission is to provide data-driven scientific research and advocacy for clean air in Pakistan, promoting data accessibility and transparency, and driving informed public engagement and effective policy development.

Our approach is built on three pillars:

Scientific research: We conduct robust scientific inquiry, to provide the evidence for effective and targeted air quality management strategies. Our research includes developing comprehensive multi-sectoral emissions inventories, analysing atmospheric chemistry, and creating foundational air quality datasets and analyses for Pakistan.

Air quality monitoring and data: We support the expansion of the national air quality monitoring infrastructure, from community-driven air quality sensor networks to robust national regulatory systems. We provide free and open access to real-time air quality data to empower citizens, researchers, and policymakers.

Policy development and advocacy: We translate scientific findings into tangible action by raising public awareness of the health and economic impacts of air pollution, providing technical advice to governmental bodies, contributing to national policy dialogues that inform strategies like the National Clean Air Policy, and working to ensure such policies are supported by robust evidence.

The challenge posed by air pollution in Pakistan is solvable through evidence-based solutions. Through science, data, and advocacy, a future with cleaner, healthier air for all Pakistanis is achievable.

Executive Summary

Pakistan is in the grip of a **public health emergency**. Toxic air pollution reduces the life expectancy of the average Pakistani by 3.9 years. In Lahore, the crisis epicentre, residents lose an average of 7 years of life to the air they breathe. For decades, a lack of credible, localised data has enabled a cycle of policy inaction, allowing this invisible killer to compromise the health of an entire generation and undermine the nation's economic vitality. This report, '*Unveiling Pakistan's Air Pollution: A National Landscape Report on Health Risks, Sources and Solutions*,' ends the era of speculation. It provides the first comprehensive, multi- sectoral emissions inventories for Pakistan's major urban airsheds, moving beyond debate to deliver a definitive, data-driven diagnosis of the crisis and a clear blueprint for action.

Lahore is a complex, three-front battle against a toxic blend of emissions from transportation (35%), heavy industry (28%), and a dense ring of brick kilns (17%).

Karachi's crisis is overwhelmingly industrial. Nearly half of its health-damaging fine particulate matter (49% of PM2.5) originates from its industrial sector and port activities.

The Islamabad-Rawalpindi airshed, with minimal heavy industry, is a stark case study of a crisis driven by urban design, with transportation (53%) as the dominant polluter.

Peshawar, trapped in a valley, is poisoned by a mix of transit trade and traditional industry, resulting in the country's highest per-capita pollution burden.

This environmental failure is underpinned by a systemic governance failure. Pakistan's national and provincial air quality standards are weaker than the World Health Organization guidelines, creating a false sense of security while leaving the public exposed to hazardous pollution on a near-daily basis. For over 20 years, the country has been caught in a vicious cycle: judicial activism forces the creation of commissions, which produce scientifically sound recommendations that are adopted into policies, which are then never fully implemented due to a lack of political will, institutional capacity, and enforcement. This has resulted in token, unscientific actions like road-washing and smog cannons, while the primary sources of pollution—identified repeatedly in policies for two decades—continue to operate with impunity.

The path to clean air is known, achievable, and offers immense public health and economic co-benefits. This report details the evidence-based interventions required. The highest-priority actions are:

Target the super-emitters: A transition to cleaner fuels (Euro-V standards), modernisation of the vehicle fleet with a focus on electrifying the 30 million two- and three-wheelers that form the backbone of urban mobility, mandatory pollution controls for industry, and a complete technological transition for the brick kiln sector will address the largest sources of pollution.

Close the governance gap: The government must align Pakistan's environmental quality standards with global health guidelines, build and maintain a robust, transparent national air quality monitoring network to inform policy and the public, and establish empowered, coordinated institutions to enforce the law without exception.

Empower the public with information: Providing citizens with reliable, real-time air quality data is a potent and cost-effective public health tool that drives protective behaviours. This must be coupled with a national effort to accelerate the transition to clean cooking solutions, which addresses a major source of indoor air pollution that disproportionately harms the health of millions of women and children.

The evidence presented in this report is a call to action. Clean air is not a luxury or a long-term aspiration; it is a fundamental human right and a precondition for a healthy, prosperous, and sustainable Pakistan. The solutions are at hand. The barrier is no longer a lack of evidence, but a lack of will. **It is time to act.**

Critical Review

Air as the Commons

by Abid Qaiyum Suleri

Clean air is the invisible infrastructure that sustains life itself. In Pakistan, this foundation is steadily eroding. Each winter, the country's plains disappear beneath a blanket of smog, turning the simple act of breathing into a daily health risk. Across much of the lowland belt, the sun fades into a yellow disc, schoolchildren walk to class in masks, and labourers inhale the fumes of our economic choices. The Energy Policy Institute at the University of Chicago estimates that polluted air robs the average Pakistani of nearly four years of life, and a Lahori of seven. This is not just an environmental concern; it is a development failure and a silent public-health emergency.

Air pollution sits at the nexus of Pakistan's three grand challenges for sustainable development: environmental degradation, economic fragility, and social inequity. It corrodes ecosystems, slashes productivity, and widens inequality. But before delving into the extent of these challenges and sharing my thoughts on what may be done about them, let me take this opportunity to congratulate Abid Omar, his team at the Pakistan Air Quality Initiative, and all the contributing authors of the volume in hand for producing such a comprehensive compilation on Pakistan's air quality landscape.

The chapters in this book are akin to a diagnostic report of the air we breathe. But unlike a typical lab report, they do not stop at identifying symptoms; they trace the underlying causes of our deteriorating air-health system and suggest ways to heal it. Whether one accepts a diagnosis or not does not change the reality of the disease. One may seek a second opinion, but when every credible laboratory confirms the same findings, denial ceases to be an option. That is what gives this volume its strength. It brings together experts from diverse disciplines, yet all converge on a single conclusion: Pakistan's air is in distress, and the treatment can no longer be deferred.[1]

The book estimates that the economic cost of pollution exceeds 6.5% of Pakistan's GDP each year, a burden borne disproportionately by those least responsible for causing it. In effect, Pakistan's poor are subsidising the pollution of the privileged.

For too long, we have pursued growth as if clean air were expendable collateral. The country's development model has treated environmental damage as an externality rather than a constraint. Dirty kilns, low-grade fuels, unregulated factories, and outdated transport fleets have powered short-term GDP gains at the expense of human longevity. The result is an invisible, regressive tax—paid not in rupees but in reduced life expectancy.

The book also marks a critical departure from conjecture to evidence. Building on work presented in Chapters 1-3 and 6, it provides Pakistan's first city-level emissions inventories and quantifies how transport, industry, kilns, and agriculture interact to poison the air. But evidence alone cannot substitute for governance. Pakistan has a long tradition of diagnosing problems with precision and implementing solutions with hesitation.

The data exposes a stark heterogeneity. Lahore's smog stems mainly from transport (35%), heavy industry (28%), and kilns (17%); Karachi's air is dominated by maritime and industrial emissions; Islamabad-Rawalpindi suffers from congestion and dust; and Peshawar endures atmospheric trapping worsened by two-stroke engines. Yet, as I have argued repeatedly, national responses still rely on uniform bans and seasonal theatrics. Washing roads, firing water cannons, or declaring ad-hoc "smog holidays" may create headlines, but they betray a policymaking culture addicted to optics.

In my opinion, **any policy to be successful requires at least five prerequisites.** The first is **adequate financial resources and budgetary allocations** to translate intent into implementation. The second is **institutional arrangement and clear ownership** so that it does not end up becoming "everyone's responsibility and no one's accountability."

[1] This introduction draws on empirical findings from the book in hand, especially Chapters 1-3, 6, 13, 14, and 17. Interpretive analysis and critique represent the author's independent assessment, informed by participation in national climate and economic advisory forums.

The third is the **availability of trained human resources and technological support**—without skilled professionals, credible data, and modern tools, even the best policies remain aspirational. The fourth is **continuity of purpose across political cycles** so that long-term reforms are insulated from short-term political turnover. The fifth, and perhaps most decisive, is **public ownership**. Unless citizens internalise the need for cleaner air and change daily behaviours accordingly, environmental reform will remain a government plan rather than a societal mission.

One can see some of these prerequisites being met in Punjab recently, which shows a glimmer of change. The Punjab Clean Air Policy (2023), real-time monitoring through the Smog War Room, conversion of brick kilns to zig-zag technology, and the introduction of electric buses and e-motorcycles mark a shift from denial to design. Waste-management pilots under Suthra Punjab further extend this effort. But progress remains fragile. Enforcement is inconsistent, funding remains donor-driven, coordination episodic, and public participation limited.

At the national level, the Nationally Determined Contribution (NDC 3.0) of September 2025 sets ambitious climate targets, aiming to reduce projected greenhouse-gas emissions by 50% by 2035 through increased energy efficiency and the adoption of clean transport. Because of the scope of NDCs, the recent version is almost silent on particulate matter, black carbon, or short-lived climate pollutants. It aims to cut carbon without curbing toxicity. One can argue that NDCs of most developing countries seek decarbonisation without detoxification. A climate strategy that fails to clean the air citizens breathe is an incomplete contract with the public.

Beyond the NDC, Pakistan is awash with frameworks: the National Climate Change Policy (2021), the National Adaptation Plan (2023), the National EV Policy (2019), and the Energy Efficiency and Conservation Policy (2023). The draft Green Taxonomy and the IMF's Resilience and Sustainability Facility (2025) add new layers of ambition. However, these instruments overlap more than they align. Their mandates compete; their enforcement capacity is thin. Pakistan does not lack policies—it lacks coherence, capacity, and continuity.

The book's Chapter 2 situates air pollution within the broader "triple planetary crisis" of climate change, pollution, and biodiversity loss. As rightly argued in that chapter, the science is incontrovertible: black carbon accelerates glacial melt, ground-level ozone reduces crop yields, and indoor smoke from biomass fuels suffocates women and children. Yet our policy debates treat these linkages as footnotes rather than front lines. Air quality is where climate, agriculture, health, and gender intersect. Pakistan's failure to act decisively here reveals a blind spot in its sustainability agenda.

Governance remains the missing piece. As Chapter 14 of the book ("The Twenty-Year Full Circle") rightly notes, Pakistan has perfected the art of producing reports without ensuring results. Commissions proliferate, recommendations repeat, but enforcement seldom follows. The political economy of pollution is entrenched: powerful lobbies externalise costs while regulators internalise risk aversion. Unless the Environmental Protection Agencies gain autonomy, resources, and political backing (the five prerequisites that I mentioned earlier) smog will remain an annual ritual of resignation.

Air does not recognise administrative borders. Pollutants drift from one province and one country to another. Chapters 13 and 17 of this report call for provincially coordinated airshed-management systems, an approach Pakistan has yet to institutionalise. The current siloed response, divided by provincial boundaries and bureaucratic turf, ensures collective failure.

At its core, the air crisis is a moral one. It reflects how a society values the lives of its children, the labour of its workers, and the rights of its citizens to breathe freely. Pakistan's poorest breathe the dirtiest air because the state has chosen convenience over justice. That is not misfortune; it is policy.

Technically, the solutions are well known. Many peers, such as Vietnam, Ethiopia, and Ghana, have improved air quality through enforcement, cleaner fuels, and civic engagement. The book's Chapter 17 outlines similar measures, from stricter vehicle inspection to kiln regulation. What we lack is not knowledge but consistency.

Viewed through the Sustainable Development Goals, clean air is both a precondition and a measure of progress: SDG 3 (Health), SDG 7 (Clean Energy), SDG 11 (Sustainable Cities), SDG 13 (Climate Action), and SDG 16 (Institutions) all converge here. The haze that blankets our cities is a visible indictment of fragmented governance. Conversely, blue skies would signify that Pakistan has finally aligned its economic and environmental ambitions.

Air is the ultimate commons, shared by all, owned by none. To pollute it is to breach a collective trust; to restore it is to renew our social contract. The task ahead demands political will, fiscal discipline, and civic participation in equal measure. A breathable Pakistan will not emerge from imported technology or temporary bans. It will come from a national consensus that equates clean air with dignity, justice, and progress.

Dr. Abid Qaiyum Suleri is Executive Director of the Sustainable Development Policy Institute (SDPI).

Founder's Note

A Crisis of Evidence

by Abid Omar

There is a particular quality to the air in Lahore in winter. Gone is the promise of clean, cold air. Instead, a kind of oppression descends: a thick, acrid haze that coats the tongue and stings the eyes. It has a weight, a physical presence. It smudges the skyline into a featureless grey canvas and turns the midday sun into a pale, distant blur. This is the air of the 'fifth season', the season of smog, a time when the simple, unconscious act of breathing becomes a deliberate, and often painful, calculation of risk.

In the winter of 2024, this seasonal affliction escalated into a full-blown atmospheric emergency. In Multan, a city of ancient saints and shrines, the Air Quality Index (AQI) thickened the air into a slurry of poison, with numbers soaring past 2000. Lahore, the city of gardens, was a suffocating blanket, crossing 1000. These are not mere numbers. They are the chemical signatures of a slow, systemic violence being inflicted on millions of lungs. To contextualise these figures is to witness the scale of the crisis: they are more than 25 times the safe limits recommended by the World Health Organization. The air is so toxic that it would shut down cities elsewhere. These figures represent a state of atmospheric siege.

And yet, for years, the official truth was that there was nothing to see. It was merely 'fog', a romantic winter guest, a trope of nostalgic poetry. The only evidence to the contrary came from the unsanctioned hum of low-cost sensors run by citizens and independent organisations—a guerilla science that dared to tell a different story in real-time. The question these small, persistent machines posed was not just about parts-per-million, but about power. Who has the right to measure the air we all share? And who has the authority to deny that measurement? This created a profound data vacuum, a space of official silence where fear, speculation, and ultimately, ineffective policy festered. In the absence of a credible, state-sanctioned narrative grounded in science, the public was left to navigate the toxic haze with little more than instinct and rumour.

The cost of this denial is written in our bodies and our graveyards. Air pollution is the country's most prolific, most democratic killer. It takes, on average, 3.9 years from the life of every single Pakistani. It has claimed more lives each year than the long and brutal war on terror did in two decades. This is not a metaphor. It is an arithmetic of loss. An entire generation of children is inhaling a future of diminished capacity, of stunted lungs and compromised minds; their cognitive development silently eroded by the air they breathe on the way to school. And the economy, tethered to this public sickness, bleeds billions of dollars in a slow, continuous haemorrhage of lost workdays, strained healthcare systems, and diminished productivity.

Faced with this mounting, undeniable crisis, the state has developed a sophisticated machinery for managing public perception. We have seen the sudden declaration of a 'war on smog', a powerful phrase that promises decisive action. But the weapons deployed in this war have been theatrical. We have seen the spectacle of major roads being washed with precious water, an act of such profound scientific illiteracy which serves only to expose a deep misunderstanding of the problem. Fine particulate matter, the primary danger, is an atmospheric phenomenon, not a terrestrial one; washing the asphalt is like trying to cure pneumonia by cleaning the floor of the hospital.

This theatre of the absurd has recently been upgraded with more impressive props. We have seen the deployment of 'anti-smog cannons'—massive misting jets that spray atomised water into the air—and installation of 'smog towers'. These are technologies of distraction, designed to create the illusion of a high-tech solution. But the science is clear: their impact is negligible, localised, and temporary. They are an attempt to scrub the symptoms from a few cubic metres of air while ignoring the multi-province, factory-and-fleet-sized sources of the pollution itself.

This performance—of road-washing, of smog guns, of sudden school closures and reactive bans—is the logical outcome of a system operating without an evidence base. When you do not know with scientific certainty where the pollution is coming from, you are forced to resort to spectacle. When you lack a detailed map of the enemy, you end up firing cannons into the fog. It is easy to critique these as drawing-room decisions made in isolation, but the reality is more systemic. They are the decisions of actors working without a script, without the foundational scientific knowledge that must precede any effective policy.

Air pollution is the country's most prolific, most democratic killer. It has claimed more lives each year than the long and brutal war on terror did in two decades.

This report is an attempt to begin writing that script. It is the work of one small, independent organisation to start building the evidence base that has been so conspicuously absent. It is not, by any means, a complete solution. It is, in fact, wholly insufficient to solve the crisis on its own. What this report offers is the first critical step: a foundational layer of data and analysis that sets the stage for the urgent, deeper scientific work that must follow. Before effective policies can be crafted, Pakistan needs a new level of scientific inquiry. We need comprehensive, nationwide source apportionment studies to chemically fingerprint pollution and trace it back to its specific origins. We need chemical speciation to understand the toxic composition of the particulate matter we are breathing. We need more granular emissions inventories that are updated annually. And we need rigorous economic cost-benefit analyses of mitigation strategies to guide investment.

This report is an argument that this work must begin now. It is an attempt to replace the architecture of apathy with an architecture of accountability, built on the bedrock of empirical evidence.

We do not offer another list of vague recommendations. Instead, we offer a detailed map of the problem as we currently understand it, a first draft of the evidence required for change. This report will:

Dissect the poison: We begin by examining the science of the pollutants themselves—the invisible assassins like PM2.5, and the precursor gases like NOx and SO2—to understand the specific chemical nature of our enemy.

Unmask the sources: This is the heart of our investigation. We present the first-ever, bottom-up emissions inventories for Pakistan's four largest and most diverse urban airsheds. This inventory ends the era of speculation, pointing with scientific clarity to the smokestacks, the tailpipes, the brick kilns, and the fires responsible for the bulk of our pollution.

Count the human cost: We move beyond statistics to document the devastating toll on our health, our children, and particularly on women, who, through social and biological factors, bear a disproportionate share of this toxic burden.

Deconstruct the governance failure: We trace the two-decade history of well-intentioned but poorly implemented policy, benchmarking our national and provincial governance frameworks against global best practices to reveal not just what is broken, but how it can be fixed.

Provide a blueprint for action: We explore the proven, technically feasible, and economically viable solutions that can lead to clean air. This is not a dream; it is a matter of engineering, economics, and, above all, political will informed by science.

This report is not for filing away on a shelf. It is an invitation to begin a new kind of conversation—one grounded in data, driven by a shared urgency, and dedicated to the principle that every citizen has a right to clean air. The air is a commons. It belongs to everyone and no one. To poison it is to poison the public trust. To reclaim it is not just a matter of public health, it is a matter of justice. The spectacle must end. The evidence is in. Clean air is not negotiable. It is time to get to work.

Abid Omar is Founder of the Pakistan Air Quality Initiative (PAQI).

Section One

Scale, Science, and Human Impact

1

1.

The Right to Breathe

by Senator Sherry Rehman

Clean air is not a privilege. It is a fundamental human right, and yet remains one of the most denied public good for citizens of Pakistan today. Without resorting to any hyperbole, the truth is that our reported and lived reality is bleak. Every breath we take seems to be laced with invisible poisons; triggering a slow form of environmental violence that shortens lives, cripples health, and weakens the very foundation of our economy and society. Given its pervasive scale and intensity, air pollution is now the country's most unacknowledged serial killer, claiming more lives each year than conflict, terrorism, or natural disasters.

Air pollution is a **public health emergency** that respects no borders, class, or gender, while its burden falls heaviest on the vulnerable, the indigent, on women, and on children.

Clean air is not a luxury, says this report. I could not agree more. It is the most basic of rights. When a child cannot walk to school without inhaling toxic smog, the state has failed in its most elementary duty of protection, of providing a safe environment for its citizens. This report by the Pakistan Air Quality Initiative (PAQI) comes at a critical inflection point. For decades, policy inertia, weak regulation, and a lack of credible data have trapped us in cycles of denial and cosmetic fixes. Too often we have seen polluted air treated as a seasonal inconvenience rather than the systemic crisis that it is. Token band-aids such as road-washing, "smog cannons", or sporadic bans have distracted us from addressing the true sources of toxic air: fossil fuels, unchecked industrial emissions, unregulated transport, burning crop residue, and weak climate governance. This report breaks through that smog of inaction with evidence, clarity, and an unflinching call to accountability.

The findings are stark, and should serve as a wake-up call. Across our cities, each airshed bears its own unique emissions fingerprint. Highest in the rankings for poor air quality, Lahore – once celebrated as the city of gardens – now battles a three-front war of vehicular emissions, heavy industrial discharge, and a dense ring of toxic smoke-spitting brick kilns. Islamabad and Rawalpindi – minus the unfiltered, dirty industrial clusters encircling Lahore – are choked instead by transport and urban design failures. Although Karachi, despite its mega-city size is lower in the rankings, its air is often heavy with chronic industrial smog, port emissions and dust.

The science is unequivocal: air pollution in Pakistan is not a monolithic landscape, but a series of localised emergencies that demand tailored solutions, especially from fine particulate matter (PM2.5) – what this report calls the "invisible assassin" – and the chemical cocktail of other pollutants that laces our air with poison.

But air pollution should not just be seen as a public health emergency; it is also a social justice crisis. The loss of 3.3 years of life expectancy for the average Pakistani, and 5.8 years for the people of Lahore, represents more than a statistic; it amounts ultimately to many lives unjustly robbed of their futures. It amounts to the erosion of rights and opportunities, disproportionately borne by those least responsible and least able to protect themselves. Women, confined by a mix of gender inequity and circumstance to poorly ventilated kitchens, are routinely exposed to harmful cooking fuels that carry a double burden of household and ambient pollution. Children in such spaces, defined by multiple social deprivations including dirty air, grow up with stunted lungs and compromised cognitive development, their potential dimmed before they have a chance to flourish.

This is why addressing air pollution must be framed not just as a technical or environmental issue, but as a question of equity, governance, and survival. Air is a public good, part of the commons we all share in governing as well as breathing. Air pollution challenges in Pakistan – whether they be residue from crop burning in Punjab, or dirty air arising from industrial emissions – need not be seen as the inevitable cost of growth. It is a problem fuelled as much by inaction as ignorance. I have often warned in Parliament that we cannot fight 21st century crises with 20th century tools or governance. Clean air is inseparable from climate resilience, economic vitality, and national security. Every region, every action has a different mix of its own contaminants in the air. Pollutants like black carbon, for instance, not only make breathing laboured, they accelerate glacier melt, and directly endanger Pakistan's water and food security.

The economic costs go hand in hand with the environmental ones. The overall toll of air pollution for Pakistan, estimated at over 6.5% of GDP annually, undermines our already fragile fiscal stability. Inaction is no longer affordable at many levels.

Yet, the path to clean air is not out of reach. The solutions are known, proven, and achievable if matched with political will. Transitioning to cleaner fuels, electrifying mass transit and two- and three-wheelers with implementation of EV policy across the board, the modernisation of brick kilns, and enforcement of real standards for industry need not feature in the public imagination as distant ideals, but immediate imperatives. Building a transparent, nationwide monitoring system, aligning our environmental standards with global health guidelines, and empowering the public with reliable data are steps that can and must be taken now. This is not tomorrow's problem. This is a crisis cutting short lives today. Every day of delay carries a human cost we cannot afford.

For Pakistan, the question is no longer whether clean air is possible. The real question is whether we have the resolve to deliver it. Our citizens have waited too long, and they cannot wait any longer. Clean air must be recognised as a core part of our social contract, as central to dignity and survival as access to water, education, or healthcare.

What this report does, with rigour and precision, is provide the evidence base to finally move from rhetoric to reform. It is a foundational document for policymakers, regulators, civil society, and citizens alike. It maps the sources of our crisis, counts the human and economic costs, and offers a blueprint for action rooted in science, feasibility, and justice. Finally, it is a call to action that we cannot afford to ignore.

On a global pie chart, Pakistan contributes less than 1% of global emissions, yet we have turned into a ground zero for climate disasters, with rankings from 2022 showing up today in 2025 as the most climate-vulnerable country in the world. The injustice is real, but so is the ownership of responsibility and national-to-local action. There are many ways to protect our own citizens from the toxic air we breathe, and to restore the purity of its quality. This report is full of them.

I commend the Pakistan Air Quality Initiative for producing this vital national assessment. Let it not be another report that gathers dust on shelves. Let it be a turning point, the moment we chose to confront the crisis with courage, science, and responsibility.

Senator Sherry Rehman

Sherry Rehman is Chair of the Standing Committee of the Climate and Environment Committee of the Senate of Pakistan. She is also a former Federal Minister for Climate Change.

A fire rages near Karachi's port area, sending plumes of black smoke into the skyline. Such uncontrolled emission events contribute significantly to the city's acute pollution episodes, adding a layer of immediate toxicity to the chronic industrial haze.
Photo by Pakistan Air Quality Initiative

2.

Anatomy of Smog

A primer on air pollution

It's not just dust: Pakistan's toxic air is a complex chemical cocktail of pollutants. The most dangerous, fine particulate matter (PM2.5) is an invisible assassin of a size 30 times smaller than a human hair, which allows it to penetrate the bloodstream and have the potential to damage every organ in the body.

Standards are the floor, not the ceiling: NEQS are weaker than WHO guidelines. Aligning fuel quality and real-world enforcement with health science is essential to bring down PM, NO2, SO2, ozone, and lead.

Protection today, prevention tomorrow: Masks, cleaner indoor air, and smart timing reduce exposure now, but only structural measures like clean fuels, vehicle inspection, kiln modernisation, waste and crop burning control, and electrified transit will deliver clean air for all.

The air that poisons us is not a single entity. It is a complex, often invisible, chemical soup, with each ingredient contributing to a different facet of the crisis. To fight this enemy, we must first know it. This chapter dissects the pollutants that define our air quality emergency, moving beyond the single metric of 'AQI' to reveal the science of what we are breathing. This is the chemical fingerprint of our national health crisis—a crisis that is measurable, understandable, and therefore, solvable.

Breathing the problem

Pakistan is among the most polluted nations in the world, with all its 238 million inhabitants exposed to unsafe levels of polluted air.[1]

Every breath in Pakistan carries more than it should. From Karachi's port corridors to Peshawar's valley basin, the air we inhale contains concentrations of pollutants far above levels considered safe for health. In November 2024, Lahore reached an AQI reading near 1900[2] and Multan climbed above 2000[3]. Those numbers are difficult to imagine until you feel the sting in the throat, the tightness in the chest, the acrid taste and accompanying haziness that lingers even indoors. These peaks are only the loudest moments in a chronic story. Day after day, Pakistan's cities and many rural districts live with particle and gas concentrations that breed disease, shorten lives, reduce productivity, and sap community energy.

It can be said with certainty that no other country suffers from a worse air pollution problem.

[1] Energy Policy Institute at the University of Chicago. (2023). Pakistan fact sheet 2023.

[2] Al Jazeera. (2024, November 4). Record-high air pollution shuts schools in Pakistan's Lahore.

[3] Gabol, I. (2024, November 9). Punjab doubles restrictions as Multan AQI tops 2,000. DAWN.COM.

This chapter explains what is in our air, why it harms us, how it connects to climate, what policy can do, and how people can protect themselves while the larger solutions take hold.[4] [5] [6]

What we mean by polluted air

Air pollution is the presence of harmful substances in the atmosphere that change its normal composition and threaten health, ecosystems, and the climate. Some pollutants are emitted directly, like soot from a diesel truck or smoke from a brick kiln. Others form in the air when primary pollutants react in sunlight and moisture. Pollutants behave differently in time and space. Some spike for hours, others linger for weeks or months, and a few persist long enough to influence regional climate. Weather and geography turn chemistry into daily exposure. Pakistan's plains and basins trap winter air under temperature inversions that act like a lid, letting pollutants accumulate near the ground with mountains to the north and slow ventilation to the east. Seasonal behaviours add fuel to the chemistry: crop residue burning after harvest, more traffic and generator use during power shortfalls, dirty biomass fuels for household cooking and heating. What looks like one brown veil is a moving blend of local and upwind emissions shaped by the day's weather.[7] [8]

Why standards matter, and where to find them

Pakistan's National Environmental Quality Standards (NEQS) set legal limits for key pollutants. They are the baseline for enforcement. The World Health Organization sets health-based guidelines that reflect the best evidence on risk. Those guidelines are a more protective target. This chapter does not repeat the detailed tables because they are presented in Chapter 3. What follows focuses on the six **criteria pollutants**[9] recognised in Pakistan's standards and in global air quality management practice: particulate matter, sulfur dioxide, nitrogen dioxide, ground-level ozone, carbon monoxide, and lead. Three other pollutant families that shape real-world exposure—ammonia, volatile organic compounds, and polyaromatic hydrocarbons—are discussed later because they drive the chemistry that produces the particles and ozone we actually breathe.[10]

Particulate matter: the invisible killer

If there is one pollutant to remember in Pakistan, it is particulate matter. PM is a catch-all term for tiny solids and droplets that float in air. PM10 is coarse particulate matter, yet small enough to enter the lungs. PM2.5 is smaller and more dangerous because it penetrates

[4] Energy Policy Institute at the University of Chicago. Air Quality Life Index.

[5] Health Effects Institute. (2024). State of global air 2024: Exposure and health impacts.

[6] The New York Times. (2024, November 7). Record air pollution hospitalizes hundreds in Pakistani city.

[7] NASA Earth Observatory. (2024, November). Smoky skies over the Indo-Gangetic Plain.

[8] World Bank. (2024, September 5). Air pollution knows no borders in South Asia, neither do solutions.

[9] They are called "criteria" pollutants because they are the most common and well-studied pollutants for which health-based criteria and ambient standards have been established by agencies such as WHO and US EPA. See WHO Global Air Quality Guidelines (2021) and US EPA's overview of the National Ambient Air Quality Standards.

[10] World Health Organization. (2021). WHO global air quality guidelines 2021: PM, ozone, NO_2, SO_2, and CO.

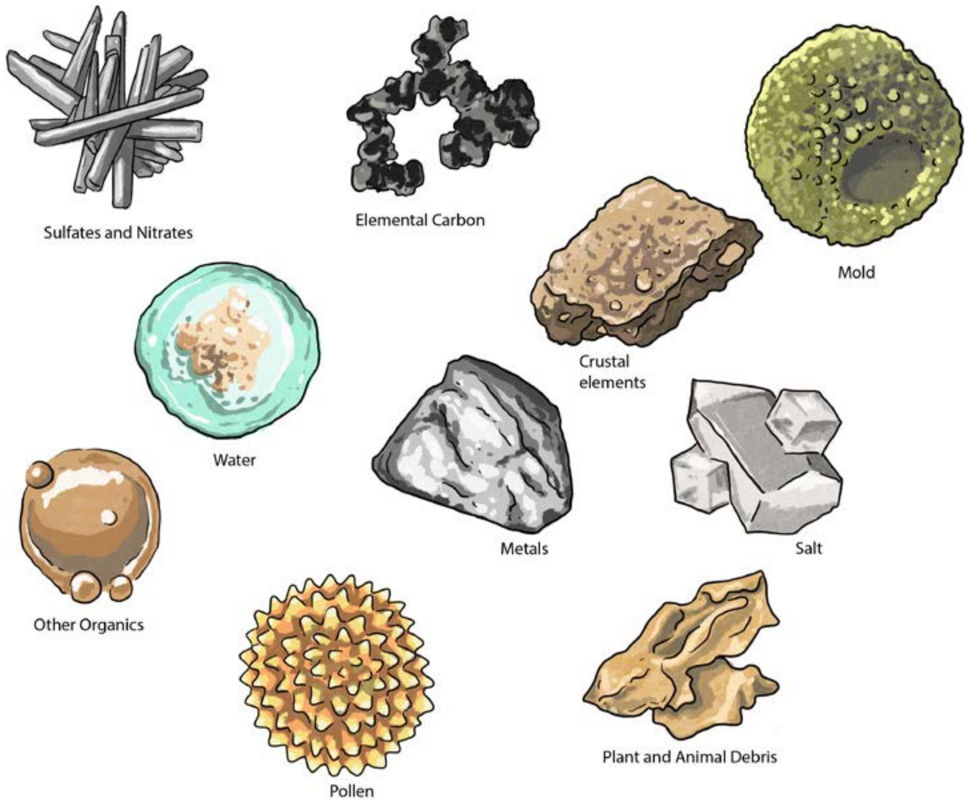


Exhibit 2.1: Composition of Particulate Matter. **A complex mixture of a variety of different substances, particulate matter comprises fine particles such as sulfates and nitrates, elemental carbon, metals, water, etc. The coarser particles include pollen, mold, salt, plant and animal debris, etc.**
Illustration by Maaz Jan/Deconstruction Station

deep into the lung and, depending on size and chemistry, can move into the bloodstream. It helps to picture the scale. A human hair is about 70 micrometres wide. A red blood cell is roughly 6 to 8 micrometres across. PM2.5 is 2.5 micrometres and below, small enough that the body's defenses often miss it.

Particles reach the air in two ways. **Primary particles** are emitted directly as soot, ash, and dust from engines, brick kilns, boilers, generators, open waste fires, construction sites, and unpaved roads. **Secondary particles** form in the atmosphere when gases such as sulfur dioxide, nitrogen oxides, and ammonia react to create sulfates, nitrates, and other compounds that then condense or cling to existing particles. Natural events add their own load, including dust storms across the plains and smoke from wildfires when they occur.[11]

The health story is blunt. Short-term exposure to high PM levels causes irritation of eyes, nose, and throat, chest tightness, coughing, shortness of breath, and asthma attacks. Longer exposure adds chronic risk: heart attacks and strokes, exacerbation or onset of chronic lung disease, a higher likelihood of pneumonia and bronchitis, complications in pregnancy and low birth weight, and growing evidence of cognitive effects. PM rarely acts

[11] United States Environmental Protection Agency. Particulate matter (PM) basics.

Exhibit 2.2: What a Particle Looks Like When You Cannot See it. PM2.5 is far smaller than the eye can perceive. Imagine a human hair at 70 micrometres, a red blood cell at about 6 to 8 micrometres, then a cluster of particles at 2.5 micrometres and below. These particles can pass into the bloodstream.
Image by Sotirios Papathanasiou

Exhibit 2.3: Dirty Fuel, Dirty Air. **The path to clean air begins at the refinery. High-sulfur fuels poison the air directly and render modern vehicle emission controls useless.**

alone. It carries metals and organic compounds that add toxicity, and particle surfaces trigger inflammation in the body. When PM concentrations climb, emergency visits and premature deaths follow.

PM also changes how the environment works and looks. It reduces visibility, creating the haze that erases our skylines. When particles deposit, they can acidify water bodies, alter nutrient balances, and coat leaves and crops, reducing photosynthesis and yields. On buildings and machinery, a film of particles accelerates wear and corrosion. PM interacts with climate too. Black carbon absorbs sunlight and warms the atmosphere and snow surfaces. Sulfates reflect sunlight and cool slightly. The local net effect depends on the mix, which is another reason to know exactly what is in our air and where it comes from.

Pakistan can reduce particle pollution quickly if it targets the sources that dominate exposure. **The policy levers are clear and proven.** Cleaner fuels are foundational because lower sulfur content reduces direct PM and unlocks modern emission controls. Rigorous inspection and maintenance for commercial diesel fleets by 'real-world' emissions testing finds and fixes the small share of vehicles that produce a large share of emissions. Urban freight management around ports and industrial corridors reduces idling and congestion. Brick kiln modernisation to zigzag designs with proper draft control cuts fuel use and PM substantially, and enforcement against burning waste and tyres closes a common loophole. Industrial boilers and furnaces can switch to cleaner fuels and install effective filters and scrubbers, verified by continuous emissions monitoring. Open waste burning is preventable through basic collection, safe disposal, and support for the informal sector that already recovers recyclables. Paying for residue management services and creating markets for straw can replace burning with income. These interventions are not conceptual. They have worked elsewhere and are locally achievable when leadership, enforcement, and practical incentives align.

Sulfur dioxide: the fuel problem you can smell

Sulfur dioxide is a sharp, choking gas released when sulfur-bearing fuels burn. In Pakistan, that means the use of coal, furnace oil and other heavy fuels in industry and power generation, and diesel with sulfur above modern specifications. Metal smelting and some chemical processes add their share. SO2 in our airsheds comes from controllable sources.[12]

In the air, SO2 oxidises to form sulfate particles that become part of PM2.5. As a gas, it irritates airways and can trigger symptoms in people with asthma. As sulfates, it reduces visibility, adds to regional haze, and contributes to acidification in soils and water. Where fuels contain a lot of sulfur, even the best emission controls struggle. Chemistry overwhelms filters and catalysts designed for cleaner inputs.

There is a direct fix with broad co-benefits. Cut sulfur in fuels at the refinery and at import, and a large part of the problem falls within weeks. Enforce sulfur specifications at the pump and at industrial boilers, backed by testing. Where heavy fuels remain, require desulfurisation and particulate controls sized for real emissions, not for theoretical fuel specs. At ports, require low-sulfur marine fuel and provide shore power so ships can turn off auxiliary engines at berth. These are the foundations of modern air quality management. They lower sulfates and PM2.5 at the same time.

Nitrogen dioxide: traffic's signature

Nitrogen dioxide forms wherever fuel burns hot. It is the brown tint over busy roads, the plume from a diesel generator in a narrow lane, the heat-blur of an industrial stack. Together with nitric oxide it is counted as NOx. NO2 inflames the lungs and worsens asthma. It narrows airways and increases reactions to allergens. Unlike PM, which sometimes shows itself as haze, NO2 can be highly local, with sharp gradients near roads and generators where people actually live and work.[13]

NO2 drives other chemistry. It helps form nitrate particles that add to PM2.5. Along with reactive hydrocarbons, it fuels the sunlight-driven reactions that create ozone downwind. Reducing NO2 can yield a two-for-one gain: lower particle levels and lower ozone peaks. In Pakistan, growth in vehicle kilometres and backup generation during power shortfalls has raised NO2 hotspots even when PM gets the headlines.

The remedy is technical and institutional. Cut NO2 where people breathe it. Use cleaner fuels so catalytic converters and diesel after-treatment work. Require periodic inspections that measure emissions and force repairs, especially for buses, trucks, and commercial

---

[12] United States Environmental Protection Agency. Sulfur dioxide basics.

[13] United States Environmental Protection Agency. Basic information about NO_2.

vans. Modernise bus fleets and expand and electrify high-frequency public transport to replace car and motorcycle trips. In dense neighbourhoods, regulate generator use and encourage shared or cleaner backup options. Manage construction traffic and freight so trucks travel at hours and on routes that minimise exposure. These steps lower NO2 hotspots and, by starving the chemistry, also reduce nitrate PM and downwind ozone.

Ozone at the surface: sunlight's unintended product

High above Earth, ozone shields life from ultraviolet radiation. Near the ground, it harms by inflaming lungs and injuring leaves. Ozone is not emitted directly. It forms when NOx and volatile organic compounds from fuels, solvents, and some industrial processes react in sunlight. Because it forms in the air, the highest concentrations often occur downwind of where the gases were emitted hours earlier. Ozone peaks on bright, stagnant afternoons. It is less of a winter headline than PM, but it damages lungs all the same and takes a real toll on crops.[14]

The health effects are clear. Ozone reduces lung function, causes chest pain and throat irritation, and triggers asthma. Repeated exposure contributes to chronic respiratory disease. On farms and in forests, ozone slows photosynthesis and growth, browns leaf tissue, and increases susceptibility to pests and disease. Because plants are the country's food and carbon budget, this damage matters. Ozone is also a short-lived climate forcer, adding warming while it persists.

Lowering ozone means cutting the ingredients that make it. Reducing NOx from traffic, generators, and industry is essential. So is reducing volatile organic compounds. That includes fuel storage and refueling vapour controls, low-VOC paints and solvents, and leak detection and repair in chemical plants. There is no machine that scrubs ozone from ambient air. The only way to fix ozone is to starve the chemistry. City plans that target PM alone will miss this problem unless they deliberately track and control the gases that create it.

Carbon monoxide: the signal of incomplete combustion

Carbon monoxide is colourless and odourless, which is part of the danger. It forms when fuels burn without enough oxygen for a complete reaction. Outdoors, CO concentrations are highest near traffic and engines. Indoors, poorly vented stoves, heaters, and generators can create lethal conditions. Carbon monoxide binds to haemoglobin far more strongly than oxygen, reducing the blood's ability to carry oxygen to tissues. High concentrations can cause dizziness, confusion, loss of consciousness, and death. Even at lower levels, people with heart disease may feel chest pain and fatigue.[15]

The good news is that CO is a marker of inefficiency. When engines and burners work

[14] United States Environmental Protection Agency. Ground-level ozone basics.

[15] United States Environmental Protection Agency. Carbon monoxide outdoor air pollution.

properly on clean fuels with the right air supply, they produce little carbon monoxide. Almost every measure that improves combustion and reduces PM and NO2 also reduces CO. Cleaner fuels, working catalytic converters, tuned engines, and well-vented appliances are the strategy.

At home, do not run generators in poorly ventilated spaces. Ensure gas or kerosene heaters are vented and maintained. Where feasible, install carbon monoxide alarms. In traffic, the same habits that reduce PM and NO2 exposure reduce CO: avoid tailpipe-to-tailpipe time in jams, recirculate and filter cabin air during peaks, and time trips to dodge the dirtiest hours.

Lead in air: a legacy hazard that still needs vigilance

Young children are most affected by air pollution because they have smaller lungs and lack the immunities that come with age. They also breathe twice as fast as adults and take in more air, often through the mouth, along with pollutants, leading to life-threatening respiratory diseases.

Phasing out leaded petrol was one of the great public health victories of recent decades. Airborne lead concentrations fell dramatically. Yet lead has not vanished. It persists near sources like metals processing, informal battery recycling, and some waste burning. Lead is a neurotoxin, and children are most vulnerable. Even low exposures impair brain development, reduce IQ, and affect behaviour. In adults, chronic exposure increases blood pressure and harms the kidneys. Lead settles onto soil and dust and can be inhaled or ingested later.[16]

The policy task is clear. Keep lead out of fuels and paint. Regulate and monitor industries that handle lead. Formalise and control battery recycling, with proper collection, smelting controls, and worker protection. Sample air and dust near suspected sources and publish the results so communities know their risk. Because averages hide hotspots, targeted monitoring around facilities is essential.

For families near industry, frequent wet cleaning reduces dust. Hand-washing before meals reduces ingestion. Pediatric screening where exposure is suspected allows early intervention. These personal steps are second best. The real solution is to stop lead at the source.

Pakistan's lead story still touches the air we breathe. While leaded petrol is gone, airborne and settled lead persist near metals processing, informal battery recycling, and in lead-containing paints that degrade into dust. A 2023 market study by Aga Khan University and the Lead Exposure Elimination Project found that 40% of solvent-based household paints sampled in Karachi exceeded Pakistan's 100-ppm legal

[16] United States Environmental Protection Agency. Lead in Air: Basic Information.

limit, with some tins reaching thousand-fold higher levels. That dust becomes indoor and outdoor airborne lead, a direct exposure pathway for children. The fix is straightforward: enforce the paint lead limit with independent testing and market surveillance, formalise and control battery recycling, and monitor air and dust near smelters and scrap yards so hotspots are visible and addressed.[17 18]

Other pollutants that shape the air we breathe

Three pollutant families deserve attention because they shape the PM and ozone that we breathe. Ammonia, largely from fertiliser use and livestock, reacts with acidic gases to form ammonium salts that contribute to PM2.5. Smarter fertiliser timing and placement, urease inhibitors, and better manure management lower particle formation without harming yields. Volatile organic compounds evaporate from fuels, paints, solvents, and some industrial processes, and they are essential ingredients in ozone and secondary organic aerosol. Controlling these vapours through tighter storage, vapour recovery at refueling, low-VOC product standards, and leak detection in industry reduces both ozone and PM. Polyaromatic hydrocarbons form during incomplete combustion. Many are carcinogenic. They ride on particles, especially black carbon, and add toxicity to the PM burden. Cutting the dirty end of combustion—waste burning, uncontrolled brick kilns, smoky engines—cuts PAH exposure.

Indoor air meets outdoor air

Not all exposure happens on the street. In homes that rely on wood, dung, coal, or waste for cooking and heat, the kitchen can be the most polluted room a family ever enters. Women and young children bear the brunt. Household air pollution is an air quality issue and an energy issue. Clean cooking fuels and technologies reduce PM, CO, and other toxic compounds inside homes and, because smoke leaks outdoors, in neighbourhoods too. Reliable electricity for ventilation and induction cooking, affordable LPG or biogas where appropriate, and safe efficient stoves are not luxuries. They are public health measures with immediate benefits.[19]

Schools can act even faster. Create clean rooms for the worst days by using portable HEPA purifiers in classrooms and clinics. Teach students how to read simple air quality graphics. Time outdoor assemblies and sports for cleaner hours. Make ventilation smart rather than constant, opening up when the air outside improves and closing when pollution surges.

Why South Asia, and why winter

The Indo-Gangetic Plain and the foothills below the great mountain ranges form one of

[17] Lead Exposure Elimination Project. (2023, February 14). Lead paint in Pakistan.

[18] Siddiqui, D.-A., Coulter, L., Loudon, C., & Fatmi, Z. (2023). The brighter the worse: Lead content of commercially available solvent-based paints intended for residential use in Pakistan. F1000Research, 12, 166.

[19] World Health Organization. (2014). Guidelines for indoor air quality: Household fuel combustion.

the world's most persistent air pollution hotspots.[20] In late autumn and winter, the lower atmosphere cools near the surface while warmer air above creates a cap. That inversion traps pollutants near the ground and slows their escape. Mountains hem the air horizontally. Seasonal behaviours add smoke and dust. Farmers needing fields cleared for the next crop burn straw because it is fast and cheap. Residents, industry, and commerce all use more fuel for heat and light as the days shorten and temperatures drop. The result is a predictable rhythm: a rise in October, a peak from November to January, then relief as wind and rain return. Satellite images from early November 2024 show the haze clearly, with a broad ribbon of smoke and stagnant air blanketing the plains.

Pollution also crosses borders. What a monitor reads in one city may come in part from a power plant upwind, a ring of brick kilns across a district line, trucks bound for another city, or crop residue burning fires far away. This is why provincial policies need coordination across districts, and why national efforts benefit from regional agreements.

Reading the numbers without getting lost

Air quality indices translate complex chemistry into simple colours and categories. They are useful for public communication and daily choices, but the underlying concentrations drive risk. Different indices use different breakpoints. Pakistan's standards differ from WHO's guidelines. One app may show unhealthy while another shows hazardous because scales differ. For policy, tie decisions to actual concentrations and to the health-based limits you plan to reach. For daily life, use one trusted local source consistently and learn the pattern in your neighbourhood.

The recent smog crisis drew global attention for a reason. In November 2024, Lahore's air turned so toxic that hospitals filled with adults and children struggling to breathe. Schools closed. Offices shuttered. Satellite images showed the plume from space. International media described the scene in stark terms, placing Pakistan's struggle alongside other megacities that faced similar episodes before choosing to act. The question for Pakistan is not whether the world has noticed. It is whether we now choose to deliver clean air as a public service that people can feel in their lungs and see in the sky.

A final word

Pakistan's air pollution is not the inevitable price of growth. It is the cost of outdated fuels and machines, weak enforcement, and decisions made without counting health. What these pages offer is a map of the air itself—what is in it, why it is there, how it harms, how it touches climate, and what works to clean it. The country has the data, the local evidence, and the global examples to act. The work ahead is to bring standards into line with health science, to build and maintain a monitoring network the public can trust, and to enforce rules with fairness and resolve. The payoffs are immediate: fewer deaths, fewer missed school days, fewer hours in hospital corridors, clearer skies above our cities, and a stronger economy below. Clean air is not a luxury. It is the baseline for a dignified life and the foundation for a modern Pakistan.

[20] Al Jazeera. (2024, April 2). Why does South Asia have the worst air pollution in the world?

How to read AQI in Pakistan

Air Quality Index	Health Category	Health Advisory
0 to 50	Good	Air quality is satisfactory, and air pollution poses little or no risk.
51 to 100	Moderate	Air quality is acceptable and within Pakistan's Environmental Quality Standards. However, some pollutants may be a moderate health concern for a small number of unusually sensitive individuals.
101 to 150	Unhealthy* for Sensitive Groups	Members of sensitive groups (e.g., individuals with lung/heart disease, pregnant women, older adults, children) may experience health effects. The general public is less likely to be affected.
151 to 200	Unhealthy	Everyone may begin to experience health effects; sensitive groups may experience more serious effects. All individuals should reduce prolonged or heavy outdoor exertion.
201 to 300	Very Unhealthy	HEALTH ALERT Increased risk of adverse health effects for everyone. Sensitive groups should avoid all outdoor activity. The general public should avoid prolonged or heavy exertion.
301 to 500	Hazardous	HEALTH EMERGENCY Hazardous conditions for the entire population. All individuals should avoid all outdoor activity. Remain indoors and keep windows closed.
500 or higher	Beyond Index	EXTREME HEALTH EMERGENCY Extremely hazardous conditions conditions. All individuals must remain indoors. All outdoor activity is extremely harmful to health.

The Air Quality Index turns complex measurements into a single number and colour that you can use; **higher means worse and it also means more risk**, regardless of the app or chart. It ranges from clean to hazardous, with colours to match.

Popular apps commonly use the United States AQI method, whereas in Pakistan, the Punjab government has devised its own index to use for government advisories. Each pollutant is measured in micrograms per cubic metre or parts per million, then converted into an index.

The highest index value from the set becomes the AQI for the hour or the day. What matters for health is that as the number rises, risk rises.

A **Good** day sits in the 0 to 50 range. Air is clean enough that outdoor activity poses little risk to anyone.

A **Moderate** day, 51 to 100, is generally fine for the public, though some unusually sensitive people may begin to notice irritation if they exercise hard outdoors for long periods.

Unhealthy for Sensitive Groups, roughly 101 to 150, is a point where children, older adults, and people with asthma or heart conditions should shorten outdoor time and keep medication at hand.

Unhealthy, 151 to 200, is the point where everyone begins to feel it. Exercise outdoors becomes unwise. People with chronic conditions should stay indoors with windows closed and ventilation managed.

Very Unhealthy, 201 to 300, is a health alert. Even healthy people can develop symptoms with exposure. Schools should move sports indoors.

And finally, **Hazardous,** above 300, is an emergency. Authorities often close schools and advise everyone to stay inside. During the worst episodes in recent years, numbers have leapt well beyond 300. On those days, a well-fitting respirator, portable air purifiers, and relocating to cleaner indoor spaces are protective steps.

AQI is not a perfect instrument. Different countries set different breakpoints. Punjab's revised index is closer to international practice than earlier versions, and that is a health gain in itself because it does not disguise danger as routine. The AQI also does not make the air safer. It allows you to make better decisions while the country does the work of bringing concentrations down. The rule is simple. Check a credible local source each morning. Change your routine when the number is high. Use cleaner air hours for ventilation. And speak up when the index tells the same bad story day after day, because persistence of the problem is not a weather report. It is a policy report.

The iconic domes of the Badshahi Masjid are barely visible through a thick blanket of winter smog. This obliteration of landmarks serves as a stark visual indicator of air quality levels that frequently cross hazardous limits, erasing the city's heritage along with its horizon.
Photo by Mahera Omar/Pakistan Air Quality Initiative

3.

A National Emergency

The scale and consequences of Pakistan's air pollution problem

Public health crisis: Air pollution is a national emergency that reduces the life expectancy of an average Pakistani by 3.9 years.

Unique local sources: Each major city has a unique emissions fingerprint requiring targeted, local solutions.

Failure of governance: Systemic failures in governance underpin the crisis, in implementing environmental regulations and National Environmental Quality Standards (NEQS).

There is a quiet war being waged on the citizens of Pakistan. It is a war fought not with armies, but with apathy, with flawed policies, and with an air so toxic that it has begun to erase our futures. For too long, the sources of this poison were allowed to remain a convenient mystery. This report is an act of defiance against that silence; it is a scientific accounting of our crisis, designed not just to be read, but to be used: as evidence, as a weapon, and as a blueprint for reclaiming the air we breathe.

Recent years have witnessed a dramatic deterioration in Pakistan's air quality, with major cities regularly recording particulate matter concentrations among the world's worst. These dangerous pollution levels translate directly to severe public health impacts, from increased respiratory and cardiovascular disease to reduced cognitive development in children. The consequences are measured in years of life lost. According to the Air Quality Life Index (AQLI), chronic exposure to particulate pollution shortens the life of an average resident of Pakistan by 3.9 years.[1]

This local crisis is part of a global pollution pandemic. The Lancet Commission on Pollution and Health found that pollution is responsible for approximately 9 million premature deaths globally each year—equivalent to one in every six deaths worldwide.[2] The commission

[1] Energy Policy Institute at the University of Chicago. (2025). Air Quality Life Index: Annual report 2025. University of Chicago.

[2] Fuller, R., Landrigan, P. J., et al. (2022). Pollution and health: A progress update. The Lancet Planetary Health, 6(6), e535–e547.

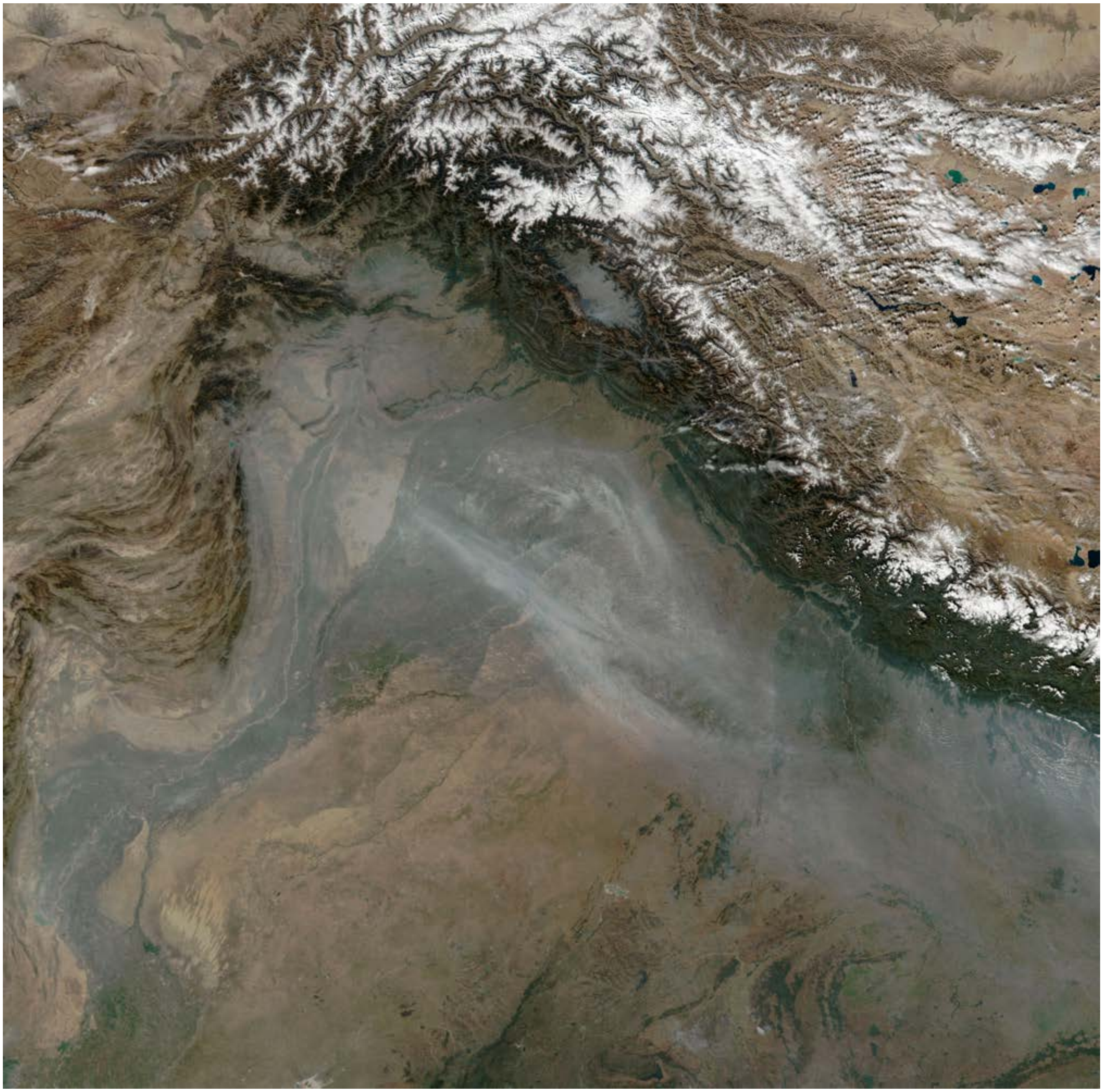


Exhibit 3.1: Smoky Skies Over the Indo-Gangetic Plain (NASA): **A view from space reveals the sheer scale of the crisis, as a thick, grey blanket of smog obscures the Indus Basin. This NASA satellite imagery underscores that air pollution is a massive, transboundary phenomenon that respects no administrative lines, trapping millions in a shared atmospheric emergency.**

		Total annual emissions in kilotons					*Emissions in kilograms per person per year*				
Airshed	**Population**	**PM2.5**	**SO2**	**NOx**	**CO**	**Kilotons**	**PM2.5**	**SO2**	**NOx**	**CO**	**Kilograms**
Karachi	21 million	39.12	51.52	100.79	203.42	789.69	1.86	2.45	4.8	9.69	37.6
Lahore	17 million	26.68	39.81	52.65	207.07	326.21	1.57	2.34	3.1	12.18	19.19
Islamabad-Rwp.	8.5 million	12.04	11.35	21.86	90.7	271.92	1.42	1.34	2.57	10.67	31.99
Peshawar	7.5 million	16.04	12.91	31.1	83.26	143.31	2.14	1.72	4.15	11.1	19.11

Exhibit 3.2: Comparison of Annual Emissions Across Pakistan's Major Cities (2021). **Karachi produces the highest absolute emissions, reflecting its industrial scale. Peshawar, however, shows the highest pollution burden per resident.**

crucially notes that deaths from modern pollution sources like industrial emissions and ambient air pollution are increasing, having risen by 66% since 2000. In Pakistan, air pollution is estimated to cost the economy over 6.5% of its GDP annually.

Despite this growing crisis, Pakistan has historically lacked the data necessary for effective pollution management. While air quality monitoring data confirms the severity of air pollution, the lack of detailed, spatially resolved, and sectorally disaggregated emissions data has constrained the ability of policymakers, regulatory agencies, and stakeholders to formulate and implement targeted, efficient, and impactful mitigation strategies. This emissions inventory addresses this critical gap, creating the scientific foundation for a new chapter in the country's air quality governance.[3]

This environmental challenge is amplified by climate change. As noted by WHO, "Air pollution and its health effects are exacerbated by climate change, which impacts levels and distribution of outdoor air pollutants such as ground-level ozone and particulate matter." This creates a vicious cycle. Localised research, such as work on heat stress in Karachi by the Karachi Urban Lab, further highlights the compound risks faced by urban populations.

The scientific foundation for action

An emissions inventory is the definitive tool for diagnosing a pollution crisis. It is a systematic accounting of pollutants discharged into the atmosphere, allowing policymakers to identify precisely who pollutes the air, with what, and by how much. The methodology is based on a fundamental principle: **Emissions = Activity Data × Emission Factor.**

Activity Data (AD) answers: What is burning, and how much? It measures the scale of a polluting activity, such as fuel consumed by vehicles or coal burned in factories.

Emission Factor (EF) answers: How toxic is the activity? It is a coefficient that quantifies the amount of a pollutant released for every unit of that activity.

[3] While some previous efforts, such as an inventory for Lahore by the Urban Unit, have been undertaken, there has been no comprehensive, multi-city, scientifically-benchmarked assessment to guide national policy.

This study employed a systematic bottom-up methodology for the baseline year 2021, focusing on four criteria pollutants with the most significant health impacts: particulate matter (PM2.5), sulfur dioxide (SO2), nitrogen oxides (NOx), and carbon monoxide (CO).

Emission sectors

The sectoral distribution reveals distinctive patterns that should guide national policy priorities. We analysed seven major emissions sectors:

Transportation: This sector is the dominant source of pollution nationally, contributing 38% of urban PM2.5 and an overwhelming share of other key pollutants—nearly 84% of NOx and 87% of CO. Diesel vehicles, particularly trucks and buses, generate disproportionate particulate emissions despite representing a minority of the vehicle fleet.

Industry: Industrial activities contribute 32% of urban PM2.5 emissions, with particularly high contributions in Karachi (49%). Steel manufacturing, cement production, and textile processing emerge as especially significant industrial sources. This also includes emissions from on-site and 'captive power' generation used by industrial units.

Brick kilns: Despite their relatively small economic footprint, brick kilns contribute 10% of urban PM2.5 emissions nationally, with higher proportions in rapidly growing cities like Peshawar (19%) and Islamabad-Rawalpindi (18%).

Power generation: While power generation contributes minimally to PM2.5 (2%), it dominates SO2 emissions (33%) due to high-sulfur fuel use in many facilities, creating distinct environmental impacts.

Waste burning: Open waste burning contributes 7% of PM2.5 emissions nationally, with significant variations between cities reflecting different waste management practices and enforcement levels.

Residential: This sector includes emissions from household activities, primarily from fuel combustion for cooking and heating.

Commercial: This sector includes emissions from commercial buildings, markets, and backup power generators.

Sector	Lahore	Karachi	Islamabad-Rawalpindi	Peshawar
Transport	35%	33%	53%	51%
Industry	28%	49%	9%	14%
Brick kilns	17%	0%	18%	18%
Waste	6%	7%	11%	7%
Other	14%	11%	9%	10%

Exhibit 3.3: Relative Contribution of Sectors to PM2.5 Emissions (2021). **This chart reveals the unique emissions fingerprint of each city, demanding tailored, not one-size-fits-all, solutions. Note the significant variation, with industry dominating in Karachi (49%) and transportation dominating in the twin cities (53%).**

Pollutant	Abbreviation	Averaging period	WHO AQG	Pakistan NEQS	NEQS is weaker by
Fine particulate matter	PM2.5	24-hour	15	35	2.3x
Coarse particulate matter	PM10	24-hour	45	150	3.3x
Sulfur dioxide	SO2	24-hour	40	120	3.0x
Ozone	O3	8-hour (peak)	100	130	1.3x
Carbon monoxide	CO	8-hour	5	10	2.0x

Exhibit 3.4: The Governance Gap in Annual Air Quality Standards. **This exhibit compares Pakistan's annual NEQS for key pollutants against WHO's health-based Air Quality Guideline (AQG) and its four interim targets. The NEQS for PM 2.5 only meets the third-strictest interim target, while its standard for PM10 fails to meet even the most lenient WHO target, while the standard for NO_2 meets WHO's Interim Target 2.**

A tale of four cities: distinct, localised crises

This inventory's most critical finding is that Pakistan's air pollution is not a single, monolithic problem, but a series of distinct local emergencies. Each city's economic DNA creates a unique emissions fingerprint, demanding a tailored response.

As Pakistan's industrial and commercial capital, **Karachi** produces the highest absolute volume of emissions. Its pollution profile is a story of chronic industrial metabolism, where emissions from factories and two major ports create a constant health emergency. Unlike any other city, industry is the single largest source of PM2.5 (49%), making industrial policy central to any clean air solution. The path to clean air for Karachi must therefore run directly through its industrial zones and port corridors, focusing on technological upgrades, cleaner fuels, and stringent enforcement. With targeted interventions in industry (20-25% PM2.5 reduction potential) and transport (15-20% potential), significant progress is achievable.

In contrast, **Lahore's** crisis is a story of a toxic, three-part blend, with near-equal contribution from transportation (35%), heavy industry like steel manufacturing (28%), and a dense ring of brick kilns (17%). This diversity of major sources makes it a uniquely complex challenge, requiring a multi-pronged strategy to tackle the severe, year-round pollution and the catastrophic winter smog episodes that define its air quality emergency. Solutions for Lahore must simultaneously address vehicle emissions, industrial smokestacks, and the thousands of surrounding kilns, with a combined PM2.5 reduction potential of over 45%.

Further north, **Peshawar** faces a challenge borne of its geography and economy. Trapped in a valley that contains pollution, its air is poisoned by heavy transit trade, traditional craft industries, and a significant brick kiln sector. This unique mix results in the highest per-person pollution burden in the country, at 2.14 kg of PM2.5 per resident annually. Cleaning Peshawar's air will require a nuanced approach that modernises its role as a trade hub (20-25% PM2.5 reduction potential) while supporting its traditional economic sectors and transitioning its brick kilns to cleaner technologies (25-30% combined potential).

