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# Impact of indoor environmental quality on occupant in the post pandemic: a literature review

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## ABSTRACT

People spend 90% of their time indoors on average even before the COVID-19 epidemic. More than ever before, people are not only concerned about the Indoor Environmental Quality (IEQ) of public buildings, but also the IEQ of residential buildings. After all, occupants are more likely to develop a number of ailments when their IEQ is compromised, and these diseases are made worse by social and economic factors. Understanding the factors that affect IEQ and how to operate buildings to provide the ideal IEQ is essential for protecting health. This research aimed to investigate how COVID-19 affected the indoor environment's impacts on occupants. We reviewed the impact on occupants of the environment of four key themes in the post-pandemic era (indoor thermal comfort, indoor air quality, acoustic comfort and visual comfort). In addition, CiteSpace is employed in this paper's visual analysis of the IEQ studies literature from 2020 to 2022 in order to determine current research hotspots and identify potential trends. In general, there has been a rise in occupant health research interest among researchers in the following of the COVID-19 epidemic, as well as an increase in interest in health-related projects. In particular, indoor air quality was the IEQ direction that received the greatest attention in the literature evaluations, with an emphasis on the health of the occupants. The results of a cluster analysis showed that the knowledge base focuses more of an emphasis on topics like "indoor air quality", "temperature", "carbon dioxide", "energy consumption", "residential heritage", and "air quality". Lastly, many studies confirmed that the COVID-19 pandemic has changed people's perceptions about how buildings affect people's health. As a result of the pandemic, people think that future building design, construction, and operation will pay more attention to people's health from the perspective of indoor air quality and indoor air pollutants.

Keywords: Indoor environmental quality, indoor air quality, CiteSpace, COVID-19 pandemic, temperature

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## MAIN PAPER CONTENT

### 1. Introduction

The rapid spread of the unprecedented worldwide pandemic COVID-19, which was caused by SARS-COV-2, had enormous repercussions all over the world, increasing the global casualty figures by 2-3% (Rodriguez-Morales et al., 2020). Mild to moderate respiratory sickness, which can escalate to pneumonia, septic shock, acute respiratory distress syndrome, and cytokine release syndrome, is the initial symptom of this extremely contagious disease that is spread through inhalation or contact with contaminated droplets (Agarwal et al., 2021). There are a number of variables that affect how quickly this virus spreads and how patients react to it. According to recent studies, researchers have been trying to quantify what has led to the explosive increase in viral transmission and mortality. Those with existing medical conditions, such as diabetes, heart disease, high blood pressure, or cancer, are at a greater risk of developing coronavirus (Zheng et al., 2020). The rising number of COVID-19 cases is also affected by socioeconomic variables, such as a lack of basic utilities or the concentration of slum regions, as well as the accessibility of public transit, the duration of travel time, and the state of infrastructure (Das et al., 2021). There is also mounting empirical information that climate parameters like temperature, humidity, indoor air quality, air quality have an effect on the seasonal dispersion of COVID-19 (Tzampoglou and Loukidis, 2020). When environmental parameters where individuals reside are unsatisfactory, promoting the spread of COVID-19, then this can be considered a risk factor for the disease (Oginawati et al., 2022).

The term "Indoor Environmental Quality" (IEQ) refers to the condition of indoor air quality, lighting, temperature, and acoustic conditions within the building, and how those factors affect the people who live or work inside. Protecting human health, enhancing quality of life, and decreasing stress and potential damage are all strategies for addressing IEQ (Godish, 2016). The last decade has seen a huge increase in interest in IEQ due to evidence that it can reduce harmful building impacts on the natural environment, boost occupant health and productivity (Awada et al., 2021). After all, considering that the average person spends 87% of their time inside a building, IEQ has become increasingly critical in contemporary buildings, and as a direct consequence of COVID-19, the same has risen to a staggering 100%.

