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Unseen crisis: Revealing the hidden health impact of indoor air pollution—A scoping review

Ranjana G. Chavan, Jasneet Kaur, Gopal S. Charan[1]

Abstract:

Indoor air pollution presents a critical public health challenge, particularly in countries such as India, where millions are exposed to harmful pollutants within their homes and workplaces. This scoping review delves into the multifaceted impacts of indoor air pollution on health outcomes, synthesizing evidence from various study designs and geographical regions A scoping review was conducted. Drawing on a comprehensive search strategy, which yielded 320 records, wherein 120 in PubMed, 108 in Web of Science, and 92 in SCOPUS. Ten studies were selected based on predefined inclusion criteria, totaling a sample size of 37,43166 individuals**.** The synthesis of findings from the selected studies reveals the multifaceted impact of indoor air pollution on health status. Respiratory symptoms and illnesses were found to be prevalent among individuals exposed to indoor pollutants, with biomass fuel combustion posing a particularly high risk for chronic obstructive pulmonary disease (COPD) in women. In addition, indoor air pollution was associated with adverse pregnancy outcomes, cardiovascular diseases, central nervous system impacts, cognitive impairment, and developmental delays. Urgent action is needed to reduce indoor air pollution, safeguard health, and promote cleaner technologies for healthier indoor environments. Vulnerable populations, such as women, children, and the elderly, are disproportionately affected by indoor pollutants, highlighting the importance of targeted interventions and policies.

Keywords:

Air pollution indoor, air pollution, chronic obstructive, pulmonary disease

Introduction

Indoor air pollution presents a critical public health challenge in India, where millions of individuals are exposed to harmful pollutants within their own homes and workplaces.[1] The term "indoor air quality" describes the state of the air inside and around residential or commercial structures. Indoor air pollution occurs when dangerous pollutants lower indoor air quality to a particular degree.[2]

In 2020, the World Health Organization (WHO) revealed a startling statistic: Each year, approximately 3.2 million lives are claimed by household air pollution. Heartbreakingly, this includes more than 237,000 young children under the age of 5 years.[3] The impact of indoor air pollution is undeniable, as evidenced by its ranking as the fourth highest cause of disability-adjusted life years in India in The Global Burden of Diseases 2015 report.[4] In various corners of the globe, an astonishing 2.3 billion people rely on kerosene and solid fuels—think wood, crop waste, charcoal, coal, and dung—to prepare their meals. This prevalent practice is especially prevalent in lower- and middle-income countries and among those living in poverty. Sadly, stark differences exist between the urban and rural areas when it comes to access to cleaner cooking options. Strikingly, in 2021, only 14% of urban residents had to resort to polluting fuels and technologies, whereas

Symbiosis College of Nursing, Symbiosis International (Deemed University), Pune, Maharashtra, India, [1]Department of Nursing, SGRD Institute of Medical Science and Research, SGRD University of Health Sciences, Amritsar, Punjab, India

Address for correspondence:
Dr. Ranjana G. Chavan, Symbiosis College of Nursing, Symbiosis International (Deemed University), Pune, Maharashtra, India.
E-mail: ranjanachavan@scon.edu.in

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nearly half of the world's population, residing in rural areas, still had no choice but to use them.[5]

The usage of insufficient and harmful fuels and technologies within households greatly contributes to the issue of household air pollution, which contains a variety of harmful pollutants that pose a threat to human health.[6] One particularly concerning pollutant is tiny particles that have the ability to enter the bloodstream and deeply penetrate the lungs. In homes with poor ventilation, indoor smoking can cause fine particle levels to exceed the acceptable levels by up to 100 times. This poses a serious problem for women and children, who often spend a considerable amount of time in proximity to domestic fireplaces and are, therefore, at a heightened risk of exposure to these pollutants.[7]

Although wealthier nations tend to have a greater abundance of reasonably clean energy sources, developing nations do not have the same problem. Here, there is a widespread usage of fossil fuels combined with a high population density and inadequate ventilation, particularly in unplanned settlements such as urban slums. Because of their unsanitary living conditions, slum residents are thus more vulnerable and are exposed to indoor air pollution at the highest rate.[8]