Finally, the **Islamabad-Rawalpindi** airshed serves as a stark warning. With minimal

	World Health Organization (WHO)					Pakistan
Pollutant	**AQG**	**IT-4**	**IT-3**	**IT-2**	**IT-1**	**NEQS**
PM2.5 (µg/m3)	5	10	15	25	35	15
PM10 (µg/m3)	15	20	30	50	70	120
NO2 (µg/m3)	10	20	30	40	N/A	40

Exhibit 3.5: The Governance Gap in Short-Term Air Quality Standards. **This exhibit shows that for daily pollution spikes, Pakistan's standards permit citizens to be exposed to pollutant concentrations far above levels considered safe by WHO, leaving the public vulnerable to acute health impacts.**

industrial sources, the capital region is choked overwhelmingly by its transport sector (53% of PM2.5). It proves that car-centric urban planning and a failure to invest in mass transit are, on their own, enough to create a severe public health emergency. The solution pathway for the twin cities is less about industrial regulation and more about a fundamental reimagining of urban mobility and development, where expanding public transport and managing construction and waste could reduce PM2.5 by over 40%.

The governance gap in air quality standards

The technical sources of air pollution are enabled and exacerbated by deep-rooted systemic issues. A persistent and costly gap exists between inefficient local practices and modern international standards in industry and transport. This is compounded by the dominance of high-sulfur fuels, particularly diesel, which renders modern vehicle emission controls ineffective and significantly increases pollution.

Underpinning these issues is a chronic failure of regulatory enforcement, which allows high-emitting activities to continue with impunity. This enforcement gap is made worse by a **historically inadequate air quality monitoring network** that has prevented both accurate diagnosis and the evaluation of policy effectiveness.

A final, critical failure lies in the standards themselves. Pakistan's National Environmental Quality Standards (NEQS) for ambient air are dangerously out of step with global health science.[4] WHO provides a series of Interim Targets as a roadmap for heavily polluted regions to make incremental progress.[5] As the following exhibits show, Pakistan's legal standards often fail to meet even the most lenient of these interim targets, creating a fundamental chasm in public protection.

This policy gap results in a state of near-constant hazard, as revealed by real-time monitoring data.

[4] Government of Pakistan, Ministry of Environment. (2010). National Environmental Quality Standards for ambient air, S.R.O. 1062(I)/2010. The Gazette of Pakistan, Extraordinary, Part II. Islamabad, Pakistan.

[5] World Health Organization. (2021). WHO global air quality guidelines: Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization.

Airshed	Good Days (within WHO Guidelines)	Unhealthy Days (within NEQS limits)	Hazardous Days (exceeding NEQS limits)
Lahore	0	148	218
Peshawar	0	140	226
Karachi	3	213	150
Islamabad	36	215	115
Rawalpindi	9	140	217

Exhibit 3.6: The Scarcity of Clean Air in Pakistan's Cities (2024). **This chart illustrates the daily reality of Pakistan's air quality crisis. For residents of Lahore and Peshawar, not a single day in 2024 met the global standard for clean air, revealing a near-constant state of exposure to toxic pollution. The data highlights the "policy gap" where days classified as "unhealthy" by global health standards are still considered legal under Pakistan's weaker National Environmental Quality Standards (NEQS).**

Beyond the urban areas

While this inventory focuses on urban airsheds, a complete picture of Pakistan's air quality crisis must acknowledge major contributing sources that are under-researched and often unregulated.

Crop-residue burning

The seasonal burning of crop residue is a major contributor to the dense winter smog that blankets Punjab. A 2020 report by FAO, R-SMOG, estimated that crop burning is responsible for 25% of air pollutant emissions in Punjab (Pakistan) during peak season.[6] As confirmed by NASA, every November, satellites detect large numbers of smoke plumes as farmers in the Punjab region use fire as a fast, inexpensive way to clear fields after the rice harvest. The influx of smoke, combined with meteorological conditions like temperature inversions that trap pollution, leads to a sharp deterioration of air quality.

This phenomenon was particularly severe in 2024. On November 3, satellite imagery captured a thick blanket of smoke streaming from thousands of small fires across the region. Air quality sensors in Lahore recorded hazardous PM2.5 levels on multiple days, prompting school closures and partial lockdowns. However, as NASA scientists explain, smoke from crop fires is not the only contributor to the haze. A toxic mix of urban emissions, from vehicles, industry, and waste burning, combines with the agricultural smoke and is trapped between the Himalayas and the Vindhya Range, creating the catastrophic smog episodes. Based on satellite data, NASA scientists projected that between 15,500 and 18,500 fires would be detected in the region in 2024, a higher number than in most recent years. The lack of effective rural air quality monitoring remains a critical knowledge gap, hindering the development of policies that promote sustainable agricultural practices and provide farmers with viable alternatives to burning.

[6] Food and Agriculture Organization of the United Nations. (2020). Remote sensing for space-time mapping of smog in Punjab and identification of the underlying causes using geographic information system (R-SMOG). FAO.

Household air pollution

Household air pollution is another understudied crisis in Pakistan. The majority of households, particularly in rural and low-income urban areas, lack access to clean cooking fuels. Limited natural gas connections and the unaffordability of LPG force millions to rely on the indoor burning of biomass, such as wood, animal dung, and crop waste, for cooking and heating. This practice releases a toxic mix of particulate matter and other pollutants directly into the living space, leading to severe health impacts, particularly for women and children who are most exposed.[7] A recent study in The Lancet highlighted that by curbing solid biofuel combustion, Pakistan could achieve a 13-21% greater reduction in health costs compared to relative improvements in air quality from other sources, underscoring the immense public health return on investment from addressing this sector.[8]

Open burning of waste

Across Pakistan's cities, a significant portion of municipal solid waste is not collected or managed safely. This leads to the widespread practice of open waste burning, both at large dump sites and on neighbourhood street corners. This uncontrolled combustion releases a hazardous cocktail of pollutants, including dioxins, furans, and black carbon. Effective solutions require a systemic transformation in waste management, applying the principles of reduce, reuse, and recycle. This includes empowering the informal sector of waste pickers, ensuring effective and consistent waste removal, and investing in modern, sanitary landfill management to prevent fires and environmental contamination.

A path forward

This inventory challenges the narrative that air pollution is an intractable issue or driven primarily by forces beyond Pakistan's control. It proves that the sources are local, measurable, and—most importantly—actionable. The science is now established, the primary sources are identified, and the technological solutions are well-understood. With this evidence as a foundation, a future with cleaner, healthier air for all Pakistanis is within reach, requiring only the political will to transform this science into clean, breathable air for Pakistan.

A note on methodology and data

This report uses the 2021 calendar year as the baseline for the emissions inventory, representing the most recent year with complete, verifiable activity data across all sectors at the time of analysis.

The analysis of daily air quality compliance (number of clean vs. hazardous days) uses real-time monitoring data from the PAQI network for the 2024 calendar year to reflect the most current state of public exposure.

[7] World Health Organization. (2014). WHO guidelines for indoor air quality: Household fuel combustion. World Health Organization.

[8] Yin, H., Brauer, M., Apte, J. S., Guttikunda, S., Harvey, B. G., Jayaraman, G., et al. (2024). Global health costs of ambient $PM_{2.5}$ from combustion sources: A modelling study supporting air pollution control strategies. The Lancet Planetary Health, 8(7), e476–e488.

The canal running through Lahore, usually a vibrant artery of city life, is muted by the seasonal grey haze. The 'fifth season' of smog transforms the city's geography, turning open spaces into reservoirs of trapped pollutants.
Photo by Mahera Omar/Pakistan Air Quality Initiative

4.

Lahore

The epicentre of the air quality crisis

Global epicentre of smog: Lahore's annual PM2.5 pollution is nearly 21 times the WHO health guideline, cementing its status as one of the most polluted cities on Earth and costing the average resident 7 years of life expectancy.

No clean air days: In the entirety of 2024, Lahore did not experience a single day of clean air that met WHO standards; on 218 days, the air was so polluted it was classified as hazardous even by Punjab's Environmental Quality Standards (PEQS).

A complex crisis: Lahore's crisis is a three-way battle against a toxic blend of emissions from transportation (35%), industrial activities (28%), and a dense ring of brick kilns (17%).

In Lahore, the poison has become a season. The arrival of winter 'smog' is treated as an inevitability, a fog to be endured rather than a public health failure to be solved. This chapter dismantles that dangerous myth, providing the scientific evidence that Lahore's crisis is not seasonal, but chronic: a year-round catastrophe driven by specific, controllable sources.

Pakistan's second-largest city and the provincial capital of Punjab, Lahore stands as the undisputed hub of the nation's air quality emergency. For years, it has captured international headlines, consistently ranking among the world's most polluted cities. Its struggle with toxic air, particularly the severe winter smog that paralyses daily life, is a crisis on the scale of other regional megacities like New Delhi; demanding a granular, evidence-based diagnosis to move beyond speculation and towards solutions.

The history of a long-known crisis

This pollution emergency did not develop overnight. Air pollution monitoring reports from the Pakistan Environment Protection Agency (Pak-EPA) dating back to 2004 documented Lahore's deteriorating air quality, leading to the 2006 Pakistan Clean Air Programme (P-CAP). While that initiative achieved limited success through banning two-stroke rickshaws and promoting CNG fuel conversion, conditions have worsened dramatically

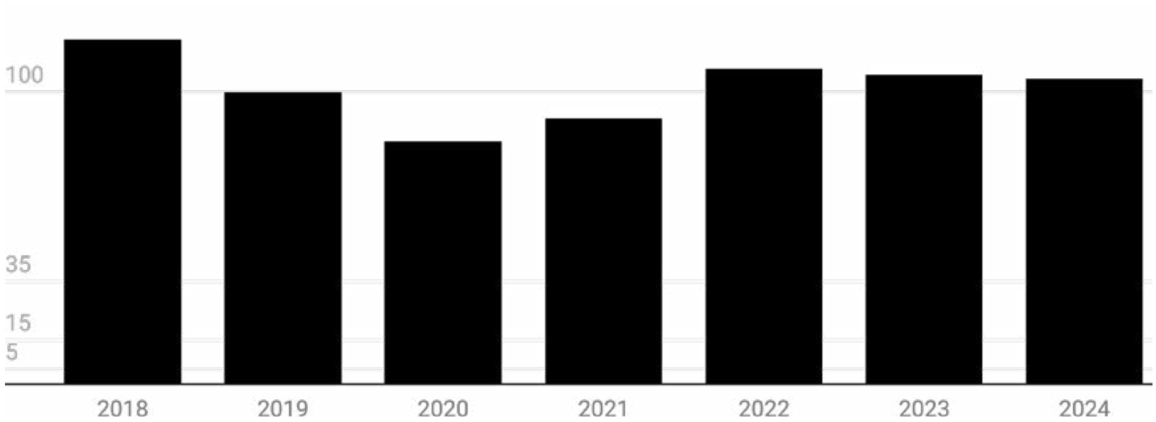


Exhibit 4.1: Lahore's Chronic Pollution Problem (Annual Averages 2018-2024). **This chart shows Lahore's staggering annual average PM2.5 concentration over the last seven years. The consistently hazardous levels—all of which dramatically exceed the WHO Guideline—illustrate a long-term, unresolved public health crisis, not a new phenomenon.**

since 2016.[1] The severity of the crisis eventually required judicial intervention through the Lahore High Court (LHC), which began directing the Punjab government to impose policies for curtailing pollution.[2]

Despite these decades of recurring crises and judicial action, Lahore has lacked both comprehensive air quality monitoring networks and systematic source apportionment studies. While some previous efforts, such as an inventory for Lahore by the Urban Unit have been undertaken,[3] there has been no comprehensive, multi-city, scientifically-benchmarked assessment to guide national policy. This emissions inventory addresses this critical gap, providing the scientific foundation needed for effective policy action.

A city breathing toxic air

The narrative of Lahore's pollution as a mere "winter smog" problem is a dangerous misconception that has delayed meaningful action. The data from PAQI's monitoring network reveals a year-round public health failure. The annual average pollution has remained stubbornly high for years, with no significant trend of improvement. In 2024, Lahore's **annual average PM2.5 concentration** was a staggering **104.6 µg/m³**. This level is not just high; it is an undeniable indictment of the city's environmental state, standing at seven times Pakistan's own National Environmental Quality Standard (NEQS) and nearly 21 times the level considered safe by the World Health Organization.

[1] World Bank. (2014). Cleaning Pakistan's Air: Policy Options to Address the Cost of Outdoor Air Pollution. Washington, D.C.: World Bank Group.

[2] The Government of Punjab. (2017). Integrated Context Analysis of Smog in Punjab. Urban Unit, Planning & Development Department.

[3] Ilyas, H., & Nissar, H. (2023). Sectoral emissions inventory of Lahore. The Urban Unit.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2017										280.8	316.7	204.0	196.3
2018	221.6	121.6	89.6	67.3	65.4	67.3	58.4	50.3	54.9	152.1	186.7	277.8	118.0
2019	192.4	116.5	83.4	70.9	65.6	55.6	50.7	48.8	63.4	117.5	139.0	195.9	100.0
2020	151.2	114.5	51.3	33.9	43.5	42.8	44.0	34.5	61.9	113.1	149.1	158.0	83.1
2021	140.0	131.5	54.3	40.3	33.5	30.9	26.7	36.1	49.8	91.8	228.5	231.9	91.0
2022	149.2	114.3	96.9	81.4	74.8	63.8	57.4	51.5	70.7	131.5	202.9	201.4	108.0
2023	156.6	130.4	86.7	58.8	58.0	49.7	42.7	44.3	57.2	128.1	252.4	208.1	105.9
2024	160.4	121.9	85.1	49.1	63.0	40.0	60.8	40.6	60.2	127.1	286.4	162.1	104.6
2025	150.7	102.7	64.9	61.3	57.2	45.1							80.3

Exhibit 4.2: The Seasonal Cycle of Lahore's Air Pollution (2016-2025). **This heatmap visualises the monthly average PM2.5 concentrations for each year, revealing a stark and predictable pattern. Pollution consistently begins to rise in October (purple), peaks dramatically during the winter months of November through February, and recedes during the monsoon season (red). This demonstrates that Lahore's 'smog season' is not an occasional event but a chronic, recurring public health threat each winter.**

The 'fifth' season of smog

Lahore's pollution crisis intensifies dramatically during winter months through a perfect storm of meteorological and human factors. Temperature inversions trap pollution near ground level from November through February, preventing vertical mixing and dilution. This phenomenon, termed a "meteorological misfortune" for the Indo-Gangetic plain,[4] essentially places a lid over the city, causing pollutant concentrations to build rather than disperse.

Compounding this, post-harvest crop burning in the surrounding region can contribute 30-50% of ambient pollution during early November. Furthermore, seasonal natural gas shortages often drive a 2-3x increase in residential emissions as households turn to burning wood, coal, and even waste for warmth.

The daily reality for Lahore's citizens is catastrophic. Data from our monitoring network shows that in the entirety of 2024, residents experienced **zero days** of air quality meeting WHO's 24-hour guideline for safe air. On **218** of those days, pollution was so severe it also breached the government's own weak legal limit, underscoring a state of near-perpetual non-compliance.

Anatomy of Lahore's pollution

This daily reality of hazardous air is a direct result of a complex mix of emission sources.

[4] Singh, S. (2018). The Great Smog of India. Penguin Viking.

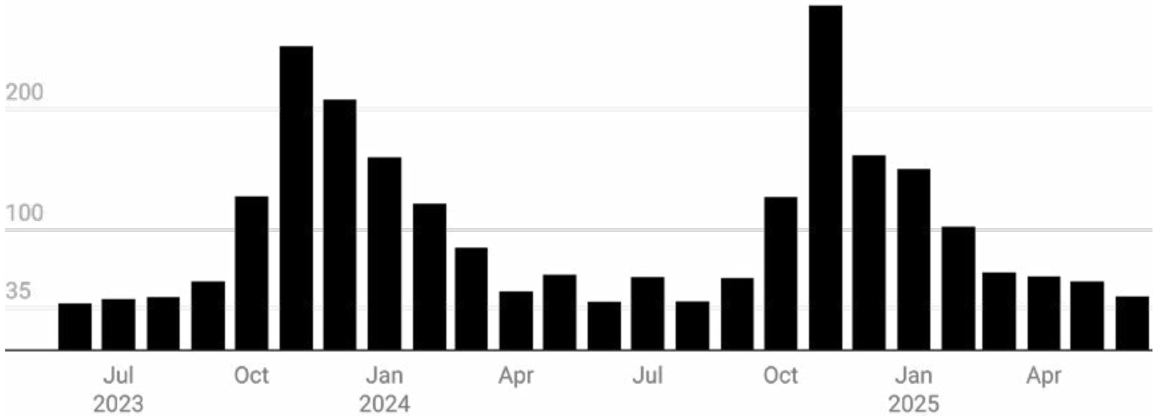


Exhibit 4.3: Lahore's Seasonal Pollution Cycle (July 2023 to June 2025). **This chart illustrates the stark seasonal pattern of Lahore's air pollution. While the air is unhealthy year-round, pollution levels begin to rise in October and soar during the winter months of November through January, creating a predictable and severe "fifth season of smog".**

This inventory estimates that Lahore's airshed is burdened annually with **26.68 kilotons of PM2.5**, 39.81 kilotons of SO2, 52.65 kilotons of NOx, and 207.08 kilotons of CO. The sectoral breakdown reveals a complex challenge dominated by three sectors.

The diesel dilemma

Within the transport sector, Lahore's 7+ million vehicles present a striking pollution paradox. Despite comprising just 20% of the vehicle fleet, diesel-powered trucks, buses, and utility vehicles generate over 65% of transportation-related PM2.5. This disproportionate contribution highlights the critical importance of addressing diesel emissions specifically. Meanwhile, the city's massive motorcycle fleet—estimated at 4.74 million vehicles—contributes disproportionately to carbon monoxide emissions through incomplete combustion, creating a dual challenge that requires differentiated strategies.

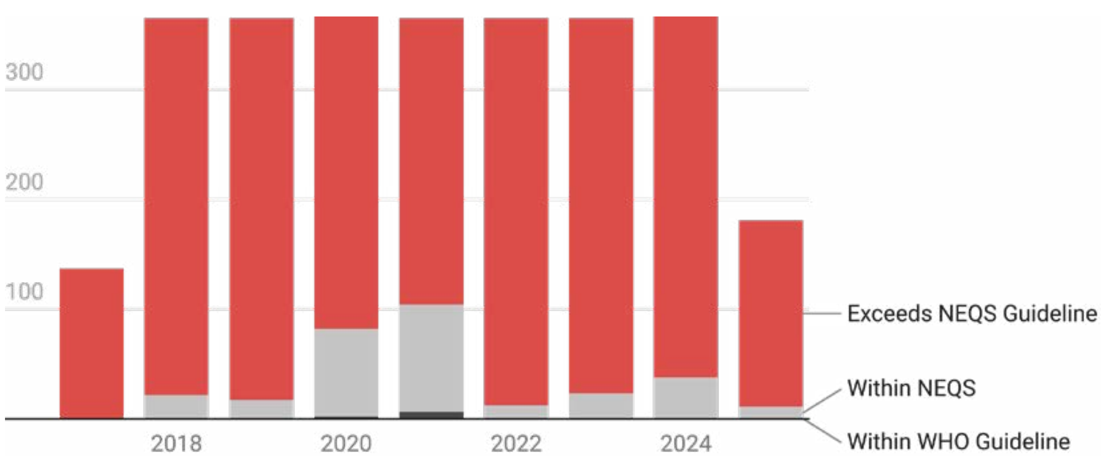


Exhibit 4.4: The Daily Health Burden in Lahore (2024). **This chart illustrates the daily reality of breathing Lahore's air. The complete absence of green ("Meets WHO Guideline") shows that not a single day in 2024 had clean air. The vast majority of days fall into categories that exceed Pakistan's national standards (yellow) or are so hazardous they also breach Punjab's own legal limits (red), demonstrating a state of perpetual crisis.**

Total annual emissions in kilotons in Lahore					
Sector	**PM2.5**	**SO2**	**NOx**	**CO**	**Total**
Transport	9.27	11.2	43.06	170.63	234.16
Industry	7.52	6.81	4.02	2.81	21.16
Brick Kilns	4.50	4.42	0.32	12.74	21.98
Power	0.09	15.88	2.61	0.24	18.82
Household	2.05	0.04	1.49	12.53	16.11
Waste	1.56	0.04	0.04	7.51	9.15
Commercial	1.69	1.42	1.11	0.62	4.84
Total	**26.68**	**39.81**	**52.65**	**207.08**	**326.22**

Exhibit 4.5: Sectoral Contributions to Air Pollutant Emissions in Lahore (2021). **The transportation sector is the primary source of NOx and CO, while the power sector is the main contributor of SO2. Industry and transport are the leading sources of health-damaging PM2.5.**

Industry and brick kilns

Lahore is encircled by a ring of industrial activity and brick kilns that operate with few emission controls. The city's industrial sector, particularly steel manufacturing and foundries, contributes 28% of all PM2.5. Despite occupying less economic space, the brick kiln sector contributes a disproportionate 17% of Lahore's PM2.5, often burning high-polluting fuels like rubber and waste in outdated, inefficient kilns.

Mapping the hotspots

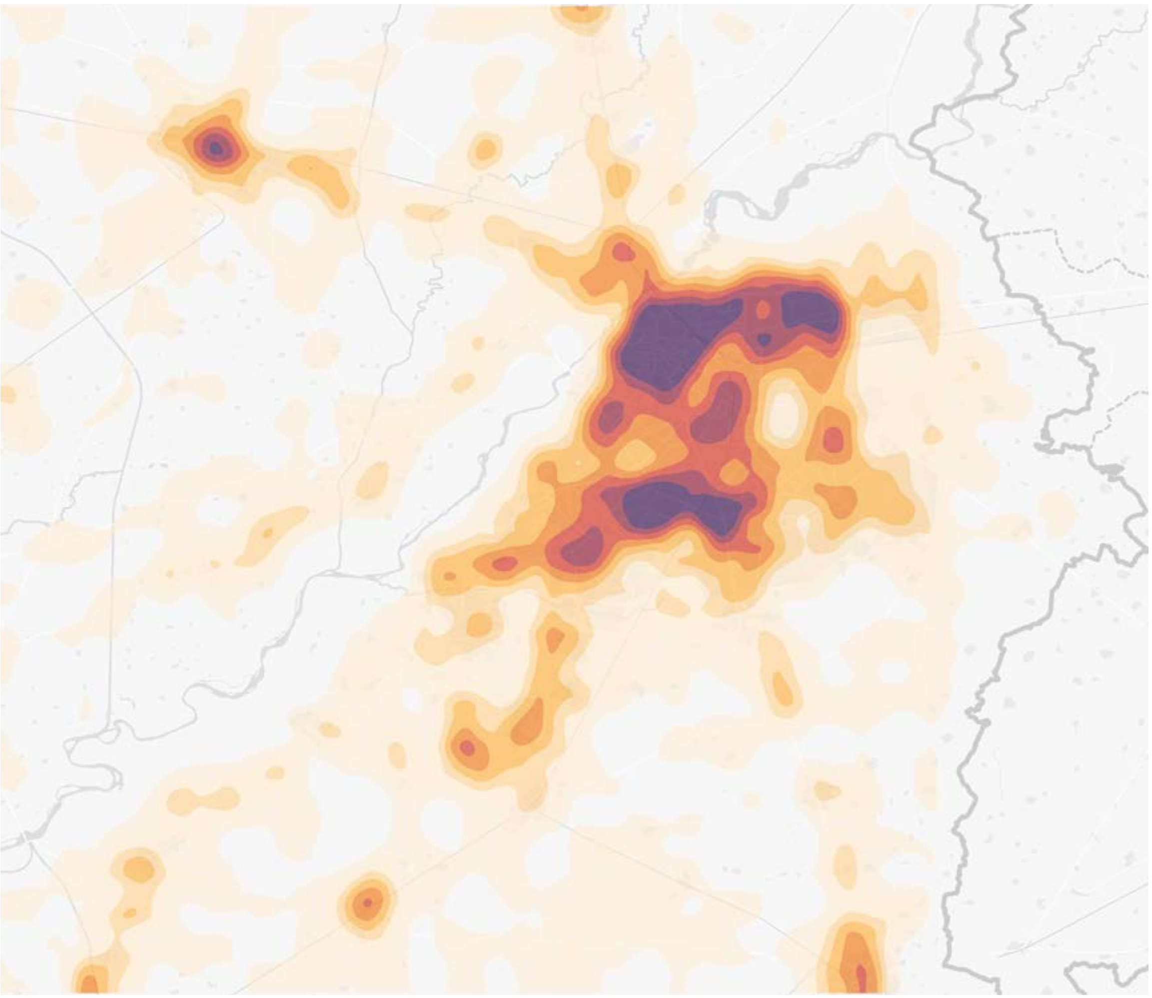
Lahore's pollution isn't distributed equally. Our spatial analysis reveals distinct concentration patterns that should guide targeted interventions. PM2.5 and NOx emissions concentrate along major arterial roads and the ring road system. Heavy particulate concentrations appear in southern and eastern industrial zones, particularly around steel manufacturing areas. The historic urban core shows higher composite pollution levels due to congestion and commercial density, while traditional brick kilns form a ring around the city perimeter, creating concentrated emission zones in peri-urban areas.

A path to cleaner air for Lahore

This emissions inventory points to a clear, evidence-based path forward. The following interventions, targeting the dominant sources identified in this report, could reduce Lahore's health-damaging PM2.5 pollution by up to 50% if fully implemented.

1. Transportation controls

As the largest single source of PM2.5 (35%) and the overwhelming source of toxic NOx and CO, Lahore's transport sector is the highest-priority area for intervention, with a **PM2.5 reduction potential of 20-25%**. A successful strategy must be surgical, targeting the super-emitting vehicles and systemic issues that drive emissions up.



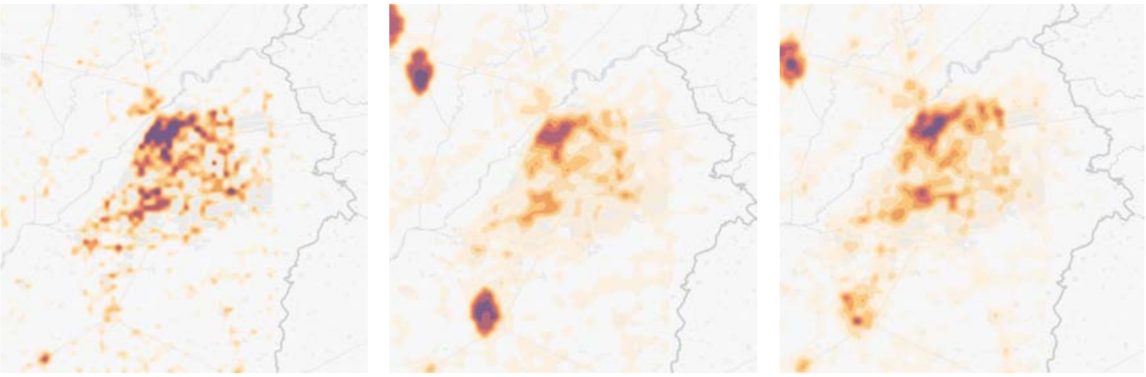


Exhibit 4.8: Spatial Distribution of Emissions in Lahore (2021). **These heatmaps show the concentration of PM2.5 (top), SO2 (left), NOx (middle), and CO (right) emissions. The data reveals pollution hotspots along major transportation corridors like the Ring Road and in the industrial zones to the south and east of the city centre.**

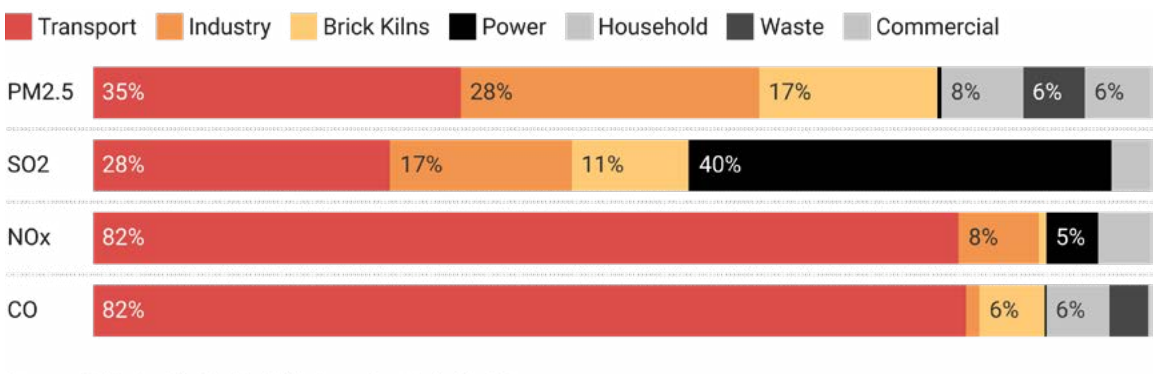


Exhibit 4.5: The Emissions Fingerprint of Lahore's Pollutants. **Lahore's air quality challenge requires a multi-pronged strategy. While the transport sector is the overwhelming source of NOx and CO, the most health-damaging pollutant, PM2.5, comes from a more complex mix of transport, industry, and brick kilns. Tackling one source alone will not solve the crisis.**

— **Vehicle inspection and maintenance:** Implement a rigorous, mandatory, and corruption-proof vehicle inspection programme specifically targeting the commercial diesel fleet (trucks and buses).

— **Low emission zones:** Establish LEZs in central Lahore to restrict or charge the most polluting vehicles, which will accelerate fleet turnover and reduce exposure in the most congested areas.

— **Fuel quality improvement:** Accelerate the transition to higher fuel quality standards, specifically mandating low-sulfur Euro-V diesel, which is critical for enabling modern emission control technologies.

— **On-road enforcement:** Deploy remote sensing technology to identify and penalise super-emitting vehicles in real-time, moving beyond traditional, and often ineffective, visual inspections.

2. Industrial emission controls

The industrial sector is Lahore's second-largest PM2.5 source (28%) and a major contributor to toxic SO2, with a **PM2.5 reduction potential of 15-20%**. The problem is driven by the widespread use of outdated production methods, particularly in steel manufacturing, and a lack of modern pollution control technologies.

— **Control technologies:** Mandate and enforce the installation of proven abatement technologies, such as electrostatic precipitators (ESPs) or fabric filters (baghouses), in all major industrial facilities, especially steel factories and foundries.

— **Fuel switching:** Support the conversion of industrial boilers and furnaces from high-polluting fuels like coal and furnace oil to cleaner alternatives like natural gas.

— **Continuous monitoring:** Require the installation of Continuous Emissions Monitoring Systems (CEMS) for all large industrial facilities to ensure compliance with environmental standards is verified with real-time data.

3. Brick kiln modernisation

This sector requires an accelerated and complete technological transformation. The disproportionate impact of brick kilns, contributing 17% of PM2.5, makes them a high-leverage target with a PM2.5 reduction potential of 10-12%.

— **Technology transition:** Enforce and accelerate the complete transition from outdated Fixed Chimney Bull's Trench Kiln (FCBTK) technology to modern, significantly cleaner zigzag kilns.

— **Fuel regulation:** Implement a strict ban on the use of all high-polluting fuels in kilns, including waste materials and rubber tires, with strong penalties for non-compliance.

— **Next-generation pilots:** Support pilot programmes for next-generation technologies, such as electric or renewable-powered kilns, to create a pathway for future modernisation.

4. Seasonal action plan

While the interventions above address the root causes of chronic pollution, a specific emergency action plan with a **winter PM2.5 reduction potential of 5-10%** is necessary to protect public health during the predictable, severe winter smog episodes.

— **Emergency response protocols:** Establish a data-driven public health alert system to trigger pre-planned, temporary restrictions on non-essential traffic, construction, and high-emitting industrial activities during severe smog episodes.

— **Regional coordination:** Enhance coordination with neighbouring districts and provinces to manage and eliminate agricultural crop burning during the critical post-harvest season.

— **Crop residue management:** Promote and subsidise alternative technologies and business models for managing crop residue, such as conversion into biofuel or animal fodder, to provide farmers with viable alternatives to burning.

Several of these recommendations were highlighted in a November 2024 letter to the Prime Minister from the Pakistan Air Quality Experts (PAQx) group—a coalition of 27 professionals. Their urgent call to action underscored the need for both emergency measures to provide immediate respite and the longer-term structural solutions detailed in this inventory.[5]

[5] Pakistan Air Quality Experts (PAQx). (2024, November). Urgent Recommendations for Addressing Pakistan's Air Pollution Crisis. Letter to the Prime Minister of Pakistan.

PAQx Pakistan Air Quality Experts' group

Pakistan Air Quality Initiative

11th November 2024

To,
The Honorable Prime Minister of Pakistan
Government of Pakistan

Subject: Urgent Action on Pakistan's Air Pollution Crisis: A Science-Based Approach to Public Health Protection

Dear Prime Minister,

The severe decline in air quality across Punjab and other regions of Pakistan has reached hazardous levels, posing a critical public health risk that demands immediate and strategic action. This situation is urgent and requires a unified effort to protect the health and well-being of millions of citizens.

Data on particulate matter pollution indicates that October and November 2024 have been the worst on record, with air quality levels exceeding World Health Organization (WHO) guidelines and surpassing Pakistan's own legal limits. The widespread impact of this pollution is being felt across major urban centers, with millions of citizens suffering from respiratory ailments and other health complications.

The Pakistan Air Quality Experts (PAQx) group, a coalition of 27 professionals from fields such as public health, environmental science, law, and economics, remains committed to addressing this public health crisis. While the National Clean Air Policy and Punjab's Clean Air and Smog Mitigation Plans are a good starting point, PAQx believes that an approach grounded in scientific evidence and global best practices is essential to effectively manage air pollution.

PAQx offers the following immediate recommendations:

1. **Shut Down All Brick Kilns:** Brick kilns are one of the largest contributors to air pollution in the region. A shutdown would immediately reduce emissions by 15%.
2. **Vehicle Emission Controls and temporary Heavy transport curtailment**: A focused crackdown on vehicles that fail to meet emissions standards and curtailing heavy transport from 10 pm to 10 am would provide an immediate reduction in harmful pollutants in urban areas by a further 15%.
3. **Shut Down All Non-Compliant Polluting Industries:** Industries that fail to comply with environmental standards should be shut down, significantly reducing air pollution levels in highly populated areas by 15%. This shutdown should be in effect during smog emergencies and continue until a roadmap for emissions controls is in place.

PAQx offers the following overall recommendations to guide the development of a sustainable plan for clean air:

1. **Proactive and comprehensive policy-making:** Air pollution is a year-round challenge that requires long-term, coordinated, evidence-based solutions across multiple sectors including health, education, energy, transport, oil standards, and finally transboundary cooperation.

Page(s) 1 / 2
Email: hello@pakairquality.com

PAQx Pakistan Air Quality Experts' group

Pakistan Air Quality Initiative

2. **Alignment with WHO Air Quality Standards:** Revising Pakistan's air quality standards to align with WHO guidelines based on health outcomes. We propose adopting interim target 1 of the WHO air quality guidelines as a short-term goal to be achieved within 3 years for designated attainment airsheds.
3. **Nationwide Real-Time Air Quality Monitoring Network**: Establishing a comprehensive, nationwide real-time air quality monitoring network is crucial for informed decision-making and responsive policymaking. Such a system would provide continuous real-time data enabling timely alerts and empowering both citizens and policymakers to take swift, effective action in managing air quality.
4. **Airshed-Level Management:** Policies should focus on managing pollution across the meteorological airshed, with localized mitigation as the starting point for transboundary cooperation.
5. **Establish clean air zones as a pilot:** Designate Lahore and the twin-cities of Ralwapindi/Islamabad as focal points for attaining clean air while policies are being planned.
6. **Sustainable Urban Planning and Transportation:** A shift toward urban planning that prioritizes sustainable public transit and low-emission technologies.
7. **Strengthening Regulatory Capacity:** Enhance the government's regulatory capacity across departments to enforce air quality standards as an overarching target to ensure compliance across all sectors.
8. **Transition to Clean Technology:** Accelerating the transition to clean technologies, such as electric mobility, clean industrial practices, and alternative cooking and heating solutions, should be prioritized along with a focus on improving overall energy efficiency.
9. **Upgrade of fuel quality:** Vehicle emissions standards to be equivalent to Euro-6 standards, along with upgrades of fuel quality available in the supply chain.
10. **Evidence-Based Decision-Making:** Prioritizing epidemiological research to better understand the health impacts of air pollution.
11. **Equitable and sustainable policies:** Air pollution disproportionately affects vulnerable communities and has significant ecological impacts. Addressing these inequalities should be a central focus of policy development.
12. **Crop Residue Management:** A targeted strategy to engage farmers and the introduction of technological solutions for residue management to support adoption of sustainable alternatives.

These recommendations reflect a collaborative, science-based approach to tackling air pollution. We believe that their implementation will help Pakistan move toward a cleaner, healthier future.

The PAQx group is fully committed to working alongside the government and other stakeholders to craft policies that address the root causes of pollution and protect public health.

Yours sincerely,
Pakistan Air Quality Experts (PAQx) group

FOR IMMEDIATE RELEASE

Contact Dawar H. Butt (Convenor, PAQx) at dawar@pakairquality.com for any inquiries.

Page(s) 2 / 2
Email: hello@pakairquality.com

Open waste burning in the Korangi Industrial Area releases untreated toxins directly into the street-level atmosphere. This common practice across Karachi creates localized hotspots of hazardous pollution, exposing nearby workers and residents to a hazardous cocktail.
Photo by Pakistan Air Quality Initiative

5.

Karachi

A metropolis under an industrial haze

An industrial crisis: Karachi's air pollution is overwhelmingly driven by its industrial sector, which is responsible for nearly half (49%) of all health-damaging fine particulate matter (PM2.5).

A constant health threat: Karachi's air was unhealthy by WHO standards on 363 days in 2024. The annual average of 46.2 µg/m³ is over 9 times the global health guideline, costing the average resident 2.7 years of life expectancy.

Unique port city challenges: Emissions from two major seaports, the nation's largest fleet of heavy-duty diesel trucks, and thousands of diesel water tankers create a pollution profile unlike any other city, demanding a strategy focused on industry, freight, and fuel quality.

For decades, Karachi's haze has been accepted as the inevitable byproduct of its economic might: the cost of being Pakistan's largest city, its industrial heart, and its gateway to the world. This chapter rejects that premise. It provides evidence to prove that the city's toxic air is not a sign of progress, but of inefficiency, and that a healthier, more competitive Karachi is possible when its industrial and economic engines are powered by clean air.

As Pakistan's largest city and economic engine, Karachi confronts a distinct air quality challenge. This is not just a city of factories, but a complex ecosystem of logistics, where the country's largest concentration of heavy-duty trucks moves between ports and industrial zones, and thousands of diesel water tankers serve as a mobile fleet of polluters. Home to 21 million people, its pollution profile is dominated by a vast industrial base and two major seaports, creating an emissions landscape different from any other Pakistani urban centre. While often perceived to have better air due to its coastal location, the data reveals a year-round public health crisis that consistently fails to meet both national standards and global health guidelines. This chapter builds upon the foundational data and analysis first presented in PAQI's 2025 emissions inventory specific to the city, *Unveiling Karachi's Air*.[1]

[1] Pakistan Air Quality Initiative (PAQI). (2025). *Unveiling Karachi's Air: A Scientific Foundation for a Clean Air City*. Karachi, Pakistan.

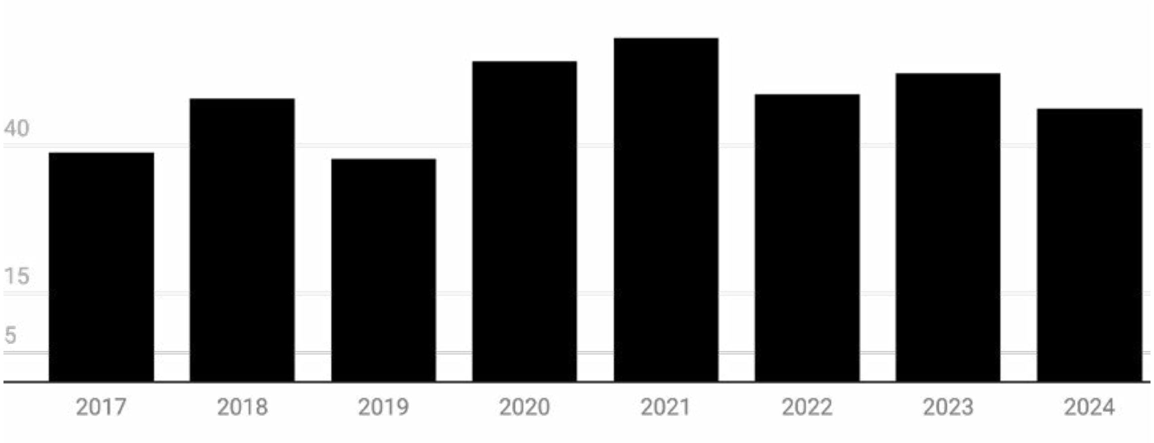


Exhibit 5.1: Karachi's Chronic Pollution Problem (Annual Averages 2017-2024). **For the last eight years, Karachi's air has never met WHO's safe guideline. The annual average pollution consistently exceeds even the National (NEQS) and provincial Sindh Environmental Quality Standards (SEQS), with no significant trend of improvement.**

An industrial city's constant haze

Karachi's air pollution is not a seasonal event but a chronic condition driven by its relentless industrial and economic activity. In 2024, the city's annual average PM2.5 concentration was **46.2 µg/m³**. This level is over 9 times WHO's annual health guideline and more than three times Pakistan's own National Environmental Quality Standards (NEQS) and the provincial Sindh Environmental Quality Standards (SEQS).[2] [3] This data confirms that even with the coastal breeze that helps disperse air pollution, Karachi's own human-caused emissions create a constant public health emergency.

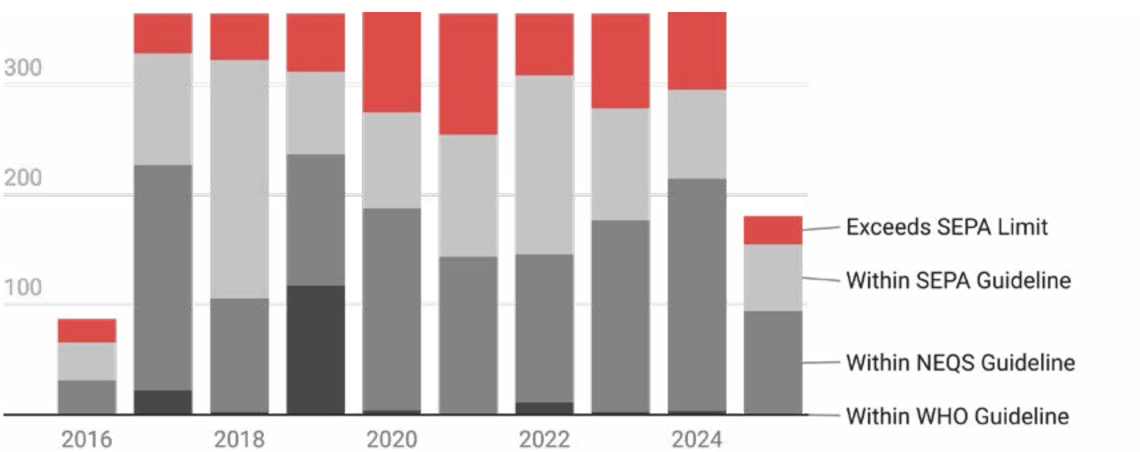


Exhibit 5.2: The Daily Health Burden in Karachi (2016-2025). **This chart illustrates the daily reality of breathing Karachi's air. The small segments at the bottom highlight how exceptionally rare clean air days are according to WHO guidelines. Note: *Data for 2016 is partial. **Data for 2025 is for the year-to-date.**

[2] World Health Organization. (2021). *WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. Geneva: World Health Organization.

[3] Government of Sindh, Environmental Protection Agency. (2016). *Sindh Environmental Quality Standards, Notification No.EPA/TECH/739/2014*.

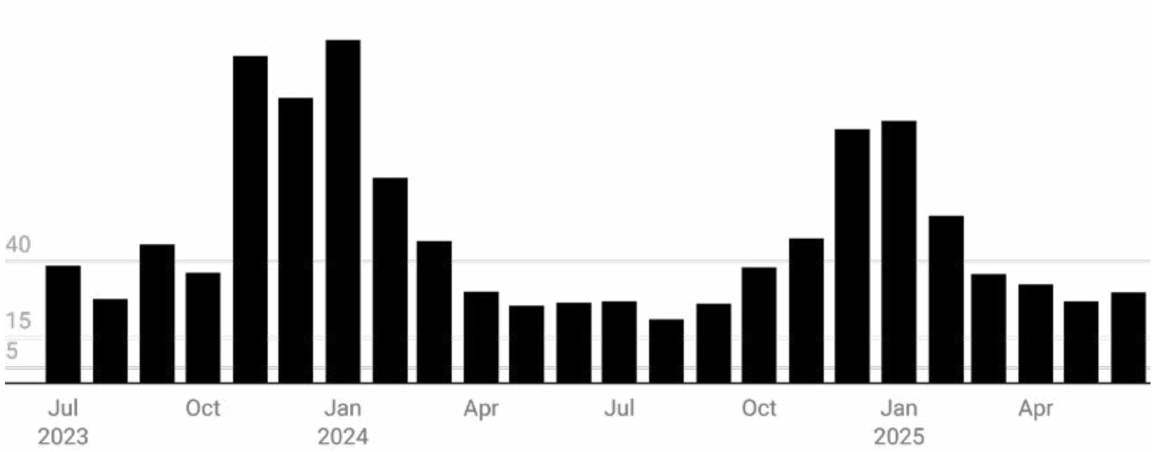


Exhibit 5.3: Karachi's Seasonal Pollution Cycle (Monthly Averages July 2023 to June 2025). **This chart of monthly average PM2.5 concentrations reveals a stark and predictable seasonal pattern. Pollution levels consistently begin to rise in October and peak dramatically during the winter months, creating a prolonged season of hazardous air.**

While Karachi does not experience the extreme winter smog of inland cities in Punjab, a clear seasonal pattern persists. During the winter of 2023-2024, pollution levels were **4.3 times higher** than the subsequent monsoon average. The sea breeze provides some dispersion, but not enough to overcome the combined effect of winter meteorology and the city's massive emissions load. In 2024, only **3 days** met WHO's daily guideline, while on **70 days**, pollution was so high it exceeded legal limits set by the Sindh Environmental Protection Agency (SEPA).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2016										27.9	63.0	65.7	53.5
2017	86.8	60.0	29.2	25.9	41.7	24.4	22.9	19.1	17.6	32.1	62.4	67.5	38.8
2018	80.8	59.3	44.6	54.1	41.7	43.2	42.5	37.2	23.1	46.3	49.8	49.4	47.9
2019	50.4	23.9	20.7	13.3	11.4	12.4	13.9	17.6	37.8	55.2	71.9	122.8	37.7
2020	83.4	72.3	42.0	27.5	26.2	27.3	26.2	26.7	33.8	52.0	109.3	126.7	54.3
2021	87.5	103.1	45.6	41.7	31.6	32.7	29.5	24.5	33.3	54.3	99.0	90.8	58.2
2022	67.1	50.8	45.0	36.9	40.5	26.3	21.0	29.7	33.0	47.9	74.8	112.1	48.7
2023	89.5	64.4	50.9	29.6	27.2	29.6	31.1	27.8	45.7	36.4	107.9	94.0	52.2
2024	113.7	67.7	46.9	30.2	25.7	26.6	27.1	21.0	26.3	38.1	47.7	83.8	46.2
2025	86.4	55.1	35.9	32.5	27.0	30.0							44.5

Exhibit 5.4: The Seasonal Cycle of Karachi's Air Pollution (2016-2025). **This heatmap visualises the monthly average PM2.5 concentrations for each year, revealing a stark and predictable pattern. Pollution consistently begins to rise in October (red), peaks dramatically during the winter months of November through February (purple), and recedes during the monsoon season (orange). This demonstrates that Karachi's 'smog season' is not an occasional event but a chronic, recurring public health threat each winter.**

Total annual emissions in kilotons in Karachi					
Sector	**PM2.5**	**SO2**	**NOx**	**CO**	**Total**
Transport	12.77	20.29	81.11	183.87	298.04
Industry	19.10	13.37	9.55	6.59	48.61
Power	1.34	15.66	8.11	0.90	26.01
Household	0.56	0.04	1.49	3.67	5.76
Waste	2.68	0.04	0.04	7.68	10.44
Commercial	2.66	2.12	0.48	0.70	5.96
Total	**39.11**	**51.52**	**100.78**	**203.41**	**394.82**

Exhibit 5.5: Karachi's Industrial-Heavy Inventory. **Unlike Pakistan's other cities, Karachi's pollution profile is defined by industry. This breakdown reveals that industrial activities generate nearly half of the city's PM2.5, overshadowing even the transport sector.**

The price of inefficient industry

Unlike any other major city in Pakistan, Karachi's air pollution is overwhelmingly driven by its industrial sector. This inventory estimates Karachi's annual emissions at **39.11 kilotons of PM2.5**, 51.52 kilotons of SO2, 100.78 kilotons of NOx, and 203.41 kilotons of CO.

Industrial sources are the largest contributor, responsible for nearly half (**49%**) of all PM2.5 emissions.

Transportation is the second-largest source at **33%** of PM2.5, but it dominates NOx emissions (80%).

Power generation facilities contribute a major share of sulfur dioxide (30%).

For Karachi, the economic case for clean air is inseparable from its identity as an industrial and commercial hub. High emissions are symptoms of inefficiency, outdated technology, and poor fuel quality—all of which undermine the long-term competitiveness of its core economic sectors. Investing in cleaner industrial processes and modernising port logistics is not just an environmental measure; it is a strategy for improving operational efficiency, reducing fuel costs, and meeting international supply chain standards.

These emissions are exacerbated by systemic challenges unique to the city. The heavy reliance on an aging diesel truck fleet is compounded by the widespread use of low-quality or smuggled fuels with high sulfur content, drastically increasing emissions. Furthermore, the city's water supply gaps have created a unique pollution source: a mobile fleet of thousands of diesel-powered water tankers operating daily. This combination of industrial scale, port logistics, and specific urban challenges defines the core of Karachi's air quality crisis.

A path to cleaner air for Karachi

Karachi's unique emissions profile requires a strategy focused on its economic drivers. The following evidence-based interventions could reduce urban PM2.5 emissions by up to 50%.

1. Industrial emission controls

With industry responsible for nearly half of all PM2.5, modernising this sector is the single most impactful intervention for Karachi, with a **PM2.5 reduction potential of 20-25%**. This requires a regulatory push to close the technology and enforcement gap.

— **Control technologies:** Mandate and enforce the use of Best Available Control Technologies (e.g., Electrostatic Precipitators, Flue Gas Desulfurisation) in all major industries, particularly in the steel, cement, and textile sectors.

— **Continuous monitoring:** Require Continuous Emissions Monitoring Systems (CEMS) for all large industrial facilities to ensure compliance and provide transparent, real-time data.

— **Fuel quality:** Enforce fuel standards for industrial boilers and furnaces to phase out the use of high-sulfur furnace oil.

2. Heavy-duty vehicle regulation

Karachi's economy runs on diesel, and the emissions from its massive fleet of trucks and buses are a primary cause of toxic NOx and a major source of PM2.5. A dedicated strategy for this sector has a **PM2.5 reduction potential of 15-20%.**

— **Vehicle inspections:** Implement a targeted and rigorous inspection and maintenance programme for commercial diesel vehicles, which are the highest emitters in the transport fleet.

— **Low Emission Zones:** Establish LEZs in port-adjacent areas and key industrial corridors

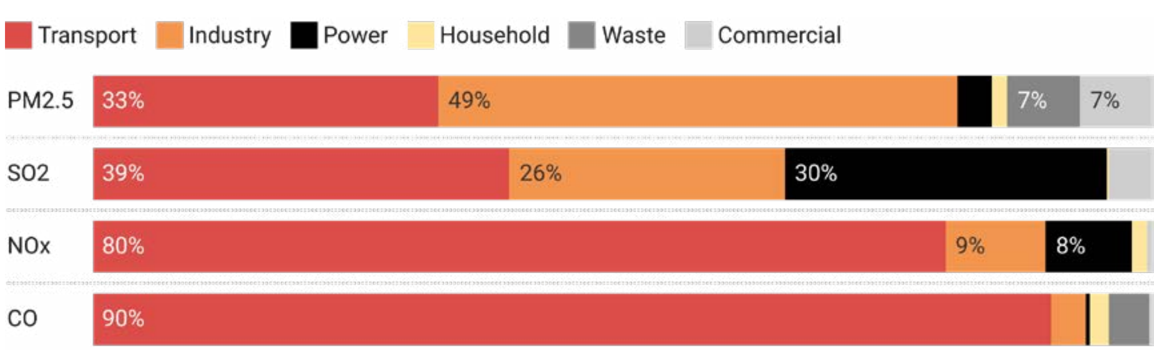


Exhibit 5.6: The Emissions Fingerprint of Karachi's Pollutants. Karachi's air is poisoned by its two great economic engines: industry and transport. Industrial emissions are the primary source of the most health-damaging pollutant, PM2.5, while the city's vast transportation network is the overwhelming source of NOx and CO. An effective clean air strategy for Karachi must therefore be a two-front war, tackling both industrial and transport sectors with equal force.

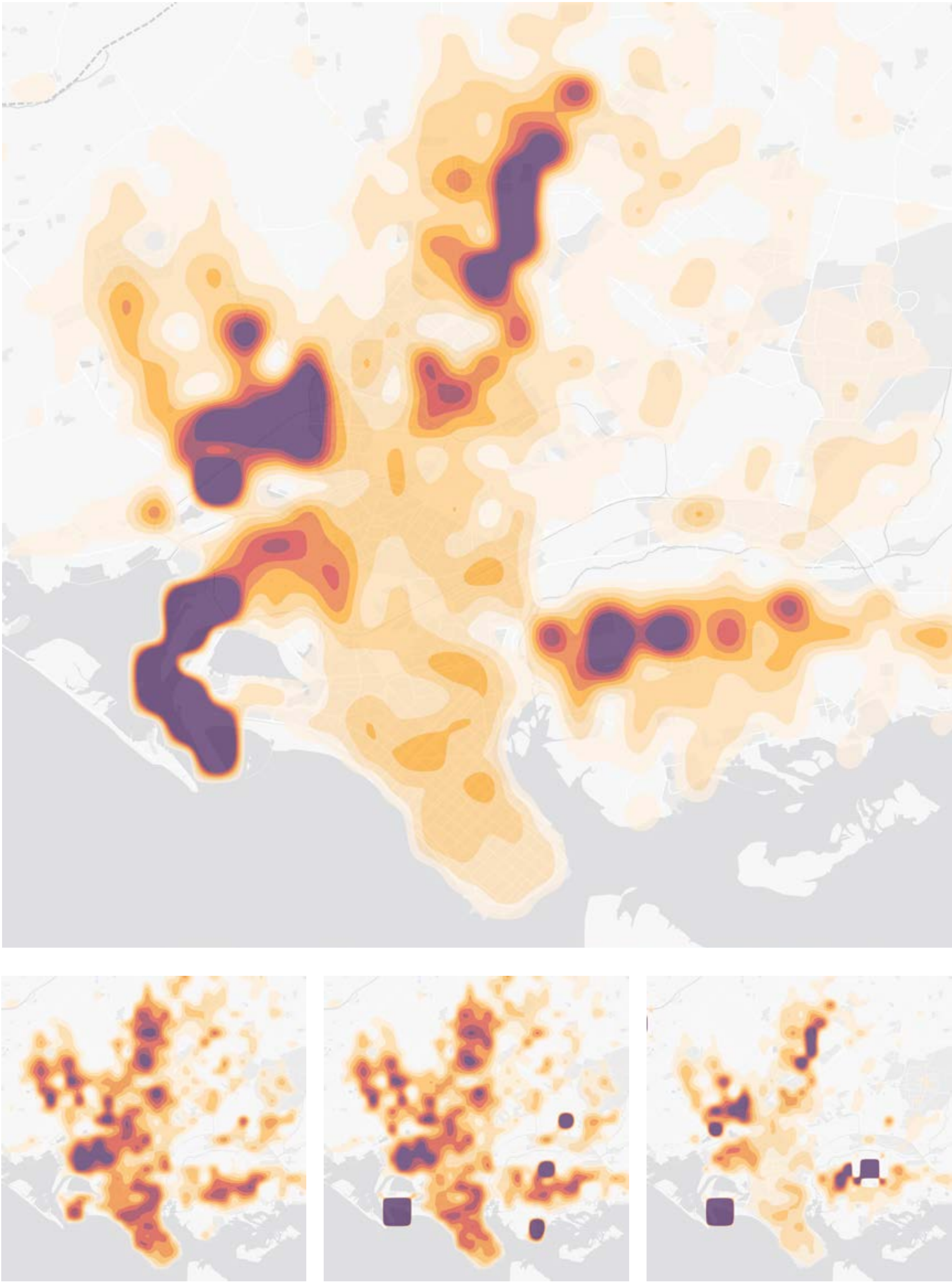


Exhibit 5.7: Spatial Distribution of Pollutant Emissions in Karachi (2021). **This series of maps illustrates the calculated distribution of annual emissions for PM2.5 (top), SO2 (left), NOx (middle), and CO (right) across Karachi at a 1km x 1km resolution. Darker shades indicate higher emission densities, highlighting hotspots in industrial zones (like Korangi and Landhi), around port areas, and along major transportation routes.**

A cargo ship emits black smoke as it enters the Phitti creek leading to Port Qasim, with residential high rises in the background. Shipping emissions, high in sulfur and particulate matter, are a significant and often overlooked source of pollution across all parts of Karachi.

to restrict the most polluting trucks and accelerate fleet renewal.

— **Freight management:** Optimise truck movements between ports and industrial zones to reduce congestion, idling times, and associated emissions.

3. Port and shipping interventions

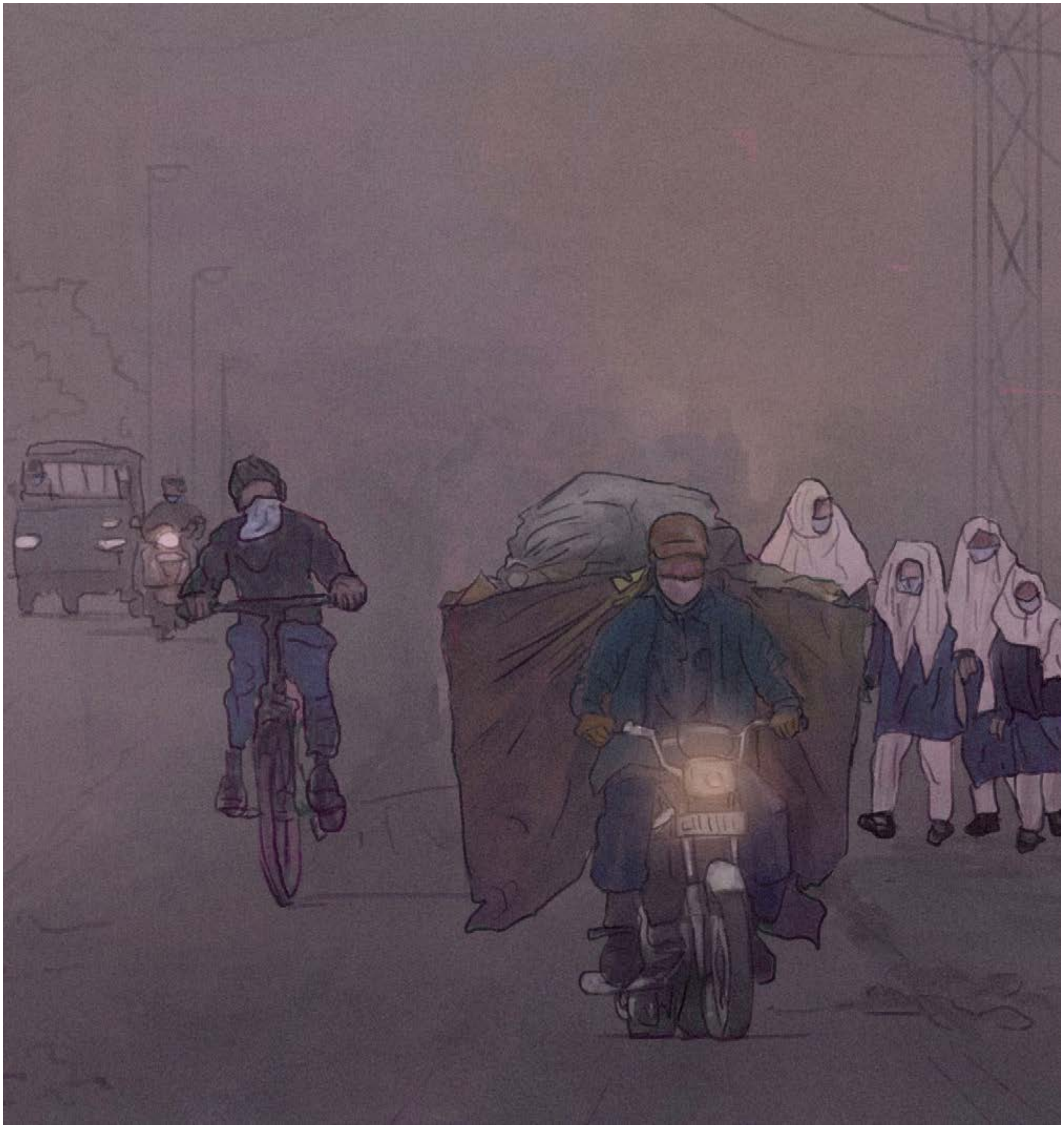
As Pakistan's primary maritime gateway, Karachi's two major ports are a unique and significant pollution source that require a dedicated strategy, with a **PM2.5 reduction potential of 8-10%.**

— **Shore power:** Introduce shore power facilities for docked vessels to allow them to turn off their high-emitting auxiliary engines while at berth.

— **Fuel sulfur requirements:** Enforce stringent fuel sulfur limits for all vessels operating within port boundaries, a proven strategy for reducing SO2 and particulate emissions.

— **Electrification:** Transition port-based cargo handling equipment from diesel to electric power where feasible.

By systematically addressing its primary industrial and maritime emission sources, Karachi can achieve a transformative improvement in its air quality and demonstrate that robust economic growth and environmental protection are complementary objectives.



Cyclists, motorcyclists, and families in open rickshaws navigate a grey, choked streetscape in this illustration by Itrat Jabeen. The work highlights the unequal burden of air pollution, where those contributing the least to emissions often face the most direct and unfiltered exposure to toxic fumes.

6.

Islamabad-Rawalpindi

A capital region choked by traffic

A crisis of urban design: The Islamabad-Rawalpindi airshed is a stark case study in how car-dependent urban planning drives pollution. The transportation sector is the dominant source, responsible for 53% of all PM2.5.

A tale of two cities: While sharing an airshed, Rawalpindi's residents face far greater risk. Its annual pollution (61.1 µg/m³) is significantly higher than Islamabad's (52.3 µg/m³), and it endured 199 hazardous days in 2024 compared to Islamabad's 168.

A solvable problem: With minimal heavy industry, the region's crisis is overwhelmingly caused by transport (53%), brick kilns (18%), and waste burning (11%). This makes it uniquely solvable through investments in public transit and sustainable urban planning.

A planned city, a capital built as a symbol of order, is now choking on the consequences of its own design. The haze over Islamabad and Rawalpindi is not the smoke of industry, but the exhaust of a million private journey—a self-inflicted crisis born from a failure to imagine a future beyond the automobile. This chapter is an accounting of that failure, providing the evidence that even without smokestacks, a city can suffocate on its own sprawl.

The Islamabad-Rawalpindi airshed, Pakistan's third-largest urban area, presents a unique air quality challenge. This contiguous region, home to 8.5 million people, is characterised not by heavy industry but by high vehicle dependency—a stark case study of how urban design and mobility choices create severe public health emergencies. Air quality monitoring data reveals that Islamabad and Rawalpindi face distinct pollution realities.

