Journal of Air Pollution and Health (Summer 2026); 11(3): 435-462

Review Article

Available online at https://japh.tums.ac.ir

Uncovering the research landscape on indoor air pollution and public health: Bibliometrics and literature review (2001-2024)

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ARTICLE INFORMATION

Article Chronology:
Received 18 February 2026
Revised 18 May 2026
Accepted 22 July 2026
Published 29 September 2026

Keywords:
Indoor air pollution; Solid biomass fuels; Particulate matter; Greenhouse gases; Public health

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ABSTRACT

The growing concern about the health risks posed by indoor air pollutants has led to extensive research on the relationship between Indoor Air Pollution and Public Health (IAPPH).

This study critically examined the scientific progress and technological developments in IAPPH research. Publication trends, bibliometric analysis, and literature review methods were employed to analyze publications indexed in the Scopus database between 2001 and 2024. The keywords "indoor air pollution," "health," and "public health" were used to identify relevant studies. Bibliometric networks and visualizations were generated using VOSviewer.

Findings revealed 151 publications, consisting of 56.29% articles, 17.88% reviews, and 11.26% conference papers. Stakeholder analysis, which considered leading authors, affiliations, funding agencies, and countries, highlighted Majid Ezzati (United Kingdom) and the University of California, Berkeley (United States) as the most productive contributors. Their high output was linked to strong financial support and international collaborations. Funding analysis indicated that organizations in the United States and China were the primary sponsors of IAPPH research. The literature review identified particulate matter, volatile organic compounds, and Carbon Oxides (COx) as major indoor pollutants that contribute to allergic, cardiovascular, and respiratory diseases, especially among women, children, and the elderly. These findings underscore the need for mitigation strategies, such as cleaner fuels, improved stove efficiency, and better ventilation systems, to minimize emissions and protect human health, safety, and the environment. Overall, the study indicates that IAPPH is a complex, interdisciplinary research field with significant social, economic, and scientific implications.

Please cite this article as: Otitolaiye VO, Omer F, Abdelrahim R, Ibrahim E, Abdullayev E, Kozhiparambath L, et al. Uncovering the research landscape on indoor air pollution and public health: Bibliometrics and literature review (2001-2024). Journal of Air Pollution and Health. 2026;11(3):435-462.
Doi: https://doi.org/10.18502/japh.v11i3.22630

Review

Anthropogenic activities such as cooking, heating, and lighting are crucial to human existence. Around the globe, the energy required to support critical human activities is provided by Solid Biomass Fuels (SBF), such as firewood, charcoal, crop residues, sawdust, and animal dung. It is estimated that about one-third of the global population (~3 billion people) depend on SBFs as their primary domestic energy source [1, 2]. However, the combustion of such fuels emits large quantities of harmful or toxic solid particles and gaseous substances, including particulate matter, aromatic hydrocarbons, sulphur dioxide, carbon monoxide, carbon dioxide, and nitrous oxides, among others [3, 4]. In addition, indoor environments may contain chemical compounds such as benzene, trichloroethylene, radon, formaldehyde and other Volatile Organic Compounds (VOCs), microbial species (bacteria and mould), and passive smoke from tobacco and chimneys [5, 6]. Over time, there has been growing evidence that SBFs are dirty fuels, and their continued use for domestic applications is a significant source of Indoor Air Pollution (IAP) [4].

According to previous studies, there are growing concerns about the public health and general well-being of citizens in lower- and middle-income nations (e.g., India, Pakistan, Nepal, Bangladesh, Sri Lanka, and Bhutan) due to high levels of IAP [7]. Many studies have reported that exposure to indoor air pollutants poses grave health and safety risks to humans and the environment [4]. High levels of indoor air pollutants resulting from the inefficient or incomplete combustion of SBFs are linked to over 3.6 million deaths yearly [4]. With long exposure periods, the risk and health impacts of indoor air pollutants from SBFs are higher in women and children [8]. Other studies have demonstrated that indoor air pollution poses significant health risks to middle-aged and older adults >65 years [9, 10].

Overall, exposure to IAPs has been reported to increase the probability of cardiovascular, respiratory, and cognitive challenges such as hypertension, lung disease, heart disease, short-term memory loss, and impaired mathematical reasoning [10].

Indoor air pollution is also closely linked to socioeconomic problems in many societies. Across the reviewed studies, the general observation is that IAP is a consequence of socioeconomic status [11]. Low-income households are more likely to select and use low-quality, polluting fuels and inefficient stoves, and to live in dwellings with inadequate ventilation [11]. Previous work has reported links between poverty, fuel choice, and exposure to IAP [12]. The socio-economic costs of indoor air pollution can be substantial. For example, one study in France showed that IAP-related pollutants such as benzene, trichloroethylene, radon, carbon monoxide, particulate matter with aerodynamic diameter less than 2.5 micrometres ($PM_{2.5}$), and environmental tobacco smoke exert both direct and indirect impacts, including premature mortality, morbidity, and loss of quality of life, with estimated costs of roughly 20 billion euros in a single year [13]. Other studies have reported that exposure to IAP varies across socioeconomic groups, resulting in health inequalities, particularly among low-income earners [14].

Based on the presented review of the scientific literature on IAP and its impact on human health, safety, and the environment, it can be reasonably surmised that the subject area has a significant research impact and societal importance. However, most existing studies and reviews focus on specific countries, pollutants, health outcomes, or interventions. While influential articles have examined the health impacts and socio-economic consequences of IAP, relatively few studies have systematically mapped the overall research landscape on Indoor Air Pollution and Public Health (IAPPH), including publication trends, key stakeholders, and collaboration patterns. In particular, there is limited work that combines bibliometric analysis with Literature Review (LR) to provide a comprehensive overview of IAPPH research over time. Such an integrated perspective is needed to understand how the field has developed, who the main contributors are, and where important research gaps remain.

Therefore, this paper seeks to systematically identify, screen, and analyze the published documents on Indoor Air Pollution and Public Health (IAPPH) from 2001 to 2024 through bibliometric analysis and literature review of documents indexed in the Elsevier Scopus database. The aim is to provide critical information and a comprehensive understanding of scientific growth and technological developments in IAPPH over the years. In line with this aim, the study addresses the following research questions:

RQ1: What are the publication trends and dominant research themes in IAPPH research from 2001 to 2024?

RQ2: Who are the main stakeholders (authors, affiliations, organisations, funding agencies, and countries) contributing to the development of IAPPH research?

RQ3: How have collaboration patterns and the overall research landscape on IAPPH evolved over the study period?

Study design and data source

This study used Bibliometric Analysis (BA) combined with a Literature Review (LR) to examine the research landscape on Indoor Air Pollution and Public Health (IAPPH). BA was applied to analyse publication trends, subject areas, and key stakeholders, including authors, affiliations, funding organisations, and countries, while the LR was used to summarise the main research themes and health impacts of indoor air pollution. All data were retrieved from the Elsevier Scopus database, which was selected as the primary data source for its broad coverage of peer-reviewed literature and suitability for bibliometric studies [15]. However, it is important to note that we may not have collected all the required data, as we relied solely on Scopus and may have missed articles indexed in other databases, such as PubMed or Web of Science [16, 17]. Despite this limitation, Scopus is a reliable research database with a user-friendly interface [18, 19]. Therefore, we believe that we have gathered sufficient data for the analyses conducted in this study.

Search strategy

A comprehensive search of the Scopus database was conducted on 3rd January 2025 to identify publications on IAPPH between 2001 and 2024. The initial search used the TITLE-ABS-KEY field to capture records containing the core terms "indoor air pollution", "health", and "public health". Boolean operators (AND, OR) were used to combine these terms with relevant synonyms to improve the search's completeness. For example, the search string included combinations such as:

("indoor air pollution" OR "indoor air quality" OR "household air") AND

("health" OR "public health") AND

("smoke" OR "biomass" OR "solid fuel").

The search was restricted to documents published in English. Following this initial retrieval, a second screening was conducted using the TITLE field to refine the results and remove records not directly related to indoor air pollution and public health. This two stage approach reduced the number of irrelevant records while maintaining broad coverage of the IAPPH literature.

Inclusion and exclusion criteria

Documents were eligible for inclusion if they met all of the following criteria: indexed in the Scopus database, published between 2001 and 2024, written in English, and focused on indoor air pollution and its human or public health implications.

