SDPI
Sustainable Development Policy Institute

NOVEMBER 2024

AIR POLLUTION AND HEALTH: PM2.5 AND AIRQ+ ESTIMATION OF HEALTH END POINTS, A REVIEW AND ANALYSIS FROM TWO CITIES OF PAKISTAN

AUTHOR: DR RAZIA SAFDAR
SENIOR POLICY ADVISOR, CENTRE FOR HEALTH POLICY & INNOVATION, SDPI- ISLAMABAD

Air Pollution and Health: PM2.5 and AirQ+ Estimation of Health End Points, A review and analysis from two urban cities of Pakistan

Dr Razia Safdar
Senior Policy Advisor,
Centre for Health Policy & Innovation

Sustainable Development Policy Institute
10-D West, 3rd Floor, Taimoor Chamber, Fazl-ul-Haq Road, Blue Area, Islamabad. Pakistan,
Tel: +92.51. 2278134, Fax: 2278135, ©2023 All rights reserved

Table of Contents

List Of Figures

All rights reserved.

No part of this report may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or information storage and retrieval system, without prior written permission of the publisher.

A publication of the Sustainable Development Policy Institute (SDPI), Islamabad. The opinions expressed in the report are solely those of the authors, and stakeholders where mentioned, and publishing them does not in any way constitute an endorsement of the opinion by the SDPI.

Sustainable Development Policy Institute is an independent, non-profit research institute on sustainable development.

Abbreviations

AP	Attributable Proportion
AP-HRA	Air Pollution Health Risk Assessment
AQGs	Air Quality Guidelines
AQI	Air Quality Index
ARI	Acute Respiratory Infection
BI	Baseline Incidence
COPD	Chronic Obstructive Pulmonary Disease
CRF	Concentration Response Function
DHS	District Health Survey
EPA	Environmental Protection Agency
ERF	Exposure Response Function
GBD	Global Burden of Disease
HIA	Health Impact Assessment
HIF	Health Impact Function
HRA	Health Risk Assessment
IER	Integrated Exposure-Response Functions
IHD	Ischemic Heart Disease
IHME	Institute for Health Metrics and Evaluation
LAP	Local Air Pollution
LMICs	Low- and Middle-Income Countries
MICS	Multiple Indicator Cluster Surveys
MOCC&CE	Ministry of Climate Change and Environmental Coordination
NCDs	Non-Communicable Diseases
NEQS	National Environmental Quality Standards
NOx	Nitrogen Oxides
PAF	Population Attributable Fraction
PDHS	Pakistan Demographic and Health Survey
PM	Particulate matter
RR	Relative Risk
SEED	Sustainable Energy and Economic Development
UHC	Universal Health Coverage
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organization

Glossary

Term	Definition
Acute Lower Respiratory Infection (ALRI)	ALRI are infections of the lower airways. These include Bronchitis, Bronchiolitis, and Pneumonia and are the major cause of morbidity and mortality in children younger than 5 years -, globally. (https://europeanlung.org/en)
Air Quality Index (AQI)	Air quality index is a weighted average of various air pollutants that communicates the current level of pollution in the ambient air.
Attributable Risk (AR)	Attributable Risk is the proportion of a disease in exposed individuals that can be attributed to an exposure.
Chronic Obstructive Pulmonary Disease (COPD)	COPD is a chronic disease of the lungs characterized by abnormalities in the small airways leading to limitation of airflow in and out of lungs. Several processes such as air pollution (household), smoking, occupational dust, childhood asthma, lead to the development of this irreversible condition with progressively difficult breathing.
Health Impact	A health impact is the change in health status resulting from (a) health risk.
Health Risk	A health risk is the chance or likelihood of how something will harm or otherwise affect (your) health.
Non-Communicable Diseases (NCDs)	NCDs are chronic health conditions that are caused by a combination of genetic, physiological, environmental, and behavioural factors. They last for a long time and require long-term treatment. Eg Diabetes Mellitus , Hypertension, Ischemic Heart Disease , chronic renal disease
$PM_{2.5}$	These are suspended air particles less than 2.5 micrometers in diameter. They pose the greatest risk to health.
Risk Ratio (RR)	A Risk Ratio is a comparison of the risk of a certain (health) event happening within one group with the risk of the same event happening in another group.

1. Introduction and Country Profile

Air pollution is recognized as a major risk for premature mortality, reduced life expectancy, non-communicable diseases and Disability-adjusted Life Years (DALYs) lost. Globally, nine out of 10 persons are exposed to poor air quality, and 6.7 million premature deaths are attributed to air pollution every year. Of these, 4.2 million deaths are attributed to ambient (outdoor) air pollution[18]. Among them, 90% of people are affected in Lower- and Middle-Income Countries (LMICs) (WHO data 2019). Vulnerable Populations including Pregnant women, children, the elderly, people with disabilities, people with preexisting conditions such as asthma, Ischemic Heart Disease(IHD) and socially and economically marginalized populations are disproportionately affected by poor ambient airquality.

Pakistan has consistently ranked in the top 5 countries with the poorest air quality globally, in the last 5 years[19]. With an average AQI of 160 and PM2.5 14.7 times higher than the WHO annual air quality guideline value(PM2.5µg microgram/ m3 annual average), Pakistan was the second most polluted country in 2023. Its metropolitan cities – Lahore, Karachi, Faisalabad, Peshawar and Rawalpindi – are the worst affected by air pollution and are the main contributors to the overall air quality of the country. The Burning off fossil fuels for transportation, heating fuel, waste incineration including stubble burning, electricity generation, and other industrial activities are significant contributors to rising pollution levels. It is estimated that air pollution in Pakistan leads up to 256,000 premature deaths per annum[20], and shortens the average life expectancy by 3.9 years[21].

Global evidence suggests that exposure to ambient air pollution and its associated disease burden can be mitigated through targeted air quality management policy actions at national and subnational levels. China for instance has integrated pollution-control targets into its most recent 5-year plan leading to reducuction in air pollution in several large urban areas[22] [23]. Mexico City, Bangkok, and other major cities have achieved some success in combating ambient air pollution[24]. While India has made strides in addressing a household air pollution, but still had the world's largest estimated number of air pollution-related deaths[25] in 2019. The European Union(EU) has implemented a domestic Zero Pollution Action Plan as part of the European Green Deal, which also includes a small international component[26].

In Pakistan, the Ministry of Climate Change and Environmental Coordination (MoCC&EC) is the federal body responsible for directing national environmental policies. In addition, Federal and provincial Environmental Protection Agency (EPAs) are responsible for evidence based policy recommendations and conducting environmental monitoring. Most recently, the MoCC&EC approved the National Clean Air Policy (NCAP) in March 2023. The policy, which has been developed with international partnership marking the first official recognition and effort at the federal level to reduce worsening air pollution. The policy emphasizing revising emission standards for industries, decarbonizing the power

18 WHO. Air Pollution. Available at https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.

19 IQ Air. Air quality in Pakistan. Available at https://www.iqair.com/pakistan.

20 State of Global Affairs. Pakistan. 2021 Available at https://www.stateofglobalair.org/data/#/air/plot

21 AQLI. Pakistan. Available at https://aqli.epic.uchicago.edu/country-spotlight/pakistan/

22 WHO. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization, Geneva2021. Available at https://apps.who.int/iris/handle/10665/345329

23 UN Environment Programme. For people and planet: the United Nations Environment Programme strategy for 2022–2025 to tackle climate change, loss of nature and pollution. United Nations Environment Programme, Nairobi, Kenya2021

24 World Bank. Clearing the air: a tale of 3 cities. World Bank, New York2020. Available at https://openknowledge.worldbank.org/handle/10986/34757

25 Pandey A, Brauer M, Cropper ML, et al. Health and economic impact of air pollution in the states of India: the Global Burden of Disease Study 2019. Lancet Planet Health. 2021; 5: e25-e38

26 European Commission. Zero Pollution Action Plan: towards zero pollution for air, water and soil. Available at https://ec.europa.eu/environment/strategy/zero-pollution-action-plan_en

sector and prioritizing the establishment of an emission inventory with annual updates. However, the advisory proposes relaxed ambient air quality standards, overlooks emission capping and does not address the transboundary nature of air pollution. There is need to direct provincial EPAs to establish city level clean Air Action plans. Linking clean air interventions with Health as a co benefit will result in tremendous economic benefits ,better livelihoods and safer climate.

This report aims to compile localized evidence for the health impacts of ambient air pollution in two urban cities of Pakistan: Islamabad Capital Territory and Peshawar. By simultaneously examining health impact assessment methodologies employed at global and regional levels, we seek to identify best practices that can be replicated at the district or subnational level to generate robust local evidence.

2. Rationale and Methodology

Pakistan faces a scarcity of peer reviewed epidemiological and ecological studies on health impact of air pollution limiting the scope of reference for this report to studies from the northern hemisphere. Their references for adult mortality and incidence data in these studies are often derived from meta-analysis of large multicity studies conducted in European countries where air quality is much better.

This analysis aims to collect regional evidence on the health impacts of air pollution, particularly particulate matter (PM),while also reviewing suitable methodologies and tools for projecting these impacts especially with in context of local environmental parameters and socio-demographic scenario. This effort will capture gaps in the existing data and serve as a foundation for a comprehensive inquiry on health risk and health impact evidence in the country.

Study Design and Background Review

This inquiry takes place in two stages. The first stage involves a situation analysis examining global, regional, and national level epidemiological and ecological studies focusing on the health risks and impacts of air pollution, over the past decade. Special attention was given to multi country studies done in Asia and South America with regional references from research publications from Bangladesh, India, and Iran. These studies were analyzed for their methodologies,including primary data collection, utilization, analytical approaches, statistical equations, and programs used.

Systematic analyses and meta-analyses of ecological time series studies, case cross over and cohort studies, focusing on both for short-term and long-term exposure brought out valuable insights. The methodology and data requirement and their sources were explored to identify the appropriate software tools which were reviewed for their applicability.

Air Pollution-Health Risk Assessment (AP-HRA) studies conducted between 2015-2021were also reviewed with focus on their basic frameworks and software tools used for estimates and the policy recommendations. The latest WHO Air Quality Guidelines 2021[27] was reviewed for standards references. Besides, the World Bank and national reports were consulted.

For demographic and health data, various national sources were consulted including the national census, Pakistan Demographic and Health Survey (PDHS), Khyber Pakhtunkhwa (KP) District Health Information System (DHIS), Maternal Mortality Survey 2019, Multiple Indicator Cluster Survey , Health Sector Review of Hospital Care by Asian Development Bank (2019), Household Surveys, Civil Registration and Vital statistics, disease registries, National Action Framework on NCDs and Mental health, and Universal Health Coverage-Monitoring Report 2021 were consulted.

In the next stage, an estimation of the long-term health effects of air pollution in the two cities is carried out. A detailed description of this is provided in the case study of each city.

27 WHO. WHO global air quality guidelines: particulate matter (PM2.5 and PM10); ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Available at https://www.who.int/publications/i/item/9789240034228

Study Setting

This analysis was conducted for the cities of Peshawar and Islamabad. Peshawar is the provincial capital of Khyber Pakhtunkhwa and the sixth largest city of Pakistan. Ambient Air Quality Ddata for both cities was collected between 2019 till 2021. The other city is Islamabad, the country's Federal capital and its ambient air quality data was gathered from 2021 till 2022.

Data Collection

The air quality variable of interest is $PM_{2.5}$, a fine particulate matter with a diameter of less than 2.5 micrometers, which can remain suspended in the air for extended periods. $PM_{2.5}$ is widely used to express the quality of ambient air and recorded by most monitoring systems . Data for Peshawar was taken from a parallel study/situation analysis of PM2.5, the Peshawar Air Quality Rapid Assessment. For Islamabad, air quality data was obtained from USEPA air quality monitor located in the United States embassy.

