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IMPROVING LAHORE'S AIR QUALITY

POLICY RECOMMENDATIONS AND STRATEGIC INSIGHTS

BACKGROUND; LAHORE'S POOR AIR QUALITY

Pakistan's air quality crisis has a devastating impact on public health. Fine particulate matter such as $PM_{2.5}$, carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) are among the most harmful pollutants affecting public health. Exposure to $PM_{2.5}$ contributed to 114,000 deaths in 2019, reducing the average life expectancy by 2.7 years (Correia et al., 2012; MoCC & EC, 2023; Pillarisetti et al., 2016). Pakistan's second-largest city, Lahore, with exceeding 13 million residents faces a serious challenge of air pollution. This issue poses significant health risks to its residents. Lahore consistently ranks among the most polluted cities globally, with high $PM_{2.5}$ concentrations i.e., up to ~60 times, far exceeding safety limits of $5 \mu g/m^3$ established by the World Health Organization (WHO).

The rapid rise in vehicles emit significant quantities of NO_2 , CO, and $PM_{2.5}$. Industrial activities, including factories and poorly regulated brick kilns, further pollute the air. Construction projects generate fugitive dust, adding to the problem. Additionally, when farmers burn agricultural residues, it causes periodic spikes in pollution levels in surrounding areas (Health Effects Institute, 2020; MoCC & EC, 2023). All these factors contribute to the annual crisis of smog that has severe health consequences for Lahore's residents, causing respiratory problems, eye irritation and even heart diseases

PROBLEM

Exposure to air pollutants can lead to respiratory illnesses including asthma, chronic obstructive pulmonary disease (COPD), and pneumonia; cardiovascular diseases such as heart attacks, strokes, and high blood pressure; lung cancer and other health problems including cognitive decline, diabetes, and even birth defects (Andersen et al., 2015; Burnett et al., 2018; Idani et al., 2020). Certain demographics, like children under 18 years, pregnant women, and older adults, are more vulnerable to health complications due to air pollution exposure (US EPA, 2024). Lahore's poor air quality is estimated to harm public health, impacting quality of life and potentially reducing life expectancy. In addition, this poor air quality situation imposes a significant burden on the healthcare system. Furthermore, smog formation reduces visibility which hinders flight schedules, directly impacts the city's economic activities due to delays in transportation, and serves as the main cause of accidents on highways and motorways. Moreover, acid rain damages ecosystems and reduces agricultural productivity. Therefore, addressing Lahore's poor air quality is essential for creating a sustainable and healthy environment for the city's residents and future generations.

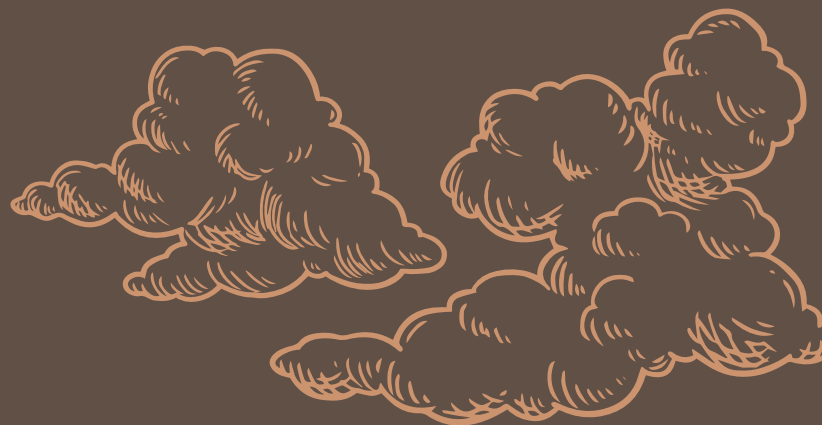
METHODOLOGY

In the case of the metropolitan city of Lahore, the literature review and data acquisition involved gathering a comprehensive and diverse set of air quality data reported and published from 2013-2024. Prominent scientific databases such as Web of Science, Google Scholar, and ScienceDirect were utilised for a thorough search of peer-reviewed scientific articles relevant to specific air pollutants in Lahore ($PM_{2.5}$ and PM_{10} , SO_2 , NO_2 , CO).

» A total of 21 scientific articles published in English language journals (local and international) related to each of $PM_{2.5}$ and PM_{10} , SO_2 , NO_2 , and CO were considered in this study.