## 2. Literature review

Despite the fact that IEQ has been proven to have a significant impact on occupants' health and productivity, the intricacy of indoor IEQ parameters and indoor pollutants can frequently leave individuals dissatisfied with their indoor environment, specifically after the COVID-19 pandemic (Jain et al., 2021). During the COVID-19 pandemic, indoor air quality is considered the most important IEQ factor (Amoatey et al., 2020; Velraj and Haghighat. 2020; Barcelo, 2020; Chang et al., 2021). This is because poor air quality may increase the mortality rate in the socioeconomic group already dealing with respiratory diseases and those over 60 years of age (Bashir et al., 2020). Combustion of fossil fuels, food preparation, household cleaning activities, and paint are the primary human-caused contributors to air pollution. These actions cause emissions (PM10, NO2, PM2.5, O3, CO, and SO2) that, if they surpass thresholds, may be harmful to an individual's health and hasten the spread of the virus (Agarwal et al., 2021). Many studies in the hardest-hit areas of the global pandemic have shown a strong correlation between PM2.5 and COVID-19 cases, hospitalizations, and fatalities (Cole, Ozgen and Strobl, 2020; Coker et al., 2020). A similar positive correlation between COVID-19 and NO2 concentration has been reported (Ogen, 2020; Wang and Li, 2021). Regarding thermal conditions, when the indoor temperature was above 22 ℃, Reinikainen and Jaakkola (2001) noticed that SBS symptoms worsened. Brown adipose tissue, which regulates the body's core temperature through the metabolic process of heat production, was activated in response to a decrease in temperature from the thermoneutral (22 ℃) to the mild (16 ℃) range for the treatment of obesity (van Marken Lichtenbelt et al., 2009). Positive effects on mood, sleep, and blood pressure perceived when exposed to natural light (Sanchez, Ikaga, and Sanchez, 2018). Vitamin D, which is produced by the skin when exposed to sunlight, protects against bone illnesses such as rickets and osteoporosis (Edwards and Torcellini, 2002). Views of nature (such as parks, woods, or lakes) have also been demonstrated to improve the mental health of office employees by helping them deal with stress and change their attitudes (Dolling, Nilsson, and Lundell, 2017). Researchers investigated the impacts of light on the human circadian system, which regulates the circadian rhythm by controlling the degree of melatonin release to modify drowsiness and alertness. When used in the workplace, circadian lighting systems (i.e., electric lighting systems that mimic sunlight based on colour, intensity, and angle of projection) have been linked to increased alertness, improved mood, increased concentration, reduced depression, better sleep, and less agitation (Plano et al., 2017). Indoors, glare, caused by an imbalance in the placement of lights, is another common problem. Even a little glare might be distracting, causing individuals to lose focus or attention (Osterhaus, 2005). Long-term glare exposure, however, has been linked to eye strain, visual impairment, and even eye injury (Hamedani et al., 2019). Concerning the acoustic environment, dissatisfaction among building occupants, notably office workers (Kim and De Dear, 2013), as well as hospital employees, patients, and visitors (Busch-Vishniac et al., 2005), is a direct result of poor acoustics. Outdoor sources, building systems, mechanical and electrical devices (such as printers, cleaning equipment, phones), and occupants may all contribute to the ambient noise level within an indoor environment. Loss of sleep due to hospital noise is associated with a slower recovery of patients (Bevan et al., 2019). Lower noise levels in the workplace have been linked to reduced levels of mental stress in workers (Spreng, 2000).

An in-depth analysis of the literature review in a field could facilitate researchers and experts to predict future developments and plan for them (Li et al., 2022). There has been an explosion of IEQ research since the COVID-19, and as a result, an abundance of quantative and bibliometric review papers have been published on the topic. Geng et al. (2017) explored the relationship between individual IEQ factors and overall satisfaction by means of questionnaire survey. Zhang, Ortiz, and Bluyssen (2019) also used questionnaire survey to analyse the IEQ preferences of school children. Rasheed and Byrd (2017) investigated the effects of IEQ on the productivity of office workers based on literature review. Additionally, Asadi, Mahyuddin and Shafigh (2017) examined the impact of IEQ-related occupant behaviour on building energy consumption through a literature review. However, in the era of post-pandemic, many studies have focused on one of the factors of IEQ, indoor air quality. Elsaid and Ahmed (2021) committed to research on efficient air filter to absorb and remove ultra-large particles as a means of preventing epidemic infection. Agarwal et al. (2021) used