Health outcomes such as all-cause mortality and cause and age specific data for both cities was not available. Consequently, the national incidence rates for all-cause and disease and age specific mortality were derived from the Global Burden of Disease Study[28]. It is important to note that, due to methodological limitations, national data may be used for subnational estimations though caution is advised while interpreting these results.

Data Analysis

Data were analyzed using the AirQ+ version 2.2, which is a software tool designed by the WHO that quantifies the short- and long-term health impact of ambient air pollution.

The data input consisted of exposed population both total and age specific. To assess the long -term impact, the annual mean value of Air quality is required. The cut-off value for $PM_{2.5}$ was set at 10 µg/m3, in accordance with WHO standards at time of study (5 µg/m3 WHO new standard 2021). This cut-off represents the mean concentration of $PM_{2.5}$ below which no health hazards are observed (in comparison Pakistan's National Environmental Quality Standards {NEQS} set this value at 15 µg/m3). Due to the unavailability of city-specific incidence data, national incidence data from the Global Burden of Disease (GBD) study and age-specific results were utilized.

The term "health endpoint" refers to the proportion of all-cause mortality attributable to air pollution (specifically PM2.5). AirQ+ requires natural-cause mortality incidence data, and Relative Risk (RR) values, which are embedded in the software and calculated from meta-analyses of epidemiological studies with broad confidence intervals. For example, the RR for lung cancer is 1.09, for stroke is 1.04, and for natural mortality in individuals aged 30 years and older is 1.062. The calculation method is a long linear model for all-cause mortality, integrating functions from both the WHO and Air Quality Guidelines (AQG) within the GBD framework.

---

28 Vos, Theo, et al. "Global Burden of 369 Diseases and Injuries in 204 Countries and Territories, 1990–2019: A Systematic Analysis for the Global Burden of Disease Study 2019." The Lancet, vol. 396, no. 10258, Oct. 2020, pp. 1204–22. www.thelancet.com, https://doi.org/10.1016/S0140-6736(20)30925-9.

3. Parameters of Air Quality

The health of an individual is a complex outcome determined by various factors, including biological characteristics and behaviors, as well as social, economic, and physical environments. Clean air, a vital aspect of the physical environment, is essential for maintaining the health of communities and populations. However, anthropogenic activities can degrade and deplete the physical environment, with significant negative impacts on health.

One of the most critical components of the physical environment is air quality, which is essential for life. Air quality is affected by pollutants—chemical, physical, or biological agents that temporarily or permanently contaminate the indoor or outdoor environment, altering the natural properties of the atmosphere. The primary sources of air pollution include household combustion devices (responsible for household air pollution), transportation, industrial operations, residential emissions, agriculture, biomass burning, solid waste management, stubble burning, and forest fires (contributing to ambient air pollution). As a result, air quality has become a major public health concern.

Various air pollutants affect air quality, including carbon Mmonoxide, ozone, sulfur dioxide, Nitrogen dioxide and particularly particulate matter (PM2.5 and PM10). The WHO guidelines also highlight other pollutants such as black carbon (soot), ultrafine particles (<0.1 micrometers), and molds though quantitative measurements for these are often lacking and more relevant in household air pollution.

Climate change and Air pollution

Air pollution and climate change are closely tied because their source – fossil fuels – are the same. Burning these fuels produces fine air pollutants (PM2.5), greenhouse gases, and short-lived climate pollutants (SLCPs) that are both air pollutants and climate warmers. Optimizing climate mitigation and air quality together will synergize the health benefits of both[29].

Air Quality Guidelines

As air quality is a public health concern, WHO has developed guidelines and tools for all countries to reduce the health risk of air pollution. Long-term Air Quality Guidelines (AQG) levels are developed to provide information to end users so that they might save themselves from the associated diseases and mortality by reducing the adverse effects of long-term exposure to air pollutants. The lowest exposure level of an air pollutant over the years and months with moderate evidence endorsed by the WHO's guideline development group (GDG) is considered significant and above that level there is an increase health risk and adverse health outcome. The systematic reviews provide a summary estimate of the Risk Ratio (RR) derived from the included meta-analyses for each pair of air pollutant and adverse health effect, a 95% CI for this estimate and a GRADE qualification for the certainty of the evidence. In principle, the GDG used this estimate for guideline derivation only if the 95% CI from a random effects meta-analysis did not include an RR of 1.

WHO Air Quality evidence-based guidelines published in 2005 set the lowest levels and

29 Fuller, Richard, et al. "Pollution and Health: A Progress Update." The Lancet Planetary Health, vol. 6, no. 6, June 2022, pp. e535–47. www.thelancet.com, https://doi.org/10.1016/S2542-5196(22)00090-0.

Table 1. Air Pollutants of interest

Pollutant	Sources	Health effects
Carbon monoxide (CO) is a colorless, odorless gas that is harmful in large quantities.	Poorly ventilated transport and other fossil-fuel-burning activities such as unvented kerosene and gas space heaters, leaky chimneys and furnaces, and gas stoves (indoor air quality)	Dizziness, disorientation, unconsciousness, and death at very high levels (indoors or in other confined places) Exposure over time might lead to symptoms that can be mistaken for the flu without the fever
Ozone (O3) is a highly reactive gas made up of three oxygen atoms. It naturally exists in the atmosphere and produced because of human activity, known as ground-level or Tropospheric ozone.	Chemical reaction of pollutants from automobiles, power plants, industrial boilers, refineries, chemical plants, and other sources, in the presence of sunshine Chemical interactions between nitrogen oxides (NOx) and volatile organic molecules (VOC)	Cough and sore throat Difficulty in breathing, painful and vigorous deep breathing Inflammation and damage of the airways Increased susceptibility of the lungs to infection Aggravation of lung diseases such as asthma, emphysema, and chronic bronchitis Increased frequency of asthma attacks.
Particulate – matter (PM) is an amalgamation of solid particles and liquid droplets that may be found in the air. Dust, grime, soot, and smoke are examples of big or black particles that may be seen with the naked eye. Others are only detectable through an electron microscope. These are separated into two main categories. PM10: Inhalable particles, with diameters that are generally 10 micrometers and smaller. PM2.5: Fine inhalable particles, with diameter that are generally 2.5 micrometers and smaller.	Directly released from a source, such as construction sites, dirt roads, fields, smokestacks, or fires. Most particles in the atmosphere form because of complicated chemical processes involving pollutants such as oxides, which are produced by power plants, industry, and transport.	Lung cancer and exacerbation of preexisting conditions like asthma, bronchitis Stroke (PM2.5 can enter circulation and atherosclerotic. IHD Cardiovascular morbidity penetrates lungs and even blood vessels.
Sulphur Di Oxide (SO2)	Fossil fuel combustion by power plants, industrial Operations ,volcanic eruptions, heavy equipment ,ships ,Vehicular emissions	Short term respiratory system impacts ,hard to breath

countries were given interim targets to achieve according to their local situation. There were three interim targets for PM2.5 over the years. New/Revised Guidelines 2021 with new evidence have reduced PM2.5 level to 5 from 10 µg/m3 with the addition of 4th Interim target. Interim targets are set for countries to mitigate and improve air quality standards with local context.

Table 2. Recommended AQG level and interim targets for Ambient PM2.5

Target PM2.5 annual average µg/m3	Interim Target 1	Interim Target 2	Interim Target 3	Interim Target 4	AQG level
WHO Air Quality Guidelines 2021	35 **µg/m3**	25 **µg/m3**	15 **µg/m3**	10 **µg/m3**	5 **µg/m3**
Pakistan NEQs			15 **µg/m3** (MoCC)		
National Clean Air Policy	35 **µg/m3**				

Conditional recommendations are also considered where evidence is less than moderate in case where exposure is widespread and effect on population is severe. There is no level of safe exposure to a pollutant.

Air Pollutant Measurements, Standards and Country policy

The US Environmental Protection Agency has earmarked six pollutants as "criteria" for air pollution because they are regulated by defining human health and environmental criteria (science-based standards) for determining permitted levels.
Pakistan Environmental Protection Agency (EPA) has notified nine pollutants to be measured for Ambient Air Quality, since 2012 National Environmental Quality Standards (NEQS) developed with lower levels according to WHO guidelines, and latest National Clean Air Policy (NCAP) 2023 has endorsed WHO 2021 interim targets. Pakistan's first National Air Pollutant Emission Inventory was developed by MOCC&EC in 2022 with identification of major contributory sectors. NCAP has set the targets for different pollutants in line with NEQs, Provincial Air Quality Standards and WHO guidelines 2021.

Table 3. Ambient Air Quality Targets (Source: NCAP 2023)

Pollutant	Frequency	Target
PM2.5	Annual average	35 µg m-3
PM2.5	24-hour	75 µg m-3
PM 10	Annual	70 µg m-3
PM 10	24-hour	150 µg m-3
Ozone (O3)	Average daily maximum 8-h concentration over highest 6-month period	100 µg m-3
Ozone (O3)	Daily maximum 8-hour	160 µg m-3
Nitrogen dioxide (NO2)	Annual	40 µg m-3
Nitrogen dioxide (NO2)	24-hour	120 µg m-3
Sulphur dioxide (SO2)	24-hour	125 µg m-3
Carbon monoxide (CO)	24-hour	7000 µg m-3

Air Quality Index (AQI)

AQI is an indicator of the current quality of air. This is used for daily reporting, to predict how clean or polluted the air is and to inform the public when the concentration has reached a health threatening level. According to WHO standards, AQI of 0 to 50 has no health impact and according to the EPA Pakistan, up to 100 is thought to be satisfactory for public health. AQI is categorized into six intervals[30], each representing a different level of health concern.

Table 4. Categories of Air Quality Index (AQI)

Air Quality Index (AQI) Values	Colours	Levels of Health Concern	Health Alerts /actions
0-50	Green	Good	Poses little or no risk.
51-100	Yellow	Moderate	Unusually sensitive to ozone may experience respiratory symptoms.
101-150	Orange	Unhealthy for sensitive groups	Persons with heart and lung diseases, older adults and children are at a greater risk due to the presence of particles in the air.
151 to 200	Red	Unhealthy	Everyone has some adverse health effects. Sensitive groups may experience more serious effects.
201 to 300	Purple	Very unhealthy	This would trigger a health alert signifying that everyone may experience more serious health effects.
301 to 500	Maroon	Hazardous	This would trigger health warnings of emergency conditions. The entire population is more likely to be affected.

30 https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information

4. Air Quality and Health

A health risk is the chance or likelihood of how something will harm or otherwise affect (your) health. Health risk factors can be biological ,chemical,physical, psychosocial ,personal and environmental. Health impact is the change in the health status resulting from a health risk. Air pollution is a health risk, and its health impact depends upon amount and duration of exposure (WHO 2010). The main causes of mortality due to air pollution include Ischemic Heart Disease (IHD), stroke, chronic obstructive pulmonary disease, acute respiratory infections and lung and respiratory tract cancers[31]. Additionally, a wide list of events is evidenced besides lung and respiratory cancer, which includes neoplasia of different organs and system[32]. Ambient air pollution PM2.5 has significant impact on progression of Non Communicable Diseases (NCDs) including mental health, with short and long term exposure. There is a complex interplay of multiple factors, that results in measurable health impacts such as development of chronic diseases.