We considered different document types, including articles, reviews, conference papers, book chapters, editorials, and letters, provided they contained empirical data, analysis, or substantive discussion of indoor air pollution and public health. Records were excluded if they dealt exclusively with outdoor air pollution or other environmental topics unrelated to indoor air, did not address health or public health outcomes (for example, purely technical or engineering studies without a health focus), or were non-research items without substantive content (such as errata, notes, or brief administrative notices). The number of records identified, screened, excluded, and finally included is summarized in a PRISMA-style flowchart (Fig. 1).

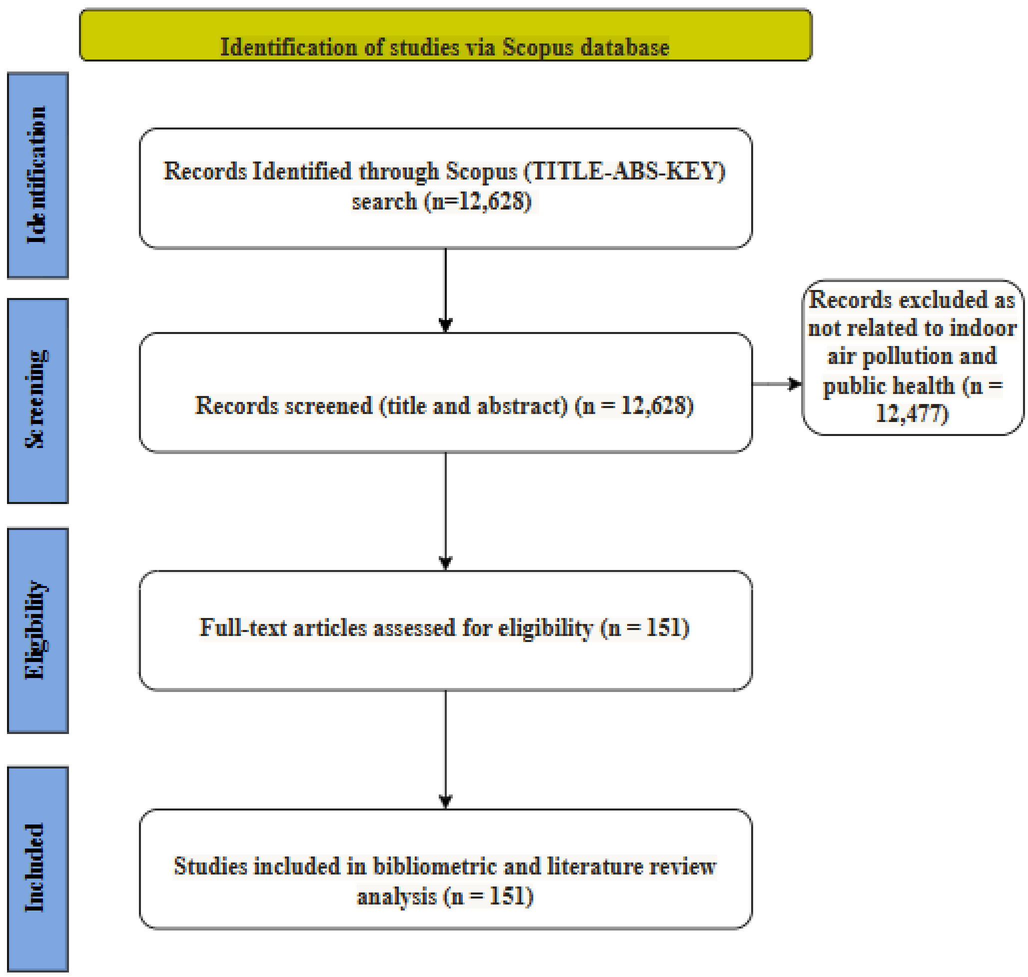

Fig. 1. PRISMA flowchart of the selection and inclusion of studies on IAPPH (2001–2024) from the Scopus database

Screening and quality assessment

All records retrieved from the TITLE-ABS-KEY search were first screened at the title and abstract level against the eligibility criteria. Full texts of potentially relevant documents were then assessed to confirm inclusion. One reviewer screened all records and carried out the full-text assessment. No formal critical appraisal tool was applied; however, only documents published in peer-reviewed sources and directly related to indoor air pollution and public health were included in the final dataset. This approach ensured that the analysis was based on studies of acceptable scientific quality while maintaining a broad and inclusive view of the IAPPH research landscape.

Bibliometric analysis

The final dataset of 151 documents was exported from Scopus in a format suitable for Bibliometric Analysis (BA). Descriptive statistics were used to examine annual publication trends, document types, and subject area distributions. Bibliometric analysis was then performed to identify the most prolific authors, affiliations, funding organisations, and countries in IAPPH research.

For the ranking analyses, ‘Top 5’ authors, affiliations, funding organisations, and countries were identified by ordering all items in the IAPPH dataset by total publication count and selecting the five with the highest counts. ‘Top 10’ highly cited publications were selected by ranking all documents by their total citation counts in Scopus and choosing the ten with the largest numbers of citations. Each publication was counted once in the total number of documents, and for productivity indicators, one full publication was credited to every co-author, affiliation, country, and funding organisation listed on the paper, without fractional counting.

Co-authorship and keyword co-occurrence analyses were conducted to explore collaboration patterns and research themes. Bibliometric networks and visualisations were generated using VOSviewer (version 1.6.17). Thresholds for inclusion in the network maps (for example, the minimum number of documents per author or country, and the minimum number of keyword occurrences) were set to focus on the most active and influential entities while preserving the overall structure of the field. For each network, the number of items, the number of clusters, and the Total Link Strength (TLS) were examined to characterise collaboration intensity and thematic connections. In VOSviewer, TLS is a summary measure that represents the sum of the weights of all links connected to a given node and is used here as an indicator of how strongly an author, country, or keyword is connected to others in the network.

Literature review

In addition to the quantitative bibliometric analysis, a literature review was carried out to synthesise the main research themes and health impacts of indoor air pollution documented in the most influential studies. Consistent with previous bibliometric studies that incorporate literature review, it was not feasible to review all retrieved articles in depth. Therefore, we focused on publications in the IAPPH dataset with higher citation counts (e.g., those with more than 25 citations). These highly cited studies were examined to identify key pollutants, exposure pathways, health outcomes, vulnerable populations, and intervention strategies. The findings from this literature review complement the bibliometric results by providing contextual and substantive insights into the scientific developments in the IAPPH field.

General publication trends

Fig. 2 presents the general publication trends on IAPPH studies in the Elsevier Scopus database. The publication search and trend analysis revealed that 151 documents (an average of 6.29 per year) on IAPPH were indexed in the Scopus database. As observed, the scientific productivity and research interest in the topic have fluctuated markedly over the years. The highest number of publications (i.e., 12) was observed in 2020, whereas the lowest (i.e., 1) was observed in 2001 and 2017.

Next, the document-type distribution of the IAPPH publications was examined. This approach is critical in analysing the nature and type of publication output, which could help readers comprehend the influence/impact and distribution of research [20]. Table 1 shows that the published documents are widely distributed.

