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Research article

The parameter of the Sick Building Syndrome: A systematic literature review

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A R T I C L E I N F O

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A B S T R A C T

Sick Building Syndrome (SBS) is a collection of symptoms assumed to be related to spending time in a certain building, most typically a workplace, but no specific cause has been identified. The need to measure and assess various types of parameters of SBS is crucial and it is important to explore what parameter has been used in the previous studies of SBS. Therefore, this study aims to systematically review the parameter that has been used to monitor the SBS. This study was conducted using the PRISMA Statement and the search was conducted using two scientific databases which were Scopus and Web of Science. After a thorough and tight process, a total of 55 articles have been finalized and selected for thematic analysis. Two themes have been identified which were a) Indoor Environmental Quality (IEQ) and b) Occupant. This study also found that the spatial distribution pattern revealed that the Sick Building Syndrome research was spread over 26 nations, with the majority of articles originating from the United States and China. In terms of context, the majority of the selected publications employed the survey approach to investigate SBS parameters. Aside from that, the most researched form of building is the business building. This study has found that it would be more impactful for the SBS study if researchers could incorporate both indoor environmental quality and occupant factors into a study, resulting in more holistic conclusions.

1. Introduction

Humans spend 90 % of their time inside, such as in their homes, offices, gyms, shopping malls, and so on, to fulfill their daily demands and routines [1]. According to Abas et al. [2], an interior environment provides several services to humans, including aesthetic, recreational, and good air quality. A good indoor environment is particularly important for human well-being, especially in terms of psychology, health, and emotion [3]. However, an unmanaged and poor-quality indoor environment will not only have a short-term impact on human health but may also have a long-term impact, potentially affecting humans for the rest of their lives. According to the World Health Organization [4], 3.2 million people would die prematurely as a result of diseases induced by home air pollution produced by the incomplete combustion of solid fuels and kerosene used for cooking. Particulate matter and other contaminants in-home air pollution irritate the airways and lungs, decrease the immunological response, and diminish the blood's

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oxygen-carrying capacity. Sick Building Syndrome (SBS) is defined as any pain or irritation without a clear cause, as indicated by WHO.

Various symptoms and disorders have been connected to nonindustrial indoor environments in recent decades [5]. In general, indoor exposure to noxious chemical, physical, and biological hazards is low. Unlike industrial or accidental exposures, such low-level indoor exposures are extremely common. Indoor environmental health concerns are among the most common environmental health issues addressed by most practitioners [6]. Sick-building syndrome (SBS) refers to non-specific illnesses such as upper-respiratory irritative symptoms, headaches, fatigue, and rash that are usually associated with a specific building due to their temporal pattern of occurrence and clustering among residents or coworkers. SBS was originally recognized in the 1970s, and 1984 World Health Organization research stated that up to 30 % of new and rebuilt buildings may have IAQ issues severe enough to induce health complaints. The most prevalent cause is inadequate building ventilation; the development of SBS in the mid-1970s has generally been ascribed to lowered ventilation rules for business buildings to promote energy efficiency following the Arab oil embargo of 1973. Chemical contaminants such as volatile organic compounds emitted by carpeting, upholstery, cleaning agents, and other sources, as well as combustion products such as particulate matter and carbon monoxide produced by heating devices such as fireplaces and stoves, are also potential contributors to SBS. Molds, pollen, viruses, bacteria, and animal droppings are examples of biological pollutants that may contribute to SBS [7].

SBS is challenging to investigate since its symptoms are frequent and can be caused by a variety of variables, such as allergies or stress, and can be impacted by psychological factors, such as dissatisfaction with one's job or workplace [8]. Furthermore, because many various features of the interior environment might contribute to SBS, identifying the reason or causes for a specific instance can be challenging, and substantial renovations may fail to alleviate the problem. In a situation of suspected SBS, there is also a natural conflict between the interests of building owners and residents. The residents may feel SBS is causing their health complaints and demand building inspections and adjustments, but the owner may not believe SBS is causing their symptoms and may be unwilling to pay for any examinations or alterations. Furthermore, some physicians feel that SBS is a meaningless word that should be dropped, whilst others suggest that research into SBS should incorporate psychological and social variables as well as physical, environmental, and biological ones [9]. The SBS is frequently prescribed based on the human body's reaction, which may include headache, eye, nose, or throat irritation, dry cough, dry or itchy skin, dizziness and nausea, difficulty focusing, tiredness, and scent sensitivity [10]. SBS is often detectable based on occupant health and building management methods, according to Nduka et al. [11]. Aside from that, the SBS is associated with the degree of indoor environmental quality, namely the quantity of indoor air pollution and the performance of the building's ventilation system [12].

