Air Quality and Health: The Impact of Respirable Particulate Matter and Tropospheric Ozone

Executive Summary

Air pollution, particularly respirable particulate matter ($PM_{2.5}$) and tropospheric ozone (O_3), presents a significant global health risk, with India experiencing some of the worst levels of pollution worldwide. This roundtable discussion delves into the urgent need for comprehensive and standardized health data systems and air quality monitoring tools to address the serious public health impact of air pollution.

Recent studies on Pollution and Health, show that air pollution is responsible for a substantial number of deaths and diseases globally, with South and East Asia, including India, bearing the highest burden. The Indian government's efforts to curb air pollution are critical, but gaps in health data collection, exposure assessments, and predictive modeling hinder effective policy-making.

The roundtable explores critical areas for improvement that include (1) enhancing the accessibility and standardization of health data, (2) expanding air quality monitoring efforts, and (3) refining health impact assessments. A key outcome is the development of an Integrative Framework that combines air pollution data with health data for more reliable exposure assessments and targeted interventions, ensuring a healthier future for communities.

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INTRODUCTION

Air pollution is a major global health threat, with respirable particulate matter ($PM_{2.5}$) and tropospheric ozone (O_3) playing key roles in exacerbating respiratory and cardiovascular diseases.

The Lancet Commission on Pollution and Health highlights that air pollution is one of the leading causes of approximately 9% of global deaths, with its contribution to global mortality varying between 2% and 15% depending on the country. In South and East Asia, air pollution accounts for 15% of global mortality.

The health impact of air pollution is especially pronounced in countries like India, where pollution levels are alarmingly high, contributing significantly to premature deaths and diseases. In India, which represents 18.1% of the global population, air pollution contributes to 26.2% of global air pollution-related Disability-Adjusted Life Years (DALYs).

Particularly high levels of ambient particulate matter pollution are found in states such as Uttar Pradesh, Haryana, Delhi, Punjab, and Rajasthan, while household air pollution remains a significant health concern in states like Chhattisgarh, Rajasthan, Madhya Pradesh, and Assam.

The rate of deaths from ambient particulate matter pollution has increased by over 115% from 1990 to 2019, with tropospheric ozone-related deaths increasing by more than 139%.

Despite recognition of these challenges, effective data collection and exposure assessment models remain inadequate. Health data related to air pollution exposure is fragmented, inconsistent, and often inaccessible.

Additionally, air quality monitoring systems are not yet fully equipped to provide real-time, precise exposure assessments that account for local vulnerabilities.

India's commitment to the 2030 Agenda for Sustainable Development Goals (SDGs) emphasizes the urgent need to reduce pollution's impact on health, particularly under Objective 3, which aims to substantially decrease deaths and illnesses from air, water, and soil pollution by 2030.

The Need

1. Strengthen Health Data Systems

There is an urgent need to improve the collection, accessibility, and standardization of health data related to air pollution. This will facilitate better health impact assessments, allowing for more informed policy decisions.

2. Enhance Air Quality Monitoring

Expanding the monitoring of $PM_{2.5}$ and tropospheric O_3. This can be achieved through a combination of ground-based certified sensors, satellite data, and AI-driven modelling for better understanding of exposure across-different regions.

3. Refine Health Impact Assessments

There is a need to develop data-driven frameworks that link air pollution with health outcomes, particularly focusing on mortality, morbidity, and disruptions in the immune system.

This roundtable has addressed critical areas necessary for assessing the public health impacts of air pollution, specifically focusing on PM2.5 and tropospheric O3 through detailed discussions. Subsequently, it has finalized an Integrative Framework assessing the health risks associated with these pollutants, ensuring a healthier future for communities.

Problem Definition

Air pollution, particularly $PM_{2.5}$ and O_3, poses serious health risks, including increased mortality rates, higher hospital admissions, and a surge in respiratory and cardiovascular diseases. Despite the availability of some health datasets, challenges in accessibility, integration, and consistency of health and pollution data limit effective policy-making and risk assessment. Inconsistent data collection methods across different institutions and the lack of standardized exposure assessment tools further hinder progress in this domain.