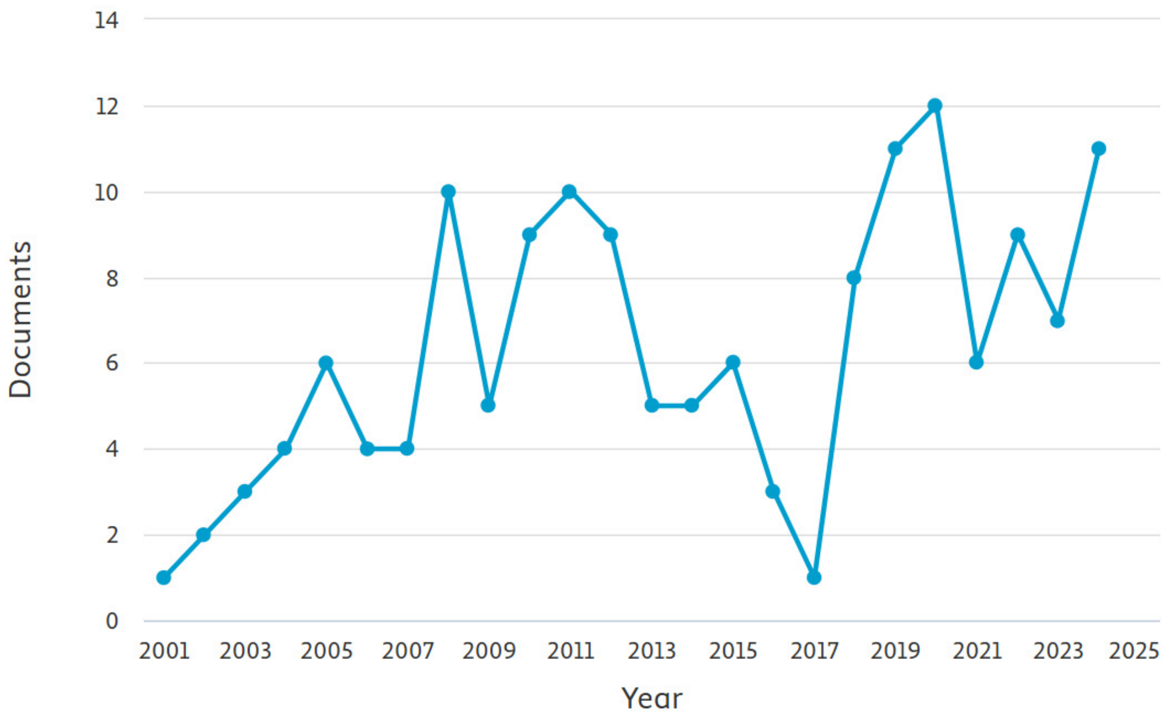

Fig. 2. Publication trends on IAPPH research studies

Table 1. Distribution of published documents

Document Type	Total Publications (TP)	Percentage Total Publications (%TP)
Article	85	56.29
Review	27	17.88
Conference Paper	17	11.26
Book Chapter	10	6.62
Editorial	4	2.65
Letter	3	1.99
Erratum	2	1.32
Note	2	1.32
Book	1	0.66
Total	151	100

The findings indicate that articles, reviews, and conference papers account for 85.43% of the Total Publication (TP) on IAPPH research. The articles account for 56.29% of the TP, whereas reviews and conference papers account for 17.88% and 11.26%, respectively. The findings indicate that articles, reviews, and conference papers are the core or benchmark document types according to Bradford's Law of Scattering [21]. Bradford's law of scattering was applied on a journal basis, using the 151 documents and their source titles. Journals were ranked according to the number of IAPPH publications and grouped into Bradford zones to identify the core set of the most productive journals in this field. The preference for articles and reviews is primarily based on their prestige, citations, academic potential, and other publication media. [22, 23].

Studies have reported that publishing articles or review manuscripts, particularly in prestigious, peer-reviewed, high-impact journals, can significantly enhance academics' career prospects and reputation [24]. Furthermore, such journal publications typically come with monetary incentives, research grants, and other financial rewards [25, 26]. Therefore, it can be reasonably surmised that the preference for articles, reviews, and conference proceedings among researchers in IAPPH research could be attributed to the outlined reasons.

Next, the study examined the distribution of publications on IAPPH research to determine its impact, multidisciplinary focus, and thematic focus. Fig. 3 shows the pie chart of the various subject areas of IAPPH. The results showed that the top 5 subject areas in IAPPH are Environmental Science (66 publications), Medicine (62 publications), Social Sciences (18 publications), Engineering (13 publications), and Biochemistry, Genetics, and Molecular Biology (9 publications). Other notable fields include Energy and Earth and Planetary Sciences. These findings highlight IAPPH as a broad, multidisciplinary research area, with publications which appear in general and specialized journals across various disciplines.

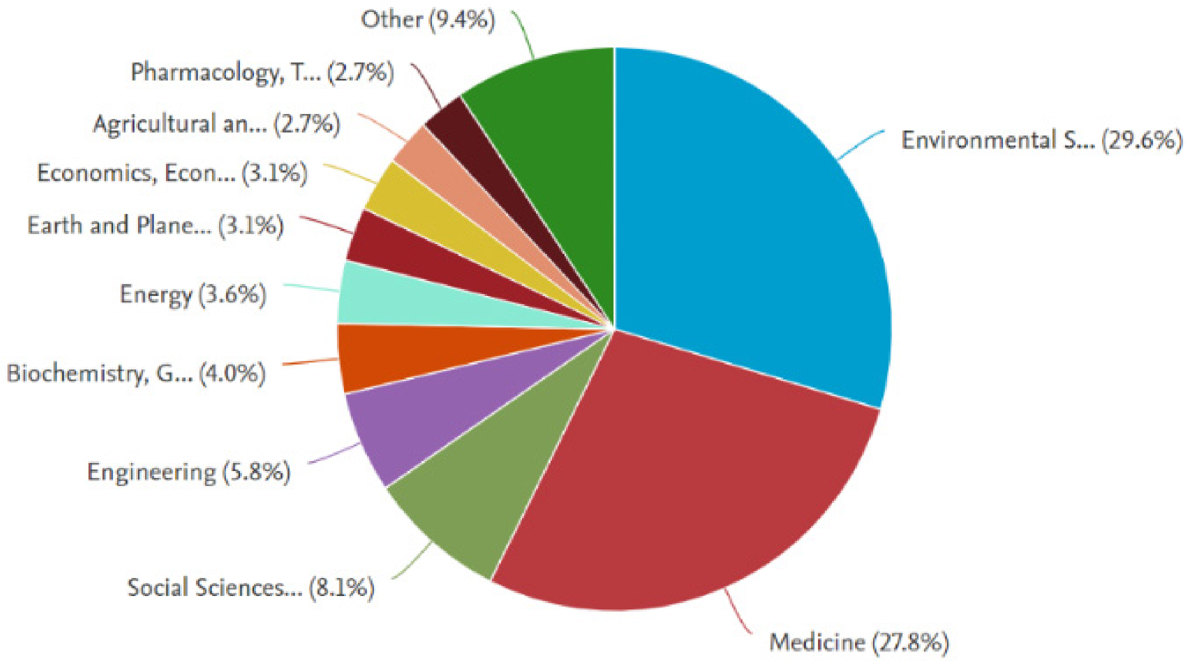

Fig. 3. Pie chart of the various subject areas of IAPPH

Furthermore, the data confirm that IAPPH is an active, multidisciplinary field with significant research impact and widespread scientific interest among various stakeholders (e.g., researchers, institutions, and countries). The next section provides an overview of the most prolific stakeholders in the IAPPH research landscape, as reported in the literature.

Top authors and affiliations

The critical analysis of the most prolific authors and affiliations enhances the understanding of their research impact and scientific contributions. Fig. 4 shows the top 5 most prolific researchers on IAPPH research deduced from the Scopus database from 2001 to 2024. The most prolific researcher on the topic is Majid Ezzati, based at Imperial College London (United Kingdom), with 5 publications. The works of Sean Semple (4) and Kirk R. Smith (4) of the University of California, Berkeley (Berkeley, United States) both rank 2nd. Other notable contributions are from Sandra Baldacci (3) of the Istituto di Fisiologia Clinica del CNR (Italy). The findings indicate that the top 5 researchers have published between 3 and 5 publications (19 publications in total or 3.8 on average). The observed productivity of the leading researchers could be attributed to numerous factors, ranging from the availability and accessibility of financial support to collaborations and co-authorship with peers nationally and globally. Other factors include the research environment, culture, and research policies of their respective research institutions, which can be examined by analysing the contributions of their affiliations.