Some may argue that SBS symptoms are minimal because there have been no reports of physical injury – symptoms that generally resolve rapidly once the afflicted individual departs the impacted building [13]. These signs are critical for workers who are impacted. SBS has far-reaching consequences: Reduced productivity: many patients report a 20 % loss in output [14]; decreased overtime; and increased staff turnover: the office worker population is unpredictable, with workers regularly changing jobs rather than devoting their career to one firm. Employment circumstances are likely to impact workers' decisions when considering a move, resulting in higher illness and absenteeism [15]. Employees who were ill as a result of contaminated air filed private lawsuits against their employers, resulting in large financial compensation. Some contaminated properties may require costly and drastic remediation work, such as replacing air conditioning systems, windows, and furnishings [16]. However, in other cases, demolition may be the only or most cost-effective choice. The Inland Revenue closed its 19-story headquarters in Bootle, Merseyside, in 1995 due to unsustainable levels of workforce absenteeism, with half of the 2000-strong workforce suffering from SBS symptoms during the previous five years [17]. As a result, the cost of lost production, replacement labor, and litigation far outweighs the benefits of prevention.

According to Engvall et al. [18], it is critical to understand what signifies the level of SBS and what indicators should be taken into consideration when managing SBS. Several studies already determined the parameter of SBS such as Huang et al. [19], Yusoff & Sulaiman [20], Ahmad & Hassim [21], Mei & Mydin [22], Annila et al. [23], Pantelic et al. [24], Nduka et al. [25], Sakellaris et al. [26], Franke & Nadler [27], Nduka et al. [11] and Kalender-Smajlovic et al. [28], which stated that the condition of human health both mentally and physically need to be measured to determine the level of SBS. Aside from that, Serrano-Jimenez et al. [29] found that the environmental quality of the building plays an important role in accelerating the SBS. Some gaps in those studies also have been identified, such as the need to comprehensively understand the specific pollutants present in indoor environments that contribute to SBS [30]. Identifying emerging pollutants, assessing their long-term effects, and establishing permissible exposure limits for a broader range of contaminants can be areas of research focus. Also, more research can be conducted on the psychological and social aspects contributing to SBS and the relationship between building maintenance practices and SBS [15]. From this, we may conclude that the SBS parameter was determined in fraction and was not well-integrated. Therefore, this study aims to systematically review the parameters of the Sick Building Syndrome (SBS). To achieve this aim, 3 objectives have been underlined, such as: i) to determine the spatial and temporal distribution of the study for the parameter of the SBS, ii) to discover the contextual issue that has been analyzed in the study for the parameter of the SBS, and iii) to develop the theme for the parameter of the SBS.

2. Research methodology

2.1. PRISMA statement (Preferred reporting items for systematic reviews and meta-analyses)

This systematic review study used the PRISMA statement [31] as the main guideline for conducting the study. PRISMA is an evidence-based minimum list of monitoring elements for systematic analyses and meta-analyses. PRISMA emphasizes the reporting of randomized trial assessment reviews but can also be used as a basis for reporting comprehensive reviews of other forms of study, particularly intervention assessments [32]. Also, few studies used PRISMA as the main guidelines for their study such as Niza et al. [33], Abas [34], Ali et al. [8], and Kapoor et al. [35].