A capital region's chronic pollution

The nation's capital region is not spared from the air quality crisis. For the 2024 calendar year, the combined airshed recorded an annual average PM2.5 concentration of **54.4 µg/m³**, over 10 times the WHO safety guideline. This combined figure masks a significant disparity: Rawalpindi's annual average was a hazardous **61.1 µg/m³**, while Islamabad's was a lower, but still dangerous, **52.3 µg/m³**. This proves that transportation-driven pollution creates severe, but uneven, health risks across the airshed. While sharing an airshed, Rawalpindi's residents face greater risk. Its annual pollution shortens the average resident's life by 4.5

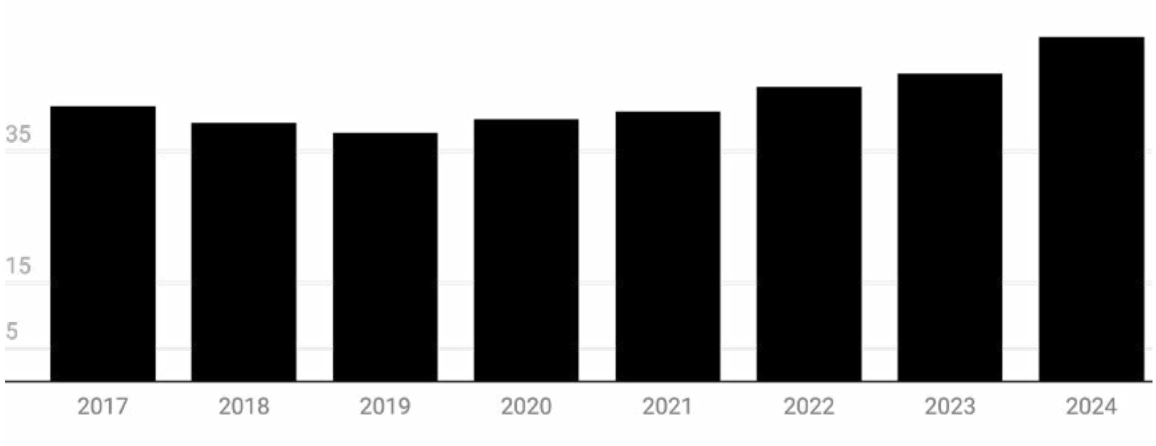


Exhibit 6.1: Islamabad's Chronic Pollution Problem (Annual Averages 2017-2024). **This chart shows the annual average PM2.5 concentration for Islamabad. While lower than in other major urban centres, the data reveals that the capital city still suffers from hazardous air quality that consistently fails to meet WHO guidelines.**

years, compared to 4.1 years for Islamabad. In 2024, Rawalpindi endured 199 hazardous days compared to Islamabad's 168.

Both cities experience a significant winter pollution peak. During the winter of 2023-2024, pollution levels surged to be **4.2 times higher** than the subsequent monsoon average across the airshed. The daily data reveals the different levels of risk. In 2024, Islamabad experienced **22 days** of good air by WHO standards. In contrast, Rawalpindi had only **11** such days. More alarmingly, Rawalpindi residents endured **199 days** where pollution exceeded the national legal limit, compared to **168** days for Islamabad.

An emissions profile shaped by mobility

The emissions inventory for the airshed reveals a profile fundamentally shaped by mobility and construction, with industry playing a minimal role. The airshed is burdened annually

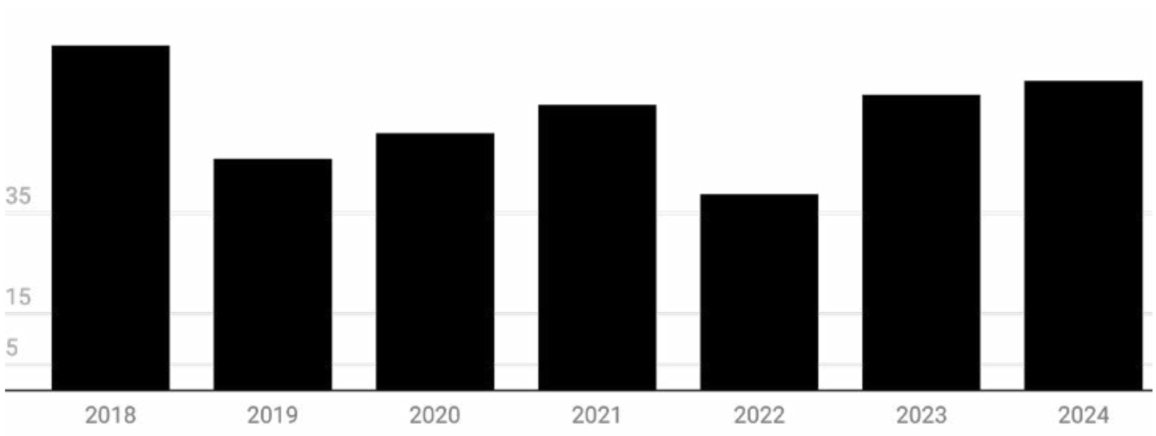


Exhibit 6.2: Rawalpindi's Chronic Pollution Problem (Annual Averages 2018-2024). **This chart shows the annual average PM2.5 concentration for Rawalpindi. The data reveals that while both cities suffer from hazardous air quality, Rawalpindi's pollution levels are consistently and significantly higher than in its twin city, Islamabad.**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2016												56.9	56.9
2017	93.7	36.9	34.9	24.8	29.8	29.0	31.6	30.4	35.7	59.9	77.5	46.0	41.8
2018	52.6	26.6	20.4	23.0	28.3	46.3	36.5	72.6	40.3	37.3	49.7	70.6	39.2
2019	37.4	24.7	18.6	17.7	24.2	25.0	31.6	29.7	43.8	46.9	50.7	102.0	37.8
2020	65.3	54.1	27.6	22.8	19.4	30.4	33.5	26.9	32.1	42.8	54.8	68.4	39.8
2021	71.6	70.3	28.8	18.3	19.2	24.6	26.9	34.5	37.5	32.0	54.1	76.2	41.0
2022	55.6	40.3	27.2	18.0	13.8	32.8	35.2	32.6	42.5	51.1	71.9	106.2	44.8
2023	75.9	53.8	39.4	26.7	24.3	30.3	26.5	33.9	34.9	45.7	73.6	96.1	46.8
2024	159.8	53.6	28.9	19.1	22.6	30.8	30.1	20.2	29.4	45.9	87.3	99.3	52.3
2025	78.3	49.2	23.0	32.0	30.8	35.2							41.4

Exhibit 6.3: The Seasonal Cycle of Islamabad's Air Pollution (2016-2025). **This heatmap visualises the monthly average PM2.5 concentrations for Islamabad, revealing a stark and predictable pattern where pollution peaks during the winter months of November through February.**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2016													
2017													
2018								50.2	37.6	44.6	73.6	117.2	68.1
2019	80.0	58.5	39.3	32.1	25.6	24.2	32.9	26.6	37.7	34.0	46.1	111.0	45.7
2020	84..0	66.8	33.2	20.7	18.7	26.7	32.3	22.7	35.4	59.6	97.4	112.6	50.9
2021	116.7	104.5	43.0	25.5	30.2	33.9	33.6	38.7	39.6	45.7	91.3	80.0	56.4
2022	46.3	31.8	21.4	16.0	12.1	12.4	8.7	8.1	19.4	59.2	108.5	143.2	38.8
2023	106.1	93.6	55.2	31.6	24.9	26.8	26.6	37.8	42.2	54.6	93.5	109.7	58.4
2024	177.8	70.5	42.7	22.9	26.8	27.1	28.9	24.8	33.8	53.5	97.0	126.2	61.1
2025	93.3	52.1	25.1	25.5	24.0	28.4							41.4

Exhibit 6.4: The Seasonal Cycle of Rawalpindi's Air Pollution (2018-2025). **This heatmap visualises the monthly average PM2.5 concentrations for Rawalpindi. The intensity of the purple during winter months is visibly more pronounced than in Islamabad, highlighting the more severe seasonal pollution episodes in this part of the airshed.**

with an estimated **12.04 kilotons of PM2.5**, 11.37 kilotons of SO2, 21.87 kilotons of NOx, and 90.71 kilotons of CO.

The primary sources of fine particulate matter are:

Transportation is the undisputed primary source, contributing **53%** of all PM2.5 emissions.

Brick kilns emerge as the second-largest source of PM2.5 at **18%**.

Waste burning contributes a significant **11%** of fine particulate matter.

Industrial activities have a minimal impact, contributing only **9%** to PM2.5 emissions.

The economic drain of congestion

The transportation-driven pollution in the twin cities imposes direct economic costs through traffic congestion, which leads to wasted fuel and lost time, draining productivity. The reliance on imported fossil fuels for private transport also contributes to the national trade deficit. Investing in a comprehensive public transit system is therefore not only an environmental solution but also a sound economic strategy.

A path to cleaner air for the Twin Cities

To address this transportation-driven crisis, interventions must focus on mobility and sustainable development.

1. Transformative public transportation

The single most effective intervention for the airshed is a decisive shift away from private vehicles, with a **PM2.5 reduction potential of 25-30%**.

— **Expand the metro bus network:** Aggressively expand the existing Metro Bus network to create a comprehensive system that serves all major residential and commercial zones across both Islamabad and Rawalpindi.

— **Electrify the public fleet:** Prioritise the electrification of the public transit fleet, including buses and government vehicles, to create a zero-emission transport backbone for the capital region.

— **Invest in non-motorised transport:** Develop safe and connected infrastructure for walking and cycling to encourage a shift away from short-distance vehicle trips.

2. Integrated waste and dust management

With waste burning and construction dust as significant secondary sources, an integrated management approach with a **combined PM2.5 reduction potential of 18-25%** is crucial.

— **Enforce dust control:** Implement and strictly enforce comprehensive dust control measures at all public and private construction sites, including mandatory wetting, covering of materials, and vehicle wheel washing.

Total annual emissions in kilotons in Islamabad-Rawalpindi					
Sector	**PM2.5**	**SO2**	**NOx**	**CO**	**Total**
Transport	6.41	5.23	20.09	78.72	110.45
Industry	1.03	0.89	0.54	0.36	2.82
Brick Kilns	2.14	2.00	0.15	5.75	10.04
Power	0.03	3.07	0.34	0.03	3.47
Household	0.30	0.02	0.65	1.91	2.88
Waste	1.34	0.02	0.02	3.84	5.22
Commercial	0.79	0.14	0.08	0.10	1.11
Total	**12.04**	**11.37**	**21.87**	**90.71**	**135.99**

Exhibit 6.5: A Transport-Driven Crisis. **This inventory confirms that the capital region's pollution is largely a result of urban design. With minimal heavy industry, the data shows that the transport sector is the overwhelming driver of the airshed's emissions load.**

— **Modernise solid waste management:** Develop and implement a modern, city-wide solid waste management system for both cities to eliminate the practice of open garbage burning.

3. Modernised brick kiln sector

The high contribution from brick kilns, despite the region's limited industrial base, makes them a key target with a **PM2.5 reduction potential of 15-18%**.

— **Accelerate technology transition:** Enforce and accelerate the complete conversion of all brick kilns in the airshed to zigzag and next-generation technologies.

— **Focus on upwind sources:** Prioritise the modernisation and regulation of kilns located upwind of Rawalpindi, which are likely to have a disproportionate impact on the city's air quality.

By pivoting decisively towards sustainable transportation integrated with smart urban development, the twin cities can transform from a car-dependent sprawl to a model of sustainable urbanism. As the nation's capital, successful air quality improvements here would demonstrate political commitment and create a powerful template for action across Pakistan.

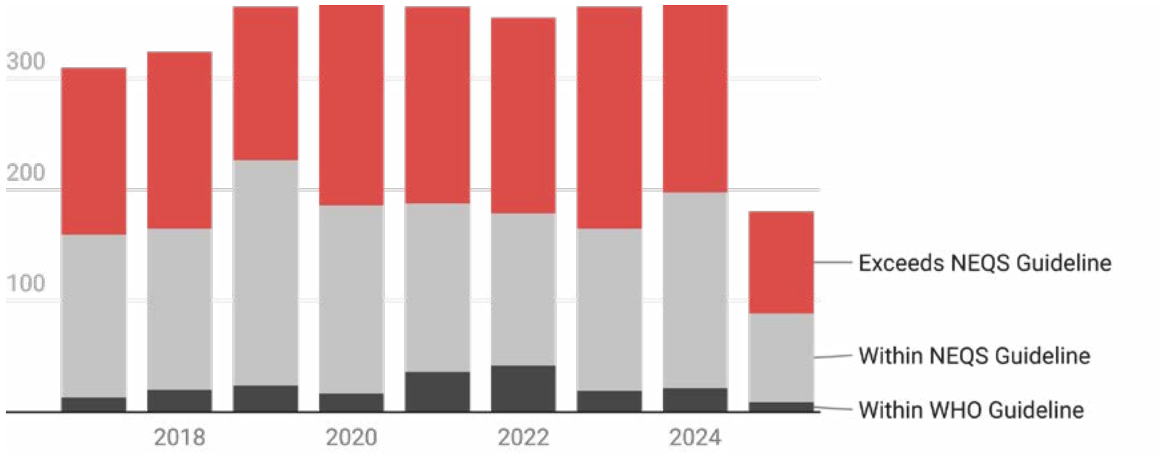


Exhibit 6.6: The Daily Health Burden in Islamabad. **This chart illustrates the daily reality of breathing Islamabad's air. Even in the capital, days meeting the WHO clean air guideline are a minority, while the number of days exceeding the national standard remains high, demonstrating a year-round health risk.**

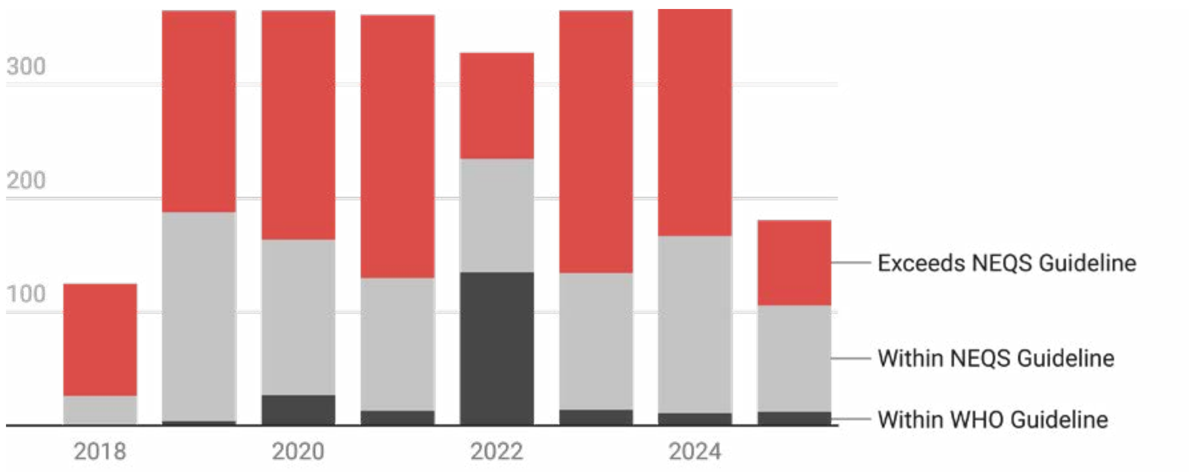


Exhibit 6.7: The Daily Health Burden in Rawalpindi. **This chart illustrates the more severe daily health burden in Rawalpindi. Compared to Islamabad, the city experiences far fewer clean air days and a significantly higher number of days when pollution breaches the national legal limit, highlighting the unequal risk within the airshed.**

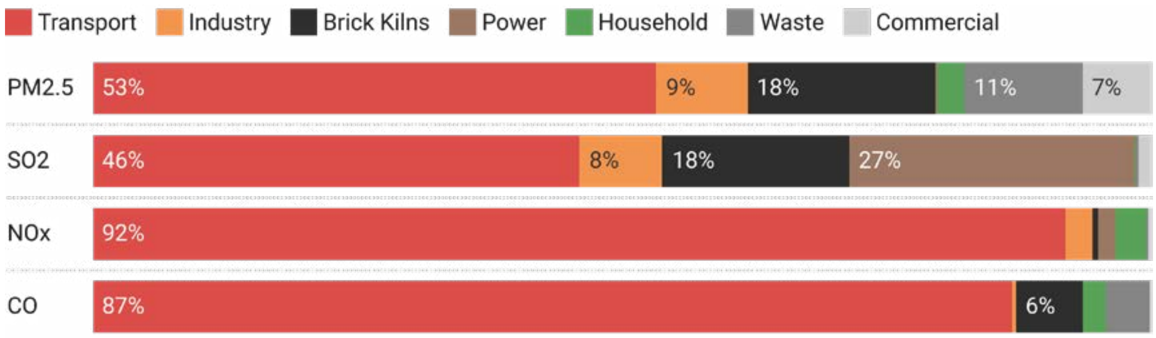


Exhibit 6.8: The Emissions Fingerprint of the Twin Cities. **In the Islamabad-Rawalpindi airshed, all roads lead to one culprit: transportation. The transport sector is the overwhelming source of nearly every major pollutant, including PM2.5 (53%), NOx (92%), and CO (87%). Unlike Pakistan's other major urban centres, this unique emissions fingerprint points to a clear and singular priority: an effective clean air strategy for the Twin Cities must begin and end with a radical transformation of its transport sector.**

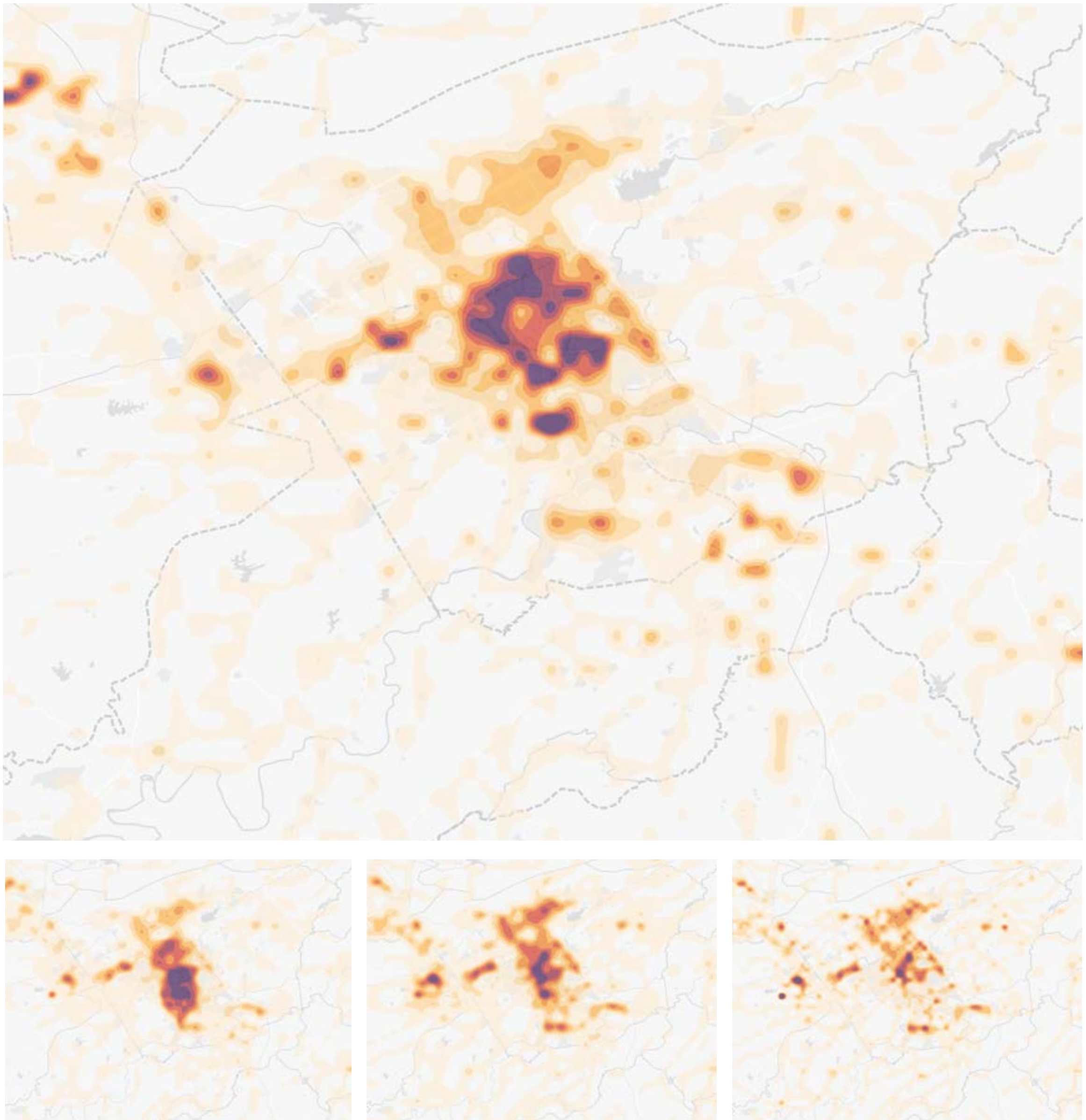


Exhibit 6.10: Spatial Distribution of Emissions in the Twin Cities (2021). **These heatmaps show the concentration of PM2.5 (top), SO2 (left), NOx (middle), and CO (right) emissions. The data reveals pollution hotspots along major transportation corridors like the Islamabad Expressway and Murree Road, which directly connect the two cities.**

Dust and debris rise from a marble processing plant on the outskirts of Peshawar, coating the surrounding landscape in a fine haze. Emissions from such industrial activity, rich in particulate matter, contribute to air pollution that often goes unnoticed in rapidly expanding urban areas.

7.

Peshawar

A valley trapped by trade and pollution

Highest per-capita burden: Peshawar's unique mix of transit trade, traditional industry, and geography gives it the highest per-capita PM2.5 emissions (2.14 kg/person/year) among Pakistan's major cities.

A devastating health burden: The city's annual average PM2.5 was 95.8 µg/m^3 in 2024—over 19 times the WHO guideline. Residents experienced zero clean air days all year, which shortens life expectancy by 5.8 years.

Where transit meets tradition: The pollution profile is dominated by transportation (51%), but with major contributions from brick kilns (19%) and small-scale traditional industries (14%).

In the historic gateway to the Subcontinent, the air itself has become a barrier. Peshawar, a city defined by its vibrant trade and deep-rooted traditions, is now trapped in a basin of its own emissions. The very activities that give the city its unique character—the flow of regional commerce and the hum of artisanal industry—have become the primary sources of a severe, and deeply personal, public health crisis. This chapter provides evidence to show that honouring tradition and ensuring a healthy future are not mutually exclusive goals.

Peshawar, the capital of Khyber Pakhtunkhwa, faces a distinct air quality challenge, blending its role as a transport hub with a legacy of traditional, often unregulated, industries. This unique combination, exacerbated by the city's location in a geographic basin that traps pollutants, results in the highest per-capita pollution levels among Pakistan's major cities, creating a public health crisis of a grand scale.

An intense and enduring public health crisis

Peshawar's air quality is severe and continuous. For the 2024 calendar year, the city's annual average PM2.5 concentration was **95.8 µg/m³**. This is over 19 times the WHO safety guideline and more than six times the national standard, cementing Peshawar's status as a city facing an intense public health threat.

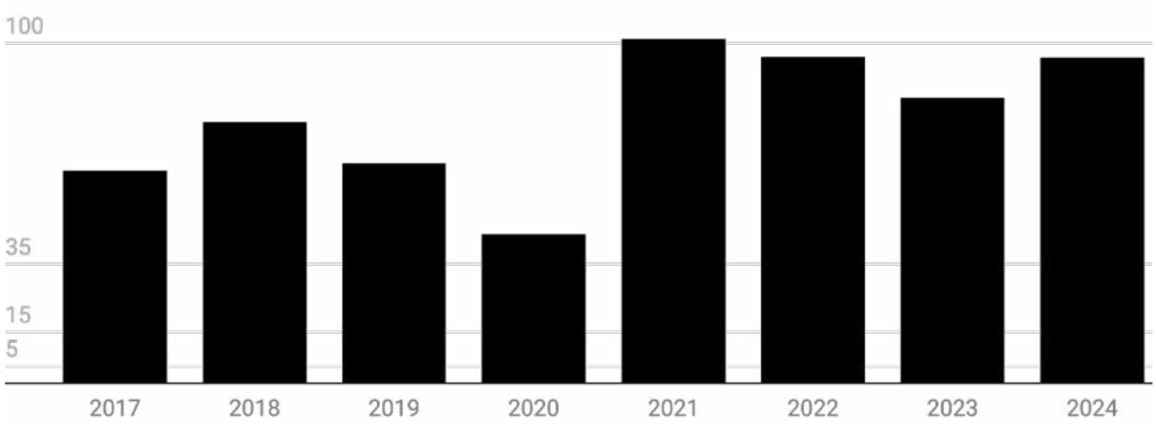


Exhibit 7.1: Peshawar's Chronic Pollution Problem (Annual Averages 2017-2024). **This chart shows Peshawar's high annual average PM2.5 concentration over the last eight years. The data confirms that the city's unique mix of transit traffic, traditional industry, and geographical constraints creates some of the most hazardous air quality in the nation.**

A valley trapped in winter haze

Peshawar's location in a basin surrounded by mountains makes it particularly susceptible to winter pollution episodes. During the winter of 2023-2024, pollution levels surged to be **4.1 times higher** than the subsequent monsoon average. Temperature inversions trap emissions from local and regional sources, creating prolonged periods of hazardous air

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2016													
2017	76.2	63.3	48.9	42.8	42.9	40.9	45.4	49.8	67.2	78.6	126.2	96.3	62.5
2018	142.0	58.1	57.5	46.7	30.8	44.5						116.1	76.8
2019	78.1	43.7	29.5	52.9	50.4	57.0	52.8	41.4	61.0	78.5	77.8	109.0	64.7
2020	54.3	44.7	35.4	27.3	30.5	40.2	38.9	36.0	42.2	48.3	43.8	87.0	43.9
2021	230.4	259.2	75.5	50.4	42.6	52.6	53.4	53.7	58.7	58.6	61.2	85.0	101.3
2022	86.1	63.7	47.0	44.0	40.0	53.5	54.2	57.4	73.8	120.5	206.2	291.3	95.9
2023	136.9	90.0	61.4	39.1	39.9	47.5	43.1	52.4	59.7	89.4	162.6	185.8	84.0
2024	256.7	95.6	56.5	35.1	37.4	40.1	41.2	43.2	65.0	110.9	162.0	203.1	95.8
2025	129.7	69.0	44.2	57.6	54.6	42.6							66.4

Exhibit 7.2: The Seasonal Cycle of Peshawar's Air Pollution (2017-2025). **This heatmap visualises the monthly average PM2.5 concentrations for each year, revealing a stark and predictable pattern. Pollution consistently peaks during the winter months of November through February (purple) and recedes during the monsoon season (red), demonstrating that Peshawar's 'smog season' is a chronic, recurring public health threat.**

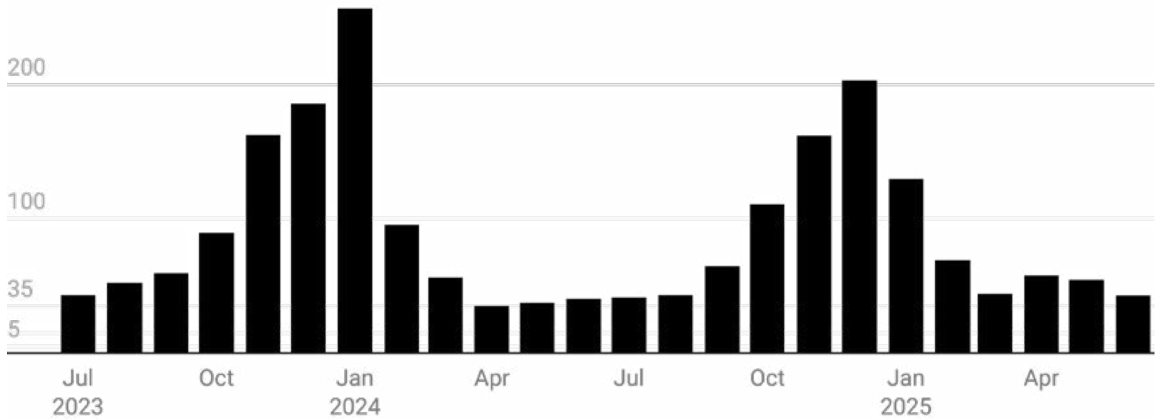


Exhibit 7.3: A Closer Look at Peshawar's Recent Pollution Cycle (July 2023 to June 2025). **This chart provides a detailed view of the most recent seasonal cycle, illustrating the dramatic rise in PM2.5 concentrations from the cleaner monsoon months to the hazardous winter peak. During the winter of 2023-2024, pollution levels were 4.1 times higher than the subsequent monsoon average.**

quality. In 2024, residents experienced **zero days** where the air quality met WHO's 24-hour guideline, while on **304 days**, pollution was so high it also breached the national 24-hour legal limit.

Where transit and tradition collide

Peshawar's emissions inventory reveals a pattern dominated by transportation but with substantial contributions from traditional industries that are central to the local economy.

— **Transportation** is the largest source, contributing **51%** of PM2.5 emissions.

— **Brick kilns** are the second-most significant source, responsible for **19%** of PM2.5 emissions.

— **Small-scale traditional industries,** such as metalworking and pottery, collectively contribute **14%** of fine particulate matter.

The economic toll of unregulated growth

Peshawar's economy is uniquely intertwined with its pollution sources. The heavy transit trade, while a vital economic driver, imposes significant health and infrastructure costs on the local population due to emissions from an aging, unregulated freight fleet. Similarly, the city's traditional craft industries provide crucial livelihoods but operate with inefficient, polluting technologies. The economic imperative here is to decouple economic activity from environmental harm by modernising the logistics and artisanal sectors.

A path to cleaner air for Peshawar

Interventions must be tailored to address this unique blend of modern logistics and traditional economy.

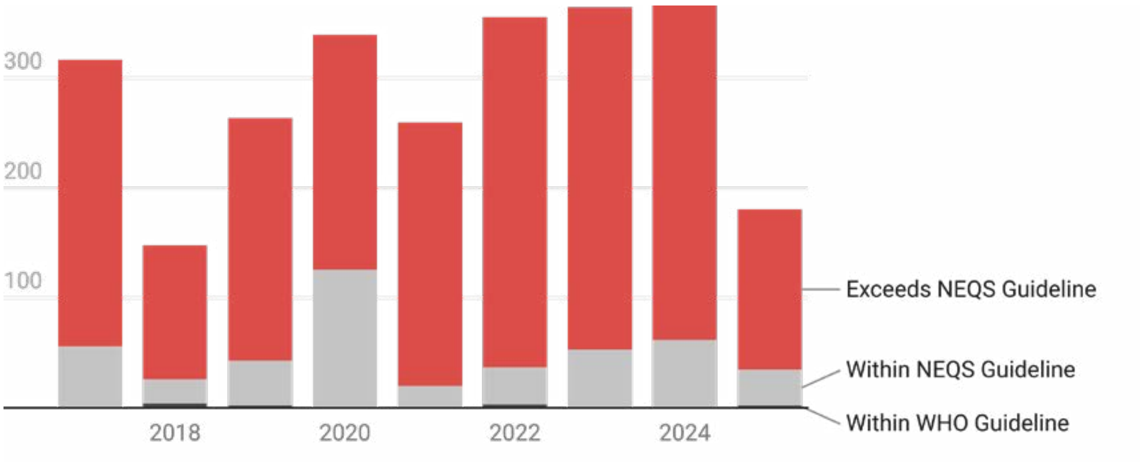


Exhibit 7.4: The Daily Health Burden in Peshawar (2024). **This chart illustrates the daily reality of breathing Peshawar's air. The complete absence of green ("Meets WHO Guideline") shows that not a single day in 2024 had clean air. A staggering 304 days were so hazardous they breached Pakistan's own National Environmental Quality Standard (NEQS), demonstrating a state of perpetual crisis.**

1. Comprehensive transportation management

Given that transportation accounts for over half of the city's PM2.5, a focused strategy to manage both local and transit traffic is essential, with a **PM2.5 reduction potential of 20-25%**.

— **Freight management system:** Implement a system to regulate transit cargo, including designated routes away from populated centres, specified hours for heavy traffic, and mandatory vehicle inspections for all freight trucks passing through the airshed.

— **Expand public transit:** Continue to expand the Bus Rapid Transit (BRT) system to provide viable, affordable alternatives to private transport for a larger portion of the city's residents.

2. Modernised brick kiln sector

The brick kiln sector is a major polluter and a prime target for high-impact emission reductions through technological upgrades, with a PM2.5 reduction potential of 15-18%.

— **Complete technology transition:** Accelerate and enforce the complete transition of all brick kilns in the airshed from traditional designs to modern zigzag technology.

— **Dedicated industrial zones:** Explore the creation of a dedicated industrial zone for brick manufacturing outside the main city basin, which could allow for shared pollution control infrastructure and better regulatory oversight.

3. Support for traditional industry

The goal for Peshawar's artisanal industries should be modernisation—not elimination—to preserve livelihoods while reducing environmental harm. This has a **PM2.5 reduction potential of 10-12%**.

— **Cleaner production centres:** Develop "cleaner production centres" for key artisanal

Total annual emissions in kilotons in Peshawar					
Sector	**PM2.5**	**SO2**	**NOx**	**CO**	**Total**
Transport	8.15	7.88	28.91	64.18	109.12
Industry	2.26	1.60	0.76	0.53	5.15
Brick Kilns	2.88	2.83	0.21	8.15	14.07
Household	1.12	0.02	0.94	6.91	8.99
Waste	1.10	0.02	0.02	3.17	4.31
Commercial	0.53	0.56	0.26	0.33	1.68
Total	**16.04**	**12.91**	**31.10**	**83.27**	**143.32**

Exhibit 7.5: A Mix of Ancient and Modern Sources. **Peshawar's inventory reflects its unique economy. The data shows a heavy reliance on transportation for transit trade, alongside significant emissions from traditional sectors like brick kilns and small-scale industries.**

industries like metalworking and pottery. These centres could provide access to modern, more efficient, and less polluting equipment, along with training on best practices.

— **Financial incentives:** Provide financial support and incentives for small-scale industries to upgrade their technology and adopt cleaner fuels.

By pursuing a balanced approach that upgrades environmental performance while respecting cultural heritage, Peshawar can chart a distinctive path towards cleaner air. This transition would not only improve public health outcomes but also demonstrate how traditional knowledge and modern environmental science can work together to create sustainable urban futures.

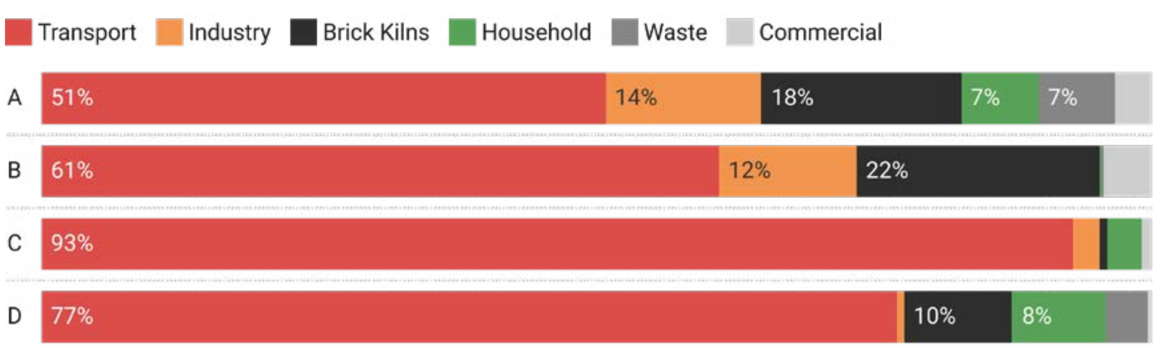


Exhibit 7.6: The Emissions Fingerprint of Peshawar. **Peshawar's air is poisoned by a trio of sources: transport, brick kilns, and industry. While the transport sector is the primary driver of NOx and CO, the most health-damaging pollutants—PM2.5 and SO2—come from a dangerous mix of all three. This complex fingerprint means that an effective clean air strategy for Peshawar requires a three-front battle.**

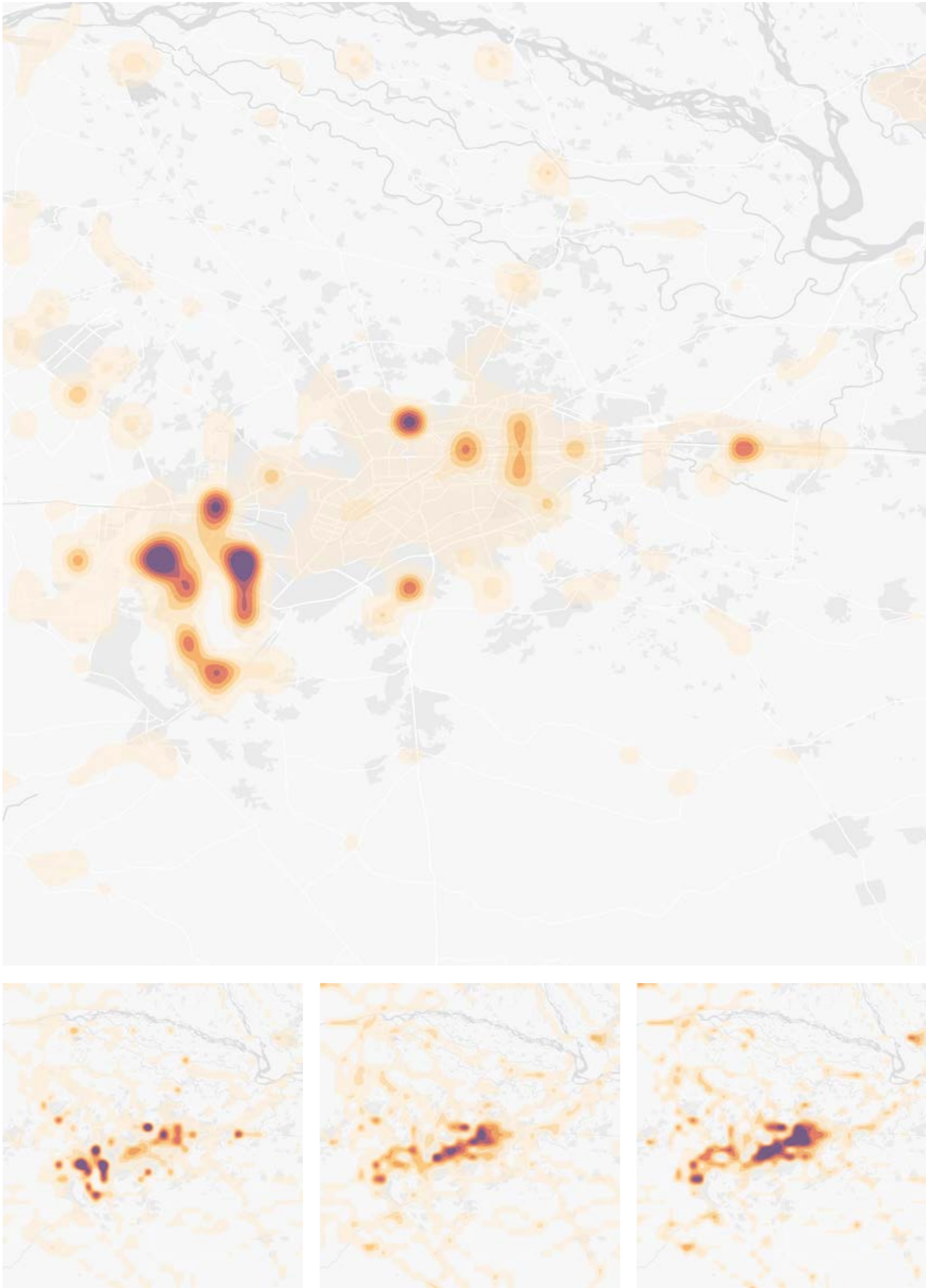
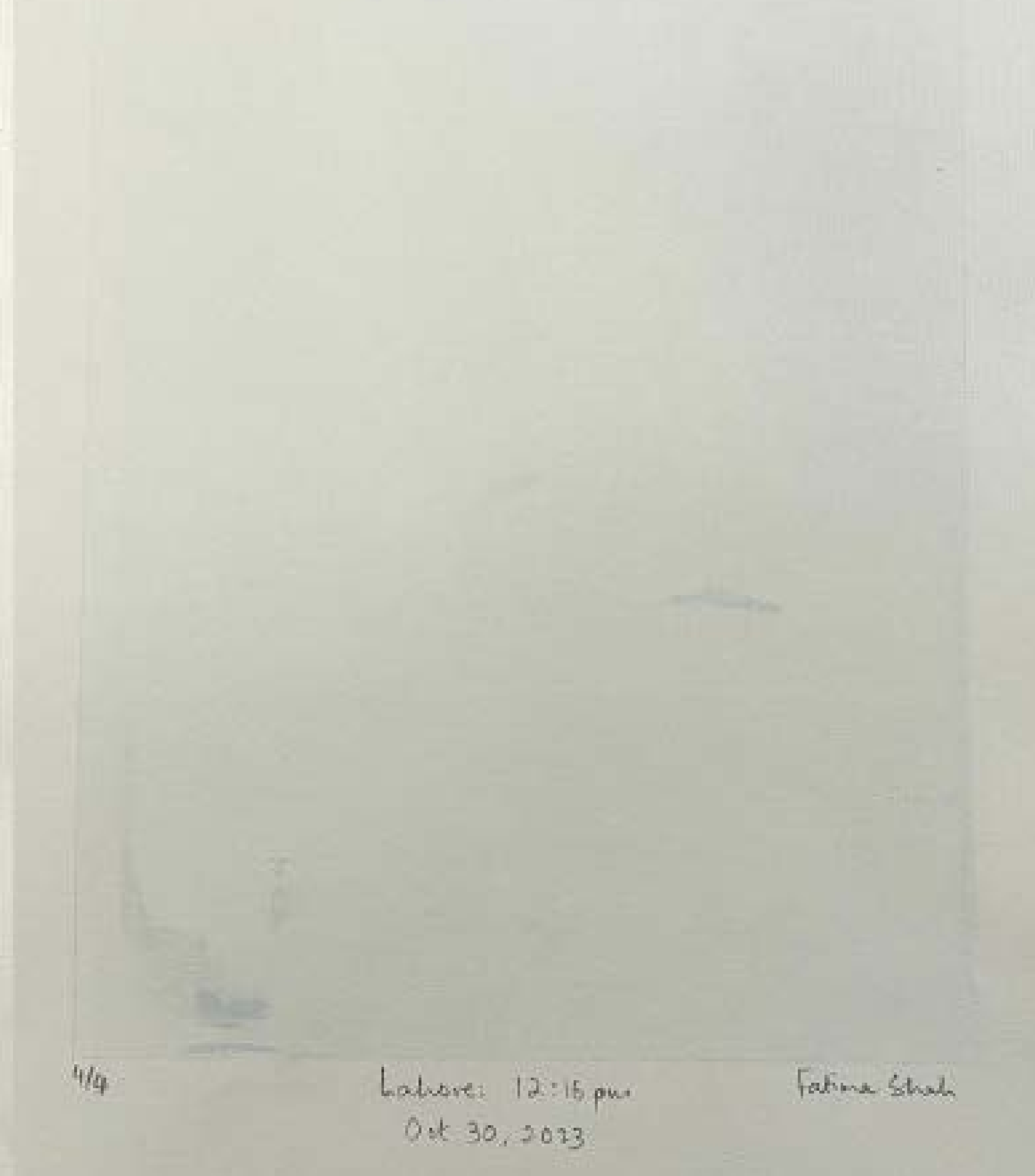


Exhibit 7.7: Spatial Distribution of Emissions in Peshawar (2021). **These heatmaps show the concentration of PM2.5 (top), SO2 (left), NOx (middle), and CO (right) emissions. The data reveals pollution hotspots along major transportation corridors and in industrial zones, while also showing high-density pollution in the urban core due to traffic congestion and commercial activity.**

1/4 Lahore: 11:24am
Oct 27, 2023
Fatima Shah '23



'Lahore: 11:24 am | Oct 27, 2023' and 'Lahore: 12:16 pm | Oct 30,2023'
Fatima Shah transforms the cyanotype process into an index of toxicity, where the smog's density dictates the print's clarity. The mesh texture evokes a visceral sense of entrapment, while the fading image reveals a terrifying reality: pollution so thick it blots out the sun, erasing the city itself.

Fact Sheet: Pakistan

An average Pakistani resident could live 3.3 years longer if particulate pollution (PM2.5) in the country was reduced to meet the World Health Organization (WHO) guideline of 5 µg/m3 (Figure 1).[1 2] In the country's most polluted regions, Lahore and Peshawar, residents could gain more than 5 years of life expectancy.

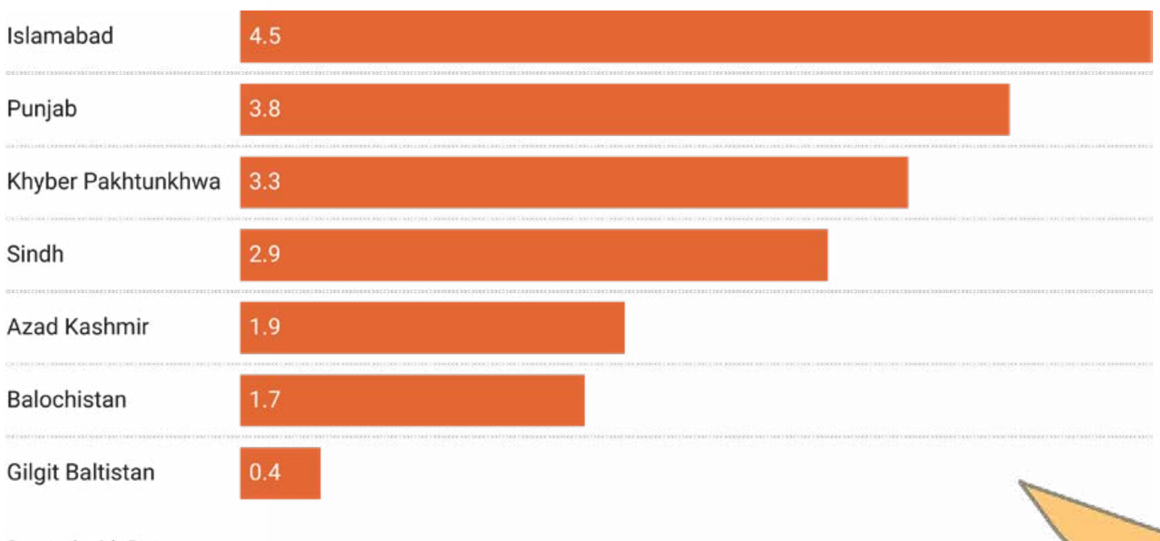


Exhibit 1: Potential gain in life expectancy from reducing PM2.5 from the 2023 levels to the WHO guideline in all provinces of Pakistan.

[1] This data is based on the data used in AQLI Annual Update 2025 and considers PM2.5 concentrations for 2023. dataset. All annual average PM2.5 values (measured in micrograms per cubic metre: µg/m³) are population weighted.

[2] World Health Organization. (2021). WHO global air quality guidelines: Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization.

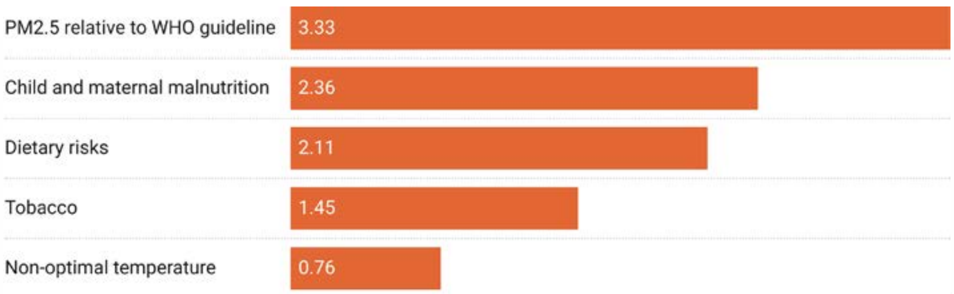


Exhibit 2: Potential gain in life expectancy from permanently reducing PM2.5 from the 2023 concentrations to the WHO guideline.

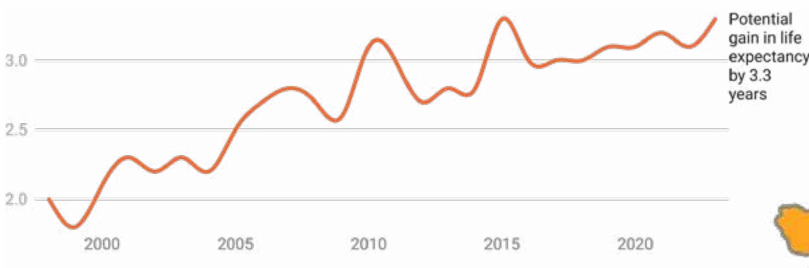


Exhibit 3: Top 5 external threats to life expectancy in Pakistan.

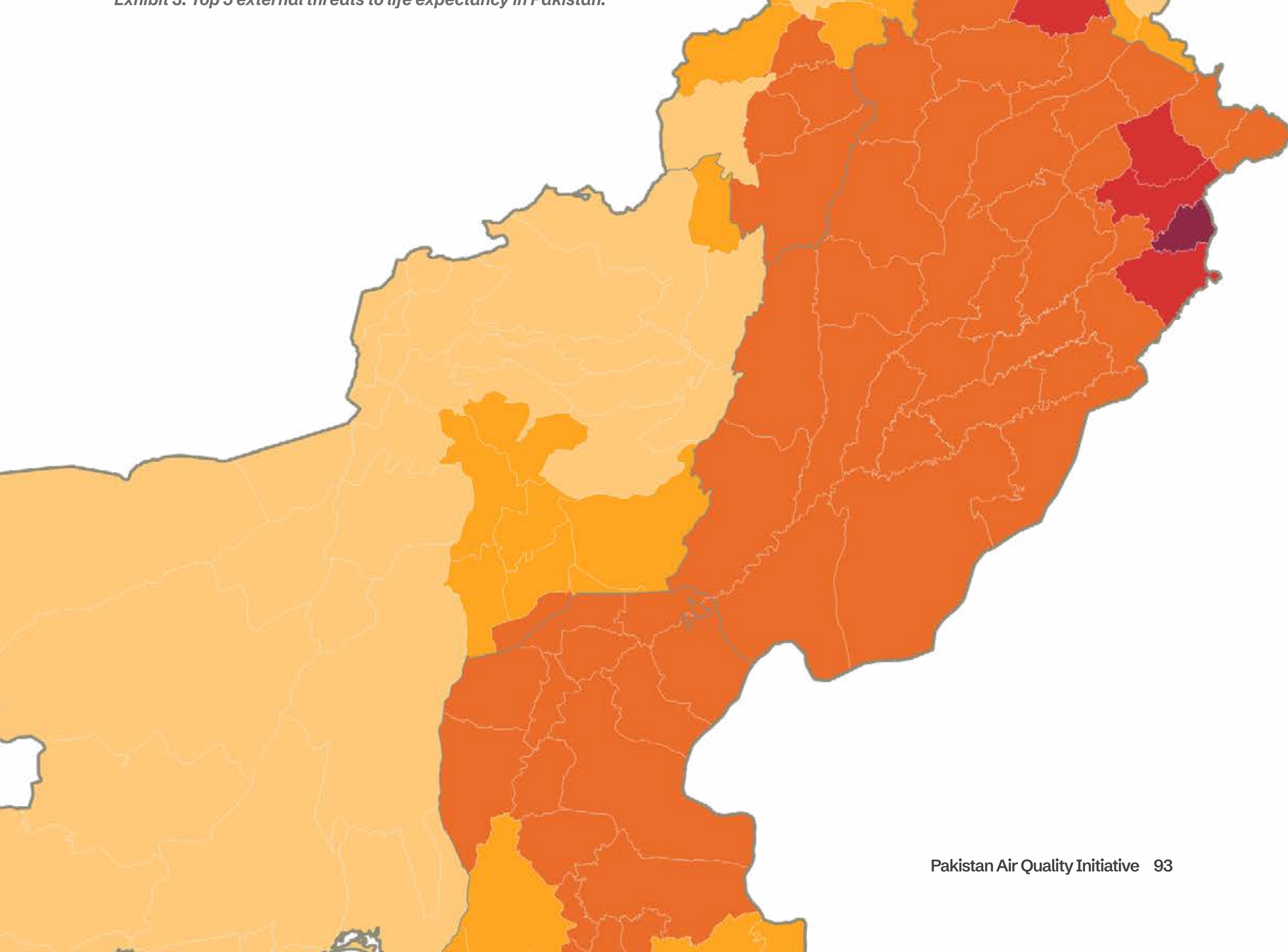


Exhibit 4: This Daily Commute for Millions is a Public Health Emergency. Dense, toxic air that compromises every breath taken highlights the urgent need for systemic solutions to clean the air in Pakistan.
Photo by Mahera Omar/Pakistan Air Quality Initiative

— Particulate pollution is the greatest external threat to life expectancy in the country. While particulate pollution takes 3.3 years off the life expectancy of an average Pakistani resident, child and maternal malnutrition, and dietary risks reduce life expectancy by 2.4 and 2.1 years, respectively (Figure 2).

— All of Pakistan's 248.8 million people live in areas where the annual average particulate pollution levels exceed the WHO guideline. 99.5% of the population live in areas that exceed the country's former, more stringent national air quality standard, while 70.7% live in areas that exceed the country's current standard. The country revised the standard from 15 µg/m3 to 35 µg/m3 in 2023.

— An average resident could live 3.6 years longer in the most polluted provinces—Islamabad Capital Territory, Punjab, and Khyber Pakhtunkhwa—if particulate concentrations met the WHO guideline. If particulate concentrations in these regions were reduced to meet the country's national standard, the potential gains in life expectancy could be 2.7 years (Figure 3).

— In Pakistan's most populous city, Karachi, residents could live 2.7 years longer if particulate concentrations met the WHO guideline.

— In Lahore, the country's second most populous city, residents could gain 5.8 years of life expectancy.

— In Islamabad, Pakistan's capital city, residents could gain 4.5 years.

— From 1998 to 2023, average annual particulate concentrations increased by 55.7%, further reducing life expectancy by 1 year (Figure 4).

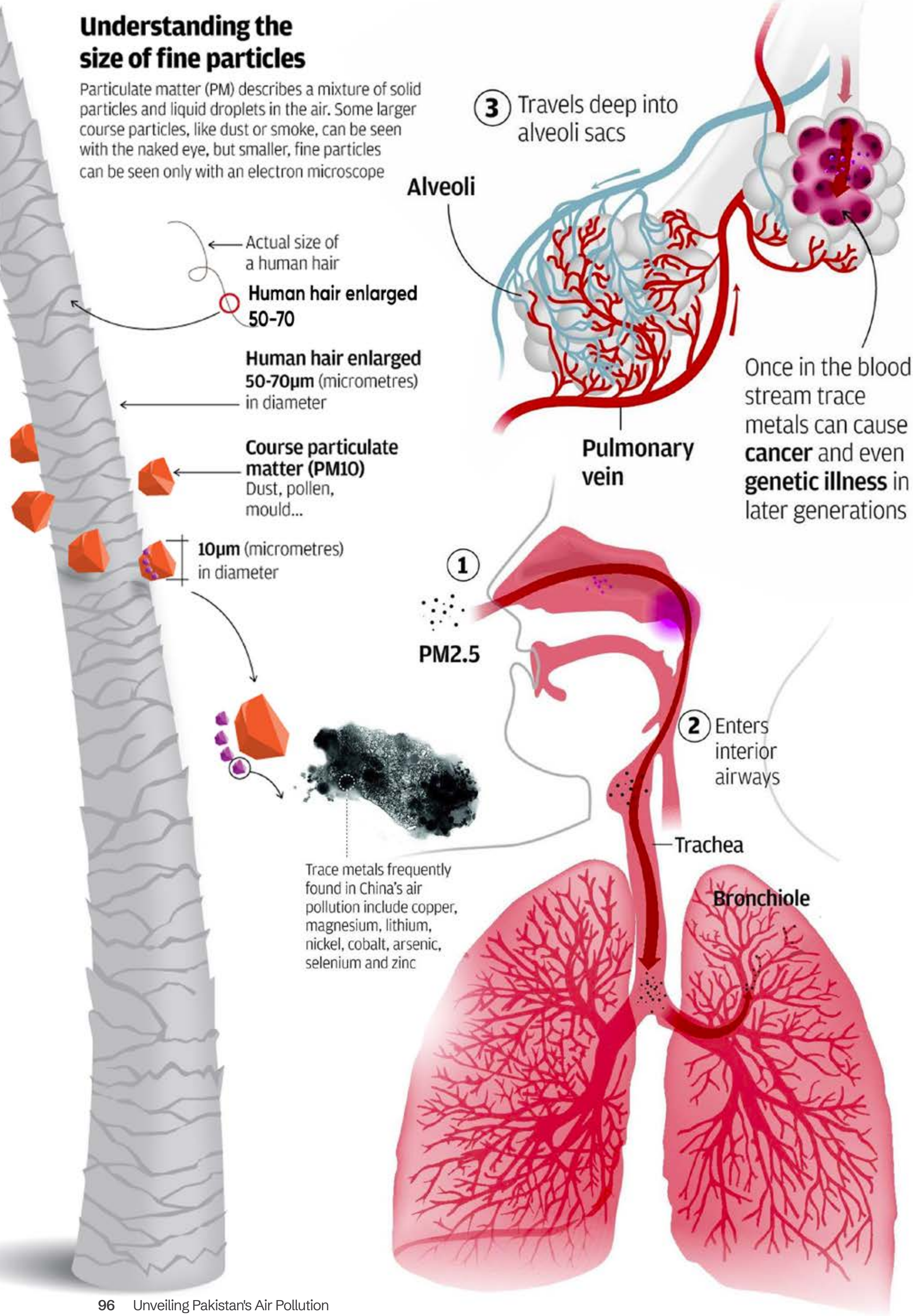
The Air Quality Life Index (AQLI) is a pollution index that translates particulate air pollution into perhaps the most important metric that exists: its impact on life expectancy. Developed by the University of Chicago's Milton Friedman Distinguished Service Professor in Economics Michael Greenstone and his team at the Energy Policy Institute at the University of Chicago (EPIC), the AQLI is rooted in research that quantifies the causal relationship between long-term human exposure to air pollution and life expectancy. The Index then combines this research with hyper-localised, satellite measurements of global particulate matter (PM2.5), yielding unprecedented insight into the true cost of pollution in communities around the world. The Index also illustrates how air pollution policies can increase life expectancy when they meet the World Health Organization's guideline for what is considered a safe level of exposure, existing national air quality standards, or user-defined air quality levels. This information can help to inform local communities and policymakers about the importance of air pollution policies in concrete terms.

The life expectancy calculations made by the AQLI are based on a pair of peer-reviewed studies, Chen et al. (2013) and Ebenstein et al. (2017), co-authored by Michael Greenstone, that exploit a unique natural experiment in China. By comparing two subgroups of the population that experienced prolonged exposure to different levels of particulate air pollution, the studies were able to plausibly isolate the effect of particulate air pollution from other factors that affect health. Ebenstein et al. (2017) found that sustained exposure to an additional 10 µg/m3 of PM10 reduces life expectancy by 0.64 years. In terms of PM2.5 , this translates to the relationship that an additional 10 µg/m3 of PM2.5 reduces life expectancy by 0.98 years. This metric is then combined with sea-salt and mineral dust removed satellite-derived PM2.5 data.

All 2023 annual average PM2.5 values are population-weighted and AQLI's source of population data is https://landscan.ornl.gov/. We are grateful to the Atmospheric Composition Analysis Group, based at the Washington University in St. Louis for providing us with the satellite data. The original dataset can be found here: https://sites.wustl.edu/acag/datasets/surface-pm2-5/.

Understanding the size of fine particles

Particulate matter (PM) describes a mixture of solid particles and liquid droplets in the air. Some larger course particles, like dust or smoke, can be seen with the naked eye, but smaller, fine particles can be seen only with an electron microscope



8.

The Health Impacts

An overview of air quality in Pakistan

Indoor air is a primary killer: Household air pollution from biomass fuels is a leading cause of death in Pakistan, with PM2.5 levels in rural kitchens measured at up to 600 times higher than in homes using clean fuel.

A whole-body assault: The health impacts of air pollution go far beyond the lungs, with Pakistani studies linking exposure to heart attacks, strokes, adverse pregnancy outcomes, and even psychological distress.

The vulnerable pay the highest price: Children face increased risks of pneumonia, stunted lung development, and elevated blood pressure, while occupational groups like traffic police and brick kiln workers show evidence of gene damage and impaired lung function.

Exhibit 8.1: Poison in the air. **This infographic, adapted from the work of Adolfo Arranz for the *South China Morning Post*, illustrates how fine particulate matter (PM2.5) bypasses the body's defenses to cause systemic damage. The health impacts of air pollution extend far beyond the lungs, contributing to cardiovascular disease, strokes, adverse birth outcomes, and neurological damage, as documented in studies across Pakistan.**

The connection between the air we breathe and the health of our bodies has been known for centuries. Dr. Saima Saeed moves beyond historical anecdote to present the specific, damning medical evidence from Pakistan. This chapter documents the toll of air pollution on our lungs, our hearts, and our children's futures, making the case for clean air as a fundamental pillar of public health.

The earliest links between air quality and health were noted by Hippocrates (c. 400 BC) and Seneca (c. 63-65 AD) who related illness to air quality and smoke. Bernardo Ramazzini, the father of occupational medicine, made significant contributions in the 18th century by documenting health effects of chemical and dust exposure among workers.[1]

The Industrial Revolution led to worsening air quality with some public policy responses to improve it. However, by the 20th century, severe pollution episodes drew concern, particularly the Meuse Valley fog in Belgium during 1930 and the Great Smog of London in 1952. These discrete events enabled direct inquiry as to how air pollution was associated with increases in morbidity and mortality. The approaches to making these links have been variable and include air quality monitoring, epidemiological studies, and geographical analysis, reflecting the interdisciplinary nature of this environmental phenomenon.

[1] Ramazzini, B. (2001). De morbis artificum diatriba [Diseases of workers]. American Journal of Public Health, 91(9), 1380–1382.

While improved policies have reduced air pollution's impact in high-income countries, the consequences of climate change, often intertwined with air quality, remain a serious threat.[2] Against this backdrop, Pakistan faces significant air quality challenges. The World Air Quality Report ranks Pakistan as the second most polluted country in the world.[3] The consequences are severe: the Air Quality Life Index found that Pakistanis die between three and four years prematurely nationwide, with residents in heavily polluted areas like Lahore losing up to seven years of life expectancy.[4] The World Health Organization estimates that the combined effects of ambient and household air pollution contribute to over 257,000 premature deaths annually in Pakistan.[5]

The National Clean Air Policy (2023) identified several major contributors to Pakistan's air pollution: poor fuel quality for transport, subpar industrial emission standards, burning of agricultural residues, open solid waste burning, and biomass cooking fuels in households.

The hazard within: Pakistan's indoor air pollution crisis

Indoor air pollution has a significant literature base supporting its association with poor health outcomes in Pakistan. The Global Burden of Disease study identified indoor air quality as a leading cause of death[6] at the national level, especially in low and middle-income countries like Pakistan.[7]

A South Asian research review examining studies from 2000 to 2020 highlighted indoor solid fuel burning as a key source of respiratory symptoms with associated incidence of respiratory tract infections and chronic obstructive pulmonary disease (COPD). Additionally, asthma, pneumonia, cardiovascular diseases, hypertension, and cataracts were linked to this common household practice.[8]

Zafar Fatmi and his group published several key papers supporting the implication of household use of biomass fuel on various health outcomes.

