Unpacking the Smog Crisis in Punjab - Key Areas of Research

Zuhair Murad Khan

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**This article is a follow-up to "Pakistan's air pollution calamity—no quick fixes" by Dr. Sanval Nasim, Assistant Professor of Economics at Colby College. It explores how researchers at the International Growth Centre are studying the major contributors to Lahore's hazardous air quality."*

Punjab, the most populous province of Pakistan, faces a severe smog crisis each winter, resulting in significant health risks and economic burdens. The smog stems from industrial emissions, agricultural crop burning, vehicular pollution, and waste burning. This note examines the health costs associated with smog in Punjab, explores interventions in key sectors, and highlights relevant projects by the International Growth Centre (IGC) aimed at mitigating air pollution in Pakistan.

Health Costs

Exposure to high levels of air pollutants, such as fine particulate matter (PM2.5 and PM10), nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3), has led to a surge in respiratory and cardiovascular diseases in Pakistan, especially in the Punjab province. According to the World Health Organization (WHO), ambient air pollution contributes to an estimated 128,000 premature deaths annually in Pakistan, with Punjab bearing a significant portion due to its dense population and industrial/agricultural activities (WHO, 2016). The Air Quality Life Index (AQLI), developed by the Energy Policy Institute at the University of Chicago (EPIC), establishes a causal relationship between PM2.5 exposure and life expectancy. According to the index, an average Pakistani loses 3.32 years on their life expectancy by breathing polluted air. This alarming figure rises to 7.5 years for people living in Lahore.

Respiratory illnesses such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) have increased markedly during smog episodes. An IGC study on clean brick kilns found that PM2.5 exposure increases the incidence of cancer and cardiovascular and respiratory diseases such as ischemia, myocardial infraction, asthma, and bronchitis (Nasim and Sharif, 2020). Hospitals in Lahore have reported a significant rise in patients presenting with respiratory conditions during high pollution periods (Khurshid et al., 2019). Children are particularly vulnerable. Studies indicate that approximately 40% of school-aged children in urban areas exhibit reduced lung function during smog events (Raza et al., 2018). Punjab experienced a pneumonia epidemic last winter, with 36,054 reported cases of

pneumonia leading to 456 deaths (Pakistan Today, 2024).

The health impact of smog translates into substantial economic costs. Increased healthcare expenditures strain both public resources and household finances. The World Bank estimates that air pollution costs Pakistan approximately 6.5% of its GDP annually, accounting for lost labour income, productivity losses and healthcare expenses (World Bank, 2019). Educational disruptions also occur, as schools often close during severe smog conditions, affecting learning outcomes.

Major Contributors to Smog

Addressing the smog crisis requires a multifaceted approach targeting the primary contributing sectors.

In the industrial sector, many factories have outdated technology leading to the release of high levels of pollutants. Mandating the installation of emission control equipment—such as electrostatic precipitators, fabric filters, and flue-gas desulphurization units—can substantially reduce emissions. Strengthening environmental regulations and ensuring strict enforcement through regular inspections and penalties for non-compliance are critical measures.

Agricultural crop burning is another major contributor to smog. Farmers often resort to burning crop residues due to economic constraints and lack of awareness of alternative methods. Promoting sustainable agricultural practices, such as the use of machinery like Happy Seeders, which allow direct sowing without removing crop stubble, can eliminate the need for burning. Providing financial incentives, subsidies, or access to affordable machinery can encourage farmers to adopt these practices. Educational campaigns are essential to raise awareness about the environmental and health impacts of crop burning and the benefits of alternative methods. Even during the COVID lockdown from March 2020 to May 2020 when vehicle usage and industrial activity was halted, Lahore recorded a maximum mean PM2.5 concentration of 108 μgm^{-3}, ranging from 51 to 215 μgm^{-3}, three times higher than Pak-EPA and US-EPA and four times higher than WHO guidelines (Mehmood et al., 2021). This demonstrates that crop burning contributes significantly to PM2.5 levels in Pakistan.