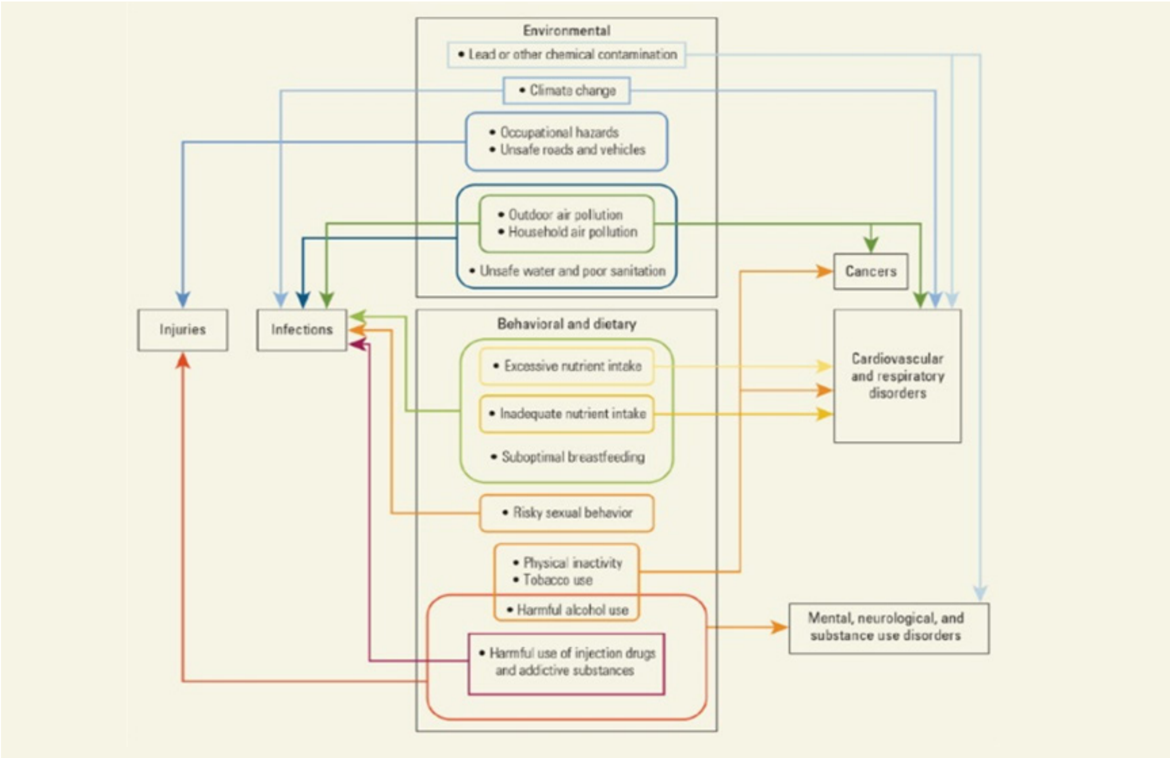


Figure 1. Conceptual model of interactions among key risk factors and diseases that can be modified
[Source: Disease Control Priority (DCP3 volume 9) Intersectoral Policy Priorities & Health]

$PM_{2.5}$ are minute respirable particles in the atmosphere. They affect fine vascular endothelium of the lungs, increasing the activity of sympathetic nervous system, causing vasoconstriction and resulting in increasing blood pressure and the risk of other NCDs. The International Agency for Research on Cancer (IARC) has classified air pollution, particularly $PM_{2.5}$ as a leading cause of cancer. Air pollutant of interest $PM_{2.5}$ is cause of decrease in life expectancy on average 1.8 years globally, 2.7 years in Pakistan and 5.3 years in Lahore[33].Long-term exposure of 5µg/m3 of $PM_{2.5}$ causes significant increase in

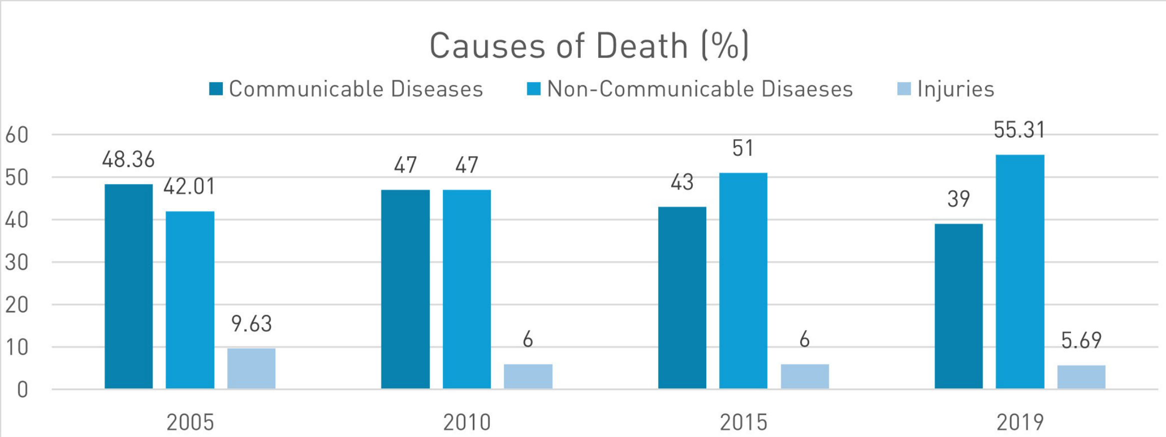
31 Cohen, Aaron J., et al. "Estimates and 25-Year Trends of the Global Burden of Disease Attributable to Ambient Air Pollution: An Analysis of Data from the Global Burden of Diseases Study 2015." The Lancet, vol. 389, no. 10082, May 2017, pp. 1907–18. www.thelancet.com, https://doi.org/10.1016/S0140-6736(17)30505-6.

32 Outdoor Air Pollution and Cancer: An Overview of the Current Evidence and Public Health Recommendations - Turner - 2020 - CA: A Cancer Journal for Clinicians - Wiley Online Library. https://acsjournals.onlinelibrary.wiley.com/doi/10.3322/caac.21632.

33 Energy Policy Institute at the University of Chicago (EPIC) 2020

stroke[34]. Figure 2.5 shows the shift of cause of mortality from communicable diseases, i.e. 48.36% in 2005 to 39% in 2019 and proportional increase in NCD mortality from 42% to 55.31%.

Figure 2.5 Pakistan Chronological Mortality Overview/



(Source: Framework for NCDs and Mental Health (MoNHSR&C)

Global Burden of Disease (GBD) ranked air pollution as the top risk factor contributing to 16% of all NCD deaths in 2016. The attributable mortality rate to air pollution according to GBD 2019 is listed in Table 5 (IHME GBD).

Table 5. Health impact of particulate matter pollution (household and ambient) (GBD)

	Disease	Global	Pakistan
1	IHD	*20.17%	34.55
2	Stroke	25.17	39.57
3	Trachea, Bronchus , Lung Cancer	18.96%	31.83
4	Diabetes	18.86%	23.19
5	COPD	39.92%	57.4
6	Maternal	19.97%	19.78
7	Lower Respiratory tract	30.04%	29.94

(Source: Global Burden of Disease, 2019 (Graphical GBD Compare))

* 20.17% of all deaths due IHD are attributed to air pollution

34 Yuan, S., Wang, J., Jiang, Q., He, Z., Huang, Y., Li, Z., Cai, L., & Cao, S. (2019). Long-term exposure to $PM_{2.5}$ and stroke: A systematic review and meta-analysis of cohort studies. Environmental research, 177, 108587. https://doi.org/10.1016/j.envres.2019.108587

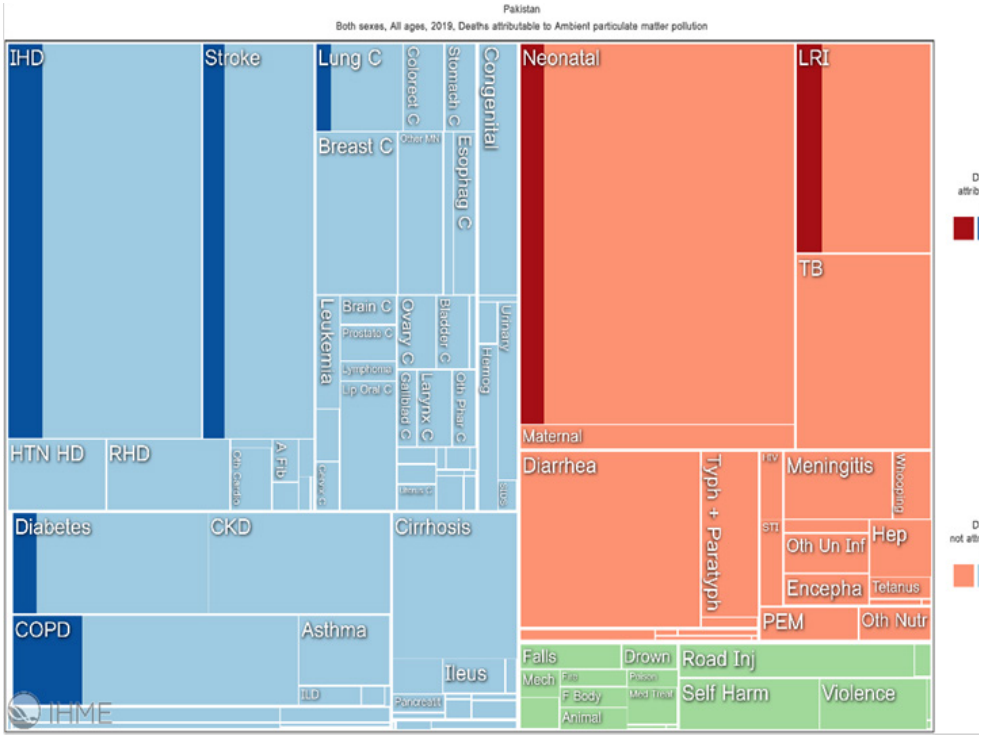


Figure 3. Causes of mortality due to ambient air pollution in Pakistan
(Source: Global Burden of Disease, 2019)

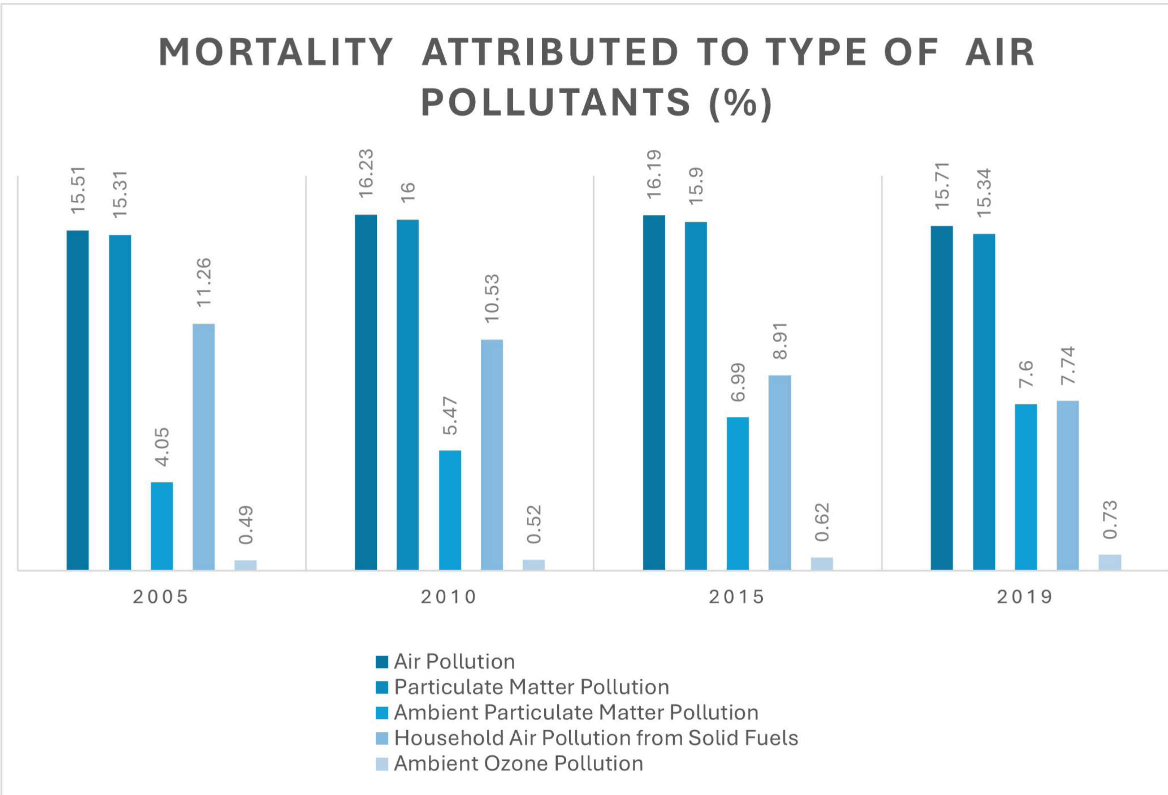


Figure 4. Attributable mortality to types of pollution
(Source: Global Burden of Disease, 2019 (author's graphical presentation))

Figure 4 is an overview of attributable mortality to different types of air pollutants . In 2005, 15.51% of all-cause mortality is attributed to air pollution and out of this total, 15.31% are due to Particulate matter pollution and 0.49% due to Ozone. Out of Particulate matter 4.05% are due to ambient Particulate matter and 11.26% are due to household air pollution from solid fuel.

