**HEALTH EFFECTS OF AMBIENT AND HOUSEHOLD AIR POLLUTION EXPOSURES IN INDIA**

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**ABSTRACT**

Air pollution has emerged as the largest environmental health risk worldwide, and in India, it ranks as a leading cause of death and disability, according to the Global Burden of Disease 2010 study. The study revealed that the combined exposure to PM2.5 from household cooking fuels and ambient air pollution contributes to a significant number of premature deaths and disability-adjusted life years (DALYs) in India, accounting for 9% of the national disease burden. The use of solid fuels for cooking, such as wood and coal, remains prevalent in India, exposing a large portion of the population, particularly women and children, to the harmful byproducts of incomplete combustion.

India is also grappling with high levels of ambient air pollution, with 13 cities ranking among the top 20 globally for annual PM2.5 levels. Weak policies on emissions control, coupled with industrial growth and increasing economic activity, pose a growing threat to air quality. Without intervention, it is projected that PM2.5 levels from transportation sources alone will double by 2030.

This study aims to examine the nature and extent of ambient and household air pollution exposures in India and their associated health effects. By considering the overlapping exposures across urban and rural areas, the study emphasizes the need for comprehensive interventions that address different pollution sources and intake fractions. Through the evidence presented, the study will offer practical recommendations to reduce exposure and alleviate the resulting health burdens. By taking proactive steps based on the study's findings, we can gain a better understanding of the health impacts of air pollution and work towards effective prevention and mitigation strategies.

**Key Words:** Health Effect, Ambient Air Quality, Household Air Pollution

## INTRODUCTION

Exposure to air pollution in whatever form, has long been globally recognized as an important risk factor for adverse health effects. However, this recognition has not yet translated into a coordinated multi-sectoral policy response that can reduce exposure and air pollution related burden of disease in India. Over 700 million people are still exposed to smoke from the use of biomass cook stoves nationwide, and India is home to 13 of the world’s top 20 cities with the worst ambient air quality, as per the World Health Organization (WHO).

The Global Burden of Disease study conducted in 2010 ranked air pollution as the leading environmental risk factor worldwide, and as a leading cause of death and disability in India. The comparative risk assessment exercise showed that approximately 1.6 million premature deaths and 59 million Disability-Adjusted Life Years (DALYs) are attributable, in India, to PM2.5 (fine particulate matter ≤ 2.5 µm in diameter), and other pollutants that are found in Household and Ambient Air Pollution (HAP & AAP). Taken together, HAP and AAP account for 9% of the national disease burden, and comprise the single largest risk factor of the over 60 risk factors examined in the study. GBD studies are evolving over time and the specific numerical estimates can be expected to change as well, but it is clear that particulate air pollution will remain one of the largest causes of ill-health in India until major efforts are made to reduce exposures in the population.

This is not surprising when we consider that the health impacts associated with exposure to air pollution are pervasive. Our review shows that exposure to air pollution, be it household or ambient, are linked to infectious diseases such as respiratory infections in infants, chronic respiratory illnesses and cancers in adults, and cardiovascular disorders such as ischemic heart disease and strokes. Further, studies conducted globally also show links to a multitude of other health outcomes at far lower exposure levels than are prevalent in India. Air pollution exposures also differentially affect particular groups due to factors such as age, sex, pre-existing conditions, socio-economic status, nutrition, and access to health care, thereby exacerbating existing vulnerabilities.



**Figure 1: Top 20 cities with highest annual average PM2.5 levels (WHO, 2014)**

Although both rural and urban populations face the risk of air pollution exposure, current air quality monitoring practices primarily focus on large cities, making it challenging to comprehend the extent and distribution of population exposures. This limited monitoring hinders our ability to fully understand the nature of air pollution exposure across different regions.

Additionally, research has indicated that emissions from biomass cooking contribute significantly to ambient PM2.5 air pollution in India. This finding underscores the interconnectedness of ambient and household air pollution, emphasizing the importance of adopting an integrated approach to mitigate and reduce the harmful effects of air pollution. By recognizing the continuum of exposure sources, we can develop comprehensive strategies that address both ambient and household pollution, leading to more effective solutions and improved public health outcomes.

**OBJECTIVE**

 The broad objectives are given hereunder:

* Focus on ambient and household air pollution and exposures in India.
* Focus on health effects of Ambient and Household Air Pollution Exposures in India.
* Focus on recommendations for Mitigating Air Pollutions and Health Impacts.

## LITERATURE REVIEW

##  Air pollution has gained global recognition as the foremost environmental health risk, with the Global Burden of Disease study highlighting its significant impact on mortality and disability in India. The study revealed that exposure to PM2.5 from both household and ambient sources is responsible for approximately 1.6 million premature deaths and 49 million Disability-Adjusted Life Years (DALYs) in the country. This combination of Household Air Pollution (HAP) and Ambient Air Pollution (AAP) constitutes the largest risk factor among the 60 factors assessed, contributing to 9% of the national disease burden.