Vehicular emissions significantly increase air pollution in Punjab, worsened by an aging fleet of vehicles and poor fuel quality with high sulphur content. Implementing stricter emission standards, such as adoption of Euro 5 or Euro 6 standards and establishing regular vehicle inspection and maintenance programs can reduce emissions[1]. Improving fuel quality by reducing sulphur content and promoting alternative fuels are important steps. Investing in public transportation infrastructure to reduce reliance on private vehicles is also crucial.

Open waste burning also contributes to smog due to inadequate waste management systems. Implementing integrated waste management practices—including proper waste collection, segregation, recycling, composting, and disposal—can mitigate this issue. Enacting and enforcing legislation prohibiting open waste burning, coupled with public education campaigns to raise awareness about the health risks, are necessary steps. While legislation exists to combat crop burning, weak enforcement and

[1]Euro 5 and Euro 6 fuel standards are benchmarks for cleaner, low-emission fuels designed to reduce harmful pollutants like sulphur oxides, nitrogen oxides, and PM2.5. Euro 6 fuel, the strictest standard, contains significantly lower sulphur levels than Euro 5, further minimizing environmental and health impacts. Pakistan, however, largely relies on low-quality Euro 2 and Euro 3 fuel with high sulphur content, which exacerbates air pollution and contributes to smog, respiratory diseases, and environmental degradation. Transitioning to Euro 5 and Euro 6 fuel can play a pivotal role in curbing emissions and addressing the country's escalating air quality crisis.

the lack of affordable alternatives have limited compliance. Punjab banned crop burning in October 2019, imposing fines of up to PKR 50,000 (US$300) per acre for violations. Farmers find these fines manageable and continue burning stubble, highlighting the need for additional measures to make the bans effective (International Growth Centre, 2022). Such measures will have to find ways to get around the political unpopularity of penalizing farmers.

IGC Research Projects on Air Quality

The International Growth Centre (IGC) has been actively involved in research and initiatives to reduce air pollution in Punjab. This section describes IGC projects and interventions aimed at potential solutions to the air pollution problem in Punjab.

A. Industrial Emissions

Researchers from the IGC are working with the Environmental Protection Department (EPD) in Punjab to pilot an emissions rating system. This research project introduces a transparent, data-driven system that ranks industrial plants based on their compliance with emissions standards[2]. Industrial units are monitored for particulate matter emissions and then rated from 1 to 5 stars depending on their adherence to EPD's regulatory benchmarks. Such programmes have proven successful internationally, creating competition among firms to maintain high environmental standards while empowering stakeholders—such as investors, customers, and civil society—to hold these firms accountable. By publicly disclosing environmental performance, these programmes incentivize firms not only to comply with emissions standards but also to adopt better pollution control technologies to protect their reputation and financial performance.

This project's experimental design involves a randomized controlled trial (RCT), with the treatment group receiving ratings based on emissions data. The researchers monitor emissions over time to evaluate whether this transparency mechanism results in significant reductions in emissions and an improvement in regulatory compliance. If successful, the findings will provide a solid case for EPD to scale up the programme to cover more firms.

B. Agricultural Emissions

An IGC project is evaluating Agriculture Department Punjab's Mechanised Management of Rice Crop Residue (MMRCR) program, which provides 80% subsidies on equipment like Rice Straw Shredders and Happy Seeders to encourage environmentally friendly farming practices[3].

Punjab's heavy reliance on rice-wheat cropping leaves significant crop residue. This is often burned by farmers, releasing large amounts of particulate matter (PM10, PM2.5) and greenhouse gases. The project focuses on addressing these emissions by evaluating whether financial support for environmentally friendly technology can encourage farmers to adopt non-burning practices. Notably, the MMRCR program aims to help farmers reduce emissions by shredding and reincorporating stubble into the soil, potentially reducing emissions by 78% or more. Green agricultural technology such as Rice Straw Shedders and Happy Seeders reincorporate the stubble back into the soil, which improves agricultural productivity. Happy Seeders save water by minimizing soil disturbance and retaining crop residue as mulch, which reduces evaporation. The mulch also helps maintain soil moisture, reducing the need for frequent irrigation.

