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Prioritizing Evidence Gaps: Air Pollution and Health Impacts of Climate Action

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Photo Credits

People pass through the rising pollution on the Delhi-Jaipur Expressway. Gurgaon, Haryana, India. Photo: Sudarshan Jha, Shutterstock, 2021.

Introduction and objectives

Globally, around 8 million deaths are associated with air pollution each year.[1,2] The vast majority of these deaths are caused by anthropogenic sources of combustion, including energy production, power generation, transport, waste burning, industry and biomass burning (for household energy and agriculture). These activities result in a complex mixture of health- and climate-damaging pollutants with warming and cooling effects, including particulate matter, ground-level ozone, carbon dioxide, nitrogen dioxides and sulfur dioxides. Climate action to address these leading global sources of pollution in a way that results in net-cooling would offer short-term benefits to health while providing longer-term benefits to the planet.

Current evidence suggests climate actions will result in larger health gains via air pollution reductions than via CO_2 and temperature reductions[3]. At the same time, more research is needed to more precisely assess the effectiveness of clean air and climate actions being taken considering how actions reduce specific health-damaging source emissions or short-lived climate forcers (SLCFs). In addition, given the increasingly warming environment, more consideration needs to be given to the joint effects of air quality and heat.

We conducted a rapid scoping activity to identify and prioritize gaps in the evidence base that may be limiting cities' and countries' abilities to demonstrate the health impacts of climate mitigation actions targeting combustion source air pollution. Given the urgency of the issue, we focused on identifying evidence gaps that may be filled over roughly five years to inform action by 2030. To ensure that research results would have meaningful application to policy and regulation, we also considered critical evidence and data gaps that may hinder the robust linkage of routinely collected local data with the global evidence base. Opportunities to advance our ability to demonstrate the health and climate benefits of air quality actions were prioritized. In addition, as we considered the feasibility of applying research results to areas most affected by climate and air quality, we also considered how current levels of data and capacity could influence policy and looked at potential regulatory opportunities that could be unlocked by filling these gaps.

Approach

We took a systematic approach with mixed methods to identify and prioritize the research gaps in air pollution and health in the context of climate change. We conducted a comprehensive search of peer-reviewed systematic reviews and meta-analyses on the health effects of air pollution to establish the current state of knowledge. This was complemented by international consultations with researchers, policymakers, technical experts and government stakeholders to gather insights and identify areas where further research is needed. A global advisory panel provided additional expertise and guidance. Identified research gaps were prioritized, based on their scientific significance, policy relevance and feasibility, before we formulated recommendations to guide future research efforts and address the identified gaps.

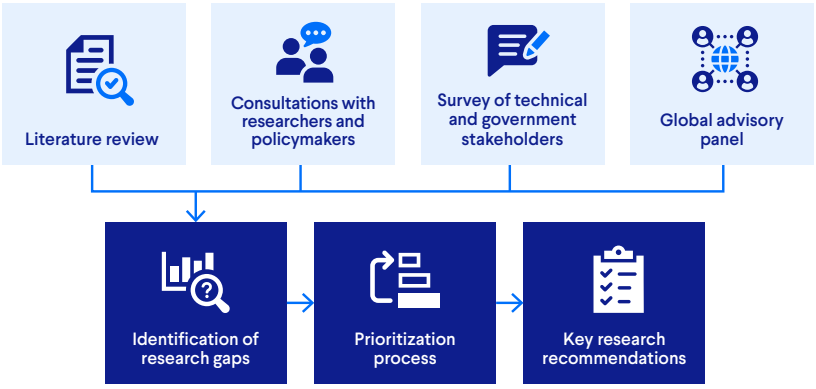


Figure 1. Summary of approach to identify and prioritize research gaps

Framing research priorities

We designed a rapid, two-stage pragmatic process to evaluate and prioritize research topics compiled through the literature review, stakeholder consultations and engagement with advisory panel members. Our goal was to prioritize research that would address critical climate, air quality and health issues in the context of broader considerations, such that research results would guide the development of effective, sustainable and ethically responsible solutions to mitigate the negative impacts of combustion.