##  Despite a gradual decline in the percentage of the population using solid fuels for cooking, the absolute number remains substantial, with 780 million people in India relying on wood, dung, crop residues, and coal. Traditional biomass combustion during cooking releases toxic byproducts, including PM2.5, equivalent to the harmful effects of burning about 400 cigarettes per hour. As a result, a significant proportion of the population, particularly women and children who spend considerable time in the kitchen, are exposed to this pollution source.

##  Disturbingly, India is home to 13 out of the top 20 cities globally with the highest annual levels of PM2.5, with Delhi ranking at the top. Inadequate policies to manage emissions from industries, transportation, and other sources, combined with escalating economic activity and industrialization, paint a bleak future. Without intervention, ambient PM2.5 levels from transportation alone are projected to double by 2030.

##  These findings emphasize the urgent need for comprehensive measures to combat air pollution in India. Efforts should address both household and ambient sources, focusing on reducing solid fuel usage, strengthening emission controls, and implementing effective policies to mitigate the growing air pollution crisis. By prioritizing air quality improvements, we can safeguard public health and create a cleaner and healthier environment for all.

## AIR POLLUTION: SOURCES, CONCENTRATION AND EXPOSURE

## Household Air Pollution:

Household air pollution (HAP) stemming from the use of solid cooking fuels arises primarily due to the challenges in achieving efficient combustion in traditional household stoves. This incomplete combustion process emits a multitude of chemical substances in the form of gases and particles. While regulations in India primarily focus on outdoor pollutants such as small particles, carbon monoxide, and nitrogen oxides, studies reveal that traditional chulhas (stoves) release numerous other harmful pollutants including formaldehyde, benzene, poly-aromatic hydrocarbons, and even dioxins.

Unlike ambient air quality, which benefits from national monitoring programs providing routine data, assessing HAP exposures has largely relied on individual research studies dating back to the 1980s. However, in recent decades, there has been a significant increase in the depth of information regarding HAP exposures in India. Measurements of short-term and 24-hour household concentrations and exposures have been conducted across various household settings in multiple states, contributing to a more comprehensive understanding of the issue. Notably, the exposure estimate for solid fuel users used in the 2010 Global Burden of Disease assessment relied on an exposure model developed specifically for India.

These advancements in HAP research and exposure assessments have contributed to our knowledge and awareness of the significant health risks associated with solid fuel usage for cooking. By recognizing the diverse range of pollutants emitted and their potential health implications, policymakers and stakeholders can develop targeted interventions and strategies to reduce exposure, improve indoor air quality, and ultimately protect the health of individuals and communities affected by household air pollution.



**Figure 2: Distribution of 24-hr average kitchen area PM2.5 concentrations in solid fuel using households across states**

**(Source: Balakrishnan et al. 2013)**

Although varying by state (Figure 2), national exposure models developed for solid fuel using household-level estimates average PM2.5 exposures of 337 µg/m3, 204 µg/m3 and 285 µg/m3 for women, men and children respectively, greatly in excess of the current WHO air quality guideline interim targets (WHO-AQG IT-1) of 35 µg/m3, or the Indian standard of 40 µg/m3.

Several recent studies (Chengappa et al. 2007, Dutta et al 2007, Balakrishnan et al 2014, Sambandam et al 2014), have also shown that many of the technologies used in the earlier or more recent models of ‘improved’ biomass cookstoves do not reduce emissions significantly enough to truly protect health. This is partly because as noted in chapter 4 of this report, the discernible health risks for most disease end points start at low levels of PM2.5 concentration. Dropping exposures from 350 to 175 µg/m3, for example, is not likely to produce much risk reduction, particularly compared to reaching the Indian standards of 40µg/m3or even lower.

**Ambient Air Pollution:**

The rapid expansion of industrial, power, and transportation sectors, along with urbanization in India, poses a significant concern for air pollution. Urban residents face escalating levels of particulate matter (PM10 and PM2.5), sulphur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), and ozone. While there has been a decrease in SO2 levels, all other pollutants consistently exceed the National Ambient Air Quality Standards (NAAQS). More than half of the cities monitored under the National Air Quality Monitoring Programme (NAMP) exhibit critical PM10 levels, with over two-thirds exceeding the safe limit of 60 µg/m3. NO2 levels are also on the rise in several cities, and Delhi frequently violates ozone standards. Although SO2 levels have decreased in general, many cities still grapple with unhealthy levels of multiple pollutants simultaneously.