an integrated strategy that incorporates both non-medicine and engineering control methods, such as upgrading the ventilation system with more effective filters to remove viral loads for the improvement of indoor air quality during the period of COVID-19. However, the detrimental effects of COVID-19 extend beyond poor indoor air quality, occupants' satisfaction will be impacted by the outdoor temperature because, during the pandemic, windows should be opened frequently to ensure indoor air movement, resulting in the outdoor temperature having a significant impact on the interior temperature. Miranda et al. (2022) indicated when the outdoor temperature was above 12 °C, the dissatisfaction rate was less than 10%, and this stayed consistent whether or not the classroom was at capacity. According to a study by Aguilar et al. (2022), they found that the acoustics in the classroom were affected by the ventilation strategies employed to bring fresh air in. Additionally, they showed that when doors and windows remained open, background noise levels might rise by as much as 12.6 dBA, compared to the same scenarios with the windows and doors closed. There was a significant increase in students' expressions of dissatisfaction with the quality of their indoor environment after the COVID-19 period. In light of this, it's obvious that several approaches, adapted to the various seasons, are required (Aguilar et al., 2022). Despite there were many reviews of IEQ before the pandemic, individuals were forced to spend even more time indoors due to the spread of COVID-19. Because of this, researchers were able to focus on how indoor environments affect people's health, which is a field that requires further research. The need for a literature review on IEQ in the post-epidemic period has arisen since earlier studies have demonstrated that occupants' adaptability to various aspects of indoor IEQ has changed (Awada et al., 2022). As a result, there are two main implications of this study. (1) The development of bibliometric and visualisation tools will allow for increased use of quantitative analysis in the IEQ field, reducing the need for subjective assessments. In this research, we applied quantitative analysis with bibliometric tools to investigate a more comprehensive field of IEQ. (2) Quantitative analyses of relevant literature were conducted using CiteSpace in this study. Using the advantages of a visual analysis tool, a more thorough and systematic review will be presented from a variety of perspectives.

## 3. Methodology

The bibliometric approach enables the quantitative, objective assessment of database information (Su, Li and Kang, 2019). In this study, we will use bibliometrics to guide our investigation into the post-COVID-19 literature on IEQ evaluation and assessment by analysing the selected articles by area, organization, authors, journal, and document.

### 3.1 Software and database selection

CiteSpace, created by Drexel University (USA) researcher Chaomei Chen in 2004, is a software that can be used to analyse, identify, and visualise patterns in scientific literature (Pan et al., 2018). CiteSpace was preferable to other software in its capability to locate frequently cited publications and explore the connections between studies in a given field. It has the potential to investigate the interconnections between various literary knowledge units and graphically represent the interrelations identified. Additionally, it provides a distinctive feature for analysing co-cited literature and can precisely and aesthetically explore research trends in a particular field of study (Li et al., 2022). In light of this, the software was used in this work to do an in-depth evaluation of the literature review. Selecting an appropriate academic search engine is a crucial first step in the process of obtaining relevant material. The Web of Science (WoS) and Scopus are two databases commonly utilized in review papers. Scientists have discovered a large data overlap phenomenon between WoS and Scopus, and they have also discovered that the search results from both databases are similar (Li et al., 2020). In addition, WoS is a widely used and acknowledged resource because of its inclusion of the Science Citation Index (SCI), the Social Sciences Citation Index (SSCI), and the Arts & Humanities Citation Index (A&HCI). What's more, CiteSpace, an analysis software for knowledge graphs, supports WoS more than any other database (Harzing and Alakangas, 2016). Therefore, this work uses WoS as its primary data source.

This paper aims to provide a comprehensive and extensive review of IEQ studies conducted in the following of the COVID-19 pandemic. This goal served as the basis for the search for relevant literature. Table 1 shows all of the keywords that may have been used to identify this paper. The intent is to ensure no related keywords are left out by employing synonyms for them. English was set as the search language. To guarantee a high-quality data source, the literature category was restricted to "journal articles". 2020 to 2022 was set as the time span. Article data was obtained by searching for corresponding keyword clouds in COVID and IEQ, and then exported to excel using WoS. Preliminary results from a search of 40463 publications were carefully reviewed to select those that might more clearly illustrate the study subject. Articles that were potentially useful in the literature search were evaluated by reviewing their titles, abstracts, and full texts. After removing duplicates, ultimately, 237 relevant articles were found after a thorough search.

Table 1. Keywords search

| Search clouds | COVID and related keywords | IEQ factors and related keywords | Number of papers (Preliminarily retrieved) | Number of papers (After carefully screen) |
|---|---|---|---|---|
| Keywords | post COVID or post pandemic | lighting or lighting system, visual condition or visual comfort | 11623 | 21 |
| | COVID-19 or COVID-19 pandemic | acoustic condition, acoustic comfort, background noise, noise level | 672 | 31 |
| | | occupants, occupancy monitoring methods, occupant health | 922 | 57 |
| | | Indoor Environmental Quality, indoor physical environment, indoor built environment, comfortable environment, indoor environmental factor | 1415 | 101 |
| | | Heating Ventilation and Air-conditioning systems or HVAC, air conditioning, natural ventilation, mechanical ventilation | 8850 | 72 |
| | | temperature, thermal comfort, solar irradiance, humidity, relative humidity, indoor thermal environment, | 7754 | 53 |
| | | building energy consumption, building performance, building performance evaluation, green house, green building | 3744 | 39 |
| | | airflow, wind speed, indoor air quality or air quality, ambient air quality, indoor air pollutants | 5483 | 74 |
| Total | | | 40463 | 448 |
| Total after screen | | | | 237 |

