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Physical environmental factors and the occurrence of pneumonia among under-five children in developing Asian countries: a scoping review

Faktor Lingkungan Fisik yang Memengaruhi Kejadian Pneumonia Balita di Negara Berkembang Asia: Scoping Review

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ABSTRACT

Background: *Pneumonia remains one of the leading causes of morbidity and mortality among children under five in developing countries and is suspected to be associated with household physical environmental factors that have not been comprehensively examined in an integrated manner.*
Objective: *This study aimed to map the scientific evidence on physical environmental factors associated with pneumonia among children under five in developing countries in Asia using a scoping review approach based on the PRISMA-ScR guidelines.*
Methods: *Literature searches were conducted in the Scopus, PubMed, and Google Scholar databases from 2015 to 2025, with inclusion criteria focusing on primary research articles addressing children under five and physical environmental factors. A total of ten articles were included and analyzed descriptively.*
Results: *The findings indicate that the most consistently associated household physical environmental factors with pneumonia among children under five include indoor air pollution from biomass fuels, inadequate household ventilation, overcrowding, and exposure to harmful gases such as carbon monoxide. In addition, poor natural lighting and high humidity were also reported to contribute to an increased risk of pneumonia. It was also found that immunization status and socioeconomic conditions influence the incidence of pneumonia.*
Conclusion: *These findings indicate that pneumonia among children under five is a multifactorial isease influenced not only by household environmental conditions, but also by biological and socioeconomic factors. Overall, household physical environmental factors remain important determinants of pneumonia among children under five, although their impact may vary depending on contextual and supporting factors.*

Keywords: *indoor air polution, physical environment, pneumonia, under-five children, ventilation*

ABSTRAK

Latar Belakang: Pneumonia masih menjadi salah satu penyebab utama morbiditas dan mortalitas pada balita di negara berkembang dan diduga berkaitan dengan faktor lingkungan fisik rumah yang belum dikaji secara terintegrasi.
Tujuan: Penelitian ini bertujuan untuk memetakan bukti ilmiah mengenai faktor lingkungan fisik yang berhubungan dengan kejadian pneumonia pada balita di negara berkembang di Asia melalui pendekatan scoping review dengan pedoman PRISMA-ScR.

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Metode: Pencarian literatur dilakukan pada basis data Scopus PubMed dan Google Scholar dari tahun 2015 hingga 2025, dengan kriteria inklusi artikel penelitian primer yang membahas balita dan faktor lingkungan fisik dan diperoleh sepuluh artikel yang dianalisis secara deskriptif.
Hasil: Hasil menunjukkan bahwa faktor lingkungan fisik rumah yang paling konsisten berhubungan dengan pneumonia pada balita adalah paparan polusi udara dalam ruang akibat penggunaan bahan bakar biomassa, ventilasi rumah yang tidak memadai, kepadatan hunian, serta paparan gas berbahaya seperti karbon monoksida. Selain itu, pencahayaan alami yang buruk dan kelembapan tinggi juga dilaporkan berkontribusi terhadap peningkatan risiko pneumonia. Ditemukan bahwa imunisasi dan kondisi sosial ekonomi juga memengaruhi kejadian pneumonia.
Kesimpulan: Temuan ini menunjukkan bahwa pneumonia pada balita merupakan penyakit multifaktorial yang dipengaruhi tidak hanya interaksi faktor lingkungan tetapi juga faktor biologis dan sosial ekonomi. Secara keseluruhan, faktor lingkungan fisik rumah tetap menjadi determinan penting pneumonia pada balita, meskipun pengaruhnya dapat bervariasi tergantung pada konteks dan faktor pendukung lainnya.

Kata kunci: balita, lingkungan fisik, pneumonia, polusi udara, ventilasi

INTRODUCTION

Pneumonia remains one of the leading causes of morbidity and mortality among children under five years of age, both globally and nationally. According to the World Health Organization (WHO), pneumonia accounts for 15% of all deaths in this age group, causing approximate 740,180 deaths among children in 2019.[1]

In Indonesia, pneumonia is among the top ten causes of death among children under five and remains a significant public health problem, particularly in areas with poor environmental and housing conditions.[2] The number of deaths from pneumonia in the same year was estimated at 19,000.[2] By age group, the highest prevalence of pneumonia occurs among children aged 1–4 years, then increases again among those aged 45-60 years, and continues to rise in older age groups. The five provinces with the highest pneumonia incidence among children under five are East Nusa Tenggara (38.6%), Aceh (35.6%), Bangka Belitung (34.8%), West Sulawesi (34.8%), and Central Kalimantan (32.7%).[3] This condition suggests that pneumonia is influenced not only by clinical factors but also by complex environmental and social determinants.