Apart from peer-reviewed scientific studies, the following data sources reporting air quality data in the mentioned period were also considered for the comprehensive assessment of Lahore's air quality:

- » Environmental Protection and Climate Change Department (EP&CCD), Punjab
- » US Consulate's Monitoring via US EPA approved Beta Attenuation Method (BAM).
- » Urban Unit's Monitoring via US EPA approved BAM.



RESULTS AND FINDINGS

 **Air pollution levels:**
Levels of air pollutants specifically $PM_{2.5}$ in various regions of Lahore are significantly higher, nearly up to 62 and 20 times higher than permissible limits of WHO ($5 \mu g/m^3$) and NEQS ($15 \mu g/m^3$), respectively. Considering $PM_{2.5}$ monitoring data, the top five polluted regions in Lahore include Jalo, Batapur, Shimla Hill, Town Hall, and Canal View Society, where $PM_{2.5}$ levels were ~22-62 times and ~7-20 times higher than WHO and NEQS limits. Therefore, air quality in Lahore is severely degraded.



Seasonal variation of air pollutants:

Throughout the year, irrespective of the seasons whether summer or winter, air pollution levels remained high. However, meteorological parameters such as ambient temperature, wind speed (WS), and rainfall (RF) exhibited significant influence on air pollutant levels. For instance, during the year 2022 the $PM_{2.5}$ levels in Township were at a minimum of $\sim 72.3 \mu\text{g}/\text{m}^3$ (although higher than the allowable limits of WHO and PEQS) during monsoon (MoS) season owing to high ambient temperatures (31.4°C), WS (8.7 mph) and RF (4.5 mm) promoting particle to gas partitioning, wet deposition and dispersion, respectively. The maximum $PM_{2.5}$ levels ($\sim 192.7 \mu\text{g}/\text{m}^3$) were found to be during winters due to low ambient temperature (13.5°C), WS (3.8 mph) and RF (1.5 mm) promoting condensation of semi-volatile particles from gas phase to particle phase, minimal wet deposition, and low dispersion, respectively.



EP & CCD–Punjab monitoring efforts and gap:

Although, extensive efforts are in place by EP & CCD-Punjab to monitor $PM_{2.5}$ levels (more than 30 regions of Lahore have been covered for monitoring purposes). However, relatively less effort has been made so far to monitor gas pollutants (NO_2 , SO_2 , CO , and O_3). Till now, in the case of gaseous pollutants, only seven sites have been covered; and levels of most gas pollutants were found to be higher than the allowable limits of WHO and PEQS. In addition, in the case of a certain region or site, simultaneous monitoring of all pollutants including $PM_{2.5}$, NO_2 , SO_2 , CO , and O_3 over a longer period such as that of years is lacking. This needs to be improved substantially as the whole data set can provide substantial information regarding relationships between various pollutants, source identification, etc., which are important for evidence-based policy making and devising regulations for effective air pollution control and mitigation.



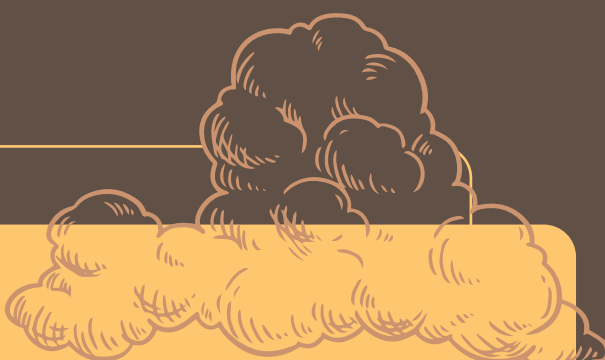
Source Apportionment Studies:

These scientific studies have identified key contributors to Lahore's visible air pollution: vehicular emissions, crop residue burning, industrial processes, coal combustion, dust and secondary aerosol formation. Focusing on $PM_{2.5}$, the primary source is typically vehicular emissions, followed by significant contributions from crop residue burning and industrial emissions, particularly those linked to coal combustion. Dust and secondary organic aerosol formation appear to have a lesser impact on $PM_{2.5}$ levels in Lahore.