However, the assessment of the contribution of different sources to air pollution in India remains inadequate. Some studies have been conducted by various agencies in selected cities, and the Central Pollution Control Board (CPCB) operates a limited number of air quality monitoring stations, primarily in larger cities. Thus, gaining a comprehensive national understanding of the issue heavily relies on satellite modeling. Satellite modeling of PM2.5 concentrations across the country, as depicted in Figure 2, reveals a stark reality of ambient air pollution in rural areas. While most of southern India adheres to the NAAQ standards, the Indo-Gangetic plain consistently shows critical levels of PM2.5 due to the prevalence of numerous brick kilns, outdated and inefficient combustion technologies, and the use of biomass and coal for household cooking and heating purposes.

These findings highlight the urgent need for comprehensive air pollution control measures that target specific pollution sources and geographical regions. Expanding the air quality monitoring network and implementing effective policies and regulations across sectors will be crucial in addressing the complex challenge of air pollution in India. By understanding the specific sources and their impact, policymakers can develop targeted strategies and interventions to mitigate pollution and safeguard public health.



**Figure 4: Ambient PM2.5 concentrations derived from satellite observations (Van Donkelaar et al., 2012)**

Studies have revealed a strong correlation between elevated levels of PM10 and SO2 and the proximity to coal-fired power plants. With the anticipated growth in coal-based power generation, and the absence of stringent regulations on stack emissions, this problem is expected to worsen over time.

Recent research has focused on exposure apportionment and identifying emission sources. However, these calculations primarily consider downwind exposure and do not account for near-field exposures, which can often be significantly higher. Nonetheless, exposure apportionment estimates can play a crucial role in designing and implementing policies to mitigate specific sources of exposure and improve traditional control measures by targeting health-related exposures more effectively.

The revised ambient air quality standards of 2009 now include six carcinogenic air toxics and heavy metals. However, data on their levels across the country is limited as cities have yet to establish continuous monitoring capacity for air toxics.

Over the past three decades, substantial progress has been made in building a global evidence base that offers a comprehensive understanding of household air pollution (HAP). The evidence base for ambient air pollution (AAP) health effects is even more extensive, encompassing thousands of studies worldwide. More recently, it has become evident that HAP significantly contributes to AAP in many countries, including India. Therefore, it is essential to examine air pollution exposure and its impacts in an integrated manner to develop comprehensive strategies for addressing this complex issue.

##

## HEALTH EFFECTS

In India, numerous studies conducted over the past decades have examined the health effects of ambient and household air pollution. These studies have utilized established techniques to estimate health effects based on findings from research conducted elsewhere. Similar techniques, employing exposure-response analyses, are commonly employed in policy frameworks addressing various environmental health risks, such as water pollution, toxic chemicals, and workplace pollutants.

The understanding of the health burden associated with ambient and household air pollution has evolved beyond respiratory outcomes in men, women, and children. It is now widely accepted that air pollution also impacts conditions like ischemic heart disease, stroke, cataracts, lung cancer, adverse pregnancy outcomes, tuberculosis, asthma exacerbation, other cancers, and cognitive impairments. As with tobacco smoking, which produces similar health impacts, air pollution necessitates its integration into public health programs addressing both non-communicable and communicable diseases.

The estimation of disease burden related to air pollution has been significantly strengthened through the development of "integrated exposure-response" (IER) relationships. These relationships utilize a vast body of health literature on outdoor air pollution (mostly from developed countries), active smoking, and household air pollution. IERs demonstrate a gradual rise in disease risk across five major categories (lung cancer, heart disease, stroke, chronic obstructive pulmonary disease, and child pneumonia), spanning a wide exposure range. Outdoor air pollution represents the lower end of exposure, active smoking the highest, and second-hand smoke and household air pollution fall in between.

The consistency of effects observed across the exposure spectrum through IERs enhances the confidence in risk estimates and enables comparison of attributable disease burden estimates across different sources of combustion. This allows for evaluating intervention options based on individual benefits as well as co-benefits. Notably, the use of IERs in the 2010 Global Burden of Disease assessment attributed approximately 1.04 million premature deaths and 31.4 million DALYs to household air pollution from solid cooking fuel use, and 627,000 deaths and 17.7 million DALYs to ambient air pollution in India.

Given the widespread prevalence of high levels of exposure across rural and urban populations, the diverse range of associated health outcomes (including those with high underlying prevalence rates), and the broad spectrum of at-risk populations (spanning all age groups, including infants and young children who do not smoke), the attributable disease burden from air pollution remains significant.