The three main causes of indoor air pollution are bioaerosols, building materials, and combustion.[9] Cooking, smoking, using electronics, using consumer goods, and emissions from building materials are just a few of the activities that can cause indoor air pollution (IAP) in homes or buildings. The hazardous materials that can be discovered indoors include carbon monoxide (CO), particulate matter (PM), aerosols, volatile organic compounds (VOCs), and biological contaminants, to name a few.[2] As a result, studies on air quality regulation have started to focus more on indoor settings during the past ten years, reflecting changes in lifestyle that are associated with higher levels of urbanization.[10] Reduced IAQ has been linked to building-associated illnesses, which can have a detrimental impact on human health.[11] Exposure to IAP can cause a variety of illnesses, both acute and chronic.[12] Thus, a key component of IAQ control is the establishment of monitoring systems.

The air we breathe inside our homes can be as dangerous, or even more so, than the air outside. This is because many things can cause poor air quality indoors, such as cooking with traditional methods, burning biomass, smoking tobacco, and not having enough ventilation. These factors create an unhealthy environment inside our homes, which can lead to health problems.[13] Indoor air pollution has a significant impact on public health in India. It can cause respiratory diseases, heart problems, and negative effects during pregnancy. Therefore, it is essential to study its effects on individuals across the country to understand its full impact.[14]

Indoor air pollution can harm health in many ways. For example, it can cause problems with fetal development, such as low birth weight or even stillbirth. It can also increase the risk of certain cancers, including those of the nose and throat (nasopharynx and larynx), lungs, and even blood (leukemia).[15] Being exposed to indoor air pollutants can lead to several respiratory issues. Common respiratory disorders such as acute respiratory tract infections, COPD, and bronchial asthma are more prevalent among those exposed to indoor air pollution. Symptoms associated with this exposure include headaches, runny nose, dry cough, and difficulty breathing. Moreover, these pollutants can exacerbate existing respiratory problems, further compromising one's health.[9] Carbon monoxide, an invisible and odorless gas, poses a threat to indoor air quality. It is emitted when fossil fuels used in appliances such as stoves, heaters, and furnaces do not burn completely. In high concentrations, carbon monoxide becomes deadly because it prevents the blood from carrying enough oxygen.[16]

The review is novel in nature as it brings a fresh perspective by delving into the often-neglected realm of indoor air pollution's health impacts. Although outdoor air quality garners considerable attention, indoor environments where people spend the majority of their time can harbor pollutants that significantly affect health. By focusing on indoor air pollution specifically, this scoping review uncovers a hidden health crisis, highlighting the diverse health consequences and emphasizing the urgent need for awareness and remedial actions. This unique approach fills a crucial gap in current air pollution discourse, underscoring the importance of recognizing and addressing indoor air quality as a vital public health concern.

The aim of this scoping review is to comprehensively investigate the impact of indoor air pollution on health status. This involves synthesizing existing research to explore the diverse health effects associated with indoor air pollution exposure, including respiratory diseases, cardiovascular conditions, neurodevelopmental outcomes, and other related health indicators. By mapping the current literature landscape, the review aims to identify gaps, trends, and methodological approaches to better understand the breadth and depth of the health implications of indoor air pollution. And finally, what is the impact of indoor air pollution on various health outcomes?

Materials and Methods

This is a scoping review. To find databases that could contain references, a variety of internet search engines were also used. The review questions served as the direct inspiration for the specified criteria for choosing the studies. We only included publications from the previous 13 years. The studies focusing at-risk groups such as children, seniors, and pregnant women, which looked specifically at exposure to air pollutants inside buildings, examined a wide variety of physical health conditions, including respiratory issues (such as asthma and COPD), heart disease, allergies, lung cancer, and other health problems linked to indoor air pollution, which evaluated the health impacts of poor indoor air quality were considered, and studies examined a wide variety of physical health conditions, including respiratory issues (such as asthma and COPD), heart disease, allergies, lung cancer, and other health problems linked to indoor air pollution were eligible for inclusion studies. No restrictions were imposed based on publication status (i.e., peer-reviewed articles, conference proceedings, and unpublished reports) or publication date. Both published and unpublished studies up to the date of the search were eligible for inclusion.