Stage 1	Stage 2—Criteria		Priority score
Focus on combustion source pollution for greatest climate and air pollution mitigation potential Transport Industry Energy generation Wildfire Waste burning Agricultural burning Household energy	Scientific value	• filling critical gap • advancing knowledge	1 Little 2 Low 3 Medium 4 High
	Decision making value	• policy relevance • scalability • replicability	
	Feasibility/merit	• cost • timing	
	Capacity strengthening potential	• data systems strengthening • local opportunity	
	Public health potential	• emissions and/or exposure reduction potential • health mitigation potential • impact on cost to health system	
	Potential to advance equity	• filling critical gap • advancing knowledge	1 Yes 0 No
	Concern for unintended consequences	• filling critical gap • advancing knowledge	

Table 1. Overview of prioritization process used to identify research gaps for air pollution and health impacts of climate mitigation

From evidence to action: mapping research gaps along the chain of accountability

Researchers and policymakers consistently emphasize the need for evidence demonstrating the effectiveness of climate and clean air actions. Where efforts to promote clean air are in place, policymakers are keen to assess the extent to which improvements in air quality, and resulting impacts, may be quantified. Leaders who are currently weighing the feasibility and potential benefits of a suite of proposed measures

would like to make decisions based on credible evidence that selected solutions will be effective. However, even when health benefits are the ultimate aim, successful implementation involves consideration of the extent to which different control measures, such as transition to alternative energy sources, electrification of vehicle fleets or establishment of low-emission zones, may influence various points along the chain, from source control to emissions reduction, air quality/pollutant concentrations, exposure, dose and health effects. In addition, mediating factors along the chain, ranging from pollutant transport and transformation to key factors influencing susceptibility—such as nutrition or socioeconomic status—must be taken into account. As we consider the added complexity of a warming environment, the interaction of air quality and heat and their wide-ranging impacts on pollutant levels and health impacts also must be better characterized across the chain.

Research recommendations have been framed based on an adapted version of the chain of accountability[4] linking actions to health effects. This approach allows us to group priorities logically along this pathway so we can clearly articulate how research to fill fundamental knowledge gaps will support the design, implementation and evaluation of current and future climate and clean air policies.