As shown in Table 1, the number of papers on the lighting of IEQ was the highest, which indicated they have attracted the most attention since the outbreak of COVID-19 among all the IEQ factors in the preliminarily retrieved. However, after carefully screen, indoor air quality and related keywords cloud was the highest, the publication number of related indoor air quality and related HVAC (Heating Ventilation and Air-conditioning) was followed. This is due to the fact that the spread of COVID-19 inside is significantly correlated with poor indoor air quality. Air pollutants ($NO_2$, CO, $SO_2$) from human activities including cooking, cleaning, painting could speed up the spread of the virus (Amoatey et al., 2020; Chang et al., 2021). Activities like switching on air conditioners may further accelerate the spread of the virus through carrying the virus from outdoor environment into indoors (Ali and Alharbi, 2020; Elsaid and Ahmed, 2021). Additionally, many studies confirmed that temperature and humidity could pose a significant impact on the virus infection (Mecenas et al., 2020; Ahlawat, Wiedensohler, and Mishra, 2020; Wang et al., 2021). Indoor transmission of the coronavirus may be facilitated by the fact that it may remain infectious for up to 2 weeks when exposed to low temperatures and low humidity (Nottmeyer and Sera, 2021), Therefore, temperature and humidity and corresponding keywords were also mostly studied. However, it is noted that acoustic and lighting received little attention from researchers. Because lighting and acoustics do not directly contribute to the transmission of COVID-19. They are mostly associated with mental health (Morganti et al., 2022).

## 4. Results and discussion

### 4.1 Region analysis

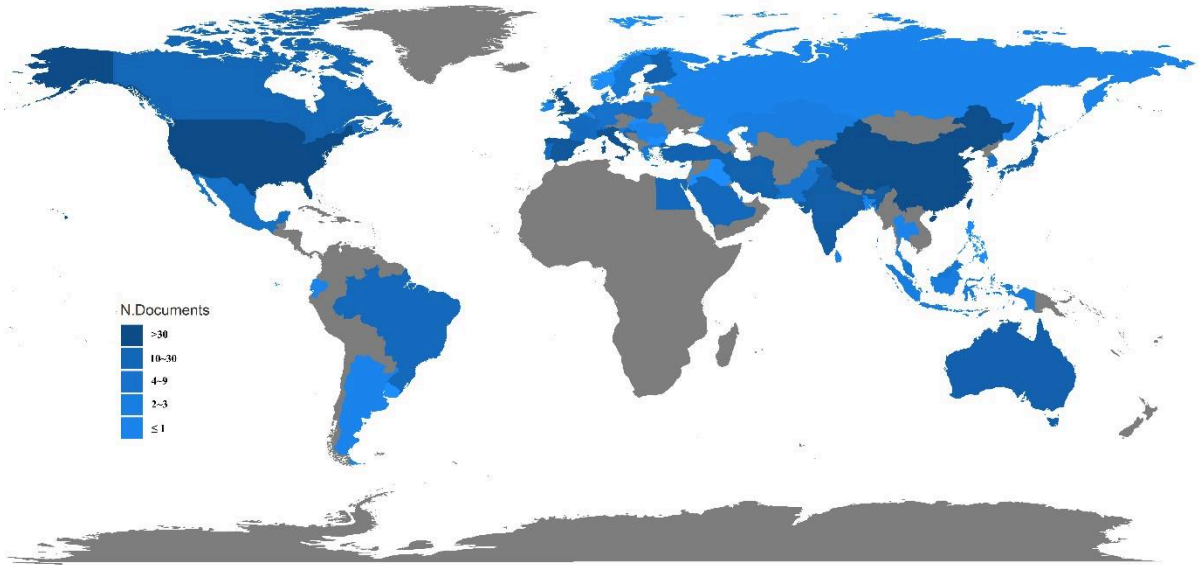


Fig. 1. Regional distribution of publications throughout the world

Fig. 1 and Table 2 show the top 10 regions that have made the most contributions to this field. China has the most papers published worldwide, followed by the USA, Italy, Spain, and the UK. The overall number of publications clearly varies considerably throughout regions, indicating a significant regional imbalance in the field of IEQ studies. Therefore, with the exception of China and India, greater focus should be given to this topic in these less developed regions. China is ranked first for total citations (TC), followed by Australia, the United States, Italy, and the United Kingdom, indicating the high quality of articles in these areas. However, Australia tops the list for average article citations, followed by China, the USA, Italy, and Portugal. China was acknowledged to play a significant role because it has the most articles, single country publications, and multiple country publications of the corresponding author's country. Portugal and Canada, on the other hand, demonstrated that these metrics were comparatively low in these ten regions. It reveals that interchange and collaboration across areas in this field are not particularly close, which does not facilitate the development of this field's study.