Data from the Basic Health Research (Riskesdas) indicate that the prevalence of pneumonia among toddlers in Indonesia remains relatively high, with a tendency to be more prevalent in areas characterized by high population density and poor environmental quality in homes.[2] This finding is in line with a UNICEF report stating that developing countries in Asia, including Indonesia, account for a large proportion of global cases of pneumonia in children under five due to a combination of environmental, economic, and health behavior factors.[4]

Etiologically, Streptococcus pneumoniae is one of the leading causes of pneumonia in children in developing countries. The transmission of this bacterium is strongly influenced by the physical conditions of the home environment, particularly poor ventilation and low indoor air quality. Research in Indonesia has shown that toddlers living in homes with substandard ventilation are a higher risk of pneumonia than those living in homes with good ventilation.[5]

Physical environmental factors in the home, such as housing density, natural lighting, humidity, and cooking fuel type, have been extensively studied in environmental health research in Indonesia. A study published in the Journal of Environmental Health found that the use of biomass fuel and inadequate home ventilation are significantly associated

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with the incidence of pneumonia among toddlers.[6] These conditions remain common in rural areas and densely populated urban areas in developing countries in Asia.

In addition, high residential density is an important risk factor for pneumonia in toddlers. Houses with many occupants disproportionate to the building's size increase the risk of respiratory infections spreading among family members. Research across several provinces in Indonesia shows that residential density is significantly associated with pneumonia incidence among toddlers, especially among families with low socioeconomic status.[7]

A study by Laliyanto et al. (2023) found an association between room temperature and the incidence of pneumonia among children under five years old. The average room humidity was recorded at 76.02%, which does not meet health standards.[8] Faturbata (2024) reported that overcrowding, humidity, and light intensity are risk factors for pneumonia, with relatively high odds ratios.[9] Hasalia and Noerjoedianto (2025) also found that overcrowding, humidity, lighting, and temperature are associated with pneumonia incidence, while floor type was not significantly associated. These findings indicate that humidity is the most dominant factor in the occurrence of pneumonia among children under five.[10]

Various studies have examined physical environmental factors associated with pneumonia among children under five, both at local and international levels. The results show variability across environmental variables and differences in the most dominant contributing factors. Several studies have focused on only one or two specific variables, without providing a comprehensive understanding of the interrelationships among physical environmental factors. However, there are still limited studies that comprehensively map all physical environmental factors contributing to pneumonia among children under five in developing countries in Asia.

In this context, scoping reviews are an appropriate methodological approach for mapping available scientific evidence. Scoping reviews enable the identification of types of physical environmental factors that have been studied, characteristics of existing studies, and research gaps that have not yet been widely explored.[11,12] This method is particularly relevant for multidimensional, context-dependent environmental health topics.

Therefore, this study aims to map and summarize the scientific evidence on physical environmental factors associated with pneumonia among children under five in developing countries in Asia using a scoping review approach based on the PRISMA-ScR guidelines. This study also focuses on identifying existing research gaps to provide direction for future research. The findings of this study are expected to serve as a scientific basis for the development of environmental health policies and more effective and context-specific interventions for pneumonia prevention in developing regions of Asia, including Indonesia.

METHODS

Study design

This study uses a scoping review design, a literature review method that systematically maps the available scientific evidence on a particular topic, identifies the characteristics of existing research, and identifies research gaps that have not been widely studied. This design was chosen because the topic of household physical environmental factors and pneumonia among children under five encompasses a wide range of variables, shows variability in research findings, and has not yet been systematically mapped. Scoping reviews are particularly suitable when the research topic is broad, heterogeneous, and has not been comprehensively summarized.[13] The

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scoping review approach in this study follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines, which provide a transparent and systematic reporting framework for literature mapping studies.[14]

The formulation of research questions in this scoping review was based on the Population, Concept & Context (PCC) framework, as recommended by the Joanna Briggs Institute (JBI) for scoping review research.[15] The PCC framework was used because it is more flexible than PICO and is suitable for exploratory studies. In this study, the population component includes children aged 0–59 months. The research concept focuses on physical environmental factors, including home ventilation, housing density, natural lighting, indoor air quality, humidity, and cooking fuel use. In contrast, the research context includes developing countries in Asia.