Ministry of National Health Services Regulations and Coordination published the National Action Framework for NCDs in November 2021. According to this situation analysis, Islamabad is most affected, as around 70% mortality is attributed to NCDs and more than 60% DALYs lost.

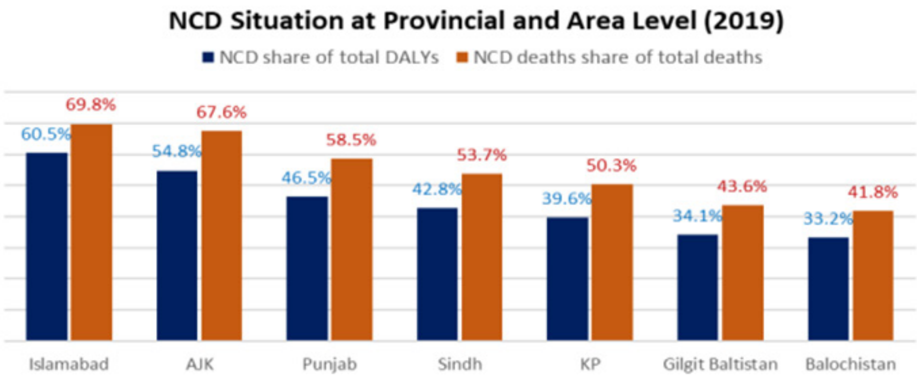


Figure: 5. Situation of Non-Communicable Diseases at Provincial and Area Level (Source: Pakistan National Action Plan Framework for NCDs 2021))

Air Pollution Health Risk Assessment (AP-HRA)

AP-HRA is a methodology/tool developed by WHO to forecast the expected health effects of policies affecting air quality under various environmental, and socioeconomic circumstances. It is a key tool for guiding public policy decisions. It synthesizes information on exposures to air emissions, health impact, and community risk used for regulatory decision-making and public participation. AP-HRAs help understand health benefits due to improved air quality and is used in many studies using Concentration Response Functions (CRFs). Around 20 studies on this tool are reported at regional and global level and two in South Asia (India and Bangladesh). The modelling requires precise population data, air quality data, baseline mortality or disease rates and risk estimation from epidemiological studies that quantify the association between effect and exposure. All-cause mortality, hospital admissions or emergency department visits by respiratory and cardiac diseases, days of restricted activity and other acute symptoms are short-term exposure impacts. For long-term exposure to respiratory and cardiovascular mortality, lung cancer, chronic incidence (respiratory and CVD), the decline in physiologic lung function and intrauterine growth restriction, with enhanced effects on vulnerable populations like children, old age and gender. For statistical quantification of health outcomes, numerous methodologies developed on exposure and used in different areas and conditions in epidemiological studies with certain generalizability & limitations. CRF links the health endpoints attributed to air pollutant concentration changes.

AIR Q+ is developed by WHO with gradual modifications and is mostly used in South Asian region. The Air Q+ tool in research is widely used in recent studies for health risk assessment. This is easy to use and is commonly used in LMICs, including Pakistan. Air Q+ with the latest version of Air Q2.2 is better than all other tools in quantifying health outcomes, sensitivity to pollutants, including black carbon, and spatial resolution at the regional, national, city level, and household (indoor) levels especially for LMICs[35]. Hassan et al. (2021) conducted a comparative analysis of the seven widely used Air Pollution Health Risk Assessment (AP-HRA) tools, and concluded that while conducting AP-HRA, there is a need-to-know what data are available and the way to communicate the results. It is also crucial to establish the assessment's technical requirements, the geographic scale, and the relevant pollutants[36].

AIR Q+ software calculates the attributable proportion, which is the fraction of health consequences in a specific population in a certain area and period to a specific air pollutant, as there is a proven causative correlation between health consequences and air pollutant exposure[37]. Gharehchahi et al. validated the suitability of the AIRQ2.2.3 tool in calculating hospitalization frequency, mortality and used calculated baseline incidence and RR in Shiraz, Iran.

Table 6. Type of data for long-term and short-term health impacts

For short-term exposure	For long-term exposure
All-cause Mortality (non-accidental)	Mortality caused by cardiovascular and respiratory disease
Hospital admissions or emergency department visits caused by respiratory diseases	Lung cancer incidence
Hospital admissions or emergency department visits caused by cardiovascular diseases	Chronic incidence caused by respiratory or cardiovascular disease
Days of restricted activity	Decline in physiologic functions
Absence from work or school	Intrauterine growth restriction
Other acute symptoms	

The vulnerable sub-groups of populations include ailing individuals, children, and elderly people. Gender differences also influence the level of burden of health effects as well.

Data Sources

As per figure 6, population data, population exposure, air quality and health outcome data is required. Population data can be extracted from latest census results by PBS and can be stratified for age specific estimations. Generally, modelling and monitoring are two major methods to estimate population exposure. Monitoring data can be directly collected (past and current) near the monitoring sites.

35 Malekafzali S, Jozi SA, Kashefiolasl M, Zarimdar M, Shati M. Scientometric analysis of health impact assessment of outdoor air pollution by WHO-AirQ tool (2005-2019). Journal of Air Pollution and Health. 2021 Dec 11;6(2):101-16.

36 Hassan Bhat T, Jiawen G, Farzaneh H. Air pollution health risk assessment (AP-HRA), principles and applications. International journal of environmental research and public health. 2021 Jan;18(4):1935.

37 Gharehchahi E, Mahvi AH, Amini H, Nabizadeh R, Akhlaghi AA, Shamsipour M, Yunesian M. Health impact assessment of air pollution in Shiraz, Iran: a two-part study. Journal of Environmental Health Science and Engineering. 2013 Dec;11(1):1-8.

5. Air Pollution Health Impact Assessment

Health Impact Assessment (HIA) is a method of estimation of the (potential) health effects of a policy, program or a project on a population. It is typically a prospective assessment of an intervention before implementation along with future projections. It also suggests interventions to reduce causal factors at source level and how to work on adaptation.

HIA starts with **screening** of potential health implications, leading to **scope** of the magnitude and spread of issue. **Appraisal** is the next step from existing evidence or generating new relevant evidence and **reporting** to the policy community concerned for suggested interventions and **monitoring** to see the impact of interventional measures.

Overview of long-term and short-term health impacts of air pollution

Globally, clear evidence regarding the health risks related to air pollution and quantified mortality due to cardiovascular diseases, cerebrovascular, chronic respiratory disease, cancers, and cognitive effects using different tools and methodologies has been established. PM_{10} and $PM_{2.5}$ are the pollutants having attributable long-term risk of NCD related mortality. Epidemiological studies quantify the incidence, prevalence and Risk Ratio (RR) of these chronic diseases. Though most of these are from the northern hemisphere where air pollution is much less, few studies in Latin America, China, India, and Iran have the same type of exposure as in Pakistan. Most of these studies are quantitative modelling of air pollution and exposure where incidence as well as relative risks have been incorporated and inferences have been interpreted according to significance.

Multiple studies have indicated a significant association of daily mortality with increasing ambient PM concentration[18] [19] [20]. Ambient air pollution has been seen to significantly contribute to diseases burden, particularly in the LMICs[21]. However, when compared to the health impact under the premise that people are constantly at home, NO_2 had a 1.2 per cent higher health impact and Ozone had a 0.8 per cent lower health impact[22]. Infants and young children appeared to be more vulnerable to ambient air pollution[23] both to PM_{10} and Ozone than the overall population[24].Pollution from brick kilns in Pakistan has been found to negatively effect children's cognitive ability and physical health. Additionally, this increases the direct health cost and long-term welfare consequences through indirect costs[25].

To establish a causal/ attributable relationship, epidemiological and ecological studies are needed for long-term data. Likewise, for short-term impacts on morbidity, daily data on air quality and daily

18 Prasannavenkatesh R, Andimuthu R, Kandasamy P, Rajadurai G, Subash Kumar D, Radhapriya P, Ponnusamy M. Assessment of population exposure to coarse and fine particulate matter in the urban areas of Chennai, India. The Scientific World Journal. 2015 Jan 1;2015

19 Liu C, Chen R, Sera F, Vicedo-Cabrera AM, Guo Y, Tong S, Coelho MS, Saldiva PH, Lavigne E, Matus P, Valdes Ortega N. Ambient particulate air pollution and daily mortality in 652 cities. New England Journal of Medicine. 2019 Aug 22;381(8):705-15.

20 Bergstra AD, Been JV, Burdorf A. The association of specific industry-related air pollution with occurrence of chronic diseases: A register-based study. Environmental Research. 2022 Jun 1;209:112872

21 Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, Balakrishnan K, Brunekreef B, Dandona L, Dandona R, Feigin V. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. The Lancet. 2017 May 13;389(10082):1907-18

22 Dhondt S, Beckx C, Degraeuwe B, Lefebvre W, Kochan B, Bellemans T, Panis LI, Macharis C, Putman K. Health impact assessment of air pollution using a dynamic exposure profile: Implications for exposure and health impact estimates. Environmental impact assessment review. 2012 Sep 1;36:42-51.

23 Romieu I, Gouveia N, Cifuentes LA, de Leon AP, Junger W, Vera J, Strappa V, Hurtado-Díaz M, Miranda-Soberanis V, Rojas-Bracho L, Carbajal-Arroyo L. Multicity study of air pollution and mortality in Latin America (the ESCALA study). Res Rep Health Eff Inst. 2012 Oct 1;171:5-86.

24 Romieu I, Gouveia N, Cifuentes LA, de Leon AP, Junger W, Vera J, Strappa V, Hurtado-Díaz M, Miranda-Soberanis V, Rojas-Bracho L, Carbajal-Arroyo L. Multicity study of air pollution and mortality in Latin America (the ESCALA study). Res Rep Health Eff Inst. 2012 Oct 1;171:5-86.

25 Nasir M, Rehman FU, Kishwar S, Bashir S, Adil M. Air pollution and child health: the impact of brick kiln pollution on children's cognitive abilities and physical health in Pakistan. Environment, Development and Sustainability. 2021 Sep;23(9):13590-606.

impact indicators are to be monitored. A four-year time-series study of ambient air pollution and daily mortality in Shanghai, China noted that an increase of 10µgm/m3 in two day moving average concentration of PM10 corresponds to 0.26% SO2, ,0.95 NO2, 0.97% O3, and a 0.31% increase in all-cause mortality[26]. Likewise, an extended follow-up of the Harvard six cities study found that the relationship between chronic exposure to $PM_{2.5}$ and all-cause, cardiovascular, and lung-cancer mortality to be linear without a threshold[27]. Synthesizing the GBD data, Anenberg et al showed that of the emergency room visits and new asthma cases, 4 to 9% of global visits are due to PM2.5 related asthma exacerbation[28].

Forestiere et al. (2014) used "The exposure-response functions (ERF)" to quantify the increase in the risks of mortality related to different levels of exposure to ambient air pollution. It is concluded that ERF provides the best approach currently available to estimate mortality attributable to $PM_{2.5}$. However, the ERF depends on assumptions that require further testing. Global Burden of Disease has used Integrated Exposure Response (IER) and Risk Ratio (RR) functions were developed over the entire global exposure range for causes of mortality in adults. Moreover, an IER model was fit by integrating available RR information from various studies. IER is found to be a good predictor of RR for burden assessment[29].