2.2. Formulation of the research question

The study questions were developed based on PICo. The PICo tool helps writers create appropriate research questions for review. Three key ideas—Population or Problem, Interest, and Context—form the foundation of PICo. These ideas served as the foundation for the study's inclusion of three key review topics, parameter (problem), Sick Building Syndrome (interest), and indoor management (context). Therefore, this systematic review study asks the following questions: 1) What is the distribution paper in the study of the parameter of SBS spatially and temporally? 2) What is the contextual issue discussed in the study of SBS? 3) What are the themes in assessing the SBS?

2.3. Systematic searching strategies

Identification, screening, and eligibility were the three primary tactics used in the systematic search techniques, as indicated in Fig. 1.

2.4. Identification

Finding the proper keywords based on research questions is the process of identification. Three keywords, as well as related phrases, synonyms, and variants, were employed in this investigation. Sick Building Syndrome and parameters were the crucial terms. The identification technique employed online thesauruses, keywords from previous studies, keywords from the Web of Science (WoS), and keywords from experts. The keywords were produced based on the study topic as proposed by Okoli [36]. This study was effective in enriching several keyword strings by searching the WoS database and Scopus for the appropriate articles, as shown in Table 1.

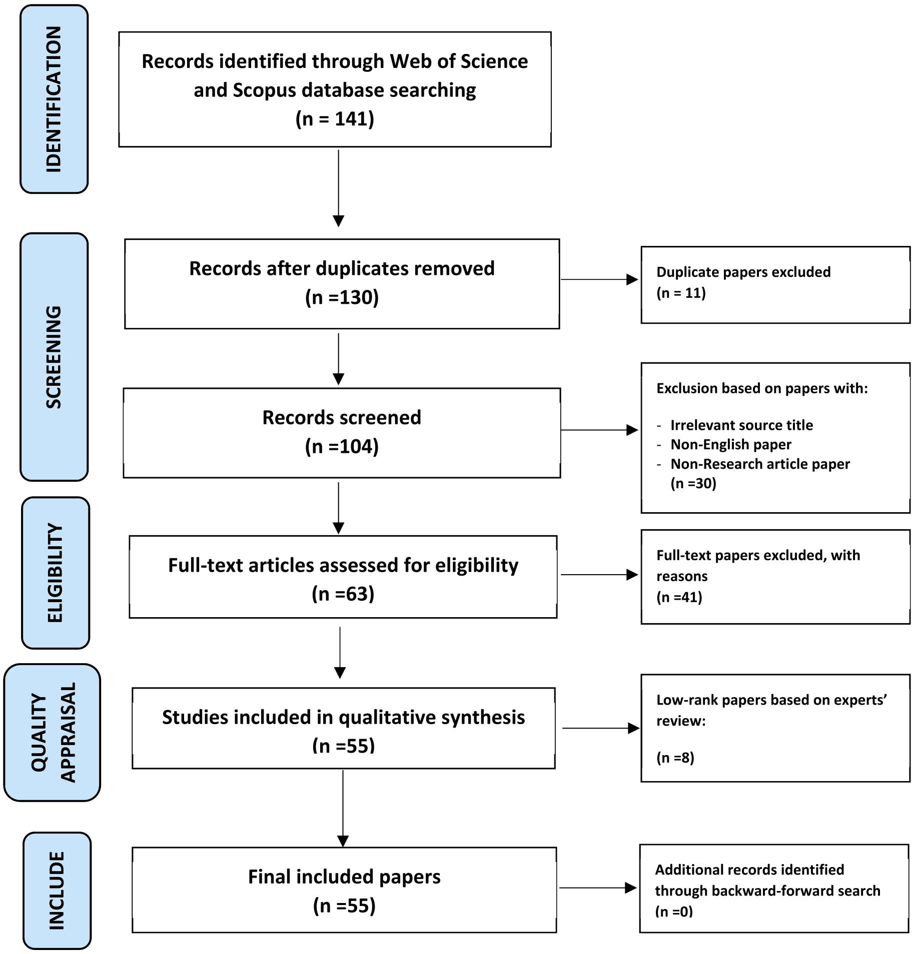

Fig. 1. A flow diagram of the process.

