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Indoor Air Pollution

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I. INTRODUCTION

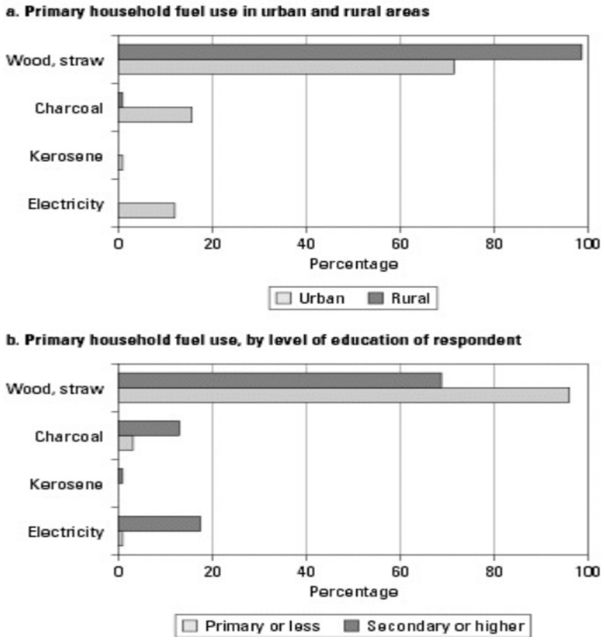
It has been stated that having access to contemporary energy sources is "an essential, but insufficient, prerequisite for economic and social growth" (IEA 2002). The fact that approximately half of the world's population still relies on inefficient and extremely polluting solid fuels, primarily coal and biomass (wood, animal dung, and crop wastes), to power their homes on a daily basis is quite concerning. Poverty and this problem are intricately intertwined. The poor are forced to use inefficient stoves and solid fuels, and many are locked in this predicament since it has negative effects on their health and finances and prevents them from changing their lifestyle. Households typically progress up the energy ladder as socioeconomic conditions improve, performing more tasks using fuels and appliances that are more efficient, clean, convenient, and pricey. The rate of development is, however, incredibly slow, and the poorest citizens of South Asia and Sub-Saharan Africa have little hope for improvement.

Demographic and health survey results for Malawi and Peru are shown in figures (a) and (b), respectively (ORC Macro 2004). To illustrate the situation in underdeveloped African and South American nations, samples were chosen from published national studies that included information on the primary cooking fuels used.

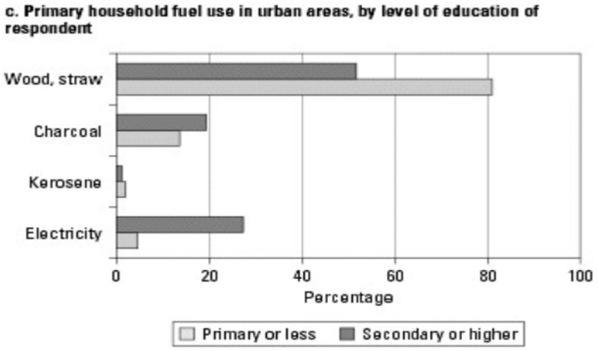
II. STATUS OF INDOOR AIR POLLUTION IN INDIA

The three main causes of indoor air pollution are bioaerosols, building materials, and combustion. While radon, asbestos, pesticides, heavy metals, volatile organic compounds, and environmental tobacco smoke are all regarded as serious indoor pollutants in industrialised countries, developing countries are primarily affected by the combustion by-products of biomass fuels. Out of the 0.2 billion people in India who use fuel for cooking, 49% rely on wood, 8.9% use cow dung cake, 1.5% use coal, lignite, or charcoal, 2.9% use kerosene, 28.6% use liquefied petroleum gas (LPG), 0.1% use electricity, 0.4% use biogas, and 0.5% use any other fuel.

The incomplete combustion by-products of biomass fuels include formaldehyde, carbon monoxide, polyaromatic hydrocarbons, suspended particulate matter, and others that are harmful to human health. Oxides of sulphur, arsenic, and fluorine are produced when coal is burned. Aldehydes, volatile and semi-volatile organic chemicals, as well as other pollutants, are created by binders, waxes, polishing agents, and cosmetics. Biological contaminants, such as dust mites, mould, pollen, and infectious agents created by stagnant water, mattresses, carpets, and humidifiers, can contaminate indoor air.



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Source: Unpublished data derived from Demographic and Health Survey.