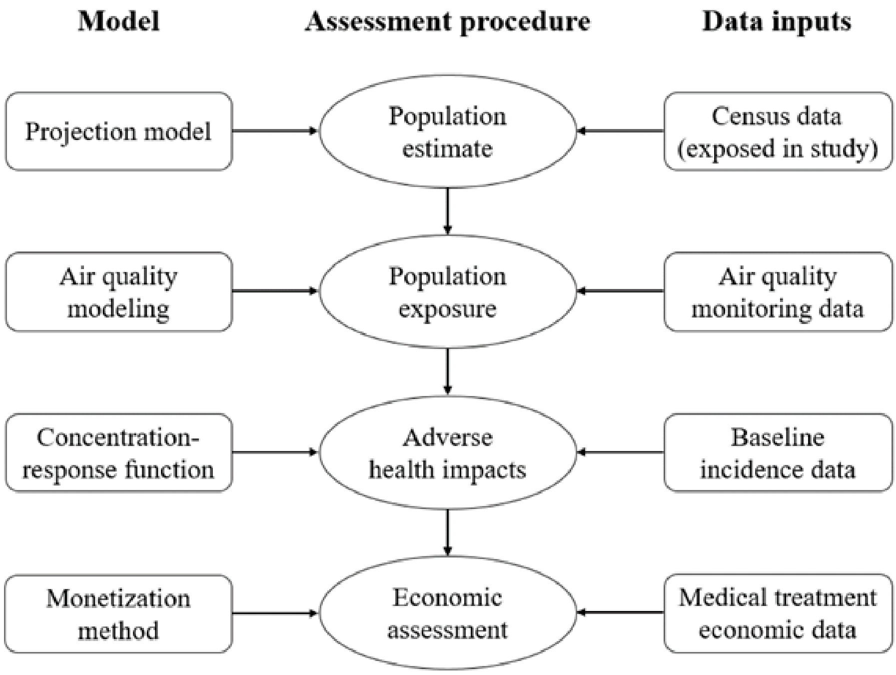


Figure 6. Flow diagram of Air Pollution Health Risk Assessment (AP-HRA) methods, typical models and data inputs

(Source: International Journal of Environmental Research and Public Health (Feb 2021))

26 Kan H, Chen B, Zhao N, London SJ, Song G, Chen G, Zhang Y, Jiang L. Part 1. A time-series study of ambient air pollution and daily mortality in Shanghai, China. Research report (Health Effects Institute). 2010 Nov 1(154):17-78

27 Lepeule J, Laden F, Dockery D, Schwartz J. Chronic exposure to fine particles and mortality: an extended follow-up of the Harvard Six Cities study from 1974 to 2009. Environmental health perspectives. 2012 Jul;120(7):965-70

28 Anenberg SC, Henze DK, Tinney V, Kinney PL, Raich W, Fann N, Malley CS, Roman H, Lamsal L, Duncan B, Martin RV. Estimate s of the Global Burden of Ambient PM 2: 5. Ozone, and. 2018(2):1-4

29 Forestiere F, Kan H, Cohen A, Europe WH. Background paper 4: Updated exposure-response functions available for estimating mortality impacts. Copenhagen: World Health Organization Europe. 2014

For short-term health impact, mortality data is secondary which can be compiled from local government records, National Database Registration Authority (NADRA), hospital records depending on the study design. Hospital admissions and emergency visits from hospital records but usually this data is not complete and primary data collection will produce correct estimates. For long-term effects, cause-specific mortality data can be explored from NADRA and local government vital registration records, cancer registry. Primary data is required for chronic disease though DHIS collects data from public sector primary and secondary health care can be considered. For reduction in lung function and intrauterine growth restriction, primary data may be collected according to study design.

6. Case study

6.1 Peshawar

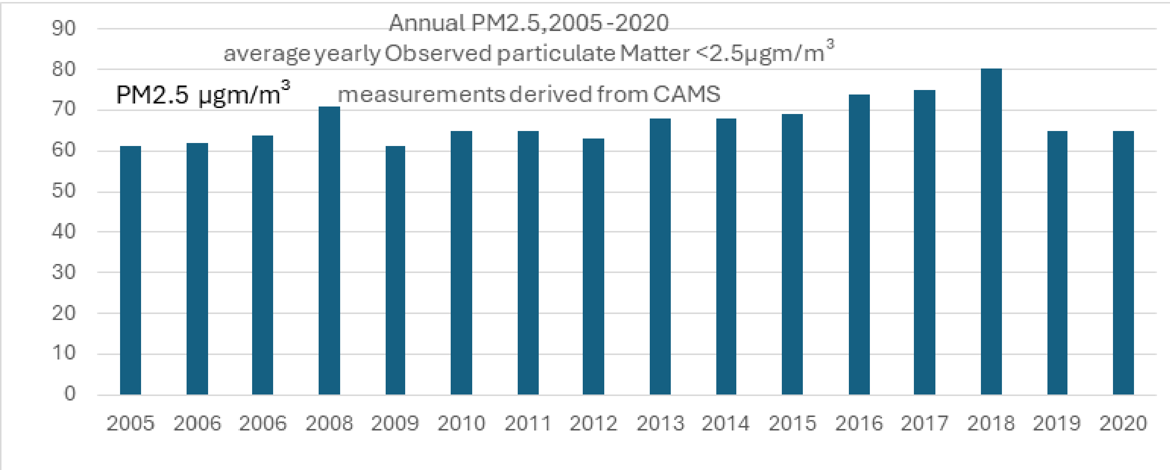
Situated in the north-west of the country, Peshawar is the sixth most populous city of Pakistan. It is the largest city and the capital of the province of Khyber Pakhtunkhwa with a district population of over 4.3 million and a population density of 3135/sq km (2023 census). Peshawar is the fourth most polluted city of Pakistan.

Peshawar Air Quality Profile

A review of Peshawar's PM2.5 levels captured by the satellite-based dataset of the Copernicus Atmosphere Monitoring Service (CAMS) from 2005 to 2020 show that its average yearly fluctuation fell between 60 and 80μgm/m3 (PAPRA). This is much higher than Pakistan National Environmental Quality Standards (NEQS), i.e. 15 μgm/m3 and is 12 to 16x higher than WHO standard of 05 μgm/m3 and more than twice the target set by NCAP(2023). As of 25th June 2024, its AQI was 158 (US AQM, IQ AIR).

There are other aerosol pollutants and hot spots in Peshawar. Peripheral zones in east and southeast of city are hot spots for Sulphur Dioxide (SO2) and Peshawar central is not at an alarming level. However, for NO2 Peshawar core is a hotspot (PCAA study).

Figure 7. Annual mean observed through CAMS



(Source: PCCA Study 2023)

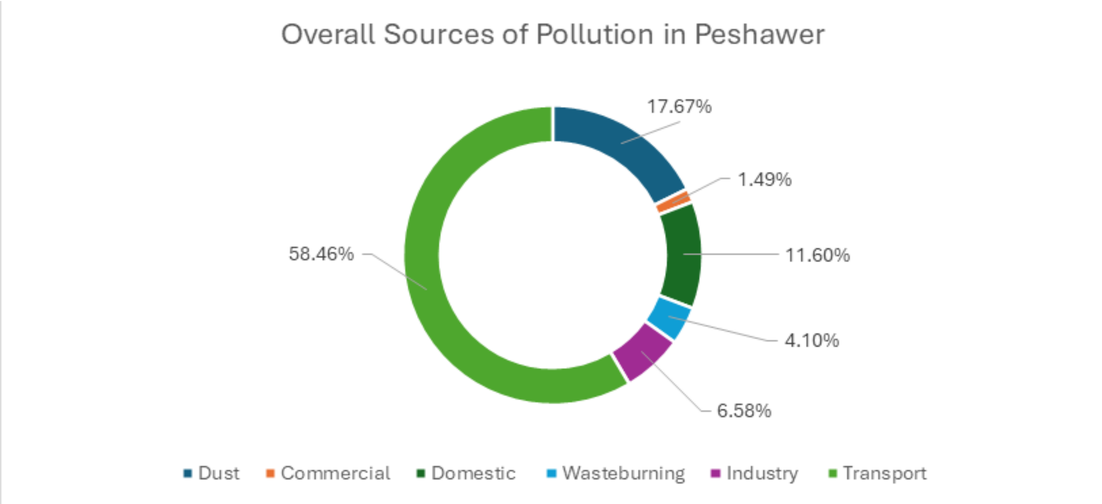


Figure 8. Source apportionment of Air Pollution in Peshawar
(Source: PCCA study)

Sources of Air Pollution in Peshawar

At least 42.7% of all KP vehicles are registered in Peshawar out of which 36.3% are rickshaws and motor cabs, while 34.7% are motorcycles and scooters. Data shows that every two in four cars and public trucks in KP are from Peshawar. 1/3rd of industrial units in KP are in Peshawar district and are spread in 100 km square area of the district. Industrial establishments in the district range from steel mills to brick kilns, which significantly contribute to air pollution. Both Local Air Pollution (LAP) and Regional Air Pollution (RAP) can impact Peshawar.

Health indicators of Khyber Pakhtunkhwa and Peshawar

The province of Khyber Pakhtunkhwa (KP) is high on disease burden and second among all provinces and regions Peshawar ranks 3rd on Universal Health Coverage Index, i.e. 59.2 (2020). It is measured through 14health indicators covering maternal child & adolescent health, communicable and non-communicable diseases, and service capacity and access. According to the District Health Information System(DHIS) report of 2017, KP's neonatal mortality rate is 34/1000 live births, with infant mortality at 53/1000 and maternal mortality 165/100,000 live births. 55.5% children up to 23 months are fully vaccinated.

KP has a total of 1,708 health facilities of all categories from primary to tertiary health care. More than 18,000 public and private hospital beds are available for more than 30 million population (6/10,000) (ADB 2017). In KP, urban areas provide 40% of OPD services and 10% inpatient beds of different levels and quality hospitals. The doctors' density is 0.3/1000 population (0.8/1000 Pakistan) with more than 90% male doctors. Lady Reading Hospital, Peshawar, the largest in KP, had 150,000 inpatients in 2017. There is a growth in average outpatient visits from 0.72 consultation per person in 2009 to 2.5 in 2015.

District Health Information System (DHIS) is the reporting system at district level and a report is published every year on reported indicators. For this study, the DHIS 2019 report has been consulted for relevant indicators.
Table 7. KP DHIS annual report 2019

Total OPD New Cases (KPK)		
Speciality	New Visits	% age
Emergency Visits	4548526	29.94
Medicine	988668	6.51
Cardiology	183883	1.21
Gynaecological & obstetrics	989799	6.51
Acute Respiratory infection	3014894	12.58
Hypertension	619548	2,58
Diabetes mellitus	369311	1.54
Asthma	234649	0.98
Ischemic Heart Disease	67138	0.28
Chronic Obstructive Pulmonary Diseases+	47235	0.2

Methodology

This case study of Peshawar city is based on the data collected on air quality from July 2019 to June 2021 for the Peshawar Clean Air Alliance study (PCCA study). This is based on the Air Quality Monitor (AQM) at the US consulate. and other measurement is from satellite CAMS. The differences between the two can be attributed to the fact that AQMS is more sensitive to high and low measurements. Whilst data from the satellite varies depending on the grid size used for data retrieval.

The per year PM2.5 average was taken as 70 for year 2019-20 and 80 for 2020-21. Cut-off value for PM2.5 was taken at 10 (WHO,2005) though NEQS (applicable to KP) is 15 .