Studies conducted solely on animal models with no direct impact on human health are not considered. Review articles, opinion pieces, letters, editorials, and commentaries are excluded because they lack new data on the relationship between indoor air pollution and health outcomes. Studies evaluating exposures or interventions not related to indoor air pollutants, such as studies on outdoor air pollution, occupational exposures, or pharmaceutical interventions, are excluded. Studies had serious methodological flaws, such as a small sample size, a lack of confounding variable control, or unreliable exposure assessment methods.

Search strategy

To explore the effects of indoor air pollution on overall health, a thorough scoping review was conducted. The main objective was to examine the relationship between indoor air quality and a range of health outcomes. Specific keywords, such as terms related to indoor air pollution with terms related to various health outcomes Search strategy involved ((“Air pollution, indoor”[MeSH Terms] OR (“Air Pollution”[MeSH Terms] OR (“Smoking”[MeSH Terms]))) AND (((((“asthma*”[Title/Abstract] OR “Pulmonary Disease, Chronic Obstructive”[Title/Abstract]) OR “Congenital Abnormalities *”[Title/Abstract]) OR “Pregnancy Outcome *”[Title/Abstract]) OR “Child Development *”[Title/Abstract]) OR (((“Lung Neoplasms”[Title/Abstract] OR “Mortality ” [Title/Abstract] OR “Heart Diseases”[Title/Abstract]))). Using search terms, databases such as PubMed, Web of Science, and Scopus were accessed to find articles related to the topic. By carefully checking the titles and abstracts, we chose articles that might be helpful for our study. The results of this review follow the PRISMA guidelines and provide useful information for more research, making policies, and putting them into practice.

Study selection

Two researchers independently reviewed all identified articles through a systematic search. They ensured accuracy by consulting a third researcher to resolve any differences by utilizing MESH terms. The chosen studies were then further evaluated for relevance. To ensure the credibility and impartiality of the review, the entire texts of the relevant studies were acquired. Two researchers independently examined each study to assess its eligibility for inclusion, minimizing potential biases. The process involved meticulously identifying and documenting the reasons for excluding studies that did not meet the pre-established criteria, promoting transparency and consistency in the selection. This stringent approach aligns with the pursuit of research excellence and ensures the robustness and reliability of the review’s conclusions.

Data extraction

Two reviewers independently collected the data from each report and worked independently**.** A structured form is developed, based on the review’s objectives, to extract relevant data from selected studies. A pilot test helps refine the data extraction process. Studies are chosen based on predefined criteria, and multiple reviewers work independently to minimize bias. Important information is systematically extracted from each study, including study characteristics, exposure details, and key findings.

Quality of bias

Quality assessment was conducted to evaluate the reliability of the studies. Based on the selection, comparability, and exposure categories, the Newcastle Ottawa Quality Assessment Scale provides as grade that is used to objectively evaluate articles. The extracted data are then synthesized to identify patterns and gaps in the research on indoor air pollution and its health effects. Transparent reporting is emphasized to enhance the credibility of the review and facilitate a comprehensive understanding of the topic.