Websites such as WoS and Scopus offer subscription access to many databases and detailed citation data for a wide range of academic subjects. Because all journals in the former underwent a rigorous editing procedure, assuring article quality before publication and retaining the journals' impact factor rankings, the current researchers chose WoS and Scopus above other search engines [37,38]. During the search technique, both databases yielded 141 papers that matched the study's research objectives.

2.5. Screening

The first step in reviewing all 141 articles was to remove any duplicate information. After 11 papers were eliminated from the database owing to duplication, there were just 130 articles remaining. To ensure the review's quality, the remaining 130 papers were screened further; only those with empirical data and journal publications were evaluated. To avoid confusion, the evaluation only featured goods written in English. This method did not contain 26 items because they did not match the criteria. The remaining 104 articles were used in the procedure's third stage, which was eligibility.

2.6. Eligibility

The third step, eligibility, involves personally checking all of the retrieved articles to make sure they all meet the requirements following the screening process. Reading the paper titles and abstracts served to complete this procedure. A total of 41 articles were disregarded because they concentrated on methods to lessen the impact of SBS, measurements of indoor air quality that did not focus on SBS, perceptions of the quality of the indoor environment, studies that focused on instruments and methods, studies on the health effects, reviews rather than empirical data, unclear methodology sections, or because they were published as chapters in books, books, proceedings, or conference papers. Thus, after this round, just 63 articles were left.

2.7. Quality appraisal

To ensure high-quality material, the remaining articles were handed to two professionals for quality review. According to Petticrew and Roberts [39], the remaining papers were categorized into three quality categories: good, moderate, and low. Only articles with high and moderate ratings were considered. The experts focused their attention on the method used by the articles to rank their quality. According to both writers, the article's quality must be at least moderate to be considered for the research. Before selecting whether or not to include or exclude items from the review, they explored any differences. Following this technique, 8 articles were classified as low, 12 as intermediate, and 43 as high. Therefore, only 55 papers could be reviewed.

2.8. Data abstraction and analysis

Thematic analysis was used to construct the subjects and sub-themes in this study. According to Braun and Clarke [40], thematic analysis discovers themes and sub-themes by detecting patterns and topics, grouping, numbering, and highlighting parallels and links that exist within the abstracted data. All relevant or related abstracted data were grouped.

3. Results

3.1. Spatial and temporal distribution of the selected article

A total of 55 articles were analyzed through a detailed screening procedure. Based on Fig. 2(a), the distribution of studies on the SBS parameters shows a fluctuating pattern since 1991 to 2022, but significantly increased in the last few years. Most papers were published in 2022 with 7 papers, then followed by 2016 with 5 papers, 2021 and 2004 with 4 papers each year, while other years, have 3 or less paper.

Meanwhile, Fig. 2(b) shows the distribution of the selected papers spatially by country. all of the 55 papers were distributed only 26 countries (less than 10 % of the total country), of which the United States of America (USA) and China had the most with 6 papers for each country, followed by Japan with 5 papers, Malaysia with 4 papers, Nigeria, Germany and Sweden each with 3 papers, and the rest have 2 or less paper.

Table 1
The search strings.

Database	Search strings
Web of Science	TOPIC: (Sick Building Syndrome) Refined by: TOPIC: (Parameters OR Parameter OR Indicators OR Indicator OR Measurement)
Scopus	TITLE-ABS-KEY (Sick AND Building AND Syndrome) AND (Parameters OR Parameter OR Indicators OR Indicator OR Measurement)