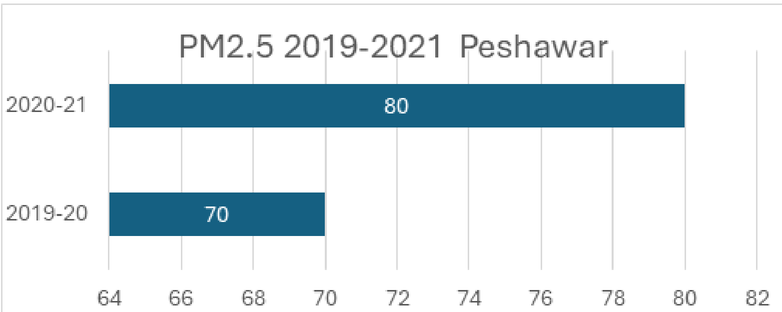


Figure 9. Comparison of PM2.5 in Peshawar from 2019 to 2021
(Source: PCCA Study 2023)

Based on the scope of this work and literature review, health impact of air pollution (end points) were all-cause mortality and cause specific mortality are those of non-communicable diseases, - IHD, COPD, lung cancer and stroke. Health endpoint data - all-cause and disease, age specific mortality incidence – is the national data for Pakistan, extracted from the GBD 2019, as local or city specific data are not availableFor this study, population exposure data has been extracted from the 2017 National Census and population above 18 to 60 years of Peshawar district comprise the sampling frame. All-cause mortality was estimated in three parameters: attributable proportion %, estimated number of attributable cases and estimated mortality/100,000 population at risk. Population Attributable Fraction (PAF) is defined as proportional reduction in disease or mortality would occur if exposure to a risk factor were reduced to an alternative ideal exposure scenario. This function will estimate % age reduction in mortality cases if PM2.5

is reduced from 70 (Peshawar average) to 10 (WHO standard) below which risk is minimal. This data was analyzed using the AirQ+ tool (WHO). This simple, user-friendly software is easily available online and is suitable for a quick assessment. While AIR Q+ tool can be used by health experts with basic training and online tutorials for updated version. Its data requirements are in line with the available data and the result end points match the objectives of this study.

Results

The findings in Table 8 are the natural cause mortality in 30+ years population when the RR is 1.064. It estimates that 4053 (2805-5087) natural deaths in a year are attributed to ambient air pollution, when average yearly PM2.5 is 70 and a rise of 10 μgm/m3units in PM2.5 results in 500 more deaths attributed (2020-2021). It is estimated that out of 100,000 cancer deaths in 25+ population, five deaths in years 2019 are due to air pollution and with almost double with 10 μgm/m3point rise in mean average PM2.5 from 70 to 80 in following year. Therefore, the impact is associated with exposure concentration and duration (long-term).

Table 8. Estimates of Health Endpoints (AIR Q+) (Peshawar)

Attributable number of all-cause mortality and disease specific due to air pollution in 2019-2021 (95% CI)			
	Diseases	2019-2020 Average PM2.5 70 μgm/m3	2020-2021 Average PM2.5 80 μgm/m3
1	Mortality due to Natural Causes - 30+ Years, RR 1.064 Incidence 621/100,000 population*		
	Estimated number of Attributable Cases	4053 (2805, 5087)	4597 (3212, 5722)
	Estimated number of Attributable Cases per 100,000 Population at Risk	188 (130, 236)	213(149, 265)
2	Lung Cancer - 25+ Years Incidence 18 /100,000*		
	Estimated number of Attributable Cases	108 (76, 136)	204 (108, 270)
	Estimated number of Attributable Cases per 100,000 Population at Risk	5 (3.5, 6.29)	9 (5, 12.54)
3	Chronic Obstructive Pulmonary Disease - 25+ Years Incidence 317/100,000*		
	Estimated number of Attributable Cases	1790 (1182, 2685)	1942 (1295, 2930)
	Estimated number of Attributable Cases per 100,000 Population at Risk	83 (55, 124)	90 (60, 135)

* Extracted from GBD 2019

Chronic Obstructive Pulmonary Disease (COPD) is impacted by concentration and duration of exposure to air pollutant. According to estimates, in Peshawar, the attributable deaths among 25+ population due to COPD are 83(55-124)/100,000 with yearly PM2.5 average of 70 μgm/m3 and 90 at 80 μgm/m3 in 2020-2021, i-e seven more deaths with 10 points increase.

Table.9 shows the cause specific mortality due to IHD at different age groups (high risk). This is age and cause specific mortality attributed to air pollution. There is seven times higher estimated number of attributable IHD mortality /100,000 population at risk at 60 to 64 years of age as compared to 40 to 45 years (109 from 15).

Table 9. Attributable risk of mortality due to Ischemic Heart Disease (IHD) (Peshawar)

Ischemic Heart Disease - 40-44 years Incidence 72.95/100,000*	**2019-2020 PM2.5, 70 µgm/m3**	**2020-2021 PM2.5, 80 µgm/m3**
Estimated Attributable Proportion (%)	21.44(14,45)	22.91(15, 47)
Estimated number of Attributable Cases	337 (271,708)	360 (240, 742)
Estimated number of Attributable Cases per 100,000 Population at Risk	15(10, 32)	16(11, 34)
Ischemic Heart Disease - 55-59 years Incidence 470.23/100,000*	2019-2020 PM2.5, 70 µgm/m3	2020-2021 PM2.5, 80 µgm/m3
Estimated Attributable Proportion (%)	16.24(11, 35)	17.39(12, 36)
Estimated number of Attributable Cases	1645 (1133,3498)	1762(1232,3722)
Estimated number of Attributable Cases per 100,000 Population at Risk	76.34(53, 162)	81(52, 172)
Ischemic Heart Disease - 60-64 years Incidence 749.1/100,000*	2019-2020 PM2.5, 70 µgm/m3	2020-2021 PM2.5, 80 µgm/m3
Estimated Attributable Proportion (%)	14.62 (9.85, 29)	15.67 (10, 30)
Estimated number of Attributable Cases	2361 (1561, 4686)	2532 (1731, 4975)
Estimated number of Attributable Cases per 100,000 Population at Risk	109 (73, 216)	117(80, 230)

* Extracted from GBD 2019

Another interesting finding is that if yearly average of PM2.5 is reduced from 80 µgm/m3 to 10 µgm/m3 (WHO), there will be 17.39% reduction of mortality due to air pollution attribution (55 to 59), 22.91% at 40-44 years and 15.67 attributable proportion at 60 to 64 years. These results are in line with other epidemiological studies, and it confirms that age plays an important risk factor for IHD. These estimates are plausible and can guide for policy interventions.

Table.10 estimates the contribution of air pollution to mortality due to stroke. Air pollution is a leading risk factor for stroke (short-term and long-term) accounting for 29% of global stroke burden with low-and middle-income countries severely affected. According to WHO analysis, stroke is the number one cause of mortality due to environmental risk factors. In this study, it was estimated that the number of deaths due to stroke is 1,154 at the age of 60 to 64 while more deaths, i.e. 2,532 secondary to Ischemic Heart Disease are attributed to air pollution, in the same age group (60-64 years) and this finding is different from global estimates.

Table 10. Age specific mortality for Stroke (attributed to air pollution) (Peshawar)

Stroke (60-64 Years) Age standardized mortality is 250*	2019-2020 PM2.5, 70 µgm/m3	2020-2021 PM2.5, 80 µgm/m3
Estimated Attributable Proportion (%)	13.91(8, 23.52)	15 (9, 25)
Estimated number of Attributable Cases	1067 (687, 1803)	1154 (748, 1957)
Estimated number of Attributable Cases per 100,000 Population at Risk	49.51 (31.88, 83.70)	53 (34, 90)

* Extracted from GBD 2019

Discussion

Estimates of this study have shown that the ambient air quality accounts for attributable pulmonary and cardiovascular diseases among groups of population with preexisting NCDs and results can be compared with multicity studies and cohort studies mostly in northern hemisphere, with one difference that stroke is not most affected by air pollution in Peshawar.

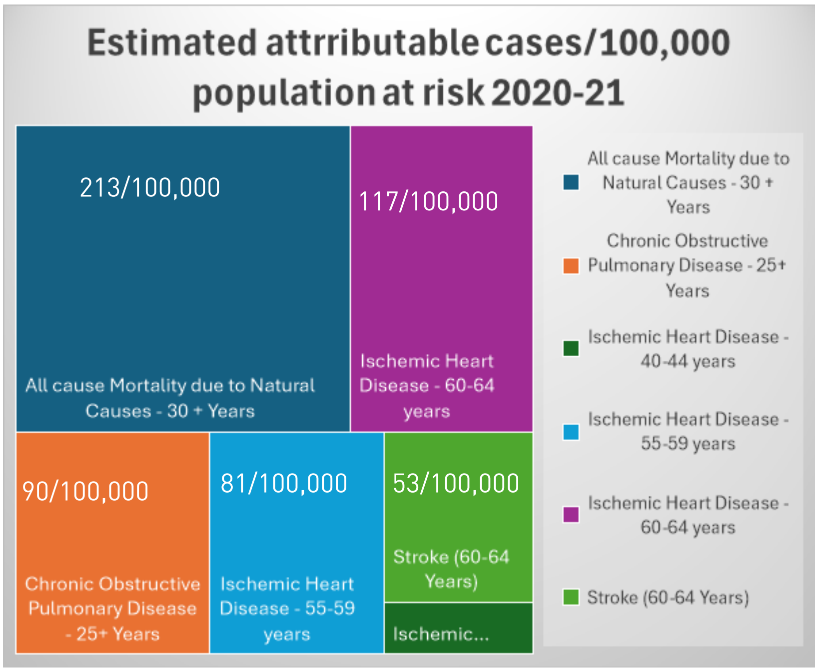


Figure 10. Islamabad's AQI variation during study period

The leading cause of age specific mortality is IHD. Age is one of the determinant/ risk factor so attributable number of cases /100,000 is five times higher in 55 to 59 years and seven times higher in 60 to 64 years as compared to 40 to 44 years. Similarly life style and co morbidities (diabetes, Hypertension) increase the risk . Same is observed in case of stroke . The results based on comparison of two years mean PM2.5 exposure with scenario building model has shown that a small increase of 10µg/m3 can result in increments in cardiovascular and respiratory mortality and case study estimates are evident.

Air pollution (ambient ,house hold) a risk factor for lung cancer has a national incidence of 18/100,000 population and our estimation has shown that there are 4 more cases /100,000 population when there is small increment of 10µg/m3 in year 2020-21(80µg/m3). Chronic Obstructive Pulmonary disease is closely correlated as long term effect of Air pollution and in our estimates

These estimates need to be validated by further studies based on primary data. As transportation is considered a major contributor of ambient air pollution in Peshawar, so other gaseous pollutants of interest other than Particulate matter need to be studied for effective policy interventions. Globally, around 8 to 20 % of asthma-related emergency room visits are due to Ozone, 4 to 6% due to PM2.5 and 0.4% due to NO2. Out of 116 million global asthma Emergency Room Visits in total , NO2 effect is underestimated.

According to Air Quality Life Index (AQLI) estimation ,currently residents of Peshawar are losing 2.3 years of their lives due to high levels of air pollution. On the other hand, if air quality PM2.5 level is compliant to the World Health Organization (WHO) guidelines can turn this estimate towards addition of these years.

The available Air Quality data for last 17 years ,indicates that Peshawar region has not complied with the WHO, National or Provincial standards for annual PM 2.5 average. This also suggests that population exposed during their growing years is in working Age and health impacts would have been considerable translated in to increased disease burden and incidence of various respiratory illnesses and emergency room visits. The current trends as shown that 58.4% of overall air pollution is contributed by transport so immediate, tangible interventions in one sector can prevent extensive Public health Impact.