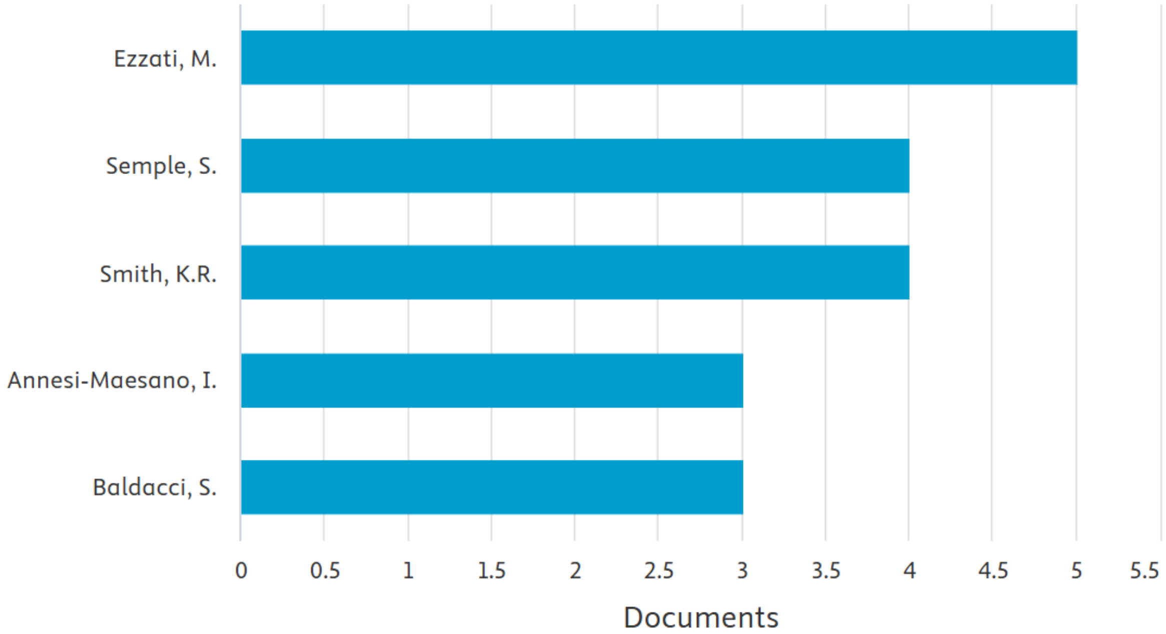

Fig. 4. Top 5 most prolific researchers on IAPPH research

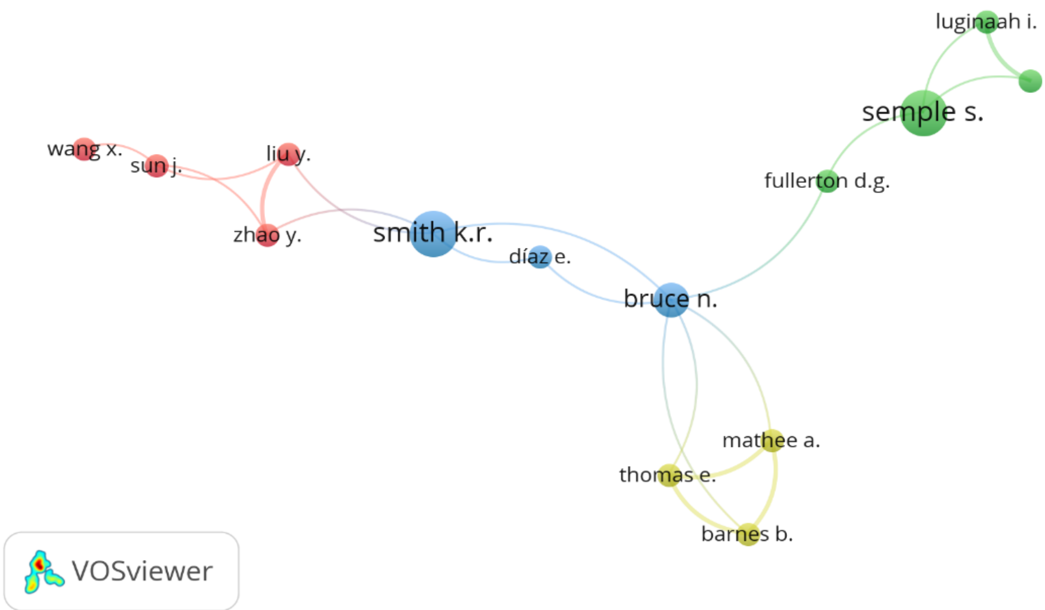

Fig. 5. NVM of co-authorship among top researchers in the IAPPH field

The productivity of top researchers in any field could also be influenced by co-authorship with peers and other leading researchers. Hence, this study examined the effect of co-authorships on the productivity of the top researchers in IAPPH using bibliometric analysis. Fig. 5 shows the Network Visualization Map (NVM) of the co-authorship trend among top researchers in IAPPH.

The VOSviewer software was used for the analysis, with at least two documents. The results showed that among the 665 authors, 73 authors satisfied the set criteria. As observed, the largest connected set of authors has 14 members, resulting in 4 clusters, each containing 3 to 4 authors. The largest cluster comprises the works of Liu Y, Sun J, Wang X, and Zhao Y, whereas the small cluster comprises Barnes B, Mathee A, and Thomas E. Overall, the NVM shows 20 links and a TLS of 25. The NVM showed that the top authors, or most prolific researchers, on IAPPH are directly linked through co-authorships, thereby enhancing their productivity, as earlier surmised.

Fig. 6 shows the top 5 most prolific affiliations/institutions on IAPPH research. The most prolific affiliation, as deduced from the Scopus database between 2001 and 2024, is the University of California, Berkeley (UCB, United States), with 7 publications. UCB's productivity can be attributed to the work of Kirk R. Smith and colleagues at the institution. The second most prolific institution is the Harvard T.H. Chan School of Public Health (US) with 5 publications. In contrast, the 3rd place is held by two institutions, Johns Hopkins University School of Medicine (US) and Sorbonne Université, with 4 publications each. The presence of Inserm (France) (4th among the top 5 affiliations) can be attributed to the work of Isabella I. Annesi-Maesano and colleagues, with 3 publications. Based on the results, it can be theorised that researchers' productivity is influenced by their respective research institutions, as stated earlier. The institutions provide an enabling environment, funding, and other resources for research in various subject areas.

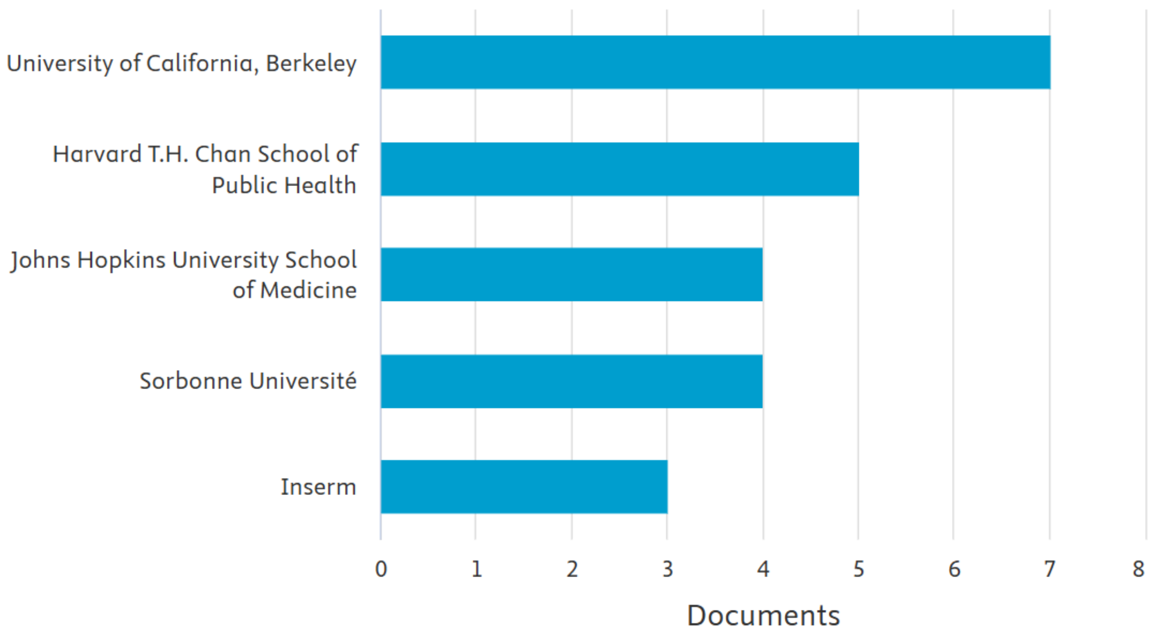

Fig. 6. Top 5 most prolific affiliations/institutions on IAPPH research (2001-2024)

Major funding organizations and countries

Fig. 7 shows the top 5 largest funding organizations for IAPPH research between 2001 and 2024. The most prolific funders of IAPPH research are the National Institutes of Health (NIH, United States), National Natural Science Foundation (NSFC, China), Department of Health and Human Services (DoHHS, US), National Institute of Environmental Health Sciences (NIEHS, US), and Ministry of Science and Technology of the People's Republic of China. The NIH is a Maryland-based United States Health and Human Services Department organization responsible for funding, organizing, and managing public health and biomedical research aimed at enhancing life, reducing illness, and preventing disability to the tune of ~US$30 billion annually.

In contrast, the NSFC (China) has an annual budget of CNY 28.04 billion (equivalent to ~US$4.5 billion) [27] for various research activities in China. The NIH has funded the research of Majid Ezzati (the most prolific researcher on IAPPH). In contrast, the NIEHS has supported the work of Kirk R. Smith of UCB. The findings indicate that the financial support provided by the funding organisations outlined has affected the research output or productivity of various researchers. Similarly, the various countries in which researchers, affiliations, and funding bodies are based play a crucial role in their research productivity. Fig. 8 shows the top 5 countries actively researching IAPPH based on data in the Scopus database from 2001 to 2024.