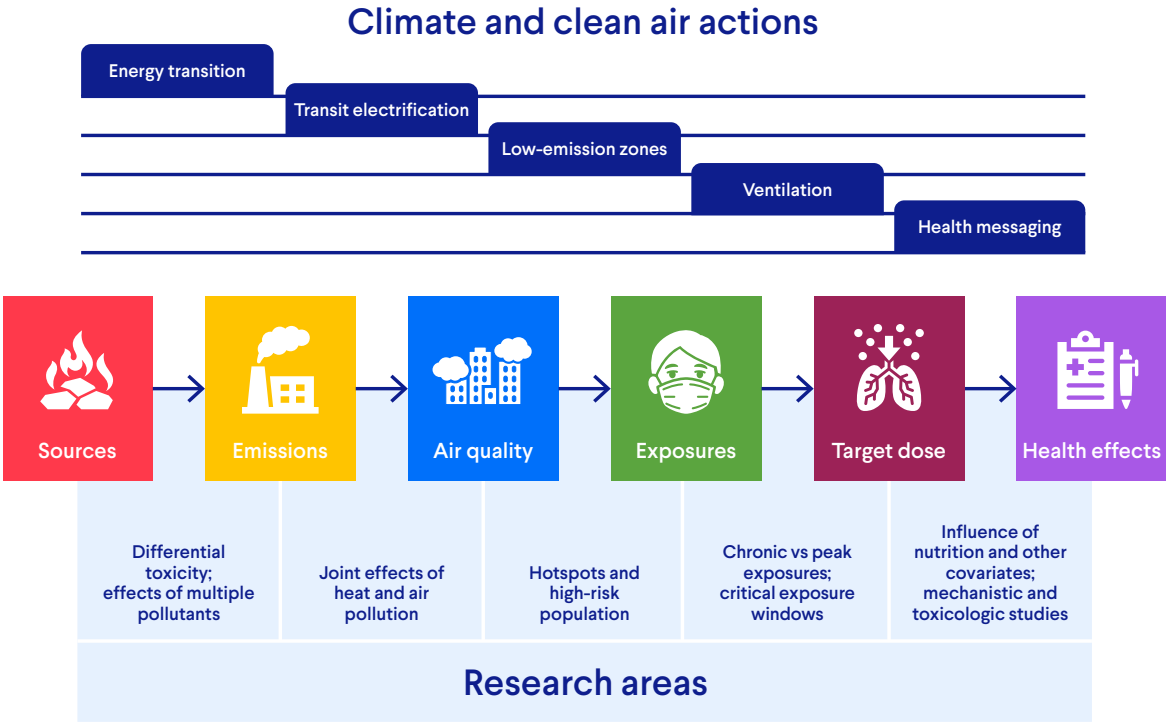


Figure 2. Modified chain of accountability for impact of climate and clean air action

Figure 2 depicts a refined chain of accountability for air pollution, expanding upon the traditional linear chain. It acknowledges the intricate interplay among sources, emissions, ambient air quality, exposures, target dose and health effects. Target clean air and climate actions (above) and illustrative examples of research areas (below) are provided along the chain.

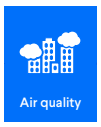
While actions are generally intended to target a specific segment along this chain, from source reduction to health outcome mitigation, it is important to recognize that these actions often have cascading effects and may influence multiple stages. This approach also allows us to better synthesize recommendations, while it avoids artificially grouping recommendations by discipline. Where warranted, we flag research recommendations that may be of global priority and are of increasing and/or particular importance for selected regions or populations.

Sources: Priority sources identified are not necessarily global sources of pollution with key evidence gaps. Rather, they reflect leading regional sources of emissions. Location-specific source apportionment is also critical as pollution sources and their impacts vary significantly between urban, rural and industrial settings.

Emissions: Foundational gaps in our understanding of emissions and their broader implications for air quality, climate and health need to be filled in order to better evaluate the impact of actions being taken. This includes:

- development of updated emission inventories
- better data on how climate actions are influencing emission patterns

Also needed is a better understanding of the complex interactions between various emission sources and atmospheric processes to improve air quality management. One key priority is examining the joint effects of air pollution and climate drivers. This topic is vital because heat can worsen both air quality (e.g., impact on ozone formation) and its health impacts. Another essential area is the development of advanced atmospheric models that incorporate real-world conditions like changing meteorological patterns, urban heat islands and secondary pollutant formation. These models are critical for predicting how emissions evolve in the atmosphere and for devising effective mitigation strategies.



Air quality: Topics to directly inform policies aimed at reducing exposure disparities and improving public health outcomes were prioritized. Research priorities included a focus on how air quality is affected by temperature, especially temperature's impact during air pollution episodes versus its longer term effects given seasonal trends in temperature and air quality. Also of interest is the interaction of temperature on formation of secondary pollutants (e.g., ozone) which may result in even greater health impacts beyond those expected from primary pollutant emissions.

Exposures: Recommendations focus on gaining a better understanding of how exposures to air pollution translate into biological doses that directly affect human health, bridging the gap between environmental exposures and quantifiable health impacts, and enabling more precise risk evaluations and tailored interventions. A key priority is investigating the relationship between exposure duration, intensity and target dose to identify the most critical exposure windows that lead to adverse health effects. Another priority is studying the life-stage-specific exposure patterns of air pollution, particularly in vulnerable populations and older adults. Mechanistic studies to explain epidemiologic results are also prioritized here. Finally, examining the impact of cumulative and combined exposures to multiple pollutants is essential to understanding how these exposures interact biologically to produce additive or synergistic effects.