Table Session I:
Navigating Air Pollution-Related Health Data

Solutions

1. Leveraging Existing Data Sources

- The Integrated Health Information Platform (IHIP) inventories health data at sentinel sites nationwide. However, access to this data remains restricted, limiting its utilization for research and policy.
- Collaborations with health institutions and hospitals to develop a comprehensive health database that integrates survey data and surrogate health indicators.
- Promoting the use of electronic health records (EHR) across hospitals to enhance real-time disease tracking and profiling.

2. Enhancing Data Collection and Standardization

- Sentinel site selection should not be limited to locations with AQI > 200 but should also include cleaner sites to provide a comparative assessment.
- Develop a standardized proforma for various diseases, including COPD, ischemic heart disease, lung cancer, and lower respiratory diseases.
- Expand demographic and occupational exposure parameters, including factors like urban-rural divide, population density, smoking patterns, kitchen ventilation, and workplace air quality.
- Establish a unified database integrating health, demographic, and air pollution exposure data to facilitate better analysis and policy recommendations.

3. Data Preparation and Structuring

- Use of GIS-based geotagging to integrate pollution data from Central Pollution Control Board (CPCB) monitoring stations with health data.
- Standardize pollutant measurement units (e.g., $\mu g/m^3$) and exposure time scales (short-term vs. long-term, seasonal variations).
- Pilot programs should be initiated in medical colleges to improve data accuracy and reliability particularly for pollution hotspots.
- Implement data cleaning techniques such as interpolation, time-series analysis, and outlier detection for better data usability.

Major Recommendations

- Mandate hospitals and healthcare providers to regularly update the IHIP dataset with real-time disease incidence reports.
- Ensure comprehensive inclusion of air quality data, GIS-based health mapping, and personal exposure indicators.
- Implement organ-specific health monitoring proforma in addition to a general disease proforma to capture detailed health impacts.
- Expand exposure assessments beyond individual levels to community and occupational health risks.
- Integrate multiple sources of air pollution data (satellite imagery, ground-based sensors, and model estimations) to improve accuracy and policy formulation.

Problem Definition

Despite an extensive air quality monitoring framework, several gaps remain, including inconsistencies in location of monitoring stations and calibration; missing data; integration between meteorological and pollution data; and limited access to air qualitydatasets. A unified, structured approach to data collection, integration, and dissemination is needed to facilitate evidence-based policymaking and health risk assessment. There is also a need to strengthen indoor air quality monitoring and ensure real-time exposure assessments.

Table Session II: Exploring Air Quality Data

Solutions

1. Purpose of Air Quality Monitoring

- Establish an Early Warning System (EWS) linking ambient air quality data.
- Integrate urban development planning and industrial expansion with air quality data to mitigate further pollution.
- Enhance indoor air quality monitoring, as people spend significant time indoors.
- Strengthen legislation for data sharing and quality control standards for air pollution monitoring.

2. Improving Data Collection and Handling

- Address inconsistencies in monitoring station locations and instrument calibration to ensure accurate geographic representation of pollution levels and data quality.
- Establish data handling protocols to manage missing data and maintain uniformity across monitoring stations.
- Utilize hospital and government-mandated health records for correlating pollution levels and disease incidences.
- Leverage satellite and sensor-based data for real-time air quality assessments in areas with insufficient monitoring stations.

3. Data Preparation and Structuring

- Access to meteorological data from Indian Meteorological Department (IMD) to enable comprehensive pollution exposure analysis.
- Integrate CPCB pollution data with meteorological data (temperature, humidity, wind speed) for better trend assessments.
- Develop a centralized air quality data repository to facilitate data sharing .
- Establish sensor calibration protocols and spatial interpolation methods to enhance the reliability of air quality data in under-monitored areas using sensors.

4. Exposure Assessment and Risk Analysis

- Use population-weighted exposure models to refine risk assessments across different demographics.
- Enhance spatial interpolation methods to estimate pollution exposure in regions lacking direct measurements.
- Standardize seasonal monitoring periods for better evaluation of $PM_{2.5}$ and O_3 variations throughout the year.
- Develop comprehensive indoor exposure monitoring strategies to complement outdoor air quality assessments.