PM2.5 levels and carbon monoxide

Households in rural Pakistan, which used biomass for cooking fuel, had PM2.5 levels that were between 380 and 600 times higher than those using natural gas. Carbon monoxide

[2] Romanello, M., Di Napoli, C., Drummond, P., Hughes, N., Jamart, L., Kurz, C., ... & Costello, A. (2024). The 2024 report of the Lancet Countdown on health and climate change: Facing record-breaking threats from delayed action. The Lancet, 404(10465), 1847–1896.

[3] IQAir. (2024). 2024 world air quality report.

[4] Greenstone, Michael et al. (2024) Air Quality Life Index.

[5] World Health Organization. (2021). Global Health Observatory: Air pollution - data by country.

[6] Momtazmanesh, S., Rezaei, N., & Vos, T. (2023). Global burden of chronic respiratory diseases and risk factors, 1990-2019: An update from the Global Burden of Disease Study 2019. eClinicalMedicine, 59, 101936.

[7] Hafeez, A., Saeed, A., Zaidi, S., Mirza, Z. M., & Bhutta, Z. A. (2023). The state of health in Pakistan and its provinces and territories, 1990-2019: A systematic analysis for the Global Burden of Disease Study 2019. The Lancet Global Health, 11(2), e229–e243.

[8] Rafiq, L., Naqvi, S. H. Z., Shahzad, L., & Ali, S. M. (2023). Exploring the links between indoor air pollutants and health outcomes in South Asian countries: A systematic review. Reviews on Environmental Health, 38(4), 741–752.

levels were also significantly higher when traditional stoves were used, rather than a chimney stove.[9]

Pulmonary tuberculosis and acute coronary syndrome links

Women and children (aged between 1–12 years) using biomass fuels were more likely to have pulmonary tuberculosis, and this risk increased in a dose-dependent way.[10] [11] Additionally, when they investigated women admitted with acute coronary syndrome and compared them with matched controls with other diagnoses, a higher risk was found in current users of biomass for cooking.[12]

Considerations in rural Sindh cardiovascular studies

Interestingly, across villages in rural Sindh, no clear association was seen in biomass use and hypertension, angina, heart attacks or coronary artery disease.[13] The authors postulated this may have been because the comparator group had used biomass in the past and had lingering health risks because of this.

Impacts of indoor air pollution on maternal health and childhood pneumonia, stunting, and mortality

The impact of indoor air pollution on pregnancy and child health outcomes has also been investigated.

Rozi et al. found poor air quality and tobacco consumption in the home to be implicated with a higher risk of stillbirth, miscarriages and preterm delivery.[14] Reitzug and colleagues will be performing a regional analysis by investigating Demographic and Health Survey (DHS) data to explore this area further.[15]

In primary health centres in peri-urban slums of Karachi, children with fast breathing pneumonia were found to have poor quality housing, but indoor air quality and exposure to tobacco smoke appeared unrelated to pneumonia recurrence in this specific study.[16]

---

[9] Fatmi, Z., Ntani, G., & Coggon, D. (2020). Levels and determinants of fine particulate matter and carbon monoxide in kitchens using biomass and non-biomass fuel for cooking. International Journal of Environmental Research and Public Health, 17(4), 1287.

[10] Rabbani, U., Sahito, A., Nafees, A. A., Kazi, A., & Fatmi, Z. (2017). Pulmonary tuberculosis is associated with biomass fuel use among rural women in Pakistan: An age- and residence-matched case-control study. Asia Pacific Journal of Public Health, 29(3), 211–218.

[11] Sahito, A., Fatmi, Z., Kadir, M. M., & Arif, F. (2022). Indoor urban environment and conventional risk factors for pediatric tuberculosis among 1–12 years old children in a megacity in Pakistan: A matched case-control study. Pediatric Allergy, Immunology, and Pulmonology, 35(4), 158–165.

[12] Fatmi, Z., Sahito, A., Ntani, G., & Coggon, D. (2020). Acute coronary syndrome and use of biomass fuel among women in rural Pakistan: A case-control study. International Journal of Public Health, 65(2), 149–157.

[13] Fatmi, Z., Ntani, G., & Coggon, D. (2019). Coronary heart disease, hypertension and use of biomass fuel among women: Comparative cross-sectional study. BMJ Open, 9(8), e030881.

[14] Rozi, S., Butt, Z. A., Zahid, N., Wasim, S., & Shafique, K. (2016). Association of tobacco use and other determinants with pregnancy outcomes: A multicentre hospital-based case-control study in Karachi, Pakistan. BMJ Open, 6(9), e012045.

[15] Reitzug, F., Luby, S. P., Pullabhotla, H. K., & Geldsetzer, P. (2022). The effect of particulate matter exposure during pregnancy on pregnancy and child health outcomes in south asia: Protocol for an instrumental variable analysis. JMIR Research Protocols, 11(8), e35249. https://doi.org/10.2196/35249

[16] Brown, N., Rizvi, A., Kerai, S., Nisar, M. I., Rahman, N., Baloch, B., & Jehan, F. (2020). Recurrence of WHO-defined fast breathing pneumonia among infants, its occurrence and predictors in Pakistan: A nested case-control analysis. BMJ Open, 10(1), e035277. https://doi.org/10.1136/bmjopen-2019-035277

Similarly, no links were found with stunting (reduced height in children due to inadequate growth and development) and household air quality when DHS data was interrogated.[17] In the under-fives, a weak association was found with all-cause mortality and indoor air pollution, with a slightly stronger association in those aged 12-59 months.[18] Others showed a higher risk of childhood pneumonia (1.25 times) and acute respiratory infections (1.5 times) in the under-five pediatric population from DHS data in 2017-18[19] and 2012-13[20] respectively.

Meanwhile, a recent cross-sectional study in rural Punjab shows an association with the secondary use of solid fuels, the type of kitchen and cooking stove, as well as the presence of the child in the kitchen, which caused health effects in those children under 12 years old. These included coughing, eye watering and irritation, runny nose and in some, asthma, tuberculosis and pneumonia.[21]

The effects of outdoor air pollution

Ambient air pollution has broad-ranging health effects in Pakistan, especially impacting younger age groups. School-going children (aged between 8-12 years) that lived in highly polluted areas of Lahore (where PM2.5 levels were measured at 183 $\mu g/m^3$) were compared with those living in low pollution areas (28.5 $\mu g/m^3$). They were found to have significantly raised systolic and diastolic blood pressures.[22]

There is a dearth of studies exploring the risk of ambient air pollution on asthma in children in Pakistan. However, we may extrapolate from reviews of studies performed elsewhere that there is association between pollutants and reduced functional development of the lungs, as well as raised asthma incidence and poor outcomes from their asthma.[23] Additionally, there are neurodevelopmental disorders, poor IQ, childhood cancers and raised risk of non-communicable diseases in adulthood documented globally.[24]

In the Malakand division of Northern Pakistan, a study of university students found that most experienced the effects of air pollution; often ENT problems, irritation and sometimes

[17] Kim, R., Mejía-Guevara, I., Corsi, D. J., Aguayo, V. M., & Subramanian, S. V. (2017). Relative importance of 13 correlates of child stunting in South Asia: Insights from nationally representative data from Afghanistan, Bangladesh, India, Nepal, and Pakistan. Social Science & Medicine, 187, 144–154.

[18] Naz, S., Page, A., & Agho, K. E. (2017). Household air pollution from use of cooking fuel and under-five mortality: The role of breastfeeding status and kitchen location in Pakistan. PLOS ONE, 12(3), e0173256.

[19] Naz, L., & Ghimire, U. (2020). Assessing the prevalence trend of childhood pneumonia associated with indoor air pollution in Pakistan. Environmental Science and Pollution Research, 27(35), 44540–44551.

[20] Khan, M. S. B., & Lohano, H. D. (2018). Household air pollution from cooking fuel and respiratory health risks for children in Pakistan. Environmental Science and Pollution Research, 25(25), 24778–24786.

[21] Zahra Naqvi, S. H., Shahzad, L., Haider Naqvi, S. L., Ayub, F., & Tanveer, R. (2025). Assessing the health consequences of indoor air pollution from biomass fuel combustion on pediatric populations in rural communities of Pakistan. International Journal of Environmental Health Research, 35(3), 620–633.

[22] Aslam, R., Sharif, F., Baqar, M., Nizami, A.-S., & Ashraf, U. (2022). Role of ambient air pollution in asthma spread among various population groups of Lahore City: A case study. Environmental Science and Pollution Research, 30(4), 8682–8697.

[23] Burbank, A. J., & Peden, D. B. (2018). Assessing the impact of air pollution on childhood asthma morbidity: How, when, and what to do. Current Opinion in Allergy & Clinical Immunology, 18(2), 124–131.

[24] Brumberg, H. L., Karr, C. J., Bole, A., Ahdoot, S., Balk, S. J., Bernstein, A. S., Byron, L. G., Landrigan, P. J., Marcus, S. M., Nerlinger, A. L., Pacheco, S. E., Woolf, A. D., Zajac, L., Baum, C. R., Campbell, C. C., Sample, J. A., Spanier, A. J., & Trasande, L. (2021). Ambient air pollution: Health hazards to children. Pediatrics, 147(6), e2021051484.

respiratory problems including wheezing. A clear link was also seen with anxiety, depression and aggressiveness.[25]

From historical antecedents to contemporary research, Dr. Saeed illuminates the scale of the challenge, the specific health outcomes associated with different types of exposure, the biological mechanisms involved, and the urgent need for targeted interventions and continued scientific inquiry.

The impact of ambient air pollution has also been explored in adult human health.

Asthmatics in Lahore were found to have a significant correlation between PM10 exposure and asthma clinic visits.[26] Mahmood and colleagues used statistical modeling with Geographic Information Systems (GIS) in Gujranwala to reveal an association with throat infections, eye irritation and runny noses as well as respiratory symptoms such as cough and shortness of breath.[27] Both studies highlighted the vulnerability of the elderly population in their study sample.

In Karachi, cardiovascular admissions and emergency assessments for ischemic heart disease, hypertension, heart failure and cardiomyopathy were all linked with ambient PM2.5 levels.

In Islamabad, a geographical sensing study revealed a relationship between residents' distance from an industrial site and its air pollution with the occurrence of cardiovascular symptoms such as angina.[28]

Along with cardiopulmonary links, the impact on cerebrovascular disease is also emerging. In a focused review for Asia, the link between short and long term air pollution and stroke and death was noted. Interestingly, there was a decline in admissions and mortality related to stroke during the COVID-19 lockdown suggesting a link to decreased levels of air pollution.[29]

Taken together, these studies build a strong body of evidence linking ambient air pollution in Pakistan's cities to a significant burden of cardiovascular and cerebrovascular disease.

[25] Ullah, S., Ullah, N., Rajper, S. A., Ahmad, I., & Li, Z. (2021). Air pollution and associated self-reported effects on the exposed students at Malakand division, Pakistan. Environmental Monitoring and Assessment, 193(11), 708.

[26] Aslam, R., Sharif, F., Baqar, M., Nizami, A.-S., & Ashraf, U. (2022). Role of ambient air pollution in asthma spread among various population groups of Lahore City: A case study. Environmental Science and Pollution Research, 30(4), 8682–8697.

[27] Mahmood, S., Ali, A., & Jumaah, H. J. (2024). Geo-visualizing the hotspots of smog-induced health effects in district Gujranwala, Pakistan: A community perspective. Environmental Monitoring and Assessment, 196(5), 457.

[28] Khayyam, U., Rayan, M., & Hussain Adil, I. (2024). Prevalence of cardiovascular disease (CAD) due to industrial air pollutants in the proximity of islamabad industrial estate (Iei), pakistan. PLOS ONE, 19(7), e0300572.

[29] Taimuri, B., Lakhani, S., Javed, M., Garg, D., Aggarwal, V., Mehndiratta, M. M., & Wasay, M. (2022). Air pollution and cerebrovascular disorders with special reference to Asia: An overview. Annals of Indian Academy of Neurology, 25(Suppl 1), S3–S8.

Important links with occupational exposure to air pollution are worth mentioning.

Brick kiln workers: impaired lung function

Brick kilns are a common trade in Punjab. Raza and colleagues describe impairment in lung function as measured by spirometry (a process of measuring lung function with a machine) along with frequent cough and shortness of breath in those workers in poor quality working sites.[30]

Exposure to polycyclic aromatic hydrocarbons (PAHs): traffic police and cooks

Kamal and colleagues have evaluated links between air quality and polycyclic aromatic hydrocarbons (PAHs), markers of gene damage that are probably carcinogenic. Traffic police officers, exposed to vehicular smoke, have higher levels of PAHs in Rawalpindi and Lahore, whilst this same profile was also seen in residential and professional cooks using biomass fuels.[31] [32] [33] [34]

How pollution attacks the body

Understanding the mechanisms linking pollutants with adverse health outcomes are crucial to develop downstream public health interventions and policies.

Current understanding shows that pollutants themselves (such as particulate matter below 2.5 microns, ozone, nitrogen oxides and transition metals) are oxidants or generate reactive oxygen species. The resultant oxidative stress triggers different biological processes such as inflammation and cell death. This manifests as asthma exacerbations, respiratory infections and the onset of chronic asthma with deficits in lung function with long term damage.[35] [36] Organ function relies on defense mechanisms such as upregulation of protective scavenging and immune systems, which may be overwhelmed by the presence of this oxidative stress.

Air pollutants deposit on the respiratory tract epithelium and cause the well-described respiratory morbidity. However, their transportation to other tissues and organs can cause significant impact, such as cardiovascular morbidity. There are thought to be multiple mechanisms at play here. Humoral (blood-borne) pathways may include activation of cytokine release causing detrimental loss of homeostasis resulting in ischaemic heart

[30] Raza, A., & Ali, Z. (2021). Impact of air pollution generated by brick kilns on the pulmonary health of workers. Journal of Health and Pollution, 11(31), 210906.

[31] Kamal, A., Qamar, K., Gulfraz, M., Anwar, M. A., & Malik, R. N. (2015). PAH exposure and oxidative stress indicators of human cohorts exposed to traffic pollution in Lahore city (Pakistan). Chemosphere, 120, 59–67.

[32] Kamal, A., Cincinelli, A., Martellini, T., & Malik, R. N. (2016). Linking mobile source-PAHs and biological effects in traffic police officers and drivers in Rawalpindi (Pakistan). Ecotoxicology and Environmental Safety, 127, 135–143.

[33] Kamal, A., Cincinelli, A., Martellini, T., & Malik, R. N. (2016). Biomarkers of PAH exposure and hematologic effects in subjects exposed to combustion emission during residential (And professional) cooking practices in Pakistan. Environmental Science and Pollution Research, 23(2), 1284–1299.

[34] Dondi, A., Carbone, C., Manieri, E., Zama, D., Del Bono, C., Betti, L., Biagi, C., & Lanari, M. (2023). Outdoor air pollution and childhood respiratory disease: The role of oxidative stress. International Journal of Molecular Sciences, 24(5), 4345.

[35] Lodovici, M., & Bigagli, E. (2011). Oxidative stress and air pollution exposure. Journal of Toxicology, 2011, 1–9.

[36] Yeates, D. B., & Mauderly, J. L. (2001). Inhaled environmental/occupational irritants and allergens: Mechanisms of cardiovascular and systemic responses. Introduction. Environmental Health Perspectives, 109(suppl 4), 479–481.

damage. Meanwhile neural (via the nervous system) pathways are implicated by direct activation of C fibres causing physiological changes such as hypotension, as well as releasing inflammatory mediators that cause cellular damage.[37]

In children, who have a described increase of risk in Pakistan, important considerations are that they are often oral breathers, thereby bypassing the nasal filter, and spend more time outdoors engaged in activities that raise their respiratory rate leading to increased inhalation. Their growing lungs are therefore at heightened risk of altered development and lung function.

An agenda for action and inquiry

Future research for air quality in Pakistan is imperative in response to the public health emergency that it has caused.

This review of the published literature highlights the multidisciplinary nature of research into air pollution's health effects, reflecting the issue's multi-faceted impact and providing an ideal foundation for interdisciplinary collaboration to create novel interventions.

Enhancing quantitative assessments and emission inventories

Whilst there have been several descriptions of the major sources of air pollution, there should be focused quantitative assessment of these due to the differing landscapes and cultures across the country. Beyond source apportionment, there should be well-demarcated, geographical emission inventories that can better differentiate rural and urban areas.

Strengthening health impact studies and registries

To date, health impact studies have been limited to discrete communities or cities. Collaboration of medical researchers across the country can build up important databases and registries which would be helpful to investigate the short and long term health effects. These can be used to identify impacts on vulnerable groups such as children, elderly and those with pre-existing conditions.

The correlations between air pollution, chronic disease, and mental health are also important areas for future investigation.

Focusing on vulnerable groups, interventional research and accessible solutions

Finally, focusing on vulnerable groups, interventional research, and accessible solutions must be a priority. Interventions need to come with effectiveness studies, participatory research and low-cost solutions to ensure acceptability, cost-effectiveness and sustainability. Community involvement is essential and should include education that is accessible to all socio-economic groups to truly create the change needed for a healthier Pakistan.

The evidence laid out in this chapter is a clear and urgent call for a public health-centred

[37] Esposito, S., Tenconi, R., Lelii, M., Preti, V., Nazzari, E., Consolo, S., & Patria, M. F. (2014). Possible molecular mechanisms linking air pollution and asthma in children. BMC Pulmonary Medicine, 14(1), 31.

approach to Pakistan's air quality. From the toxic air in our kitchens to the hazardous haze in our cities, the burden of disease is a systemic crisis that can no longer be ignored. The research agenda outlined here is not a call for passive study, but a blueprint for informed action. Bridging these knowledge gaps is essential, not as an academic exercise, but as a fundamental step in crafting the life-saving policies and interventions that the people of Pakistan deserve.

Dr. Saima Saeed is a Respiratory Medicine consultant at the Indus Hospital and Health Network, where she has initiated multiple services to promote lung health. She is a keen advocate for multidisciplinary approaches to addressing significant risk factors for lung disease, namely air quality and tobacco.

Maria Adil's digital collage, ***Choking on Toxic Air,*** surrealistically depicts the stifling reality of breathing in a polluted metropolis. The artwork visualizes the psychological and physical encroachment of smog, where the simple act of survival becomes a struggle against the environment.

9.

The Disproportionate Gendered Burden

The often-overlooked gender aspect of air pollution

Exposure shaped by society: Traditional roles as primary caregivers and managers of the home place women and girls at the forefront of the indoor air pollution crisis, exposing them to PM2.5 levels that can be hundreds of times higher than safe limits.

A threat to mothers and children: Air pollution is linked to severe adverse pregnancy outcomes in Pakistan, including stillbirth and miscarriages, and has long-term consequences for fetal health, lung function, and immune system development.

A policy blindspot: Despite clear evidence of differential impacts, Pakistan's key environmental laws and clean air policies (including the National Clean Air Policy 2023) are gender-blind and lack specific measures to protect women.

The haze that blankets our cities is not gender-neutral. Sara Hayat moves beyond generalised health statistics to reveal the specific, disproportionate, and often invisible burden that air pollution places on the health, economic potential, and reproductive lives of Pakistan's women. This chapter is a call to action against a fundamental policy blindspot, providing the evidence needed to build a truly equitable clean air strategy.

Air pollution has a profound and disproportionate impact on women, arising from both their exposure levels linked to traditional societal roles and their distinct physiological characteristics. Pregnant women and fetuses face particularly heightened risks with potentially long-term consequences. Despite startling evidence of these differential impacts, a dire need for greater female representation and perspective in environmental decision-making remains, as Pakistan currently lacks gender-sensitive environmental laws and policies.

Air pollution impacts women and men differently due primarily to two interacting factors: first, the conventional roles often assigned to women as primary caregivers and managers of the domestic sphere, which can increase their exposure duration, especially to indoor pollutants; and second, physiological differences that may render women more vulnerable to the health effects of certain pollutants. These factors necessitate gender-specific considerations in public health responses and air pollution mitigation strategies. For example, respiratory diseases like asthma often manifest differently in females and males, with research suggesting women are more likely to suffer from severe, treatment-resistant forms of asthma. Indicative local data showed that 64% of asthma patients reported in selected Lahore hospitals were females primarily involved in indoor activities, pointing towards potential links with household exposures.[1]

Furthermore, women are disproportionately represented in Pakistan's informal economy, often concentrated in low-skilled jobs. This frequently means they lack access to crucial information regarding their occupational rights, health and safety protocols, and specific workplace environmental protections. This vulnerability exacerbates the health impacts of air pollution they might face both at work and at home, while limiting their capacity to adapt or seek remediation. Interestingly, however, a study conducted in Pakistan's Swat region revealed that females exhibited greater awareness than men regarding the consequences of air pollution and were more likely to believe that protecting health is more important than prioritising GDP growth.[2]

This suggests that with access to consistent, reliable information, women could serve as highly effective agents of change within their communities. A significant roadblock, however, remains the lack of updated, gender-disaggregated data within Pakistan on how air pollution specifically affects women's health across different life stages and socio-economic groups. This data gap severely hampers efforts to design targeted prevention strategies and provide equitable diagnosis and treatment.

The hazards within: indoor air pollution and women's health

Indoor air pollution, primarily driven by fine particulate matter (PM2.5) released from burning solid fuels, has particularly harmful effects on women's health due to the significant amount of time they typically spend indoors engaged in domestic work, especially cooking and cleaning near the source of emissions. Social factors such as poverty, gender invisibility in policymaking, and broader societal inequalities often intensify these impacts on women compared to men. The documented physical health effects are extensive and include respiratory diseases, exacerbation or onset of asthma, allergic reactions, cardiovascular problems, lung cancer, and other serious conditions.[3]

The primary cause of hazardous indoor air pollution in many Pakistani households is the burning of traditional biomass fuels—wood, dung cakes,[4] crop residue—and sometimes kerosene for cooking and heating. These fuels remain prevalent in rural and peri-urban areas often due to easier access and lower (or zero) direct monetary cost compared to

[1] Kausar, A., Ahmad, I., Zhu, T., & Shahzad, H. (2023). Impact of indoor air pollution in pakistan—Causes and management. Pollutants, 3(2), 293–319. https://doi.org/10.3390/pollutants3020021

[2] Ullah, S., Ullah, N., Rajper, S. A., Ahmad, I., & Li, Z. (2021). Air pollution and associated self-reported effects on the exposed students at Malakand division, Pakistan. Environmental Monitoring and Assessment, 193(11), 708. https://doi.org/10.1007/s10661-021-09484-2

[3] Ali, M. U., Yu, Y., Yousaf, B., Munir, M. A. M., Ullah, S., Zheng, C., Kuang, X., & Wong, M. H. (2021). Health impacts of indoor air pollution from household solid fuel on children and women. Journal of Hazardous Materials, 416, 126127. https://doi.org/10.1016/j.jhazmat.2021.126127

[4] Dung produces hydrocarbon emissions that are harmful to women and children, depending on the degree of exposure.

cleaner alternatives. A survey involving 252 households in Pakistan's Abbottabad and Haripur districts confirmed that reliance on solid fuels, the resultant pollution exposure, and cooking in enclosed kitchens without adequate ventilation have significant negative impacts on respiratory health.[5]

The World Health Organization (WHO) reinforces this danger, reporting that indoor smoke levels in poorly ventilated dwellings using traditional fuels can contain fine particle concentrations approximately 100 times higher than safe limits.[6]

Indoor air pollution, primarily driven by fine particulate matter (PM2.5) released from burning solid fuels, has particularly harmful effects on women's health due to the significant amount of time they typically spend indoors engaged in domestic work.

Evidence indicates that women exposed to such indoor pollution suffer disproportionately, experiencing conditions like chronic obstructive pulmonary disease (COPD) at rates potentially twice as high as men in similar environments. Beyond direct inhalation exposure, the lack of access to clean energy imposes further burdens. Women and girls are often tasked with collecting firewood, requiring them to walk long distances, sometimes in harsh weather conditions. This not only exposes them to risks of sexual violence, harassment, and animal attacks but also involves strenuous physical activity that can damage musculoskeletal health. This time-consuming drudgery also represents a significant opportunity cost, consuming time that could otherwise be spent on education, income generation, or rest.

Addressing exposure to indoor air pollution requires tackling the reliance on polluting fuels. Shifting from traditional biomass to cleaner fuels, like LPG, offers a significant improvement. Ideally, transitioning towards renewable energy solutions like solar-powered electric cooking would eliminate household emissions entirely, though these currently face significant adoption challenges related to the high costs of procurement, operation, and maintenance, particularly for off-grid and low-income populations.

Raising awareness among women about the specific health effects of indoor air pollution is critically important. Even simple behavioural changes, where feasible, such as ensuring ventilation by keeping windows and doors open during cooking or positioning stoves in outdoor or semi-outdoor areas, can help reduce direct exposure. However, such awareness and behavioural change initiatives face considerable challenges. These include the limited social mobility experienced by many women, particularly in rural areas; reduced access to information channels like the internet, smartphones, and social media; and the reality that household financial decisions, including

[5] Abedullah, & Tanvir, M. (2020). Unveiling the effects of indoor air pollution on health of rural women in Pakistan (PIDE-Working Papers No. 2020:12). Pakistan Institute of Development Economics.

[6] World Health Organization. (n.d.). Household air pollution.

those related to energy expenditure or stove purchases, are often made predominantly by men without adequate consideration of women's health or preferences. Empowering women to adopt cleaner cooking methods, potentially through targeted financial support or income-generating opportunities, can yield substantial co-benefits, including improved family health, significant time savings previously spent collecting biomass, and potentially enabling women to pursue economic independence.

According to WHO, household air pollution resulting from the incomplete combustion of solid fuels and kerosene causes an estimated 3.2 million premature deaths globally each year. These deaths primarily result from ischemic heart disease (accounting for 32% of deaths), strokes (23%), lower respiratory infections (21%), chronic obstructive pulmonary disease (COPD) (19%), and lung cancer (6%). In 2019 alone, household air pollution was responsible for the loss of approximately 86 million healthy life years globally, with women, particularly those in low- and middle-income countries like Pakistan, bearing the largest share of this immense burden.

Dust represents another significant, though often less discussed, contributor to indoor air pollution, especially in developing countries. Sources are varied and include outdoor particulate matter tracked indoors via human activity or traffic, emissions from electronic devices and building materials, residues from pest control actions, and shedding from furniture like sofas and carpets, which can be major reservoirs. Concerningly, studies conducted in Pakistani cities including Lahore, Faisalabad, and Bahawalpur detected very high concentrations of potentially harmful polychlorinated biphenyls (PCBs) in household dust.[7] Ingesting or inhaling contaminated dust can lead to various health issues, including skin damage, liver and gastrointestinal diseases, impairments to the immune and nervous systems, and elevated cancer risks. Women may face greater vulnerability due to their traditional roles in cleaning and dusting, and also because cultural practices like purdah may require them to spend more time indoors, increasing their overall exposure duration.[8]

The compounded risks of outdoor air

The health risks for women are compounded when exposure to indoor air pollution is combined with exposure to ambient (outdoor) air pollution. Women who experience prolonged indoor air pollution exposure may develop reduced lung function, making them subsequently more vulnerable to the damaging effects of outdoor pollutants. This dual exposure can exacerbate existing respiratory problems or contribute to the development of new ones.

Research increasingly points towards physiological differences influencing susceptibility. A 2022 study examining the effects of diesel fume exposure on lung diseases in non-smoking men and women used advanced analytical techniques to identify changes in body proteins following controlled exposure. Preliminary findings indicated that women were more likely to suffer from severe forms of asthma that were resistant to standard

[7] Kausar, A., Ahmad, I., Zhu, T., & Shahzad, H. (2023). Impact of indoor air pollution in pakistan—Causes and management. Pollutants, 3(2), 293–319.

[8] Cultural and religious dictates that require women to remain in purdah: keeping away from men she is not related to, and/or male relations she can marry.

treatments, suggesting potential sex-based physiological differences in response to air pollution's harmful components.[9][10]

Cognitive function also appears to be affected differently by air pollution across genders. A 2018 South Korean study investigated the effects of outdoor air pollution on cognitive function in elderly women across four different regions. The results confirmed a growing body of evidence indicating a relationship between air pollution exposure and declining cognitive function, with women showing a potentially higher risk for cognitive decline associated with increased exposure to both PM_{10} and PM2.5. This study also found that the adverse effects of nitrogen dioxide (NO_2) exposure on cognitive function appeared greater in women than in men, possibly due to underlying neurological structural differences influencing how cognitive processes respond to pollutant-induced stress.[11]

A substantial body of research now demonstrates clear connections between exposure to air pollution and a range of negative effects on female fertility, pregnancy outcomes, and subsequent fetal health and development.

Interestingly, a large 2017 Chinese study examining the impact of air pollution on verbal and mathematics test scores yielded contrasting gender-specific results. The study, involving subjects older than 10 years, found that both contemporaneous and cumulative exposure to air pollution negatively affected test scores, with a greater impact observed on verbal skills compared to mathematical abilities. However, contrary to some other findings, this study reported that men performed worse than women on both types of tests despite experiencing identical pollution exposure levels. This gender difference in performance impact was more pronounced among older and less educated individuals within the study cohort. The researchers hypothesised that this specific gender gap might relate to known differences in brain composition; men, on average, have a smaller volume of white matter (which facilitates communication between brain regions) activated during general cognitive testing compared to women. Since air pollution is believed to potentially reduce white matter density, this could explain the differential impact observed on verbal scores and the greater vulnerability of men in this specific cognitive assessment.[12][13] These varying findings

[9] Kitanovska, S., & Zenger News. (2022, September 2). Women are more affected by air pollution than men: study. Newsweek.

[10] Hemshekhar, M., Mostafa, D. H. D., Spicer, V., Piyadasa, H., Maestre-Batlle, D., Bolling, A. K., Halayko, A. J., Carlsten, C., & Mookherjee, N. (2022). Sex dimorphism of allergen-induced secreted proteins in murine and human lungs. Frontiers in Immunology, 13, 923986.

[11] Kim, H., Noh, J., Noh, Y., Oh, S. S., Koh, S.-B., & Kim, C. (2019). Gender difference in the effects of outdoor air pollution on cognitive function among elderly in korea. Frontiers in Public Health, 7, 375.

[12] IZA Institute of Labor Economics. (2017). Smog in our brains: Gender differences in the impact of exposure to air pollution on cognitive performance.

[13] Zhang, X., Chen, X., & Zhang, X. (2018). The impact of exposure to air pollution on cognitive performance. Proceedings of the National Academy of Sciences, 115(37), 9193–9197.

highlight the complexity of neurobiological responses to pollution and underscore the urgent need for more Pakistan-specific research. However, the broader body of evidence confirms that cognitive health for both genders is at significant risk from air pollution

Emerging research is also strengthening the link between air pollution exposure and an increased risk of breast cancer. A large-scale study conducted by the US National Institutes of Health (NIH), involving over 500,000 participants, found the highest incidence of breast cancer among women who had elevated levels of PM2.5 near their homes. Sources contributing to these PM2.5 levels included vehicle exhaust, various combustion processes, wood burning, and industrial emissions.[14]

Air pollution's impact on women extends beyond direct physical health effects, significantly diminishing their ability to participate fully in the workforce. This occurs both through damage to their own health and by compromising the health of their dependents, for whom they often serve as primary caregivers. When children or elderly family members fall ill due to pollution-related ailments, women frequently must reduce their working hours or leave employment altogether to provide necessary care. A comprehensive 20-year study from Santiago, Chile, confirmed this dynamic; while overall working hours across the population were not significantly reduced by air pollution fluctuations, the hours worked specifically by women did decrease, especially for those with children. This gender difference in work hours widened notably during weeks with high pollution levels (exceeding 100 $\mu g/m^3$), primarily attributed to women needing to care for children kept home from school due to pollution advisories.[15] Ambient air pollution thus directly contributes to gender inequality in the labour market and exacerbates economic disparities through the gender-biased distribution of unpaid care responsibilities. Even for women not currently employed, the burden of caring for dependents made routinely ill by air pollution can significantly impede their potential entry into the labour force.

A period of critical vulnerability: pregnancy and fetal health

Reproductive health is particularly sensitive to environmental toxins originating from various anthropogenic sources, including agrochemicals, vehicle emissions, and industrial waste. A substantial body of research now demonstrates clear connections between exposure to air pollution and a range of negative effects on female fertility, pregnancy outcomes, and subsequent fetal health and development. Managing exposure during pregnancy presents unique challenges because harmful levels of pollutants can be encountered in both outdoor environments and enclosed indoor spaces, particularly those where biomass fuels are used.

Exposure to poor air quality during pregnancy is associated with several serious

---

[14] White, A. J., Fisher, J. A., Sweeney, M. R., Freedman, N. D., Kaufman, J. D., Silverman, D. T., & Jones, R. R. (2024). Ambient fine particulate matter and breast cancer incidence in a large prospective US cohort. Journal of the National Cancer Institute, 116(1), 53-60.

[15] Montt, G. (2018). Too polluted to work? The gendered correlates of air pollution on hours worked. IZA Journal of Labor Economics, 7(1).

complications, including preeclampsia (a dangerous condition characterised by high blood pressure), stillbirth and spontaneous miscarriages, gestational diabetes mellitus (GDM), and the development of high blood pressure in the mother.[16] A study conducted in New York found that exposure to PM2.5 during the fifth and sixth months of pregnancy, as well as exposure to NO_2 around the time of conception (periconception), were linked to significantly higher odds of developing GDM.[17] According to other research reviews, the first 1000 days of life—spanning from conception to approximately two years of age—represent a particularly critical window of susceptibility to the harmful effects of air pollution.[18]

Research from Kansas specifically suggests that exposure to ozone during the second and third trimesters of pregnancy may be the most sensitive period for adverse birth outcomes, including low birth weight.[19] Furthermore, during fetal development itself, air pollution exposure can interfere with proper organogenesis, leading to outcomes such as poor lung development, low birth weight, and premature birth. It can also impair the proper development of the immune system, potentially increasing susceptibility to infections and diseases later in life.

Exposure to household air pollution during infancy has been linked to a 19% increase in the risk of postnatal stunting. Beyond these immediate developmental consequences, poor air quality exposure early in life can predispose individuals to greater vulnerability to chronic diseases in adulthood. Compounding these biological impacts, in most societal contexts, the demanding task of caring for an unwell infant or managing a child's long-term health conditions falls primarily upon mothers, contributing significantly to their workload and increasing their physical and mental stress.

Policy blindspots: a gender-insensitive framework

Despite the clear and growing body of international and emerging local evidence indicating that air pollution disproportionately harms women's health and wellbeing, Pakistan's existing environmental laws and air quality policies largely fail to acknowledge or address this critical gender dimension. Specific remedial measures tailored to women's unique vulnerabilities are conspicuously absent.

An examination of key policy documents reveals this gap. The National Clean Air Policy 2023 mentions the term "gender" only once, and solely within the context of urban planning and infrastructure development, without delving into health or socio-economic disparities. The country's primary environmental legislation, the Environmental Protection Act 1997, completely overlooks gender considerations in its framework for environmental protection and pollution control.

[16] Rani, P., & Dhok, A. (2023). Effects of pollution on pregnancy and infants. Cureus, 15(1), e33906.

[17] Zhu, K., Mendola, P., Barnabei, V. M., Wang, M., Hageman Blair, R., Schwartz, J., & Mu, L. (2024). Association of prenatal exposure to PM2.5 and NO2 with gestational diabetes in Western New York. Environmental Research, 244, Article 117873.

[18] Rani, P., & Dhok, A. (2023). Effects of pollution on pregnancy and infants. Cureus, 15(1), e33906.

[19] Hao, H., Yoo, S. R., Strickland, M. J., Darrow, L. A., D'Souza, R. R., Warren, J. L., ... Chang, H. H. (2023). Effects of air pollution on adverse birth outcomes and pregnancy complications in the U.S. state of Kansas (2000–2015). Scientific Reports, 13(1), 21476.

Despite the clear and growing body of international and emerging local evidence indicating that air pollution disproportionately harms women's health and wellbeing, Pakistan's existing environmental laws and air quality policies largely fail to acknowledge or address this critical gender dimension.

Furthermore, the R-Smog Report 2018, commissioned by the Food and Agriculture Organization (FAO) and the Punjab Government as the first comprehensive geospatial research initiative on the causes of smog in the province, makes no mention of gender at all.[20] This omission is particularly notable given the report's stated aim was to promote the "development of appropriate strategies and necessary action plans" to combat smog.[21]

Currently, the only national policy document that directly addresses some of these issues is the Climate Change Gender Action Plan (ccGAP) 2022. This plan acknowledges the adverse health impacts of indoor air pollution on women, highlights the significant underrepresentation of women employed in the energy sector, and correctly notes the pervasive gender blindness that characterises most energy sector policies in Pakistan. However, its scope is primarily focused on climate change adaptation and mitigation, rather than providing a comprehensive framework specifically for addressing the gendered health impacts of air pollution itself.

An agenda for an equitable future

The evidence compellingly demonstrates that air pollution impacts females more severely than males across various health domains, affecting their physical wellbeing, economic opportunities, and reproductive outcomes. Recognising this disparity is not about fostering competition between sexes, but rather about acknowledging differential vulnerabilities to ensure that gender-specific laws, policies, and interventions become systematic priorities within environmental health governance.

For Pakistan to successfully move towards more equitable and effective air quality management, several key actions are essential:

Enhance women's representation and meaningful participation in environmental decision-making bodies and policy management processes at all levels. Ensuring women's insights, experiences, and expertise are actively sought and taken seriously is crucial for developing relevant and effective policies.

Centre women's health concerns explicitly within national and provincial air quality

[20] FAO. (2018). Remote sensing for spatio-temporal mapping of smog in Punjab and identification of the underlying causes using GIS techniques (R-SMOG).

[21] IUCN Pakistan (2022). Climate Change Gender Action Plan of the Government and People of Pakistan. IUCN Pakistan, Pakistan. xii + 107 pp.

management strategies, as well as broader climate change adaptation and mitigation plans. This requires enacting gender-sensitive environmental laws and policies that recognise differential exposures and vulnerabilities.

Develop and invest in Pakistan-specific research and data collection that is disaggregated by gender and other relevant socio-demographic factors. This will reduce reliance on international studies, allow for a better understanding of local contexts and specific vulnerabilities within Pakistan, and provide a stronger evidence base for targeted interventions.

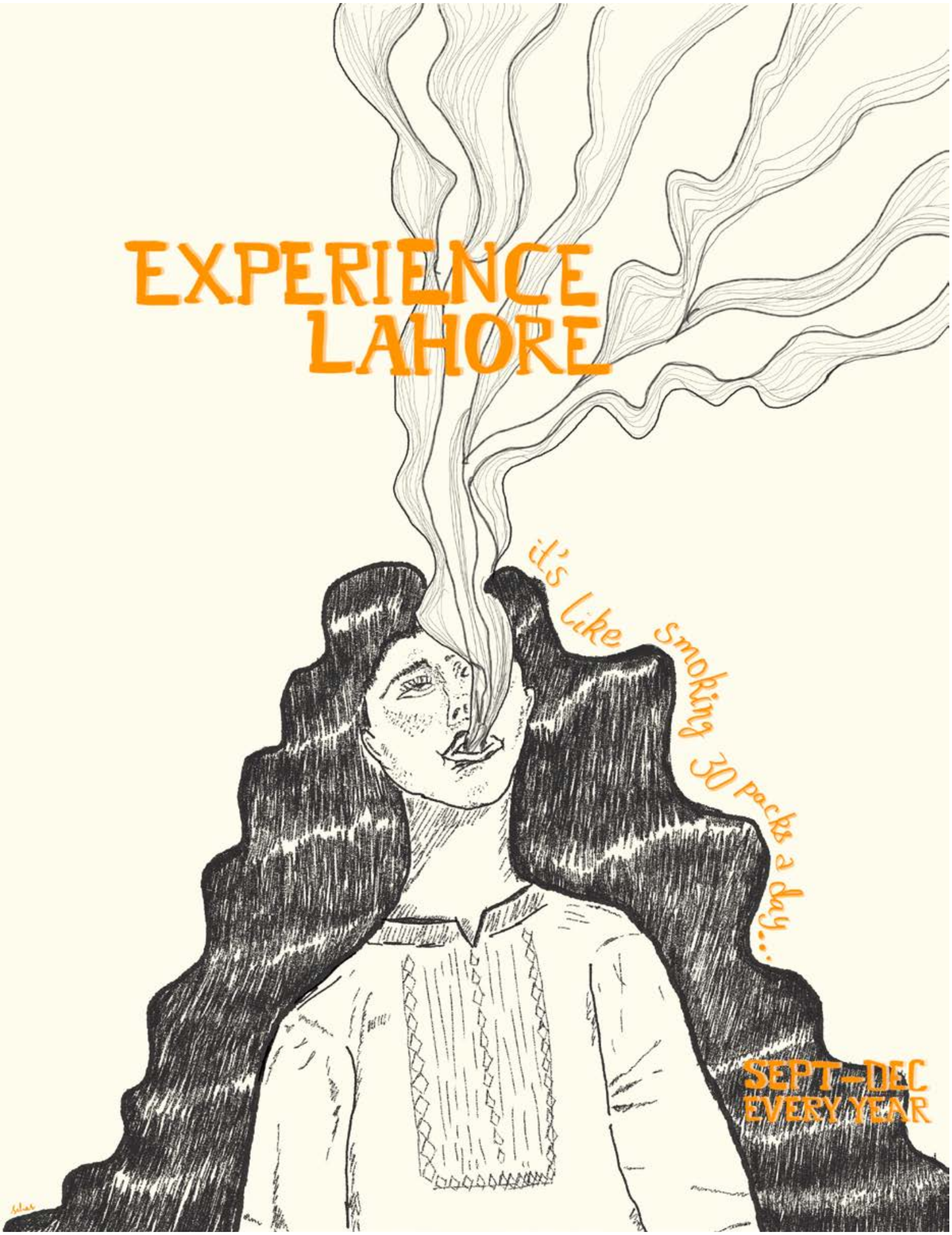
Raise targeted awareness among women and girls about the specific health impacts of both indoor and ambient air pollution. This knowledge can empower them to take protective measures where possible and also enable them to convey crucial health information to their families and communities.

Include men and boys in awareness and engagement efforts, particularly targeting those who often hold primary decision-making power within households and communities. Acknowledging and addressing the adverse effects of air pollution on women requires the understanding and cooperation of men.

Empower women economically by promoting access to and control over income, assets, and financial resources. Economic empowerment can provide women with greater agency to make health-protective choices for themselves and their families, such as investing in cleaner cooking methods or accessing better healthcare.

By systematically addressing these priorities, Pakistan can begin to close the significant gender gap in air pollution impacts, fostering environmental justice and creating more equitable health protections for all its citizens.

Sara Hayat is a lawyer specialising in climate change law and policy, and is a consultant and founding partner at Climate Change, Sustainability and Resilience Consultants.



Adopting the visual language of a vintage travel poster, artist Saher Salman Haider offers a grim invitation to 'Experience Lahore.' The illustration satirises the city's winter smog season, equating the simple act of breathing the ambient air to a heavy smoking habit, thereby visualising the invisible, cumulative damage inflicted on residents' lungs.

Section Two

Addressing Key Pollution Sources

2

Driven by the tight window between rice harvest and wheat planting, farmers resort to burning crop residue as a quick clearing method. This widespread agricultural practice releases massive plumes of smoke that combine with urban emissions to trigger the region's catastrophic winter smog episodes.

10.

Crop Burning

Controlling crop burning in South Asia through local government actions

A solvable crisis: Crop residue burning, responsible for an estimated 66,000 deaths and USD 66 billion in economic damages annually across South Asia, is not an intractable problem.

Bureaucrats respond to local harm: District administrators are 10-13% more likely to enforce anti-burning laws when weather patterns predict the smoke will pollute their own district, suggesting local incentives drive action.

Targeted enforcement works: Punishing a single farmer creates a powerful deterrent effect, making other farmers in the area 13% less likely to burn. This shows that strategic, limited enforcement can have a broad impact on compliance.

The smoke from burning fields that chokes our cities each winter is more than an agricultural problem—it is a governance problem. Gemma Dipoppa and Saad Gulzar move the focus from the farmer's field to the district administrator's office, asking a critical question: What makes the State act? The answers, grounded in extensive data, reveal the hidden incentives that drive local enforcement and offer a powerful, evidence-based argument for empowering local government as a primary line of defense in the fight for clean air.

Air pollution from crop residue burning in South Asia ranks among the world's greatest public health threats. Estimates indicate that up to 60% of severe winter air pollution in parts of Pakistan and India can be attributed to this seasonal practice. Farmers often resort to burning crop residue as a quick and inexpensive method to clear fields for the next planting cycle, a practice much cheaper and widely accessible than mechanical alternatives.. However, this convenience comes at an immense cost to public health.

A Global Burden of Disease study attributes 66,000 deaths per year directly to crop residue burning across the region, corresponding to staggering economic damages estimated at USD 66 billion.[1] The costs of this pollution are so high that analysis suggests compensating each farmer for the entire cost of adopting non-burning methods would

[1] GBD 2019 Risk Factors Collaborators. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet, 396(10258), 1223–1249.

likely be cost-effective from the State's perspective.[2] While farmers responsible for burning are often themselves economically marginalised, the continued practice of crop burning nevertheless leads to the preventable loss of thousands of lives annually.

This chapter investigates a crucial, often overlooked, aspect of pollution control: the role of district bureaucrats in enforcing anti-burning laws and the incentives that shape their actions. District administrators operate under conflicting pressures, needing to address crop burning while managing numerous other administrative tasks. We explore how these officials respond to varying pressures and incentives, the conditions under which their interventions yield effective results, and the potential impacts of their actions on public health and environmental quality. Our research provides insights into whether meaningful control over crop burning through bureaucratic action is achievable and the mechanisms through which such control could be exercised.[3]

The view from the district office: pressures and priorities

At the district level, designated administrators are primarily responsible for enforcing bans on crop burning. Both Pakistan and India have enacted laws making crop residue burning illegal, with violations potentially punishable by fines or even imprisonment. Administrative pressure on bureaucrats to curb burning originates from several sources, although the intensity of this pressure can vary significantly.

Legal mandates and judicial directives

Bureaucrats are legally obligated to enforce anti-burning laws, including by issuing penalties for farmers outlined in national and regional legislation. Furthermore, judicial directives, such as those issued by the Supreme Court of India, have reinforced this necessity, mandating state-level administrators to take decisive action against crop burning. In Pakistan, administrators possess powers under Section 144 of the Code of Criminal Procedure, which can be invoked to restrict activities like crop burning during high-risk periods.[4]

Public pressure and media scrutiny

Growing public awareness, particularly during the peak winter smog season, amplified by media attention, creates significant pressure on bureaucrats to demonstrate action. Increased access to real-time air quality data and consistent reporting by news organisations have fueled citizen concern and demands for action. The health impact is often immediate and visible; for example, around two million people reportedly visited medical facilities for respiratory issues in Pakistan's Punjab province between October and

[2] Jack, B. K., Jayachandran, S., Kala, N., & Pande, R. (2024). Money (not) to burn: Payments for ecosystem services to reduce crop residue burning. American Economic Review Insights. Forthcoming.

[3] Here, we summarise the main findings from this research; interested readers are encouraged to consult the main scientific paper published in Nature for complete technical details: Dipoppa, G., & Gulzar, S. (2024). Bureaucrat incentives reduce crop burning and child mortality in South Asia. Nature, 634, 1125–1131.

[4] Government of Pakistan. (1898). The Code of Criminal Procedure, 1898. Section 144.

November 2024 due to extremely polluted air.[5]

Performance monitoring and career incentives

District administrators are subject to monitoring by senior officials, with performance related to crop burning control increasingly becoming a factor. Documented inaction can lead to formal reprimands and potentially harm an administrator's career trajectory, as feedback from superiors influences evaluations, promotions, and transfers.

Despite these converging pressures, the actual enforcement of crop burning bans varies significantly across different districts. Several factors contribute to this heterogeneity. Bureaucrats retain discretion in allocating their time and resources across a multitude of competing tasks; and since the number of tasks they need to attend to is large, it is conceivable that they may not allocate high priority to controlling crop burning amidst other pressing duties. Furthermore, the degree of local embeddedness and accountability of district-level staff can differ, potentially influenced by whether they are recruited at the state/provincial or federal level. Pressure from farmers to halt the enforcement of anti-burning laws, especially when well-organised, can also contribute to restricting the margin of action for bureaucrats. These dynamics collectively contribute to substantial variation in the effort each administrative unit devotes to controlling crop burning.

Asking the right questions: a new research approach

Our research sought to answer three key questions regarding the potential for bureaucratic control over crop burning.

Does self-interest motivate action?

Prior research suggests pollution often increases in areas that bear the externalities of their neighbour, implying that bureaucratic inaction can exacerbate pollution problems.[6] [7] [8] We explored the converse: do bureaucrats take active steps to reduce pollution when it directly impacts their own jurisdiction? If district administrators reduce burning to minimise local pollution, this indicates a willingness to act contrary to the assumption of bureaucratic inaction towards exerting any control over crop burning.

Can limited enforcement create broader deterrence?

Bureaucratic interventions, such as fines or penalties, might influence not only the farmers directly punished but could also discourage others by increasing the perceived risk of punishment. If such bureaucratic deterrence is effective, even limited enforcement actions could significantly reduce overall crop burning through spillover to other farmers.

[5] Chaudhry, A. (2024, November 15). 2 million seek treatment as smog chokes Punjab. Dawn.

[6] Sigman, H. (2002). International spillovers and water quality in rivers: Do countries free ride? American Economic Review, 92(4), 1152–1159.

[7] Kahn, M. E., Li, P., & Zhao, D. (2015). Water pollution progress at borders: The role of changes in China's political promotion incentives. American Economic Journal: Economic Policy, 7(4), 223-242.

[8] Lipscomb, M., & Mobarak, A. M. (2016). Decentralization and pollution spillovers: Evidence from the re-drawing of county borders in Brazil. The Review of Economic Studies, 84(1), 464-502.

A holistic approach that combines appropriately targeted enforcement with robust support measures for sustainable farming practices offers the most promising pathway towards resolving South Asia's crop burning crisis, aligning local incentives with critical regional public health and global environmental priorities.

How does bureaucratic action impact health outcomes?

By understanding the relationship between bureaucratic action to reduce crop burning and critical health indicators like infant mortality, we can estimate the human cost associated with varying levels of enforcement. Connecting pollution from burning to health impacts allows an assessment of the potential benefits achievable through increased enforcement.

To address these questions, we gathered and analysed extensive satellite and administrative data spanning 12 years from the northern Indian subcontinent. This region included the states of Punjab in both Pakistan and India, Haryana, Delhi, Uttar Pradesh, and Bihar; encompassing an area home to approximately 500 million people. Our dataset comprised 18 million observations, allowing for granular analysis down to a 5-kilometre grid level. This large-scale, long-term dataset enabled us to gain robust insights into the potential for bureaucratic intervention in curbing crop burning.

Our study yielded several important findings, as follows.

Local incentives drive administrative action

Contrary to the notion that bureaucrats are largely passive regarding air pollution, our results demonstrate that district administrators and their teams do respond to crop burning when the resulting pollution affects their own jurisdictions. We found that the number of crop burning fires detected via satellite decreases by 10-13% on average when meteorological conditions predict that the pollution generated will predominantly impact the bureaucrat's home district. This translates into an estimated annual reduction of approximately 54-72 fires per district. The effect is notably amplified during critical rice harvest seasons, when detected fires decrease by an average of 46%. These findings suggest that the internalisation of pollution's negative externalities serves as a significant motivator for bureaucratic action, challenging the common perception that local officials have limited influence over complex environmental issues like crop burning.

Targeted enforcement creates broader compliance

Bureaucratic punishment generates a demonstrable deterrent effect, particularly in areas where farmers perceive a higher likelihood of future enforcement. Our analysis indicates that farmers are approximately 13% less inclined to burn crop residue if they anticipate potential intervention from authorities. This finding implies that administrators do not necessarily need to penalise every single offending farmer; rather, strategically targeted enforcement in high-risk or highly visible areas can significantly influence compliance with crop burning bans. This insight is valuable as it suggests that enforcement efforts can effectively reduce burning without resorting to widespread punitive measures, which could be politically difficult and logistically challenging.

Reducing fires saves children's lives

We combined output from a meteorological model, which calculates the atmospheric dispersion of polluting particles, with an instrumental variable approach to rigorously estimate the causal link between crop burning pollution and child health outcomes. Our analysis reveals a substantial increase in in-utero exposure to pollution originating from crop burning (specifically, a one standard deviation increase in exposure, corresponding roughly to a 70% rise in pollution levels relative to the mean in our sample) raises infant mortality by an additional 30-36 deaths per 1000 live births. This finding powerfully underscores that bureaucratic enforcement actions which successfully reduce crop burning yield significant public health benefits, particularly for vulnerable infant populations exposed to high levels of particulate matter during critical developmental periods. The findings on the health impact of crop burning underscore the critical role that local government action can play in mitigating the human costs of air pollution.

From evidence to action: a blueprint for local governance

Our findings offer several actionable implications for environmental governance and policy aimed at controlling crop burning in Pakistan and the wider region.

Empower district administrators

Given the impactful role that district bureaucrats can play in reducing crop burning when motivated, policies should focus on empowering these local administrators. This could involve providing additional resources specifically allocated for monitoring and enforcement activities, aligning performance incentives more closely with measurable pollution reduction targets, and offering more substantial operational support, particularly during the peak winter burning seasons. Strengthening local capacity could enable more proactive and effective responses to seasonal air quality crises. A similar focus on local enforcement in China yielded significant results; for instance, the Henan county government reportedly collected USD 37 million in penalties related to crop burning, contributing to a substantial reduction in air pollution.[9]

Strategic targeting of enforcement

Since deterrence effects can amplify the impact of limited bureaucratic resources and actions, enforcement efforts should be strategically focused. Prioritising areas with the highest historical incidence of burning or the greatest potential for repeat violations can maximise impact. By targeting a smaller number of violators within these high-risk zones, especially during peak burning seasons, administrators can achieve broader compliance

[9] Jitendra, V. S., Kukreti, I., Pandey, K., Niyogi, D. G., & Mukerjee, P. (2017). India's burning issue of crop burning takes a new turn. Down to Earth.

with fewer resources than attempting universal enforcement.

Leverage public engagement

Increased public awareness and active citizen involvement can significantly bolster official enforcement efforts, particularly when cyclical public pressure aligns with periods of heightened air pollution and media attention. Enhancing transparency regarding enforcement actions and resulting air quality improvements can help sustain public support for anti-burning measures and increase accountability for administrators to achieve tangible results.[10]

Improve cross-jurisdictional coordination

Crop burning and the resulting air pollution are inherently transboundary issues, crossing district, provincial and national boundaries. Our findings indicate a marked increase in pollution near the borders of administrative units that fail to coordinate their control efforts. Therefore, establishing institutional mechanisms that facilitate collaborative planning and action between jurisdictions, as well as between different government departments (e.g., agriculture, environment, revenue), is crucial. Such coordination can improve resource allocation, enable more comprehensive policy implementation, and significantly enhance overall enforcement effectiveness.

Develop farmer-centric alternatives

Enforcement, while necessary, is unlikely to be a sustainable long-term solution on its own. Policymakers must address the underlying economic and practical reasons why farmers resort to burning. This requires actively promoting and supporting viable alternatives. Key strategies could include subsidising the purchase or rental of mechanised equipment for residue clearing and incorporation, supporting research and extension services for crop diversification towards less residue-intensive rotations, and implementing positive incentive programmes rewarding farmers for adopting sustainable, non-burning farming practices. Policies that balance enforcement measures with accessible support for alternative methods are most likely to encourage widespread and lasting adoption of non-burning practices.

Our research highlights the significant, though often underestimated, potential for local bureaucratic action to mitigate the severe air pollution resulting from agricultural crop burning in South Asia. While this practice is frequently viewed as an intractable problem driven by deep-seated agricultural traditions and economic constraints, our findings suggest that district-level administrators already play a role in reducing pollution, particularly when they internalise its direct impacts on their own jurisdictions. By leveraging their discretion and implementing targeted enforcement, these officials can create deterrent effects that amplify the impact of their actions, yielding meaningful reductions in burning even within challenging institutional and resource contexts.

We demonstrate that district administrators possess greater potential to influence crop burning practices than is typically recognised. With appropriate resources, strategic

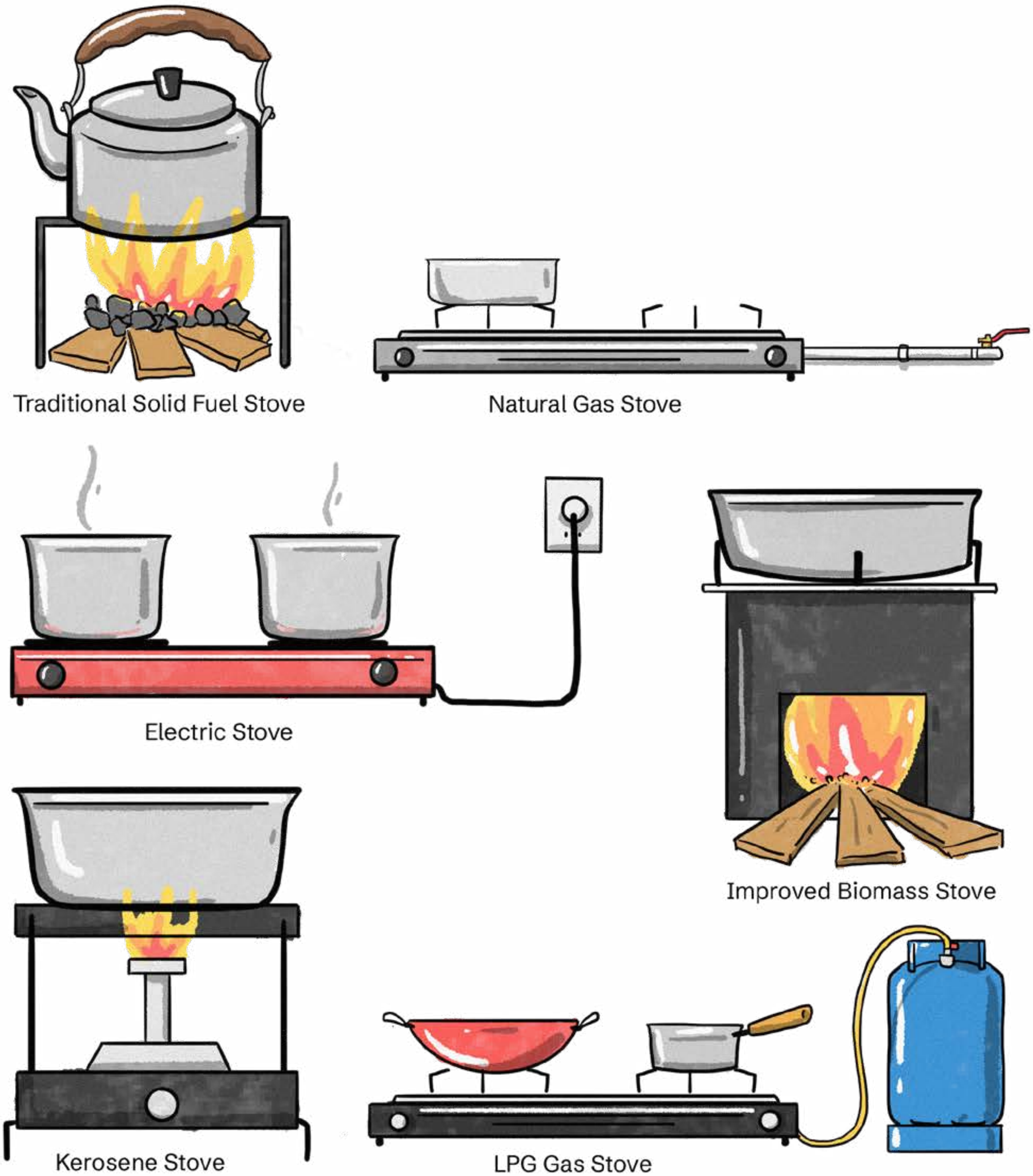
[10] Anderson, S. E., et al. (2019). Non-governmental monitoring of local governments increases compliance with central mandates: A national-scale field experiment in China. American Journal of Political Science, 63(3), 626–643.

targeting, and alignment of incentives, local bureaucrats can make a meaningful difference in controlling one of the top contributors to unhealthy air in South Asia. Our results encourage a re-evaluation of the role of local government in environmental management, emphasising that existing governance structures, if effectively activated and supported, hold significant promise for driving positive change.

Future research should delve deeper into the dynamics of bureaucratic action in environmental governance. Studying the specific interactions between local officials, various sectoral departments (agriculture, environment, etc.), and citizen groups can provide a more comprehensive understanding of how governments can better manage multifaceted environmental challenges like air pollution. Additionally, investigation into the motivations, constraints, behaviours, and decision-making processes of farmers themselves will be essential for designing policy responses that are both effective and equitable. Ultimately, a holistic approach that combines appropriately targeted enforcement with supportive measures for sustainable farming offers the most promising pathway towards resolving South Asia's crop burning crisis, aligning local incentives with global public health and environmental priorities.

Gemma Dipoppa is an Assistant Professor in Political Science at Columbia University, studying the political economy of migration, crime, and environment.

Dr. Saad Gulzar is an Associate Professor of Political Science and Global Affairs at the University of Notre Dame. His research is on the political economy of development and environment, focusing on South Asia.



In this visual taxonomy, Maaz Jaan contrasts the traditional stoves that trap women in a cycle of indoor pollution with the modern solutions that offer a way out. The illustrations highlight the stark technological gap that defines energy poverty, showing how a shift to clean cooking is a matter of life and death.

11.

Clean Cooking

Exploring the barriers and challenges of clean cooking adoption

A 10-million household crisis: An estimated 10 million households in Pakistan still rely on polluting open fires or inefficient traditional stoves for their daily cooking needs.

Beyond technology: Adoption of cleaner stoves is not hindered by a lack of technology, but by a complex web of barriers including low purchasing power, mismatched culinary needs, and gender dynamics where men often control finances but are not the primary users.

Government support is essential: A sustainable market for clean cooking solutions cannot be built on market forces alone. It requires a robust national strategy with government support for local manufacturing, consumer awareness, and innovative financing.

The smoke that fills the lungs of millions of Pakistani women and children is a daily crisis born from a simple act: cooking a meal. Khizr Imran Tajammul moves beyond the lab and into the village, drawing on years of field experience to explain why so many well-intentioned clean cooking solutions have failed. This chapter is a clear insight into the stubborn realities of poverty, culture, and gender that technology alone cannot solve and delivers a roadmap for effective solutions.

The off-grid world, an estimated three billion people globally, relies on combusting solid biomass—such as firewood, crop residue, and animal manure—to cook food and heat their homes.[1] This practice extends to agriculture, where agrarian communities often burn stubble to clear fields, contributing further to air pollution. Pakistan mirrors these trends; in the agricultural heartland of Punjab alone, up to 8.5 million tonnes of stubble are burned annually.[2]

Furthermore, a significant portion of Pakistan's population lacks access to modern energy infrastructure. An estimated 56 million people live without electricity, and approximately 78% of the nation's 240 million people lack access to the natural gas network. Consequently, households utilise varying proportions of traditional biomass and, where affordable, Liquefied Petroleum Gas (LPG) for their cooking and heating needs.

[1] Nijhuis, M. (2025). Three billion people cook over open fires, with deadly consequences. National Geographic.

[2] Food and Agriculture Organization of the United Nations (FAO). (2018). Remote sensing for spatio-temporal mapping of smog in Punjab and identification of the underlying causes using GIS techniques (R-SMOG).

Based on these energy access limitations, an estimated 10 million households in Pakistan still use some form of open fire or inefficient traditional stoves (often called 'three stone stoves' or 'mud stoves') for daily cooking. These methods combust fuel inefficiently, releasing harmful emissions and wasting energy. Undoubtedly, these households stand to gain significantly from adopting clean cooking solutions—defined here as fuel-efficient alternatives that reduce emissions, prevent respiratory illnesses linked to indoor air pollution, and conserve fuel resources.