Table 2. Top ten regions

| | | | | Corresponding author's country | | |
|---|---|---|---|---|---|---|
| Region | F | TC | AAC | A | SCP | MCP |
| CHINA | 45 | 3276 | 86.21 | 38 | 26 | 12 |
| USA | 37 | 1241 | 41.37 | 30 | 23 | 7 |
| ITALY | 27 | 541 | 25.76 | 21 | 13 | 8 |
| SPAIN | 27 | 149 | 6.77 | 22 | 19 | 3 |
| UNITED KINGDOM | 23 | 163 | 14.82 | 11 | 6 | 5 |
| AUSTRALIA | 14 | 1480 | 185 | 8 | 5 | 3 |
| INDIA | 12 | 130 | 13 | 10 | 7 | 3 |
| CANADA | 11 | 52 | 10.4 | 5 | 3 | 2 |
| JAPAN | 10 | 131 | 16.38 | 8 | 7 | 1 |
| PORTUGAL | 7 | 124 | 24.8 | 5 | 4 | 1 |

Note: F, frequency; TC, total citations; AAC, average article citations; A, articles; SCP, single country publications (intra country collaboration); MCP, multiple country publications (inter country collaboration)

### 4.2 Institution analysis

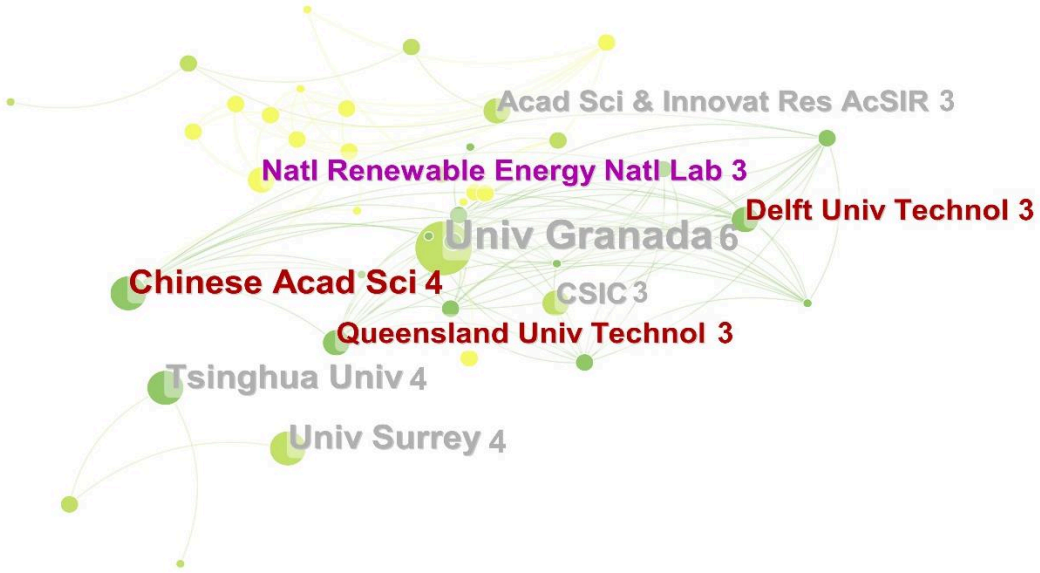


Fig. 2 The institution analysis network map and the number of corresponding institution citation

The institutional analysis network was developed using Citespace (Fig. 2). Among the total of 108 institutions, 58 were entirely unconnected to each other. As a result, these institutions were excluded, and the cooperative network of 50 institutions was preserved. More than half of the institutions were removed, showing that institutions have not yet created close collaboration, which is consistent with the findings of the regional study. The University of Granada was the highest cited institution, which demonstrated its substantial impact in this field. Followed by Tsinghua University, the Chinese Academy of Science and the University of Surrey, demonstrating China's considerable impact in this field.