**Diarrhea / LRI / Other Infectious Cardio & Circulatory**

**Chronic Respiratory**

**Figure 5: Ranking of risk factors based on DALY contribution in India (GBD, 2010)**

**RECOMMENDATIONS**

Given the complex nature of air pollution, characterized by multiple sources and impacts, it is evident that there is no single solution that can effectively address the problem. Resolving this issue necessitates a multi-sectoral approach, guided by robust environmental and health data, scientific research, and evidence-based practices. The development, strengthening, and implementation of policies and programs to combat this significant risk factor in our national disease burden demand a unified and coordinated effort across various government entities. While the Ministry of Health and Family Welfare (MoHFW) can undertake certain actions outlined below, many others will require the involvement of other ministries and agencies.

We recognize that reducing both emissions and exposures is crucial to safeguarding public health. However, in prioritizing interventions, it is vital to base decisions primarily on exposure, as it directly influences health outcomes. Therefore, while we strongly advocate for reducing emissions to minimize overall population exposure, the highest immediate priority should be assigned to sources that contribute the most significant levels of exposure and adverse health impacts.

**SOURCE-WISE ACTIONS TO REDUCE EXPOSURE**

We recommend focusing on key air pollution sources that are implicated in long-term and episodic exposures. In each category, we list following sources in order of priority, based on exposure estimates, to reduce health impacts from air pollution.

**LONG-TERM EXPOSURES**

***Household air pollution:***

To address household air pollution, it is crucial to adopt WHO-recommended emission rate targets for PM2.5 and CO in vented and unvented kitchens, which requires a shift towards cleaner household energy sources. There are two primary options to consider: making clean energy sources readily available, such as electric cooking or gas, or focusing on making widely used biomass sources cleaner. In the former case, particular attention should be given to implementing fiscal policies and developing distribution systems that ensure affordable and accessible clean energy options for the economically disadvantaged. In the latter case, existing biomass stove standards in India need to be revised to align with the emission rate targets set by WHO, driving the adoption of advanced stove technologies that reduce pollution. Additionally, community-level approaches should be emphasized for effective intervention strategies in addressing household air pollution.

Achieving widespread adoption of clean cooking energy and transitioning away from traditional sources and practices will require insights from behavioral and social sciences. Drawing from successful health interventions like improved sanitation, vaccine delivery, safer sex, and malaria control, these disciplines can provide valuable knowledge and strategies. It is essential to coordinate efforts among different ministries and leverage existing initiatives such as the National Biomass Cookstove Program of the Government of India to ensure improved access to clean cooking energy within specified timeframes.

***Vehicular pollution:***

###  To address the health impacts of vehicular pollution, a range of control measures can be implemented. We recommend adopting an "avoid-shift-improve" framework to prioritize actions and manage the health effects of vehicles.

###  The "avoid" aspect involves minimizing vehicle use, especially in areas with large or dense populations, through integrated land-use planning that effectively manages transport demand. In the short term, targeted approaches can be implemented, such as implementing financial disincentives like higher fuel taxes, congestion pricing, and increased parking fees in heavily-populated areas. Regulatory measures can also be employed, such as creating vehicle-free zones in high-density areas or implementing broader restrictions on vehicle use.

###  The "shift" component emphasizes transitioning to transportation modes that reduce pollution and overall impact while still facilitating the movement of goods and people. This can be achieved by promoting the availability of mass transport options like buses and metro rail systems, as well as encouraging non-motorized transport modes such as bicycles. By increasing the usage of these cleaner modes of transport, the health impacts per passenger-kilometer traveled can be reduced.

###  The "improve" element focuses on enhancing vehicle technologies to minimize pollutant emissions per kilometer traveled. This can be accomplished through significantly tighter emission and fuel standards, resulting in reduced emissions per vehicle-kilometer and preventing the proliferation of polluting technologies in the new vehicle fleet. Stringent checks on on-road vehicles should also be implemented to ensure they do not exceed emission limits. Prioritizing health-based criteria can drive the adoption of Euro VI emission standards by 2020, reducing toxic risks associated with diesel emissions.

###  It is crucial to understand that there is no singular solution to reduce transport emissions, and a comprehensive range of measures is necessary to mitigate these emissions. Therefore, adopting an integrated approach to address the health impacts of vehicle pollution is essential.

### Trash burning:

###  Trash burning in highly populated areas, such as residential neighborhoods, significantly contributes to pollution in cities. To control this practice, strict enforcement of existing legislation banning trash burning is necessary, along with improved infrastructure for waste collection, composting of vegetative waste, and overall waste management.

### Diesel generator sets:

 Diesel generator sets located in residential and commercial areas are another major source of pollution in cities. Discouraging their use and promoting more efficient and less polluting alternatives, such as BEE-rated diesel generators, can help reduce emissions. Additionally, tightening emissions standards for generator sets would be beneficial.