[2]Ali Habib, Sanval Nasim, Usman Naeem and Michael Greenstone. Emissions rating programme: environmental impacts and firm behaviour. IGC Pakistan, 2020.
[3]Usman Naeem, Michael Greenstone and Kelsey Jack. Can subsidizing green agricultural technology reduce smog? An experimental study. IGC Pakistan, 2022.

This study also uses a Randomized Controlled Trial (RCT) approach dividing farmers into two groups: those who receive subsidies for equipment (treatment group) and those who do not (control group). This allows researchers to examine how the subsidies influence three outcomes: the adoption of the equipment, the reduction in stubble burning, and potential improvements in crop yields due to better soil health. To gather data, researchers conduct random field visits to observe whether farmers are using the equipment and to look for signs of burning. They are trained to identify indicators such as partially burnt vegetation, baled straw, and the presence of equipment like the Happy Seeder in fields. This detailed monitoring ensures accurate measurement of the program's impact on farming practices and environmental outcomes.

The outcomes of this study will help the Punjab government to refine the MMRCR program. Beyond measuring immediate environmental benefits, the project aims to inform future program adjustments, such as targeted subsidy approaches or establishing a rental market to make the technology more accessible. These insights are intended to provide scalable solutions for air quality improvement, offering a model for other regions grappling with similar agricultural pollution challenges.

C. Vehicular Emissions

IGC researchers are also addressing Lahore's air pollution crisis by studying the overlooked effect of public transport on emissions. Vehicular emissions are a major contributor to Lahore's air pollution, with idling alone accounting for 31% of the city's transport-related CO emissions and consuming 26% of annual fuel—emissions comparable to melting 1% of the Siachen Glacier each year.

IGC researchers are examining how mass transit systems can reduce congestion and pollution in rapidly growing cities[4]. As private car and motorcycle ownership increases, urban areas face rising traffic, air pollution, and accessibility challenges, especially for low-income residents. This study evaluates Lahore's Metrobus BRT system using a quasi-experimental method, comparing areas served by the BRT to those awaiting service. Findings to date show that the BRT has cut commuting costs and time, leading to a 24% increase in public transit use among nearby commuters, with 35,000 people switching to the system citywide. This shift has reduced CO2 emissions by 82,320 metric tons annually. The Metrobus also attracts more educated users, highlighting its quality and reliability.

D. Citizen Engagement

IGC researchers have investigated the impact of improved indoor air quality on student learning in Lahore[5]. A completed study employed a randomized design across 132 schools in Lahore. Air purifiers were installed in Grade 2 classrooms in 60 schools (the treatment group), and air quality monitors were deployed in 100 schools to measure PM2.5 levels inside classrooms. The study was conducted over three months, covering both low and high pollution seasons. The results showed significant improvements in indoor air quality in the treated classrooms. These reductions averaged at least 0.5 standard deviations[6] lower PM2.5 levels compared to classrooms without purifiers.

[4]Hadia Majid and Kate Vyborny. Urban Transportation, Labour Markets and Access to Economic Opportunity: Evidence from Lahore's Bus Rapid Transit System. IGC Pakistan, 2018.
[5]Samreen Malik, Talha Naeem, David Blakeslee, Torsten Figueiredo Walter, Nitin Bharti. Clean Air in the Classroom: Environmental Inputs and Human Capital Formation. IGC Pakistan, 2023.
[6]Standard deviation measures the spread of a number from the mean. A low standard deviation means most numbers are close to the average, while a high standard deviation means they vary widely.