### 4.3 Author co-citation analysis

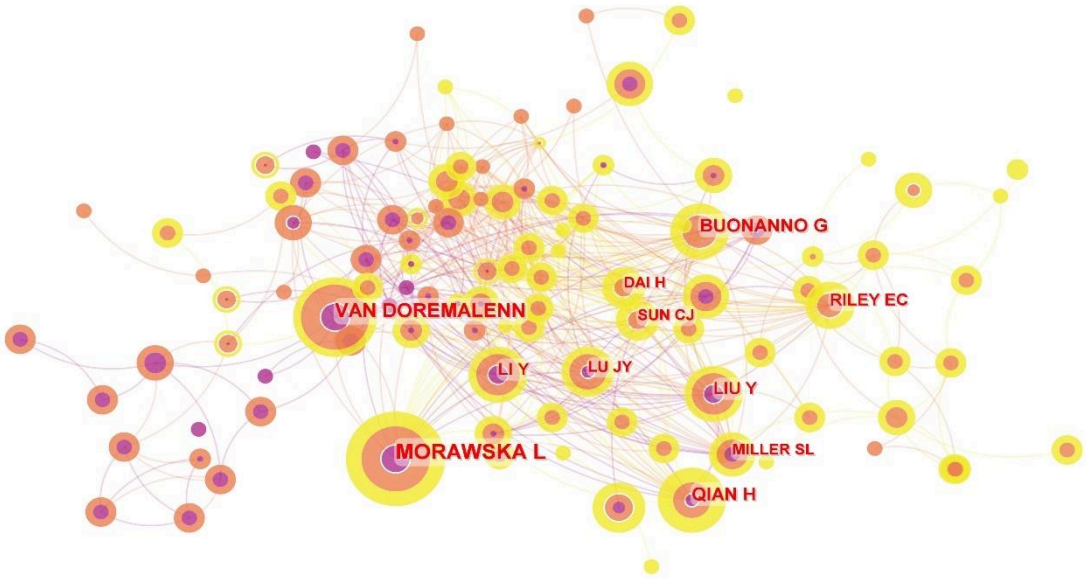


Fig. 3. Network for author cocitation analysis.

Fig. 3 illustrates the findings of the author co-citation analysis, which investigated the principal authors of the co-cited papers. The largest node is Morawska, Lidia (frequency = 68), indicating this author has the highest co-cited frequency. The following authors are van Doremalen Neeltje (frequency = 54), Buonanno Giorgio (frequency = 38), Qian Hua (frequency = 37). It's noteworthy

that all the authors have low betweenness centrality. It demonstrates that not too much in-depth exploration has been done in this field. As this article concentrates on the development of IEQ after COVID-19, the search time span is 2020-2022; however, the burst strength is not presented due to the limited time span.

### 4.4 Journal analysis

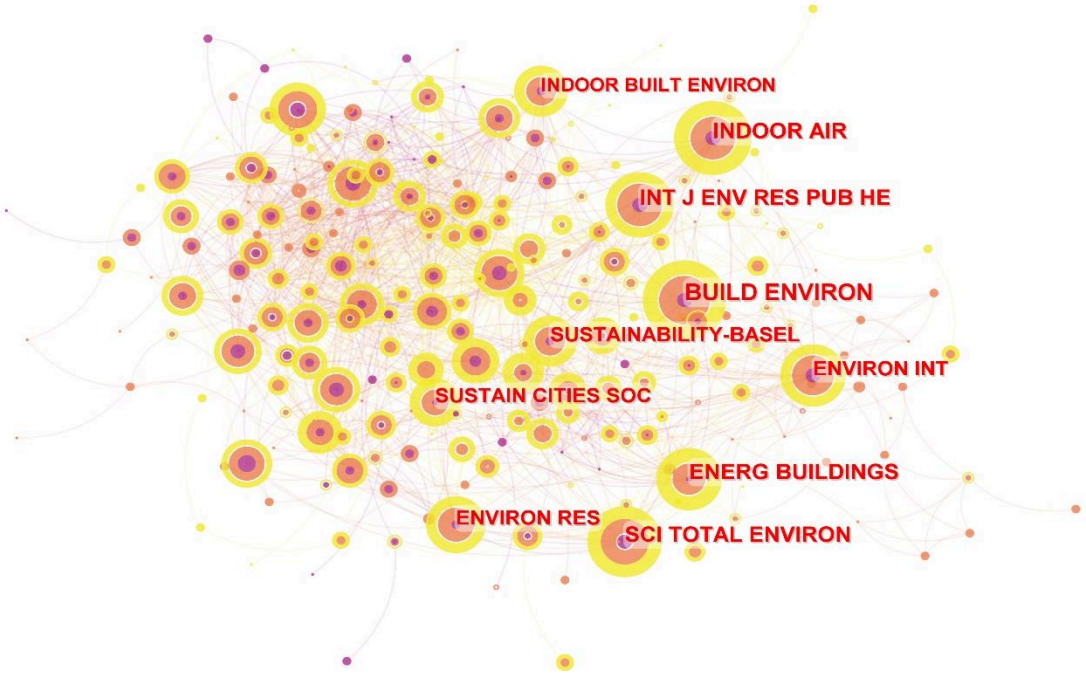


Fig. 4. Journal co-citation analysis network

The 237 selected articles and their citations were published in 318 international journals, indicating that this field is a broad and widely recognised research topic (Fig. 4). The top 10 cited journals are listed in Table 3, and Building and Environment had the largest number of cited journals, followed by Journal of Indoor air, Science of The Total Environment, Energy and Buildings and International Journal of Environmental Research and Public Health. It is noted that the top 10 cited journals account for around 22% of the selected articles, meaning most researchers in this field highly recognised these journals, and these journals were found to be the most influential journals.