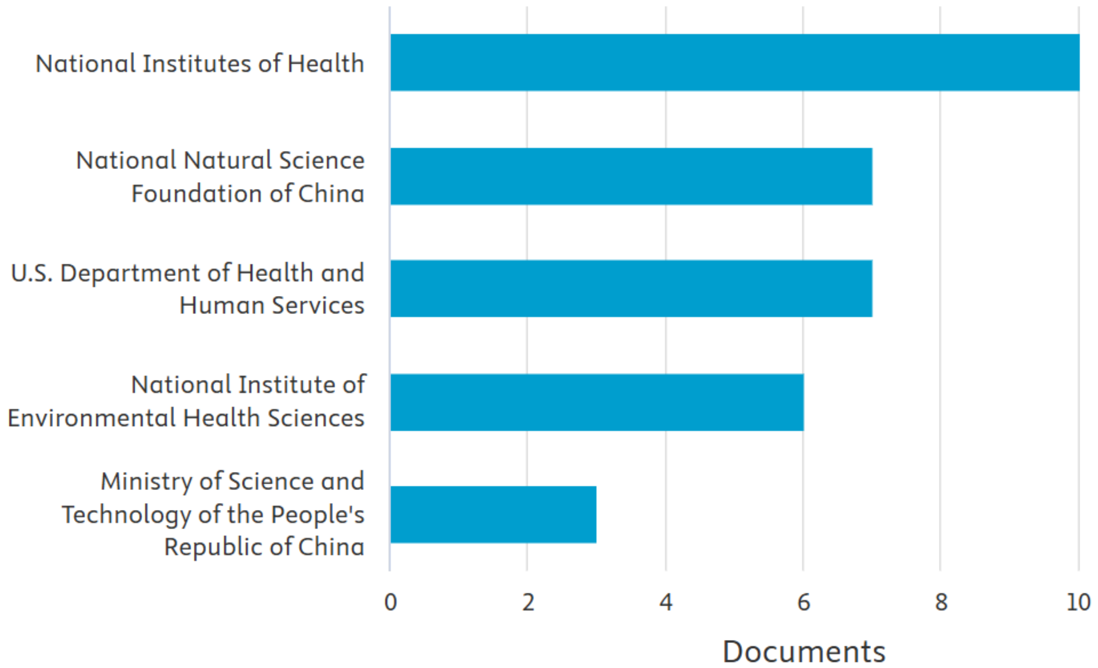

Fig. 7. Top 5 largest funding organizations on IAPPH research (2001-2024)

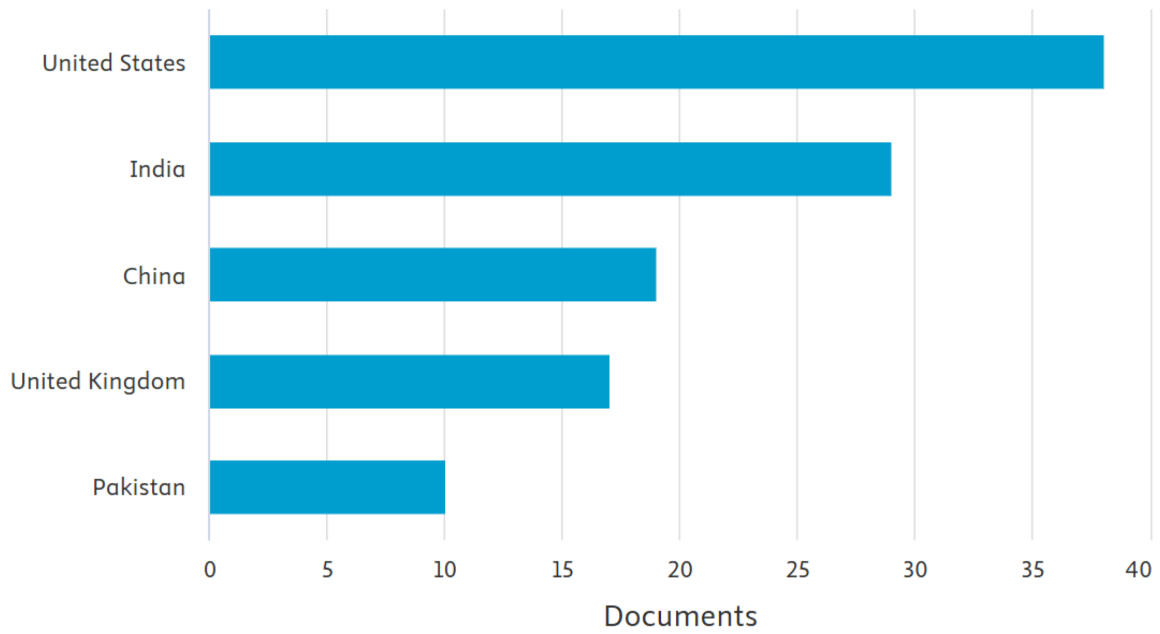

Fig. 8. Top 5 research-active countries on IAPPH research (2001-2024)

The results show that the top 5 countries actively researching IAPPH topics have produced 5 or more published documents over the years. As observed, the most productive research country is the United States, followed closely by India and China.

The dominance of these nations could be attributed to abundant research resources, as evidenced by funding bodies such as the NIH, NIEHS, DoHHS, and NSFC, based on Scopus data from 2001 to 2024. The influence and support of the funding organizations and nations can significantly enhance productivity and citations, which are crucial to examining the research impact and knowledge base of any given area of research or subject area. High output among nations has also been ascribed to collaborations. The impact on the IAPPH research landscape was examined in this study.

Fig. 9 shows the network visualisation map of co-authorship among the most productive nations from 2001 to 2024. In the country co-authorship analysis, a minimum publication threshold was applied to include only countries with multiple IAPPH publications in the network. The results show that 13 of the 66 countries identified in the IAPPH dataset have co-authored 5 or more publications, resulting in four clusters, each containing 2 to 4 countries. The largest or red cluster consists of Canada, India, South Africa, and the UK, whereas the smallest clusters consist of Nepal and the United States. Despite being in the smallest cluster, the US is the most influential, with the highest TLS of 13, followed by the United Kingdom at 11 and China at 8. Further analysis of the clusters showed that 12 out of the 13 most prolific nations have co-authored publications, corresponding to 92.31% (12/13), and this high proportion suggests that collaboration has played an important role in the productivity of nations involved in the IAPPH landscape during the study period.

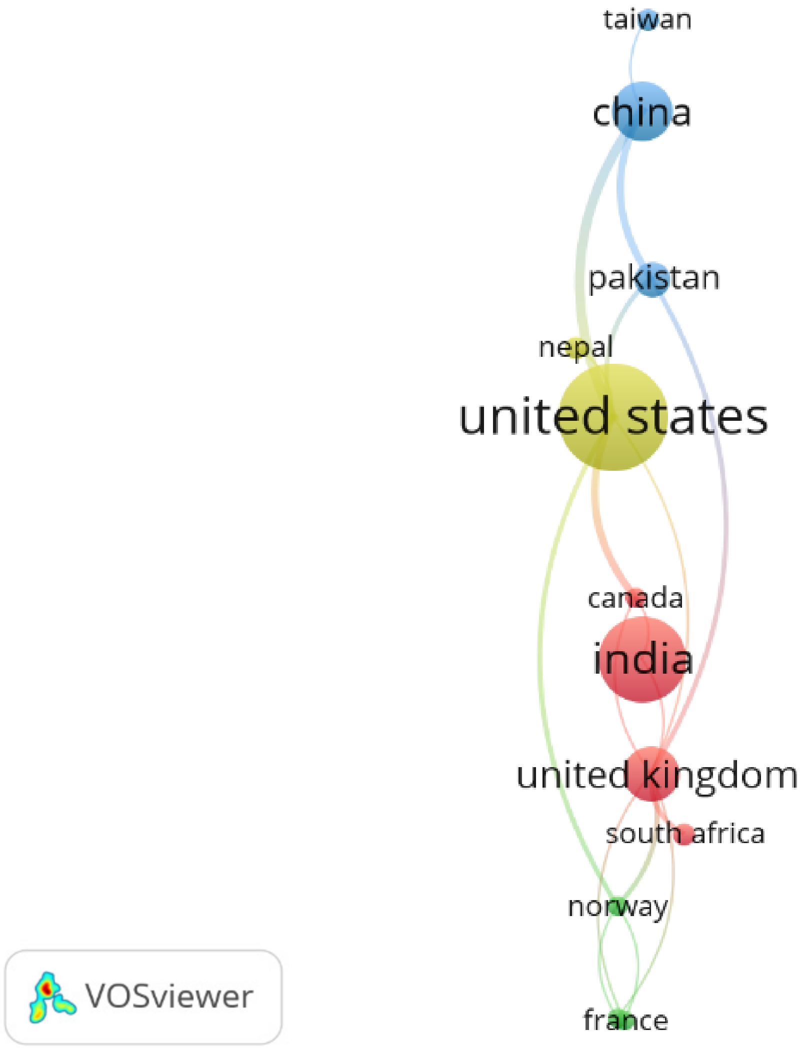

Fig. 9. NVM for co-authorship among nations on IAPPH (2001-2024)