### Road and construction dust:

 Dust from local sources, including areas with little green cover, construction sites, and road dust resuspension, contributes to particulate matter levels in cities. Effective strategies to manage this form of pollution include adopting dust control regulations, implementing street design guidelines with vegetative barriers, limiting vehicular speed, enforcing truck loading guidelines, using appropriate covers for trucks, and implementing gravel paving for haul routes. Enforcing good construction practices, safe disposal and recycling of construction waste, and stricter compliance with environmental impact guidelines can address pollution from construction dust.

### Brick kilns and other local industries:

 Brick kilns and other local industries located near cities are significant contributors to pollution due to their use of highly polluting fuel sources. Phasing out inefficient and polluting technology, implementing emissions standards, enforcing bans on inefficient kilns, and promoting alternative building materials are key steps to tackle emissions from these sources.

### Large sources (such as industries and power plants):

 Large sources such as industries and power plants require emissions standards to promote the uptake of clean technologies and reduce overall emissions nationwide. Strict particulate standards, as well as standards for nitrogen oxides, sulfur dioxides, and mercury, should be introduced to reduce exposure to power plant emissions. Siting policies should also be implemented to ensure that these sources are not located close to densely populated areas, and strong compliance monitoring is necessary.

***Episodic Pollution***

 Episodic pollution sources, including biomass burning, vehicular pollution during peak travel times, and seasonal crop burning, result in high-pollution episodes. While the health impacts of short-term high exposures are not as well-studied as chronic exposure, they are known to be detrimental, especially for vulnerable populations. Strategies to control episodic pollution should be implemented, and health advisories or public warning systems should be developed to protect vulnerable groups. Reporting air pollution-related hospital admissions during high episodic pollution events can contribute to a better understanding of the exposure-response relationship.

**THE SPECIAL ROLE OF MINISTRY OF HEALTH AND FAMILY WELFARE**

The establishment of the Steering Committee by the Ministry of Health and Family Welfare (MoHFW) signifies its acknowledgment of the significant impact of air pollution exposure, both household and ambient, on public health in India. This recognition places air pollution on par with or even surpassing various other risk factors such as poor nutrition, smoking, alcohol, high blood pressure, and obesity in terms of its adverse health effects. Given the magnitude of this health challenge, it is imperative for the Ministry to enhance and focus its substantial health systems to effectively respond to the health implications associated with air pollution. Strengthening and directing resources towards addressing this issue will enable the Ministry to adequately tackle the multifaceted impact of air pollution on the well-being of the population.Steps that can be taken by the MoHFW include:

***Better integration of air pollution and public health policies***

 The existing legal framework falls short in effectively addressing the comprehensive reduction of total exposure to air pollution and achieving clean air targets. To address this gap, explicit provisions should be incorporated into the statutory framework, such as the Air Act (1986), that specifically target the management of household air pollution. Furthermore, integrating policy drivers aimed at addressing household air pollution within the mechanisms of the Ministry of New and Renewable Energy (MNRE) would contribute to tackling this issue holistically.

 A thorough review of the current legal framework for addressing air pollution and public health is recommended to establish a roadmap for a health-based decision-making process and an effective compliance system, with the overarching goal of reducing overall exposure to protect public health. The ongoing reforms of various environmental laws present a valuable opportunity to address this issue comprehensively. Notably, the recent decision by the Ministry of Environment to include an objective health indicator in the Comprehensive Environmental Pollution Index for critically polluted areas marks an important first step in this direction.

***Integrate care pathways into existing national frameworks or programmes***

 The implementation of the RSBY, a prominent national health insurance scheme, along with similar state-run initiatives, has played a significant role in reducing the financial hardships associated with healthcare expenses. These schemes have primarily focused on providing coverage for in-patient services in both public and private healthcare facilities. However, data indicates that a substantial portion of healthcare expenditure in the country is directed towards outpatient services and medication costs.

 It is worth noting that the majority of Disability-Adjusted Life Years (DALYs) linked to air pollution exposure are attributed to non-communicable diseases (NCDs), specifically respiratory and cardiovascular conditions, which require long-term and continuous care. The ongoing discussions surrounding the National Health Assurance Mission (NHAM) have emphasized the importance of enhancing access to essential medicines and integrating mechanisms for managing chronic illnesses. This includes expanding allopathic care and promoting the incorporation of indigenous medical practices like AYUSH.

 To effectively address the considerable disease burden associated with air pollution exposure, it is crucial to develop and implement care pathways within national programs such as the NHAM. Given that air pollution exposure disproportionately affects the poor and vulnerable populations, integrating comprehensive care strategies through these initiatives becomes imperative.

***Strengthen policy-making capabilities in the area of air pollution and health***

 To ensure sustained engagement with the air pollution and health issue, the Ministry of Health and Family Welfare (MoHFW) should develop internal processes that enable the utilization of evidence derived from toxicological, epidemiological, and other scientific research to inform policy-making and the development of enhanced air pollution regulations. This would involve integrating scientific findings into the decision-making process, fostering evidence-based policies, and promoting continuous improvement in air quality management.