Table 3. Top 10 cited journals of 237 literatures

| No. | Cited Jounals | Frequency | Percent |
|---|---|---|---|
| 1 | Building and Environment | 147 | 3.51% |
| 2 | Indoor Air | 125 | 2.99% |
| 3 | Science of The Total Environment | 111 | 2.65% |
| 4 | Energy and Buildings | 104 | 2.49% |
| 5 | International Journal of Environmental Research and Public Health | 90 | 2.15% |
| 6 | Environment International | 79 | 1.89% |
| 7 | Environmental Research | 77 | 1.84% |
| 8 | Sustainable Cities and Society | 68 | 1.63% |
| 9 | Sustainability | 65 | 1.55% |
| 10 | Indoor and Built Environment | 63 | 1.51% |
| Total | | 929 | 22.20% |

### 4.5 Cluster analysis and keywords analysis

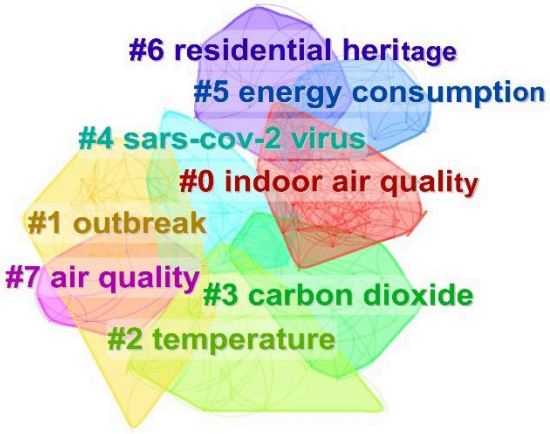


Fig. 5. Network of document co-citation cluster

CiteSpace's most notable and important feature is its ability to do cluster analysis of co-cited papers, which more accurately reflects the knowledge base of the research topic. A cluster network that was constructed by using extracted keywords as clustering labels can be seen in Fig. 5. There are 174 nodes and 782 connections in this network. This clustering network is reasonable and effective, with Q = 0.7737 and S = 0.7798, specifically, the modularity Q and the mean silhouette scores are two crucial metrics that reveal the network's worldwide structural features. In this research, a modularity Q value of 0.7737 indicates that the network is adequately partitioned into loosely linked clusters. The average silhouette (S) score of 0.7798 indicates that the homogeneity of these clusters is very high. Finally, 8 clusters were retained, and they will be discussed.

Indoor air quality (#0) and air quality (#7), as important transmission vectors for COVID-19, are the most critical topics of discussion in the relationship between post-pandemic and IEQ and have been widely used in many research fields. In the field of IEQ, especially after the epidemic, in order to reduce the transmission of illness, indoor air quality has been a focus of investigation (de la Hoz-Torres et al., 2021; Salamone et al., 2021; Agarwal et al., 2021). Mathai et al. (2021) indicated that when the distance between the infected person and the exposed person is less than 1.5 metres, the infected person's aerosol is inhaled directly by the exposed person. Second, the droplet nuclei migrate and enter the system of the exposed person when the aerosol produced by the infected person's actions (such as sneezing, coughing, etc.) is mixed in the room air and with air flow. This often happens across very long lengths, those exceeding 1.5-2.0 m. After all, the human health benefits of breathing clean air (Agarwal et al., 2021); Continuous exposure to aerosols, increases the chance of mortality from any cause, lung cancer, and other pulmonary disorders, let alone infectious aerosols (Heal, Kumar and Harrison, 2012). Indoor air quality is closely related to ventilation systems (Ma et al., 2021). It is commonly known that CO2 concentrations can be a reliable indication of ventilation in occupied spaces (Franco and Schito, 2020). Therefore, the carbon dioxide (#3) also as a keyword cluster. Lovec, Premrov, and Leskovar (2021) evaluated the practical impact of the pandemic on indoor air quality; they found before and after the pandemic, the average number of people in a classroom dropped from 83% to 72.5%, and the concentration of carbon dioxide in indoor air dropped by 20%. Additionally, Sanguinetti et al. (2022) investigated the relationship between teachers' experiences of ventilation and HVAC system, they revealed that teachers need to know that they can safeguard their students' and their own health by monitoring CO2 levels and receiving appropriate training. In relation to temperature (#2), according to a study by Abbas and Dino (2021) and they investigated factors that biological contaminants pose a risk to the health of occupants in shared spaces. The simulation findings showed that increasing the temperature of the indoor air significantly reduce the probability of COVID-19 infection. Kakoulli, Kyriacou and Michaelides (2022) revealed under regulated aerosolization processes, air temperature and relative humidity were two of the major influencing elements on the viability, survival, and stability of the virus. However, the cluster keyword in this study did not include relative humidity. Numerous research suggest that COVID-19 dissemination can be significantly influenced by both indoor temperature and meteorological