III. LEVELS OF POLLUTION AND EXPOSURE

Particulate matter (PM), carbon monoxide (CO), sulphur oxides, nitrogen oxides, aldehydes, benzene, and polyaromatic compounds are only a few of the harmful pollutants released by biomass and coal smoke (Smith 1987). The main ways that these pollutants harm the lungs are by inflaming them, reducing ciliary clearance, and impairing immunological response (Bruce, Perez-Padilla, and Albalak 2000). Systemic consequences also occur, for instance, when carbon monoxide reduces the blood's ability to carry oxygen, which may contribute to intrauterine growth retardation (Boy, Bruce, and Delgado 2002). Evidence of the effects of particles on cardiovascular disease is only now becoming available from wealthy nations.

PM10 concentrations ranged from 300 to 3,000 (or more) micrograms per cubic metre (g/m3) on average across 24-hour periods. Although annual averages have not been calculated, the 24-hour concentrations can be used as an acceptable approximation as these levels are observed practically every day of the year. Comparatively, the yearly PM10 air pollution standard set by the U.S. Environmental Protection Agency is 50 g/m3, which is between one and two orders of magnitude less than the concentrations seen in many houses in poor nations. Much greater levels of PM10—up to 30,000 g/m3 or more—have been observed during cooking, when mothers and very young children spend most of their time in the kitchen and close to the fire.

A. Health Impacts of IAP

Recently, a systematic assessment of the evidence for the effect of IAP on a variety of health outcomes was conducted. In addition to a number of other outcomes with currently insufficient data, this evaluation found three key outcomes with sufficient evidence to include them in the burden-of-disease calculations.

Table 42.1 Status of Evidence Linking Biomass Fuels and Coal with Child and Adult Health Outcomes

Health outcome	Age	Status of evidence
Sufficient evidence for burden-of-disease calculation		
Acute lower respiratory infections	Children < 5 years	*Strong.* Some 15–20 observational studies for each condition, from developing countries. Evidence is consistent (significantly elevated risk in most though not all studies); the effects are sizable, plausible, and supported by evidence from outdoor air pollution and smoking.
Chronic obstructive pulmonary disease	Adult women	
Lung cancer (coal exposure)	Adult women	
Chronic obstructive pulmonary disease	Adult men	*Moderate-I.* Smaller number of studies, but consistent and plausible.
Lung cancer (coal exposure)	Adult men	
Not yet sufficient evidence for burden-of-disease calculation		
Lung cancer (biomass exposure)	Adult women	*Moderate-II.* Small number of studies, not all consistent (especially for asthma, which may reflect variations in definitions and condition by age), but supported by studies of outdoor air pollution, smoking, and laboratory animals.
Tuberculosis	Adult	
Asthma	Child and adult	
Cataracts	Adult	
Adverse pregnancy outcomes	Perinatal	*Tentative.* Adverse pregnancy outcomes include low birthweight and increased perinatal mortality. One or a few studies at most for each of these conditions, not all consistent, but some support from outdoor air pollution and passive-smoking studies.
Cancer of upper aerodigestive tract	Adult	
Interstitial lung disease	Adult	
Ischemic heart disease	Adult	Several studies from developed countries have shown increased risk for exposure to outdoor air pollution at much lower levels than IAP levels seen in developing countries. As yet, no studies from developing countries.

Household fuels can provide regional problems in several nations. According to estimates, more than 2 million people in China have skeletal fluorosis, which is partly brought on by the usage of fluoride-rich coal (Ando and others 1998). Another coal-related pollutant, arsenic, raises the risk of lung cancer in China (Finkelman, Belkin, and Zheng 1999). However, there have been worries that lowering smoke could raise the danger of vector-borne illnesses, such as malaria. According to certain research, biomass smoke can deter mosquitoes and lower their bite rates.

IV. RESEARCH ON EXPOSURES

Such devices may not necessarily need to have the high accuracy and precision expected in developed-country settings in order to contribute useful information because of the weak existing database, the relatively high concentrations, and the restricted resources available.

1) Like the smoke from the biomass that has been the subject of the most research, tobacco, smoke from wood, crop waste, and dung also contains a number of harmful contaminants. However, the two most reliable indicators of the health risk for these other biomass smokes are likewise particles (or "tar") and CO, which should likely be the initial foci for instrument development. These indications were also chosen for the warnings on cigarette packs. It would seem like a good strategy for creating devices for monitoring pollution levels in households in developing countries to adapt the common and affordable "smoke" and CO devices marketed by the millions as alarms for families in affluent countries.

2) Low-cost instruments that can be used to calculate mean concentrations for a week. Such technology is required because such homes' large daily changes make it difficult to assess the efficacy of therapies without longer-term exposure controls.