Despite these clear benefits, numerous public and private sector efforts to introduce and scale up clean cooking solutions in off-grid Pakistan, dating back to the 1960s, have largely failed to achieve widespread adoption. This chapter delves into the complex barriers hindering this transition, drawing heavily on the experiential lessons learned by Jaan Pak, a clean cooking company that has been developing solutions for Pakistan's off-grid communities since 2014.

The national context: a difficult starting point

Before examining household-level barriers, it's crucial to acknowledge how broader macro level issues in Pakistan impact the clean cooking landscape, particularly concerning public health priorities and national energy infrastructure.

Health priorities and environmental management

Respiratory illnesses, largely stemming from poor air quality (both indoor and ambient), represent a major health burden—yet they often do not receive commensurate priority within the public health agenda, despite claiming more lives annually in Pakistan than malaria and HIV combined. The national response to air pollution often appears inadequate. Access to reliable public information on air quality can be limited or subject to manipulation, potentially hindering public awareness and governmental accountability for environmental management. Furthermore, enforcement of environmental regulations, including bans, taxes or fines on environmental offenders can be inconsistent, and are governed through antiquated, ill-defined policies that persecute the poor and pardon those in power. In the recent past, often at the peak of the smog season, we see small-scale farmers behind bars for burning stubble while coal power plants and industrial polluters puff up tonnes of greenhouse gases into the atmosphere every day. Within this context, developing and implementing a comprehensive national clean cooking strategy often remains an aspirational goal within broader social development policy frameworks rather than a high-priority, well-resourced national programme.

Energy policy constraints

Pakistan's national energy policy, particularly regarding the pricing and accessibility of natural gas and LPG, presents another significant macro-level constraint. Given the historically subsidised price of natural gas for connected households, widespread natural gas access would make alternatives like LPG and other clean cooking solutions uncompetitive. Therefore, Pakistan's policies governing the supply, distribution, and pricing of these primary fuels are intimately connected to the feasibility and potential scale of any national clean cooking strategy.

Why good stoves fail: understanding the user

Beyond the variables highlighted above, clean cooking solution providers will need to consider the following barriers to customer adoption in Pakistan.

Economic realities

Off-grid households typically have limited purchasing power, representing a fundamental barrier to adopting new technologies. In simple terms, putting food on the table is more important than cooking efficiently without fumes. While clean cooking enterprises can emphasise that fuel-efficient stoves save money over time, this argument resonates most strongly in communities that primarily purchase fuel rather than gathering it at no direct monetary cost. For instance, agrarian communities in Punjab often utilise readily available dung cakes and crop residue, making them less immediately motivated by fuel savings compared to communities in northern regions like Gilgit Baltistan, where biomass scarcity necessitates purchasing expensive fuel.

Jaan Pak found week-long cookstove trials effective in demonstrating fuel savings to fuel-purchasing communities, leading to customer conversions. However, such trials are resource-intensive.

Microfinance institutions offer a potential avenue to bridge the affordability gap, though experience suggests microfinance may be more readily adopted for enabling entrepreneurship through investments in small business ideas, like sourcing cattle or funding inventory for a new retail store, rather than for cost-saving devices like cookstoves. A clean cookstove leads to fuel savings, but for low-income households to protect those savings for micro-loan payments may be more challenging than setting aside revenue from a new business.

Regional differences in existing practices also influence willingness to pay. Communities in Balochistan, Khyber Pakhtunkhwa , Gilgit Baltistan, and Azad Jammu & Kashmir are already accustomed to purchasing metal sheet cookstoves and tin chimneys to remove harmful solid fuel fumes from their homes. These communities are generally more willing to pay for a fuel-efficient, clean cooking technology similar to what they already use. The behaviour challenge here is "spending more money towards a longer lasting, more fuel efficient product".

Conversely, in Punjab and Sindh, many off-grid households use mud or cement stoves made by hand at home, with virtually no money. The very idea of "buying" a cookstove can seem absurd to many, although adoption can still occur. Jaan Pak, for example, achieved some success in Punjab where a small percentage of adopters across larger, densely packed communities has led to more customers than a larger percentage across smaller, less dense communities.

Lastly, the "power" in purchasing power largely resides with men, who may not be the primary users of the cookstove and thus less motivated by its benefits. The off-grid marketplace – both suppliers and consumers – are mostly men. Gaining the interest of men, unlikely users of a clean cooking product, can be challenging.

Gaining men's interest requires specific strategies. For example, the company Biolite integrated a thermoelectric generator into their cookstove, allowing users to charge mobile phones while cooking, successfully capturing male interest in India—an approach worth exploring in Pakistan. However, technology isn't the only solution in a male-dominated marketplace; leveraging women's existing informal economic networks is crucial. Jaan Pak successfully collaborated with the Rural Support Programme Network to train and onboard over 50 women entrepreneurs as retailers. Engaging other influential women, such as community midwives, could further enhance adoption, necessitating field teams composed primarily of women.

It is incumbent upon Pakistan's governmental bodies to develop the prerequisite policies, infrastructure, financing mechanisms, and supportive legislation needed to establish and sustain a thriving clean cooking industry.

Culinary preferences and technology fit

Replacing an open fire with a clean cooking solution sounds straightforward in theory, especially when it provides substantial health, environmental and economic benefits. However, a closer look reveals how complex implementation really is.

Local culinary practices are deeply ingrained and highly variable. How communities cook their meals and what they cook matters. Since culinary behaviours vary globally and food preparation is unique to each community, the first step in developing a clean cooking solution is understanding the specific culinary behaviour of the target community. In Pakistan, where roti and rice are often accompanied with lentil, vegetable and meat curries, the diversity in utensils, recipes and varying sizes of roti play a major role in determining suitable clean cooking technologies.

Jaan Pak learned this lesson when initially importing and piloting internationally best-selling biomass cookstoves from companies like Envirofit, Biolite, and Burn Manufacturing. These imported models often proved unsuitable for several reasons: their combustion chambers were too small or poorly designed for local fuels like large dung cakes or irregular wood pieces, requiring more work to break fuel down before combustion; their stove top openings were often too narrow for making roti on traditional dome-shaped utensils (an inverted *tawa*); they struggled to accommodate the large cauldrons used for cooking meals for extended families, leading to instability or uneven heating; and finally, import costs (freight, customs, taxes) made them prohibitively expensive, significantly inflating the final price.

These challenges compelled Jaan Pak to develop a locally designed, "Made in Pakistan" clean cooking solution tailored to local needs. After 51 prototype iterations, the "Supreme Stove" was launched in 2017 as a single burner stove top for families of 7-10 individuals in Punjab. Four additional versions were to cater to diverse culinary preferences encountered across the rest of the country.

Unexpected pain points

Beyond broad economic and culinary factors, specific adoption drivers and deterrents can vary significantly between provinces, districts, and even contiguous communities. Field experience often uncovers poorly documented, unexpected issues. In Punjab, for instance, Jaan Pak found that many potential customers don't fully understand or believe in the ill effects of solid fuel fumes. They don't necessarily link respiratory illnesses to poor air quality, so health concerns aren't major drivers of adoption. Environmental concerns rank even lower. Instead, Jaan Pak customers reported two smoke-related problems: eye irritation and clothes smelling of smoke as frequently cited concerns. Another adoption driver was the novelty of a product that better organised cooking fuel and didn't blacken utensils as much as an open fire. Counterintuitively, some Punjab households even perceived that eliminating fumes was actually detrimental because smoke repelled flying insects that would otherwise enter cooking pots and spoil food – a surprising barrier with no immediate remedy.

An estimated 10 million households in Pakistan still use some form of open fire or inefficient traditional stoves. These methods combust fuel inefficiently, releasing harmful emissions and wasting energy.

In KPK, extreme price sensitivity meant many households preferred cheap, disposable cookstoves made from tin chimneys and recycled vegetable oil containers that cost only PKR 300, but which lasted only a few months. Conversely, when attempting to offer higher-quality stoves via microfinance, Jaan Pak encountered resistance from lenders who found the products "not expensive enough" to create sustainable financial models. One solution to bundle cookstoves with essential household items like solar electrification or energy-efficient cooking utensils emerged as a potential solution to increase loan viability.

In AJK, households often desired stoves for both cooking and heating and with relatively higher purchasing power, showed strong demand for efficient biomass models. Gilgit Baltistan presented the easiest market access, with communities readily attending demonstrations and exhibiting higher awareness of respiratory health and environmental issues, likely linked to higher literacy rates and the significant cost of purchased fuel in the region.

These diverse experiences underscore the necessity of in-depth community investigation, as no two are exactly alike. Door-to-door surveys and analysis of existing-energy-use profiles can provide a head start towards achieving the right product-market fit.

The promise and peril of climate finance

Following the inception of the Global Alliance for Clean Cookstoves (now the Clean Cooking Alliance) in 2010, impact investment and development funding spurred the growth of numerous clean cooking startups globally. Initial excitement centred on market-based solutions driven by patient capital, fuel savings, health benefits and economies of scale.

However, the influx of multiple products, particularly in sub-Saharan Africa, sometimes led to "stove stacking", where households acquired multiple stoves but continued using traditional methods, often perceiving the new stoves as temporary offerings lacking ongoing support. This limited the actual impact, dampened investor confidence due to low revenue generation, and made the sector less attractive.

Concurrently, carbon markets emerged as a potential revenue stream, supporting cookstove companies through carbon offset projects. Initially nascent with low carbon prices, these markets offered limited financial contribution. Today, however, monitoring, reporting, and verification standards for cookstove carbon projects are more robust, allowing for more reliably verifiable emission reduction claims that can generate valuable carbon credits. To leverage this finance, companies must navigate complex requirements. This involves using appropriate technologies certified for high combustion efficiency (e.g., at least 35% improvement over open fires) and durability (e.g., five-year lifespan), and adhering to methodologies like the Gold Standard foundation's "Simplified Methodology for Clean and Efficient Cookstoves" for designing, monitoring, reporting, and verification systems that ensure carbon revenue outweighs project costs.[3] However, the barrier to entry remains high, demanding specialised knowledge and potentially expensive protocols. Furthermore, minimum efficiency thresholds (e.g., 25%) can exclude many existing or lower-cost stoves, requiring technology upgrades and certified testing. Some carbon offset developers may also focus on larger-scale projects, creating difficulties for smaller enterprises.

The missing ecosystem: why businesses struggle

Establishing any business is challenging; doing so in an emerging industry serving low-income customers with limited purchasing power is far more challenging. In Pakistan, a clean cooking business often operates outside established industrial categories and faces low intrinsic demand, as solutions are often perceived as nice add-ons rather than necessities, particularly since they are often offered free or highly subsidised. This positions many clean cooking ventures as social enterprises heavily reliant on external support to address open fire cooking practices for millions of households.

No new clean cooking business can tackle Pakistan's open fire problem alone. Substantial public sector support is indispensable. This requires coordinated action from government institutions responsible for off-grid energy, public health, agriculture, manufacturing (e.g., for metal sheet fabrication), information dissemination, and education. To cultivate a thriving clean cooking industry for 10 million households in Pakistan, the government could play a crucial role by establishing testing laboratories to certify locally produced models, encouraging manufacturers through business loans or incentives, and providing tax benefits or subsidies to ease market entry. Such support would generate indirect positive impacts on the environment, health (especially maternal and child), household income and savings, and potentially gender empowerment. The Climate and Clean Air Coalition (CCAC) has previously funded the development of a national clean cooking strategy for Pakistan; how the government acts upon such frameworks will significantly influence the future of clean cookstove businesses and consumers nationwide.

[3] 'The Gold Standard Simplified Methodology for Clean and Efficient Cookstoves'. Gold Standard for the Global Goals.

Strategies for a clean cooking transition

The arguments for promoting clean cookstoves are compelling. A single improved stove can prevent the emission of 1-2 tonnes of carbon equivalent annually, mitigate fatal respiratory illnesses linked to indoor air pollution, and generate significant savings on fuel costs, especially where biomass must be purchased. Reducing overall biomass demand could also alleviate pressure on Pakistan's dwindling forest resources, which are reportedly disappearing at an alarming rate of 47,000 hectares per year. Critically, since women and children are the primary users and beneficiaries of cleaner cooking, fostering this market creates unique economic opportunities for women entrepreneurs to retail solutions directly within their communities.

Addressing the complex challenges and establishing a viable, scalable market requires clear government ownership and robust support for a national clean cooking strategy. Generating sustained consumer demand hinges significantly on policy interventions that actively discourage traditional open fires, effectively communicate the health and environmental hazards of indoor air pollution, and promote the benefits and availability of certified clean cooking products. While manufacturers and retailers would benefit immensely from government-sponsored awareness campaigns, their capacity to supply quality products must be established beforehand.

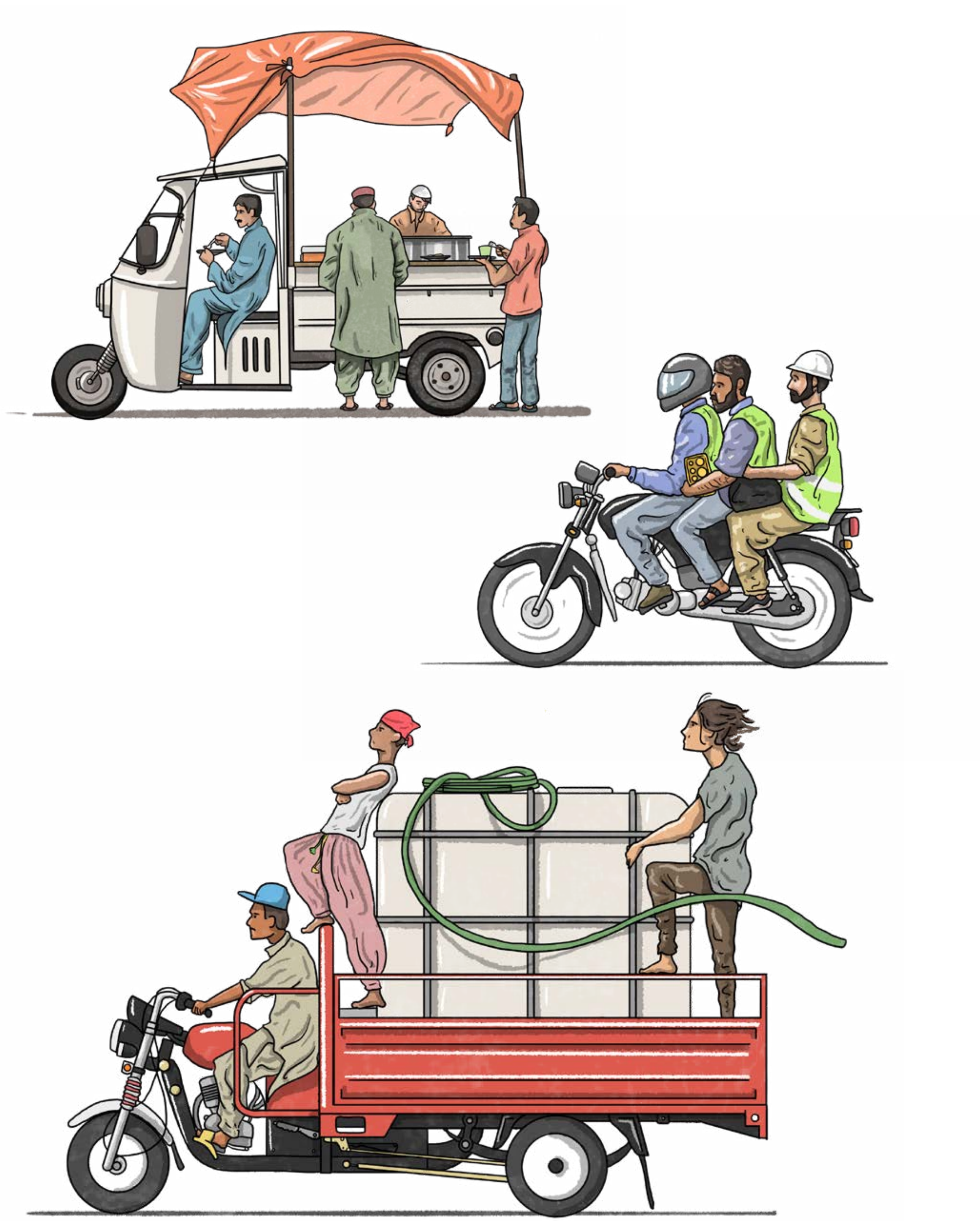
Khizr Tajammul explores past initiatives, market dynamics, and behavioural factors, offering insights into the multi-pronged strategies needed to accelerate a just and sustainable clean cooking transition in Pakistan.

Without dedicated public sector support—including potential consumer subsidies, capacity building for local manufacturers, widespread education on the dangers of open fires, access to business financing, and reliable testing infrastructure—clean cooking businesses face an uphill battle surviving solely on market forces, especially when serving low-income populations.

While the global energy transition progresses to clean energy, potentially reducing the size of the off-grid population over time, the market for clean cooking solutions in Pakistan remains vast and critically important today. The significant environmental, economic, and public health benefits offered by transitioning away from traditional cooking methods cannot be ignored. Among the numerous barriers to adoption, affordability and culinary compatibility emerge as major determinants of consumer behaviour. While businesses must undertake thorough, context-specific research to understand their potential customers, it is incumbent upon Pakistan's governmental bodies—at national and provincial levels—to develop the prerequisite policies, infrastructure, financing mechanisms, and supportive legislation needed to establish and sustain a thriving clean cooking industry capable of reaching millions.

PAQI researcher Mahad Naveed walks past the 'Saans Lenay Do!' (Let Us Breathe!) billboard, a stark public health installation. Designed to mimic human respiration, the artificial lungs trap particulate matter from the ambient air, slowly turning from white to black to offer a visceral, undeniable proof of the toxic emergency unfolding in Lahore.

Khizr Imran Tajammul formerly led GHG accounting, inventory management and emissions mitigation for the Government of Northwest Territories in Canada. He is the co-founder of Jaan Pak and a Policy Analyst at Natural Resources Canada



From the weaving rickshaw to the delivery loader, Maaz Jaan (@deconstruction_station) illustrates the 'people's chariots' that drive Pakistan's economy. While these vehicles are essential for mobility, they are currently the primary source of street-level pollution, making their transition to electric power the single most critical step for urban public health.

12.

Electrifying the People's Chariot

Navigating the complex terrain of transitioning to electric mobility

The 85% opportunity: Two and three-wheelers make up a staggering 85% of all vehicles in Pakistan, making their electrification the single most impactful strategy for cleaning up transport-related urban air pollution.

Overcoming key barriers: The transition is currently stalled by high upfront costs for consumers and a near-total lack of public charging infrastructure.

The game-changer: battery swapping: A model where batteries are leased and swapped at stations—rather than owned and charged at home—can make electric vehicles as affordable as petrol models and as convenient to "refuel", removing the two biggest hurdles to mass adoption.

The roar of motorcycles and the weave of rickshaws is the soundtrack to urban life in Pakistan. These vehicles are not a luxury but a lifeline—the engines of mobility for the masses. Yet, they are also a primary source of the toxic air choking our cities. Muhammad Huzaifa Qasmi explores the immense opportunity to transform this fleet, moving from a legacy of pollution to a future of clean, electric mobility. This chapter is a roadmap for electrifying the people's chariot—a transition that is not just possible, but essential for our public health and economic future.

In the bustling streets of urban Pakistan, two and three-wheeled vehicles represent more than mere transportation—they are economic lifelines embedded in the fabric of daily life. These "people's chariots" navigate the narrow alleys of Lahore, weave through Karachi's chaotic traffic, and transport goods through Peshawar's crowded markets. Yet beneath their essential utility lies a growing environmental crisis: these ubiquitous vehicles contribute significantly to the dangerous air pollution choking Pakistan's cities, with profound implications for public health and environmental quality.

As Pakistan's urban centres expand, the dual challenges of air pollution and traffic congestion intensify. Electric two and three-wheelers offer a promising pathway towards healthier, more sustainable urban environments. However, this transition requires more than a simple technological swap—it demands addressing interconnected financial, infrastructural, technological, and social barriers through coordinated policy action and strategic investments.

The backbone of urban mobility

Two and three-wheelers dominate Pakistan's transportation landscape, accounting for approximately 30 million of the country's 35.5 million registered vehicles—roughly 85% of the total fleet.[1] Their prevalence reflects their fundamental role in the mobility ecosystem and the country's socioeconomic structure.

Their rise parallels Pakistan's urbanisation trajectory. As populations migrated to cities seeking economic opportunities, the need for affordable, flexible transportation became essential. Two-wheelers emerged as the primary personal mobility solution, while three-wheelers filled critical first and last-mile connectivity gaps in the fragmented public transport network. This trend accelerated dramatically in the early 2000s when Pakistan opened its market to locally manufactured Chinese motorcycles, triggering a 60-80% surge in two-wheeler sales and democratising access to motorised mobility.

Several factors make these vehicles indispensable to daily life;

Economic accessibility
They represent the most affordable means of motorised transport, particularly for Pakistan's working class and lower-income segments.

Operational flexibility
They provide door-to-door service even in neighbourhoods where conventional public transport cannot reach due to narrow or undeveloped roads.

Fuel efficiency
Their relatively low fuel consumption makes them especially valuable in an economy where fuel prices significantly impact household budgets.

Spatial advantage
Their compact size enables navigation through congested urban environments where larger vehicles prove impractical, particularly in historic city centres and informal settlements.

The ownership patterns reflect their socioeconomic significance. Approximately 90% of motorcycles in Pakistan are privately owned and primarily used for personal transportation.[2] However, the rise of digital platforms has created new economic opportunities, with many owners now leveraging their motorcycles for ride-hailing and food delivery services to generate additional income. These vehicles also play a vital role in Pakistan's urban logistics networks, handling small-scale courier deliveries and goods transport in congested commercial areas.

Three-wheelers primarily serve as commercial passenger vehicles, with over 90% used

[1] Ministry of Finance. (2024). Pakistan economic survey 2023-24 (pp. 157-159).

[2] Determining precise percentages for two-wheeler usage in Pakistan by ownership and purpose (personal, rental, commercial services such as ride-hailing and delivery) is challenging due to limited publicly available data. However, based on available market news, articles and anecdotal evidence, the vast majority of motorcycles in Pakistan are privately owned and used primarily for personal transportation.

for public transport services.[3] Whether through traditional street-hailing or newer app-based platforms, these vehicles provide essential mobility services to millions daily. They also fill crucial gaps in the urban freight ecosystem, particularly for small deliveries in congested areas where larger vehicles face access limitations.

The hidden cost of the people's chariot

The degradation of air quality in Pakistan's urban centres represents a silent but devastating public health emergency. Like an invisible illness slowly eroding health, air pollution seeps into the lungs and lives of millions every day.

This environmental crisis translates into tangible suffering: asthmatic children struggling to breathe in classrooms, roadside vendors battling chronic respiratory infections, and rising rates of cardiovascular disease among urban residents. According to the Global Burden of Disease study, air pollution contributes to approximately 128,000 premature deaths annually in Pakistan—making it one of the country's leading environmental health risks.

Two and three-wheelers contribute disproportionately to this crisis due to several factors: poor vehicle maintenance, inadequate emission control technologies, adulterated fuels, and inefficient two-stroke engines in older models. These factors collectively result in the thick black smoke commonly visible on Pakistani roads, which contains harmful levels of particulate matter, carbon monoxide, and volatile organic compounds.

Recent emissions inventories across Pakistan's major cities confirm the transport sector's significant contribution to urban air pollution. As highlighted in the previous chapters, transportation contributes 51% of fine particulate matter (PM2.5) in Peshawar, 53% in Islamabad-Rawalpindi, 35% in Lahore, and 33% in Karachi. One report by the Urban Unit places transportation emissions as high as 80-85% in Lahore. Within this sector, two and three-wheelers represent a substantial portion of both vehicle numbers and total emissions.

In cities like Lahore and Peshawar, the air quality index (AQI) frequently reaches hazardous levels, particularly during winter months when meteorological conditions trap pollutants near ground level. This phenomenon, increasingly referred to as Pakistan's "fifth season", has become an annual public health emergency in northern Punjab.

The health implications are severe. Research from Aga Khan University reveals that Karachi's air contains dangerously high levels of PM2.5, which can penetrate deep into the lungs and bloodstream. Hospitals across Pakistan's urban centres report increasing cases of respiratory and cardiovascular diseases, with the elderly, children, and those with pre-existing conditions most vulnerable. Medical professionals warn that without addressing air pollution, the public health burden will continue to grow, straining an already challenged healthcare system and reducing economic productivity through increased sick days and healthcare costs.[4]

[3] Same argument as earlier.

[4] Ilyas, F. (2024, October 26). Study raises alarm over harmful particles in Karachi's air. Dawn.com.

Transitioning to electric two and three-wheelers, which produce zero tailpipe emissions, offers a powerful solution to this growing crisis. This shift has the potential to dramatically reduce urban air pollution, particularly in high-traffic corridors and dense urban areas where exposure to vehicle emissions is highest.

Navigating the electric transition

Pakistan's journey towards electric vehicle adoption formally began in 2019 with the announcement of its National Electric Vehicle Policy, which established ambitious targets: 30% of new vehicle sales to be electric by 2030 and 90% by 2040. In 2021, the government integrated specific incentives into the Auto Industry Development and Export Plan (AIDEP 2021-26), creating a more concrete policy framework for the transition.

The global COVID-19 pandemic temporarily disrupted this momentum as travel restrictions and supply chain challenges halted progress. However, as economic conditions stabilised in late 2022, Pakistan's nascent EV industry began to regain traction. More than 45 manufacturers have now secured licenses to produce electric vehicles in Pakistan, with the majority focusing on two-wheelers. While significant progress has been made in establishing the foundation for an electric mobility ecosystem, achieving the policy's ambitious targets will require accelerated implementation and additional supportive measures.

The transition faces several interconnected challenges that must be addressed through coordinated approaches.

Charging infrastructure deficit

Perhaps the most visible barrier is the lack of public charging infrastructure. While Pakistan has extensive networks of petrol stations, electric charging facilities remain scarce. This creates "range anxiety"—the fear that vehicles will run out of power before finding a charging point—which significantly deters potential buyers.

Higher upfront costs

Electric vehicles typically cost up to twice as much as their conventional counterparts, primarily due to battery expenses. This price premium represents a significant adoption barrier in a price-sensitive market where many buyers are economically constrained. Although lifetime operating costs are lower, the higher initial investment remains prohibitive for many potential users, particularly those who rely on these vehicles for their livelihoods.

Regulatory uncertainty

Pakistan's policy framework for electric vehicles continues to evolve. This regulatory uncertainty creates hesitation among manufacturers, investors, and consumers, who require clear, consistent policies to make long-term decisions. Without comprehensive and stable regulations covering vehicle standards, charging infrastructure, and grid integration, the market will struggle to achieve scale.

Despite these challenges, the potential benefits remain compelling and achievable with the right strategies. As battery technology advances and global production scales up, prices continue to fall, improving economic feasibility. Strategic investments in charging infrastructure can overcome range anxiety, while well-designed financial incentives can bridge the upfront cost gap during the transition period.

This moment represents a critical juncture for Pakistan's transportation sector. We are witnessing one of the most profound technological transitions in modern history—a fundamental reshaping of global mobility systems. Nations like China and India have recognised this shift and positioned themselves as leaders in electric mobility, particularly in the two and three-wheeler segments.

Pakistan's vehicle technology currently lags behind global and regional standards, but this transition offers a unique opportunity to leapfrog outdated technologies. By strategically embracing electric mobility, Pakistan can transform from an import-dependent consumer to a competitive manufacturer in the global transportation landscape. This shift would generate economic benefits through local manufacturing, reduce the country's substantial fuel import bill, and create new jobs in emerging technology sectors.

Changing public perception: from skepticism to acceptance

Public acceptance is fundamental to the successful adoption of any new technology, and electric mobility is no exception. In Pakistan, the electric vehicle narrative is just beginning to take shape, and as with most technological transitions, initial skepticism is common.

The introduction of electric two and three-wheelers represents both a technological and cultural shift in a country where generations have relied on petrol and LPG-powered vehicles. Common concerns include:

"Will the battery last long enough for my journey?"
"What if I can't find a charging station?"
"How will I be able to buy such an expensive vehicle?"
"How can we afford charging our vehicle when the electricity bill is already so high?"

However, public perception is gradually evolving as awareness of air pollution's health impacts grows. The younger generation, in particular, demonstrates greater environmental consciousness and increasingly views electric vehicles as a solution to urban air quality challenges. Social media platforms and environmental advocacy have accelerated this awareness, creating more receptive attitudes towards sustainable transportation options.

Pilot projects and demonstration initiatives are playing a crucial role in influencing public perception. For example, recent deployments of swappable battery-based electric three-wheelers in Lahore and Multan allow communities to directly experience these vehicles' benefits. While limited in scale, these projects build confidence in electric mobility by demonstrating reliability, performance, and economic advantages in real-world Pakistani conditions.

Educational campaigns highlighting the economic benefits—particularly lower operating costs—are also proving effective in changing perceptions. As more drivers realise they can save substantially on daily expenses, interest in electric options increases despite higher upfront costs. This shifting perception creates a foundation for broader adoption as technology improvements and policy support make electric vehicles increasingly accessible.

Battery swapping: a game-changing solution

How can electric two and three-wheelers become affordable and practical for ordinary Pakistanis? Battery swapping technology offers a particularly promising solution that could accelerate Pakistan's electric mobility transition.

This approach has gained significant traction globally as an alternative to traditional charging. In China, NIO has established extensive networks of automated battery swapping stations. In India, companies like Sun Mobility are creating swapping infrastructure specifically for two and three-wheelers, while Taiwan's Gogoro has built a comprehensive ecosystem around swappable batteries that has transformed urban mobility.

Battery swapping fundamentally changes the economics of electric vehicle ownership. Instead of purchasing both the vehicle and its battery—where batteries can account for 40-50% of an electric vehicle's cost—consumers buy only the vehicle. The batteries themselves are managed by service providers who handle charging, maintenance, and replacement. This model is analogous to purchasing a vehicle and then paying for a fuel service rather than the fuel itself.

This approach offers several compelling advantages for the Pakistani market.

Affordability

By separating battery costs from vehicle purchase, the upfront price drops dramatically—potentially reaching parity with conventional vehicles. This addresses the most significant adoption barrier in Pakistan's price-sensitive market.

Rapid refueling

Battery swapping eliminates long charging times. Drivers can exchange depleted batteries for fully charged ones in less than five minutes—comparable to traditional refueling—enabling continuous operation without extended downtime.

Elimination of range anxiety

The availability of swapping stations throughout urban areas removes concerns about running out of power, as drivers can simply exchange batteries when needed rather than planning around charging station availability.

Battery lifecycle management

Service providers handle battery maintenance, quality assurance, and eventual recycling. As battery technology improves, the network can introduce newer, higher-capacity models without requiring vehicle replacement.

Consistent resale value

Since the vehicle's value is no longer tied to battery condition, resale values remain more stable. This resolves a significant concern in conventional electric vehicles, where battery degradation substantially impacts residual value.

Recent pilot projects demonstrate the viability of this approach in Pakistan. In partnership with LUMS, USAID Pakistan launched a Low-Speed Electric Vehicles (LSEV) pilot in Multan in December 2023, deploying 20 electric rickshaws with swappable batteries supported by two swapping stations, including one powered by solar energy.

Initial results from this pilot offer encouraging insights. Drivers report seamlessly integrating battery swapping into their daily routines, with the process becoming as routine as traditional refueling. The operational benefits translate into tangible economic advantages—drivers experience both higher daily earnings due to increased operational hours and lower operating costs. Passengers, particularly environmentally conscious youth, have responded positively to the vehicles' quieter operation and pollution-free transport.

The electrification of the 'people's chariot' is not merely an environmental necessity but an economic opportunity and public health imperative. The time for this transformation is now.

These preliminary findings suggest that swappable battery technology could provide a practical path forward for Pakistan's electric mobility transition, particularly for commercial applications where daily usage is high and operating economics are critical.

Financing the electric mobility transition

Transitioning to electric mobility requires not just technological solutions but also innovative financial mechanisms to make these technologies accessible to the millions who rely on two and three-wheelers daily.

A key strategy lies in blended finance approaches that combine concessional loans, grants, revolving funds, guarantees, and equity investments. These instruments can effectively mitigate financial risks for early investors and help scale electric vehicle deployment across Pakistan.

Globally, this financing approach has mobilised substantial resources for sustainable transportation, with approximately USD 336 billion directed towards clean transportation initiatives in 2021-22 alone. For Pakistan, blended financing can attract capital from multiple sources: Development Financial Institutions (DFIs) can provide concessional loans with favourable terms; State-Owned Entities (SOEs) can offer guarantees to reduce investment risk; and Commercial Financial Institutions (CFIs) can develop specialised EV lending products once initial market barriers are addressed.

The financing challenge is particularly acute for Pakistan's low-income and working-class populations, who typically lack access to traditional banking services due to limited credit histories or insufficient collateral. This is where Non-Banking Financial Institutions (NBFIs) can play a crucial role by offering microloans with flexible terms specifically designed for electric two and three-wheeler purchases.

These smaller, more accessible loans—often with lower down payments, extended repayment periods, and Islamic (non-interest) financing options—can enable individuals who depend on these vehicles for income to transition to electric alternatives without financial hardship. NBFIs can partner with vehicle manufacturers and dealerships to create integrated financing packages covering not just vehicle costs but also maintenance services and battery leasing arrangements.

Government support for these lending programmes is essential to ensure their sustainability and reach. This could include credit guarantees, interest subsidies, or risk-sharing mechanisms that encourage NBFIs to expand lending in this emerging sector.

Pakistan also has significant opportunities to leverage international climate finance. Organisations such as the Green Climate Fund (GCF), Climate Investment Funds (CIF), Mitigation Action Facility (MAF), and Global Environment Facility (GEF) provide grants and low-interest financing specifically for emissions reduction initiatives in developing countries.

Accessing these funds requires strong collaboration between public institutions, private sector partners, and civil society organisations to develop comprehensive proposals demonstrating both environmental benefits and economic viability. These resources could be particularly valuable for financing charging infrastructure, battery swapping networks, and manufacturing capacity—the foundational elements of an electric mobility ecosystem.

The economic case for electric mobility

A frequent question from potential buyers is: "Why should I invest in an electric vehicle when they cost more upfront?" The answer requires looking beyond the purchase price to consider the total economic picture throughout the vehicle's lifespan.

Total Cost of Ownership (TCO) analysis reveals that electric two and three-wheelers typically become more economical than conventional alternatives within 2-4 years of operation, despite their higher initial purchase price. This economic advantage stems from several factors.

Lower energy costs

Electric motors convert energy much more efficiently than internal combustion engines, resulting in significantly lower per-kilometre operating costs. Electric two-wheelers can travel approximately three times farther on the energy equivalent of one litre of petrol.

Reduced maintenance requirements

Electric vehicles have fewer moving parts, no oil changes, no fuel filters, and simplified transmission systems. This translates to approximately 40% lower maintenance costs over the vehicle's lifetime.

Extended vehicle lifespan

The simpler drivetrain of electric vehicles typically lasts longer than internal combustion engines, particularly in stop-and-go urban traffic conditions that characterise Pakistani cities.

Operational reliability

Electric vehicles offer greater reliability with fewer mechanical failures, reducing costly downtime for commercial operators.

Quantitative analysis demonstrates these advantages clearly. Annual operational costs for electric motorbikes are approximately 50% lower than conventional models, while electric three-wheelers can reduce operating expenses by up to 70%. For commercial drivers, these savings significantly impact daily earnings and long-term financial security.

Consider a typical office worker in Karachi who commutes by motorcycle. While an electric model might cost more initially, the cumulative savings on fuel and maintenance begin to offset this premium by the second year of ownership. By year three, the economic advantage becomes substantial. Similarly, for a rickshaw driver in Lahore, the transition to electric can increase daily profits through both lower operating costs and increased operational hours.

These economic benefits extend beyond individual vehicle owners to the broader economy. Pakistan currently spends approximately USD 20 billion annually on petroleum imports, placing enormous pressure on foreign exchange reserves and contributing to economic instability. By transitioning to domestically powered electric vehicles, Pakistan can reduce this import dependency while creating new jobs in manufacturing, charging infrastructure, and battery services.

Cleaner at the tailpipe and at the grid

A common concern about electric vehicles in Pakistan centres on the country's electricity generation mix: "If our electricity comes from fossil fuels, aren't electric vehicles just shifting pollution from roads to power plants?"

This perspective overlooks several critical factors that make electric vehicles substantially cleaner even in Pakistan's current energy context. Pakistan's electricity generation is considerably cleaner than often assumed. According to the National Transmission and Despatch Company (NTDC), approximately 43% of Pakistan's electricity generation comes from low-carbon sources:[5]

— Hydropower (25.4%)

— Nuclear (11.4%)

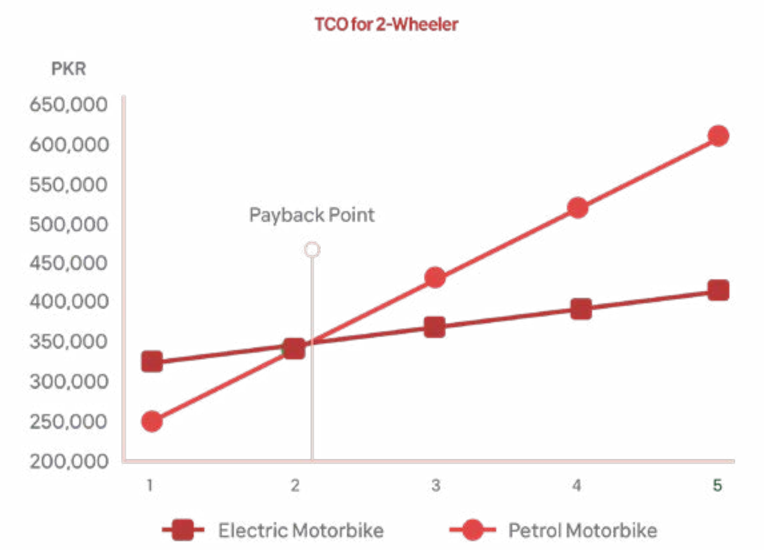
[5] National Transmission and Despatch Company. (2024). Indicative generation capacity expansion plan (IGCEP 2024-34) (pp. 15-16).

— Wind (4.8%)

— Solar (1.1%)

— Bagasse (0.3%)

Additionally, 26% comes from medium-carbon natural gas and RLNG plants, which produce significantly fewer pollutants than the diesel engines in conventional vehicles. NTDC's Integrated Generation Capacity Expansion Plan (IGCEP) reports that the current emissions factor of Pakistan's electricity mix is approximately 340 gCO2 per kWh—lower



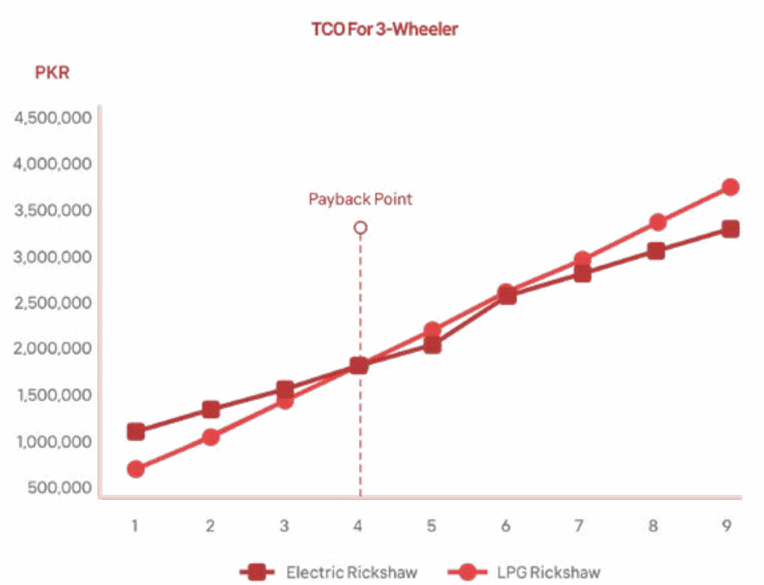


Exhibit 12.1: The Economic Tipping Point for the People's Chariot. **The higher sticker price of electric vehicles is deceptive. Whether for a two-wheeler or a commercial three-wheeler, dramatic savings on fuel and maintenance create a clear economic tipping point. As these analyses show, the electric motorcycle becomes the cheaper option in just two years, while the electric rickshaw pays for its premium in four. This powerful economic case makes electrification the clear long-term financial choice for the vast majority of vehicle owners in Pakistan.**

than many other regional countries.[6]

This emissions profile continues to improve as Pakistan increases its renewable energy capacity in line with national targets of 30% renewable energy by 2030. The country's rapidly growing solar photovoltaic deployments and wind power suggest this transition will accelerate in coming years.

Beyond the generation mix, electric vehicles offer inherent efficiency advantages. While conventional internal combustion engines convert only 20-35% of fuel energy into actual movement (with the rest lost as heat), electric motors achieve 85-90% efficiency in energy conversion. This means that even when powered partially by fossil fuel-generated electricity, electric vehicles use that energy more efficiently and produce fewer emissions per kilometre traveled.

The emissions benefits are substantial and quantifiable. Analysis shows that electric two-wheelers in Pakistan's context reduce CO2 emissions by approximately 80% compared to conventional motorcycles, while electric three-wheelers reduce emissions by about 70% compared to traditional auto-rickshaws.

Pakistan's ongoing solar transition further enhances these benefits. The rapid growth of

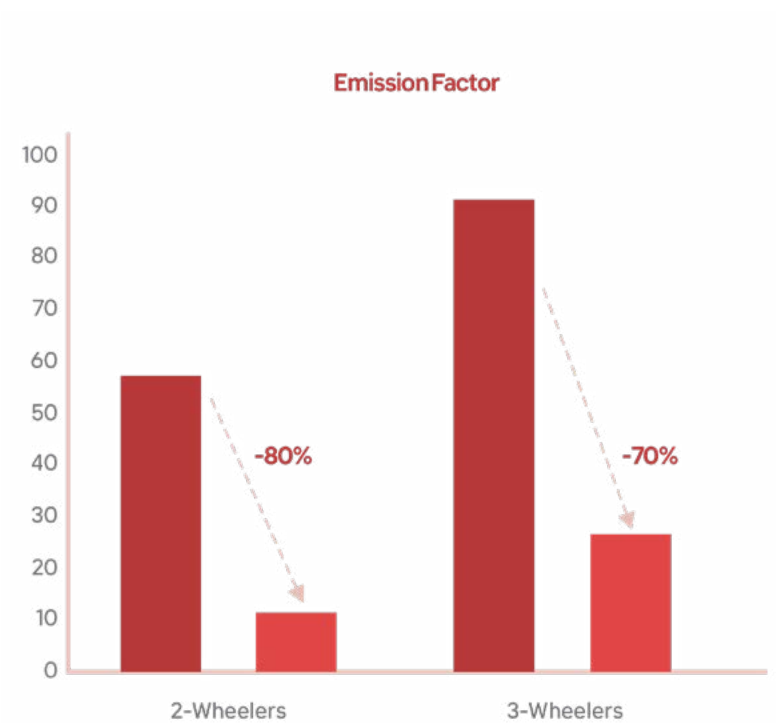


Exhibit 12.2: A Drastic Reduction in Carbon Emissions. **The argument that EVs merely shift pollution to power plants overlooks a critical fact: Pakistan's grid is cleaner than commonly believed. With over 40% of electricity generated from low-carbon hydro and nuclear sources, the energy powering EVs is already significantly less polluting than the petrol and diesel they replace.**

[6] National Transmission and Despatch Company. (2024). Indicative generation capacity expansion plan (IGCEP 2024-34) (p. 75).

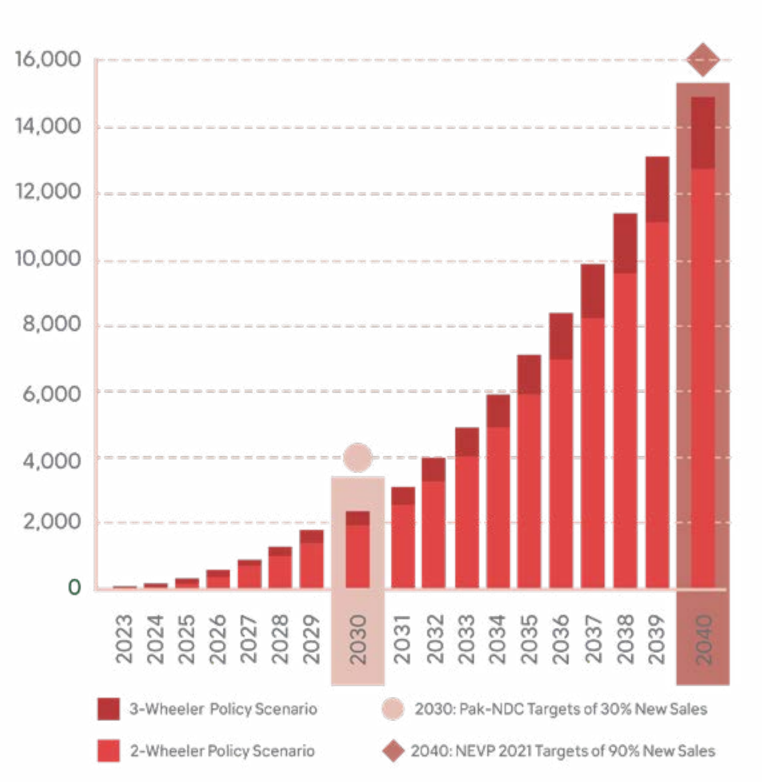


Exhibit 12.3: A 70% Cut in Carbon Emissions. Electrification offers a powerful climate co-benefit. **The superior efficiency of electric motors means that even on Pakistan's current grid, switching a single motorcycle or rickshaw to electric slashes its carbon footprint by over 70%, representing one of the most effective and immediate climate actions available.**

rooftop solar installations across residential, commercial, and industrial sectors creates opportunities for clean charging. As electric vehicles enter the market, this distributed solar capacity can power them with truly zero-emission electricity while reducing pressure on the national grid.

Perhaps most immediately important for urban residents is that electric vehicles produce zero tailpipe emissions. Unlike conventional vehicles that release pollutants directly into street-level air where people breathe, electric vehicles eliminate local pollution entirely. These vehicles, being virtually silent and emission-free at the point of use, deliver two significant urban benefits simultaneously: they help reduce the dangerous levels of air pollution in Pakistan's cities and substantially decrease noise pollution, which the WHO recognises as a serious environmental health threat linked to stress, hearing loss, and cognitive impairment in children.

For Pakistan's congested urban centres suffering from critical air quality challenges, this local pollution reduction represents an immediate and tangible public health benefit that complements the longer-term climate advantages.

A cleaner and sustainable urban future

The electrification of Pakistan's two and three-wheelers represents more than a technological transition—it offers a transformative opportunity to reimagine urban mobility while addressing the urgent air quality crisis affecting millions of citizens. By focusing on these ubiquitous vehicles, Pakistan can achieve substantial environmental and public health benefits while creating new economic opportunities in manufacturing, services, and technology.

The path forward requires a multifaceted approach: innovative financing to overcome initial cost barriers; infrastructure development to support charging and battery swapping; regulatory frameworks that provide certainty and stability; public education to build acceptance and understanding; and targeted incentives that accelerate adoption among commercial users who can achieve the greatest immediate benefits.

With strategic implementation of these measures, Pakistan can transform its urban transportation landscape—preserving the mobility advantages of two and three-wheelers while eliminating their environmental impacts. The result would be cleaner air, quieter streets, reduced import dependency, new jobs, and improved quality of life for millions of urban residents. The electrification of the "people's chariot" is not merely an environmental necessity but an economic opportunity and public health imperative. The time for this transformation is now.

Muhammad Huzaifa Qasmi is an Energy and Environment Specialist at the LUMS Energy Institute, leading initiatives in electrification, emissions reduction, and electric mobility across Pakistan.

A view of Lahore's Qaddhafi Stadium is nearly obscured by a thick shroud of smog. The haze disrupts not only daily life but also cultural and sporting events, symbolising how air pollution holds the city's vitality hostage.
Photo by Mahera Omar/Pakistan Air Quality Initiative

13.

Power and Pollution

Analysing Lahore's power plants

A double burden: Aging thermal power plants around Lahore are a major source of pollution and a significant economic drain, costing the public billions in fixed capacity payments even when they operate infrequently.

The high cost of inefficiency: These plants run on expensive imported fuels and operate at low efficiency, making their electricity among the most expensive in the country and contributing to high consumer bills.

A profitable path to retirement: The economic case for shutting down the oldest, most polluting plants is clear. Retiring them early would save hundreds of millions of dollars in excess payments and unlock existing grid infrastructure for cheaper, cleaner renewable energy.

Haneea Isaad

The smokestacks on Lahore's horizon are more than just sources of pollution; they are monuments to an outdated and expensive energy system. Haneea Isaad dissects the hidden costs of the city's aging power plants, revealing a double burden of toxic emissions and economic inefficiency. This chapter presents a clear, data-driven financial case for a strategic energy transition—proving that the path to cleaner air is also the path to a more affordable and sustainable energy future.

The electric grid around Lahore is served by a cluster of fossil fuel-based thermal power plants concentrated in three main areas: Sheikhupura, Raiwind, and Balloki. These facilities predominantly operate on furnace oil or natural gas/regasified liquefied natural gas (RLNG), with most plants falling into the middle-aged category (13-15 years old). These aging plants are characterised by low utilisation rates and capacity factors, operating intermittently and inefficiently—with the notable exception of the newly constructed RLNG plants at Bhikki and Balloki, which boast higher efficiency and utilisation rates.

The geographic distribution of these plants creates varying levels of exposure and health risks for nearby populations. While power plants in Sheikhupura and Balloki are situated within industrial zones at some distance from central Lahore, the Raiwind area is more densely populated and serves as a hub for domestic and commercial activities. Consequently, power plants located there pose greater health risks to local residents. Of the three plants operating in Raiwind, it's worth noting that the generation licenses

Power plant	Location	Capacity	Date (Age)	Efficiency	Utilisation	Capacity factor
NG/HSD						
NPPMCL	Balloki	1,276	2018 (6)	59%	72%	61%
QATPL	Bhikki	1,231	2018 (6)	62%	65%	59%
Sapphire Electric	Muridke	235	2010 (14)	51%	32%	31%
Orient Power	Balloki	225	2010 (14)	51%	49%	35%
Halmore Power	Bhikki	225	2011 (13)	51%	31%	30%
RFO						
Atlas Power	Sheikhupura	224	2009 (15)	45%	35%	32%
Nishat Chunian	Qasur	202	2010 (14)	45%	46%	38%
Reshma Power	Raiwind	200	2011 (13)	10-15%	8-10%	10-15%
Saba Power	Farooqabad	136	1999 (25)	31%	16%	16%
Japan Power	Raiwind	135	1994 (30)	10-15%	8-10%	10-15%
Southern Electric	Raiwind	117	1994 (30)	10-15%	8-10%	10-15%

Exhibit 13.1. Characteristics of Thermal Power Plants Around Lahore. **Most furnace oil power plants have low utilisation rates, serve peak load demand, or provide reactive power compensation and ancillary services during grid congestion and high demand. According to the USEPA, operating thermal power plants at lower loads or changing loads frequently yields lower efficiency and higher levels of incomplete combustion, resulting in increased ecological emissions and health impacts.**

for Southern Electric Power and Japan Power expired in 2019 and 2020, respectively.[1] Meanwhile, Reshma Power, initially acquired under a 'rental' model has operated only sporadically despite being technically available.[2] [3]

Beyond these larger independent power plants (IPPs), numerous smaller captive power plants (1-5 megawatts) dot the Sheikhupura industrial zone.[4] These smaller facilities, typically running on furnace oil or diesel, contribute significantly to environmental emissions and localised air pollution despite their modest size.

The emissions burden: quantifying the impact

The environmental impact of these power plants varies significantly depending on their fuel source and operational efficiency. High-efficiency gas/RLNG-fired power plants

[1] NEPRA. (2022). State of the Industry Report. National Electric Power Regulatory Authority.

[2] Rental Power Plants (RPPs) were set up in Pakistan between 2007-2012 as a short term solution to the 10-20 hour loadshedding the country was experiencing at that time, due to a power supply gap of 5000 MW. As opposed to conventional thermal power plants which took 3 years to build, RPPs were supposed to have a construction timeline of 6 months and a short-term (2-5 years) power supply contract with the government. After the end of the contracted agreement period, the power plants would be dismantled or moved to a new location or in some instances, as in the case of Reshma Power, the power supply contract could get extended as well.

[3] NEPRA. (2023). State of the industry report. National Electric Power Regulatory Authority.

[4] A captive power plant is an industrial/commercial electricity generation facility that produces power for on-site consumption.

generally produce fewer particulate matter and sulfur oxide emissions, but they still release considerable amounts of nitrogen oxides (NOx) and carbon monoxide (CO) into the atmosphere.[5]

In contrast, furnace oil or diesel-based power generation facilities emit large volumes of sulfur oxides (SOx), volatile organic compounds (VOCs), and NOx—prime contributors to acid rain and smog formation.[6] These emissions are widely associated with numerous respiratory and cardiovascular diseases, with amplified health impacts on children and individuals with pre-existing respiratory conditions. All fossil fuel-based plants also emit significant volumes of carbon dioxide (CO2), the leading greenhouse gas driving climate change.

Most furnace oil power plants in the region operate at low utilisation rates, primarily serving peak load demand or providing reactive power compensation and ancillary services during grid congestion and high demand periods. According to the USEPA, operating thermal power plants at lower loads or frequently changing loads results in reduced efficiency and higher levels of incomplete combustion, which translates to increased emissions and greater health impacts.

Data compiled by PAQI estimates that the 11 power plants operating in Lahore's vicinity have cumulatively released 2,800 kilotons (kt) of CO2, 2kt of CO, 19.4kt of NOx, and 65kt of SOx between 2017 and 2022—a substantial contribution to the region's pollution burden.

The economic burden: high costs, low efficiency

Beyond their environmental impact, these thermal power plants impose a significant economic burden. Plants running on partial load operate less efficiently, resulting in higher fuel charges per kilowatt hour (kWh) generated, costs which are ultimately passed on to consumers.

The high cost of imported RLNG, diesel, and furnace oil has pushed all the power plants in Lahore's vicinity to the bottom of the merit order list maintained by NTDC. The merit order list published by NTDC for September 2024 places the marginal (variable) cost of operating these plants between PKR 28-57/kWh, depending on the type of fuel consumed.[7]

This high operating cost severely limits their dispatch frequency. However, under the current two-part tariff system, these plants receive fixed capacity charges for 100% availability regardless of actual power generation. They are also entitled to Partial Load Adjustment Charges (PLAC) when operating at partial load despite full availability. The State of the Industry Report 2022 reveals that PLAC payments for the Sapphire and Halmore power plants have increased over time, with each facility receiving PKR 1.25 billion and PKR 1.04 billion respectively during 2022.[8]

[5] United States Environmental Protection Agency. Chapter 3: Fuel oil combustion.

[6] Asian Development Bank. Thermal power plants in Pakistan.

[7] NTDC. (2024, September 16). Merit order dispatch list.

[8] NEPRA. (2022). State of the industry report. National Electric Power Regulatory Authority.

These plants thus represent a double burden—they degrade air quality while simultaneously imposing a substantial economic cost on the state and its citizens.

A path to cleaner air and energy

A legacy of outdated regulations

While environmental regulations and quality standards imposed by the Punjab government mandate regular monitoring and reporting of emissions by thermal power plants with third-party validation, robust implementation of these regulations remains inadequate, particularly for smaller power generators.

Year-round emissions from power plants located on the city's outskirts and near densely populated centres contribute significantly to the consistently 'unhealthy-hazardous' air quality rankings that plague Lahore.

The provincial environmental regulations largely derive from the first National Environmental Quality Standards (NEQS) established in 1999. No significant upgrades or increased stringency have been introduced since then, leaving little incentive for power generators to improve efficiency or install advanced environmental controls.

The economic case for early retirement

Early closure of furnace oil-based power plants may prove economically advantageous, especially for facilities that are 12-15 years old with diminished debt obligations. A report by the Institute for Energy Economics and Financial Analysis (IEEFA) suggests that the economic cost of immediately retiring the Sapphire and Halmore power plants could range between USD 47 million and USD 51 million each. Allowing these plants to operate somewhat longer but still retiring them ten years earlier than their contracted lifetime would reduce each plant's valuation to between USD 17.5 million and USD 18.6 million.

In contrast, if these plants continue operating as currently projected, they would receive up to USD 205 million each in excess capacity payments due to their low utilisation rates.

Additionally, early retirements would yield significant environmental benefits. IEEFA's analysis predicts emissions savings of 5 million tonnes of CO_2 per plant if the Sapphire and Halmore facilities are retired immediately.[9]

Repurposing infrastructure for a renewable future

After these thermal power plants cease operations, their sites could be repurposed for rooftop or ground-mounted solar photovoltaic (PV) installations. Since these facilities are

[9] IEEFA. (2024, October). Making the energy transition meaningful: A case study from Pakistan.

located near high-load centres and already connected to the grid, existing interconnections could be utilised for renewable energy integration without significant modifications or upgrades.

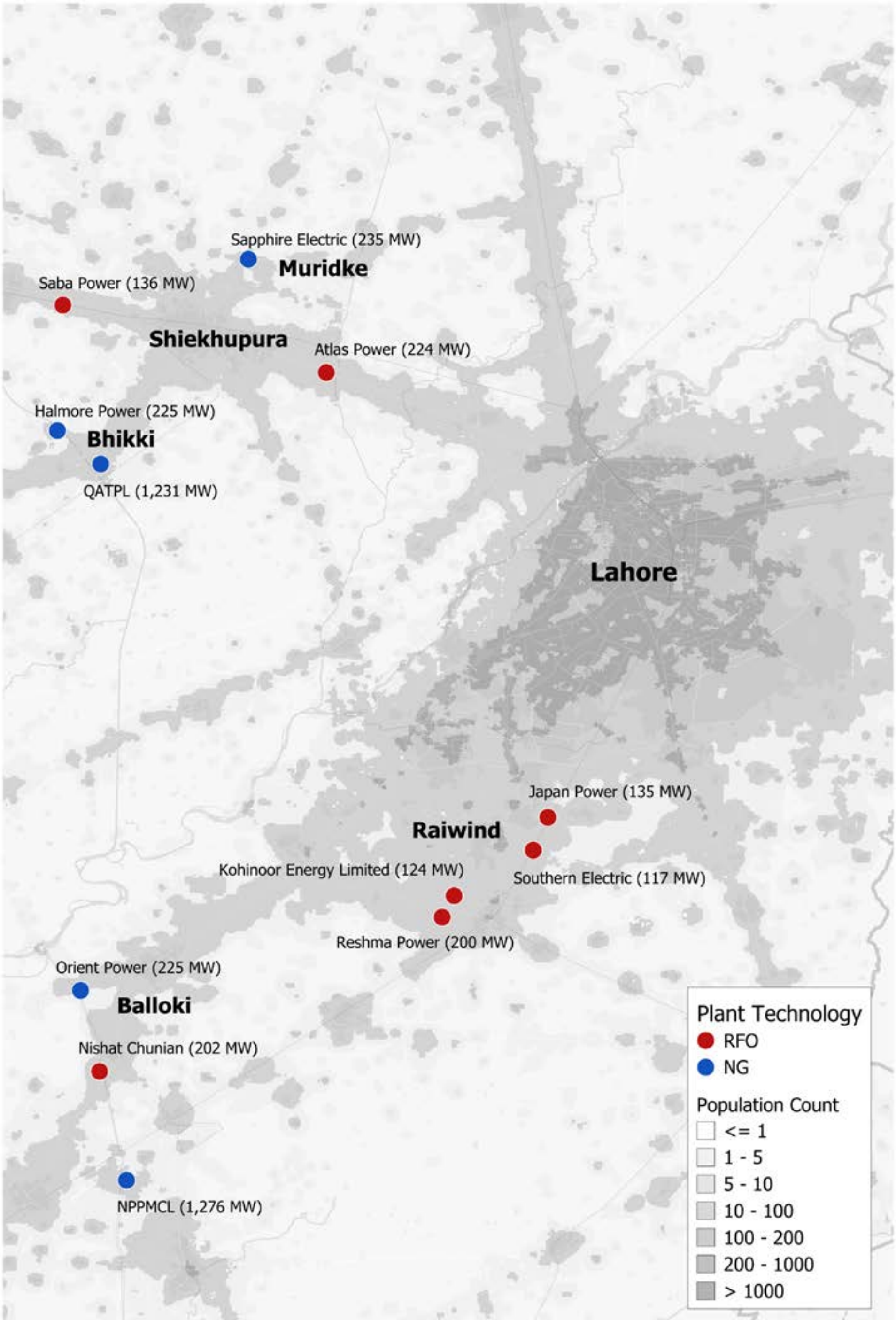
The city and provincial governments should ensure that future industrial and residential capacity demands are met through renewable energy projects such as solar or biomass-fired power generators. The rapid adoption of distributed rooftop solar across Pakistan—with 2.2 gigawatts (GW) of documented net-metered rooftop solar capacity installed as of June 2024—demonstrates the cost-effectiveness of solar PV technology compared to fossil fuel-based power. This growth has been enabled by a consumer-friendly net metering policy that offers attractive incentives.

While the national grid's current surplus power capacity has prompted the government to discourage captive power plant operations for industries,[10] making an extension of similar incentives for industry potentially challenging at present, careful planning, optimisation of renewable energy resources, and the phased retirement of inefficient and costly thermal power plants would offer a sustainable pathway for future energy growth while significantly improving Lahore's air quality.

Through this strategic approach to energy transition, Lahore can address one of the major contributors to its air quality crisis while moving towards a more sustainable and economically sound energy future.

[10] Associated Press of Pakistan. (2024, August 27). Senate body on petroleum discusses gas supply cessation to captive power plants.

Exhibit 13.2 Lahore's Ring of Power. **This map visualizes the proximity of thermal power plants to Lahore's densely populated zones. The clustering of plants using hazardous fuels near residential hubs like Raiwind creates a direct corridor of exposure for millions of citizens.**

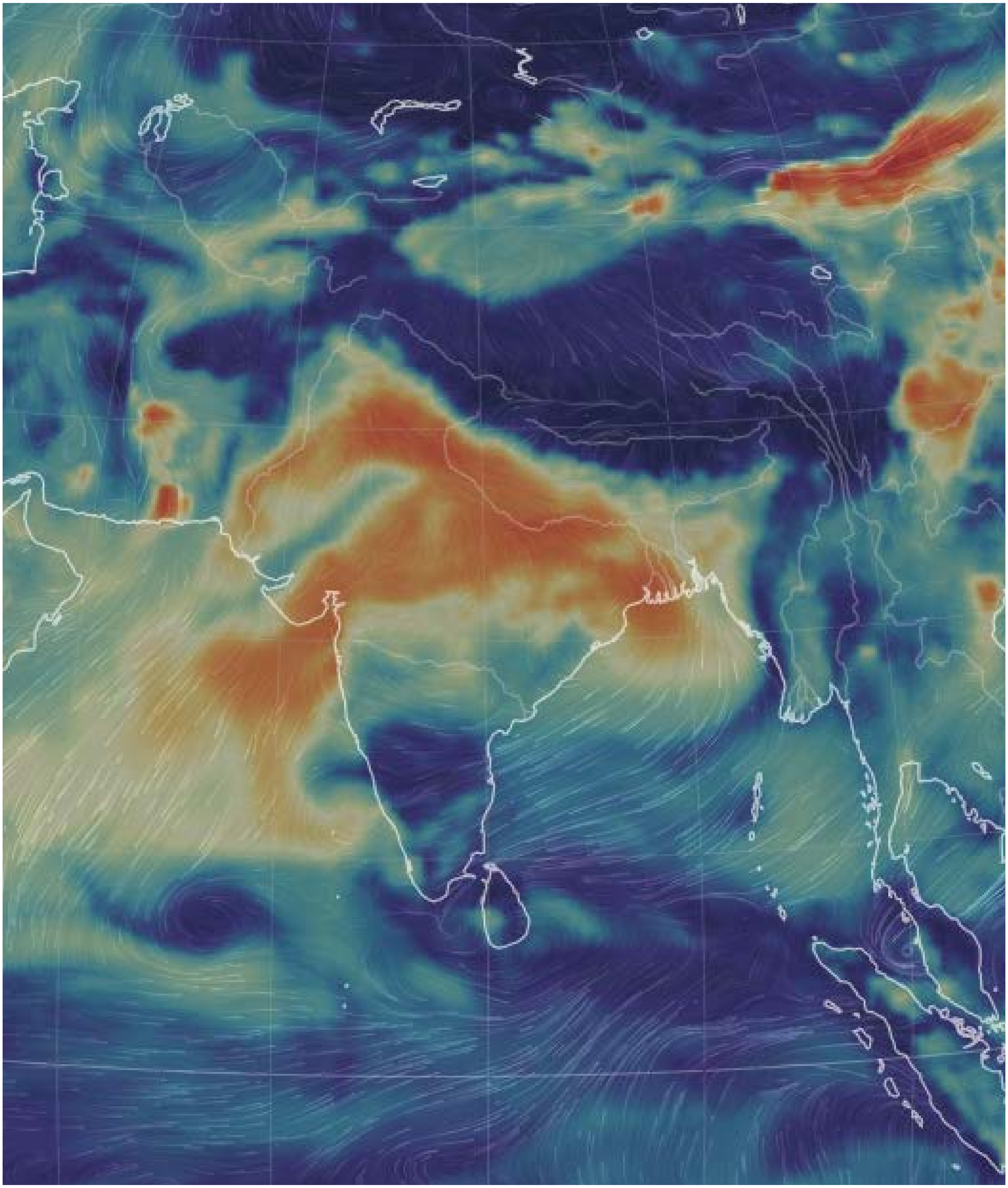


Haneea Isaad is an Energy Finance Specialist at the Institute for Energy Economics and Financial Analysis (IEEFA).