conditions (Méndez-Arriaga, 2020; Lolli et al., 2020; Mohammadi et al., 2021; Habeebullah, Abd El-Rahim and Morsy, 2021). Therefore, our research has shown temperature as a cluster keyword.
The pandemic outbreak (#1) has contributed to an increase in healthcare demand and hospital staff pressure (Vizheh et al., 2020). During the epidemic, the hospital employees faced elevated levels of occupational stress. Healthcare worker turnover, performance, and work satisfaction could all be negatively impacted by stress (Zhang et al., 2020). Increasing numbers of research are focusing on these fileds (Eijkelenboom, Ortiz and Bluyssen, 2021; William et al., 2022). Some studies confirmed that work dissatisfaction and hospital staff turnover were strongly connected with noise discontent (Chmielewska, Stokwiszewski and Hermanowski, 2020) and long duration of sunshine exposure (Pan et al., 2021). On March 11, 2020, the World Health Organization (WHO) announced a pandemic due to the sars-cov-2 virus (#4) that causes COVID-19, a respiratory disease (Ortiz-Prado et al., 2020). The speed with which the disease is spreading has surprised experts in the medical and scientific communities. Numerous research started to concentrate on the disease and its origin. As a result, outbreak and sars-cov-2 virus are two key cluster keywords in this field. Energy consumption (#5) and residential heritage (#6) are related to the lockdown policies implemented by many cities during the epidemic, which means that homes become main workplaces for many people (Su et al., 2022). Because of the increasing trend toward using private residences as workplaces in addition to living spaces, it is now imperative to renovate the residential heritage in place to ensure the habitability of these buildings (Muñoz-González et al., 2021). Muoz-González et al. (2021) aimed to increase the levels of natural illumination in residential heritage buildings in order to promote people's well-being while decreasing energy expenditure on lighting, since lighting systems accounted for 40–50% of the total electric usage during the lockdown period. They discovered that older properties often had adequate daylighting for office use during business hours. In addition, Mokhtari and Jahangir (2021) indicated a 32% reduction in energy consumption is achievable with an optimization algorithm and an optimal population distribution.

## 5. Conclusion

IEQ evaluation in the context of a pandemic is crucial to furthering the field because of the complexities involved. An increasing amount of research has focused on indoor environmental quality (IEQ) concerns in relation to COVID-19 in recent years. However, there has been no systematic research on this subject. With such in mind, this study presents a quantitative review to investigate the past and current situation of this field of expertise. Through searching WoS, 237 articles on IEQ studies in the post pandemic from 2020 to 2022 were identified. The selected papers were visually analysed using CiteSpace. China, the USA and Italy are the regions with the largest number of publications. Among all institutions, the University of Granada has the highest cited frequency. According to the analysis of author co-citations, the most influential researchers were Lidia Morawska, Neeltje Doremalen, Giorgio Buonanno, and Qian Hua. Maintaining a track of their research findings is essential. The most significant journals in this field are Building and Environment, Indoor Air, Science of The Total Environment, and Energy and Buildings, despite the fact that numerous journals are interested in it. Researchers may find the author's and journal's analysis to be instructive. Cluster analysis of co-cited references has shown that "indoor air quality," "outbreak," "temperature," "carbon dioxide," "air quality," "energy consumption," and "residential heritage" are among the most often used keywords in this field's body of knowledge.

The above findings, including the knowledge base, will undoubtedly improve researchers' understanding and create a solid foundation for future study on IEQ, which is expected to remain a significant research field in the coming years. In this paper, IEQ studies conducted during and after the epidemic have been statistically and thoroughly analysed using visual software. For review studies in this field, a more detailed summary from the perspective of IEQ factors at the micro level, such as indoor air quality, indoor air pollutants, and temperature, might give a nuanced perspective on this research topic. In addition, different bibliometric and visualisation tools with unique functional capabilities may be used to assess the studies in this field from various perspectives.

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