3) 24-h values, especially for monitoring individual exposure. It's also necessary to have reliable, affordable tools for keeping track of time-activity patterns.

4) Continuously keeping an eye out for peaks is important during cooking, especially when fuel is being added to the fire. There is evidence to suggest that peaks rather than means may be more effective at predicting effects for particular endpoints.

5) Although it's commonly believed that exposures to benzene, 1.3-butadiene, toluene, styrene, formaldehyde, benzo-pyrene, and other chemicals are mostly connected with industrial, urban, and transportation contexts, biomass smoke also contains considerable levels of these compounds Therefore, biomarkers for these compounds as well as those specific to biomass smoke might be useful additions to the assessment of exposure.

6) Solid fuels' poor combustion performance in basic devices causes a large amount of fuel carbon to be diverted to incomplete combustion products (PIC; generally 5-20%; Smith et al., 2000b). These PIC include a variety of greenhouse gases in addition to the main health-damaging pollutants. The most significant of these is methane, which has around 20 times more carbon atoms per unit of global warming potential than carbon dioxide. Therefore, dependable portable field monitoring tools are required to measure methane and combustion efficiency in order to assess the performance of stoves as well as the global warming potential of substitute fuels and stoves. This data would be useful in supporting claims for clean fuels and stoves on a global scale.

Table 1
Physical/chemical properties of the most relevant indoor air pollutants.

Compound	CAS number	Molecular weight (g/mol)	Boiling point (C at 1 atm)	Vapor pressure (mmHg at 25 C)	Water solubility (mg/L at 25 C)	Environmental risks[a]	Henry constant (mol/m^3$Pa)
CO	630-08-0		191.7	35 atm	26.8 at 20 C		9.64E-06
NO_2	10102-44-0	46.0	21.0	720	Reacts		1.20E-04
O_3	10028-15-6			>1 atm	570 at 20 C	H400; H410	1.10E-04
Benzene	71-43-2	78.1	78.8	101	940.0	H412; P273	1.70E-03
Toluene	108-88-3	92.1	110.6	27.7	320.0	H412	1.50E-03
Ethylbenzene	100-41-4	106.2	136.2	9.21	110.0	H412	1.30E-03
o-xylene	95-47-6	106.2	145.9	5.99	120.0	H412; P273	2.08E-03
m-xylene	108-38-3	106.2	140.6	7.61	99.0	H412; P273	1.37E-03
p-xylene	106-42-3	106.2	139.6	7.94	100.0	H412	1.48E-03
Naphthalene	91-20-3	128.2	221.5	0.159	140.0	H400; H410	2.20E-02
Formaldehyde	50-00-0	30.0	19.5		$1.98 \cdot 10^5$		3.20E01
TCE	79-01-6	131.4	87.2	72.4	390.0	H412; P273	9.50E-04
a-pinene	80-56-8	136.2	157.9	3.5	8.9	H411	2.12E-04
Limonene	138-86-3	136.2	175.4	1.54	3.4	H400; H410; P273	6.27E-04

[a] Code: H400: very toxic to aquatic life; H410: very toxic to aquatic life with long lasting effects; H411: toxic to aquatic life with long lasting effects; H412: harmful to aquatic life with long lasting effects; P273: avoid release to the environment.

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V. INTERVENTIONS AND POLICY

The ways in which energy is used in homes—for heating, cooking, and serving as a focal point for social interactions, for instance—have distinctive characteristics that are particular to the region, each household, and their culture. They are frequently tied to ingrained customs and strongly held beliefs. It has not been simple to encourage the use of cleaner and more efficient energy technologies by some of the world's poorest people, but in recent years, both the creation of supportive legislation and the availability of technology that is fit for households' needs has advanced.

VI. POVERTY REDUCTION AND THE MILLENNIUM DEVELOPMENT GOALS

Given the strong correlation between socioeconomic circumstances and the use of solid fuels, a crucial component of policies to reduce IAP must be poverty reduction. The United Nations Millennium Development Goals define objectives for eradicating poverty, enhancing health and education, and protecting the environment; they serve as the generally acknowledged framework for the international community to make verifiable progress (United Nations Statistics Division 2003). While reducing IAP can help with a number of these objectives, it is especially important for lowering child mortality (GOAL 4 from ALRI).