Search results

A Boolean search for relevant phrases was performed yielded altogether 320 records. This restricted the number of records to 120 in PubMed, 108 in Web of Science, and 92 in SCOPUS. PRISMA’s flow diagrams were created, as shown in Figure 1. Certain elements were removed because they had no bearing on the

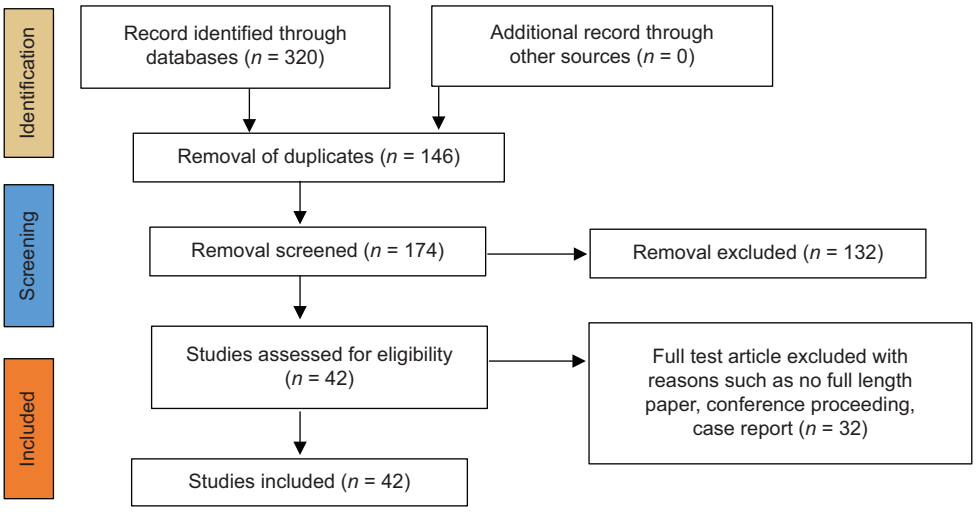

Figure 1: PRISMA flowchart

study's topic. The abstracts of every article were looked at after the duplicates were eliminated. After 146 duplicates were eliminated, 174 records were deemed appropriate and qualified for the further screening. 2 independent authors performed the screening where 132 records were excluded with reasons (interventions were not based on indoor pollution n = 72, pollution pertaining to outdoor activities n = 20, interventions were not related to desired outcomes n = 40). Of the leftover 42 articles, 32 articles were removed because no full-length article was available (n = 18), conference proceeding (n = 20), and case reports (n = 4)

Synthesis of results

The results were summarized in Table 1. The synthesis of these findings underscores the multifaceted and profound impact of indoor air pollution on health status, encompassing a wide range of respiratory, cardiovascular, developmental, and cognitive health outcomes across different population groups. Two studies[8,17] highlighted a high prevalence of symptoms associated with indoor air pollution exposure, including respiratory issues, eye irritation, dizziness, and breathing difficulties among participants. Maharana *et al*.[18] underscore the significant health impacts of indoor air pollution on women and children, with findings linking exposure to solid fuels with symptoms such as dry cough, suffocation, low birth weight, and higher odds of cognitive impairment. Two studies[19,20] suggest a correlation between indoor air pollution and chronic diseases, including chronic obstructive pulmonary disease (COPD) in women and cognitive impairment in adults. Two studies[21,22] highlight the adverse effects of indoor air pollution exposure on birth outcomes, including low birth weight and an increased risk of congenital heart disease among infants born to mothers exposed to indoor air pollutants during pregnancy.

Results

The total 10 studies were finalized as per the inclusion and exclusion criteria. The five studies are cross-sectional in nature[8,19,20,24,26,27] one case-control studies,[22] one case crossover,[23] one prospective cohort design[25] one survey,[21] and one complimentary design.[28] The selected studies are from China,[8,19,22,26,27] Bangladesh,[21] USA,[23,25] Guatemala,[28] and Germany.[24] The diverse geographical inclusion makes the study results more generalizable. The total sample includes 37,43166, which is large and extensive enough to generalize the findings. The factors are identified, and the impact of indoor air pollution is assessed. The results are described under the various effects as impact of indoor pollution.