Section Three

Governance, Policy, and Public Engagement

3



A visualisation of surface-level PM2.5 on November 22, 2025 reveals the intensity of South Asia's pollution burden. The deep reds and oranges across the Indo-Gangetic Plain illustrate hazardous concentrations of fine particulate matter during the peak smog season, marking the region as a global hotspot that demands a coordinated, cross-border response. Image source: earth.nullschool.net by Cameron Beccario.

14.

The 20-Year Full Circle

The development of air pollution policy in Pakistan

From courts to commissions: For two decades, the fight for clean air has been led not by proactive policy, but by judicial activism, with courts repeatedly forcing the government to form commissions and create plans.

The implementation gap: Despite a host of sophisticated policies on paper, on-ground enforcement has been weak, inconsistent, and often focused on politically convenient targets rather than the largest polluters.

The politics of denial: A persistent lack of investment in a credible, nationwide air quality monitoring network has allowed for a culture of "plausible deniability", enabling authorities to dispute independent data and avoid accountability for the true scale of the crisis.

To understand why Pakistan's air remains toxic, we must look beyond the smokestacks and into the corridors of power. Ahmad Rafay Alam provides a critical, 20-year history of the country's struggle with air pollution policy, revealing a vicious cycle of judicial activism, reactive policymaking, and failed implementation. This chapter is an essential accounting of how, despite commissions, court orders, and a proliferation of new rules, we are still where we started—choking on the consequences of inaction.

Air pollution in Pakistani cities, especially Lahore, is among the worst in the world. This did not just happen overnight. It has taken years of effort and after two decades, we appear to be right back where we started.

Let me explain how this has happened, by providing a historical overview of the various legal, judicial and policy-based attempts to regulate or improve air pollution in Pakistan. Since Lahore's air pollution has been the most widely reported, for reasons that will be made clear consequently, the major part of this overview will cover the regulatory attempts made in Punjab, as this is where the policy battle has been most intensely fought.

The era of judicial activism

In 1997, a writ petition was filed in the Lahore High Court by then-lawyer Syed Mansoor Ali Shah in the public interest and on behalf of the citizens of Lahore complaining of the quality of air in Lahore.[1] The petition contended that air pollution has a "severe effect on human life, specially on newborn and unborn infants" and asserted that "motor vehicle emissions account for approximately 90% of total annual emissions of hydrocarbons, aldehydes, carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen oxide".

In response, the Lahore High Court constituted a Commission chaired by Senior Advocate and the pioneer of Environmental Law in Pakistan, Dr. Parvez Hassan and tasked it "to submit a report on feasible and practical solutions and measures for monitoring, controlling and improving the vehicular air pollution in the city of Lahore".[2]

The Commission executed its terms of reference, including the hosting of Pakistan's first international air quality workshop in 2005, and filed its report before the Court. In this report, the Commission highlighted the need to have ambient air quality standards in line with WHO guidelines, improved air quality monitoring and planning, cleaner fuels for automobiles, standards for public buses and rickshaws, and vehicle emission standards.

The case was decided in 2006 with the Lahore High Court issuing directions to the Government of Punjab to introduce CNG for Euro-II fuel compliant rickshaws, phase out wagons for public transport and replace them with minivans, set ambient air and fuel quality standards, and prioritise the establishment of air quality monitoring stations, amongst other things.[3]

As a result of this case, four-stroke CNG rickshaws were introduced into the market and fuel quality standards were established for the first time.

The 18th Constitutional Amendment was passed in 2010 and took effect in 2012. As a result, a number of subjects of governance were devolved to the provinces, including environmental regulation. By 2014, all four provinces had passed their own environment laws, establishing their own environment protection agencies (EPAs) and conferring on them the powers to enforce quality standards etc.

Each of the provinces have since adopted their own quality standards for industrial gaseous emissions, ambient air as well as for automobile exhausts. By and large, these emissions standards are the same (with the exception of PM10 and PM2.5 levels for ambient air in Sindh and the method of measurement of PM in Punjab).[4] Provincial environment protection laws also confer onto provincial EPAs the power to require automobiles to use particular fuels and air pollution devices to control vehicle pollution but, till the writing of this article, none of the EPAs have exercised this power.

[1] Syed Mansoor Ali Shah and others v. Government of Punjab and others. Writ Petition No. 6927 of 1997, Lahore High Court (unreported).

[2] Dr. Parvez Hassan, Judicial Commissions and Climate Action in Pakistan, (2018).

[3] Syed Mansoor Ali Shah and others v. Government of Punjab and others. (2006). PLD 2007 Lahore 403, Lahore High Court (consolidating Writ Petitions Nos. 6927 of 1997 and 8491 of 2001).

[4] The Sindh Environment Quality Standards for Ambient Air set the 24-hour average for PM2.5 at 75 micrograms per cubic metre whereas they are otherwise 15 micrograms per cubic metre in the other provinces and Islamabad Capital Territory. In Punjab, the method of measurement of PM2.5 is “preferably” Beta Ray Absorption Method whereas in the other provinces it is only Beta Ray Absorption Method, giving the EPA Punjab some flexibility in the type of equipment that may be used to measure PM2.5.

The smog crisis of 2016 and the rise of citizen data

In November 2016, Lahore and its surrounding areas witnessed a dramatic smog event.

Smog—literally smoke and fog—is an air pollution phenomenon when air pollution remains trapped near the surface of the earth by an inversion cloud.

For a day or two, Lahoris, deceived by what they thought was the early onset of winter and their much-beloved dhund, found themselves with sore throats and patchy eyes. The inversion cloud dissipated, the smog dispersed, and public attention was soon drawn to other things. However, a public interest writ petition was filed, seeking directions from the Court to EPA Punjab to take notice of the deteriorating air quality situation in the city. The case was taken up by Justice Mansoor Ali Shah, who directed the Environment Protection Department (EPD) of the Government of Punjab to come up with a policy to combat the "smog".[5]

By this time, the Pakistani Air Quality Initiative (PAQI) had been set up by Karachi-based Abid Omar, who had just returned to Pakistan after working several years in Beijing, China. Abid had been struck by the response the Chinese had to air pollution—they immediately took it as a challenge to be bested. And much of that response had to do with citizen awareness playing a crucial role.

Air quality data made available from monitoring devices set up at the US diplomatic missions in Beijing and Shanghai and published on the internet gave citizens real-time information about the quality of air they were inhaling. The Chinese administration was forced to respond to a massive public reaction. Similarly, PAQI's monitoring network was noting the deteriorating air quality in Pakistani cities and realised that something had to be done.

PAQI started by installing low-cost air quality monitors in Karachi, Lahore, Islamabad and Peshawar, one in each city. A second monitor was added in Lahore by early 2017, and the data was made available through the website of the monitoring devices as well as on social media. Concerned citizens of these cities could now have a sense—albeit a very unrefined one—of the poison they were inhaling into their lungs.

Understanding the year-round haze

As the summer of 2017 began to give way to winter, the changing weather brought with it something all Pakistanis living in and around cities are now familiar with: poor air quality.

There are a number of reasons why air quality in Pakistani cities further deteriorates in the winter. This is not to say that air pollution is absent at other times of the year. Not at all. Poor air quality is a year-round public health emergency, only made worse in the winter. As temperatures drop, there is less tendency for the pollution generated to dissipate with rising hot air. With cooler temperatures, pollution tends to remain close to the surface of the

[5] Walid Iqbal v. Federation of Pakistan and others, Writ Petition No. 34789/16, Lahore High Court (Nov. 14, 2017) [Smog Health Emergency Action Plan], 2017 LHC 3605. (the petitioner was PTI Senator Walid Iqbal).

earth. While pollution levels are lower in the summer, they are still way above safe limits. It isn't that there are less emissions in the summer. On the contrary, the same number of vehicular, industrial and other emissions are being produced the whole year round, more or less.

Another factor is geography. The South Asian subcontinent was formed millions of years ago through continental drift; with the part of India south of the Deccan Plateau colliding with the continent of what is now Asia. This collision resulted in the creation of a gigantic wall: the Hindu Kush, Karakoram and Himalayan mountain ranges. Over the millennia, water deposited on these ranges by the summer monsoon froze and became ice, and in turn, that ice melted into the streams and lakes forming the Indus and Ganges basins. The Indo-Gangetic Plains are like a trough between the HKH Ranges and the Deccan Plateau. And air pollution, especially in winter, tends to get stuck in this trough. Any satellite image of air pollution of South Asia reveals the startling truth: air pollution is a regional problem stretching from Kabul to Dhaka.

This historical trajectory reveals that Pakistan has built a substantial legislative framework for environmental protection over decades, yet the practical implementation of these laws has remained a persistent challenge.

The smog commissions: policy by court order

As directed by the Lahore High Court, the Environment Protection Department of the Government of Punjab formulated a “Policy and Action Plan for Control, Mitigation, Advisory and Protective Measures in Extreme Weather Conditions of Dense Smog in the Punjab” in September 2017. This Policy recommended the introduction of low-sulfur fuels and adoption of Euro-II fuel quality standards for vehicles, the use of pollution control devices such as catalytic converters in automobiles, better traffic management, controlling the burning of municipal and crop residue, the establishment of a network of air pollution monitors, controlling dust from construction and road shoulders, planned urban development and regional cooperation in reducing environmental pollution.[6]

This Policy also adopted an air pollution index which linked specific action at particular air pollution levels. This index resembled the US EPA's Air Quality Index but set the categories for harmful levels of air pollution much higher than the US EPA. Also, this air pollution index remains at odds with the National Environmental Quality Standards for Ambient Air, which require the assessment of nine different air pollutants.

This 'Smog Policy' was placed before the Lahore High Court during its November 2017 hearing of the Walid Iqbal case and incidentally, at the time of another smog event. Justice

[6] Government of Punjab, Environment Protection Department. (2017). Policy and Action Plan for Control, Mitigation, Advisory and Protective Measures in Extreme Weather Conditions of Dense Smog in the Punjab 2017.

Mansoor Ali Shah had become the Chief Justice of the Lahore High Court by then. He was not impressed with the Policy and in December 2017, he ordered the formation of a Commission, to be chaired, again, by Dr. Parvez Hassan to "combat smog and to formulate a Smog Policy for Punjab, which identifies the root causes and prescribes a plan to protect and safeguard the life and health of the people of Punjab".

By this time, the media coverage of the Walid Iqbal proceedings as well as air quality data made publicly available by PAQI led to the news that Lahore's air pollution was some of the worst in the world. Articles appeared in the international media such as *New York Times, Associated Press, The Guardian* as well as local newspapers. PAQI's mission to raise awareness about air quality was beginning to work.

The citizens of Pakistani cities deserve more than token policymaking for the sake of policymaking... the ones that have successfully addressed the issue all have one thing in common: a shared vision of a clean air future that is longer and more sustainable than the five-year election cycle.

Chief Justice of Lahore High Court Mansoor Ali Shah was elevated to the Supreme Court of Pakistan in early 2018. However, then-Chief Justice of Pakistan Saqib Nisar had taken suo motu notice of the deteriorating air quality in the country in March 2018 and directed the Commission formed by Justice Shah to submit its report to the Supreme Court instead of the Lahore High Court. Following these orders, the Commission filed its report before the Supreme Court in May 2018.

This Smog Commission's report set out 17 voluntary and mandatory recommendations. The voluntary actions were that rice growers, brick kiln and steel re-rolling mill owners agreed to not burn rice stubble, shift to zig-zag brick kiln technology and shift to cleaner production methods respectively.

The mandatory actions recommended by the Smog Commission were comprehensive and multifaceted. They called for the strict implementation of the ban on burning municipal waste and urban biomass, alongside the adoption and full implementation of the Punjab Clean Air Action Plan previously formulated under the "Smog Policy" of 2017. A significant directive was for the Health and Environment Protection Departments to employ the Public Health (Emergency Provisions) Ordinance, 1944, enabling them to mobilise various government departments by making rules, prohibiting harmful activities, relocating medical personnel, and allocating resources to tackle high levels of air pollution on an emergency basis. Further actions included the gathering of data from public and private hospitals and clinics regarding patients suffering from air pollution, and the requirement for Health and Environment Protection Departments to adopt standard operating procedures for smog response as well as set up dedicated smog response desks. A key recommendation urged the immediate adoption, dissemination, and subsequent implementation by the Government of the Punjab of Standing Instructions for Management of Episodes of Poor Air Quality, with the Commission specifically advising health alerts for preventive action when the AQI crossed the 300 threshold. Finally, the mandatory actions encompassed a targeted afforestation campaign, the placement and regular updating of air quality data on the Environment Protection Department website, and the pursuit of a transboundary agreement for controlling air pollution.

The Supreme Court of Pakistan appreciated the work of the Smog Commission and directed the contents of the report be read as part of its own order, thereby making the recommendations of the Smog Commission binding and enforceable.

Plausible deniability: the monitoring gap

General elections took place in Pakistan in August 2018 and a PTI government assumed charge of the Federal and Punjab governments. The considerable policy work that had been undertaken as a result of judicial activism came to the aid of the new Government of Punjab, which focused primarily on tree plantation drives (as part of its 10 Billion Tree Tsunami Project), crackdown on crop burning and compelling brick kiln owners to adopt zig-zag brick kiln technology.

At the same time, PAQI's network of low-cost air quality monitors was expanding. Over a dozen monitors had been installed in Lahore, Islamabad and Karachi. However, all provincial EPAs, without exception, disputed the accuracy of these monitors and denied the record air pollution levels they were displaying.

This position stems from the method of measurement prescribed in the ambient air quality standards adopted by the provinces. The low-cost air monitors installed by PAQI use lasers to measure PM2.5 levels. The ambient air quality standards require Beta Ray Absorption as the means to measure PM2.5. The problem here is that the machinery required to measure the nine pollutants scanned for in the ambient air quality standards is very expensive. On the other hand, the public has a right to know the quality of air it is exposed to.

Having a network of reference-standard air quality monitors that comply with the quality standards is prohibitively expensive whereas low-cost monitors can be set up throughout cities and provinces for a fraction of the cost.

There must be a way for a low- and middle-income country (LMIC) like Pakistan to use reference-standard air quality monitors along with a network of low-cost monitors to provide reliable real-time air quality data. Without a network of air quality monitors, it is impossible to measure air quality, and equally impossible to do anything about it.

This "plausible deniability" of the data collected by PAQI's low-cost monitoring network has allowed the EPA Punjab to rely instead on the two or three working reference-standard air quality devices in its possession. While these machines may be accurate and their data uploaded onto the website of the Environment Protection Department fairly regularly, they cannot and do not present an accurate picture of the air quality of Lahore, let alone the province of Punjab. It has also not stopped the local and international media from using the PAQI data to constantly report the poor air quality in Pakistani cities.

The paradox of policy: declaring a calamity

The winter of 2019 also saw elevated levels of air pollution. A particularly bad spell of air pollution in November prompted the Government of Punjab to close all schools in the Lahore, Gujranwala and Faisalabad districts for a day.

The lockdowns in 2020 due to the COVID-19 pandemic saw reduced levels of air pollution arising from restricted automobile use and minimal industrial activity. I recall the clear skies during the lockdown period. It became clear to me that we knew not only what needed to be done to improve air quality but that tangible results were only a few days of effort away.

Ahmad Rafay Alam highlights the persistent disconnect between policy intent and on-ground reality, the challenges of institutional memory, and the "vicious cycle" of decision-making, ultimately questioning the efficacy of past approaches and setting the stage for a re-evaluation of governance strategies.

The onset of winter in 2021 saw the Government of Punjab take the unusual step of declaring smog a "calamity", "especially in the territorial limits of the city of Lahore". Under the Punjab National Calamities (Prevention and Relief) Act of 1958, whenever any part of the Punjab is affected by floods, famines, locust of pests, fire, epidemics or other calamities, the Government of Punjab has the power to declare the whole or any part of the province as a calamity-affected area and to appoint a Relief Commissioner to maintain order, check or control the calamity or reduce its extent and severity. In doing so, the Relief Commissioner has vast powers, including the power to direct any person to abstain from a certain act or to take certain measures with regard to certain property in his possession or under his management.

In declaring smog a calamity, the Government of Punjab appointed the Punjab Disaster Management Authority under the Board of Revenue as Relief Commissioner. A series of orders prohibited, within Lahore, the burning of crops, smoke-emitting vehicles, any industry working without an emission control system, stone crushers operating without wet scrubbers, the burning of solid wastes, rubbers and plastics, the use of sub-standard fuel and "any unauthorised activities which may cause pollution".

In addition, the Relief Commissioner directed businesses within the territorial limits of Lahore to ensure that 50% of their employees work from home, and that public and private educational institutions increase the use of buses and vans by 50%. These orders remained in force for the winter of 2021-2022, which reflected the Government of Punjab treating air pollution as a seasonal issue, and not a year-round public health emergency.

Similar calamity orders were issued by the Relief Commissioner during the onset of winter in 2022 and 2023. While wide-ranging, the directions of the Relief Commissioner are not enforced across the board. Enforcement usually takes the shape of filing of criminal cases against farmers for crop burning and the sealing of brick-kilns that have not been converted to zig-zag technology. There has been no appreciable increase, for example, in the number of buses used by educational institutions.

Perhaps the reasoning for employing the Calamities Act rather than implementing court orders lies in the EPA field formation. The Punjab EPA focuses mainly on industrial pollution which is mostly concentrated in the urban areas of Punjab. It does not have the field formation to enforce zig-zag brick kiln formations, which are mostly in the rural areas. The PDMA and Board of Revenue, on the other hand, has a network of revenue officers throughout every district of the province and are perhaps better placed to carry out such conversions and enforcement. What they did not have in 2021, however, were air quality monitoring devices.

A flurry of policies, a failure to implement

In December 2022, the Punjab Environment Protection Council adopted the Health Advisory System for Critical Air Pollution Events (HAS-CAPEs). A Critical Air Pollution Event (CAPE) is a period of air pollution exceeding moderate AQI (more than 150) for at least five days. If a CAPE takes place, the HAS-CAPEs seeks to provide a mechanism for the issuance of health advisories so that remedial action may be taken by relevant government agencies.

The HAS-CAPEs envisages a Steering Committee chaired by the Chief Secretary of Punjab that will oversee the monitoring and management of health advisories as well as provincial and district CAPEs committees that will declare/undeclare CAPEs and ascertain what information needs to be disseminated. The schedule to the HAS-CAPEs provides a comprehensive list of measures that need to be taken and by which government agency, at differing levels of air pollution.

In April 2023, the Punjab Environment Protection Council approved the Punjab Clean Air Policy (with a phased action plan). This Policy seeks to improve air quality through emissions reductions and sustainable green development. It aims, for example, to reduce PM2.5 concentration by 30% by 2030 in Lahore, Faisalabad, Gujranwala and Multan; to reduce major air pollutants by 25% by 2030; to reduce greenhouse gasses by 30% by 2030; to install and operate 30 air quality monitoring stations by 2024; convert 100% of brick kilns to zig-zag technology by 2030; and increase urban forest cover by 10% by 2030 (all compared to 2022 levels).

In order to do so, the Policy sets out a number of interventions in the transport, municipal, industrial, agriculture, energy, housing and infrastructure sectors. The implementation of the Policy rests on the enforcement of the HAS-CAPEs and the Action Plan set out in the schedule to Policy. The Action Plan lists in detail the short, medium and long-term initiatives to be carried out in the various identified sectors. The Policy also adopts an AQI classification system that is closer in line to the US EPA classifications, compared to the classifications adopted in the 2017 Smog Policy.

Interestingly, just a month later, in May 2023, the Federal Government adopted the National

Clean Air Policy (NCAP). This was unusual as the responsibility of governing environment issues such as air quality fell solely to the provinces after the 18th Amendment.

Nevertheless, the NCAP aims to reduce emissions in the five priority sectors of transport, industry, agriculture, waste and household/residential by 21% by 2030 and by 70% by 2040 (compared to 2020 levels).

And, as if to complete a loop that started nearly 20 years ago with the Syed Mansoor Ali Shah case filed in the Lahore High Court, NCAP seeks to improve fuel quality in transport by shifting to Euro-V by 2025 and Euro-VI by 2030. In the transport sector, the NCAP seeks to improve the capacity of motor vehicle testing, the phasing out of obsolete technologies and the promotion of electric vehicles. However, despite the detailed interventions for each sector mentioned in this Policy, the fact remains that transport, agriculture and waste management are all subjects of provincial governance responsibility. The NCAP appears to make policy promises for the provinces to carry out and pay for.

In June 2023, the Environment Protection Department notified the Punjab Environmental Protection (Smog Prevention and Control) Rules. Although made after the Punjab Clean Air Policy, these Rules do not reference or mention it and instead seek to address smog by stipulating Standard Operating Procedures (SOPs) for brick kilns, industrial units, resource recovery units, tyre pyrolysis plants, stubble and waste burning and motor vehicles. These SOPs range from requiring the installation of pollution control devices (for industry) to a complete prohibition on activity (for tyre pyrolysis plants). Violations of the SOPs are met with penalties prescribed in the rules which range from fines (for motor vehicles, industrial units and burning crop stubble or waste) to demolition (in the case of brick kilns).

Twenty years later: a full circle of failure

In the two-decades of air policy formulation in Pakistan, some clear trends are apparent.

For the first decade, air pollution policy was spearheaded by judicial activism, starting from the Mansoor Ali Shah case and ending with the Smog Commission. In the last decade, air pollution policy has emerged from the government itself. Further, almost all the policy development has been focused on Punjab, and specifically Lahore, and ignores the fact that air pollution afflicts every major city of Pakistan. Lastly, air pollution is many times confused with smog and treated, as a result, as a seasonal phenomenon rather than the year-round issue that it is.

Analysing the implementation of the policies that have emerged since the beginning of this century, it is apparent that while these policies have from the beginning identified automobile fuels and the transport sector as the major contributor to year-round air pollution, considerable action has only been taken mostly against brick kilns and crop burning.

The impression that one can be forgiven for getting is that the implementation tends to focus on the poor and politically less influential. And after 20 years, there is still no effective air quality monitoring system relied on by the EPAs. The deteriorating air quality in Pakistani cities is as much caused by pollution as it is by poor and ineffective governance.

The detail and nuance of the policies evolved in Punjab should give rise to some optimism. The Punjab Clean Air Policy (and phased action plan), if acted upon, could improve air quality in Punjab dramatically. Despite the Government of Punjab adopting this policy, policymakers appear to not have read or want to comply with it. Despite the caretaker Government of Punjab adopting the Policy and Smog Rules, the enforcement actions it took in the winter of 2023 included washing some of the main roads in Lahore with water and attempting cloud seeding (neither of which are mentioned in the Punjab Policy).

The citizens of Pakistani cities deserve more than token policymaking for the sake of policymaking. Other cities around the world have also faced air pollution issues and the ones that have successfully addressed the issue all have one thing in common: a shared vision of a clean air future that is longer and more sustainable than the five-year election cycle.

Ahmad Rafay Alam is an environmental lawyer specialising in the energy, water, natural resources, and urban infrastructure sectors.

Hazem Asif's satirical poster, Smogzilla Attacks Punjab, reimagines the pollution crisis as a giant, destructive monster besieging the city. The piece uses the visual language of vintage cinema to critique the scale of the threat and the urgency required to defeat this modern-day monster.

15.

Policy Gaps

Assessing the gaps in Pakistan's air quality governance

A retreat on public health: Pakistan's 2023 National Clean Air Policy proposes weaker air quality targets than the country's own standards from 2010, moving further away from, not closer to, WHO health guidelines.

Policies without teeth: Key national and provincial policies lack legally binding emission reduction targets for specific sectors or cities, making it impossible to measure progress or enforce accountability.

Flying blind: A critical lack of a comprehensive, nationwide air quality monitoring network means that policymakers are often creating plans without the foundational data needed to target the right sources or measure success.

This chapter has been adapted from the Center for Research on Energy and Clean Air (CREA) report "Air Quality Governance in Pakistan" by Dawar H. Butt and Sunil Dahiya, with additional contributions received from Chengcheng Qiu in China and Manoj Kumar in India.

The path to clean air is not a mystery; it has been charted by others. While cities from Beijing to London have proven that a transition from hazardous pollution to blue skies is possible, Pakistan's policies have yet to deliver meaningful results. This chapter provides a crucial benchmark, measuring our national and provincial strategies against the successful governance frameworks of China and India. It is an unflinching look at the gaps in our standards, monitoring, and enforcement, providing a clear, evidence-based roadmap for building a system that doesn't just create policies, but achieves clean air.

Air pollution is a persistent global challenge, and Pakistan is acutely affected. While cities like London, Los Angeles, and Beijing have navigated periods of extreme air pollution and demonstrated pathways towards cleaner air, many cities across South Asia, including those in Pakistan, continue to grapple with hazardous pollution levels, often showing limited progress in mitigation.

The scale of Pakistan's crisis is stark. The 2023 World Air Quality Report ranked Pakistan as the second most polluted country globally based on annual average PM2.5 concentrations, with major cities like Lahore and Peshawar frequently listed among the world's top 10 most polluted urban areas.[1] The health consequences are devastating; the Health Effects Institute's State of Global Air 2024 report attributes up to 256,000 premature deaths annually in Pakistan directly to poor air quality.[2]

[1] IQAir. (2023). World's most polluted cities. https://www.iqair.com/world-most-polluted-cities

[2] Health Effects Institute. State of Global Air 2024 Pakistan country profile. https://cdn.zevross.com/hei/country-reports/v2/pdf/Pakistan.pdf

Although comprehensive air quality data and research within Pakistan remain limited compared to the scale of the problem, available information consistently reveals hazardous pollution levels across various parts of the country. The issue garnered significant media and public attention around 2017, following prolonged episodes of thick “smog” blanketing Lahore, the capital of Punjab province. Responding to the escalating crisis and public outcry, both the Lahore High Court and the Supreme Court of Pakistan issued directives between 2016 and 2018, compelling the Punjab provincial government to devise policies aimed at mitigating the worsening air quality. While most subsequent government actions have remained concentrated on Lahore, recent years have seen growing awareness of the need to monitor, understand, and regulate rising air pollution levels in other cities and provinces, and indeed, at the national level.

A legacy of legislation, a history of delay

Pakistan’s legislative journey on environmental protection has often mirrored international developments. Following the landmark 1972 Stockholm Declaration on the Human Environment, Pakistan established the Ministry of Environment in 1975.[3] The foundational Pakistan Environmental Protection Ordinance (PEPO) was promulgated in 1983, creating key institutions like the Environment Protection Agency (Pak-EPA) and the Environment Protection Council (EPC) at the federal level, with provincial EPAs established subsequently.[4]

The Pakistan Environmental Protection Act (PEPA) of 1997 superseded the 1983 ordinance and remains the principal environmental law governing federal and provincial actions today.[5] PEPA 1997 paved the way for various implementing rules and regulations, including those establishing environmental tribunals (1999),[6] procedures for sample collection (2001),[7] requirements for industrial self-monitoring (2001),[8] and environmental impact assessment (EIA) processes (2000).

National Environment Quality Standards (NEQS) were first introduced in 1993, subsequently revised in 1999, and later expanded in 2009 to include standards for motor vehicle emissions.[9] A National Environment Policy was approved in 2005, explicitly recognising the problem of worsening urban air quality. In 2010, crucial NEQS for ambient air were approved, setting legally binding annual and daily limit values for various key pollutants,

---

3 Asian Development Bank. (2013). Environmental law and jurisprudence in Pakistan.

4 Ministry of Law and Justice, Pakistan. (1983). The Pakistan environment protection ordinance, 1983.

5 Government of Pakistan. (1997). Pakistan Environmental Protection Act, 1997.

6 Environment Tribunal: Established under PEPA 1997, the Tribunals hold the status of a Sessions Court and Civil Court, have the same powers vested in them, as outlined in the Code of Criminal Procedure and Code of Civil Procedure, respectively. The Tribunals also hold appellate jurisdiction to an order of the relevant EPA. It can impose penalties and issue bailable warrants for violations.

7 Samples: Rules for collection of environmental samples defined by the EPA. Consultants and laboratories operating privately also have to comply with these rules, and get registered with the EPA for samples to be considered for reporting and monitoring.

8 Self-monitoring: SMART or Self-Monitoring and Reporting requires all registered industrial units in the territory to routinely submit reports to the EPA. The frequency of the reporting period (monthly or quarterly) depends on the type of industry and its emissions intensity, i.e. highly polluting industries report on a monthly basis. The reports must follow sampling rules.

9 Government of Pakistan. (2010). National Environmental Quality Standards (NEQS) for air, water, and noise.

including particulate matter.

A significant constitutional shift occurred with the 18th Amendment in 2010, which devolved the subject of environmental protection and pollution control primarily to the provinces. Following this devolution, each province enacted its own environmental protection acts, largely based on the federal PEPA 1997 framework. Provinces also adopted the national standards (NEQS) as their provincial standards, although Sindh province notably relaxed its ambient air quality limits in 2016 compared to the national standards.[10] Since 2017, responding to court orders and the visible crisis of smog, the Punjab government has issued several policies related to air quality, culminating in the Punjab Clean Air Action Policy[11] and a Smog Mitigation Plan announced in 2023 and early 2024.[12]

Policies on paper: a critical assessment

In March 2023, Pakistan approved the National Clean Air Policy (NCAP),[13] representing the first federal-level policy attempt to systematically address the worsening air pollution situation since a previous plan from 2009 failed[14] to be implemented. The NCAP targets five key sectors, proposing one major intervention in each: enhancing transport fuel quality standards (to Euro-V and Euro-VI); enforcing emission standards for industry; preventing agricultural residue burning in agriculture; preventing open burning of municipal solid waste; and promoting low-emission cooking technologies for households. The policy projects a 21% reduction in PM2.5 emissions by 2030 compared to 2020 levels, increasing to a 70% reduction by 2040.[15]

While the NCAP takes some positive steps, a critical analysis reveals significant shortcomings alongside its strengths. On the positive side, the policy highlights the need to revise existing industrial emission standards and establish sector-specific limits, restricts new industrial development within city boundaries, promotes decarbonisation of the power sector, prioritises establishing emission inventories with annual updates, and mandates periodic reviews of the policy and its implementation plan.
However, several critical gaps undermine its potential effectiveness. Most concerningly, the NCAP proposes ambient air quality targets that represent a retreat from previously established, stricter standards. Instead of aligning with the WHO's updated 2021 air quality guidelines[16] [17] or maintaining the stricter NEQS 2010 limits (which were intended to be fully implemented by 2013), the NCAP adopts the WHO's older, less protective interim targets, effectively increasing allowable PM2.5 levels by potentially more than 50% compared to

[10] Government of Sindh. (2016). Sindh Environmental Quality Standards (SEQS).

[11] Government of Punjab. (2019). Punjab clean air action policy (Gazette notification).

[12] Government of Punjab. (2024). CM Punjab's Smog Mitigation Plan 2024.

[13] Ministry of Climate Change, Pakistan. (2023). National Clean Air Policy (NCAP).

[14] Punjab Board of Investment and Trade. (n.d.). Pakistan Clean Air Programme.

[15] It should be noted that the document refers to the forecasted "Business As Usual" emissions as "baseline" instead of a static baseline value.

[16] WHO global air quality guidelines: Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. (2021).

[17] There is a noticeable drafting error in this major policy document: the 24-hour target stated for carbon monoxide (CO) is incorrectly written as 7,000 µg/m3 instead of 7 µg/m3.

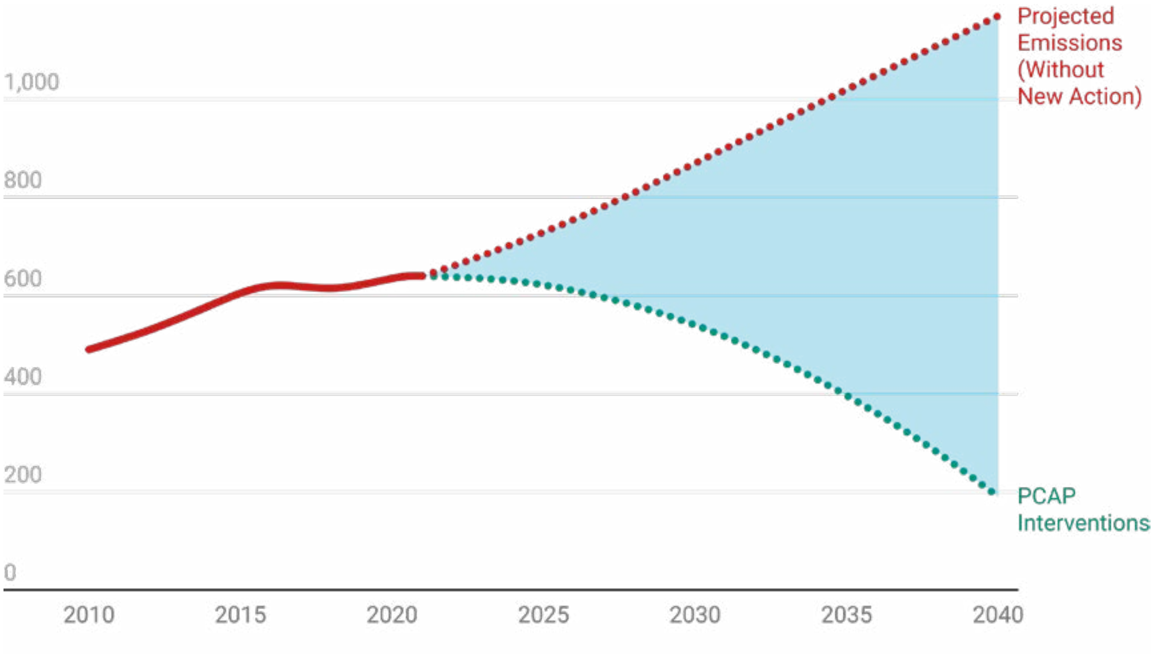


Exhibit 15.1: The Policy Gap Visualised. **The shaded area represents the vast gulf between two possible futures: the escalating crisis of unchecked emissions, and the cleaner air promised by the National Clean Air Policy. This is the 'policy gap' made visible. Closing it—and turning the promise of the green line into reality—depends entirely on overcoming the failures in standards, monitoring, and enforcement that have historically kept such plans on paper.**

the 2010 NEQS.[18] Furthermore, the policy lacks specific emission load reduction targets for key polluting sectors, major cities, or provinces, making progress difficult to measure and enforce. It also largely ignores the issue of transboundary air pollution and fails to propose mechanisms for airshed-level management, which is crucial in the South Asian context. The NCAP provides insufficient direction to provincial EPAs on developing detailed regional and city-level clean air action plans based on local data. Crucially, the policy lacks legal backing; it serves as an advisory document without clear enforcement mechanisms or penalties for non-compliance.

The Punjab Clean Air Policy (PbCAP), approved in April 2023 shortly after the NCAP, sets provincial targets of achieving 30% reductions in particulate matter and 25% reductions in gaseous pollutants by 2030.[19] [20] It outlines short-term (2024), medium-term (2026), and long-term (2030) sectoral milestones. While more specific than the NCAP, both policies suffer from a significant limitation: the apparent lack of comprehensive, up-to-date emission inventories underpinning the target-setting process.[21] Although the NCAP mentions developing a national inventory and a provincial inventory for Punjab (covering 1990-2020) was published after the PbCAP's adoption, it remains unclear whether this

[18] Ahmed, S. (2022). Lahore's air quality worsens as smog season begins. Dawn.

[19] Government of Punjab. (2019). Punjab clean air action policy (Gazette notification).

[20] Government of Punjab. (2017). Policy on controlling smog (Final).

[21] The Urban Unit. (2023). Sectoral Emission Inventory of Lahore.

Time-period	NEQS 2010	NEQS 2013	WHO 2021	NCAP 2023
24-hours	40	35	15	75
Annual	25	15	5	35

NCAP Proposed WHO, 2021 interim guideline

Exhibit 15.2: The Governance Gap in PM2.5 Standards. **This table compares Pakistan's past and proposed national air quality standards (NEQS and NCAP) for PM2.5 against the World Health Organization's (WHO) 2021 health-based guidelines. It reveals a significant governance gap: the proposed national standard for annual exposure (35 µg/m³) is seven times weaker than the level WHO advises for protecting public health (5 µg/m³). By proposing to adopt the WHO's most lenient interim target instead of the guideline itself, the policy risks locking in a level of air pollution that is officially recognised as dangerous to human health.**

detailed data truly informed the reduction targets specified in the policies.[22] Moreover, these and later inventories may not fully account for secondary particulate formation, a major component of PM2.5 pollution.[23]

The effective implementation and monitoring of these policies are further undermined by the inadequacy of air quality monitoring networks. While Punjab has made some progress under the World Bank-supported Green Development Programme from 2018, aiming to operationalise 30 monitoring stations by 2024 (not fully deployed at time of publication), the NCAP lacks clear objectives for establishing a robust national monitoring network. Monitoring capacity remains virtually non-existent in Balochistan, Khyber Pakhtunkhwa, and Sindh, creating significant data gaps across large parts of the country.

The path to blue skies: lessons from China and India

Examining the air quality management journeys of other countries facing similar challenges, particularly China and India, offers valuable insights for Pakistan.

China: a 10-Year journey from grey to blue skies

China's remarkable transition over the past decade provides key lessons. After initially establishing air quality standards in 1982 (revised significantly in 2012), China launched comprehensive air pollution control policies between 2013 and 2017, followed by a second phase from 2018 to 2020. Their current policies include ambitious targets for reducing PM2.5, NOx, and VOCs by 2025.

Key elements underpinning China's success include: building a comprehensive **national monitoring network** (expanding from 74 cities in 2013 to 338 cities and 1,436 stations by 2015, supported by substantial investment); adopting a **regional airshed management** approach with coordinated efforts at multiple governance levels and special focus on heavily polluted regions; establishing stringent, **sector-specific emission standards**, including ultra-low emissions policies for power plants (2014), steel (2019), and cement

[22] Food and Agriculture Organization of the United Nations (FAO). (2018). Remote sensing for spatio-temporal mapping of smog in Punjab and identification of the underlying causes using GIS techniques (R-SMOG).

[23] Urban Unit. (2023). Emission inventory of Punjab 1990-2020.

Targeted Reductions	Policy	Reduction Target (1%)	Baseline Year
PM2.5	NCAP	38% vs BAU, 21% vs 2020	Baseline / 2020
	PbCAP	30%	2022
NOx	NCAP	No target Specified	
	PbCAP	25%	2021
SO2	NCAP	No target Specified	
	PbCAP	25%	2021
Ozone	NCAP	No target Specified	
	PbCAP	25%	2021
CO	NCAP	No target Specified	
	PbCAP	25%	2021

Exhibit 15.3: Gaps in Ambition: Comparing National and Punjab Clean Air Targets. **This table compares the pollution reduction targets of the National Clean Air Policy (NCAP) and the Punjab Clean Air Plan (PbCAP). It reveals two critical governance gaps: first, the national policy only sets a target for a single pollutant (PM2.5), leaving four other major pollutants unregulated at the federal level. Second, the two policies use different baseline years, making a direct comparison of their ambition challenging and highlighting a lack of a unified, nationwide strategy for air quality management.**

industries (2024); implementing a strong accountability system featuring remote quality control, severe penalties for data tampering, and public availability of hourly monitoring data; and demonstrating **high-level political commitment** and enforcement, including significant penalties for manipulating air quality data following President Xi Jinping's 2015 pledge.

India: policymaking for unique South Asian challenges

India shares many geographical and pollution source challenges with Pakistan, particularly across the Indo-Gangetic Plain. India's air quality management efforts began with monitoring in ten cities in 1978, expanding into a National Ambient Air Quality Monitoring programme by 1984-1985. Ambient air quality standards were established in 1982 and revised in 1994 and 2009.

India's evolving approach incorporates several key features: an **extensive monitoring network**, which grew from seven stations in 1984 to 549 continuous monitoring stations and over 1,000 manual stations by 2024; a gradual shift towards **airshed-based planning**, moving beyond purely administrative boundaries, exemplified early on by the Taj Trapezium Eco-Sensitive Zone established in the 1980s; the implementation of **crisis response mechanisms**, such as the Graded Response Action Plan (GRAP) initiated in 2017 for managing hazardous air quality episodes in the National Capital Region; the establishment of dedicated **accountability structures**, like the Commission for Air Quality Management for the National Capital Region (CAQM) formed in 2020-2021; and setting **targeted reduction goals** through initiatives like the National Clean Air Programme (NCAP), launched in 2019, which specifies PM2.5 and PM_{10} reduction targets for major non-attainment cities.

AQI	PM 2.5	US-EPA Health-based AQI	Punjab 2017 AQI	Punjab 2021 AQI
0-50	0-9.0	**Good**	**Good** 0-100 AQI, 0-35 PM2.5	**Good** (0-50 AQI, 0-15 PM2.5)
51-100	9.1-35.4	**Moderate**		**Satisfactory** (51-100, 16-35)
101-150	35.5-55.4	**Unhealthy***	**Satisfactory** 101-200 AQI, 36-70 PM2.5	**Moderate** (101-150 , 36-70)
151-200	55.5-125.4	**Unhealthy**		**Unhealthy*** (151-200, 71-150)
201-300	125.5-225.4	**Very Unhealthy**	**Moderate** 201-300 AQI, 71-105 PM2.5	**Unhealthy** 201-300 AQI, 151-250 PM2.5
301-500	225.5-325.4	**Hazardous**	**Poor** 301-400 AQI, 106-140 PM2.5	**Very Unhealthy** 301-400 AQI, 251-350 PM2.5
			Very Poor 401-500 AQI, 141-300 PM2.5	**Hazardous** 401-500 AQI, > 350.1 PM2.5
> 500	> 325.4	**Beyond Index**	**Severe** > 500 AQI, > 300 PM2.5	

Exhibit 15.5. The Governance Gap in Air Quality Communication. **This unified table compares Punjab's 2017 and 2021 air quality standards against the health-based US-EPA benchmark. Anchored by consistent PM2.5 pollution levels (left column), the table reveals how local policies have used different health categories and numerical breakpoints to describe the same air. The discrepancy is most stark under the 2017 policy, where air pollution classified as 'Unhealthy' was officially communicated to the public as 'Satisfactory,' dangerously misleading citizens about the true threat to their health.**

A blueprint for effective governance

Drawing lessons from these international best practices and analysing the gaps in Pakistan's current framework, strengthening the nation's air quality governance requires focusing on several key areas:

— **Enhanced monitoring:** Significantly expand the air quality monitoring network across both urban and rural areas to accurately understand pollution sources, track trends, assess policy effectiveness, and direct targeted interventions.

— **Tighter standards:** Strengthen Pakistan's ambient air quality guidelines progressively, aligning them with the WHO's 2021 recommendations over a defined timeline, rather than relaxing existing standards or adopting outdated interim targets.

— **Emission load reduction targets:** Move beyond ambient concentration targets alone and establish legally binding, time-bound emission load reduction targets for key pollutants (PM2.5, SO_T, NOx, VOCs) across major polluting sectors, large cities, and provinces.

— **Airshed-based planning:** Adopt a scientifically determined airshed management approach, developing comprehensive, coordinated clean air action plans at regional (airshed), provincial, and national levels that address pollution sources holistically, including transboundary contributions.

— **Costed transition plans:** Develop detailed, costed transition plans for key pollution-contributing sectors (e.g., industry, transport, power, agriculture, waste management) that outline specific mitigation measures, required investments, and funding sources, integrated into annual planning and budgeting cycles.

Year	Policy / Legislation
	Federal
1983	Pakistan Environmental Protection Ordinance
1997	Pakistan Environmental Protection Act
2001	National Environmental Action Plan
2005	National Environmental Policy
2010	National Environment Quality Standards (Ambient Air)
2023	National Clean Air Policy (NCAP)
	Provincial
2012	Punjab Environmental Protection Act
2012	Baluchistan Environmental Protection Act
2014	Khyber Pakhtunkhwa Environmental Protection Act
2014	Sindh Environmental Protection Act
	Punjab
2017	Policy on Controlling Smog
2018	Punjab Clean Air Action Plan
2018	Standing Instructions for Managing Poor Air Quality
2022	Health Advisory System for Critical Air Pollution Events
2023	Punjab Clean Air Policy (PbCAP)
2023	Punjab Smog Prevention and Control Rules
2024	Smog Mitigation Plan

Exhibit 15.5. Timeline of Environmental Legislation. **This table chronicles over four decades of key federal and provincial policies, acts, and rules related to environmental protection in Pakistan. It highlights a significant acceleration in policy-making, particularly in Punjab since 2017, in response to the worsening smog crisis. The persistence of hazardous air quality, despite this legislative activity, points to a critical gap between policy on paper and effective implementation on the ground.**

— **Evidence-based response protocols:** Create data-driven Graded Response Action Plans (GRAPs) or similar protocols for major cities and polluted regions to trigger specific, pre-defined actions (e.g., traffic restrictions, school closures, industrial curtailments) based on monitored or forecasted air quality levels, prioritising public health protection during severe pollution episodes

— **Industrial accountability and transparency:** Revise and rigorously enforce tighter emission standards for major industrial sectors, incorporating continuous emission monitoring systems (CEMS) requirements for large polluters, and enhance transparency through mandatory public disclosure of emissions data and compliance status.

Implementing these recommendations would significantly strengthen Pakistan's air quality governance framework, aligning it more closely with successful international approaches and creating a viable pathway towards achieving meaningful and sustained improvements in air quality across the country.

In her series ***Navigating Matter,*** Lahore-based artist Maryam Rahman captures the physical weight and oppressive texture of the city's smog. The work renders the air not as empty space, but as a tangible, suffocating substance that alters the perception of the urban landscape.

16.

Politics and Policies

Sifting through the smog of air pollution governance

A cycle of failure: For 20 years, Pakistan's air quality policy has been a "vicious cycle" of court orders leading to commissions that produce recommendations, which are then adopted into policies that are ultimately not implemented, leading back to crisis.

The implementation gap: Despite a robust legal framework dating back decades, a persistent lack of political will, fragmented institutional responsibility, and weak enforcement have rendered most policies ineffective.

Action vs. optics: The official response to severe pollution often defaults to token, unscientific actions like road-washing, highlighting a deep-seated reluctance to tackle the primary sources—transport, industry, and fuel quality—identified in policies for years.

When the official response to a public health emergency is to wash the roads, it signals a profound disconnect between science, policy, and politics. Dr. Imran Saqib Khalid dissects that disconnect. This chapter provides a critical history of Pakistan's two-decade-long struggle with air pollution governance, revealing a vicious cycle of well-meaning policies, institutional apathy, and a persistent failure to implement. It is an essential analysis of why we remain trapped in the smog, and how we might finally break free.

A headline in *Dawn* newspaper on 10 December, 2023 had me do a double take. It read: "Road-washing drive launched to rid Lahore of smog." It quoted Mohsin Naqvi, then Chief Minister of the Punjab province as saying, "The washing of roads in Shahdara area will be undertaken tonight. We want either to entirely eliminate dust or at least minimise it. Hopefully, smog will be reduced with the reduction of dust through washing."[1]

Consider the above statement in light of the elaborate National Clean Air Policy and Punjab Clean Air Plan, both promulgated earlier in 2023. Consider, too, the plethora of other initiatives to combat air pollution over the years and one gets a sense of ever burgeoning dissonance with respect to science, policy and politics vis-à-vis environmental governance in Pakistan. The statement by the Chief Minister signifies a disconnect with the on-ground reality when it comes to the air pollution crisis in the country.

While Lahore has regularly been listed as one of the most polluted cities in terms of air

[1] Gabol, I. (2023). Road-washing drive launched to rid Lahore of smog. Dawn.com.

pollution, it is not the only Pakistani city to figure in global rankings. Peshawar, Rawalpindi and Karachi, for example, have also comfortably found their spots in the list of top 10 cities with the poorest air quality.

Over the past decade, the political and bureaucratic response to the crisis has been to either reject the air pollution data or blame transboundary sources of air pollution from India for poor air quality locally. In 2018, an official from the Ministry of Climate Change said that “Pakistan’s own contribution” is minimal and that “up to 70% of it could be from across the border”.[2]

The head in the sand approach to resolving Pakistan’s air pollution crisis has not worked. As the winter dawned in late of 2024, the Air Quality Index across many parts of Pakistan reached hazardous levels with Multan, the erstwhile City of Saints, crossing the 2,000 mark and signifying the scale of the problem facing the country.[3]

This gap between scientific understanding and political action is particularly troubling given that we now have more robust data than ever before. As detailed in the emissions inventories in this report, we have gained significant insights into the major sources of pollution across Pakistani cities, providing the scientific foundation needed for targeted interventions.

A legacy of laws, a history of inaction

Environmental management has a long history in the country and the region. The history of environmental legislation dates back to pre-Independence days. The Factories Act of 1934 stipulated effective arrangements for proper “disposal of wastes and effluents”. This would entail eliminating burning of solid and/or chemical and hazardous wastes.[4]

The Pakistan Environmental Protection Ordinance of 1983 first spelled out actionable steps for the protection of the environment, including improving ambient air quality. It was followed soon after with the formation of federal and provincial environmental protection agencies (EPAs).[5]

A National Conservation Strategy was conceived in 1992 following a detailed stakeholder engagement process. Among various other environmental issues, it provides a detailed overview of air pollution and its sources. Moreover, it provides an in-depth analysis of what needs to be done to counter industrial and vehicular air pollution.

In 1997, the Pakistan Environmental Protection Act (PEPA) was promulgated. Thereafter, following the devolution under the 18th Amendment in 2010, the four provinces adopted the Act while PEPA 1997 continues to be in vogue for Islamabad Capital Territory.[6]

[2] India responsible for 70 percent smog in Pakistan. (2018, November 12). The News.

[3] Gabol, I. (2024). Punjab doubles restrictions as Multan AQI tops 2,000. Dawn.com.

[4] Pakistan Factories Act, 1934 (XXV of 1934).

[5] Government of Pakistan. (1981). Pakistan Environmental Protection Ordinance, 1983.

[6] Government of Pakistan. (1997). Pakistan Environmental Protection Act.

The Act specifically prescribed measures to counter environmental pollution, which entail: "The contamination of air, land or water by the discharge or emission of effluent or wastes or air pollutants or noise or other matter which directly or indirectly or in combination with other discharges or substances alters unfavourably the chemical, physical, biological, radiational, thermal or radiological or aesthetic properties of the air, land or water, or which may, or is likely to make the air, land or water unclean, noxious or impure or injurious, disagreeable or detrimental to the health, safety, welfare or property of persons or harmful to biodiversity."

The PEPA empowers the federal and provincial Environmental Protection Agencies to enforce the Act as well as the National and Provincial Environmental Quality Standards (PEQS) and the National Ambient Air Quality Standards (NAAQS). The Environmental Protection Act set up Environmental Tribunals whose responsibility is to support the Environmental Protection Agencies. In addition, under the "pollution pays" principle, pollution charges have also been employed by the Environmental Protection Act to address this issue. Yet, as highlighted by Habib et al, the rules regarding pollution charges "have remained dormant since their inception".[7]

The federal and provincial Environmental Protection Agencies are overseen by statutory bodies called Environment Protection Councils. Ostensibly high level and representative, with presence of not only the Prime Minister or Chief Minister but also stakeholders from government and the civil society, these Environment Protection Councils are conspicuous by their absence. From 2000 to 2010, prior to devolution, the Pakistan Environmental Protection Council was rarely convened even though it was mandated to meet twice annually. The record for its provincial counterparts, post devolution, has been equally abysmal in this respect.[8]

This historical trajectory reveals that Pakistan has built a substantial legislative framework for environmental protection over decades, yet the practical implementation of these laws has remained a persistent challenge. The disconnect between policy formulation and enforcement has its roots in this history of institutional neglect and insufficient political commitment.

The implementation gap: why policies fail

The promise and pitfalls of past initiatives

In 2008, Pakistan launched the Clean Air Programme (PCAP) which aimed to address the air pollution problem across the country. It entailed a list of interventions that included, but were not limited to, vehicular pollution, industrial emissions, burning of solid waste, and natural dust. The Programme also called for development of an air pollution regulatory framework or a set of legal stipulations to address air pollution. It called for a central apex organisation to serve as a coordination mechanism to manage "intergovernmental and intersectoral coordination" between and amongst the provinces and centre. Furthermore,

[7] Habib, A., Malik, A., Pomiankowski, R., & van Gevelt, T. (2021). Charting Pakistan's air quality policy landscape. International Growth Centre.

[8] Pakistan Today (PT). (2011). Toothless Pakistan Environmental Protection Council.

it recommended that enhanced air quality management (AQM) policies be designed with focus on building human resources capacity. Finally, it called for an investment in an effective air quality monitoring programme to understand the scope and scale of the problem, and the strengthening of judiciary bodies so that they are able to address environmental issues appropriately.[9]

It seemed that the government was finally on track to deliver on its promises. One of the key interventions following the promulgation of the PCAP was the role of Japanese International Cooperation Agency (JICA) in assisting the Government of Pakistan in developing an air quality monitoring network. Fixed and mobile air monitoring stations were set up in provincial capitals and a data centre and a central lab was also opened. It fell to the provincial and federal EPAs to operate the monitoring units and develop plans to address air quality issues locally.

Policies beget policies and commissions and committees beget some more commissions and some more committees. Meanwhile the on-ground situation remains tentative.

The lack of capacity within the EPAs meant that outside consultants had to be hired and trained by JICA to operate the monitoring stations. This, however, was a short term measure with the aim being that soon after, the federal and provincial EPAs will be able to run the system on their own. Yet, by the time JICA ended its assistance programme, the EPAs had still not taken control of the operation and maintenance of the programme.

Following the end of the JICA programme, the programme was essentially shut down. Malik Amin Aslam who was the then Minister of State for Environment when the Clean Air Action Plan was launched, would later go on to highlight that with the provincial governments failing to build on JICA's interventions, the necessary expertise required for the sustainability of the initiative faded quickly as the experts found jobs in the Middle East. Soon thereafter, the monitors were transferred to storage facilities where many sensors were stolen and sold in the open market.

While the National Environmental Quality Standards were first developed in 1993 and then revised (with less stringent stipulations) in 1999, the NEQS for ambient air quality were developed in 2010. Major pollutants outlined in the NEQS for ambient air include sulfur dioxide (SO2), nitrogen oxides (NOx), ozone (O3), suspended particulate matter, fine particulate matter (PM 2.5), lead (Pb) and carbon monoxide (CO).

Since then, the provinces have adopted the standards as-is, with the exception of Sindh, which has watered down the PM2.5 standards. PM2.5 is an extremely hazardous pollutant. The 2.5 refers to the size of the particulate matter in microns or micrometres. The PM2.5 pollutants are so fine that they can find their way into lungs and enter the bloodstream resulting in—and exacerbating—respiratory and cardiovascular disease. The PM2.5 standard across Punjab, Khyber Pakhtunkhwa, Balochistan and at the federal level is 15

[9] The cost of air pollution: strengthening the economic case for action (2016). World Bank.

ug/m3 for 24 hours and 35 ug/m3 for annual average. Meanwhile, Sindh Environmental Quality Standards for ambient air stipulate 40 ug/m3 for 24 hour average and 75 ug/m3 for annual average.

These standards are not in line with World Health Organization standards. In 2005, WHO had set the annual average for PM 2.5 at 10 ug/m3 and the 24-hour average at 25. When Pakistan's ambient air quality standards were being developed, the Government of Pakistan chose to relax the stipulated guidelines. On what basis did Pakistan relax these guidelines is a question that needs to be addressed.

Moreover, what is equally concerning are the diluted standards for Sindh. The provincial governments were all quite aware of the deepening air pollution crisis across the country while promulgating these guidelines. Yet, environmental protection and the corresponding impact on citizens' health was not on their priority list. It can be speculated that initiatives such as the China Pakistan Economic Corridor (CPEC) with its focus on developing coal powered plants in Sindh resulted in weakened stipulations for the province. Here, the role of the Provincial Environmental Protection Council needs to be questioned as well since its approval was required to amend the existing regulations.

These are questions that will need answering if we are to holistically understand the reasons for the gap in global guidelines and local ones. WHO revised its standards in 2021, with the annual average at 5 ug/m3 and the 24-hour average at 15 ug/m3. The United States Environmental Protection Agency (US-EPA) followed WHO by reducing its annual average for PM2.5 from 12 ug/m3 to 9 ug/m3.

Standards and enforcement: a persistent disconnect

The 18th Amendment passed in 2010 was to be the harbinger of a new beginning for environmental protection in Pakistan. Yet, as the management of the air pollution crisis shows, it merely ended up highlighting the dire state of apathy with respect to governance and decision making.

By 2015, Pakistani cities were regularly being highlighted at the top of "Most Polluted Cities" listings.[10] For example, a WHO database of PM2.5 pollution listed Karachi, Peshawar and Rawalpindi in the top 10 polluted cities. Lahore, which would eventually be near the top of such lists in the coming years, was conspicuous by its absence. This, primarily, had more to do with inadequate or perhaps even complete lack of data rather than air pollution mitigation measures by the city's government.

In fact, with the spread of portable air monitoring by the Pakistan Air Quality Initiative (PAQI), for example, and the setting up of air monitoring units at US Consulates across Pakistan (including Lahore), the city was soon to find itself close to the top in all future rankings. This led to global media attention focusing on Lahore and the city finding itself in an unflattering limelight. Politicians and bureaucrats would take turns blaming air pollution on transboundary sources from across the border or simply deny that there was an air pollution problem to even begin with. The efficacy of portable monitors was called into question by government officials.

[10] Mathiesen, K. (2015, December 2). Where is the world's most polluted city? The Guardian.

At one event in Islamabad in 2019, the author personally witnessed a very senior official of the EPA calling the setting up and broadcast of air pollution information in the capital city by the US Embassy "a step against the sovereignty of Pakistan". Meanwhile, social media posts would regularly highlight the air pollution quality levels from across the country.

With the government having receded into its shell and not imparting real time air quality information, the portable monitors indicated the air pollution crisis was unfolding not only in Lahore but across Pakistan.

Dr Imran Saqib Khalid navigates the historical landscape of environmental legislation, critiques institutional weaknesses, and examines the socio-political dynamics—including misplaced economic priorities and political volatility—that have historically undermined sustained action.

The vicious cycle: commissions, data, and denial

The lack of reliable official data has historically undermined policy effectiveness. However, the recent development of comprehensive emissions inventories for major Pakistani cities, as detailed earlier in this report, represents a significant breakthrough. These inventories provide the scientific foundation that has long been missing, identifying the relative contributions of various sources—from transport and industry to residential and agricultural activities. This data could serve as the cornerstone for more targeted and effective interventions if properly integrated into the policy process.

The mid 2010s also saw an enhanced interest by media entities vis-à-vis environmental degradation in Pakistan. The 2015 Paris Climate Agreement had recently been promulgated and the general public was interested in learning more about the state of the environment in the world, and more so at home, in Pakistan. Each global ranking that saw Pakistan near the top of pollution charts saw more interest by print and television media in the country. Along with the burgeoning social media interest in these issues, the federal and provincial governments—particularly Punjab—had to face questions as to the efficacy of mitigation measures.

In December 2017, the then Chief Justice of Lahore High Court, Mansoor Ali Shah formed the Smog Commission to formulate a "smog policy for Punjab which identifies the root causes and prescribes a plan to protect and safeguard the life and health of the people of Punjab". Dr Parvez Hassan was made Chairperson of the Commission which included various environmental, technical and legal experts, and practitioners.

Perhaps not so ironically, the final report of the Commission notes that the Lahore High Court had similarly appointed a Lahore Clean Air Commission in 2003, also under the chairmanship of Dr Parvez Hassan, and that many recommendations of that Commission "remain relevant in this Report of the Smog Commission". This statement highlights the vicious cycle of environmental decision-making in the country.[11]

In other words, while there may be no need to reinvent the wheel, we still try to do it anyway because we have no institutional memory. This would be ironic and perhaps even funny if it were not for the cost in human life and suffering that results from an apathetic approach to persistent public policy problems such as air pollution.

Needless to say, six years after the Smog Commission report, and 21 years following the Lahore Clean Air Commission report, we are no closer to addressing the smog in Lahore or air pollution across Pakistan. What we do have are political actors with little understanding of environmental problems facing our communities looking for photo ops and headlines, all the while undermining any efforts to address the issues in a holistic manner.

It is important to link source emissions to ambient air quality standards so as to address air pollution at the individual source or facility level (unit level), e.g., when it comes to specific industries. However, the provincial EPDs have not disclosed the method through which they are scientifically measuring industrial emissions so as to be in line with regulations. This poses an important question about the process through which emission standards are developed and whether they have been developed through an informed and collaborative process.

Breaking the cycle: understanding barriers to effective implementation

A number of provincial and national level policies that aim to address air quality woes in the country have been promulgated. These include the Punjab Smog Mitigation Plan in 2024,[12] National Clean Air Policy in 2023, Punjab Clean Air Policy in 2023[13] and the Smog Commission Report in 2018. This is in addition to the Pakistan Clean Air Programme in 2008. Furthermore, given that air pollutants fall under the category of Short-Lived Climate Pollutants (SLCP), even the Climate Change Policy 2014 (revised 2021) and the Nationally Determined Contributions (NDCs 2021) highlight mechanisms to bridge the gap between ambition and inaction.

Yet, what begs the question is continued failure of policy interventions to make a difference on the ground. Recent research is unequivocal in highlighting the complex nature of policy making and implementation. Surely, policy making and its promulgation is the easy part. The questionable aspects come to the fore in regard to implementation—or lack thereof—of the said policies.

Policies beget policies and commissions and committees beget some more commissions and some more committees. Meanwhile the on-ground situation remains tentative. Consider that a quarter century has passed since the Environmental Protection Act was promulgated and we are still discussing the lack of apportionment studies and inadequate monitoring of air quality across the country. By the same token, focus on Lahore alone is a disservice to communities who are affected by air pollution across the country.

[11] Government of Pakistan. (2018). Report of the Smog Commission: Walid Iqbal vs Federation of Pakistan, Writ Petition No. 34789/2016.

[12] Government of the Punjab (2024). Chief Minister Punjab's Roadmap for Smog Mitigation in Punjab 2024-2025.

[13] Government of the Punjab (2023). Punjab Clean Air Policy (with phased action plan).

What is required, in essence, is the need to focus on collaborative and deliberative policy making that does away with a siloed approach to efforts to engage environmental governance. This entails concerted efforts to engage with affected communities, scientists and practitioners, elected officials, bureaucrats and civil society at large.