Highly cited publications

The most highly cited published documents in any given field of research or subject area are an essential measure of the field's research impact [28]. It is also crucial to examine scientific growth and research developments [29]. This study identified the top 10 most-cited publications on IAPPH by ranking all documents in the dataset by their total citation counts in Scopus; these are summarised in Table 2. The findings show that the top-cited publications on IAPPH have gained between 122 and 573 citations (i.e., 2,680 in total or 268 citations on average). The most cited publication is Fullerton et al. [2], whereas the 2nd and 3rd most cited publications are the works of Bernstein et al. [5], and Ezzati and Kammen [1]. The high citation counts across the trio of studies indicate that the findings have had significant research impact and social relevance, resulting in co-citations. The impact of co-citations on citation rates can be examined using BA. Hence, the citation analysis feature of VOSviewer was used to investigate the degree of co-citation among various studies in the IAPPH subject area.

Table 2. Highly cited publications on IAPPH

Study Title	Source Title	Cited by	References
Indoor air pollution from biomass fuel smoke is a significant health concern in the developing world.	Transactions of the Royal Society of Tropical Medicine and Hygiene	573	[2]
The health effects of nonindustrial indoor air pollution	Journal of Allergy and Clinical Immunology	481	[5]
The health impacts of exposure to indoor air pollution from solid fuels in developing countries: Knowledge, gaps, and data needs	Environmental Health Perspectives	358	[1]
Indoor air pollution: A global health concern	British Medical Bulletin	328	[30]
Respiratory health effects of indoor air pollution	International Journal of Tuberculosis and Lung Disease	239	[31]
Quantitative assessments of indoor air pollution and respiratory health in a population-based sample of French dwellings	Environmental Research	189	[32]
Indoor air pollution, health, and economic well-being	Sapiens	137	[33]
Indoor air pollution in India: Implications on health and its control	Indian Journal of Community Medicine	131	[34]
Health impacts of indoor air pollution from household solid fuel on children and women	Journal of Hazardous Materials	122	[4]
Indoor air pollution and health in developing countries	Lancet	122	[35]

Literature review

This section of the paper examined and reviewed the most relevant published documents on IAPPH. The papers were selected based on the most influential publications from 2001 to 2024. Based on the Literature Review (LR) procedure described in the Methodology, a total of 19 highly cited IAPPH studies were selected for in-depth analysis and thematic synthesis. Previous bibliometric analyses employing the LR component have highlighted the impracticality of thoroughly reviewing all retrieved articles [36]. This study followed a similar approach; therefore, only articles with more than 25 citations were used for the literature review. Table 3 presents the LR on IAPPH from 2001 to 2024.

Table 3. Literature review on IAPPH (2001-2024)

References	Objectives	Summary of findings
[37]	To examine the effect of indoor air pollution on the respiratory health of urban and rural dwellers in China	Indoor PM_{10} and SO_2 levels in urban and rural Chinese homes were associated with chronic cough, phlegm, wheeze, and shortness of breath, but not asthma. Measured indoor PM_{10} and SO_2 concentrations were substantially above typical guideline values.
[1]	To investigate the health impacts of indoor air pollution and exposure to solid fuels in developing countries.	Nearly 3 billion people in developing countries are exposed to indoor air pollution from solid biomass fuels, leading to a wide range of respiratory and other health problems. The authors call for multidisciplinary housing and energy interventions to reduce these risks.
[30]	To review the causes of IAP, its effects, and related concerns on global health	Indoor air pollution from solid fuel combustion poses serious health risks, particularly in developing countries, by exposing residents to numerous toxic chemicals. The study links these exposures to rising rates of autism, asthma, infant cancers, and other unexplained illnesses.
[38]	To examine the health benefits of various intercession measures for addressing the IAP caused by solid fuel combustion.	Indoor air pollution from solid fuels is strongly linked to acute lower respiratory infections in young children and chronic obstructive pulmonary disease in adults. The study recommends cleaner fuels, improved stoves, and awareness campaigns as key mitigation strategies.
[39]	To examine the link between exposure to indoor air pollution arising from household energy use.	Biomass and coal used for cooking and heating are major sources of IAP and associated health risks, especially in developing countries. The authors argue that focusing only on household technologies overlooks crucial behavioural, economic, and infrastructural factors that shape exposure and intervention success.

Table 3. Continued

References	Objectives	Summary of findings
[40]	To examine the health effects or reduced IAP from solid fuel utilization in household's solid fuel use through the use of abatement scenarios.	Using exposure–response functions and disease burden estimates, the study suggests that over 3 million premature deaths in China are attributable to indoor air pollution from solid fuels. The authors demonstrate that modest changes in fuel type and quality, particularly in rural areas, could substantially reduce mortality compared with the WHO's fuel-based approach.
[2]	To review and highlight the health impacts of biomass fuel smoke on IAP in the developing world.	About one-third of the global population relies on biomass fuels such as wood, dung, and charcoal for domestic energy, generating high levels of IAP. This exposure is linked to respiratory diseases (tuberculosis, pneumonia, COPD), low birth weight, cardiovascular problems, cataracts, and increased mortality.
[5]	To examine the health effects of non-industrial IAP	Indoor pollutants act as respiratory irritants, toxicants, and carriers of allergens, contributing to a range of allergic and non-allergic conditions. The study emphasises the need to systematically assess patients' exposure to indoor triggers to better understand health impacts.
[41]	To examine the impact of improved cookstoves on IAP among Honduran women.	Improved cookstoves in Honduras reduced personal and indoor $PM_{2.5}$ and CO concentrations by more than 60–70% compared with traditional stoves. Users of improved stoves reported fewer respiratory symptoms, supporting their effectiveness as a health-protective intervention.
[32]	To quantitatively examine the effect of IAP on the respiratory health of respondents in France.	In French homes, specific VOCs (e.g., N-undecane, 1,2,4-trimethylbenzene, trichloroethylene, ethylbenzene, xylenes) were associated with higher risks of asthma and rhinitis. Elevated aromatic and aliphatic hydrocarbons were linked to increased respiratory morbidity in adults.
[42]	To assess the effectiveness of improved cookstoves in lowering IAP and human health in Nepal	In Nepal, improved cookstoves reduced indoor $PM_{2.5}$ and CO levels by about 60% and lowered symptoms such as cough, phlegm, and eye irritation compared with traditional stoves. The authors conclude that improved cookstoves are a suitable intervention to reduce IAP in rural kitchens.

Table 3. Continued

References	Objectives	Summary of findings
[9]	To examine the effect of IAP on the respiratory health of aged people	Among people aged 65 years and older, exposure to major indoor air pollutants was associated with multiple short- and long-term respiratory outcomes including wheeze, breathlessness, cough, COPD, and lung cancer. Environmental tobacco smoke showed the most consistent association with COPD, and the authors call for more research on causal mechanisms in the elderly.
[43]	To examine the relationship between exposure to IAP exposure and respiratory health in Turkey	In Turkey, indoor air quality parameters (PM, TVOCs, bacteria, mould, CO_2) showed seasonal and spatial variation, with higher PM, TVOC, and CO_2 in winter and higher microbial loads in summer. Poor IAQ was directly associated with respiratory symptoms, particularly shortness of breath, in participants.
[3]	To examine the impact of IAP on the health of women in India	In India, women exposed to biomass fuels for cooking experienced higher levels of indoor air pollution and related health problems. The study concludes that wider access to efficient, cleaner household fuels could substantially reduce IAP-related diseases in this population.
[13]	To examine the socio-economic and public health implications of IAP in France	In France, indoor exposure to pollutants such as benzene, trichloroethylene, radon, CO, $PM_{2.5}$, and environmental tobacco smoke was estimated to cost about €20 billion in 2004. Radon contributed around 75% of the total cost, and premature death and quality-of-life loss accounted for roughly 90% of the burden.
[7]	To examine the levels of IAP from PM (particulate matter) emissions and their health impacts in South Asian nations.	In South Asian countries, heavy reliance on biomass fuels has led to high levels of indoor PM emissions and marked increases in respiratory and non-respiratory diseases and mortality. The authors recommend implementing reduction strategies to improve indoor air quality and public health in the region.
[10]	The impact of indoor air pollution on health outcomes and cognitive abilities: empirical evidence from China	In China, indoor air pollution significantly increased the probability of respiratory and cardiovascular diseases and impaired cognitive functions such as mathematical reasoning and short-term memory. Middle-aged and older adults were particularly vulnerable to these adverse health effects.