Impact of indoor air pollution

Slightly more than half of the study participants reported experiencing at least one indoor air pollution-related symptom. Certain factors were linked to reporting three or more symptoms, including being female, being part of the lower-middle socioeconomic class, living in a house without moisture issues, exposure to second-hand smoke, using mosquito repellents, and having the kitchen in the same space as the living area.[8]

Respiratory impacts and respiratory illness

A study in India found that 56.8% of participants reported one or more symptoms related to air pollution, with eye irritation (30%) and respiratory issues (23%) being the most common. Another study in India highlighted that women who spend more than two hours a day cooking with solid fuel in kitchens have an increased risk of chronic obstructive pulmonary disease (COPD).[8] However, it has also been noticed that ladies who make >2 hours a day in the kitchen preparing food by utilizing solid fuel hava shown an increased risk

Table 1: Study characteristics

Author and Year	Country	Design	Sample	Intervention	Key outcome
(S. Dutta *et al*., 2022)[8]	India	Cross-sectional study	220	NA	56.8% of the participants in the research reported having one or more symptoms. The most often reported symptoms (30%) were eye irritation and respiratory issues, with headache complaints coming in second with another 23% of respondents.
(Yoo *et al*., 2024)[23]	USA	Case crossover design	3655497	NA	Air pollution can put individuals with risk of mental disorder
(Bergamaschi *et al*., 2017)[24]	Germany	Cross-sectional	278	NA	Air pollution may be a risk factor for MS favoring inflammatory exacerbations and multiple sclerosis
(Johnson *et al*., 2011)[19]	India	Cross-sectional study	900	NA	Ladies who make >2 h a day in the kitchen preparing food. Using solid fuel has been linked to an increased risk of COPD
(Haider *et al*., 2016)[21]	Bangladesh	Survey	8,753	NA	Burning biomass fuel can damage fetuses in pregnancy by polluting the air and creating respiratory ailments.
(Grippo *et al*., 2023)[25]	USA	Prospective cohort study	4735	NA	The likelihood of failing in the personal, gross motor, and development domains is higher in environments with indoor pollution
(Dakua *et al*., 2022)[26]	India	Cross-sectional study	72,250	NA	Cognitive impairment was more common in elderly rural women from lower socioeconomic backgrounds who used solid fuel.
(Krishnamoorthy *et al*., 2022)[27]	India	Cross-sectional study	295	NA	People who are exposed to indoor air pollution had twice the likelihood of experiencing cognitive impairment (aPR=2.18, *P*=0.003)
(Sun *et al*., 2022)[22]	China	Case–control study	44 cases 75 controls	NA	During pregnancy, mothers who breathe air with high levels of certain chemicals (VOCs and PMs) inside their homes may increase the likelihood that their child will be born with a heart defect (CHD).
(McCracken *et al*., 2011)[28]	Guatemala	Complementary study designs	119	Stove intervention	Exposure to wood smoke in the home can alter ventricular repolarization and perhaps compromise cardiovascular health.

of COPD[19] Biomass fuels, such as wood, crop residues, and animal dung, are commonly used for cooking and heating in many parts of the world. When these fuels are burned, they release a variety of pollutants into the air, including particulate matter, carbon monoxide, and various toxic compounds. These pollutants can be harmful to respiratory health, leading to conditions such as asthma, bronchitis, and other respiratory infections. Haider *et al*.[21] reported that the process of burning biomass fuels, which can contribute to air pollution, not only leads to respiratory illnesses in individuals but also has potential effects on the health of fetuses developing in the womb.

Cardiovascular impacts

Numerous studies have shown that air pollution from fine particulate matter (PM) can lead to cardiovascular problems.[28] Researchers wanted to investigate if replacing chimneys with stoves reduced the odds of ST-segment depression and heart rate variability (HRV) issues. After controlling for various potential influences, the research found that women from households using the stoves experienced a 74% lower chance of nonspecific ST-segment depression during the study. In a different study design, researchers observed a 72% decrease in abnormal heart rhythm (nonspecific ST-segment depression) among women who used the new stoves compared with those using the traditional ones. This suggests that reducing exposure to wood smoke in homes through the use of cleaner-burning stoves may have a positive impact on heart health by preventing irregular heart function.