7. Case study

Islamabad

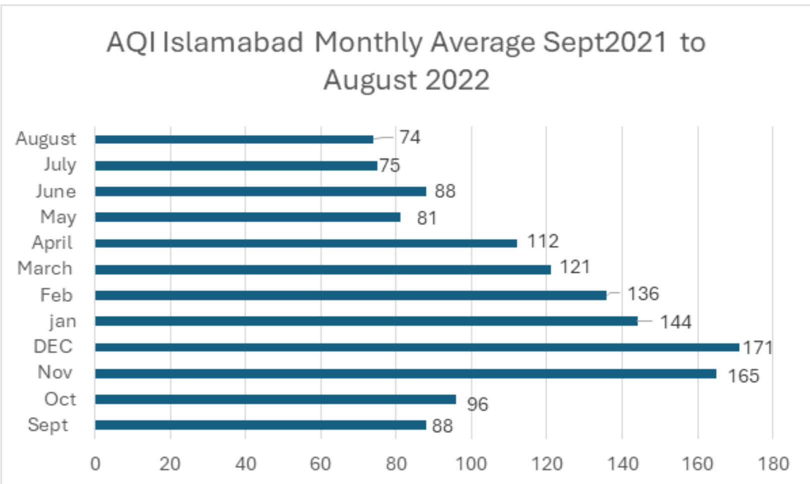
Islamabad is the capital city of Pakistan located on the junction of the Punjab and Khyber Pakhtunkhwa province. This expanding city has a population of more than 2.2 million (2023 census) making it the ninth most populous city of Pakistan. With a population density of 2,207 persons/sq. km (https://ictadministration.gov.pk/), It is adjacent to Rawalpindi, and they are commonly referred to as the twin cities. Owing to their close vicinity, both cities greatly influence and are, by each other's air qualities.

Islamabad Air Quality Profile

A review of Islamabad's PM2.5 levels captured by the Air Quality Monitoring Station (AQMS) from 2019 to 2022 shows that its yearly average AQI ranged between 110 and 115. As of 25th June 2024, its AQI was 85 (US AQM, IQ AIR). According to World Air Quality Report 2022 Pakistan was no 1 in central and south Asia with PM2.5 70.9 and Islamabad is 40.6 average (our study 38.5 on AQM).

Sources of Air Pollution in Islamabad

Islamabad has undergone urbanization and extension in the last decade. Construction activities have become a source of dust and particulate pollution. The junction between the twin cities and the entrance point for Rawalpindi and Islamabad from different cities and nearby rural areas, Faizabad, is one of their busiest roads and is a congested area with high traffic flow throughout the day. The emissions from vehicular exhaust triggers higher atmospheric levels of pollutants locally, especially emissions from vehicles driven on diesel. The industrial area of Islamabad (I-9, I-10) is also located near the Faizabad interchange. Emissions from these facilities also drive pollutants into the local air. Villages and rural areas surrounding the city do not have the facility of natural gas and they depend on wood for cooking purposes, and wood fire a contributory factor towards Air Quality.



Fig'; 11

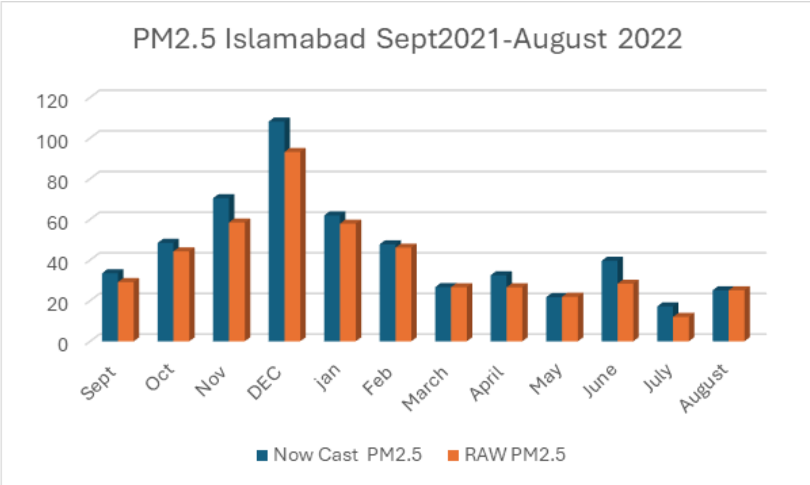


Fig12. created by author from Open Source data USEPA / AQM at US Embassy , used in study.

PM2.5 yearly Average during study period is 41.71 both from Raw data and Now cast data*.

Health indicators of Islamabad

Islamabad ranks 7th on Universal Health Coverage Index, i.e. 56 (2020), having consistent improvement in this indicator. Islamabad faces highest risk of non communicable diseases mortality 69.8% of total deaths and 60% of Daly,s /100,000 are NCD associated (Fig 5).Maternal Mortality Ratio is 157.5/100,000 population. Islamabad has Under 5 mortalty 49/1000 live births. Full immunization coverage is 68% (PDHS2018) NCD Aggregate score of Islamabad is 55.2(UHC 2023) smoking is prevalent in 29.5% of male population of Islamabad.

Methodology

This secondary analysis was conducted using the air quality data from the USEPA air quality monitors in the US embassy in Islamabad. This open-source data was compiled from September 2021 tillAugust 2022. The daily and hourly data was converted into a monthly average and for long term impacts, the yearly average was calculated. AQI and PM2.5 were the variables of interest.

The health end points investigated for this inquiry were all-cause mortality, age-specific and cause specific mortality mainly of non-communicable diseases, (IHD, COPD and Lung Cancer). The Global Burden of Disease study (2019) was used as reference the national disease incidence. Population attributable fraction (PAF) for morbidity and mortality was estimated using the AirQ+ 2.2 version model (WHO)Like Peshawar, population exposure data for Islamabad has been extracted from Census 2017 and population between 18 to 60 years has been studied.

Results

Islamabad's AQI varied between about 74 µgm/m3 (moderate) and 178 µgm/m3 (unhealthy) during the study period. It was the worst during the winter periods, i-e between November to January (Figure 10).

Population Exposure to Air Quality is directly proportional to health Impacts. The following figure is from World Air Quality Report 2022 and has shown %age of different Air Quality exposure and yearly change over four years.

In table 11, the natural cause mortality in 30+ population at an RR of 1.064 and an average yearly PM2.5 of 40.6 is estimated at 1640 (1095, 2125 wider CI). These attributable deaths to ambient air pollution decrease by about 600 when PM2.5 decreased by 8.5 points arbitrarily. This decrease in the PM2.5 has been arbitrarily chosen as a scenario of a lower than existing level of the PM2.5.

Table 11. Estimates of Health Endpoints (AIR Q+) (Islamabad)

Attributable number of all-cause mortality and disease specific due to air pollution in 2021-2022 (95% CI)		
Mortality due to natural causes - 30+ Years RR 1.064; incidence 621/100,000 population*	2021 Average $PM_{2.5}$ 40.6µgm/m3	Scenario (decrease of 10) Average $PM_{2.5}$ 30.6 µgm/m3
Estimated Attributable Proportion (%)	13.1 (8.8,17.08)	8 (5-11)
Estimated number of Attributable Cases	1640 (1095, 2125)	1073 (710, 1407)
Estimated number of Attributable Cases per 100,000 Population at Risk	81 (54, 106)	53 (35, 70)

* incidence Extracted from GBD 2019

Similarly, a decrease in attributable risk mortality of IHD was noted by about 50 and approximately over 300 cases are reduced for the age groups 40-44 and 60-64, respectively, when the ambient PM2.5 decreased by 10 µgm/m3 (Table 12). Once again, this 10 point difference in the PM2.5 for the one year of the study period and scenario, is to estimate the effects on the attributable mortality when the air quality improves. As mentioned earlier PM2.5 of 30 l is less than (WHO guide lines 2021) interim target 1 of 35 and NEQs Pakistan but it is not safe and long term exposure has more impact particularly on NCDs. It is estimated that there will be 17 less cases /100,000 population of IHD in age 60 to 64 (vulnerable) when air quality is improved by 10 points . WHO guidelines 2021 has set the target 5 µgm/m3 below which there is no health impacts.

Table 12. Attributable risk of mortality due to Ischemic Heart Disease (IHD) (Islamabad)

Ischemic Heart Disease - 40-44 Years Incidence 72.95/100,000*	2021-22 $PM_{2.5}$ 40.60 µgm/m3 (CI)	Scenario 10 points reduction $PM_{2.5}$ 30.6 µgm /m3 (CI)
Estimated Attributable Proportion (%)	14 (09,33)	11.58 (6.94, 26.39)
Estimated number of Attributable Cases	217 (134,488)	169 (101, 386)
Estimated number of Attributable Cases per 100,000 Population at Risk	10 (6, 24)	8 (5, 19)
Ischemic Heart Disease - 60-64 Years RR 1.084*	2021 $PM_{2.5}$ 40.6 µgm/m3	$PM_{2.5}$ 30.6 µgm/m3
Estimated Attributable Proportion (%)	10 (6, 20)	7.76 (4.8, 16)
Estimated number of Attributable Cases	1503 (964,3088)	1166 (724,2400)
Estimated number of Attributable Cases per 100,000 Population at Risk	75 (48, 154)	58.14(36, 120)

*incidence Extracted from GBD 2019

Table 13. Lung Cancer mortality in 30+ years attributed to air pollution (Islamabad)

Lung Cancer - 30+ Years RR is 1.064*	2021 $PM_{2.5}$ 40.60 µgm/m3	Scenario reduction in PM 2.5 $PM_{2.5}$ 30.6µgm/m3
Estimated Attributable Proportion (%)	18 (09, 26)	12 (5,17)
Estimated number of Attributable Cases	76 (36, 109)	50 (23, 74)
Estimated number of Attributable Cases per 100,000 Population at Risk	3.9 (1.8, 5.4)	2.5 (1.1, 3.6)

* incidence Extracted from GBD 2019

Cases of lung cancer in ages 30 and above decreased by 20 (Table 13). And a 4% decline in the attributable proportion of COPD was noted with a reduction in the PM2.5 (Table 14).

Table 14. Attributable risk for Chronic Obstructive Pulmonary Disease (COPD) (Islamabad)

Chronic Obstructive Pulmonary Disease - 30+ years; RR is 1.064*	2021 $PM_{2.5}$ 40.6 µgm/m3	Scenario reduction in PM 2.5 $PM_{2.5}$ 30.6µgm/m3
Estimated Attributable Proportion (%)	16 (10, 25)	12 (07, 18)
Estimated number of Attributable Cases	1073 (668, 1591)	800 (480, 1170)
Estimated number of Attributable Cases per 100,000 Population at Risk	53 (33, 79)	40 (23, 58)

* Extracted from GBD 2019

Air pollution in Islamabad was noted to contribute 81/100,000 mortality from all causes. There are 168 deaths with IHD are attributed as impact of air pollution and second is COPD contributing 83 and 4 cases of lung cancer are attributed to Islamabad Air quality in 2021.