Table 3. Continued

References	Objectives	Summary of findings
[44]	To examine the levels of IAP and their impact on school children's physical, comfort, and health.	Exposure to $PM_{2.5}$, VOCs, ozone, radon, and related indoor pollutants in schools was associated with increased respiratory and allergic symptoms and sick-building-type complaints in children. Improved ventilation reduced several symptoms, highlighting the importance of air-quality interventions in school environments.
[4]	To examine the health-related impacts of solid fuel-based IAPs on the health of children and women.	Indoor air pollution from solid fuel combustion can trigger oxidative stress, DNA methylation, and other toxicity mechanisms, leading to acute respiratory infections, low birth weight, anaemia, and premature death in children. In women, IAP is linked to COPD, cardiovascular disease, lung cancer, disability, and early mortality, underscoring the need for effective interventions and policies.

The studies summarised in Table 3 broadly examine the retrieved documents related to IAPPH. As the table shows, the documents focus on the health effects of IAP, primarily driven by the combustion of SBF and residential practices. Despite the drawback of reviewing only the most relevant articles, the selected studies in Table 3 revealed both parallels and divergences in their key findings. While some studies focused on the effects of IAP on respiratory health, others emphasized the effect of IAP on the general health of humans. For example, Venners et al. [37] revealed that higher concentrations of SO_2 and PM_{10} in homes are associated with several manifestations, including chronic cough, chronic phlegm, wheezing, and shortness of breath. However, asthma was not reported after examining the situation across several Chinese cities. Likewise, Mehta and Shahpar [38] highlighted a significant association between biomass fuel use and diseases such as acute lower respiratory tract infections in Children and Chronic Obstructive Pulmonary Disease (COPD) in adults. The study underscored the importance of adopting cleaner fuels and advanced stove technology to reduce the health risks associated with biomass fuel usage.

Moreover, Bernstein et al.[5] investigated the health impacts of non-industrial IAP. The study aimed to provide allergists with vital knowledge regarding IAP beyond traditional perennial allergens. They revealed that indoor pollutants are toxicants, respiratory irritants, and potential vehicles for transmitting allergens. Findings from their study underscore the importance of assessing patients' exposure to both allergic and non-allergic triggers to fully understand how IAP affects human health. Furthermore, a quantitative study was conducted to analyse the impact of IAP on respiratory health in France. Results from their study revealed that asthma

(8.6%) was strongly associated with exposure to N-undecane and 1,2,4-trimethylbenzene. Likewise, rhinitis (38.3%) was associated with exposure to trichloroethylene, ethylbenzene, and m/p-/o-xylene. Additionally, their study emphasized that both aromatic and aliphatic hydrocarbons were linked with increased risks of respiratory illnesses, such as rhinitis and asthma, indicating a direct correlation between higher levels of VOCs and respiratory illnesses among adults Billionnet et al.[32]. Similar findings can be gleaned from the study by Mentese et al. [43], which assessed the association between IAP exposure and respiratory illnesses among participants in 3 towns in Turkey. Results revealed seasonal and spatial variations in the measured Indoor Air Quality (IAQ) parameters, including Particulate Matter (PM), Total Volatile Organic Compounds (TVOCs), Total Bacteria Concentration (TBC), Total Mould Concentration (TMC), and Carbon Dioxide (CO_2). The highest concentrations of TVOC, CO_2, and PM were observed in winter, whereas the highest levels of TBC and TMC were observed in summer. Notably, similar to earlier studies reviewed, their study also showed that IAP is directly linked to the respiratory health of participants in the target location, with shortness of breath recognized as the most obvious respiratory symptom.

The effect of indoor air pollution on the respiratory health of people aged 65 years and above was examined by Bentayeb et al. [9]. The study showed a direct link between exposure to major indoor air pollutants and various short- and long-term respiratory health outcomes, such as wheezing, breathlessness, cough, phlegm, asthma, COPD, lung cancer, and, more rarely, lung function decline. Furthermore, the most consistent relationship discovered in the study was the link between environmental tobacco smoke and COPD. However, the authors recommended further studies to help define causal relationships between IAP exposure and underlying mechanisms in this sub-population among elderly people.

While the above studies highlight the role played by increased IAP levels in inducing respiratory ill health conditions among humans of varying sociodemographic groups, similar results are discernible when IAP was examined against other adverse ill health conditions like eye and systemic disorders among school children, anaemia, low birth weight and increased premature death across other studies [3, 4, 44]. These studies all advocated adopting mitigation strategies such as cleaner fuels and enhanced ventilation rates.

Another area of focus, as shown in Table 3, is the Health Impacts of IAP from SBFs. For example, Ezzati and Kammen [1] provided an expansive perspective by emphasising the magnitude of the problem, noting that around 3 billion people are exposed to IAP from the combustion of solid biomass fuels. The findings indicated that robust research and interdisciplinary solutions are essential to addressing health risks associated with IAP. The findings align with Jin et al.[39], who found that biomass and coal used as fuel for cooking and heating are primary sources of IAP, which causes health and environmental health risks, mainly in developing nations.

Similar concerns were echoed by Zhang and Smith [30], who stressed that the combustion of SBFs could lead to serious health conditions, including emerging issues such as autism and infant cancers. This expands the discussion beyond traditional respiratory illnesses to encompass broader health outcomes. Mestl et al. [40] examined the health effects of reduced

IAP from SBF use across several abatement scenarios. The authors proposed an alternative methodology that incorporates exposure-response functions and current mortality and morbidity rates to estimate the disease burden caused by IAP in China. The results indicated that over 3 million people suffer premature death due to IAP, accounting for 47% of all deaths in China. They opined those marginal changes, such as improved types and quality of cooking and heating fuels, particularly in rural areas, could significantly enhance health outcomes and reduce mortality rates. Furthermore, they demonstrated that their novel methodology is more reliable than the World Health Organization's fuel-based approach.

A series of studies, including those by Clark et al. [41], Singh et al. [42] assessed the effectiveness of improved cookstoves in reducing IAP. The findings indicated significant reductions in $PM_{2.5}$ and CO levels, directly correlating with decreased respiratory symptoms among users. The findings suggest that technological interventions can yield substantial and potentially immediate health benefits. The socio-economic implications of SBF utilisation were examined by Fullerton et al. [2] the study, which revealed that 33.33% of the global population relies on such fuels, a reliance that contributes directly to health crises. Moreover, Boulanger, et al. [13] quantified the economic burden of IAP in France, estimating costs associated with premature death and quality-of-life loss due to various indoor pollutants. This suggests that tackling IAP may result in substantial economic benefits.

Studies have also examined IAPPH from regional perspectives and its cognitive impacts. For instance, separate studies by Junaid et al. [7] and Qiu et al. [10] examined IAP and its link to cognitive decline in South Asian nations and China, respectively. They highlighted that exposure could lead to both impaired cognitive abilities and physical health challenges, especially among the elderly, and advocated considering IAP's multifaceted impacts on societal health. While significant progress has been made, as Jin et al. [39] pointed out, gaps remain in understanding the complex interplay among behavioural, technological, and economic factors that influence IAP exposure. The authors suggested that future research should focus on comprehensive, integrated approaches that consider local contexts to develop effective interventions.

Across the studies summarised in Table 3, several research gaps emerge. First, most investigations have focused on respiratory and cardiovascular outcomes, whereas fewer have examined the long-term cognitive and psychosocial effects of indoor air pollution, particularly among older adults and children in low and middle-income countries. Second, evidence on the effectiveness and sustainability of interventions such as improved cookstoves, cleaner fuels, and ventilation improvements is often limited by short follow up periods and context specific designs, making it difficult to generalise findings. Third, only a minority of studies explicitly integrate behavioural, technological, and socio economic factors into comprehensive models of exposure and risk, underscoring the need for more interdisciplinary and longitudinal research to capture these interactions. Finally, relatively little work has addressed the implementation and equity dimensions of indoor air pollution mitigation policies, including how interventions can be adapted to different cultural and socio economic settings.