Central nervous system impacts

Bergamaschi *et al*.[24] suggest that air pollution, specifically particles smaller than 10 micrometers (PM10), may be linked to inflammation in the brains of people with multiple sclerosis (MS). This inflammation can be detected using magnetic resonance imaging (MRI) with gadolinium (Gd). The study implies that air pollution could contribute to the worsening of inflammation in MS. Further research is needed to explore the potential effects of environmental factors on the progression of MS.[24]

Impacts on outcome of pregnancy

Pregnant women in developing countries often have to cook with inefficient stoves.[29] This exposes them to harmful pollutants, such as carbon dioxide and carbon monoxide. These pollutants can lead to decreased oxygen supply to the fetus, leading to various types and degrees of IUGR.[30,31] Research suggests that exposure to wood fuel while cooking during pregnancy is significantly associated with a higher likelihood of having a low birth weight baby (by 86%) and a lower average birth weight (by 82 grams). This relationship remains significant even after considering other relevant factors. Surprisingly, a higher frequency of cooking was linked to a heavier average birth weight, possibly because families with more financial stability can afford to cook more often.[21]

It has been noticed that exposure of mothers to volatile organic compounds (VOCs) and particulate matter (PMs) within indoor environments during pregnancy could be associated with greater chances of having a child with

congenital heart disease (CHD). A logistic regression model adjusted for confounders revealed that exposure to high levels of indoor TVOCs (AOR 7.09, 95% CI 2.10–23.88) during pregnancy was associated with risks of CHD and the occurrence of some major CHD subtype in offspring. These risk effects were enhanced in pregnant women living in a newly renovated house but were mitigated by household use of smoke ventilators when cooking. We observed a positive interaction of maternal exposure to TVOCs and $PM_{2.5}$ and the risk for CHD.[22]

Cognitive impacts

These women, especially those who were middle-aged or older, had lower cognitive abilities compared with those not exposed to IAP. The negative impact of IAP on cognitive function was observed in both unadjusted and adjusted models. In addition, elderly rural women from disadvantaged socioeconomic backgrounds were found to be more vulnerable to cognitive impairment as a result of IAP.[26] In a group of participants, about 25% were exposed to indoor air pollution, and over 25% of those exposed showed signs of cognitive impairment. This is twice as high as the rate of cognitive impairment seen in the general population.[20]

Developmental impacts

Unclean cooking fuel use and passive smoke exposure[32] during pregnancy and early life were associated with developmental delays. It has been observed a positive association of unclean cooking fuel exposure with failing any, gross motor, communication, and personal-social developmental domains, and passive smoke exposure with developmental delay in problem-solving skills among children of nonactive smokers during pregnancy.[33] Indoor pollution is associated with increased odds of failing development domain, gross motor domain, and personal domain.[25]

Discussion

This study warns about the dangers of using biomass fuels for cooking and heating for our health. Many people who use these fuels have health problems, and women exposed to this smoke have an increased risk of a lung disease called COPD. We urgently need ways to reduce air pollution in homes to protect people's health, especially pregnant women and other vulnerable groups. This means we need to use cleaner cooking methods and reduce the use of biomass fuels.[34] Research in this article highlights the effects of indoor air pollution on health, expanding our knowledge of this significant public health concern. The study meticulously examined the link between indoor air pollutants and health outcomes.[35] A major discovery is the widespread occurrence of respiratory issues and illnesses in those exposed to indoor air pollution. Prolonged exposure to indoor air pollution significantly increases the likelihood of developing respiratory problems, such as asthma, COPD, and lung infections.[8,19,21] Emphasizing the critical necessity for actions to mitigate air pollution and preserve respiratory well-being, the study identified indoor air pollutants believed to contribute to health conditions such as asthma.[36,37] The association between indoor air pollutants such as particulate matter, volatile organic compounds, and carbon monoxide with respiratory disorders such as asthma, chronic obstructive pulmonary disease (COPD), and acute respiratory infections highlights the need for urgent action to mitigate indoor air pollution.[38]