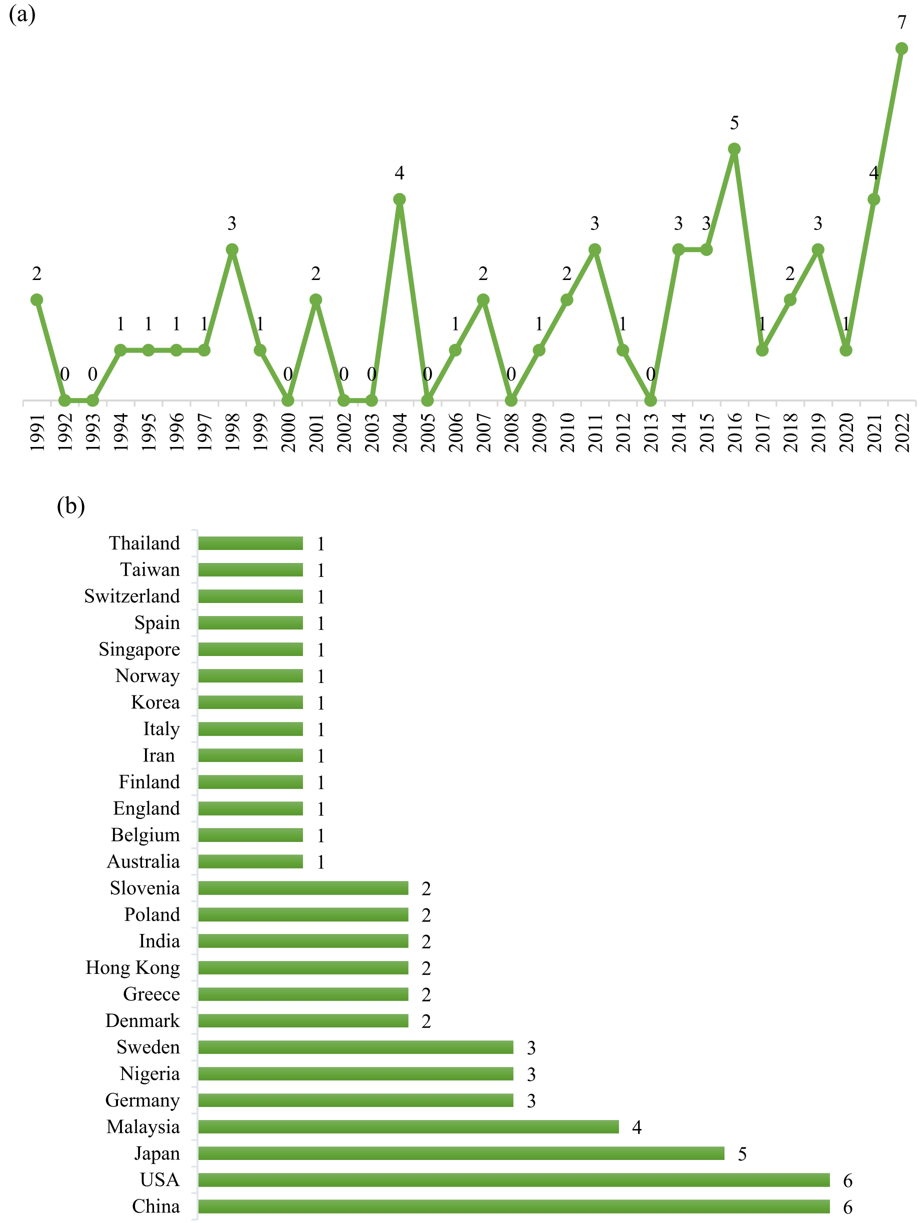

Fig. 2. (a) Temporal distribution of the selected papers. Fig. 2(b) Country distribution of the selected papers.

3.2. The parameters of the Sick Building Syndrome - contextual issue

To determine the contextual difficulties raised in the study of the sick building syndrome's parameters, all 55 of the chosen publications were analyzed. This study identified three key contextual issues, which are a) the method applied in the selected articles, b) the type of building and c) the keyword co-occurrence analysis. According to Fig. 3(a), the majority of the chosen papers (67 %) studied the assessment of the ill building syndrome using numerous types of approaches, which account for 54.55 % of the total. The multiple kind of method is typically a blend of survey and experimental design types of methods. Then, experiment came in second with 34.55 %, followed by survey at 5.45 %, observation at 3.64 %, and document at 1.82 %. Fig. 3(b) shows that 52.37 % of the articled studied the residential building and the least studied is the assembly building with only 1.82 %. At the other hand, Fig. 3(c) shows the keywords co-occurrence analysis that been conducted by using VOSviewer software. From the figure, there are 3 main clusters of keywords with the keyword 'volatile organic compound' is the highest occurrence in the cluster no. 1, meanwhile 'environment' is the highest for cluster no 2 and 'occupational stress' is the highest for cluster no. 3.