Search strategy

The literature search was conducted using three main electronic databases, namely Scopus, PubMed, and Google Scholar, which were selected for their multidisciplinary coverage and relevance to public health and environmental health. The search strategy employed a combination of keywords and terms tailored to each database, including pneumonia, children under five, physical environment, housing conditions, and developing countries in Asia.

The literature search was limited to articles published between 2015 and 2025 to ensure the timeliness of the data used. The use of multiple databases was intended to minimize publication bias and enhance the completeness of literature coverage, as recommended in systematic and scoping review studies.[11] The included articles were publications in English and Indonesian and were available in full-text form. The use of multiple databases was intended to broaden the scope of the literature and to minimize limitations in data sources.

Eligibility criteria

Inclusion and exclusion criteria were determined to ensure the relevance of the articles to the research objectives. This selection approach aligns with the principles of literature selection in public health research as described by Notoatmodjo (2018).[12] Inclusion criteria included primary research articles (quantitative, qualitative, or mixed-methods), in which the research subjects are toddlers (aged 0–59 months), the research examines the relationship between physical environmental factors and the incidence of pneumonia, the research is conducted in developing countries in Asia, and the articles are available in full text.

The exclusion criteria in this scoping review included articles in the form of reviews, editorials, or opinions; studies that did not specifically discuss physical environmental factors as determinants of pneumonia incidence; studies conducted in developed countries; and articles that used research populations other than toddlers.

Study selection process

The study selection process was conducted in stages: article identification, title and abstract screening, full-text eligibility assessment, and article selection for inclusion in the scoping review. Each stage of the selection process was conducted based on the predefined inclusion and exclusion criteria. This selection flow follows the stages of Identification, Screening, Eligibility, and Included, as recommended in the PRISMA-ScR guidelines.[11]

The entire study selection process is visualized using the PRISMA-ScR flow diagram to increase transparency and reproducibility. This diagram illustrates the number of articles at each selection stage and the reasons for exclusion at the full-text assessment stage.

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Data extraction

Data from the included articles were extracted using a charting table. This process involved developing a data extraction table containing key information, such as the authors' names, year of publication, country of study, study design, population characteristics, types of household physical environmental factors examined, and the main findings.

The data charting process was conducted systematically to ensure consistency in data extraction across articles. The extracted data were then analyzed descriptively to identify patterns of findings, similarities among variables, and variations in study results.[15] Based on the literature selection stages that followed the PRISMA-ScR guidelines in a systematic and structured manner, a total of 2,599 articles were identified from three main databases, namely Scopus, PubMed, and Google Scholar, through a comprehensive literature search process. All identified articles were collected and managed to ensure no data duplication.

Next, a multi-layered screening process was carried out, which included removing duplicate articles, assessing the suitability of titles and abstracts for the research objectives, and evaluating the feasibility of full-text articles against pre-determined inclusion criteria. Articles that were not relevant to the research focus or did not meet the criteria were excluded from the selection process. Through this rigorous selection process, ten articles were deemed eligible and included in the final synthesis stage for further analysis and summarization. The selection and screening process for this study is presented in detail and systematically in the following PRISMA Flow Diagram.

After going through the process of identifying, screening, and assessing the eligibility of articles as described in the PRISMA-ScR flow chart , ten primary research articles were declared to meet the inclusion criteria. They were then included in the analysis stage. The selected articles were then systematically extracted to identify study characteristics, research context, and physical environmental factors studied. And key findings related to pneumonia in young children in developing countries. Data extraction was conducted to provide a comprehensive overview of the variation in study design, study location, population characteristics, types of household physical exposures in the home, and key research findings.