 To facilitate these efforts, the MoHFW could establish a standing expert group dedicated to air pollution and health. This expert group would serve as a valuable resource, providing inputs and advice to the MoHFW on various aspects, including the monitoring and evaluation of existing programs and initiatives. Additionally, the expert group could assess the ever-evolving state of science in relation to air pollution and its implications for policy, enabling the MoHFW to stay updated and responsive to emerging research findings.

 By establishing a standing expert group, the MoHFW would enhance its capacity to effectively address the complex challenges posed by air pollution and its impact on public health. This collaborative approach, combining scientific expertise with policy-making, would foster informed decision-making, strengthen regulatory frameworks, and contribute to the overall improvement of air quality and public health in the country.

***Air pollution data collection and health impacts research***

 To address the urgent need for comprehensive air pollution monitoring, with a specific focus on key pollutants from a health perspective, it is crucial to establish a robust monitoring network. This network should encompass the monitoring of both particulate matter (PM2.5) and other relevant pollutants to ensure a comprehensive understanding of air quality and mitigate potential trade-offs between pollutants. Priority can be given to PM2.5 monitoring for immediate implementation, while ensuring coverage in both urban and rural areas to accurately estimate population exposures. The Ministry of Health and Family Welfare (MoHFW) should play a central role in driving the collection of such data, recognizing its significance in shaping effective air pollution management strategies.

 Collaboration with institutions such as the National Family Health Survey and the National Sample Survey Organization is vital. The MoHFW should convene a group comprising relevant stakeholders to enhance existing standardized household survey questions. This enhancement will enable a better assessment of the health risks associated with household air pollution and facilitate the monitoring of changes over time. Additionally, conducting risk assessments and economic analyses of both the health impacts of air pollution and mitigation strategies would provide valuable insights for evidence-based policy-making.

 By taking a proactive approach to enhance data collection, refine survey questions, and conduct comprehensive risk assessments, the MoHFW can contribute significantly to understanding and addressing the health risks posed by air pollution. This collaborative effort will strengthen the knowledge base, inform policy decisions, and support the development of effective mitigation strategies to protect public health.

***Capacity building for public health practitioners and health care providers***

 Healthcare providers play a crucial role as key stakeholders in addressing air pollution and its health impacts. They should receive training to effectively deliver harm-reduction strategies to their patients within their clinical practice. This training will enable healthcare professionals to provide relevant information and guidance to patients on mitigating the health risks associated with air pollution. Moreover, incorporating modules on air pollution and health into the curricula of medical and nursing schools across the country will help raise awareness and ensure that future healthcare professionals are well-informed on this critical issue.

 Medical Associations can serve as powerful partners in raising awareness and advocating for inter-sectoral cooperation to tackle air pollution. These associations can play a vital role in disseminating information, organizing awareness campaigns, and facilitating collaboration among healthcare professionals, policymakers, and the public. As independent and credible sources, medical professionals can effectively translate scientific information into actionable recommendations for policymakers and the general public.

 Considering the widespread and significant health impacts of air pollution in India, it is important to develop national clinical criteria for evaluating patient risk specifically related to air pollution. Disseminating these criteria to health workers will enhance their ability to identify air pollution-related symptoms and provide appropriate guidance to patients. This step will help ensure that healthcare providers are knowledgeable about protective measures that can be recommended to individuals at risk, promoting proactive management of air pollution-related health issues.

***Information-dissemination strategies to reduce air-pollution-related health impacts***

The Ministry of Health and Family Welfare (MoHFW) can utilize its existing service infrastructure, such as Accredited Social Health Activists (ASHAs), public health clinics, and primary health centers, to disseminate air pollution-related information and promote measures for reducing exposure. These channels can be utilized to educate and raise awareness among vulnerable groups, especially pregnant women and young children, about the health risks associated with air pollution and provide guidance on ways to minimize their exposures.

 To enhance public understanding of pollution levels, information on air pollutant concentrations should be made readily available to the public. This transparency can empower individuals and communities to make informed decisions and take necessary precautions to protect their health.

 Integrating the Air Quality Index (AQI) and other early-warning systems into public communication strategies can serve as effective risk communication tools. By contextualizing health messages based on real-time air quality data, individuals can better understand the potential health risks and make informed choices to mitigate their exposure to air pollution.

 Drawing inspiration from successful anti-smoking campaigns, the MoHFW could launch an anti-pollution campaign with a specific focus on household air pollution (HAP). This campaign could include initiatives such as establishing "smokeless village" awards, similar to the recognition given to villages for achieving open defecation-free status. Additionally, a media campaign can be initiated to promote the provision of clean cooking technologies as wedding gifts to encourage families to adopt cleaner cooking practices, as has been done in Gujarat to promote the construction of toilets.