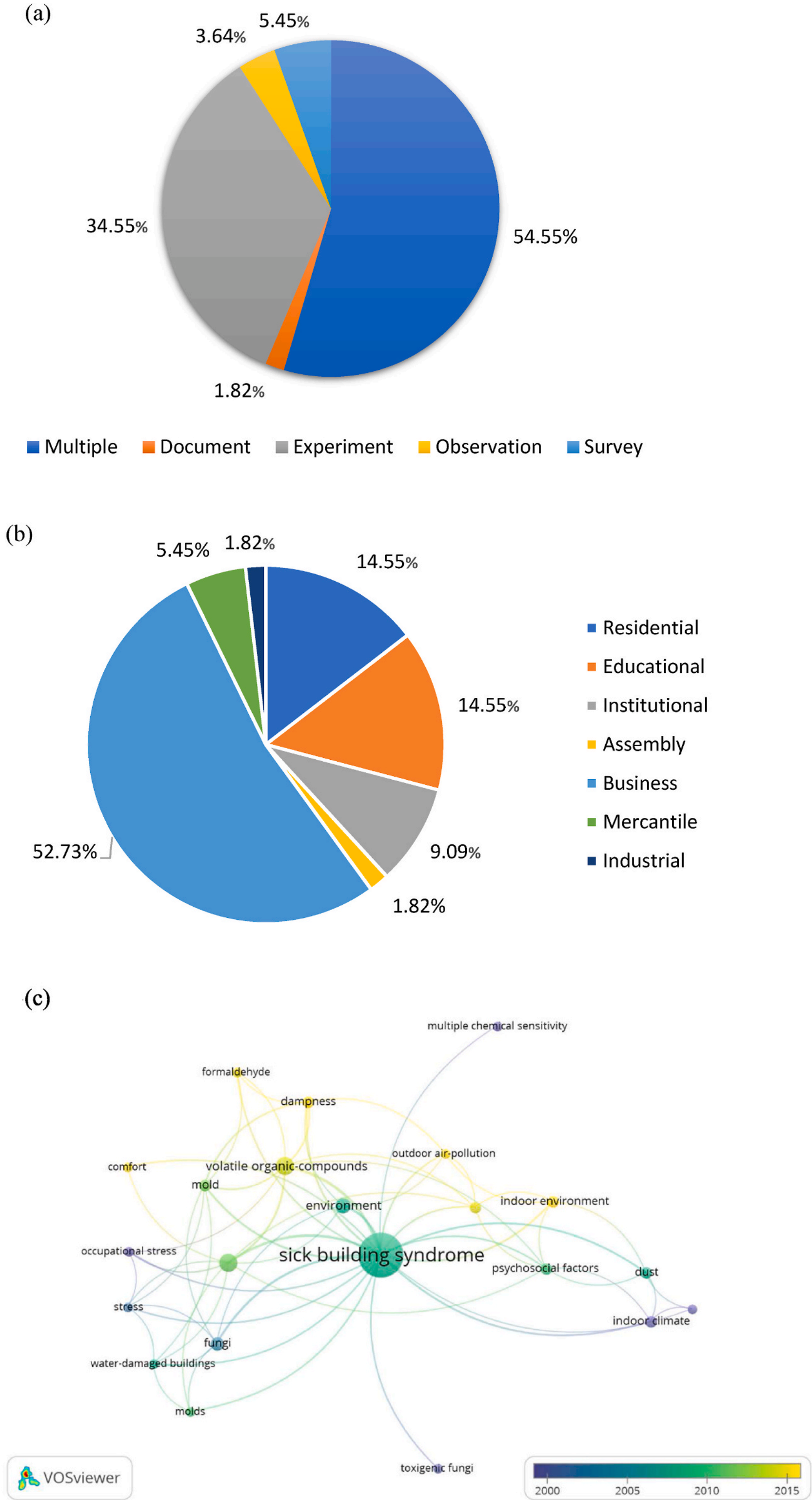

Fig. 3. (a) Methods used from the selected articles. Fig. 3(b) Type of Building. Fig. 3(c) Keywords Co-occurrence Analysis.