A. Interventions

Although IAP is the primary emphasis of this chapter, the numerous additional ways that household energy consumption can impact health and development highlight the need for initiatives to target a variety of advantages, such as the following:

1) lowered IAP and human exposure levels improved fuel economy
2) An overall improvement in the quality of the home environment,
3) particularly the working environment and conditions for women, was made possible by less time spent gathering fuel and using inefficient stoves,
4) less stress on the local environment, and more options for money generating

B. Effectiveness

The majority of existing research for evaluating the efficacy of interventions focuses on how interventions affect IAP levels and, in some circumstances, personal exposure. In Guatemala, a randomised trial of an upgraded chimney stove is now being conducted with a focus on ALRI in infants up to 18 months of age (Dooley 2003).

Due to the study's limited sample size of kids, such effect estimates need to be confirmed (93 children under age five, living in 55 homes). In a 16-year retrospective cohort research in rural China, Lan and colleagues (2002) revealed adjusted hazard ratios of 0.59 (95 percent confidence interval: 0.49 to 0.71) for men and 0.54 (0.44 to 0.65) for women when utilising upgraded coal stoves versus conventional open coal fires.

1) Improved stoves with flues have received a lot of promotion in a number of Asian and Latin American nations, however many of these stoves are discovered to be in poor condition after a few years. A few Indian studies have indicated only little or insignificant decreases in PM (Ramakrishna 1988; Smith, Aggarwal, and Dave 1983). Although the relatively high baseline levels meant that families with stoves still recorded total suspended particle values of 1,000 to 3,000 g/m3 during cooking, other studies, from Nepal, have demonstrated reductions of roughly two-thirds.
2) Kerosene and LPG can produce substantially lower pollution levels, according to solid evidence, albeit it's vital to assess how much biomass the cleaner fuel is replacing. The plancha stoves consequently produced the least emissions in that environment (Albalak and others 2001). Nevertheless, a number of studies, many of which are from India, demonstrate that the introduction of kerosene and LPG significantly lowers kitchen pollution, which may be due to differing cooking needs and a reduced need for space heating. In rural Tamil Nadu, two-hour (during mealtime) kitchen respirable PM levels using gas and kerosene were 76 and 101 g/m3, respectively, while levels using wood and animal dung ranged from 1,500 to 2,000 g/m3 (Parikh and others 2001).
3) The majority of the poor who have access to electricity can only afford to use it for lighting and running low-demand electrical equipment since doing so would need considerable infrastructure. Electrification has minimal potential to result in significant reductions in IAP if socioeconomic conditions do not significantly improve. One of the rare nations with a sizable rural population historically dependent on biomass that also has the means to electrify its rural areas is South Africa. A study of three rural villages in the North West province, two of which were not electrified and one of which was, revealed that, on average, 3.6 years after being connected to the grid, 44 percent of the electrified homes had never used an electric cooker.

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C. Control Measures

We have enough data from studies conducted in India to conclude that indoor air pollution is a major contributor to rising morbidity and mortality rates and that immediate action is required. People's choices about energy and cooking are influenced by social, cultural, and economic considerations. Other considerations include the accessibility and adaptability of conventional fuels, the nature of the food produced, its flavour, smoke concerns, the visual attractiveness of stoves, and users' perceptions of other options. The list of proposed actions that should be taken to stop the threat of indoor air pollution is provided below.