Target dose: Research in this area delves into how combined environmental stressors affect target doses. This also involves a focus on the combined impacts of air pollution and heat. Additionally, some source-specific studies may warrant a focus on specific diseases, as well as the compounded impact of wildfire smoke and heat, emphasizing the complexity of air pollution's health effects.

This area also includes a focus on dose-response relationships in vulnerable populations such as children, elderly people and those with preexisting health conditions, and research on socioeconomic modifiers of health outcomes as this is vital to address health disparities and to design equitable public health policies.

These topics must be prioritized because they provide a deeper understanding of how air pollution can manifest in diverse health outcomes on a warming planet, considering individual and contextual vulnerabilities.

Additional needs to advance climate and clean air policies for health

There were a few additional areas of research that were flagged by both technical and policy stakeholders as being of critical importance to 1) make the case for actions to be taken, and 2) marshal the widespread public support needed for successful implementation of actions to be taken. These include policy-relevant impact assessments to quantify the health and economic benefits of local actions using approaches that harness the best available global evidence and available local data. Also prioritized was social science research to promote increased awareness and behavior change. We would also recommend investing in the development of new methodologies or technical guidance that can direct the assessment of the health, climate and economic impacts of clean air and climate mitigation policies under consideration and/or in progress. This would help ensure the robustness of assessments to be undertaken, especially when coupled with efforts to strengthen local capacity to collect and integrate relevant data.

Pragmatic considerations

Addressing critical data and capacity gaps: Effective evaluations require clear baseline data on air quality and health outcomes. In some places this data may not be routinely collected or be readily accessible in an easily usable format. Many places with the greatest air quality concerns face capacity gaps in air quality data collection infrastructure, particularly for routinely updated emissions data, real-time air quality monitoring, and individual exposure assessment. Filling these gaps is essential to increase the global distribution of policy-relevant accountability research and help to ensure that interventions are evaluated rigorously.

Leveraging ongoing studies: Given the interest in generating evidence in the short term, opportunities to retrofit existing cohorts and other similar longitudinal studies are particularly valuable. The integration of routine and complete health data is also essential for understanding the relationship between pollution exposure and health outcomes. However, several gaps may hinder the ability to derive robust conclusions and implement effective interventions, due to fragmentation of health and exposure data sources, underrepresentation of vulnerable populations, and inconsistencies in data reporting and completeness. Impediments to timely data access and integration also need to be considered, including legal and ethical barriers, lack of interoperability between disparate data systems, and technological constraints to large-scale data integration.

Conclusion

Through this rapid scoping exercise, a common theme has emerged from our engagement with technical experts and policy stakeholders focused on air quality around the world: The priority should be to evaluate the effectiveness of climate actions taken, with a focus on assessing measurable impacts on public health. In order to do this effectively, there are critical and fundamental research gaps to be filled along the modified accountability chain linking climate and air quality action to health effects. This includes a range of epidemiologic and mechanistic studies focused on characterizing the impact of actions taken to address climate forcing emissions, and/or overall air quality on exposures and health effects. Mediating factors along the chain, ranging from pollutant transport and transformation to key factors influencing susceptibility, such as nutrition or socioeconomic status, need to be taken into account. New evidence emerging from targeted efforts to fill these gaps will serve as essential inputs to further research and practices as we aspire to maximize the measurable health benefits of climate and clean air action.

Given the urgency of this issue, for both people and the planet, we must prioritize research results that may be achieved over the short term, ideally over the next five years. At the same time, there are critical data and capacity gaps that are currently hindering ability to conduct research in a timely manner. Support to strengthen the research infrastructure, with a focus on the availability of routinely collected air quality and health data, will pave the way for a more robust research infrastructure moving forward.

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