This will ensure buy-in and salience when policies are eventually developed. A policy developed in closed environs with little insight from all the stakeholders is bound to fail. Moreover, policy making is a continual process whereby such engagement needs to happen frequently so as to inform the policy implementation process. Of course, this is a time-consuming process and given the time-sensitive nature of bureaucratic postings and political process, it is largely ignored, and at great peril to the health and wellbeing of the people in this country.

Another key issue is the dispersed nature of environmental governance. The disparate and ad hoc approaches to addressing air pollution problems in Pakistan have gained salience after the 18th Amendment, with Exhibit A being the lack of uniformity in air quality standards. In this regard, a holistic evaluation of the federal nature of environmental protection laws needs to be done so as to chart the way forward for effective mitigation of air pollution across the country.

The political cycle and its quirks also deserve a mention here. Elected officials tend to downplay the impacts of a complex policy issue primarily because its resolution would likely surpass their tenure and as such, may have implications on their political future come election time. This can lead to development of policies without enhanced stakeholder engagement, which leads to ineffective measures to address the air pollution crisis.

Policy tracking in terms of analysing the performance of organisations in implementing the relevant policies, addressing potential problem areas, and re-assessing policies and plans are essential to effective environmental governance. Yet, here too as has been discussed above, we have been lacking severely. Thus, policies have not been aligned with national level political decision making, resulting in a truncated vision in terms of addressing the country's air pollution woes.

Integrating approaches: lessons in collaboration

Air pollution is a global concern. While examples from the Global North abound in terms of how developed countries were able to address air quality issues, we now have the benefit of the experience of developing countries too—in terms of how they have successfully approached or are approaching the problem, particularly in terms of collaboration or partnership between various stakeholders.

It starts with acknowledging the problem and developing an understanding of its scope and scale. Here, the government can rely on universities, not-for-profit entities and even citizens to understand the extent of the air pollution woes affecting the country. This would entail not only understanding the state of air quality in the country but also identifying sources of pollution via source apportionment studies. Next, we need to align our air quality standards with those of the World Health Organization, which is indeed the gold

Needless to say, six years after the Smog Commission report, and 21 years following the Lahore Clean Air Commission report, we are no closer to addressing the smog in Lahore or air pollution across Pakistan. What we do have are political actors with little understanding of environmental problems facing our communities looking for photo ops and headlines, all the while undermining any efforts to address the issues in a holistic manner.

standard when it comes to criteria that cater to public health. Once we have identified the scope, scale and nature of the problem, the next step would be to address it in a manner that hinges upon collaborative and integrative approaches. Command and control decision making seldom results in enhanced environmental decision-making, as we have seen in the case of stubble burning. This requires a concerted effort that emphasises consensus development through effective environmental communication.

Integrated approaches to planning can be witnessed in places like Bogota, Colombia where nearly 3000 people die prematurely due to PM2.5 air pollution. Vehicular pollution contributes heavily to this. As such, the city is implementing the 'Barios Vitales' or 'vital neighbourhood' strategy under which five neighbourhoods are being redesigned with the aim to minimise vehicle use, centralise resources and encourage walking and use of bicycles. In order to ensure that this initiative succeeds, the city developed a comprehensive engagement strategy with community members and other stakeholders. It included focus group discussions, perception surveys and co-creation exercises so as to develop a holistic initiative.[14]

Another example from Latin America is Mexico's Guadalajara metropolitan area which suffers from high air pollution levels. The Metropolitan Planning Institute of Guadalajara (IMEPLAN) came together with World Resources Institute (WRI) Mexico and the State of Jalisco to develop a detailed integrated emissions inventory which identifies the sources of air pollution in the region. The tool plays an instrumental role in calculating and compiling estimates of emissions which are most significant for improving air quality as well as reducing pollutants that contribute to global warming.

The inventory served as a baseline for WRI as it evaluated how a new bus rapid transit (BRT) line in the region will impact air quality. It was determined that "if truck traffic were replaced with travel on the new BRT line (that uses buses with the latest Euro VI low emission technology), the region could avoid about 27 pollution

[14] Street Experiments Tools (SET). Vital neighbourhoods.

related cardiovascular deaths and around 715 lost workdays in the year 2030".[15] This is a very practical example of how data sets can be utilised to effectively inform local level planning. It can go a long way in addressing air quality issues in Pakistan and other parts of South Asia.

Pakistan now has a similar opportunity with the newly developed emissions inventories presented in this report. These inventories provide exactly the kind of scientific foundation that enabled successful interventions in places like Guadalajara. By integrating this data into the policy process, Pakistani authorities could similarly model the health and economic impacts of specific interventions, prioritising those with the greatest potential benefits.

Data availability and reliability remains a point of contention in Pakistan. However, there are global case studies that can help bridge this longstanding gap. Take the example of City AQ—a partnership between WRI, NASA Global Modeling and Assimilation Office and a number of cities including Addis Ababa, Bogota, Jakarta, Kigali, Monterrey, Guadalajara and Sao Paulo—which uses emissions inventories, satellite imagery and local air quality data and machine learning to provide local air quality forecasts. The information allows cities to address potentially hazardous conditions and communicate with the general public in a timely manner. It also allows local governments to anticipate and address air quality concerns on the basis of scientific information.[16]

Transboundary air quality management is yet another area where Pakistan and other countries in South Asia can learn from best practices in other regions of the world. The Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia was adopted in 1999 by eight countries of South Asia.[17] It remains dormant. In this regard, we can learn from the Tripartite Policy Dialogue on Air Pollution (TPDAP)—which brings together Japan, Republic of Korea and People's Republic of China on an annual basis to exchange information on air pollution mitigation and develop initiatives for cooperative engagement. Earlier in 2024, the 11th Policy Dialogue was held. The Dialogue was set up in 2013 during a Tripartite Environment Ministers meeting among Korea, China and Japan (TEMM), formed in 1999.[18]

Another example is the efforts by ASEAN member states to promote regional collaboration with the aim to address transboundary haze pollution from land and forest fires. Initiatives include formation of the Regional Cooperation Plan on Transboundary Pollution (1995),[19] Regional Haze Action Plan (1997), ASEAN Agreement on Transboundary Haze Pollution ratified by all countries in 2015.[20] In 2016, the Roadmap on ASEAN Cooperation towards Transboundary Haze Pollution Control with Means of Implementation was adopted.[21]

[15] Orloff, M., & Anzilotti, E. (2023). How data and integrated planning approaches can help cities fight air pollution. Shift Cities.

[16] World Resources Institute (WRI). (2021). City AQ.

[17] The South Asia Co-operative Environment Programme (SACEP). (1998) Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia.

[18] Trilateral Cooperation Secretariat. (1999) Tripartite Environment Ministers Meeting (TEMM).

[19] ASEAN Co-operation Plan on Transboundary Pollution. (1995). ASEAN Economic Bulletin, 12(1), 89–95.

[20] ASEAN. Regional Policy Framework, ASEAN Haze Portal.

[21] ASEAN. Roadmap on ASEAN cooperation towards transboundary haze pollution control with means of implementation, ASEAN Haze Portal.

These various agreements have been listed here to highlight the progression in terms of policy dialogue over a period of over 20 years, such that each subsequent step is more comprehensive in terms of addressing the issue. Pakistan could adapt these regional cooperation models to revitalise the dormant Malé Declaration and establish more effective transboundary coordination in South Asia.

Beyond rhetoric: a framework for accountability

Air pollution has taken on crisis level proportions in Pakistan. However, the response has not been in line with the nature of the crisis. Ad hoc decision-making in this realm has resulted in enhanced risk for vulnerable segments of society including the children, the elderly and the ill. Often, they are the voiceless.

Indeed, what we are faced with is a social justice issue. As the discussion above shows, policy making is the easy part of the equation. In fact, the plethora of policies and plans that purport to cater to air pollution should be a cause for concern. This depicts a gap in comprehending the scope and scale of the problem leading to public policy responses that are laughable at best and dangerous at worst. Dangerous because they can lull us into thinking that we are doing something to truly address the issue, and not going around in circles—which seems to be the reality that we have been living with over the past 20 years with not much having changed for the better.

While most government actions have remained concentrated on Lahore and Punjab, recent years have seen growing awareness of the need to monitor, understand, and regulate rising air pollution levels in other cities and provinces, and indeed, at the national level.

But we need not lose heart as all is not lost. The examples from around the world cited earlier highlight cases from the local to the regional level, where a broad array of stakeholders come together to address the complex environmental issue that air pollution is.

Continual improvement is emphasised and mechanisms are developed in a way so that progressive advances can be made in terms of mitigation efforts. The timelines at play do not cater to finances, political differences, administrative issues and personal conflicts as much as they account for them. It is understandable that policy making entails these concerns yet the greater public good demands that none of them are singularly or jointly able to short circuit the policy implementation process.

The iterative nature of decision making on display elsewhere needs to be replicated in Pakistan with the aim to holistically address the policy-implementation gaps. To make meaningful progress, Pakistan should take these three immediate steps:

— **Establish an independent air quality monitoring and evaluation authority that transcends political cycles, with representation from academic institutions, civil society, and technical experts.**

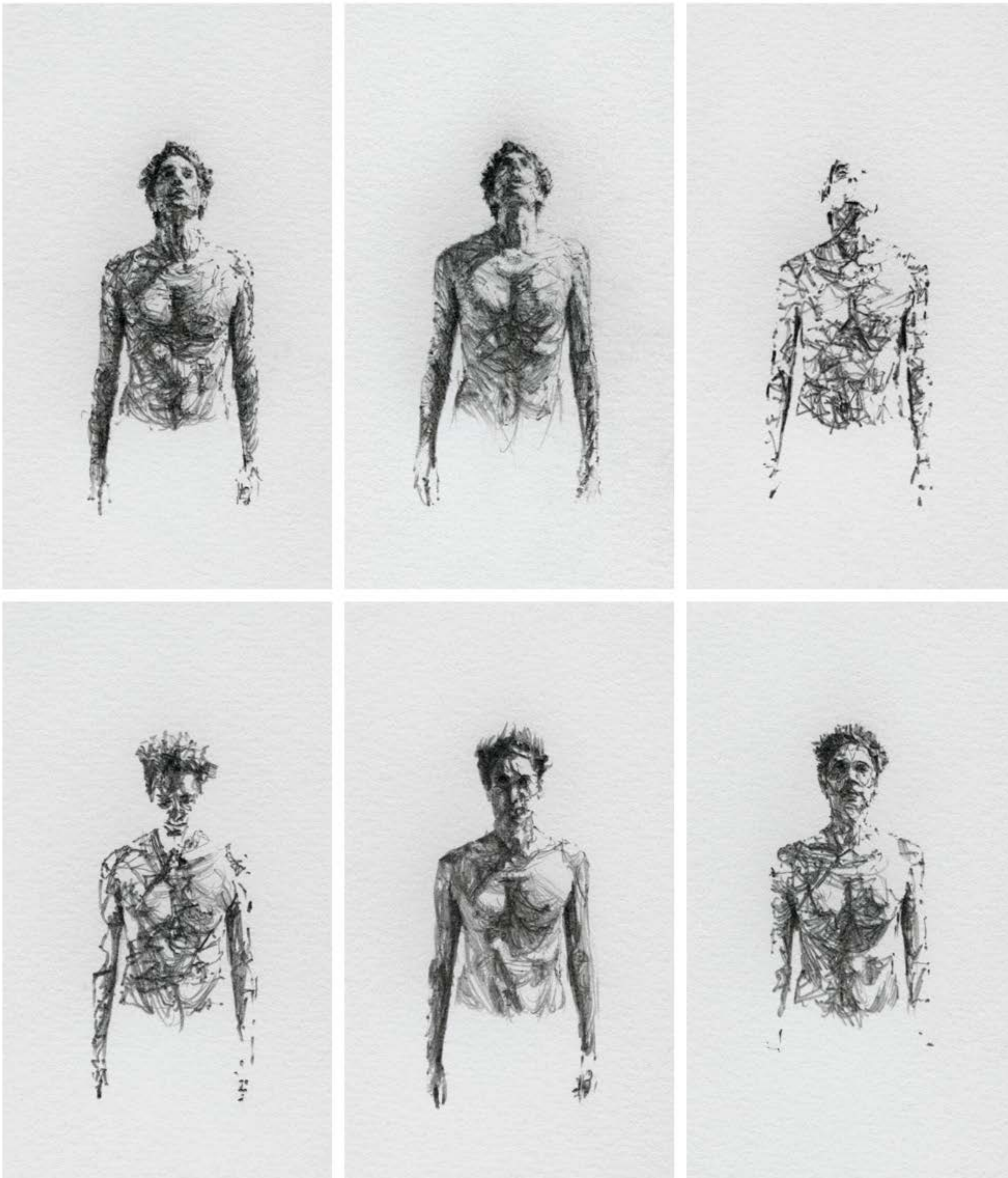
— **Integrate available emissions inventory data into all levels of planning, requiring impact assessments of major infrastructure and development projects.**

— **Create formal mechanisms for stakeholder engagement in environmental decision-making, ensuring that affected communities have meaningful input into pollution control measures.**

These steps would help break the cycle of perpetual policy development without implementation, creating greater accountability and continuity in Pakistan's air quality management approach.

The path forward will be time consuming, require resource allocation, and may not yield immediate political benefits, but it will make a difference in the lives of all Pakistanis that are exposed daily to air pollution, especially those who are most vulnerable.

Dr. Imran Saqib Khalid is a climate and sustainability thought leader whose work focuses on regions and communities most vulnerable to environmental degradation and climate change.



These composite sketches are part of Dryden Goodwin's Breathe project, which animates the act of breathing to make the invisible visible. By capturing campaigners frame-by-frame, including Rosamund Adoo-Kissi-Debrah (mother of the late Ella Kissi-Debrah) in London and Abid Omar in Lahore, Goodwin connects the personal tragedy of air pollution with the universal fight for a breathable future.

17.

Air Quality Management

Lessons from global experience for an effective AQMS

It's a continuous journey, not a one-time fix: As London's multi-decade story shows, air quality management is an ongoing process of adaptation as cities grow, economies change, and new pollution sources emerge.

Good data is the starting point: Successful turnarounds, like Mexico City's, began with a rigorous, scientific effort to collect credible data, identify the most harmful pollutants, and pinpoint their primary sources before formulating a plan.

Collaboration is non-negotiable: Air pollution does not respect administrative boundaries. Effective management requires a coordinated "airshed" approach, bringing together different government departments, provincial and federal authorities, and the public to tackle the problem collaboratively.

Kulsum Ahmed

The solutions to air pollution are well-known, yet the air in our cities remains toxic. This paradox reveals a deeper truth: clean air is not the result of a single policy or a new technology, but of a robust, adaptive, and relentless system of management. Kulsum Ahmed draws on decades of global experience—from the smog of London to the crises in Mexico City and Delhi—to outline the essential architecture of an effective Air Quality Management system. This chapter provides a blueprint for moving beyond reactive, piecemeal efforts to build the lasting institutional capacity Pakistan needs to secure a breathable future.

Solutions on how to tackle specific sources of air pollution can be found throughout this report and in many other resources; indeed, a quick online search will instantly produce a lengthy list. So, technical solutions abound. Yet, the journey to achieving and sustaining cleaner air is rarely straightforward. This is because one-off solutions typically yield only partial or temporary results. Ultimately, for lasting improvement, a comprehensive Air Quality Management (AQM) system needs to be put in place, with key attributes for success.

Successful AQM should, firstly, be conducted in a continuous, stepwise, and scientifically robust manner. Secondly, it must be designed to strategically reduce specific air pollutants that are known to adversely affect public health. Thirdly, and crucially, it must take into account the societal context, including the trade-offs that communities and policymakers are willing and able to make in the pursuit of cleaner air.

How then can Pakistan approach this complex challenge? This chapter draws on important lessons from diverse AQM experiences around the world to provide guidance on what an effective AQM system could look like for Pakistan.

A continuous journey: lessons from London's long smog

London was a city with highly polluted air in the 1940s and 1950s, suffering from "pea soup fogs" that were so bad that one could not see through them—rather like the situation in Lahore during winter. Prominent figures like Prime Minister Winston Churchill used to blame these debilitating fogs—which led to traffic accidents, business closures, and significant impacts on health and productivity—primarily on adverse weather conditions. However, this reflectedan incomplete understanding; a significant part of air pollution was attributed to the burning of coal in individual homes for cooking and heating, as well as by industries and power stations.[1]

A particularly severe episode, now infamously known as “The Great Smog of London”, occurred in mid-December 1952. Official estimates placed the number of resulting deaths at over 4,000, with more than 100,000 people falling ill due to acute respiratory illnesses. More recent estimates put the number of dead at 12,000. Four years later, following public debate and increased awareness of the effects of air quality on health and national productivity, the United Kingdom passed its first Clean Air Act in 1956. This put in place a number of measures to reduce air pollution, and was a milestone in initiating a national dialogue on environmental regulation and public health.

Fast forwarding to today, while London's air quality is significantly better than it was in the 1940s and '50s, it still faces challenges, particularly with levels of PM2.5—the pollutant most detrimental to health—often exceeding the World Health Organization’s (WHO) 2021 guidelines. Today, however, the primary sources of air pollution have shifted. With a vastly increased population, the expanded physical size of the city, and a larger vehicle fleet, the major contributor to London's remaining air pollution is now personal car usage, despite the city's extensive public transport system. Hence, congestion charges, dedicated bike lanes, and capped maximum daily fares for public transport are all instruments for discouraging personal car use and encouraging a shift in behaviour towards cleaner transport mechanisms.

London's example demonstrates that AQM is not a one-time fix but a continuous, adaptive operation as both pollution sources and solutions can change over time. Similarly, scientific knowledge in terms of health effects of different air pollutants is constantly evolving. This new knowledge must be continuously re-evaluated, and AQM plans updated to remain effective.

The context is critical: geography, growth, and weather

London's experience highlights crucial lessons for AQM. As cities grow, the concentration of people and activity inevitably leads to a pooling of polluting emissions. These emissions then undergo complex chemical reactions to yield air pollutants, some of which are highly

[1] Ahmed, K. (2017, December 22). Learning from London. Dawn.

detrimental to human health, contribute to the warming of Earth's atmosphere (climate change), and affect the ozone layer in the upper atmosphere which protects life on Earth from harmful ultraviolet (UV) radiation.

The picture is further complicated by meteorology. Wind patterns, for instance, can blow pollution away from a city at certain times of the year, as is often the case in Karachi for nine months of the year due to a strong sea breeze. Conversely, meteorological conditions can also result in holding the pollution in place over a city in what are termed “thermal inversions”. This is the case in many cities with persistently high levels of air pollution, such as Mexico City, Beijing, Delhi and, notably, Lahore.

Delhi provides a pertinent example. Between 1994 and 2002, the city undertook major programmes to address its severe urban air pollution. These efforts included measures to improve fuel quality by reducing sulfur content, reducing diesel use, relocating polluting industries (such as brick kilns) out of the city, and upgrading the public transport vehicle fleet to shift to cleaner technologies like Compressed Natural Gas (CNG) for buses and taxis.[2] However, Delhi's continued growth means air pollution persists and can worsen, exacerbated by the sheer number of residents and businesses, their daily activities, and the city's geographical location, which makes it prone to thermal inversions. This experience suggests that rapidly growing cities situated in locations susceptible to thermal inversions face particularly formidable AQM challenges, offering important lessons for Pakistani cities like Lahore to consider in their long-term planning.

Climate change adds another complication, as it affects meteorology. Changes in heat and humidity alter prevailing weather systems, including winds. It also remains unclear how these changes may affect the complex chemical reactions that form secondary pollutants in the air, and what the resultant ambient air quality will be. Even in cities with generally low levels of PM2.5 such as Washington DC, unusual climatic conditions can lead to acute pollution episodes with high levels of ozone resulting in health alerts to stay at home.

Given these complexities, how does one even begin to put an AQM system in place? In the late 1980s and early 1990s, some of the world's most polluted cities were located in Latin America. Today, these cities rarely appear in the top 10 global AQI rankings for worst air quality. Their journeys towards cleaner air offer valuable insights.

Start with the science: lessons from Mexico City

In the early 1990s, Mexico City had a very serious air pollution problem, leading to increased cardiovascular and respiratory illnesses, and frequent closures of businesses and schools, significantly impacting productivity. Working with the World Bank and a range of external and internal advisors—in what was the first-ever air quality improvement project financed by the institution—the Mexican authorities initially focused on thoroughly understanding the situation.[3]

[2] World Bank. (2005) For a breath of fresh air: Ten years of progress and challenges in urban air quality management in India, 1993-2002.

[3] World Bank. (1991) Mexico - Transport Air Quality Management Project For the Mexico City Metropolitan Area.

Data on different pollutant levels in the air was collected, followed by a health risk assessment to determine the relative impact of each pollutant. Airborne lead (primarily from leaded petrol) emerged at the top of the toxicity-weighted list due to its severe neurotoxic effects, particularly its impact on cognitive function in children, followed by pollutants like nitrogen oxides (NOx) and particulate matter (PM_{10}). The major sources of these pollutants were road transport, industry, commercial and service sector activities, waste disposal practices, and natural sources (like dust). Road transport was by far the most significant source, accounting for 84% of the total mass of emissions (and 55% on a toxicity-weighted basis). Subsequent analysis delved deeper into the causes of high transport emissions, identifying factors such as the large size and poor condition of the vehicle fleet, poor-quality fuel, unpaved roads in peripheral areas, and chronic traffic congestion. The scale of the challenge—encompassing the overhaul of an entire vehicle fleet and a fundamental shift to better quality fuel, in a country facing numerous other pressing development priorities—seemed daunting.

Air pollution readily travels across regional and national boundaries. It is therefore essential to consider the entire 'airshed' and to put in place mechanisms for coordination even across national jurisdictions.

However, the Mexican authorities developed a comprehensive plan of action. Unleaded gasoline was made available, and incentives were implemented to ensure people chose this cleaner fuel. Stringent vehicle emissions standards, coupled with an inspection and maintenance programme, further improved emissions from the existing fleet and encouraged a gradual shift towards cleaner vehicles over time.

Eight years after the project's initiation, ambient lead concentrations in Mexico City had been reduced by 98%. Sulfur dioxide levels had been reduced sufficiently to meet health-based air quality standards, and violations of the carbon monoxide standard had become infrequent. While ozone and PM_{10} levels remained challenging, there was a discernible downward trend in their highest concentrations.[4]

Perhaps the project's greatest long-term contribution, however, was the implementation of an integrated institutional system for transport and air quality management within the metropolitan area. This involved strengthening the scientific basis underlying the air quality programme, and creating a dedicated institutional setup—the Metropolitan Environmental Commission—to focus attention and coordinate action. This Commission comprised representatives from different government sectors and jurisdictions, all of whom had a role to play in ensuring cleaner air. These elements collectively provided the essential building blocks for a system capable of continuously moving towards cleaner air.

[4] World Bank. (2000). Mexico - Transport Air Quality Management Project for the Mexico City Metropolitan Area, Implementation Completion and Results Report. http://documents.worldbank.org/curated/en/604161468050352711

Building consensus for the long haul: lessons from Colombia

Colombia's air quality journey began from a different starting point. By 2003, the country's rapid population growth and urbanisation had resulted in nearly half its populace living in its four largest cities (each with over 100,000 inhabitants), leading to aggregated health effects primarily from particulate matter pollution. The capital city, Bogota, suffered from severe pollution, a situation exacerbated by frequent thermal inversions similar to Mexico City and Santiago.

A decade earlier, in 1994, a World Bank-supported project had helped establish an institutional framework for environmental management in these cities within the Ministry of Environment. This project also provided technical assistance for establishing air quality standards and initiating air quality monitoring. However, the standards were not based on local pollution levels, and the monitoring network often produced unreliable results.[5]

The World Bank conducted an extensive series of analytical studies in close coordination as part of a wider effort focused on sustainable development. The studies aimed to understand the nature and scale of the air pollution problem, disseminate the results to citizens, and finally, discuss potential solutions. A wider range of stakeholders were involved, and this consultative process culminated in the development of a comprehensive air quality action plan featuring short, medium, and long-term measures.[6] This plan was subsequently implemented, strengthening the air quality emissions and ambient standards for cities with over half a million inhabitants, and reducing sulfur content in diesel fuel proved to be two of the most impactful measures for improving air quality across the country.[7]

The evaluation noted that the process of conducting extensive analytical work and stakeholder consultation was as important as the technical results themselves, as it helped to build crucial consensus among diverse stakeholders on the most appropriate and feasible solutions. Equally vital, effective inter-institutional coordination—both across different sectors and across vertical levels of government (national, regional, municipal)—was identified as a key element associated with successful AQM outcomes.

Thinking beyond borders: the airshed approach

The global experiences highlighted above, from London's long battle with smog to the more recent efforts in Mexico City and Colombia, underscore several common attributes crucial for effective air quality management.

The examples clearly illustrate that the institutional governance setup is paramount. Air quality solutions invariably cut across multiple sectors; for instance, addressing crop

[5] World Bank. (2003). Colombia - Urban Environmental Management Project, Implementation Completion and Results Report.

[6] World Bank. (2007). Sanchez-Triana, E., Ahmed, K., Awe, Y. Environmental priorities and poverty reduction: a country environmental analysis for Colombia.

[7] World Bank (2010). Colombia - First, Second, and Third Programmatic Development Policy Loan for Sustainable Development Project, Implementation Completion and Results Report.

burning involves agricultural departments, controlling solid waste burning involves municipal authorities, improving the transport fleet involves transport and industry regulators, setting environmental standards involves environment agencies, adjusting fuel quality involves energy ministries, and managing road and building construction involves planning and development authorities. Furthermore, different jurisdictional levels of government (federal, provincial, local) will typically be responsible for implementing different components of potential solutions.

Dr. Ahmed emphasises that while solutions must be tailored to local contexts, fundamental principles—such as robust data, stakeholder engagement, inter-jurisdictional coordination, and a commitment to continuous improvement—are universally applicable. These are lessons for Pakistan to develop its own unique and effective AQM system capable of delivering cleaner air and better public health.

Hence, any institutional mechanism that facilitates coordination will yield faster and sustainable solutions. Such coordination mechanisms can also help to quickly identify and mitigate potential problems of simply shifting pollution from one location or sector to another, rather than achieving genuine overall reductions. For example, a rapid increase in electric vehicles powered by electricity generated from poor-quality coal burned in power plants lacking adequate pollution control equipment risks merely relocating the pollution burden, potentially with different but still severe environmental consequences. Sulfur dioxide emissions from such plants, for instance, can travel long distances and return to earth as acid rain; destroying crops and significantly reducing agricultural yields.

Air pollution also readily travels across regional and national boundaries. It is therefore essential to consider the entire "airshed"—a geographic area within which pollutants tend to be contained and transported—and to put in place mechanisms for coordination even across national jurisdictions.

This was highlighted in the context of recent wildfires in North America, with smoke plumes from Canada leading to unusually high air pollution levels in major US cities in June 2023. PM2.5 levels in New York City reached 400 micrograms per cubic metre, topping global AQI lists.[8] If pollution crossing borders originates from similar types of sources on both sides (as could be the case for agricultural crop burning in the Punjab region spanning the India-Pakistan border), then bilateral or regional coordination can facilitate the sharing of experiences and best practices, fostering a wider range of solutions and enabling countries to tackle the shared problem in

[8] Srivastava, S. (2023, June 5). No more yellow sky: Reducing air pollution from smoke and dust. World Bank Blogs.

partnership.

Partnerships with other jurisdictions facing similar problems, even if they do not share an airshed, can also be immensely powerful. In the Mexico City case, collaboration and the sharing of expert experience and advice with Los Angeles—another large city historically grappling with thermal inversions and transport-related air pollution—proved highly valuable. In both instances, the effective airshed was significantly larger than the administrative boundaries of the city itself, necessitating the involvement of all relevant jurisdictional authorities in the decision-making and implementation processes.

The double benefit of clean homes

Discussions around indoor air pollution typically focus on pollutant exposure from burning firewood or charcoal for cooking and heating in low-income rural households, where pollution levels can be many times worse than ambient outdoor conditions. Unfortunately, comprehensive data on specific pollutant exposure levels and their subsequent health effects in these settings is often scarce. Addressing this data gap and advancing clean energy solutions in countries with low electrification rates or limited access to affordable clean fuels warrants dedicated effort. The associated health effects are not only extremely distressing for the affected populations, predominantly women and children, but also significantly reduce household productivity and perpetuate cycles of poverty.[9]

However, the historical example from London illustrates that household fuel use can have broader impacts. There, the widespread use of coal by individual households for heating resulted in significant pollution—not only deteriorating indoor air quality but also contributing to the city's infamous outdoor smog. In Pakistan, many low-income households face challenges accessing cleaner alternatives: LPG can be unaffordable or inconsistently available, while electricity supply may be unreliable or prohibitively expensive. In this context, effectively addressing indoor air pollution presents a significant opportunity for a "double benefit". Prompt action can improve household health directly while also contributing to reducing outdoor air pollution, thereby enhancing the overall quality of life, particularly in densely populated urban areas.

Financing the transition: the climate co-benefit opportunity

Achieving cleaner air invariably requires substantial human resources and financial investment. Many successful AQM programmes have utilised development loans from international financial institutions, recognising that poor air quality diminishes individual quality of life and collectively impacts national productivity and economic growth. For countries already facing high national debt, such as Pakistan, securing adequate financing for comprehensive AQM presents a significant challenge.[10]

[9] Ahmed, K. et al. (2005) Environmental health and traditional fuel use in Guatemala.

[10] Ahmed, K. (2018). Greening economic growth. Dawn.

However, an important opportunity exists because many pollutants that harm human health also contribute to global warming. Consequently, actions to reduce local air pollutants can simultaneously decrease global greenhouse gas levels, yielding valuable climate mitigation co-benefits. The financing infrastructure and mechanisms established for climate change mitigation could therefore be tapped to secure these dual benefits—locally through improved health and cleaner air, and globally through reduced climate impact.

When approaching climate finance, certain caveats warrant consideration. Large-scale international climate funds often operate at a stage and scale of grant-making different from what might be needed for initial AQM capacity building or specific local projects. The era when individual, isolated projects (like capturing landfill gas from a single site to displace fossil fuel electricity) could readily access climate finance, based solely on direct emission reductions has largely passed. Successfully approaching major climate funds today typically requires a more strategic, programmatic, and transformative approach. For instance, in a populous country like Pakistan—where formal landfills are scarce and unmanaged waste is often openly burned—a proposal for a permanent, countrywide systemic approach to waste management, including capturing and utilising landfill gas for energy, would exemplify the kind of transformative shift likely to attract significant climate funding.

Carbon market approaches also have important prerequisites and are subject to ongoing debate. Currently, the formal government-to-government (compliance) carbon market remains relatively small, with the voluntary carbon market—where entities voluntarily purchase carbon offsets—being more dominant.[11] A key focus in voluntary carbon markets has been the urgent need to enhance the integrity, monitoring, and reporting of offset projects. Recent analyses have unfortunately revealed instances where actual carbon sequestration or emission reductions were considerably less than initially promised or claimed. Best practices from international financial institutions and reputable carbon standard bodies emphasise the critical importance of standardised rules for transparency, robust monitoring, independent verification, and clear accountability throughout the lifespan of carbon offset programmes.[12] This need for integrity directly underscores the foundational requirement for strong national monitoring systems and institutional capacity for AQM; robust local systems are more likely to contribute to addressing the challenges of carbon market credibility.

A blueprint for a Pakistani AQM system

The path to cleaner air is unique for each country. While important lessons can be learned from these global experiences, each country must ultimately determine the specific

[11] It is difficult to estimate the value of the total voluntary carbon market accurately due to challenges in carbon pricing and accurate sequestration levels. According to Citigroup, "The VCM is currently valued at approximately USD 2 billion, but many project that it will scale up significantly over the next decade as more companies invest in voluntary carbon credits to reduce their residual emissions." Citigroup's own projections for 2030 include a broad range of estimates, varying from USD 5-50 billion. See Voluntary Carbon Markets. (2023)

[12] Climate Explainer: What You Need to Know About the Measurement, Reporting, and Verification (MRV) of Carbon Credits. (2022).

approaches and institutional arrangements that make sense in its own context, guided by established AQM principles. It is crucial to acknowledge that Pakistan, like many developing nations, is rapidly urbanising and experiencing significant population growth. The 2023 census placed Pakistan's population at 241 million, with an urban share at 39% and at least 10 cities housing over one million inhabitants. This demographic reality leads to concentrated pollution from urban activities and resultant air quality challenges. Some suggestions on how Pakistan could strategically approach the development of its own AQM system are outlined below.

A primary consideration is the governance structure, where provincial governments are responsible for managing air pollution within their respective provinces; yet, some main determinants of air pollution, such as national fuel quality standards for transport and industry, are federally regulated. This division necessitates strong federal-provincial coordination. Furthermore, pollution levels often vary significantly even within a single province (e.g., Lahore versus Multan versus Bahawalpur in Punjab). The current lack of empowered local governance structures may not always allow for the differential treatment and tailored solutions that these varying local contexts require.

This governance landscape suggests that mechanisms akin to the environmental commissions established for Mexico City—which included a variety of government, academic, and private sector stakeholders—may need to be set up in Pakistan. These do not necessarily need to be new institutional structures, rather, they could be dedicated mechanisms for regular, mandated inter-institutional coordination, perhaps modelled on successful ad-hoc bodies like the National Coordination Committee that operated during the COVID-19 pandemic, but with a permanent mandate for air quality.[13]

A crucial element is the scientific basis for any air quality action plan. Without it, considerable resources risk being expended without achieving tangible air quality improvements. This requires not only systematically gathering ambient air quality data and developing comprehensive emission inventories but also fostering a better understanding of local health effects and how emissions from different sources translate into ambient air quality under specific meteorological conditions. The proposed environmental commissions would therefore need strong technical representation. Rather than solely increasing bureaucratic staff, Pakistan should strategically tap into the existing expertise within its universities and research organisations. This approach also allows technical professionals from diverse disciplines—such as engineering, public health, atmospheric science, economics, and urban planning—to collaborate on AQM challenges and contribute to training the next generation of experts. For instance, London's Mayor relies heavily on technical advice from local universities for air quality management. Fostering partnerships between Pakistani universities and established international research efforts can further enhance local capacity and facilitate cross-boundary learning.[14]

Data is the lifeblood of effective AQM. Here again, Pakistan could benefit from involving a wider set of stakeholders in data generation and dissemination. The use of personal and community-based low-cost air quality monitors should be encouraged and

[13] Ahmed, K. (2020, October 12). Climate lessons from Covid-19. Dawn.

[14] Ahmed, K. (2019, February 10). Clean air revisited. Dawn.

supported to create denser monitoring networks across cities, complementing reference-grade regulatory stations. More precise, localised information—identifying months with consistently worse pollution (due to emissions, meteorology, or both) and pinpointing daily pollution peaks—will enable more informed public advisories and better-targeted, effective solutions.

Karachi offers a case in point. During winter months, meteorological patterns often trap pollution over the city. In the winters of 2021-2023, extensive road works for an urban drainage project left a high percentage of roads unpaved for prolonged periods. The dust from these roads, combined with other sources, is believed to have caused Karachi to frequently rank above Lahore on global AQI lists. A simple administrative requirement to repave roads within a short, defined period following excavation could have potentially mitigated this specific dust problem much more quickly—significantly reducing adverse health effects. Similarly, medical professionals could be systematically trained to identify, record, and raise alarms upon observing unusual spikes in health conditions exacerbated by air pollution, such as increased incidences of strokes, COPD, or severe respiratory illnesses in children.

Engaging external expertise, partnering with other cities facing similar challenges, and ensuring robust coordination within shared airsheds can often be facilitated through existing international forums and platforms. The Cities Alliance, for example, is a global partnership enabling city leaders to connect and learn from one another. International financial institutions like the World Bank and the Asian Development Bank also have established programmes and expertise in air quality management from which Pakistan can benefit.

Translating these broad principles into a concrete way forward means that Pakistani cities or provinces genuinely interested in cleaner air could begin by establishing effective institutional coordination mechanisms. They would then need to systematically gather local data (on both emissions and ambient quality). Based on this evidence, a comprehensive strategy and time-bound action plan for cleaner air should be prepared, ensuring that necessary trade-offs and responsibilities are openly discussed and agreed upon among all relevant city-level stakeholders.

Ultimately, the goal is to implement an effective and adaptive AQM system, utilising existing institutions where possible and in the most efficient manner. Such a system must continuously monitor air quality and emission sources, flag emerging problems, enable informed decisions, systematically tackle diverse pollution sources, and coordinate action effectively within coherent airsheds and across governance levels. Transparently informing, actively involving, and genuinely engaging all stakeholders—government agencies, the private sector, academia, civil society, and the general public—is indispensable for shifting societal behaviour towards cleaner air solutions. Using evidence-based air quality emission standards and ambient air quality guidelines, clearly linked to documented health effects, is typically the most fundamental instrument to encourage all parties to reduce air pollution. Finally, tackling solutions that deliver quick, visible wins is also important for building public confidence and creating the necessary momentum for sustained, long-term change.

Is it worth going through all this trouble?

What, then, is the rationale for action on air quality, for undertaking such comprehensive and challenging action on air quality? Well, we all have to breathe to live. If the air quality continues to deteriorate, polluted cities become less attractive places to live and work. People and businesses start to move out of the city. Usually the first to go are the ones at the upper end of the economic spectrum. As people and businesses depart, a cultural and physical asset—namely the Pakistani way of life—in a specific city is lost.

The air will, of course, become clean eventually, as less people and less economic activity will result in a natural cleaning of the air. But this is a path of decline, not progress. So ultimately, the need to address air quality stems from our own collective interests: the need for a better quality of life today, the need to protect public health, the need to ensure economic vitality, and the fundamental responsibility of preserving Pakistan's vibrant cities and communities for future generations.

Dr. Kulsum Ahmed is a former World Bank manager and lead technical specialist. In her 24-year career at the Bank, she was part of the operations and advisory products described in this chapter and led the World Bank's multi-sector Air Quality Thematic Group for several years.

Sweepers clean a narrow alley in Lahore, kicking up dust that is visibly highlighted by shafts of sunlight. This resuspension of road dust is a major contributor to the city's particulate matter load, turning routine maintenance into a secondary source of pollution.
Photo by Pakistan Air Quality Initiative

18.

Data and Behaviour

Empowering citizens through data and information

Information is a valued commodity: Lahore residents are willing to pay for reliable air quality forecasts, valuing a three-month subscription for up to PKR 238—roughly the cost of a monthly mobile data plan.

Knowledge empowers action: Providing daily forecasts and a single hour of training significantly improves citizens' ability to predict pollution and leads to tangible behavioural changes, such as buying N95 masks and altering outdoor activity to avoid peak pollution.

Content is king, but familiarity builds trust: While citizens value useful data regardless of whether it comes from a public or private source, their trust in a specific source grows over time with consistent exposure, highlighting the importance of sustained information delivery.

In the fight for clean air, information is both a shield and a weapon: a shield for citizens to protect themselves from daily harm, and a weapon to demand accountability. Dr. Sanval Nasim presents groundbreaking research from the streets of Lahore, proving that when people are given the truth about the air they breathe, they act. This chapter is a powerful, evidence-based argument for a radical shift in policy: from withholding data to empowering the public with the knowledge they need to survive.

Air pollution poses an immense public health challenge in developing regions such as South Asia, where many cities (such as Lahore, Delhi, Dhaka, Kathmandu) consistently experience some of the worst air quality in the world. The primary pollutant affecting these cities is fine particulate matter (PM2.5), particles small enough to enter the lungs and bloodstream, leading to respiratory illnesses, cardiovascular problems, and shortened life expectancy. In developing cities—which often have limited access to reliable healthcare and advanced pollution mitigation technologies—high air pollution levels place citizens at dire health risks. This can create a vicious cycle where poor air quality hinders economic growth and vice versa, as governments face increasing pressure to balance development needs with demands for greater environmental protection.

Lahore, the capital of Pakistan's Punjab province and the country's second-largest metropolis, frequently ranks high on the list of the world's most polluted cities. Lahore's air pollution levels consistently exceed both local Pakistani standards and international guidelines set by the World Health Organization (WHO), posing severe health risks to its 14.4 million residents. PM2.5 levels in Lahore surpassed WHO-recommended safe levels nearly

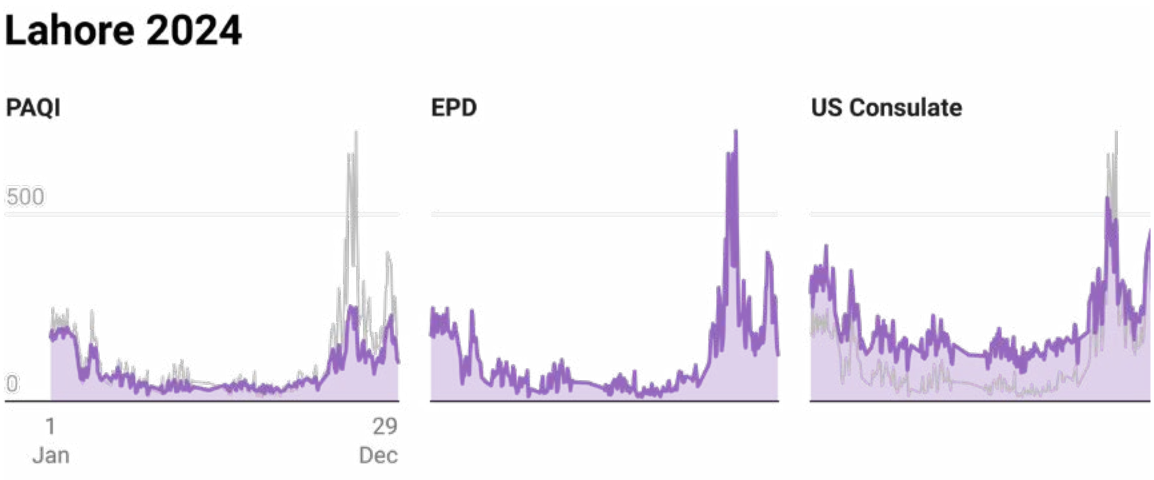


Exhibit 18.1: Lahore's Daily Air Quality Reality (Feb-Aug 2023). **This chart shows the daily PM2.5 levels recorded by three different monitoring networks in Lahore: 1) United States Consulate, Lahore (blue trend line); 2) Pakistan Air Quality Initiative (PAQI; orange trend line); and 3) Environment Protection Department Punjab (EPD; green trend line). It reveals two critical truths: the air consistently and dramatically exceeds WHO's safe guideline (black line), and there is significant variation between different data sources, highlighting the challenge citizens face in accessing a single, reliable source of information.**

every day during the observed period (February-August 2023). This extreme exposure has profound health consequences, contributing significantly to premature deaths and reducing the quality of life for millions. Achieving a reduction in Lahore's PM2.5 levels to meet WHO's stringent guidelines could potentially add up to 7.5 years to the average resident's life expectancy. Beyond such direct health impacts, air pollution also adversely affects cognitive development, educational outcomes, and overall productivity, making it a high-cost, multifaceted problem demanding urgent policy attention.

Information as a public health tool

While addressing the root causes of air pollution requires large-scale, long-term policy interventions—such as abating industrial emissions, transitioning to cleaner energy sources, and improving urban planning and transportation systems—providing the public with timely and reliable air quality information can serve as a crucial tool for mitigating the immediate health effects. Access to such information encourages beneficial behavioural adaptations. For instance, informed citizens may choose to invest in protective goods such as N95 masks (specifically designed to filter fine particulates) or strategically adjust their daily schedules and activities, such as minimising outdoor exertion during peak pollution times.

However, a significant challenge in cities like Lahore lies in the often inconsistent availability and perceived quality of air quality information.[1] Public authorities may struggle to install and maintain the extensive infrastructure required for accurate, real-time air pollution monitoring and effective, widespread data dissemination. This can leave large segments of the population uninformed about daily risks and unprepared to take protective measures

[1] This article synthesises insights from two field experiments on air pollution in Lahore. These insights have previously appeared in different forms as blogs published by the International Growth Center and *The Friday Times*.

Our findings suggest that the content of the forecasts, rather than the specific source providing it, was the primary driver of their demand. Residents appear to value access to reliable data perceived as useful for reducing health risks, regardless of its origin.

against hazardous air quality. Community initiatives, such as the Pakistan Air Quality Initiative (PAQI), have worked to narrow this information gap by providing real-time data via social media platforms and mobile applications. Yet, important questions persist regarding the level of public trust in different information sources (public vs. private) and the extent to which citizens are willing to pay to receive reliable air quality data.

Here, key findings from two Randomised Controlled Trials (RCTs) have been synthesised. An RCT is a research method involving randomly assigning participants to different groups to test the causal effect of an intervention. These RCTs broadly explore how providing air pollution information (specifically, forecasts), attributing it to different sources, and offering brief skills training impacts citizens' behaviour, their beliefs about pollution, and their willingness to pay for pollution avoidance measures. These studies offer critical insights into how enhancing access to air pollution information and improving the public's forecasting ability can empower residents to make more informed decisions to protect their health.

Proof of concept: valuing forecasts and skills

The first RCT experimentally tested whether Lahoris value air quality forecasts and how the provision of daily forecasts and brief training could enhance their forecasting skills and influence pollution avoidance behaviours.[2]

We developed a model to forecast daily PM2.5 levels using a combination of real-time air pollution data from the US Consulate monitor in Lahore and two distinct satellite data sources. These daily forecasts were then disseminated via SMS messages to a randomly selected sample of roughly 1,000 participants over an eight-month period. Additionally, a subset of these participants received a one-hour, in-person training session focused on basic forecasting techniques. This training, drawing on principles from behavioural economics and cognitive psychology, aimed to reduce common judgmental errors that often hinder individuals from making accurate predictions based on available data.

The primary research questions were: whether citizens value air pollution forecasts; can targeted forecasting training improve their ability to forecast air pollution; and how do these forecasts influence behaviour (particularly demand for N95 masks and pollution avoidance across time).

[2] Ahmad, Husnain F.; Gibson, Matthew; Nadeem, Fatiq; Nasim, Sanval; Rezaee, Arman. (2024). Expectations and adaptation to environmental threats. https://doi.org/10.26085/C3K88B

Citizens highly value air quality forecasts

We found compelling evidence that residents significantly valued receiving air quality forecasts. Using an incentivised mechanism designed to elicit truthful valuations, participants indicated a willingness to pay an average of PKR 93 to continue receiving the daily SMS forecasts for an additional three months (Exhibit 18.2). This amount, while modest in absolute terms, represented approximately 60% of the prevailing monthly cost of basic 4G mobile internet access at the time, underscoring the perceived importance and utility of air quality information, even among low-income populations with limited discretionary funds.

Training improves forecasting accuracy

The study further revealed that both receiving the SMS forecasts and participating in the brief in-person training session led to measurable improvements in participants' ability to predict near-term pollution levels. Participants in these treatment groups reduced their average error in predicting next-day PM2.5 levels by approximately 5 micrograms per cubic metre ($\mu g/m^3$). This reduction is noteworthy, representing about 20% of WHO's recommended safe 24-hour exposure limit (25 $\mu g/m^3$ at the time of the study). Importantly, these improvements in forecasting accuracy persisted for several months after the initial training, demonstrating that even short, relatively low-cost educational interventions can equip individuals with durable skills for anticipating air pollution risks.

Information changes protective behaviours

We also observed tangible behavioural changes resulting from our interventions. Providing forecasts increased residents' demand for N95 particulate-filtering masks; those who received forecasts were willing to pay approximately 5% more for these protective masks compared to participants in the control group who did not receive forecasts. Furthermore, residents receiving forecasts demonstrably adjusted their daily outdoor activities based on the predicted pollution levels. They increased their time spent outdoors by about 16% on days forecasted to be relatively clean, while correspondingly reducing their outdoor time by about 3% on days predicted to have higher pollution levels. These behavioural adaptations were particularly pronounced among individuals who had expressed greater concern about air quality before the study began.

Who to trust? The source vs. the signal

In the second RCT, my co-authors and I investigated whether the source of air quality information affects citizens' willingness to pay for it and their beliefs about its reliability.[3] In developing cities like Lahore, air quality data often originates from both public agencies (like the EPD) and private initiatives (like PAQI). However, little was previously known about public perceptions of these different sources.

We conducted this experiment with a sample of 1,000 residents from a lower-middle-income neighbourhood in Lahore. Participants were randomly assigned to receive identical daily air pollution forecasts (created by averaging real-time data from both EPD and PAQI

[3] Imtiaz, I. (2025). Beliefs, signal quality, and information sources: Experimental evidence on air quality in pakistan. https://doi.org/10.26085/C3FG6D

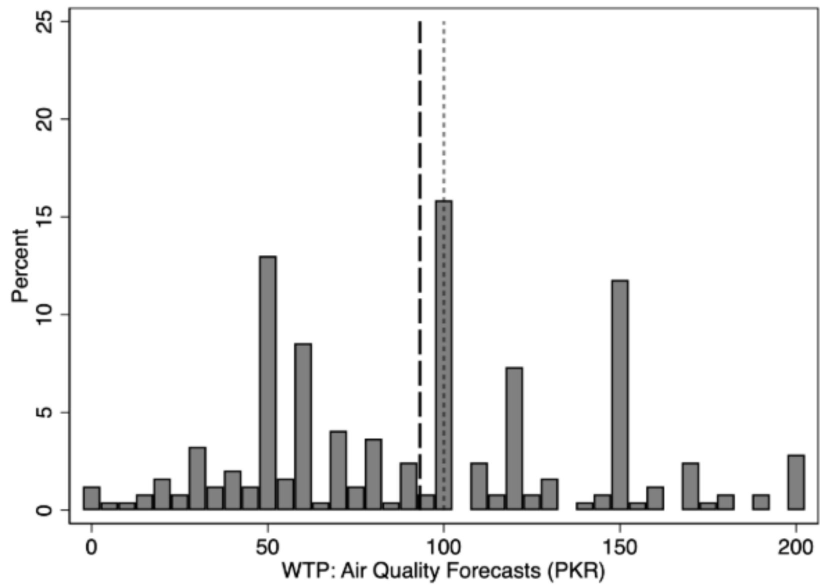


Exhibit 18.2: The Value of a Forecast. **This chart demonstrates a clear public demand for air quality information. On average, residents were willing to pay over PKR 93 for a three-month subscription to daily SMS forecasts, a significant amount for low-income households, proving that such data is not a luxury but a valued tool for health protection.**

sources), but we experimentally varied the attributed source. One group was told the forecasts came from the public agency (EPD), while the other was told they came from a private initiative (PAQI). This design allowed us to isolate the effect of the perceived source on participants' willingness to pay for continued forecast access and their beliefs about air quality conditions.

Content matters more than source for value

Participants were willing to pay PKR 238 on average for a three-month subscription to the air pollution forecasts—an amount roughly equivalent to the cost of monthly prepaid mobile phone and data services, and slightly higher (even after adjusting for inflation) than the valuation found in the first RCT. Crucially, however, we found no statistically significant difference in willingness to pay between participants who received forecasts attributed to the government source (EPD) and those who received forecasts attributed to the private source (PAQI). This suggests that, for the residents in our study, the informational content of the forecasts, rather than the specific source providing it, was the primary driver of their demand. Residents appear to value access to reliable data perceived as useful for reducing health risks, regardless of its origin.

Trust varies by source but doesn't affect demand

Although willingness to pay was similar across groups, participants' stated beliefs about the accuracy of the forecasts did differ based on the attributed source. Those who received forecasts attributed to the EPD anticipated, on average, a 12% higher margin of error compared to those who received forecasts attributed to PAQI, indicating greater skepticism towards the government-provided data. Despite this difference in perceived accuracy, participants were still willing to pay the same amount for forecasts from either source. This reinforces the finding that the public places a high value on the mere availability and potential utility of air quality information, even if they harbor some doubts about its precision depending on the provider.

Familiarity influences trust

The experiment also revealed an interesting dynamic regarding trust over time. At the beginning of the study, most participants expressed relatively balanced preferences when asked to allocate hypothetical funds towards improving monitoring by either EPD or PAQI. However, after receiving daily forecasts attributed to one specific source for two months, participants showed an increased preference for funding the source they had been assigned to (Exhibit 18.3). This suggests that familiarity and repeated exposure to information from a particular source can influence users' trust and preferences over time.

> **Dr. Nasim provides compelling evidence that accessible air quality information is a valued public health tool, offering practical policy recommendations for information dissemination strategies that can help mitigate exposure risks while longer-term pollution reduction efforts are underway.**

A blueprint for an informed public

The findings from these two RCTs offer important policy lessons for developing cities like Lahore, which grapple with hazardous air quality affecting millions daily. These insights suggest several practical approaches to help mitigate the health impacts of air pollution while longer-term structural solutions to reduce emissions at the source are pursued.

Expand access to reliable air quality information

Our studies clearly show that citizens significantly value air quality forecasts and are willing to pay for them, even in low-income settings. Public-private partnerships could be explored to scale up air quality monitoring and forecasting efforts cost-effectively. Given the high expense associated with regulatory-grade monitors, leveraging data from existing credible sources (like consulate monitors or validated private networks) and integrating information from calibrated low-cost sensor networks may offer viable interim solutions to increase data coverage.

Focus on information availability rather than worrying excessively about the source

While trust levels may vary, our findings indicate that the source attribution did not significantly affect citizens' demand for the information itself. Policymakers should prioritise ensuring that citizens can easily access timely air quality data, regardless of whether it originates from government agencies or reputable private organisations. Utilising multiple dissemination channels—SMS, mobile apps, social media, traditional media—is important to reach diverse demographic groups effectively.

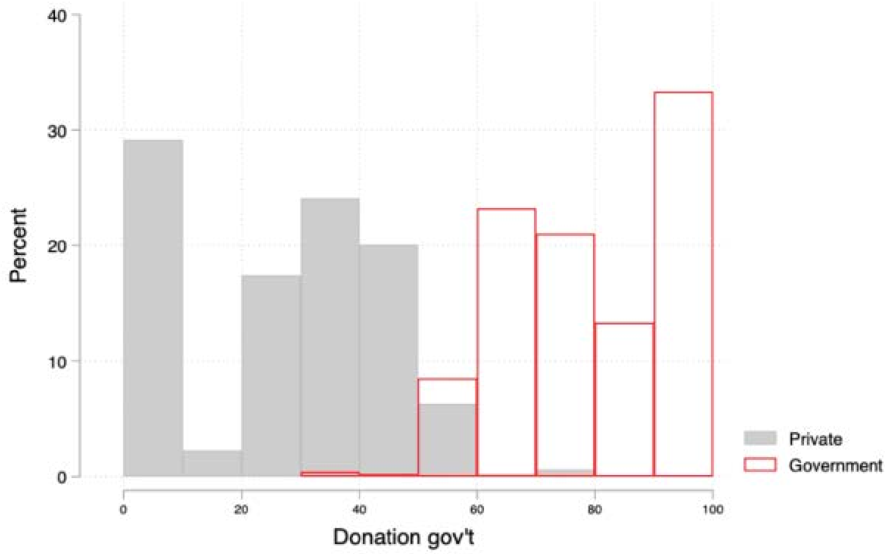


Exhibit 18.3: How Familiarity Builds Trust. **This exhibit shows how repeated exposure to information from a specific source influences public trust. Participants who received forecasts attributed to the government (EPD, red bars) were more likely to allocate hypothetical funds to it over time, and the same was true for those who received forecasts attributed to a private source (PAQI, grey bars).**

Implement scalable forecast training programmes

The demonstrated success of our relatively brief, low-cost forecast training intervention highlights the potential for scalable programmes to durably improve residents' ability to understand and anticipate air pollution levels. Similar training modules could be developed and disseminated through digital platforms, such as instructional videos or interactive mobile applications, potentially reaching a much larger audience at minimal cost. Even modest educational interventions can empower citizens with lasting skills to better navigate air pollution risks.

Promote protective behaviours and the use of avoidance goods

The observed increase in demand for N95 masks following the provision of forecasts suggests that targeted public information campaigns can effectively encourage the adoption of protective measures during high pollution episodes. Strategies combining widespread information dissemination with possibly modest subsidies for essential avoidance goods like certified masks could significantly mitigate acute health risks. Mobile technologies, given their increasing penetration even in lower-income areas, offer a powerful and cost-effective channel for delivering both information and behavioural nudges to broad audiences.

These information-based approaches can serve as valuable, cost-effective, and immediately implementable interventions while the more complex and resource-intensive work of reducing pollution at its sources continues. By empowering citizens with the information and skills needed to protect themselves, cities like Lahore can significantly reduce the immediate health burden of air pollution, even as they strive towards achieving cleaner air in the long term. The evidence clearly demonstrates that information access is not merely an issue of transparency—it is a potent public health tool capable of changing behaviour in ways that meaningfully reduce exposure to harmful pollution.

As Pakistan continues to develop and refine its comprehensive air quality policies, ensuring robust, accessible, and reliable information systems should be considered an essential and integral component of the overall national strategy. Because a public that is informed is a public that is empowered to protect itself and demand change.

Dr. Sanval Nasim is Assistant Professor of Economics at Colby College. His research broadly focuses on the environment, climate change, and political economy.


SHE
HZiL

19.

Citizen Action

Translating numbers to narratives for driving public awareness and action

Beyond the "smog season": Public and media attention often peaks during the visible winter smog, creating a cycle of crisis and amnesia. Year-round data is crucial for addressing the chronic, invisible sources of pollution that cause harm throughout the year.

From data to dialogue: The rise of accessible air quality data from low-cost sensors and citizen-led initiatives like PAQI has been the single most important factor in breaking the silence around air pollution in South Asia.

A global model for change: Grassroots movements from Kyrgyzstan to Poland to Pakistan prove that when communities are equipped with reliable information, they can successfully drive policy change and hold authorities accountable.

Shehzil Malik's vibrant illustration depicts a woman wearing a mask, merging cultural aesthetics with the dystopia of modern environmental survival. The work underscores the gendered burden of pollution, highlighting how women must navigate public spaces that have become increasingly hostile to health.

Silence is the greatest ally of a crisis. For decades, air pollution has persisted in Pakistan, unmeasured and unmentioned. Dr. Pallavi Pant chronicles the rise of a new force in the fight for clean air: the citizen scientist. She explores how accessible, real-time data has shattered the silence, empowered communities, and turned passive victims into active agents of change. This chapter is the story of how a simple number; the AQI, can become the most powerful tool for reclaiming our right to breathe.

I knew something was changing when my parents started sending me WhatsApp messages about air quality and snapshots from the balcony showing polluted skies and poor visibility. Or when a friend—who usually didn't think twice about such things—casually called me to ask which air purifier they should buy and how effective that might be for their kid with asthma. For many, air quality alerts and face masks have now become as routine as morning chai.

But for people working daily-wage jobs, air pollution isn't just a new concern making headlines, it is a constant part of their reality. A taxi driver I spoke with years ago comes to mind. He had recently moved to Delhi, chasing economic opportunity in the nation’s capital. “Within weeks,” he told me, “I started coughing all the time, and my eyes would burn, and I had the sensation that I could not breathe.” He knew the air was to blame, but his options were limited. He was supporting a family back in his village, where the skies were blue and the air was still clean. For him, breathing in pollutants was an unwelcome but unavoidable side effect of earning a living.

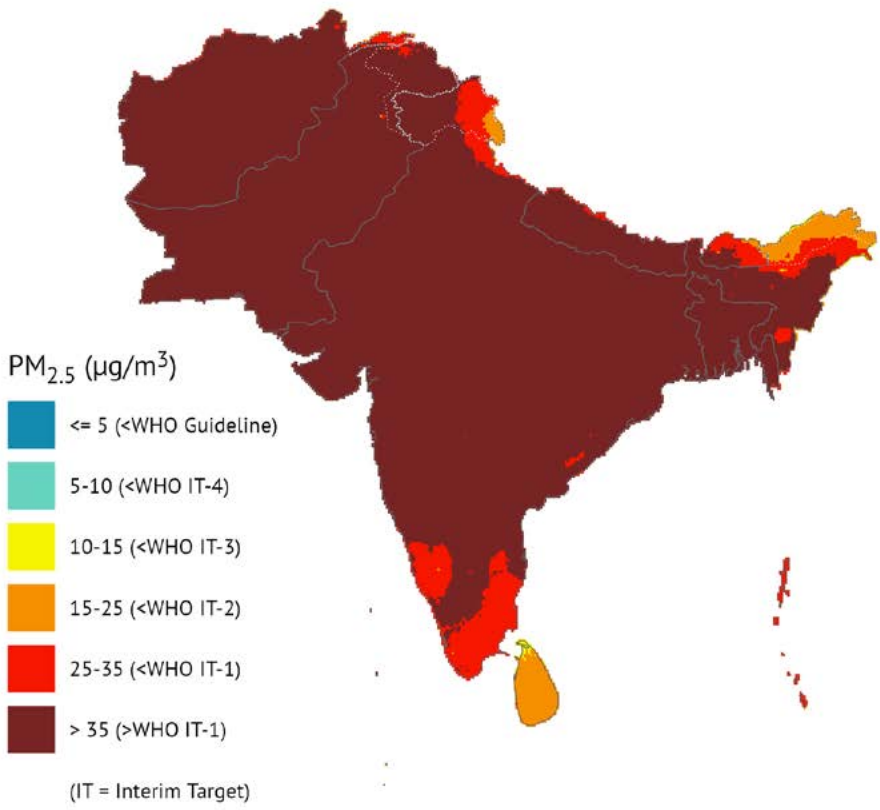


Exhibit 19.1: A Region Under a Cloud of Pollution. **This map illustrates the scale of the air quality crisis across South Asia, where a significant portion of the population is exposed to PM2.5 levels that far exceed WHO guidelines, making it one of the most polluted regions on Earth.**

It strikes me that while some of us are lucky enough to adapt—to buy air purifiers, monitor air quality apps, or even consider moving to a less polluted area—others don't have that luxury. They're exposed to the same harmful air day after day because, for them, work and survival are non-negotiable. It is a jarring reality: the very air that powers our lives in cities is also silently eroding the health of those who keep them running.

A shared crisis across South Asia

In Pakistan, the period between November and February has been colloquially referred to as the fifth season, or the season of smog.[1]

Year after year, between October to January each year, millions of people across Pakistan, India, Nepal and Bangladesh experience smog-filled skies. The blame shifts between the farmers who burn the agricultural residue, or the urban poor who burn solid fuels for heating or cooking, or better yet, the pollution coming from elsewhere.

Air pollution is the leading environmental risk factor for poor health across South Asia, and levels of air pollutants—especially fine particulate matter (PM2.5)—are often several

[1] Zahra-Malik, M. (2017, November 10). In Lahore, Pakistan, Smog Has Become a 'Fifth Season.' The New York Times.

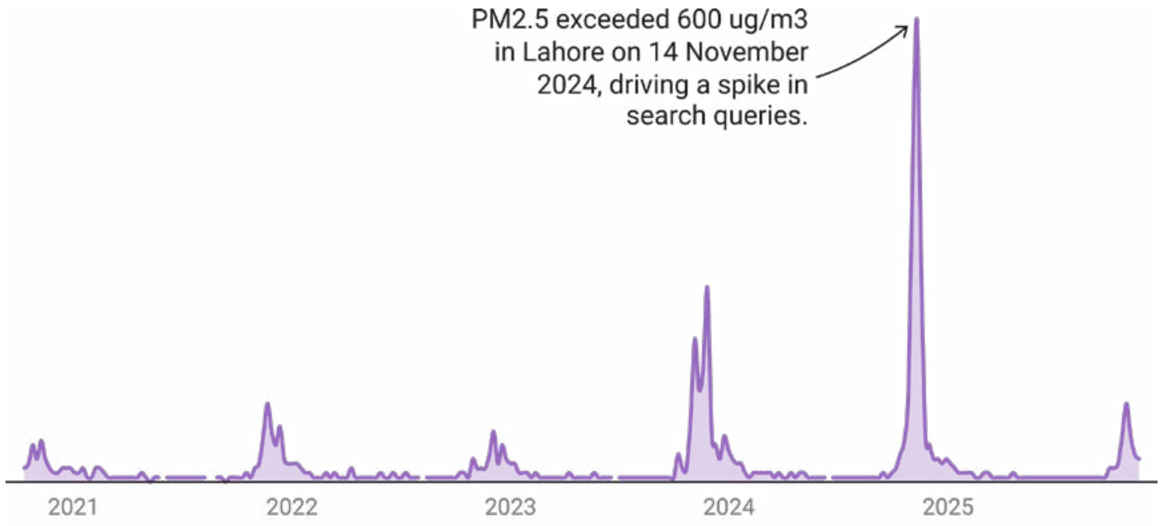


Exhibit 19.2: The Seasonal Spike in Public Interest. **This chart of Google search trends for "air quality" in Pakistan reveals a predictable pattern: public attention soars during the visible winter smog season and fades during the rest of the year, even though hazardous pollution is a year-round problem.**

fold higher than national air quality standards (Exhibit 19.1). High levels of air pollution have been linked to poor quality of life, and other societal and economic impacts including loss of worker productivity, high healthcare expenditure, reduction in travel and tourism and impact on crop productivity, among other things. Across the region, exposure to air pollution was estimated to cause 2.6 million deaths in 2021, and reduced life expectancy at birth by up to two years.[2] The economic impacts are also significant. According to a World Bank estimate, air pollution contributes to 9% of gross domestic product (GDP) equivalent loss in Pakistan.[3] In India, poor air quality can cost businesses in India as much as 3% of the total GDP.[4]

The 'fifth season': a cycle of crisis and amnesia

While air pollution is a year-round problem, the issue is often in the public discourse only during the winter months when the effects are often more salient, or visible to the eye. The story is no different in Pakistan where the Google searches for ‘air quality’ tend to peak each winter, with limited activity during other months.