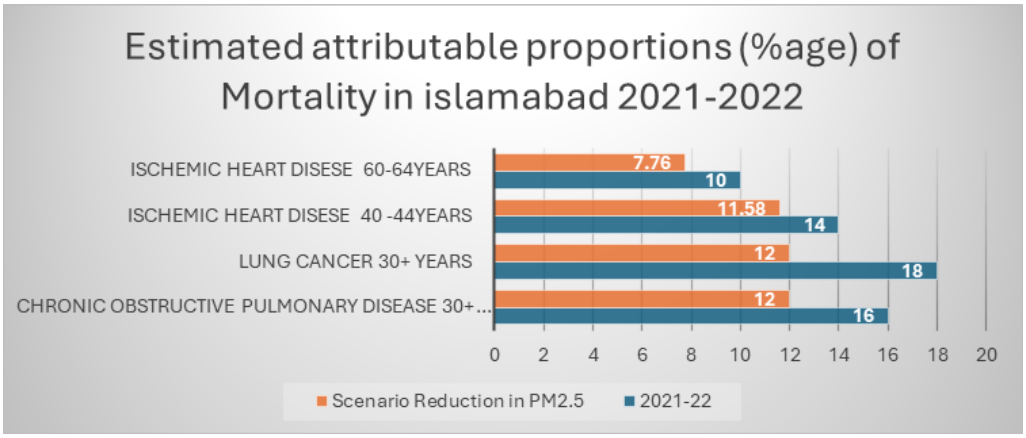
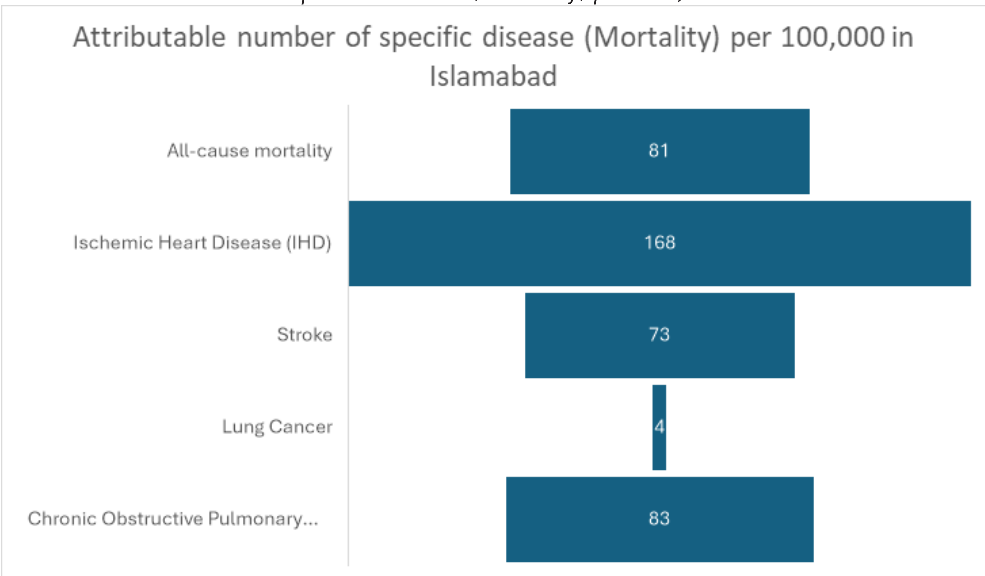


Figure13; proportion of case mortality Attributed to Air Pollution

Table 15. Attributable number of specific disease (Mortality) per 100,000

All-cause mortality	81
Ischemic Heart Disease (IHD)	168
Stroke	73
Lung Cancer	4
Chronic Obstructive Pulmonary Disease (COPD)	83

Figure 14: Attributable number of specific disease (Mortality) per 100,000 in Islamabad



Discussion

Estimates of this study show that poor air quality accounts for attributable cardiovascular and pulmonary diseases among groups of population. A 10-point reduction in PM2.5 results in approximately 600 lives that can be saved in Islamabad. 26 less deaths from lung cancer and 200 lives may be saved from COPD by enhancing the air quality.

It is interesting to note that cardiovascular diseases have mostly been observed in developed and high-income countries rather than in the developing low-income countries exposed highly to air pollution[38]. This was also found in this analysis.PM2.5 is attributed to more deaths in Islamabad in global comparison[39]. Extremes of age are vulnerable groups but, in some cases, younger groups more are affected. Mortality was seen to increase with increasing age. The average life expectancy in Pakistan would increase by 2.6 years if the country reached the WHO interim target 4 value of 5 μg/m3 (2021)(42)

Conclusion

38 Burroughs Peña MS, Rollins A. Environmental exposures and cardiovascular disease: a challenge for health and development in low- and middle-income countries. *Cardiol Clin*. (2017) 35:71–86. doi: 10.1016/j.ccl.2016.09.001

39 Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019 (GBD 2019) Disease and Injury Burden 1990-2019. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME), 2020.

42. Ali, Manzoor. (2022, April 21). Air pollution brings down life expectancy in Peshawar: Study. Retrieved from Air pollution brings down life expectancy in Peshawar: study - Pakistan - DAWN.COM

Though this study based secondary data utilization and attribution estimates with wider uncertainties and there is plausible evidence to support the fact that PM2.5 concentration and long term exposure has health impact and public health issue. This study also provides an insight for sectoral interventions and multisectoral approach for policy interventions.

Avenues for Policy Research and Recommendations

Bridging the gap between Air pollution and Health

There is clear and extensive data on the harmful link between air pollution and health. However, most of this evidence comes from the global north and cannot be generalized to our local context. There is a need to establish an environmental health consortium that initiates epidemiological studies (May be Cohort) to generate local data.

Pakistan does not have robust data and evidence of its own. There is a need to creating capacity and mechanisms for accurate air pollution data collection , analysis and periodic reporting along with the development of disease registries in the public and private health sectorb. Source apportionment studies from Pakistan has used outdated data analysis methods, short-term sampling and lack generalizability[40]. The spatial and temporal dynamics of emission sources require further research to understand their composition, location, and contribution to overall emissions. This will contribute to the emission reduction approach through emission load caping and reduction targets for key sectors and cities and provinces. Another important contributor to ambient air pollution and health outcome is Household Air Pollution (HAP) by fossil fuel combustion. Children and women are the affected most. Studies have shown significant impact on the developing fetus[41]. There is no comprehensive study done in Pakistan & it is required to generate knowledge on household components of gaseous and particulate matter. This groundwork will underscore the potential health costs of air pollution(frequent pediatric ward visits), address the science of air pollution and health within an economic framework.

A multi-stakeholder group of experts from disciplines such as health, transport, industry, meteorological departments and policy makers can be established that will devise a road map to reduce ambient air pollution and its associated risks. Guided by the DCP3 inter-sectoral interventions, this group can interact at different points in time to help identify gaps in knowledge and suggest future research and policy directions.
Effects of air pollution (both the indoor and the outdoor) are just estimates with wider uncertainties yet giving an insight into the gravity of situation. A national expert policy dialogue is required to reshape the existing policies and implementation mechanisms so as to bridge the gap between SDG 3 and 7.

Improved air quality monitoring

Enhancing ambient air quality monitoring across cities and rural areas by installation of ground level monitors, especially those known to have a poor AQI, will capture the widespread nature of air pollution. This surveillance can double as an early warning system for events like sand and dust storms. The surveillance system of SMOG in region needs to be established.

40 Faridi, Sasan, et al. "Source Apportionment, Identification and Characterization, and Emission Inventory of Ambient Particulate Matter in 22 Eastern Mediterranean Region Countries: A Systematic Review and Recommendations for Good Practice." Environmental Pollution, vol. 310, Oct. 2022, p. 119889. ScienceDirect, https://doi.org/10.1016/j.envpol.2022.119889.

41 43. Gordon, Stephen B., et al. "Respiratory Risks from Household Air Pollution in Low and Middle Income Countries." The Lancet Respiratory Medicine, vol. 2, no. 10, Oct. 2014, pp. 823–60. www.thelancet.com, https://doi.org/10.1016/S2213-2600(14)70168-7.

Adequacy of health data

Pakistan's NCD mortality data is not updated and has quality concerns. Risk factor surveillance is also absent. Morbidity data is scant as there are no systematic clinic or hospital-based registries of public and private health facilities. Creation of dashboards with relevant indicators will centralize reporting of the data collected, allowing this information to flow within out mixed health system.

Pakistan does not have robust data and evidence of its own. There is a need to creating capacity and mechanisms for accurate air pollution data collection , analysis and periodic reporting along with the development of disease registries in the public and private health sector

Pakistan should develop healthy policies based on cross-cutting environmental issues including air pollution and their effects on health of different age groups and vulnerable populations.

Increased access to data about ambient air

Sharing of data between the Environment Protection Agencies and Department of Health should be mandatory besides devising coordination mechanisms for health alerts, etc. Capacity building of health and EPA human resources is needed on surveillance and tools/software. Coordination mechanisms can be devised in the form of a committee with specific roles and high-level political commitment.

Community Engagement and Awareness

Community Enhancing the polluting sectors' reporting of emissions to the public will lead to greater accountability. This needs to happen in tandem with strict implementation of the NEQs. Youth involvement particularly high school students for public awareness.

Revision and Implementation of National and Provincial air quality standards

National Environmental Quality Standards (NEQS) 2012 approved by the Ministry of Climate Change are the guiding rules to set the standards and targets. Punjab drafted and approved the environmental quality standards in 2016. .

We can also follow the regional best practices. In latest WHO Air Quality Guidelines 2021, the lowest safe level is 5 µgm/m3/year average, (<15 µgm/m3/day) which is difficult to achieve in our setting. Interim Targets (IT) identification will be more realistic [IT1, 35 µgm/m3 through IT4,10 µgm/m3 (Table 2)].

National Clean Air Policy (NCAP) 2022 has set the PM2.5 baseline of 35 Microgram/MM3 which is much higher than WHO guide lines 2021(5µgm/mm3) but equaling to Interim Target 4. Implementation of National Clean Air Plan will be catalyst to achieve and reaching to the WHO PM2.5 safe level & above mentioned recommendations. Pakistan s first national Air Pollutant Inventory is in place which includes first ever Quantification of

Black Carbon and other Air pollutants at National and Provincial scale. What required is to identify and mitigate Air pollution Strategies , out line a plan for coordinating action on air quality management.

Limitations

Non-availability of relevant compiled health indicators data for short-term and long-term studies is not available. Such data is useful for calculating /projecting population attribution fraction which is useful to understand policy implications. For short-term impacts, daily air quality data is required. Specific health indicators like data on emergency hospital visits and admissions of specific pre-existent disease conditions and about vulnerable groups like children, elderly and preexisting morbidity was unavailable in all consulted data sets. A novel survey may be conducted which can be later incorporated in the Health Management Information System (HMIS) for future reference

The findings of these analyses are rough estimates. Exact attribution is NOT possible due to absence of actual Cause Specific Mortality data from Pakistan. So estimates has wider uncertainties and confidence intervals which can be improved by robust systematic data collection. Absence of exact population exposure data is another limitation and may have resulted in overestimation or underestimation of results.

This case study is limited to impact assessment and the health endpoint of natural (all-cause) mortality, age and disease specific mortality. Health data used from IHME (GBD) is not city specific. As national estimates are usually lower than city specific, so there can be much higher impact if calculated with city specific primary data.

Air Q+ works on single pollutant estimation model and combined effect of different pollutants can be cumulative with over estimation or under estimations. Indoor air pollution outcomes need to be considered in all-cause mortality.

Although particulate matter data is the primary data, the population of Peshawar city is dense and higher than recommended for fixed monitoring stations. The same is true for Islamabad, where data was collected from one fixed monitoring station which cannot fully capture the extent of air quality in other, more polluted areas of the city.

Acknowledgements

We acknowledge the work done by Peshawar Clean Air Alliance (CSO) on Air Quality Monitoring and apportionment study (supported by Sustainable Energy and Economic Development (SEED) Peshawar Clean Air Alliance is primarily driven by civil society members, to achieve its vision for improved quality of air for Peshawar residents.

We acknowledge 1. Miss Heba Safi Technical advisor on chemical safety WHO /Centre for Environmental Health Action (CEHA) Jordan. For review and being panelist at Islamabad study presentation in March 2023. 2. Dr Ejaz Khan Associate professor Health Services Academy Islamabad for his review and guidance.

2022 World Air Quality Report visualization framework

Annual PM2.5 breakpoints based on WHO guideline and interim targets	PM2.5	Color code	WHO levels
Meets WHO PM2.5 guideline	0-5 (µg/m³)	Blue	Air quality guideline
Exceeds WHO PM2.5 guideline by 1 to 2 times	5.1-10 (µg/m³)	Green	Interim target 4
Exceeds WHO PM2.5 guideline by 2 to 3 times	10.1-15 (µg/m³)	Yellow	Interim target 3
Exceeds WHO PM2.5 guideline by 3 to 5 times	15.1-25 (µg/m³)	Orange	Interim target 2
Exceeds WHO PM2.5 guideline by 5 to 7 times	25.1-35 (µg/m³)	Red	Interim target 1
Exceeds WHO PM2.5 guideline by 7 to 10 times	35.1-50 (µg/m³)	Purple	Exceeds target levels
Exceeds WHO PM2.5 guideline by over 10 times	>50 (µg/m³)	Maroon	Exceeds target levels

Source. world Air Quality Report 2022.

SDPI

Sustainable Development Policy Institute