 By leveraging existing platforms, disseminating information, and launching targeted campaigns, the MoHFW can effectively raise awareness about air pollution and encourage communities to take actions to reduce their exposures, thereby protecting the health of vulnerable populations.

***Strong and sustained linkages to other actors/programs***

 To effectively address the health impacts of air pollution, it is essential to establish a multi-sectoral framework involving multiple ministries and agencies. The Ministry of Health and Family Welfare (MoHFW) should play a central role as the coordinator of this framework. To ensure comprehensive action, other relevant ministries such as environment, power, new and renewable energy, and rural/urban development should be engaged and involved in assessing the health impacts of major projects that may have implications for public health.

 The MoHFW should collaborate with state-level health agencies to raise awareness about the health impacts of air pollution and provide guidance on the most effective strategies for addressing this issue. This collaboration can enhance the capacity of state-level health agencies to tackle air pollution-related health challenges and implement appropriate interventions.

 Given the significant health implications of air pollution and the existing focus on cleanliness and sanitation through the Swachh Bharat Abhiyan (Clean India Mission), it is crucial to link air pollution control efforts with this initiative. By integrating air pollution concerns into the Swachh Bharat Abhiyan, a comprehensive approach to improving public health can be achieved, addressing both indoor and outdoor pollution sources.

 Through a coordinated multi-sectoral framework, active engagement with state-level health agencies, and integration with existing initiatives, the MoHFW can lead efforts to address the health impacts of air pollution and promote a healthier and cleaner environment for all.

***International Linkages and Agenda-Setting***

 Establishing international linkages, particularly with organizations like the World Health Organization (WHO), is crucial for the Ministry of Health and Family Welfare (MoHFW) to stay updated on the latest developments in addressing air pollution and to explore potential collaborations with other countries. These linkages can foster knowledge exchange, build synergies with global programs, and facilitate the sharing of success stories from India's efforts. Additionally, organizing a global meeting to showcase the committee's approach and recommendations would enhance the MoHFW's reputation as a leader in addressing air pollution both nationally and globally.

 In order to strengthen the evidence base for policymaking, it is essential to increase investments in health research. By supporting research initiatives focused on air pollution's impact on various health outcomes, the MoHFW can generate evidence-based policies and risk-based assessments. These research efforts will provide valuable insights into the specific health risks associated with air pollution in India, enabling targeted interventions and effective strategies to protect public health.

 Through international collaborations and increased investments in health research, the MoHFW can leverage global expertise, share experiences, and advance scientific understanding to address the complex challenges posed by air pollution and ensure evidence-based policies for safeguarding public health.

**CONCLUSION**

 Air pollution in India arises from diverse sources and has significant health consequences. To comprehensively address this issue, a range of recommendations and steps must be taken to understand the health impacts of air pollution and prevent and mitigate its adverse effects. It is crucial to recognize that there is no singular solution or "silver bullet" to tackle this complex problem.

 Efforts to combat air pollution require a multi-sectoral approach that integrates environmental and health data, scientific research, and evidence-based practices. The formulation and implementation of policies and programs aimed at reducing this major risk factor in our national disease burden necessitate a coordinated effort across various government entities.

 While it is important to focus on both emission reduction and exposure reduction to protect public health, prioritizing interventions based on exposure levels becomes paramount. Identifying sources that contribute to high levels of exposure and adverse health impacts should receive immediate attention.

 In summary, addressing air pollution in India demands a comprehensive and collaborative approach that encompasses multiple sectors, leverages scientific knowledge, and prioritizes actions based on exposure and health outcomes. By reducing both emissions and exposures, we can work towards safeguarding public health from the detrimental effects of air pollution.