Quality assessment / Risk of bias

Methodological quality assessment and risk of bias evaluation were not conducted in this study. Although this scoping review adopted the Joanna Briggs Institute (JBI) framework through the Population, Concept, and Context (PCC) approach, critical appraisal was not performed because the primary objective of this review was to map and summarize the available evidence rather than to critically assess the methodological quality of individual studies.[13]

Data synthesis / Data analysis

The extracted data were subsequently analyzed descriptively to identify patterns of findings, similarities among variables, and variations in study results. Household physical environmental factors in this study were categorized according to the main characteristics commonly used in environmental health research: overcrowding, ventilation, lighting, temperature, humidity, floor type, and building materials. This categorization was conducted to facilitate the mapping of the most frequently studied factors as well as those that play a dominant role in the incidence of pneumonia among children under five. The results of the analysis were presented in tables and thematic narratives, without conducting a methodological quality assessment or a meta-analysis, in accordance with the characteristics of a scoping review.[13]

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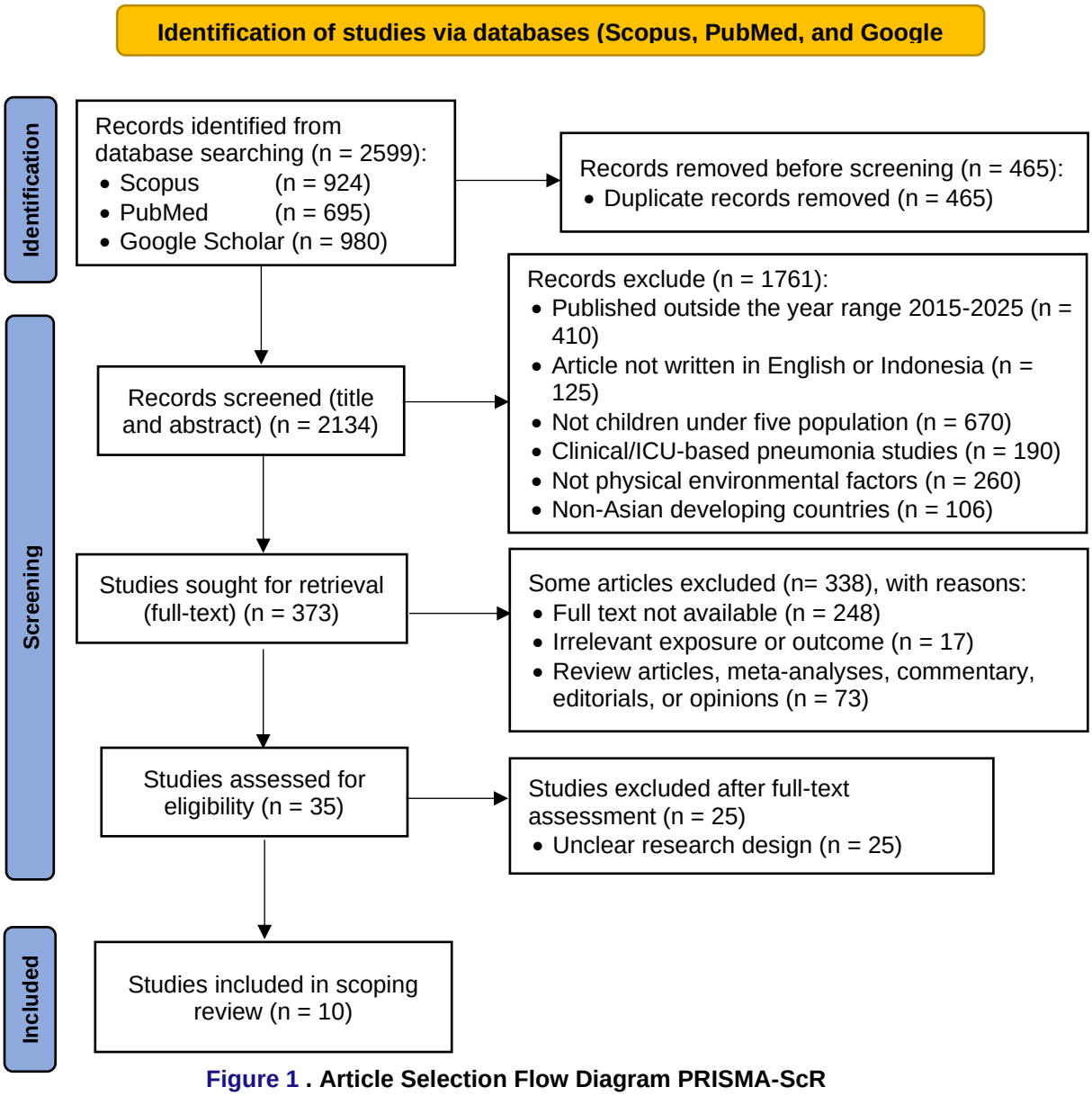

Figure 1 . Article Selection Flow Diagram PRISMA-ScR

RESULTS

A review of 10 articles indicates that physical environmental factors influence the incidence of pneumonia among children under five, although the strength of the association varies across studies. Of the 10 reviewed studies, 7 studies (70%) reported statistically significant associations between at least one physical environmental factor and pneumonia incidence, while 3 studies (30%) reported non-significant findings for the primary environmental variables examined.