This trend is no different in other South Asian countries, including in India, where air pollution is often in the news cycle during the winter season, and the discourse is often Delhi-centric, despite significant impacts of air pollution on millions of people across northern India. The information is not just anecdotal; an exploratory analysis of English news media articles in India found both a temporal and a geographical bias, indicating that

[2] State of Global Air. (2024). Health Effects Institute.

[3] World Bank. (2022). The global health cost of PM2.5 air pollution: A case for action beyond 2021. The World Bank.

[4] Air pollution in India and the impact on business. (2021). Clean Air Fund.

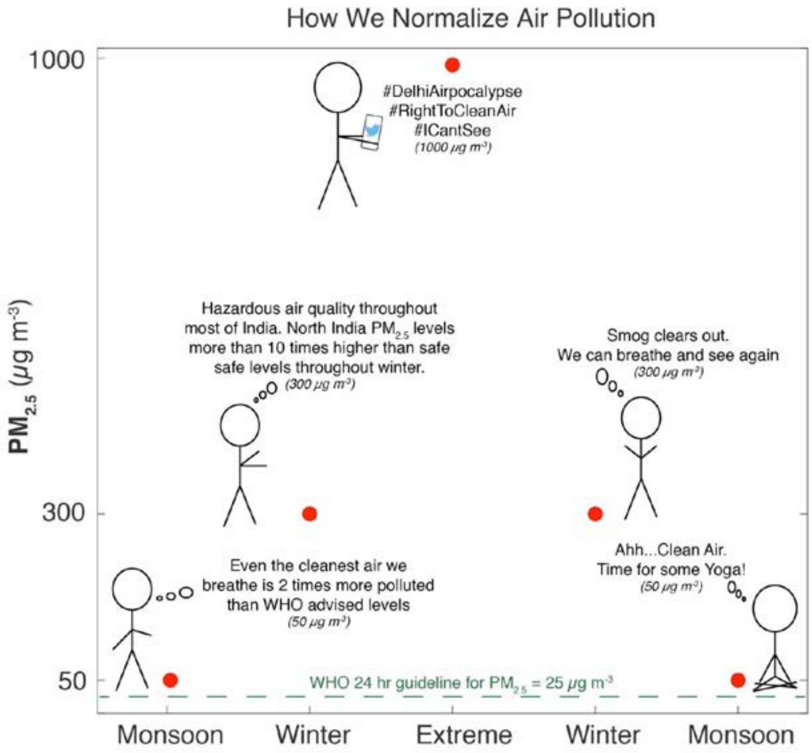


Exhibit 19.3: Where Unhealthy is the new Normal. **The data shows that air quality remains poor across most of South Asia throughout the year with levels of PM2.5 often exceeding 35 µg/m3, the least stringent Interim Target recommended by WHO. Graphic by Shahzad Gani and Pallavi Pant.**

media articles were focused on larger cities.[5] A larger analysis of media stories across several Asian countries between 2015-2018 also reported a similar trend, with a higher number of media stories during winter months.[6]

Undoubtedly, the levels of air pollutants including PM2.5 are particularly high during the winter season, but research has shown that air quality remains poor in the region year-round, with levels of PM2.5 often exceeding the least stringent Interim Target (35 µg/m3) recommended by the World Health Organization. Furthermore, in this seasonal discourse, the focus is often placed on immediate, visible sources such as agricultural stubble burning, while not interrogating year-round sources such as waste burning, transportation or energy production. To see measurable progress, however, there is a need for year-round discourse as well as targeted action on air pollution.

The power of a number: making pollution understandable

A key tool for disseminating air quality data and its potential public health implications is

[5] Patel, K., Adhikary, R., Patel, Z. B., Batra, N., & Guttikunda, S. (2022). Samachar: Print news media on Air Pollution in India. ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies (COMPASS), 401–413.

[6] Mehta, A., & D'souza, R. (2019). Hazy perceptions: Public understanding of air quality and its health impact in South and Southeast Asia, 2015-2018. Vital Strategies.

the Air Quality Index (AQI). The AQI translates complex air pollution measurements into a simplified, colour-coded, multi-point numeric scale, specifically designed to indicate the level of health concern posed by local air quality. Higher index values directly correlate with greater air pollution and, consequently, increased health risks. This index typically uses a green-yellow-red colour scheme to denote pollution severity: green generally represents good air quality with minimal health risk, while red signifies higher pollution levels and more significant health concerns. Crucially, AQI values are usually published with health advisories tailored to different pollution levels, offering guidance on reducing exposure and protecting health. For example, in the US AQI system, an index value between 101 and 150 is accompanied by the message:

"Members of sensitive groups may experience health effects. The general public is less likely to be affected."

The break points and descriptions used to define and describe different AQI categories often vary by country and are based on the national air quality standards and other available health evidence. Countries also include different combinations of air pollutants in estimating the AQI values. For example, in Europe, the European AQI (EAQI) includes PM_{10}, PM2.5, ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), whereas in China, 10 addition to the aforementioned pollutants, carbon monoxide (CO) is also included in the calculation of AQI values.

In India, the National Air Quality Index (NAQI) was launched in 2015 and has been used to communicate air quality levels across India; with data publicly available through an app, Sameer, as well as an online data dashboard.[7]

Pakistan's Punjab province established its own AQI as part of the Policy on Controlling Smog 2017, and in 2023, revised the AQI cut-off values under the Punjab Clean Air Plan 2023.[8] [9]

In an increasing number of cities, information about AQI is now routinely included in media reports across print and digital media.

The rise of the citizen scientist

Despite the gaps that remain, there has been progress on air pollution awareness and action in the last decade across South Asia, to which several factors have contributed. In addition to ground monitoring using reference-grade monitors, there are now a plethora of other data sources: low-cost sensors, satellite observations, and simple or sophisticated air quality models. This dynamic, ever-expanding data landscape has enabled in-depth analysis of spatial and temporal patterns of air quality, identification of hotspots, and the opportunity to assess changes in air quality over time. The availability of data, both directly through data dashboards, apps, and websites, and through new research, reports, or publications, has also increased opportunities for print and digital media stories on air

[7] Central Pollution Control Board (CPCB). https://cpcb.nic.in/National-Air-Quality-Index/

[8] Policy on Controlling Smog. Enviromnetal Protection Department, Government of The Punjab. (2017).

[9] Punjab Clean Air Policy. Environmental Protection Department, Government of The Punjab. (2023).

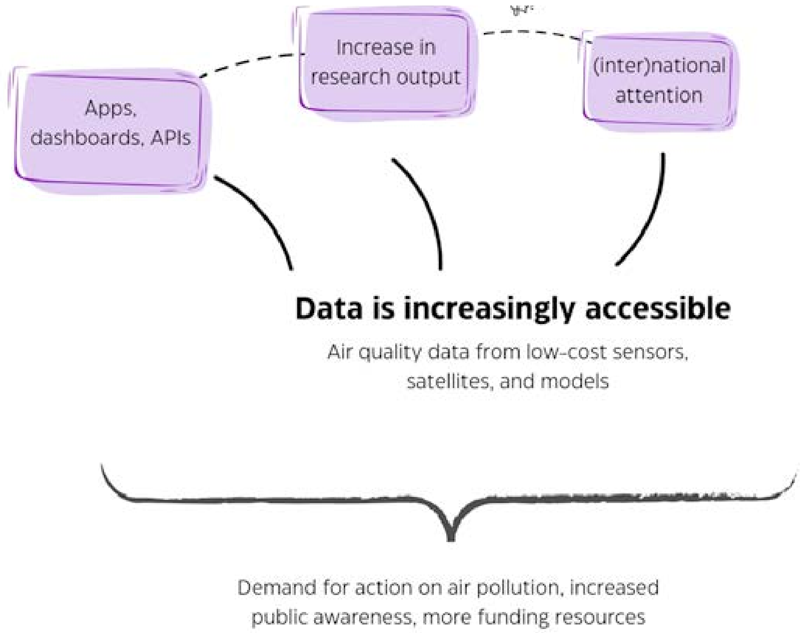


Exhibit 19.4. Accessibility of Air Quality Data Enhances Research, Awareness and Action. **As air pollution gains visibility through apps and websites, public awareness and demand for action rise. Data-driven stories and online platforms amplify real-time air quality information, empowering communities to advocate for cleaner air.**

quality. In India, for instance, a correlation was reported between availability of air quality data and an increase in media coverage on the topic of air pollution.[10]

Low-cost sensor technology is increasingly playing a vital role in supplementing traditional air quality monitoring efforts, especially in areas where comprehensive reference-grade networks are limited. Recognising their utility, some local governments have deployed these more accessible sensors to generate initial data on air pollution levels in the absence of reference-grade data. Furthermore, and often in response to gaps in official data availability or accessibility, many civil society organisations and individual citizens have embraced low-cost sensors, utilising them to measure local air quality and foster community-level awareness.

As the issue gains more visibility through news, digital, and social media, public awareness on the issue is also growing. Stories drawing on data and personal experiences related to air pollution are now available widely and create momentum for action. Social media platforms, in particular, amplify real-time air quality data, empowering communities to advocate for change and push policymakers to take action towards cleaner air. An example of the influence of social media can be seen in China where researchers reported that social media exerts a "positive influence on air quality improvement".[11] Collectively, these enablers—community-driven monitoring, the growth of data and research, and the influence of media—are catalysing a societal push towards cleaner air and healthier environments.

[10] Patel, K., Adhikary, R., Patel, Z. B., Batra, N., & Guttikunda, S. (2022). Samachar: Print news media on Air Pollution in India. ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies (COMPASS), 401–413.

[11] Wang, J., & Jia, Y. (2021). Social media's influence on air quality improvement: Evidence from China. Journal of Cleaner Production, 298, 126769.

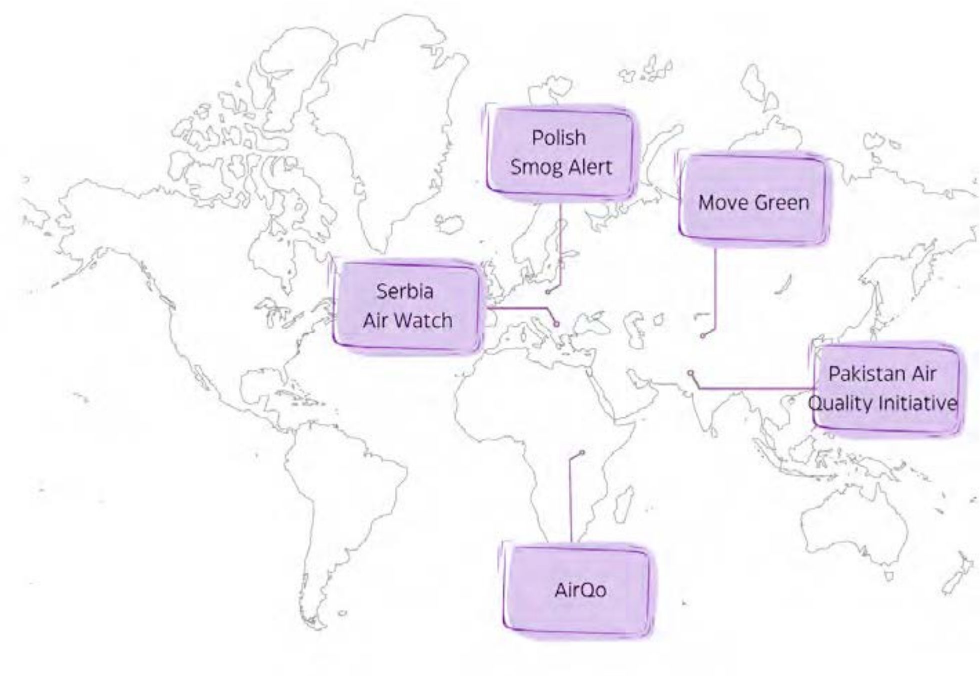


Exhibit 19.5. Citizen Science Monitoring Networks and Groups Around the World That Have Created Impact. **Over the past decade, citizen science monitoring networks have made data more accessible, sparking media attention and calls for action.**

Stories of change: how data empowers communities

Air quality data is increasingly being used for public engagement and outreach in many cities and countries. In the last decade, there have been multiple inspiring examples where access to data through independent, local citizen science monitoring networks has resulted in increasing public awareness and related media coverage, and ultimately, the need for action. Collectively, the examples below underscore the critical role of accessible, understandable information plays in mobilising effective air quality interventions.

One notable example comes from Bishkek, Kyrgyzstan, where the environmental organisation MoveGreen established AQ.kg—a publicly accessible network of low-cost air quality sensors—to monitor real-time air quality in the capital city and other parts of the country.[12] The network's data is freely available online, and MoveGreen has worked extensively to increase public access to, and understanding of, air pollution data and its profound impacts on health and well-being. MoveGreen was also instrumental in establishing the Central Asia Air Quality Platform, a regional initiative with over 30 members that fosters "constructive partnerships among members of civil society, scientific and academic communities, businesses, media and government agencies to support the clean air movement".[13]

[12] Movegreen.

[13] Air Quality Central Asia.

Similarly, in Kraków, Poland, a campaign initially launched by a small group of concerned friends—Anna Dworakowska, Andrzej Gula, and Ewa Lutomska—focused on highlighting the severe health effects of local air pollution. This grassroots effort rapidly transformed into the influential Polish Smog Alert initiative.[14] [15] The work undertaken by the Kraków Smog Alert team not only dramatically raised public awareness about the city's poor air quality but also directly influenced the municipal government's landmark decision to ban the use of solid fuels (like coal and wood) in domestic boilers. This policy change, in turn, has led to measurable improvements in the number of good air quality days experienced in the city. The Smog Alert model has since spread to other cities across Poland, and the initiative aims to expand its advocacy work to other central and eastern European countries facing similar challenges.

In Delhi, India, the Mahila Housing Trust undertook an innovative project training women construction workers, who are often disproportionately exposed to pollution, as “AQI Ambassadors”. Equipped with portable air quality monitors and basic training, these women not only monitored local conditions but also effectively raised awareness about air pollution risks within their communities and mobilised local action to address specific pollution sources or advocate for protective measures.

Another example comes from Belgrade, Serbia, where the Belgrade Open School’s project, Serbian Air Watch, installed 50 air quality sensors across five Serbian cities.[16] By connecting these sensors to the publicly accessible Luftdaten platform, the project aimed to significantly raise public awareness about local air pollution levels and empower communities with the data needed to advocate for change.

Finally, within Pakistan itself, the Pakistan Air Quality Initiative (PAQI), founded by Abid Omar, has been a leading force in engaging the public on the critical issue of air pollution.[17] Starting with just a handful of air quality sensors installed in private homes across major cities like Lahore, Karachi, and Islamabad, PAQI has consistently worked to bring the often-ignored reality of Pakistan's poor air quality into the public discourse. Through its persistent efforts in data sharing (primarily via social media and its website) and advocacy, the initiative has significantly expanded public access to real-time air quality data and fostered a much broader national conversation about the urgent need for, and opportunities for, clean air action in the country.

The path forward: from data to dialogue

The challenge of air pollution is neither new nor unique to Pakistan. Historical accounts remind us that humans have recognised poor air quality for millennia—as evidenced by Seneca's relief upon leaving Rome's "oppressive atmosphere" and "poisonous fumes" in AD 61.[18]

[14] Polish Smog Alert.

[15] Follow the Data Podcast: Tackling Air Pollution Across Poland. Bloomberg Philanthropies.

[16] Serbian Air Watch, Belgrade Open School.

[17] Pakistan Air Quality Initiative.

[18] Seneca, L. A. (c. 61 AD). Letters from a Stoic: Epistulae morales ad Lucilium.

"No sooner had I left behind the oppressive atmosphere of the city [Rome] and that reek of smoking cookers which pour out, along with clouds of ashes, all the poisonous fumes they've accumulated in their interiors whenever they're started up, then I noticed the change in my condition."

Throughout history, severe pollution episodes have catalysed meaningful action: London's Great Smog of 1952, the Los Angeles valley smog crisis of the 1970s, and Beijing's more recent air quality transformation all demonstrate a consistent pattern: sustainable improvements come through comprehensive, science-based strategies addressing emissions at their source. China's recent progress offers a compelling model, combining data-driven policies, research investment, and strengthened regulatory capacity across all governance levels.

There is no silver bullet solution for air pollution.

Key sources of air pollution in South Asia include energy production and use, industries, transportation, construction and other dust, waste burning, seasonal sources (such as stubble burning) and those relatively unique to the region (such as brick kilns, *tandoors*, etc.) collectively contribute to high ambient air pollution.

Residential fuel use, contributing 20-30% to outdoor PM2.5 in many South Asian contexts remains particularly important in regions with limited access to clean energy alternatives, as large proportions of the region's population lack access to affordable, clean fuels.[19]

In Pakistan, emissions inventories from the major urban centres identify multiple significant contributors: transportation (approximately 38% of urban PM2.5), industrial activities (around 32%), and brick kilns (about 10%)—with important variations between cities that necessitate locally-tailored approaches.

While the mainstream discourse has focused on air pollution in urban areas in Pakistan and across South Asia, the problem also remains relevant across peri-urban and rural areas. Across the region, transboundary pollution also significantly contributes to elevated pollution levels.

The path towards cleaner air in Pakistan requires leveraging available data and evidence to shape policies and measure progress. Equally important is incorporating the lived experiences of those who suffer the most as a result of air pollution; these perspectives must be considered in decision-making to ensure that policy action is equitable and brings benefits to all.

By combining rigorous technical analysis with community perspectives, Pakistan can develop interventions that deliver cleaner air and better health outcomes for all its citizens. This is how we ensure that a family's health is no longer determined by their ability to afford an air purifier, but by their right to breathe clean air.

[19] While this regional pattern holds true in many South Asian contexts, recent Pakistan-specific emissions inventories show significant variation across cities, with residential contributions ranging from just 1% in Karachi to 5% in Peshawar, highlighting the importance of locally-relevant data for effective policy development.

Pallavi Pant is an air quality scientist with 15 years of experience working on air pollution and health, particularly in LMICs. She has contributed extensively to public engagement, capacity strengthening, and science communication, working to increase awareness of air pollution and its health impacts.

20.

Our Smogasbord of Apathy

A grim look at what the future holds if necessary action keeps getting deferred

Adopting the intricate style of a Mughal miniature, Rohama Malik presents a jarring vision of the future where clean air is a distant memory. The traditional aesthetic, typically used to depict courtly splendor, here illuminates a 'Smogasbord of Apathy'—a society that has normalised toxicity rather than fighting for a breathable future.

The final, most formidable obstacle to clean air is not found in policy or science, but in ourselves. After 19 chapters of evidence and analysis, Rimmel Mohydin's concluding piece confronts the crisis of apathy that allows the poison to persist. It is a visceral, personal, and ultimately damning account of our collective inaction, a final reminder that the most significant barrier to change may well be our own.

The best and worst thing about humans is that we are as quick to forget as we are often slow to react. It wasn't long ago that it was mandated by law to wear masks. Now, even hospitals—institutions most profoundly affected by the contagion—count masking up as a luxury. And while the pandemic is thankfully over, its exposure of the world's weaknesses, fissures, and inequalities has been added to the pile of things that we should be acting against, but don't.

Like smog.

The fifth season in Punjab, where breathing becomes a burden; a token of decades of uncontrolled emissions, low fuel quality, crop burning and climate change.

We know it's coming. We know what it does to us, our children, our sick, our elders. We also know that its arrival will be met with a vague government response, in the form of yet another committee, yet another hollow promise and perhaps, an accusation of manufacturing panic to sell more air purifiers. And we know still, that our best bet is to hope for rain in months where it rarely does. The state stalling until there is deliverance from nature seems to be as close to an anti-smog policy as we can get. We know it. They know we know it. And they also know that they will get away with it.

You see, the government relies on our acquiescence by way of our collective outrage going nowhere. They understand their public better than we will ever understand them. This is why they are so successful in staying in power when they do so little to deserve to. They know that inflation, the absence of political agency, the ceaseless stream of all kinds of life endangering crises will exhaust us. And this careful curation of our fatigue is fed into systems that are designed to punish honest, hard work and reward corrupt shortcuts. The result is that we can count on our fingers the days when Lahore's air doesn't actively poison us—and smog still hardly figures anywhere on the political agenda.

The problem with living where the sky seems to be falling nearly every day is that eventually you make peace with being crushed by it. You adjust your posture and find the reinforcements you can pay for. That is certainly what the elite in Pakistan have done, with air purifiers humming in bedrooms in posh neighbourhoods of the dirtiest cities.

School calendars are disrupted with a few hours' notice with mandatory closures, because it is assumed that all children will have access to the internet and a device that can connect them virtually. We tell our infirm to stay indoors, taking it for granted that they do not need to work to put food on the table.

And of course, there are those who do get broken by the collapsing sky. Think of the language fluency that has become commonplace around air quality. There are mobile apps that tell us how many cigarettes we have smoked, despite not bringing even one to our lips. We speak in terms of AQI, or Air Quality Index, a unit that measures whether the air is safe to breathe or not. We know the ranges, and the advisory that each carries. We know not to get surgical masks or even N95 ones. It's the bulky air respirator that does the trick.

Those who need to make use of this knowledge the most remain unaware of it or unable to protect themselves from this risk.

Lahore is a storied city, steeped in history and literature, both a backdrop and muse to many artists. It is also one of major inequalities. A labourer, a farmhand or a construction worker will likely be poisoned faster because their work keeps them outside. It is unlikely that they can take a day off to save themselves from the smog, because they count on daily wages. The fact is that even though they form the city's largest demographic, their suffering will be largely consequence-free for the state they break their backs paying exorbitant taxes to.

Despite all the little ways the elite might soothe themselves about having done enough to protect themselves, the truth is that smog is as inescapable as breathing is essential to stay alive. When evidence of the consequences is so dire, their arrival all but confirmed, one can be forgiven for believing this is yet another example of our long-cultivated apathy.

The reality is much worse. We've been putting more cars on the road, building more underpasses and signal-free corridors, and doing next to nothing to improve fuel quality. We parade public transit projects as revolutionary solutions even while they are utterly inadequate. We criminalise crop burning, but fail to provide the already beleaguered farming community with alternative solutions. We have no plans to stop burning fossil fuels to feed our evergrowing energy requirements. Billion tree plantations do nothing to check the horrifying deforestation rates that rank among the highest in the world. There is no attention being paid to the actual causes of smog, and so where does it stop looking like an active choice to enable the infrastructure for our complete obliteration?

Let me take you to the Lahore of tomorrow—though 'tomorrow' feels less like a distant future and more like the next season of smog. This isn't some far-off dystopia—it's the reality we're building with each policy neglected, each warning ignored.

Consider, then, the path these choices are paving for us:

This isn't some far-off dystopia—it's the reality we're building with each policy neglected, each warning ignored.

An invisible city, engulfed in smoke, is home to many of us. Sulfur dioxide, PM2.5, volatile organic compounds, nitrogen oxide and the like give the air a pungence that salts our insides.

A respirator that resembles a hazmat suit helmet is a necessity but not ubiquitous. Its price tag ensures that it is of use to only the richest. At any rate, they are not ergonomically designed for people who earn their keep through manual labour. There never was anything—personal protection equipment or intention—designed to prevent them falling into the cracks.

Our lung capacities have shrunk and oxygen cylinders have become pantry items, stacked next to packets of sugar and tea. Hoarding them has also slowly crept into what we consider socially acceptable. After all, aren't we all fast becoming patients wrestling with respiratory illness, besides what are we meant to do when we have young children in the house? Who wants to trek all the way to a hospital, when they can never really keep up with the demand for oxygen cylinders anyway.

School buildings now lay abandoned, as parents opt to keep their children at home. In fact, the only reason why children are taken out of the protection of their four walls is to be rushed to the hospital. Their lungs were never built to breathe smoke instead of reasonably clean air. But children are children, and sometimes they like to play outside. An unguarded window or door, a momentarily distracted caregiver and the curiosity inherent to young, developing minds is all it can take.

When someone around us dies, and they often do, we add five years to their age at the time of death. Or maybe by then, life expectancy will be shortened even more. Somehow, in smog-ridden cities, people are always dying before their time.

Newer strains of respiratory illnesses abound, and modern medicine has simply not been able to keep up. And even if it did, saving brown lives in a low priority country like Pakistan is not something that dominates the global pharmaceutical market. So as the Global North continues to outsource manufacturing to the South in a bid to fatten their profits with cheap labour and undervalued raw material with flexible standards for workplace safety, their skies remain clear and if it's happening far away to brown people, does it even happen at all?

No fresh food is grown because anyone who works in the field for too long does not return the next day. The crops that do somehow sprout are often diseased and stunted, and because they grow in poison, they tend to absorb some of it. Rest assured, by the time the rice and pulses reach your plate, it does not contain the nutrients you're hoping to nourish yourself with. Very often, we're ingesting something toxic—except the choices have become few and far between.

There are no longer any traffic lights in Lahore. The project to turn every major road into an artery of a signal-free corridor is complete. And there have never been more car accidents, owing to the low visibility. The sun barely cuts through so the streetlights—that need to be on during the day now—never had much of a chance. Everyone that spent their savings on installing solar panels on their roof rue the day, because there never is enough sun to generate the electricity they need. There is darkness when there should be day.

When we walk into hospitals in a future as imminent as the next generation, we'll recall the days when masking up was all it took to feel protected. As we hold our wheezing children, we will wonder why anything else seemed more important when there was still time to act. We will look to the leaders; some of whom will be in cleaner cities, cloistered in luxurious apartments; and gawk at how we could form a politic that could possibly be occupied by an issue other than the air we breathe.

And perhaps then, when suffocation becomes mercy, we'll be grateful for the years that smog can cull from our lives.

Rimmel Mohydin is a human rights and advocacy expert.

Appendix: **Glossary**

This glossary provides definitions for key technical terms and concepts used in air quality management to help readers better understand the science and policy of air pollution.

18th Constitutional Amendment. A landmark 2010 amendment to the Constitution of Pakistan that devolved significant legislative and executive authority from the federal government to the provinces. In the context of this report, it made Environmental Protection and Pollution Control primarily a provincial responsibility, leading to the creation of distinct provincial environmental standards and policies.

Aerosol. A suspension of fine solid particles or liquid droplets in a gas, such as air. In the context of air quality, the term is often used interchangeably with Particulate Matter (PM) to describe the complex mixture of particles that make up haze and smoke.

Aerosol Optical Depth (AOD). A measure used in satellite-based monitoring that indicates how much direct sunlight is blocked by aerosol particles (like PM2.5) in a column of air from the ground to the satellite. AOD provides broad spatial coverage but is not a direct measurement of ground-level pollution and requires calibration with in-situ data to be accurate.

Air Quality Index (AQI). A system used to communicate the level of air pollution according to its health impacts to the public. The AQI translates complex measurements of multiple pollutants into a single number and a corresponding colour-coded category (e.g., Good, Unhealthy, Hazardous) to indicate the immediate health risk. A higher AQI value means greater air pollution and greater health concern. Different countries use different calculations and categorisations.

Air Quality Life Index (AQLI). A metric developed by the Energy Policy Institute at the University of Chicago (EPIC) that translates particulate air pollution concentrations into their impact on human life expectancy. The AQLI quantifies the number of years of life that could be gained if a specific location's PM2.5 pollution were reduced to meet the World Health Organization (WHO) guideline.

Airshed. A geographic area within which pollutants from common sources are often trapped and transported. Because air pollution does not respect administrative boundaries, effective management requires a coordinated approach across an entire airshed.

Airshed management. A governance approach to controlling air pollution that is based on the entire airshed, rather than on administrative or political boundaries. It requires coordinated planning and enforcement among different cities, districts, and even provinces that share the same air.

Ambient air quality. The concentration of pollutants in the outdoor air that people breathe. National Environmental Quality Standards (NEQS) set legal limits for ambient air quality in Pakistan.

Beta Attenuation Monitor (BAM). A widely used automated instrument for measuring particulate matter concentrations continuously. It is a common example of a Federal Equivalent Method (FEM) as designated by the US EPA. It works by passing air through a filter tape and measuring the reduction (attenuation) in beta particles that can pass through the collected dust. This provides near real-time, hourly PM data and aligns with the "Beta Ray Absorption Method" specified in Pakistan's NEQS.

Black carbon. A major component of PM2.5, produced by the incomplete combustion of fossil fuels, biofuels, and biomass (e.g., from diesel engines and crop burning). It is a potent "super-pollutant" that harms human health and significantly contributes to climate change by absorbing sunlight and accelerating the melting of glaciers.

Bottom-up emissions inventory. A method of calculating emissions that starts with detailed, ground-level data on polluting activities (e.g., fuel consumption by every factory, traffic counts on every road). This is a more granular and precise method than "top-down" inventories, which often rely on national-level statistics or satellite data.

Carbon monoxide (CO). A colourless, odourless gas formed when carbon in fuel is not burned completely. It is a primary pollutant from vehicle exhaust and inefficient stoves. At high concentrations, it is toxic because it reduces the blood's ability to carry oxygen. It is measured in ambient air using Non-Dispersive Infrared (NDIR) photometry.

Chemical speciation. The process of identifying and quantifying the specific chemical components that make up a pollutant sample, such as particulate matter. For example, a PM2.5 sample can be speciated to determine its percentage of sulfates, nitrates, black carbon, and heavy metals. This "chemical fingerprint" is crucial for source apportionment.

Congestion charge. A fee levied on certain vehicles for entering a specific, high-traffic area of a city during peak hours. While its primary goal is to reduce traffic congestion, it also has the co-benefit of reducing vehicle emissions and improving air quality. The system in London is a globally recognised example.

Continuous Emissions Monitoring Systems (CEMS). A set of instruments installed on a smokestack that automatically measures pollutant emissions in real-time, 24/7. CEMS provide regulators and facility operators with continuous data to ensure compliance with emission limits, a significant improvement over periodic manual testing.

Crop residue fires. The practice of setting fire to the stubble and other plant matter left in a field after a harvest to quickly clear it for the next planting cycle. This is a major seasonal source of PM2.5 and smog in Pakistan and across South Asia.

Criteria pollutants. A set of six common air pollutants regulated by environmental authorities worldwide due to their significant health and environmental impacts: particulate matter (PM2.5 and PM10), ground-level ozone (O3), carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), and lead (Pb).

Dispersion. The process by which pollutants spread out and mix with the surrounding air, reducing their concentration at the source. Meteorological conditions like wind speed and atmospheric stability are critical factors that control the rate of dispersion. Temperature inversions severely limit dispersion.

Emission Factor. A coefficient that quantifies the amount of a pollutant released into the atmosphere per unit of a specific activity. For example, kilograms of SO2 emitted per ton of coal burned. It is a key component in calculating an emissions inventory.

Emissions inventory. A systematic and detailed accounting of all pollutants discharged into the atmosphere from every identifiable source in a specific geographic area over a set period of time. It is the foundational scientific tool for diagnosing the sources of air pollution and is calculated using the formula: Emissions = Activity Data × Emission Factor.

Federal Equivalent Method (FEM). A designation by the US EPA for an automated, continuous air monitoring method (e.g., BAM, TEOM) that has been scientifically proven to produce data of equivalent quality and accuracy to the more labour-intensive Federal Reference Method.

Federal Reference Method (FRM). A designation by the US EPA for the most accurate, "gold standard" method for measuring the concentration of a pollutant (e.g., the Gravimetric Method for PM). FRMs are used to calibrate other instruments but are often not suitable for continuous, real-time monitoring.

Fenceline monitoring. The placement of air quality monitors at the boundary, or "fenceline" of an industrial facility, power plant, or landfill. This measures the pollution escaping from the site and directly impacting the adjacent community.

Filter-based gravimetric samplers. The instruments used to perform the Gravimetric Method of PM measurement. These devices work by pulling a specific volume of air through a fine filter over a 24-hour period. The filter is weighed before and after sampling to determine the precise mass of the collected particulate matter.

Fog. A natural meteorological phenomenon consisting of a visible cloud of tiny water droplets suspended in the air at or near the Earth's surface. Unlike smog, which is composed of harmful pollutants, fog is composed of water. In Pakistan, the term “fog” has often been used incorrectly to describe smog events, downplaying the public health crisis.

Fuel quality standards. Government regulations that set specific limits on the chemical composition of fuels sold commercially. These standards are critical for controlling air pollution and often mandate reductions in harmful components like sulfur, benzene, and heavy metals.

Graded Response Action Plan (GRAP). A set of pre-defined, escalating emergency actions that are automatically triggered when air quality deteriorates to a certain threshold. Developed in Delhi, India, these actions can include banning construction, restricting traffic, and shutting down industries to prevent severe pollution episodes from worsening.

Gravimetric method. The "gold standard" for measuring particulate matter mass concentration, designated as the Federal Reference Method by the US Environmental Protection Agency. It involves using a filter-based sampler to collect particles over a 24-hour period and then physically weighing the filter in a lab. The difference in weight provides a highly accurate PM measurement but does not provide real-time data.

Ground-level ozone (O3). A harmful secondary pollutant that is not emitted directly but is formed when nitrogen oxides (NOx) and volatile organic compounds (VOCs) react in the presence of sunlight. It is a major component of smog and can damage the lungs and reduce crop yields. It is measured in ambient air using UV photometry.

Humidity. A measure of the amount of water vapour present in the air. High humidity can influence atmospheric chemistry, sometimes accelerating the chemical reactions that form secondary pollutants like sulfate aerosols from sulfur dioxide emissions.

In-situ data. Data collected directly at the source or on-site ("in position"). In air quality, this refers to measurements from ground-based monitoring stations. In-situ data is essential for validating and calibrating remote sensing data from satellites.

Light-scattering. The measurement principle used by most low-cost sensors to estimate particulate matter concentration. A laser inside the sensor illuminates particles in an air sample, and a detector measures the amount of light that the particles scatter. This is an indirect optical measurement that is less accurate than reference methods and requires careful calibration. See also Nephelometer.

Low-cost sensors. Affordable air quality monitoring devices. While they are generally less accurate than regulatory-grade monitors, their low cost allows for the creation of dense monitoring networks by citizen scientists and communities, which is invaluable for raising public awareness and identifying pollution hotspots.

Low-sulfur diesel. A cleaner diesel fuel that has a significantly reduced sulfur content compared to conventional diesel. The use of low-sulfur diesel is a critical fuel quality standard because it directly reduces emissions of SO2 and PM2.5 and is essential for the proper functioning of modern vehicle emission control technologies like diesel particulate filters.

National Environmental Quality Standards (NEQS). The set of legally enforceable standards in Pakistan that specify the maximum allowable concentration of pollutants in ambient air, water, and industrial emissions, as well as the prescribed measurement methods. The report finds that Pakistan's NEQS for ambient air are significantly weaker than World Health Organization guidelines.

Nephelometer. An instrument that measures particulate matter concentration by determining the amount of light scattered by particles suspended in the air. It is a more sophisticated and precise type of light-scattering device than those typically used in low-cost sensors.

Nitrogen dioxide (NO2) / nitrogen oxides (NOx). A group of highly reactive gases, primarily formed during high-temperature combustion in vehicle engines, power plants, and industrial furnaces. NO2 is the reddish-brown gas visible in urban haze, irritates the lungs, and is a key precursor to the formation of secondary PM2.5 and ground-level ozone. They are measured in ambient air using chemiluminescence.

Open waste burning. The uncontrolled combustion of municipal solid waste in open dumps or on street corners. It is a significant source of toxic pollutants, including PM2.5, black carbon, dioxins, and furans.

Coarse particulate matter (PM10). Inhalable coarse particles with a diameter of 10 micrometres or less. Sources include dust from roads, construction sites, and crushing operations. They can irritate the eyes, nose, and throat.

Fine particulate matter (PM2.5). Extremely fine inhalable particles with a diameter of 2.5 micrometres or smaller (about 30 times smaller than the width of a human hair). Due to their minuscule size, PM2.5 particles can penetrate deep into the lungs, enter the bloodstream, and cause severe health impacts, including respiratory diseases, heart attacks, and strokes. It is widely considered the most health-damaging air pollutant.

Population-weighted exposure. A method of measuring air pollution exposure that accounts for both the concentration of pollutants in an area and the number of people who live there. By giving more weight to pollution levels in densely populated areas, this metric provides a more accurate assessment of the overall public health burden and risk compared to simple monitor averages.

Precursor gases. Primary pollutants, such as nitrogen oxides (NOx) and volatile organic compounds (VOCs), that react in the atmosphere to create more dangerous secondary pollutants like ground-level ozone and secondary particulate matter.

Public Health (Emergency Provisions) Ordinance, 1944. A pre-partition law that grants the government broad powers to take emergency measures to protect public health. This ordinance, along with the Punjab National Calamities Act, has been used by the Punjab government to declare smog a "calamity" and enforce temporary restrictions.

Punjab Environmental Quality Standards (PEQS). The specific set of environmental laws and standards applicable within the province of Punjab, enforced by the Punjab Environmental Protection Agency (EPA).

Punjab National Calamities (Prevention and Relief) Act of 1958. A provincial law that allows the Government of Punjab to declare an area as "calamity-affected" in the event of floods, famines, epidemics, or other disasters. This Act has been invoked to classify severe smog as a calamity, giving authorities the power to enforce emergency measures like closing schools or restricting industrial activity.

Regulatory-grade monitoring stations. Highly accurate and expensive air monitoring stations operated by government agencies to determine compliance with legal standards like the NEQS. These stations use official measurement methods defined by national regulations, which are benchmarked against internationally recognised Federal Reference Methods (FRM) and Federal Equivalent Methods (FEM) developed by the US EPA.

Satellite-based monitoring. The use of instruments on satellites orbiting the Earth to measure air pollutants over large geographical areas. This method is especially useful for tracking the movement of transboundary pollution and identifying large-scale emission sources. Its primary measurement is often Aerosol Optical Depth (AOD).

Secondary pollutants. Pollutants that are not emitted directly into the air but are formed in the atmosphere through chemical reactions between primary pollutants. Ground-level ozone and a significant portion of PM2.5 (sulfates and nitrates) are key secondary pollutants that make up a large part of regional haze and smog.

Sindh Environmental Quality Standards (SEQS). The specific set of environmental laws and standards applicable within the province of Sindh, enforced by the Sindh Environmental

Protection Agency (SEPA). Notably, the SEQS for ambient PM2.5 are less stringent than the national NEQS.

Smog. A common term, not a precise scientific one, created by blending the words "smoke" and "fog". It refers to severe, visible air pollution where high concentrations of pollutants, especially ground-level ozone and particulate matter, accumulate in the lower atmosphere. This often occurs under a temperature inversion, resulting in a thick, stagnant haze that reduces visibility and poses significant health risks. It is a man-made phenomenon and distinct from natural fog.

Source apportionment. A scientific method used to identify and quantify the contribution of different pollution sources (e.g., traffic, industry, biomass burning) to the ambient air pollution measured at a specific location. It involves chemically "fingerprinting" pollutants to trace them back to their origins and is a more advanced step than an emissions inventory.

Stack emissions. Pollutants released from a smokestack (or flue-gas stack), which is a tall chimney or vent at an industrial facility or power plant designed to disperse emissions into the higher atmosphere.

Sulfur dioxide (SO2). A pungent, corrosive gas produced when fuels containing sulfur, such as coal and furnace oil, are burned in power plants and industrial boilers. In the atmosphere, it reacts to form sulfate particles, a major component of PM2.5 and acid rain. It is measured in ambient air using UV fluorescence.

Tapered Element Oscillating Microbalance (TEOM). A common Federal Equivalent Method (FEM), as designated by the US EPA, for providing continuous, real-time measurements of particulate matter. It works by collecting particles on a filter attached to an oscillating glass rod; the change in the rod's oscillation frequency corresponds directly to the mass of the collected particles.

Temperature inversion. A meteorological condition where a layer of warm air sits on top of a layer of cooler air near the ground. This acts like a lid, trapping pollutants close to the surface and preventing them from dispersing, leading to severe smog episodes, particularly during winter months in cities like Lahore and Peshawar.

Transboundary pollution. Air pollution that originates in one administrative or political jurisdiction (e.g., a district, province, or country) but is transported by wind to another, impacting the air quality of the downwind region.

Ultra Low Emission Zone (ULEZ). A defined area within a city where vehicles must meet strict exhaust emission standards (e.g., Euro VI for diesel) to enter without paying a daily charge. Its primary goal is to improve air quality by discouraging the use of older, more polluting vehicles. The London ULEZ is a prominent example.

Ultra-low emissions standards. A term associated with China's air quality management, referring to a set of extremely stringent emission limits for major industrial sectors (like coal power plants and steel mills) that are often stricter than standards in Europe or the US. This policy has been a key driver of China's rapid reduction in industrial pollution.

Vehicle emission standards (e.g., Euro Standards). A set of regulations that define the maximum permissible levels of pollutants (such as NOx, CO, and PM) that can be emitted from the exhaust of a new vehicle. Euro Standards, originating from the European Union, are a widely adopted international benchmark, with progressively stricter tiers (e.g., Euro I, Euro II... Euro VI) introduced over time to force improvements in engine technology and emission controls.

Volatile organic compounds (VOCs). A large group of carbon-based chemicals that evaporate easily at room temperature. They are emitted from a wide variety of sources, including vehicle exhaust, industrial processes, paints, and solvents. Along with NOx, they are primary ingredients in the formation of ground-level ozone.

Appendix: **Tables**

This appendix contains summary statistics and a sample of the daily 24-hour average PM2.5 data from the PAQI monitoring network used in the analysis for this report.

Table A1: Sample of Daily 24-Hour Average PM2.5 Concentrations (µg/m3) for all major cities in Pakistan (December 2024 - June 2025)

Date	Lahore	Karachi	Islamabad	Rawalpindi	Peshawar
28 December 2024	90.5	92.4	78.1	104.2	297.4
29 December 2024	79.9	78.0	85.7	118.9	241.6
30 December 2024	107.3	91.3	105.6	130.6	243.1
31 December 2024	159.9	92.8	128.3	130.8	257.0
01 January 2025	173.2	101.4	194.6	164.6	288.2
02 January 2025	178.7	130.8	105.9	162.7	222.8
03 January 2025	245.9	138.2	58.3	111.0	88.1
04 January 2025	159.9	80.0	51.8	72.8	93.0
05 January 2025	121.1	86.8	77.7	83.8	82.3
06 January 2025	153.1	79.3	60.8	59.8	93.0
07 January 2025	107.9	60.5	52.1	61.0	110.2
08 January 2025	124.9	96.1	52.3	65.6	98.2
09 January 2025	229.2	105.1	65.8	77.1	105.1
10 January 2025	120.8	98.3	94.3	92.9	98.3
11 January 2025	121.5	87.5	111.2	111.3	146.6
12 January 2025	70.2	102.7	91.3	112.4	209.3
13 January 2025	111.8	110.2	94.2	107.4	166.0
14 January 2025	118.2	108.6	111.2	121.2	196.0
15 January 2025	157.0	107.1	112.1	124.5	164.1
16 January 2025	134.1	125.9	77.2	91.9	186.9
17 January 2025	148.7	71.6	82.0	94.0	137.3
18 January 2025	270.6	89.3	80.5	123.9	184.3
19 January 2025	275.5	90.7	77.9	124.6	109.1
20 January 2025	156.5	91.8	61.4	94.0	85.1
21 January 2025	99.2	113.1	59.0	63.7	103.1
22 January 2025	92.6	98.9	58.0	71.0	108.2
23 January 2025	88.9	53.2	51.2	60.5	103.9
24 January 2025	91.8	45.6	42.4	45.0	95.1
25 January 2025	135.0	54.5	43.8	56.9	95.6
26 January 2025	154.8	84.9	70.8	91.3	103.2
27 January 2025	157.9	66.8	83.8	107.4	134.9
28 January 2025	172.6	80.9	95.7	105.0	140.0
29 January 2025	174.5	26.2	103.8	107.2	141.0
30 January 2025	156.4	47.6	57.9	74.0	69.0
31 January 2025	170.1	46.3	48.0	54.1	64.4
01 February 2025	153.8	67.5	42.9	41.1	95.0
02 February 2025	122.8	57.4	61.5	67.6	75.6

Date	Lahore	Karachi	Islamabad	Rawalpindi	Peshawar
03 February 2025	115.1	61.3	54.0	70.1	99.5
04 February 2025	109.5	35.1	77.2	81.7	90.8
05 February 2025	130.9	55.0	74.9	84.9	76.8
06 February 2025	125.3	70.9	58.2	65.6	74.9
07 February 2025	91.0	47.1	60.2	69.6	74.0
08 February 2025	118.9	65.4	66.4	68.1	82.6
09 February 2025	148.8	93.4	71.5	74.3	115.9
10 February 2025	169.5	41.9	66.6	83.3	92.6
11 February 2025	119.6	35.6	59.1	47.4	62.7
12 February 2025	72.2	71.7	39.3	41.3	59.9
13 February 2025	80.4	117.0	36.5	40.6	56.2
14 February 2025	98.9	32.9	54.2	49.8	109.3
15 February 2025	80.5	25.5	47.0	53.2	102.4
16 February 2025	128.9	23.2	37.9	42.1	107.6
17 February 2025	120.3	55.3	47.7	43.0	67.3
18 February 2025	117.4	43.1	38.8	43.4	68.7
19 February 2025	111.8	20.8	54.5	44.8	53.4
20 February 2025	43.0	47.8	18.7	16.7	28.8
21 February 2025	46.2	82.3	36.3	34.4	53.1
22 February 2025	64.5	65.9	43.4	48.8	38.2
23 February 2025	88.2	57.0	41.5	46.7	58.4
24 February 2025	117.6	47.3	45.3	52.4	72.5
25 February 2025	98.2	91.1	54.0	52.2	14.4
26 February 2025	82.0	71.7	32.2	37.5	21.2
27 February 2025	70.4	34.0	35.5	38.8	37.0
28 February 2025	50.9	26.1	23.7	19.3	43.3
01 March 2025	45.5	33.8	26.2	28.9	35.5
02 March 2025	69.2	37.4	33.1	39.0	29.3
03 March 2025	64.3	30.1	15.7	17.5	13.6
04 March 2025	27.6	44.9	15.0	16.2	37.5
05 March 2025	36.9	42.1	14.5	19.4	34.3
06 March 2025	71.5	37.2	20.2	29.4	54.0
07 March 2025	111.0	40.6	21.5	30.9	56.9
08 March 2025	89.5	49.5	18.1	25.9	23.6
09 March 2025	69.7	49.1	25.8	29.1	61.3
10 March 2025	98.6	63.2	35.3	35.0	32.8
11 March 2025	63.3	58.5	39.1	30.2	37.4

Date	Lahore	Karachi	Islamabad	Rawalpindi	Peshawar
12 March 2025	69.5	33.3	24.9	24.4	37.7
13 March 2025	62.3	26.6	23.0	19.2	45.3
14 March 2025	42.8	27.5	22.2	17.5	33.1
15 March 2025	52.0	42.1	15.8	12.8	44.6
16 March 2025	52.0	40.8	17.0	18.3	33.4
17 March 2025	67.7	38.0	20.2	20.6	67.0
18 March 2025	62.4	32.6	23.2	27.3	63.7
19 March 2025	82.6	24.7	20.2	22.7	43.5
20 March 2025	57.0	25.6	15.8	17.6	41.7
21 March 2025	73.1	41.1	19.8	23.3	61.4
22 March 2025	79.7	32.8	18.0	27.1	51.9
23 March 2025	106.9	23.8	22.7	25.9	89.5
24 March 2025	91.7	23.1	34.1	40.0	89.9
25 March 2025	72.0	20.0	47.2	47.0	76.6
26 March 2025	74.6	21.4	28.7	29.1	28.6
27 March 2025	65.8	31.9	31.4	27.5	28.2
28 March 2025	33.1	39.0	10.3	11.3	17.5
29 March 2025	31.5	46.8	14.4	16.9	25.9
30 March 2025	45.4	35.6	18.6	25.7	34.0
31 March 2025	43.3	20.5	22.5	23.0	40.3
01 April 2025	49.4	20.1	39.7	32.9	34.2
02 April 2025	71.3	26.1	40.0	31.2	33.2
03 April 2025	51.8	29.5	33.2	26.6	29.1
04 April 2025	36.3	35.4	27.5	21.7	27.3
05 April 2025	49.8	22.9	30.1	27.0	38.6
06 April 2025	74.9	22.2	28.9	27.1	64.6
07 April 2025	82.6	29.3	32.9	32.7	70.7
08 April 2025	76.1	38.2	45.5	36.1	65.4
09 April 2025	74.5	37.4	27.9	20.8	43.2
10 April 2025	65.9	34.5	22.2	17.4	37.4
11 April 2025	33.3	32.0	15.6	12.5	42.3
12 April 2025	61.7	32.6	16.3	14.3	43.6
13 April 2025	42.2	31.5	24.9	18.8	70.3
14 April 2025	73.8	39.0	34.4	27.2	81.7
15 April 2025	57.8	33.5	48.3	36.1	78.2
16 April 2025	62.3	30.7	49.4	35.5	88.8
17 April 2025	51.6	27.3	31.4	27.7	77.8

Date	Lahore	Karachi	Islamabad	Rawalpindi	Peshawar
18 April 2025	54.3	25.5	32.3	27.8	70.3
19 April 2025	42.7	44.3	29.0	23.0	33.2
20 April 2025	53.9	50.3	39.7	29.0	23.3
21 April 2025	52.2	41.5	31.3	19.3	51.9
22 April 2025	54.7	37.5	35.3	21.8	77.4
23 April 2025	65.2	33.9	33.9	21.6	74.9
24 April 2025	98.2	31.6	21.0	19.9	64.0
25 April 2025	50.2	31.3	20.6	13.6	56.7
26 April 2025	59.2	40.3	18.4	16.6	38.6
27 April 2025	65.9	32.2	19.2	17.0	61.9
28 April 2025	81.5	28.8	22.7	21.7	62.9
29 April 2025	75.4	27.7	41.1	35.9	70.9
30 April 2025	68.7	26.8	67.2	53.2	114.9
01 May 2025	75.2	25.4	63.0	55.2	112.2
02 May 2025	37.0	27.2	19.2	18.5	26.8
03 May 2025	47.9	28.9	26.2	23.9	42.2
04 May 2025	38.9	28.0	30.2	21.7	58.1
05 May 2025	42.6	54.6	33.7	25.0	64.8
06 May 2025	57.3	29.7	34.9	28.6	67.1
07 May 2025	77.8	24.4	50.8	39.3	83.0
08 May 2025	65.4	21.3	63.9	51.7	65.9
09 May 2025	61.8	24.1	39.8	31.0	52.9
10 May 2025	77.6	32.7	31.1	22.2	39.9
11 May 2025	73.3	35.7	28.2	18.8	44.5
12 May 2025	57.3	33.5	15.4	11.6	36.6
13 May 2025	81.5	25.9	23.3	15.6	39.8
14 May 2025	77.4	23.8	23.3	19.3	45.8
15 May 2025	65.8	22.9	31.0	23.5	65.6
16 May 2025	51.2	19.7	27.9	19.3	60.8
17 May 2025	78.3	19.9	28.1	18.9	63.2
18 May 2025	63.3	19.2	40.5	29.6	64.5
19 May 2025	71.4	21.8	24.1	18.8	37.6
20 May 2025	78.6	21.9	38.1	25.5	58.4
21 May 2025	64.8	24.9	38.8	30.0	57.8
22 May 2025	42.8	26.5	45.8	31.2	70.4
23 May 2025	40.3	23.9	34.5	25.7	49.1
24 May 2025	41.0	21.3	33.4	24.6	50.8

Date	Lahore	Karachi	Islamabad	Rawalpindi	Peshawar
25 May 2025	21.9	23.9	14.3	15.5	34.3
26 May 2025	44.5	27.3	19.6	18.9	50.5
27 May 2025	62.2	26.5	24.4	17.8	58.8
28 May 2025	36.9	28.5	18.3	17.0	58.2
29 May 2025	57.3	31.7	23.7	20.2	77.1
30 May 2025	38.1	33.2	14.8	14.1	27.3
31 May 2025	42.1	30.0	14.5	12.4	29.5
01 June 2025	32.8	28.3	14.0	14.4	52.3
02 June 2025	38.1	39.2	13.6	11.4	50.7
03 June 2025	19.3	36.7	12.2	8.2	21.7
04 June 2025	26.0	26.9	17.9	11.6	25.6
05 June 2025	30.0	24.1	27.9	18.9	38.3
06 June 2025	43.6	24.6	41.4	29.3	60.9
07 June 2025	48.2	25.0	39.4	27.9	47.5
08 June 2025	33.4	24.4	28.1	18.0	31.0
09 June 2025	35.8	21.8	36.1	22.5	55.3
10 June 2025	32.2	21.0	33.2	25.4	48.9
11 June 2025	42.0	22.5	33.9	25.0	60.2
12 June 2025	44.9	23.1	34.8	22.3	41.0
13 June 2025	55.5	24.3	39.2	30.9	23.8
14 June 2025	41.7	26.6	35.3	26.7	20.9
15 June 2025	39.4	32.7	30.5	26.5	19.9
16 June 2025	55.7	36.6	39.4	28.0	77.7
17 June 2025	42.7	38.0	39.6	32.2	38.0
18 June 2025	48.9	31.9	40.6	32.1	52.9
19 June 2025	55.4	32.1	51.5	41.7	55.9
20 June 2025	45.4	28.2	58.2	48.5	59.2
21 June 2025	45.2	29.8	56.2	47.4	54.1
22 June 2025	51.0	31.9	23.1	19.0	29.8
23 June 2025	68.4	33.7	40.3	35.6	44.8
24 June 2025	45.3	35.4	61.9	51.9	52.5
25 June 2025	62.8	34.5	37.1	33.9	39.1
26 June 2025	44.2	38.6	30.6	27.1	32.9
27 June 2025	67.6	38.6	23.9	28.4	38.9
28 June 2025	60.3	39.6	40.8	38.5	34.1
29 June 2025	60.4	18.2	43.0	40.8	51.2
30 June 2025	38.2	32.8	32.4	27.1	20.1

Months	2017	2018	2019	2020	2021	2022	2023	2024	2025
Jan	141.6	221.6	192.4	151.2	140.0	149	156.6	160.4	150.7
Feb	109.6	121.6	116.5	114.5	131.5	114.3	130.4	102.9	102.7
Mar	89.4	89.6	83.4	51.3	54.3	96.9	86.7	85.1	64.9
Apr		67.3	70.9	33.9	40.3	81.4	58.8	49.1	61.3
May		65.4	65.6	43.5	33.5	74.8	58.0	63.0	57.2
Jun		67.3	55.6	42.8	30.9	63.8	49.7	40.0	45.1
Jul		58.4	50.7	44.0	26.7	57.4	42.7	60.8	
Aug		50.3	48.8	34.5	36.1	51.5	44.3	40.6	
Sep		54.9	63.4	61.9	49.8	70.7	57.2	60.2	
Oct	280.8	152.1	17.5	113.1	91.8	131.5	128.1	127.1	
Nov	316.7	186.7	139.0	149.1	228.5	202.9	252.4	286.4	
Dec	204.0	227.8	195.9	158.0	231.9	201.4	208.1	162.1	
Average	**196.3**	**118.0**	**100.0**	**83.1**	**91.0**	**108.0**	**105.9**	**104.6**	**80.3**

Table A2: Monthly and Annual Average PM2.5 Concentrations (µg/m³) in Lahore (2017-2024). **Lahore's "fifth season" of smog is evident in the dramatic winter spikes, with monthly averages in November and December frequently exceeding 200 µg/m³, more than 40 times the WHO guideline.**

Months	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Jan		86.8	80.8	50.4	83.4	87.5	67.1	89.5	113.7	86.4
Feb		60.0	59.3	23.9	72.3	103.1	50.8	64.4	67.7	55.1
Mar		29.2	44.6	20.7	42.0	45.6	45.0	50.9	46.9	35.9
Apr		25.9	54.1	13.3	27.5	41.7	36.9	29.6	30.2	32.5
May		41.7	41.7	11.4	26.2	31.6	40.5	27.2	25.7	27.0
Jun		24.4	43.2	12.4	27.3	32.7	26.3	29.6	26.6	30.0
Jul		22.9	42.5	13.9	26.2	29.5	21.0	31.1	27.1	
Aug		19.1	37.2	17.6	26.7	24.5	29.7	27.8	21.0	
Sep		17.6	23.1	37.8	33.8	33.3	33.0	45.7	26.3	
Oct	27.9	32.1	46.3	55.2	52.0	54.3	47.9	36.4	38.1	
Nov	63.0	62.4	49.8	71.9	109.3	99.0	74.8	107.9	47.7	
Dec	65.7	67.5	49.4	122.8	126.7	90.8	112.1	94.0	83.8	
Average	**53.5**	**38.8**	**47.9**	**37.7**	**54.3**	**58.2**	**48.7**	**52.2**	**46.2**	**44.5**

Table A2: Monthly and Annual Average PM2.5 Concentrations (µg/m3) in Karachi (2016-2025). **Karachi's winter months (Nov-Jan) consistently show the highest PM2.5 levels, with several years exceeding 100 µg/m³ in monthly averages, over 20x WHO guidelines.**

Months	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Jan		93.7	52.5	37.4	65.3	71.6	55.6	75.9	159.8	78.3
Feb		36.9	26.6	24.7	54.1	70.3	40.3	53.8	53.6	49.2
Mar		34.9	20.4	18.6	27.6	28.8	27.2	39.4	28.9	23.0
Apr		24.8	23.0	17.7	22.8	18.3	18.0	26.7	19.1	32.0
May		29.8	28.3	24.2	19.4	19.2	13.8	24.3	22.6	30.8
Jun		29.0	46.3	25.0	30.4	24.6	32.8	30.3	30.8	35.2
Jul		31.6	36.5	31.6	33.5	26.9	35.2	26.5	30.1	
Aug		30.4	72.6	29.7	26.9	34.5	32.6	33.9	20.2	
Sep		35.7	40.3	43.8	32.1	32.1	42.5	34.9	29.4	
Oct		59.9	37.3	46.9	42.8	42.8	51.1	45.7	45.9	
Nov		77.5	49.7	50.7	54.8	54.8	71.9	73.6	87.3	
Dec	56.9	46.0	70.6	102.0	68.4	68.4	106.2	96.1	99.3	
Average	**56.9**	**41.8**	**39.2**	**37.8**	**39.8**	**39.8**	**44.8**	**46.8**	**52.3**	**41.4**

Table A4: Monthly and Annual Average PM2.5 Concentrations (µg/m³) in Islamabad (2016-2025). **Even the capital is not immune to the winter crisis; while cleaner in summer, Islamabad sees monthly averages surge past 150 µg/m³ in January, indicating a severe seasonal deterioration in air quality.**

Months	2018	2019	2020	2021	2022	2023	2024	2025
Jan		80.0	84.0	116.7	46.3	106.1	117.8	93.3
Feb		58.5	66.8	104.5	31.8	93.6	70.5	52.1
Mar		39.3	33.2	43.0	21.4	55.2	42.7	25.1
Apr		32.1	20.7	25.5	16.0	31.6	22.9	25.5
May		25.6	18.7	30.2	12.1	24.9	26.8	24.0
Jun		24.6	26.7	33.9	12.4	26.8	27.1	28.4
Jul		32.9	32.3	33.6	8.7	26.6	28.9	
Aug	50.2	26.6	22.7	38.7	8.1	37.8	24.8	
Sep	37.6	37.7	35.4	39.6	19.4	42.2	33.8	
Oct	44.6	34.0	59.6	45.7	59.2	54.6	53.5	
Nov	73.6	46.1	97.4	91.3	108.5	93.5	97.0	
Dec	117.2	110.0	112.6	80.0	143.2	109.7	126.2	
Average	**68.1**	**45.7**	**50.9**	**56.4**	**38.8**	**58.4**	**61.1**	

Table A5: Monthly and Annual Average PM2.5 Concentrations (µg/m³) in Rawalpindi (2018-2025). **Rawalpindi consistently experiences more intense pollution than its twin city, with winter monthly averages peaking above 170 µg/m³, driven by heavy traffic and urban density.**

Months	2017	2018	2019	2020	2021	2022	2023	2024	2025
Jan	76.2	142.0	78.1	54.3	230.4	86.1	136.9	256.7	129.7
Feb	63.3	58.1	43.7	44.7	259.2	63.7	90.0	95.6	69.0
Mar	48.9	57.5	29.5	35.4	75.5	47.0	61.4	56.5	44.2
Apr	42.8	46.7	52.9	27.3	50.4	44.0	39.1	35.1	57.6
May	42.9	30.8	50.4	30.5	42.6	40.0	39.9	37.4	54.6
Jun	40.9	44.5	57.0	40.2	52.6	53.5	47.5	40.1	42.6
Jul	45.4		52.8	38.9	53.4	54.2	43.1	41.2	
Aug	49.8		41.4	36.0	53.7	57.4	52.4	43.2	
Sep	67.2		61.0	42.2	58.7	73.8	59.7	65.0	
Oct	78.6		78.5	48.3	58.6	120.5	89.4	110.9	
Nov	126.2		77.8	43.8	61.2	206.2	162.6	162.0	
Dec	96.3	116.1	109.0	87.0	85.0	291.3	185.8	203.1	
Average	**62.5**	**76.8**	**64.7**	**43.9**	**101.3**	**95.9**	**84.0**	**95.8**	**66.4**

Table A6: Monthly and Annual Average PM2.5 Concentrations (µg/m³) in Peshawar (2017-2025). **Trapped by its valley geography, Peshawar records some of the highest concentrations in the country, with monthly averages in January soaring past 250 µg/m³, creating a profound winter health emergency.**

Note on Complete Dataset: The tables above presents a sample of daily data. The complete, unabridged dataset, spanning from October 2016 to the present, is openly available for research, public use, and verification. The full dataset has been permanently archived and can be accessed and cited via the following Digital Object Identifier (DOI): https://doi.org/10.5281/zenodo.17629179

Air pollution is a **national emergency** that reduces the life expectancy of the average Pakistani by 3.9 years.

"With rigour and precision, [this report] provides the evidence base to finally move from rhetoric to reform. It is a foundational document for policymakers, regulators, civil society, and citizens alike. It maps the sources of our crisis, counts the human and economic costs, and offers a blueprint for action rooted in science, feasibility, and justice. Finally, it is a **call to action** that we cannot afford to ignore."

Senator Sherry Rehman
Former Federal Minister for Climate Change

"A comprehensive framework for addressing the issues of air pollution... [serving] as a 'living document' to address emerging concepts and issues in the ever-evolving science of climate change."

Justice Syed Mansoor Ali Shah
Senior Puisne Judge, Supreme Court of Pakistan

Pakistan Air Quality Initiative

Pakistan Air Quality Initiative (PAQI) is an independent research and advocacy organisation dedicated to providing robust scientific insights and data-driven solutions to overcome Pakistan's air pollution crisis.

9 786277 928025