**REFERENCES**

1. Balakrishnan, K., Cohen, A. & Smith, K.R., 2014. Addressing the burden of disease attributable to air pollution in India: The need to integrate across household and ambient air pollution exposures. Environmental Health Perspectives, 122(1), pp.6–7. Available at: <http://ehp.niehs.nih.gov/wp-> content/uploads/122/1/ehp.1307822.pdf.
2. Chafe, Z.A. et al., 2014. Household Cooking with Solid Fuels Contributes to Ambient PM 2 . 5 Air Pollution and the Burden of Disease. Environmental Health Perspectives, 122(12), pp.1314–1320. Available at: [http://ehp.niehs.nih.gov/wp-content/uploads/122/12/ehp.1206340.alt.pdf.](http://ehp.niehs.nih.gov/wp-content/uploads/122/12/ehp.1206340.alt.pdf)
3. Chengappa, C. et al., 2007. Impact of improved cookstoves on indoor air quality in the Bundelkhand region in India. Energy for Sustainable Development, 11(2), pp.33–44. Available at: [http://www.sciencedirect.com/science/article/pii/S0973082608603981.](http://www.sciencedirect.com/science/article/pii/S0973082608603981)
4. CPCB, 2009a. Comprehensive Environmental Assessment of Industrial Clusters, Delhi. Available at: [http://cpcb.nic.in/divisionsofheadoffice/ess/NewItem\_152\_Final-Book\_2.pdf.](http://cpcb.nic.in/divisionsofheadoffice/ess/NewItem_152_Final-Book_2.pdf)
5. CPCB, 2009b. National Ambient Air Quality Standards. Ministry of Environment & Forests. Available at: [http://cpcb.nic.in/National\_Ambient\_Air\_Quality\_Standards.php.](http://cpcb.nic.in/National_Ambient_Air_Quality_Standards.php)
6. CPCB, 2010. Air quality monitoring, emission inventory and source apportionment study for Indian cities: National Summary Report, New Delhi, India. Available at: <http://www.moef.nic.in/downloads/public-> information/Rpt-air-monitoring-17-01-2011.pdf.
7. CPCB, 2011. Air quality monitoring, emission inventory and source apportionment study for Indian cities, Available at: [http://cpcb.nic.in/FinalNationalSummary.pdf.](http://cpcb.nic.in/FinalNationalSummary.pdf)
8. CPCB, 2012. Environmental Data Bank. Ministry of Environment & Forests. Available at: [http://cpcbedb.nic.in/.](http://cpcbedb.nic.in/)
9. GAINS, 2010. Greenhouse Gas and Air Pollution Interactions and Synergies - South Asia Program, Laxenburg, Austria.
10. HEI. 2010. Outdoor air pollution and health in the developing countries of asia: A comprehensive review. Boston:Health Effects Institute.
11. IARC. 2010. Household use of solid fuels and high-temperature frying. Lyon, France:International Agency for Research on Cancer, World Health Organisation.
12. IHME. 2013. The global burden of disease: Generating evidence, guiding policy-south asia regional edition. Institute for Health Metrics and Evaluation. Available at: <http://www.healthdata.org/sites/default/files/files/data_for_download/2013/WorldBank_SouthAsia/IHME_GB> D\_WorldBank\_South Asia\_FullReport.pdf.
13. NCEP, 2014. National Weather Service. National Centers for Environmental Prediction. Available at: [http://www.ncep.noaa.gov/.](http://www.ncep.noaa.gov/)
14. SAFAR, 2013. Monitoring Air Quality and Weather Forecasting Services. Indian Intitute of Tropical Meteorology. Available at: [http://pune.safar.tropmet.res.in/AQI.aspx.](http://pune.safar.tropmet.res.in/AQI.aspx)
15. Sambandam, S. et al., 2014. Can Currently Available Advanced Combustion Biomass Cook-Stoves Provide Health Relevant Exposure Reductions? Results from Initial Assessment of Select Commercial Models in India. EcoHealth, pp.1–17. Available at: [http://link.springer.com/10.1007/s10393-014-0976-1.](http://link.springer.com/10.1007/s10393-014-0976-1)
16. TERI, 1995. Biomass fuels, indoor air pollution and he alth: A multi-disciplinary, multi-centre study., New Delhi.
17. USNRC, 1991, Human Exposure Assessment for Airborne Pollutants: Advances and Opportunities. National Research Council, National Academy of Sciences, Washington, DC.
18. USNRC, 2012, Exposure Science in the 21st Century: A Vision and a Strategy, National Research Council, National Academy of Sciences, Washington DC.
19. Van Donkelaar, A. et al., 2010. Global estimates of ambient fine particulate matter concentrations from satellite-based aerosol optical depth: Development and application. Environmental Health Perspectives, 118(6), pp.847–855. Available at: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2898863/pdf/ehp-118-> 847.pdf.
20. WHO Regional Office for Europe, 2006, WHO Air Quality Guidelines for Particulate Matter, Nitrogen Dioxide, and Sulfur Dioxide: Global Update for 2005, World Health Organization, Copenhagen, Denmark, 484 pp.
21. WHO, 2006. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: global update 2005: summary of risk assessment, Available at: [http://whqlibdoc.who.int/hq/2006/WHO\_SDE\_PHE\_OEH\_06.02\_eng.pdf?ua=1.](http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf?ua=1)
22. WHO. 2006. Who air quality guidelines 2006 update. Geneva:World Health Organisation.
23. WHO. 2014. Who indoor air quality guidelines: Household fuel combustion. Geneva:World Health Organisation.
24. Government of India Ministry of Health and Family Welfare (Govt. of MoHFW) 2015. Report of the Steering Committee on Air Pollution and Health Related Issues, August 2015