Indoor air pollution was the most frequently studied and reported variable. Out of the 10 reviewed studies, 8 (80%) specifically analyzed smoke exposure and cooking fuel types. Overall, 5 out of 8 studies (62.5%) reported a statistically significant relationship, while 3 studies (37.5%) found no strong direct link between fuel type and severe pneumonia after adjusting for other variables. The findings are summarized in the table below:

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Table 1. Summarizes of Findings on Indoor Air Pollution and Fuel

Researcher (Year)	Study Location	Primary Variable	Finding	Risk Score (OR/RR/IRR)
Sonego et al. (2015)[16]	Global (LMICs)	Solid Fuel Use	Significant	OR 3.02
Karki et al. (2015)[17]	Nepal	Smoky Stove (*Chulo*)	Significant	OR 3.76
Naz & Ghimire (2020)[18]	Pakistan	Polluting Fuel	Significant	OR 1.25
Kinney et al. (2021)[19]	Ghana	Carbon Monoxide (CO)	Significant	RR 1.10
Bahri et al. (2023)[20]	Indonesia	Indoor Lighting/Bacteria	Significant	OR 2.12
Gothankar et al. (2018)[21]	India	Cooking Fuel Type	Not Significant	$p > 0.05$
McCollum et al. (2024)[22]	Multi-country	LPG Intervention	Not Significant	IRR 0.96
McCracken et al. (2025)[23]	Multi-country	PM2.5 & CO Exposure	Not Significant	RR 1.03

Sonego et al. (2015) reported that indoor air pollution increased pneumonia-related mortality with an odds ratio of 3.02.[16] Naz and Ghimire (2020) also found that the use of biomass fuels increases the risk of pneumonia, with an odds ratio of approximately 1.25.[18] Karki et al. (2015) reported that exposure to cooking smoke increases the risk of pneumonia by 3.76 times.[17] However, McCollum et al. (2024) and McCracken et al. (2025) found no significant association between PM2.5 exposure and pneumonia incidence.[22,23] Kinney et al. (2021) reported that prenatal carbon monoxide exposure increased pneumonia risk (RR 1.10).[19]

The variable of overcrowding was analyzed in 5 studies (50%). The results indicate that cramped living spaces contribute to the transmission of respiratory pathogens. Of these studies, 3 out of 5 studies (60%) established overcrowding as a primary risk factor. In Indonesia, toddlers in overcrowded homes are 2.75 times more likely to suffer from pneumonia.[20] In Pakistan, national survey data showed a 1.27 times increased risk in crowded households.[18] Global meta-analyses also confirmed this trend, though they noted moderate heterogeneity across different developing countries. However, 2 out of 5 studies (40%) reported non-significant results. In India, despite the presence of crowded homes, the factor was not directly linked to pneumonia, likely because high immunization coverage in the study area mitigated the risk.[21] In Karachi, bedroom crowding was not found to be a strong independent predictor of recurrent pneumonia.[18]

Physical building quality, such as floor material and humidity levels, was examined in 4 studies (40%). In Central Java, Indonesia, soil flooring was found to increase pneumonia risk by 3.16 times, while humidity levels outside the 40-70% range increased risk by 2.92 times.[20] In Pakistan, low-quality "katcha" houses (made of mud and straw) were the strongest predictors for recurrent pneumonia, with odds ratios between 2.43 and 2.44.[18] The material of house walls in Indonesia did not show a significant association ($p=0.412$), suggesting that walls may not be as critical a transmission pathway as flooring and humidity.[20] Parental smoking habits and exposure to secondhand smoke were studied in 4 research papers (40%). Overall, 2 out of 4 studies (50%) showed a close link. A global meta-analysis indicated that parental smoking increases the risk of pneumonia mortality with an OR of 1.52.[16] In Nepal, an OR of 2.21 was found for children with smoking parents, but this did not reach statistical significance ($p=0.26$), possibly due to a small sample of smokers.[17] In a nested case-control study in

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Pakistan, smoking was not significantly associated with recurrent pneumonia, which researchers suspect was due to confounding with higher family wealth.[18] Table 2 summarizes the extracted study findings.