Health risk assessment:

The health risk was evaluated by estimating the Health Hazard Quotient (HHQ) for all three age groups (infants, children and adults), during the period between June 2021 and March 2024 in the case study of Township, Lahore, which suggested that the HHQ values varied in the range of 27.8-34.2 and 9.3-11.1 concerning HHQ criteria of 1.0. The former and later HHQ ranges were estimated considering permissible limits of WHO ($5 \mu\text{g}/\text{m}^3$) and PEQS ($15 \mu\text{g}/\text{m}^3$), respectively, suggesting high health risk for the residents throughout the year.



POLICY RECOMMENDATIONS

Considering poor air quality in Lahore, the following are the policy recommendations which can be beneficial in significantly improving air quality, thereby, maintaining a sustainable and healthy environment for its residents.

I. Low-cost sensor-based monitoring (Short-term):

Low-cost sensor-based air quality monitoring systems (LC-AQMS) have emerged as crucial tools for air quality data collection, monitoring and analysis, source identification, and forecasting. These systems, comprising sensors, hardware, and software, measure pollutants such as $PM_{1.0}$, $PM_{2.5}$, NO_2 , SO_2 , NH_3 , and O_3 . In addition, they are significantly more affordable than traditional Reference Grade Monitors (RGM) (costing \$200-\$1000 compared to \$20,000-\$30,000). In recent years, LC-AQMS have seen widespread adoption in both developed and developing nations. While traditional RGM networks remain crucial, they are often limited by cost and infrastructure, leaving significant gaps in air quality data, particularly in low and middle-income countries. A prime example is the WHO report published in 2023 indicating that only eight per cent of settlements with RGM data were in low- and middle-income countries (Shairsingh et al., 2023; WHO, 2023). To bridge this gap, LC-AQMS have emerged as a valuable tool to employ and expand air quality monitoring efforts across the globe. LC-AQMS have gained significant traction in Pakistan due to their affordability and potential to fill gaps in air quality monitoring infrastructure. However, the utilisation of LC-AQMS in Pakistan for air quality monitoring, respective evidence-based policy development and decision-making is still limited. Therefore, in the case of Lahore, considering LC-AQMS's air quality monitoring effectiveness and low cost, their utility will be effective in air quality monitoring and evidence-based decisions.

II. Transportation sector; Implementing Euro VI standards (Short-term):

In Pakistan, Euro II vehicular emission standards are implemented. European countries are complying with Euro VI emission standards which are more stringent than Euro II emission standards. Developed countries including the US, Japan, South Korea, etc., have implemented vehicular emission standards which are comparable to and/or more stringent than Euro VI standards for vehicles. In the case of regional countries such as China and India, both have implemented stringent standards which are comparable with Euro VI emission standards for vehicles. Therefore, in Pakistan's case and specifically in Lahore and various districts of the Punjab province dealing with terrible air pollution levels, it is important to adopt more stringent vehicular emission standards such as implementing Euro VI standards. In addition to implementing Euro VI standards, other policy interventions can be considered, for instance, relatively new vehicles which were registered in the year 2020 and onwards must comply with Euro VI standards. Relatively older vehicles can comply with less stringent emission standards such as Euro IV or maybe Euro II. In this context, criteria can be established in consultation with relevant stakeholders.

III. Transportation sector; Implement mandatory vehicular emission testing (Short-term):

In developed countries, a Vehicle Emission Certificate (VEC) from a certified motor testing service provider is mandatory for any vehicle to be able to legally operate on roads and highways. In the case of Pakistan, the Punjab Government took a great initiative in 2016 and inaugurated the Punjab Vehicular Inspection and Certification System (VICS) under Public Private Partnership (PPP). There are two primary functions of VICS. (i) To check the general health of the vehicle considering safety and (ii) to conduct vehicular emission tests. Currently, VICS services are optional. It can be made mandatory in major districts of Punjab including Lahore. Also, considering effective implementation and motivating the general public to get their vehicular emission certifications, a financial subsidy can be given in terms of a reduction in yearly token tax, which is mandatory for each registered vehicle. On the other hand, non-compliant vehicles with no or failed emission tests can be handled by imposing fines and taxes.

IV. Transportation sector; Integrated traffic management via Low-cost Air Quality Monitoring (Medium-term):

Specifying air pollution hotspots within various regions of Lahore using an integrated low-cost air quality monitoring systems (LC-AQMS) and synchronized traffic management such as during peak hours of vehicular traffic and providing alternate routes to avoid traffic congestion can appreciably reduce the localized emissions of vehicular pollutants to already compromised air quality.