3.3. The parameters of the Sick Building Syndrome - thematic analysis

To identify the theme for the sick building syndrome's parameters, a thematic analysis of all 55 of the chosen papers was done. Thus, the three major themes for the parameters of the ill building syndrome identified by this study were: Indoor Environmental Quality (IEQ), Occupant, and IEQ & Occupant. Based on Fig. 4(a), 49.09 % of the total papers that were chosen researched IEQ parameters, 40 % studied IEQ and occupants, and the remaining 10.91 % studied solely building occupants.

3.4. Indoor environmental quality (IEQ)

Based on Fig. 4(b), there are three sub-types of parameters under the IEQ parameter to measure the SBS which are; a) Chemical, b) Physical, and c) Biology. The most studied parameter is chemical with 33 papers, followed by physical with 26 papers, and lastly biology with only 6 papers.

a) Chemical

Chemical parameters are one of the important aspects of Indoor Environmental Quality (IEQ), which refers to the quality of the indoor environment in buildings and structures as it relates to the health and well-being of the occupants. Chemical parameters of IEQ

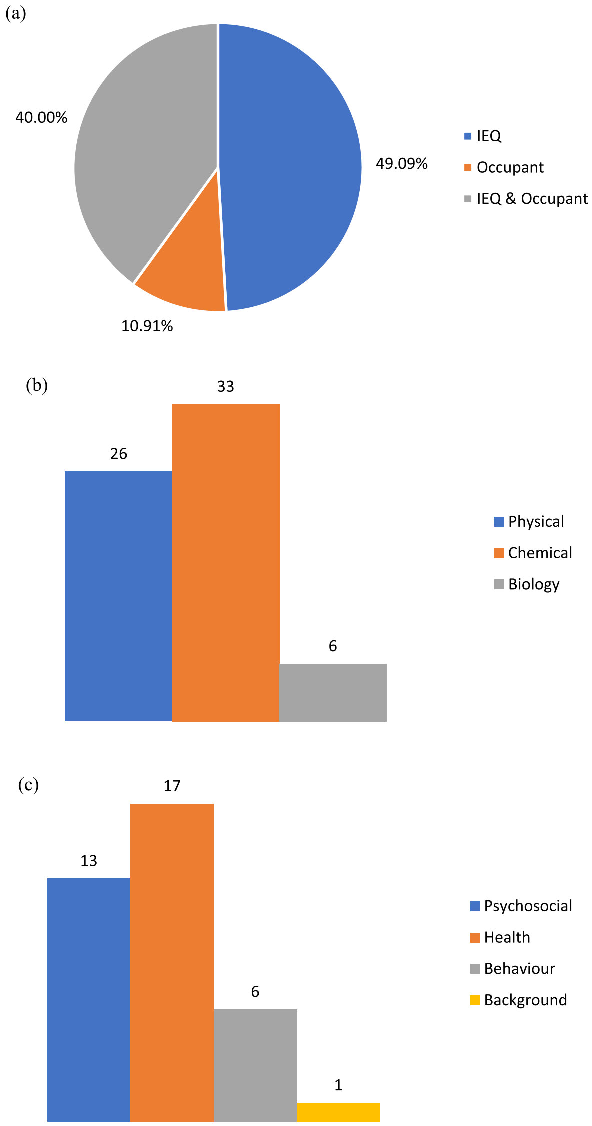

Fig. 4. (a) Type of Parameters of the SBS. Fig. 4(b) Sub-type of Parameters of the SBS (IEQ parameters). Fig. 4(c)Sub-type of Parameters of the SBS (Occupant parameters).

refer to the presence and levels of certain chemical compounds and substances that can affect the quality of indoor air. These parameters include:

i) Volatile Organic Compounds (VOCs)