Table 2. Summarizes of Study Findings from the 10 Journals

Author (Year)	Method	Sample Size	Physical Environmental Factors	Exposure Parameters	Key Findings
Karki et al. (2015)[17], Nepal	*Case-control Non-probability purposive sampling*	200 Children under 5 years old	Use of biomass fuel and exposure to cigarette smoke	The presence of biomass stoves (chulo) in homes and the smoking habits of parents	The use of smoky biomass stoves is significantly associated with an increased risk of pneumonia in children under five.
Naz & Ghimire (2020)[18], Pakistan	Analysis of national survey data (DHS)	±29.000 Children under 5 years old	Indoor air pollution and population density	Use of unclean cooking fuel and crowded living conditions	The use of unclean fuels and housing density are associated with the incidence of pneumonia in children under five.
McCracken et al. (2025)[23], Guatemala	Prospective cohort study	3061 Infants under 12 months of age	Household air pollution from biomass	Exposure to $PM_{2.5}$ and CO from cooking with biomass	High exposure to household air pollution increases the risk of severe pneumonia in infants.
McCollum et al. (2024)[22], Malawi	Randomized controlled trial (RCT)	3061 Infants	Types of cooking fuel	Comparison of LPG and biomass usage	No significant difference in the incidence of severe pneumonia was found between the LPG and biomass groups.
Gothankar et al. (2018)[21], India	*Community-based cross-sectional*	3671 Children under 5 years old	Ventilation, housing density, and cooking fuel	The ventilation conditions of the house, the density of occupants, and the type of fuel	Poor ventilation, crowded living conditions, and the use of biomass fuels are associated with pneumonia.
Bahri et al. (2023)[20], Indonesia	*Case-control Purposive sampling*	130 Toddler	Physical condition of the house and the amount of airborne bacteria	Ventilation, lighting, humidity, and airborne bacteria count.	Poor ventilation, low lighting, and high levels of airborne bacteria are associated with pneumonia.
Brown et al. (2020)[24], Pakistan	*Nested case-control*	4003 Infant	Household air pollution	Use of biomass fuel and ventilation	Exposure to household air pollution increases the risk of recurrent pneumonia.
Sonego et al. (2015)[16], Developing	*Systematic review & meta-*	198.359 Children under 5	Home environment factors	Exposure to smoke indoors and housing	Exposure to household smoke increases the risk of death from lower

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Author (Year)	Method	Sample Size	Physical Environmental Factors	Exposure Parameters	Key Findings
countries (multiple countries)	*analysis*	years old		conditions	respiratory tract infections.
Havens et al. (2018)[25], Malawi	*Cross-sectional*	1.928 Children under 5 years old	Carbon monoxide exposure	Levels of CO and carboxyhemoglobin in the blood	CO exposure from cooking activities is associated with an increased risk of pneumonia.
Kinney et al. (2021)[19], Ghana	*Randomized controlled trial*	1414 Children under 5 years old	Prenatal and postnatal household air pollution	Exposure to $PM_{2.5}$ during pregnancy and after birth	Prenatal and postnatal exposure to household air pollution increases the risk of childhood pneumonia.

DISCUSSION

The findings from these various studies reveal striking heterogeneity regarding the extent to which physical environmental factors contribute to pediatric pneumonia. While common sense suggests that a cleaner home leads to healthier lungs, the data indicates that pneumonia is not just a result of air quality, but rather a complex interaction between the physical environment, the child's immune system (host), and broader socioeconomic determinants.[16,20]

The Air Pollution Paradox: Observational Evidence vs. Randomized Trials

One of the most significant points of debate in recent literature is the discrepancy between observational studies and large-scale randomized controlled trials (RCTs). Observational data, such as the meta-analysis by Sonego et al. (2015) and the national survey in Pakistan by Naz & Ghimire (2020), consistently identify solid fuel use as a "prime suspect" for pneumonia, often showing a direct link between smoke exposure and mortality.[16,18] However, the HAPIN trial a massive multicountry study found that providing free LPG stoves and fuel did not significantly reduce the incidence of severe pneumonia in infants.[22,23] This paradox can be explained by several factors. First, even though LPG stoves reduce pollutants in the kitchen, the levels of fine particulate matter (PM2.5) often remain above the safety thresholds set by the WHO.[22] Second, the concept of "neighborhood pollution" plays a critical role. Children in rural settings are not just exposed to their own kitchen smoke; they also inhale pollutants from neighbors' trash burning, agricultural fires, and kerosene lamps used for lighting.[23,25] Consequently, an intervention in a single household is often insufficient to lower a child's total exposure below the biological threshold required to prevent deep-lung infections.[23]