V. Agricultural sector; Crop Residue Management via Farmer's Capacity Building and Alternative Uses (Medium-term):

Considering crop residual burnings, a significant policy intervention can be the capacity-building of farmers to implement already established techniques such as compost preparation and mulching of their crop residues. In this context, the role of NGOs such as WWF-Pakistan can be substantial considering its exemplary role in similar capacity-building initiatives. For instance, recently, WWF-Pakistan successfully conducted capacity-building programmes for farmers of the Jhang district in Punjab, to enhance the productivity and yield of sugarcane crops. WWF-Pakistan also promoted alternative energy solutions among off-grid rural communities and small culinary vendors by distributing agro-waste gasifier units. Therefore, launching such capacity-building initiatives and programmes can have a significant impact not only on the skill development of farmers to produce compost (i.e., natural fertilizer) but also on economic benefit by replacing costly synthetic fertilizers with compost. In addition, this could have a positive impact on air quality by reducing emissions from crop burning.

VI. Industrial sector; Promoting renewables and enforcing compliance (Medium to Long-term):

In case of the industrial sector such as textile factories, foundries, steel mills, and other manufacturing facilities, especially those located in Lahore and its vicinity, must have air pollution control devices in place, particularly where solid fuels are burned in boilers. Shifting to biomass for steam generation should be promoted, as it creates a win-win situation where agricultural residues are not only properly managed but also become a source of low-carbon energy for the industry. However, these systems must be designed to control particulate emissions associated with biomass combustion; otherwise, they become consistent point sources of particulate emissions. A successful case study is the 41 MW biomass-based power plant at Bulleh Shah Paper Mills in Kasur, Punjab. Additionally, switching to clean energy sources like solar PV can reduce thermal requirements, decreasing the need for solid fuel combustion.

VII. Construction sector; Policy considerations to minimize fugitive dust (Short-term):

Fugitive emissions, primarily dust and fine particulates (i.e., $PM_{2.5}$) released during construction activities, are a significant environmental concern. Specific measures should be implemented to such emissions during construction activities including fencing the construction parameters to control wind erosion using nets, covering construction materials such as sand, gravel, etc., using tarpaulins, utilising enclosed conveyers for transferring materials, spraying waters during demolition and excavation activities, etc., for effective control of fugitive emission during construction activities. In addition, establish designated routes for traffic with low specified speeds where applicable. Such measures, if implemented in true letter and spirit during the execution of construction projects can substantially minimise fugitive dust emissions for better air quality and human health protection.

VIII. Transportation sector; Promoting EVs (Medium to Long-term):

Rapid adoption of EVs in Pakistan and specifically Lahore can significantly reduce fossil fuel-based vehicular emissions which is the leading contributor to fine particulates $PM_{2.5}$ leading to poor air quality in urban centres such as Lahore. However, a comprehensive approach is required as explained in EV policy 2019. This mainly includes offering financial subsidies and establishing EV charging infrastructure. In addition, EV-based public transport systems can also play a pivotal role in improving air quality.

IX. Development sector; Expanding mass transit network (Long-term):

In most of the urban areas of developed countries, mass transit networks are extensive for public mobility. For instance, in Seoul, the capital of South Korea with a population of 10 million, the Seoul metropolitan subway length is approximately 1300 km. Currently in Lahore, two major mass-transit projects including Metro Bus and Orange Line Metro Train are successfully implemented and under operation under Punjab Mass-transit Authority. With a population of nearly 13 million, Lahore's planned expansion of currently operated mass-transit projects, considering economic factors, can potentially allow the general public to utilise it effectively for transportation purposes.

X. Development sector; Promoting sustainable urban development (Long-term):

Comprehensive land-use planning is essential for sustainable urban development. This requires creating detailed master plans for cities and their surrounding areas. Strict adherence to these plans is crucial. Industrial zones should be designated, and existing industries within urban areas relocated to these zones within specified timelines. Furthermore, the development of housing societies near industrial areas should be banned.

DISCLAIMER:

This policy brief is based on WWF-Pakistan's report titled "Situational Analysis of Air Quality in Lahore". This publication has been produced with the assistance of the European Union. The contents of this publication are the sole responsibility of the author and can in no way be taken to reflect the views of WWF-Pakistan and European Union.



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