To assess learning outcomes. standardized tests were administered to both treatment and control schools at two points: midline (after one month of exposure to clean air) and endline (following the winter holiday break). Midline data revealed a notable 0.19 standard deviation improvement in test scores among students in treated classrooms, suggesting that sustained exposure to clean air positively influences cognitive performance. The endline results did not reflect a meaningful effect of the air purifiers, due to the fact that it was conducted a week after a prolonged winter break which undid the benefits of the cleaner air in school.

This research highlights the value of sustained, cumulative exposure to clean air to realize cognitive benefits, emphasizing that short-term exposure alone may not yield enduring results. The findings call into question the current policy of school closures during peak pollution periods, suggesting that reducing indoor air pollution in classrooms is a more practical and effective approach to supporting children's cognitive and health outcomes.

Another IGC study looks at the impact of providing air quality forecasts to empower residents to make informed decisions to protect their health. Conducted in working-class neighbourhoods in Lahore, this study ran two pilot programs involving nearly 1,000 participants. In the first, participants were divided into four groups: a control group, a forecast-only group receiving SMS alerts, a training-only group, and a combined group that received both forecasts and training. A second pilot examined the demand for forecasts attributed to government versus private sources.

The findings revealed a strong demand for air quality information, with residents willing to pay for daily forecasts at a rate comparable to 60% of monthly mobile internet costs[7]. Exposure to forecasts significantly influenced behaviours: participants used N95 masks more frequently and adjusted outdoor time by 16% on low-pollution days and 3% on high-pollution days. Notably, residents showed equal willingness to pay for information from government and private sources, despite concerns about the perceived accuracy of government data. Forecasting and training reduced errors by 5 μg/m³ PM2.5—about 20% of WHO's exposure threshold—demonstrating the long-lasting benefits of forecast accuracy.

E. Identifying Smog Hotspots

At the request of the Environmental Protection and Climate Change Department, Punjab (EPCCD), the IGC will pilot two distinct smog alert systems: one for government officials and another for citizens[8]. The initiative digitizes newly established protocols that outline roles for various departments—transport, agriculture, police, and education—during smog emergencies, as well as citizen guidance on protective measures. The government protocol mobilizes agencies for quick responses, while the citizen alert differentiates standard and sensitive groups, providing each with targeted risk information and protective steps.

These systems will be developed as apps in partnership with computer scientists and will draw on real-time air quality data from industrial-grade monitors installed by the EPCCD across Lahore, with backup readings from other established sources like the US Consulate's monitor and low-cost private sensors. By leveraging a pre-existing pollution forecasting model, these monitors will enable timely air quality predictions to trigger alerts.

[7]Monthly mobile data costs are roughly 238 PKR for a social bundle. For example, the Social Plus plan by Jazz includes 10Gb of data, 300 minutes of calls in-network, 50 minutes out-of-network, and 1,000 SMS messages and is priced at PKR 260 as of August 2023.

[8]Sanval Nasim and Arman Rezaee. Developing a Smog Alert System in Lahore to enhance Public Response and Policy Decisions. IGC Pakistan, 2024.

The apps will be piloted with officials and 500 households in a representative neighbourhood in Lahore, such as Walton or Harbanspura. Through surveys and focus group discussions, the study will examine responses to smog alerts among both government agents and citizens. For bureaucrats, the project will assess whether they act on their assigned tasks under various pollution levels and identify any operational challenges they face. For citizens, the focus is on how alerts influence avoidance behaviors—like spending more time indoors or using N95 masks—and whether government responsiveness impacts their likelihood to engage in collective action, such as lodging complaints via the government's Citizens' Portal.

This project aligns with the IGC's goals by addressing both mitigation and adaptation to pollution. It enhances interdepartmental coordination for mitigation while equipping citizens with information to protect their health. Building on previous research showing high citizen demand for air quality information, this project will provide citizens with knowledge and a potential mechanism for accountability. Insights from this pilot will inform a larger study to deepen our understanding of how real-time air quality alerts impact public and government behaviours.

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Zuhair Murad Khan

About the Author

Zuhair Murad Khan is a Country Economist at the International Growth Centre (IGC), Pakistan.

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