Major Recommendations

- Improve air quality monitoring stations through proper placement, equipment upgrades and periodic calibrations.
- Establish data-sharing protocols to increase transparency for researchers and policymakers.
- Build a unified repository integrating meteorological, pollution, and health records.
- Strengthen source apportionment studies to identify dominant regional pollution sources
- Implement structured seasonal assessments to support long-term policy strategies.
- Expand rural monitoring to improve data coverage and spatial interpolation using satellite data.
- Establish data validation protocols to ensure the accurate pollution exposure assessments.

Table Session III: Understanding Health Impacts of $PM_{2.5}$ and O_3

Problem Definition

Air pollution models used in developing countries often rely on frameworks and exposure-response relationships derived from developed nations. These models do not adequately account for geographical, social, and biological vulnerabilities specific to the Indian population. Additionally, there is a lack of indigenous exposure models and comprehensive health datasets to validate existing frameworks.

Solutions

1. Local Data & Indigenous Models

- Generate local data to assess exposure and health risks specific to India's diverse environmental and health conditions.
- Develop indigenous models using local data to reflect geographical, social, and biological vulnerabilities.
- Integrate regional health data to reflect urban–rural exposure differences.

2. Promoting Intersectoral Collaboration

- Foster collaboration among ministries, researchers, and health institutions to improve data collection, integration, and utilization.
- Involve experts from air quality, health, and epidemiology for better policy and model development.
- Form a multidisciplinary consortium including biostatisticians, epidemiologists, air pollution modellers, and immunologists.

3. Strengthening Data Collection & Tracking

- Equip primary health Centres (PHCs) to collect pollutant exposure and health data.
- Establish a referral system to track exposure histories, ensuring comprehensive data collection from patients
- Anonymize and share health data publically whilst ensuring data security and privacy.
- Set up stations to monitor under-measured pollutants like Polycyclic Aromatic Hydrocarbons (PAHs) affecting cognitive health.

4. Adapting Models to Local Conditions

- Adapt models to India's high exposure levels and regional variability.
- Conduct chemical characterization of particulate matter (PM) to develop India-specific dose-response functions.
- The inclusion of social, biological, and geographical vulnerabilities is essential in model development for more accurate risk assessments.