The research highlights that indoor air pollution has a more severe impact on certain vulnerable groups, particularly women and children. These groups spend more time indoors, potentially encountering harmful pollutants in their homes. Consequently, they face a higher risk of adverse health effects, such as poor birth outcomes, respiratory issues, and various health conditions. Specifically, pregnant women exposed to indoor volatile organic compounds (VOCs) and particulate matter (PM) may have an increased likelihood of their babies being born with congenital heart defects (CHD)[22] as well as adult heart problems.[28] Pregnant women living in recently remodeled homes face increased health risks, particularly due to indoor air pollution. However, studies show that using smoke ventilators while cooking helps mitigate these risks.[22] This emphasizes the importance of initiatives and policies aimed at minimizing air pollution in homes, especially in communities with high-risk populations, to address health disparities.[39]

This study helps us understand where indoor air pollution comes from and what we can do to stop it. By identifying common sources such as cooking, smoking, and household products, we can focus on specific actions to reduce our exposure to air pollution and improve indoor air quality. Simple steps such as improving ventilation, cooking more cleanly, and changing our habits can go a long way in reducing pollution and protecting our health.[40]

The review's findings highlight the necessity of implementing comprehensive air quality management strategies to protect public health by lowering exposure to pollutants. This could entail targeting pollution origins, enhancing ventilation systems, educating the public, and encouraging collaboration between policymakers, specialists, and community groups.[35] To address indoor air pollution, the Indian government has established the Pradhan Mantri Ujjwala Yojana program, which offers qualified households free LPG gas connections.[41] This transition from harmful solid fuels

to cleaner LPG can improve health by reducing risks from smoke exposure.[42] Public awareness campaigns and education programs can provide information on the dangers of indoor air pollution and promote actions to lower exposure. These initiatives should prioritize vulnerable groups such as children, the elderly, and those with health issues.[43,44]

Strengths and limitations

The strength of this study includes the inclusion of various study designs, such as cross-sectional, case-control, prospective cohort, survey, and complementary designs and provides a comprehensive view of the impact of indoor air pollution. Studies from different countries, including China, India, Bangladesh, USA, Guatemala, and Germany, enhance the generalizability of the findings to diverse populations. The total sample size of 37,43166 is substantial, which increases the reliability and validity of the study's findings. Despite the study's findings, it faces limitations. The design of some studies (e.g., cross-sectional, case-control) limits the ability to prove a direct cause-and-effect relationship between indoor air pollution and health outcomes. Also, although including different locations improves the generalizability of the results, cultural and environmental variations within countries may limit how well the findings apply to other populations. Finally, although the study examines a range of health impacts because of indoor air pollution, certain areas may not be fully explored, such as long-term effects or exposure to specific pollutants.

Conclusion

This study shows how important it is to act now to improve indoor air quality and reduce the health issues it causes. The study found that people who are exposed to indoor air pollution have a high rate of respiratory problems and illnesses. This shows that there is an urgent need for steps to make the air inside buildings better. The study looked at how indoor air pollution affects many different parts of health, such as the lungs, heart, nervous system, pregnancies, brain, and growth. It gives a complete picture of the problem by doing this. Understanding the causes and effects of indoor air pollution is essential for creating targeted interventions and policies to: Reduce pollution levels and protect vulnerable groups such as women, children, and older adults. The study's findings, which link indoor air pollution symptoms to factors such as gender, income, and housing, provide valuable information for designing effective interventions. Essential steps to improve indoor air quality and protect public health include: encouraging cleaner cooking methods, enhancing ventilation, and raising awareness about the health risks of indoor air pollution. Addressing it calls for collective efforts, including policies, technological advancements, and personal actions to improve indoor air quality. Recognizing and addressing these impacts enables us to create healthier indoor spaces and protect the well-being of present and future generations. To tackle the issue of indoor air quality, it requires a collaborative approach involving government policies, technological advancements, and individual actions. By acknowledging and addressing the negative effects of poor indoor air quality, we can establish healthier indoor environments that safeguard the health of individuals now and in the future.

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Conflicts of interest

There are no conflicts of interest.

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