Interpretation of findings

The study contributes to the extant literature and underscores the severe global health problems associated with IAPPH. By analysing 151 documents indexed in the Scopus database from 2001 to 2024, this study offers a broad overview of the trends, impacts, and stakeholders linked with IAPPH research. This study revealed several noteworthy trends which align with and extend the findings of previous studies in the field. Firstly, Fig. 2 notes an average of 6.29 publications per year from 2001 to 2024, indicating a moderately fair, albeit stable, research output. This publication trend contrasts with other areas of environmental health research, which typically demonstrate exponential growth [45]. The study also observed a notable decline in publication output in 2017. A plausible reason for this decline was the reduction in environmental research funding during this period. Many councils and environmental agencies faced budget cuts that hindered their ability to support air pollution research [46, 47]. This particularly impacted research initiatives focused on vulnerable communities and public health studies relating to IAP. The prevalence of articles (56.29%) and reviews (17.88%), as shown in Table 1, aligns with publication patterns observed in other public health domains. This reflects the emphasis on scholarly, peer-reviewed modes of communication. This trend is attributable to the academic reputation associated with published documents on these platforms. Additionally, these trends may result from rewards and incentive strategies used by several academic institutions that offer financial recognition for peer-reviewed articles and reviews rather than other forms of publication [48].

Based on the analysis of institutional impact in Fig. 6, this study revealed that the University of California Berkeley, is at the forefront, followed by Harvard T.H. Chan School of Public Health. These findings reflect a concentration of expertise within these established institutions. This trend contrasts with some emerging areas of environmental and public health where leadership is geographically dispersed [49]. The analysis of the major funders of IAPPH research, as shown in Fig. 7, revealed that organizations in the US and China are the leading funders. These outcomes are consistent with our earlier observations in this study, which noted that institutions and organizations from both nations are at the forefront of environmental health research. However, the non-participation of EU funding agencies is evident, suggesting opportunities to increase support. As indicated in Fig. 8, this study further observed that, based on research leadership, the US, India, and China lead in IAPPH research. This is in consonance with the findings of studies in the literature [45, 50]. This finding reflects their dominance in environmental health research. This may be because these nations acknowledge the huge financial cost of poor indoor air quality [51-53]. For instance, in China, attributable cost implications amounted to 6.6% of the nation’s GDP in 2017 [54]. This financial burden has triggered interest in this area.

Furthermore, the high collaboration rate of 92.31% among productive nations, as shown in Fig. 9, suggests that IAPPH research may be characterised by relatively strong international collaboration, although this comparison with other environmental fields should be interpreted with caution. This finding is consistent with that of Sweileh, Al-Jabi [55], who reported a high rate of collaboration in their study on outdoor air pollution. It is important to note that air pollution poses grave global challenges, prompting international collaboration [55]. This phenomenon may be partly related to the activities of agencies such as the WHO, which have developed collaboration centres for air quality management and air pollution control, working with member nations to promote cooperation in air quality initiatives through networking and interaction [56].

According to the reviewed literature, substantial emphasis has been placed on the respiratory and cardiovascular effects of IAP, consistent with previous systematic reviews. For example, a systematic review by Bruce et al. [57] emphasized the adverse health effects of IAP, including respiratory and cardiovascular impacts, particularly in developing countries where SBF utilisation is common. Nevertheless, the current examination indicates a growing focus on socio-economic and cognitive effects, particularly in developing nations. The reviewed studies underscore the need for coordinated efforts to address IAP through policy interventions, technological innovations, and health education to reduce the health burdens borne by susceptible populations, especially in resource-limited settings. Consequently, intervention strategies such as cleaner fuels, efficient stoves, low-carbon lighting, and proper ventilation are required to safeguard the health, safety, and well-being of SBF users in developing countries.

Implications

This study presents several theoretical implications that warrant highlighting. First, by identifying specific pollutants and how they trigger respiratory and other health outcomes, the study helps develop theoretical frameworks for understanding the health effects of IAP. This helps to understand environmental health research. Secondly, the study contributes to the extant literature by providing evidence of numerous health effects associated with several IAPs and showing how these impacts differ across environments and populations. Thirdly, the need for multidisciplinary solutions informs theoretical models which integrate social science, environmental science, and public health. This approach can help foster a broader approach to addressing IAP. Fourthly, this study analysed the authors' collaboration and the countries' collaboration. Findings from such analysis can benefit IAPPH scholars who intend to collaborate with other productive authors and countries and contribute to the development of IAPPH. Practically speaking, this study also presents key implications for policymakers and practitioners. First, the study can help policymakers design policies and regulations that improve air quality standards in residential homes. This includes offering incentives for using clean energy sources in homes to improve ventilation. The study also emphasizes the need for interventions and campaigns for public health to reduce exposure to indoor air pollutants. This includes promoting cleaner fuels and advanced stove technologies to reduce SBF emissions. Furthermore, the focus on demographic groups like the elderly and children suggests that resources and support should be allocated to these groups to reduce the risk of adverse health outcomes linked with IAP in these groups.

Limitations and future direction

This BA has some limitations which need to be addressed. Firstly, the investigation was confined to articles indexed in Scopus.

While Scopus is one of the most essential comprehensive databases globally, it does not cover every research article within the field of IAPPH. Additional international databases, like Web of Science and PubMed, could be utilized to compare their results to this study's. Furthermore, this study included only papers written in English, potentially overlooking some vital studies. Thus, the applicability of the results of this study requires additional research. Hence, data from various languages (Chinese, Japanese, French) could be incorporated into the IAPPH research to verify this study's results. Furthermore, this study used Scopus to identify authors and institutions active in IAPPH research. However, there might be inconsistencies in authors' names and profiles, which could affect their research rankings and outputs. The same applies to authors' institutions, if they are written differently across several articles. This study analysed highly cited publications in IAPPH. This presents another limitation, as citation does not provide a true picture of influential work in an area because citation trends are dynamic and may reflect self-citation rather than true impact. Despite the limitations mentioned earlier, this study provided a robust overall assessment of IAPPH over the last two decades, offering an informative perspective on the existing research trends in this area. This study also identified directions for future research, for instance, the need to adopt a combined, broader approach that considers the interactions among economic, behavioural, and technological elements affecting exposure to IAP. This may involve collaboration across disciplines in social science, public health, and environmental studies to create holistic strategies. Future studies should investigate the relationship between exposure to IAP and cognitive decline in vulnerable groups like the elderly. This will enhance strategies required in public health to reduce the impact of IAP.

Conclusion

This study analysed 151 publications on IAPPH indexed in Scopus between 2001 and 2024 and found that scientific output has increased over time, with the highest annual publication count observed in 2020. Articles were the dominant document type, followed by reviews and conference papers, and Environmental Science and Medicine were the leading subject areas, with Social Sciences, Engineering, and Biochemistry, Genetics and Molecular Biology making smaller but still important contributions, confirming the multidisciplinary nature of IAPPH. The analysis identified key authors such as Majid Ezzati and colleagues, leading institutions including the University of California, Berkeley and the Harvard T.H. Chan School of Public Health, and major funding organisations such as the National Institutes of Health and the National Natural Science Foundation of China, while the United States, India, and China emerged as the most productive countries and co-authorship networks showed tightly connected clusters of collaborating authors and nations. The literature review further showed that particulate matter (especially PM_{10} and $PM_{2.5}$), volatile organic compounds, and carbon oxides are consistently associated with respiratory and cardiovascular outcomes in vulnerable populations, whereas evidence on long-term cognitive, psychosocial, and socio-economic effects, and on the sustained impact of intervention strategies, remains relatively limited. Taken together, these findings indicate that IAPPH is a growing, collaborative, and multidisciplinary research area, and they highlight the need for continued investment in cleaner household energy, improved stove and ventilation technologies, and interdisciplinary research that addresses under-studied health and socio-economic outcomes.

Financial supports

No funding was received for this research work.

Competing interests

The authors declare no competing interests.

Acknowledgements

The authors wish to acknowledge The International College of Engineering and Management, Seeb, Muscat, Oman.

Ethics considerations

not applicable. Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/ or falsification, double publication and/ or submission, redundancy, etc) have been completely observed by the authors.

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