Timing of Exposure: The Critical Prenatal Window

Heterogeneity is also evident in *when* the exposure occurs. While most studies focus on the air the child breathes after birth, research in Ghana (GRAPHS) provides compelling evidence that the damage may start in the womb. Maternal exposure to carbon monoxide (CO) during pregnancy was found to be a significant predictor of severe pneumonia during the infant's first year of life.[19] This finding suggests that HAP exposure may "program" fetal lung development or cause oxidative stress, making the child more vulnerable to respiratory pathogens from day one.[19] This explains why many postnatal interventions fail; if the child's respiratory foundation is already compromised during gestation, simply cleaning the indoor air after birth might be "too little, too late."

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This underscores the need for environmental health policies that specifically target pregnant women to protect the next generation.[19]

Housing Quality as a Mirror of Multidimensional Poverty

Variables like overcrowding and building materials show inconsistent results because they act as proxies for broader poverty. In the peri-urban slums of Karachi, poor-quality "katcha" housing (made of mud and straw) was a powerful independent predictor of recurrent pneumonia.[24] Such housing is not just about structure; it reflects a lack of sanitation, poor nutrition, and higher exposure to pathogens.[16,24] Similarly, Bahri et al. (2023) found that soil flooring and high humidity in Indonesia significantly increased risk. Humidity and lack of natural light create a micro-environment where bacteria thrive and are easily transmitted in crowded spaces.[20] These environmental conditions may facilitate the survival and transmission of respiratory pathogens in crowded households. However, when studies are conducted in slightly better-off areas, like Pune, India, these physical factors often lose their statistical significance because families have better literacy and higher immunization rates that mitigate environmental risks.[21] This confirms that physical housing conditions cannot be viewed in isolation from the socioeconomic status of the family.

The Mitigating Power of Immunization and Nutrition

The role of vaccines is perhaps the strongest "confounder" that explains why some studies show no link between environment and pneumonia. In regions with high coverage of the Pneumococcal Conjugate Vaccine (PCV) and Hib vaccines, the biological "insult" from indoor smoke may be less likely to progress into severe clinical pneumonia.[22] Gothankar et al. (2018) noted that partial immunization was a far more dangerous risk factor than any environmental variable they measured.[21]

Furthermore, nutrition remains the ultimate "host" defense. Sonego et al. (2015) highlighted that severe malnutrition increases the risk of pneumonia death by over four times, a risk magnitude that dwarfs almost all environmental factors.[16] A well-nourished, fully vaccinated child is significantly more resilient to the negative effects of a smoky kitchen or a crowded bedroom than a malnourished, unvaccinated peer.[16,21]

Methodological Limitations and Measurement Bias

Finally, the heterogeneity of findings is driven by how researchers measure exposure. Studies that rely on maternal self-reports or questionnaires (e.g., Karki et al., 2015; Naz & Ghimire, 2020) are prone to recall bias and may overestimate the impact of "visible" smoke.[17,18] In contrast, studies using personal monitoring devices often find that what looks like a "clean" house actually has high levels of invisible pollutants.[25] Objective biomarkers, like carboxyhemoglobin (COHgB) in the blood, reveal that children are often exposed to tobacco smoke-equivalent levels of CO, even if the parents don't perceive the air as "smoky".[25]

CONCLUSION

This study shows that indoor air pollution, exposure to tobacco smoke, and household physical conditions such as overcrowding, inadequate ventilation, and high humidity are the factors that most contribute to the incidence of pneumonia among children under five, although some findings remain variable. The striking differences in findings between observational studies and clinical trials suggest that household-level fixes, such as providing a gas stove, are necessary but insufficient on their own. Pneumonia is a disease of poverty that thrives on a "perfect storm" of prenatal insults, poor housing quality, neighborhood-wide pollution, and gaps in healthcare. Future research should adopt approaches that provide more accurate exposure measurements. Health policies should focus on improving indoor air quality, reducing exposure to tobacco smoke, and strengthening immunization and family education.

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