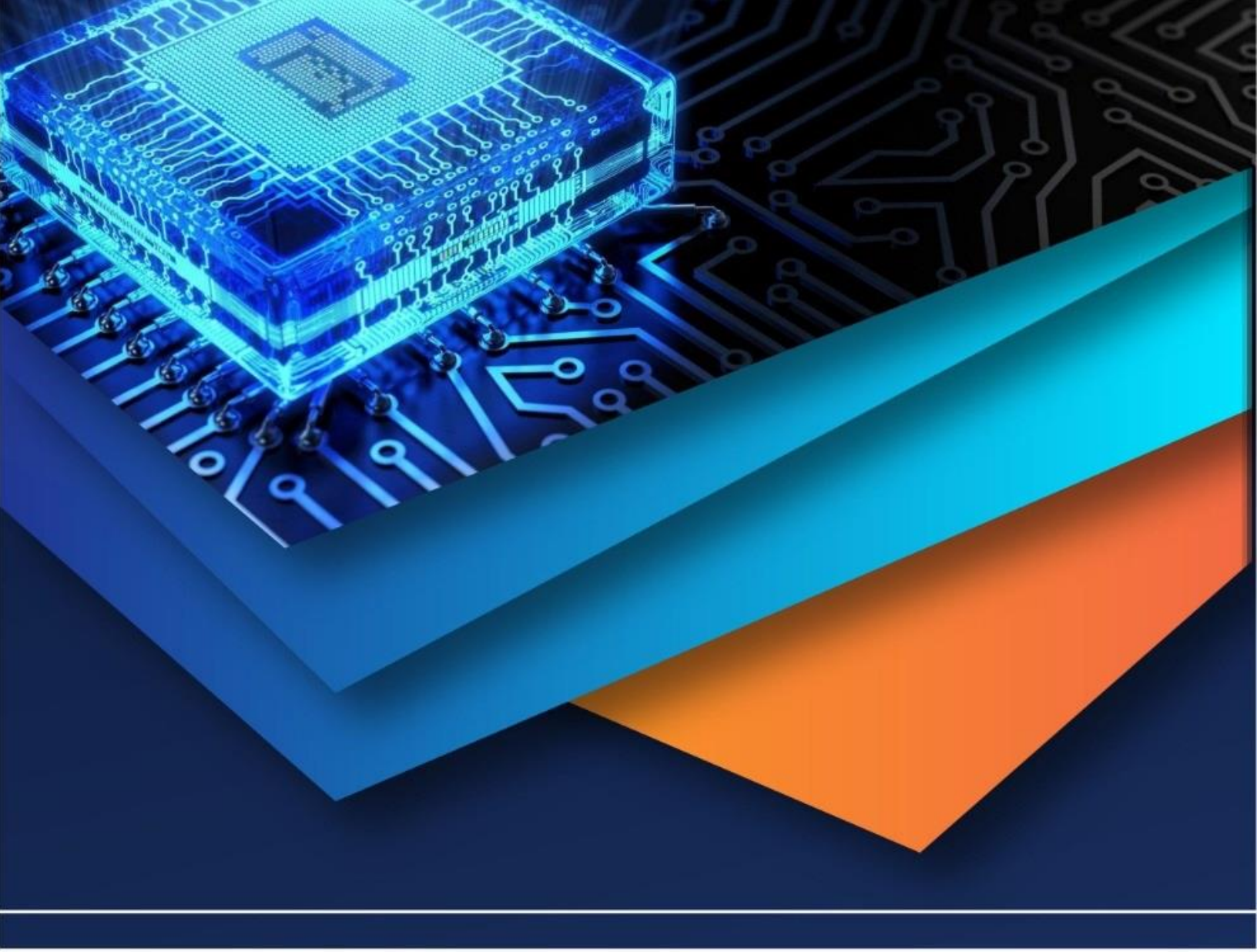
1) *Public Awareness:* Raising people's knowledge of the problem and the grave risk it presents to their health and welfare is one of the most crucial measures in the prevention of indoor air pollution. People should discover diverse approaches to decreasing exposures with improved kitchen management and at-home kid safety with the use of education. Additionally, the usage of alternate, cleaner energy sources should be made known to the public as a viable alternative to the direct burning of biomass fuel. Politicians and administrators must be included among the stakeholders in order to secure their commitment and raise their understanding of the negative impacts of indoor air pollution on people's health.
2) *Change in Fuel Consumption Patterns:* Fuel use is influenced by habit, accessibility, and most crucially, affordability. Since it is the cheapest and simplest option available to them, the majority of low-income families currently only use direct combustion of biomass fuels for their cooking needs. However, this situation could be changed by encouraging the use of cleaner energy sources, such as gobar gas, which uses cow dung to produce gas for cooking.
3) *Modification of Design of Cooking Stove:* The design of cooking stoves should be changed from the conventional, leaky, smoke-filled stoves to more energy-efficient, smokeless stoves with an outlet (such as a chimney) for interior pollutants. One excellent illustration is the stove developed by the National Biomass Cookstoves Initiative of the Ministry of New and Renewable Energy under a Special Project on Cookstove during 2009–2010, with the main objective of enhancing the availability of clean and efficient energy for the country's energy-deficient and poorer regions.
4) *Increasing Ventilation:* The need of proper ventilation should be considered while building a home; for inadequately ventilated homes, interventions such a window over the stove and cross ventilation through doors should be used.
5) *Global Initiative and cross-sectoral Cooperation:* Only through coordinated and persistent efforts from several sectors involved in housing, energy, environment, health, and rural development can indoor air pollution be reduced.

VII. CONCLUSION

Even though there is evidence that indoor air pollution is on the rise in India and that it is linked to higher rates of morbidity and mortality, more research is still required to determine the extent of indoor pollution exposure and to support the link between indoor pollutants and conditions like cancer, tuberculosis, cataract, asthma, and cardiovascular disease. Effective interventions are also required right now, from education to altering fuel usage patterns to constructing homes and stoves properly to a dedicated and determined intersectoral collaboration to advance public health.

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