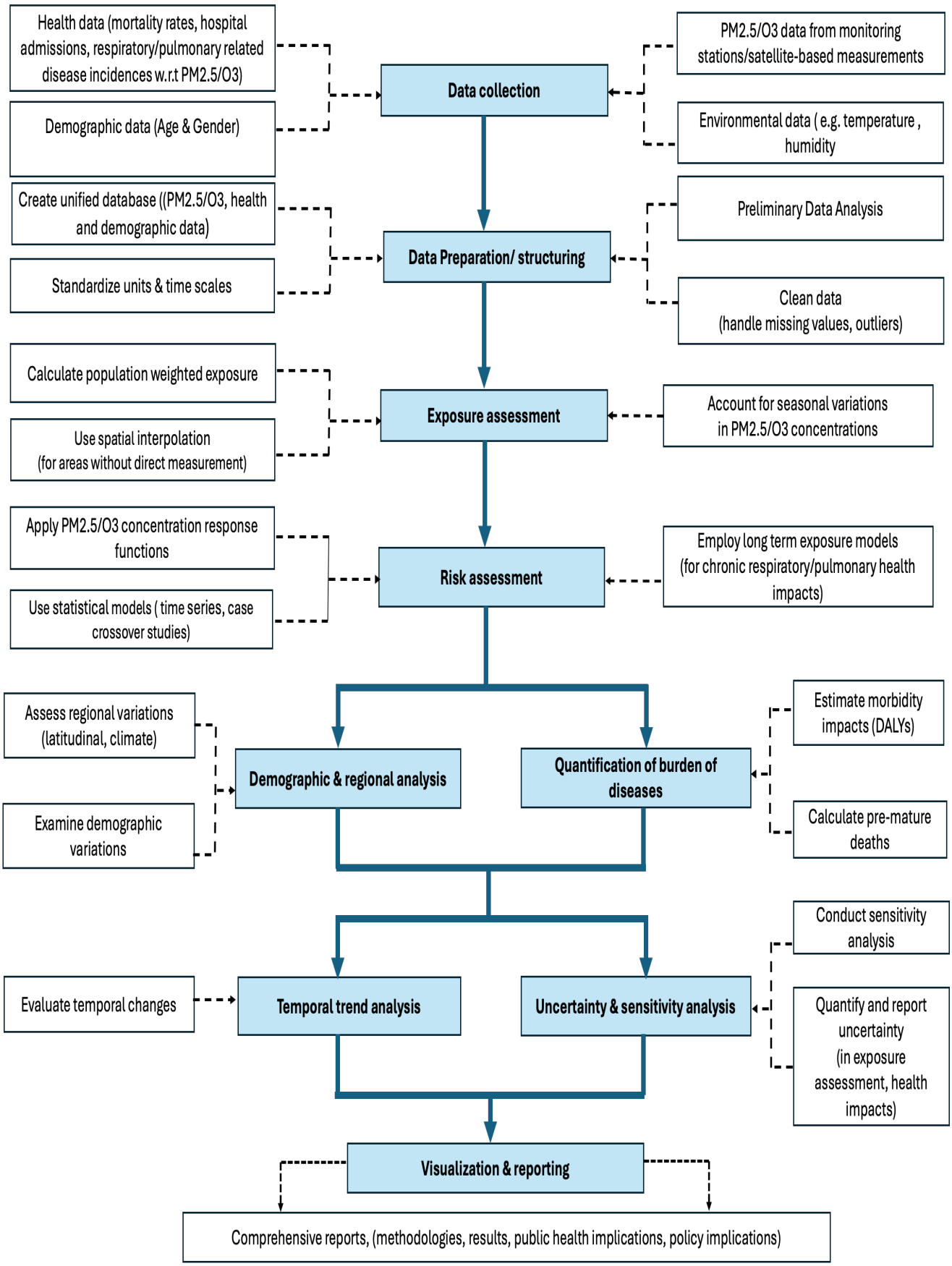
5. Exposure & Risk Analysis

- Use real-world data to quantify pollution-related morbidity and mortality.
- Develop India-specific exposure-response relationships using synthetic cell line studies and other advanced techniques.
- Include human to directly assess immune perturbation and epigenetic studies to assess long-term health impacts.

Major Recommendations

- Generate local data for accurate health and exposure assessments.
- Strengthen collaboration across ministries, research, and medical institutions to improve data collection and model development.
- Enable PHCs to collect exposure data and implement referral systems to track patient histories.
- Encourage bottom-up community engagement for collective responsibility.
- Establish monitoring stations for cognitive-impact pollutants like PAHs.
- Expand rural monitoring and use satellite data to bridge urban-rural gaps.
- Develop indigenous models tailored to India's high exposure and environmental conditions.
- Investigate epigenetic and long-term health impacts to understand the full scope of air-pollution's effects on public health.

Integrative Framework for Assessing Health Risks from PM2.5 and Tropospheric Ozone



Conclusion

- The Roundtable on Air Quality and Health has underscored the critical and urgent need for a cohesive, data-driven approach to tackling the public health crisis posed by respirable particulate matter ($PM_{2.5}$) and tropospheric ozone (O_3).
- As India continues to grapple with some of the highest pollution levels globally, the limitations of fragmented health datasets, underdeveloped exposure models, and inconsistencies in monitoring station locations hinder our ability to develop effective interventions and policies.
- Through focused discussions across three key sessions—health data, air quality data integration, and air pollution modeling—the roundtable has identified actionable solutions to bridge the current knowledge and policy gaps.
- These include improving the accessibility and standardization of health data, expanding air quality monitoring networks with advanced tools, promoting intersectoral collaboration, and developing indigenous exposure-response models grounded in local realities.

A key outcome of the roundtable is the proposal of an Integrative Framework that merges environmental, meteorological, and health data to enable more accurate exposure assessments and targeted health interventions. This framework emphasizes inclusivity, regional specificity, and real-time analysis to support informed decision-making and long-term policy planning. Ultimately, addressing the health impacts of $PM_{2.5}$ and O_3 pollution in India requires systemic changes-strengthening institutions, enabling cross-sector data sharing, investing in research and infrastructure, and empowering communities. By aligning efforts with the Sustainable Development Goals (SDGs), particularly SDG 3 on good health and well-being, this white paper aims to serve as a foundation for transformative action in air quality governance and public health resilience.

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