These are organic substances that can be released as gases by building materials, paints, adhesives, cleaning products, and other sources. High levels of VOCs can cause eye, nose, and throat irritation, headaches, dizziness, and other health effects [19,30,41–45]. VOCs can significantly affect indoor air quality. Poor indoor air quality is a key factor in Sick Building Syndrome. Buildings with inadequate ventilation or a high concentration of VOC-emitting sources can result in the accumulation of pollutants, leading to SBS symptoms among occupants. Some building materials and furnishings release VOCs over time, a process known as off-gassing. This can be particularly problematic in new or recently renovated buildings. Low-VOC or VOC-free alternatives for building materials and furnishings are available to reduce the impact on indoor air quality.

ii) Carbon dioxide (CO_2)

CO_2 is a natural byproduct of human respiration and combustion, and it may build up in poorly ventilated areas. High CO_2 levels can cause drowsiness, headaches, and impaired cognitive function [18,30,41,43–48]. The number of occupants in a space and the design of the building can influence CO_2 levels. Overcrowded spaces or buildings with inadequate ventilation systems may experience higher CO_2 concentrations. Proper design and planning for ventilation systems, including the placement of air intakes and exhausts, can help maintain acceptable CO_2 levels.

iii) Carbon monoxide (CO)

CO is a poisonous gas that is created by combustion sources such as gas stoves, fireplaces, and heaters. High-level CO exposure can cause headaches, dizziness, nausea, and even death [21,22,30,41,49,50]. Carbon monoxide is a significant indoor air pollutant, and its presence can compromise indoor air quality. Buildings with poor ventilation or improper exhaust systems may have elevated levels of carbon monoxide, leading to discomfort and health issues among occupants. Heating systems, gas stoves, and other combustion appliances need to be properly installed, maintained and vented to ensure that carbon monoxide does not accumulate in indoor spaces. Regular inspections and servicing of these appliances are essential to prevent the release of carbon monoxide.

iv) Formaldehyde

Formaldehyde is a colorless gas released by some building materials, furniture, and consumer goods. High amounts of formaldehyde can cause eye, nose, and throat irritation, as well as respiratory issues [21,44,45,50–54]. Formaldehyde is a common indoor air pollutant, and its presence can contribute to poor indoor air quality, which is a key factor in Sick Building Syndrome. Buildings with insufficient ventilation or a high concentration of formaldehyde-emitting sources can lead to an accumulation of pollutants, triggering SBS symptoms among occupants. Pressed-wood products, which are common in furniture, cabinets, and building materials, can off-gas formaldehyde over time. New or recently renovated buildings may have higher formaldehyde levels. Choosing low-formaldehyde or formaldehyde-free alternatives for building materials and furnishings can help mitigate the impact on indoor air quality.

v) Particulate matter (PM)

PM refers to microscopic particles floating in the air, such as dust, pollen, and smoke. High levels of PM can cause respiratory issues such as asthma and lung cancer [18,30,41,44,47,50,55,56]. Particulate matter significantly affects indoor air quality. High concentrations of PM can lead to poor indoor air quality, a key factor in Sick Building Syndrome. Insufficient ventilation and air exchange can contribute to the accumulation of particulate matter indoors. Heating, ventilation, and air conditioning (HVAC) systems play a crucial role in controlling indoor air quality. If not properly maintained, HVAC systems can become a source of particulate matter. Inadequate filtration or dirty filters can allow particulate matter to recirculate in the indoor air, affecting occupants.

vi) Others

PTEs that can harm human health include Sulphur Dioxide (SO), Nitric Dioxide (NO), Nicotine, Toluene, Aerosol, and others that are produced by household activities [18,41,50,57–59]. Some building materials, especially those used in older structures, may contain PTEs. As these materials degrade over time, they can release particles or dust containing toxic elements into the indoor environment. Contamination of indoor surfaces, such as floors and walls, with PTEs, can occur due to factors like deteriorating lead-based paint or the presence of leaded plumbing fixtures. Water sources within buildings, such as plumbing systems, can be a potential route for PTEs to enter indoor environments. Lead, for instance, can leach into drinking water from lead pipes or plumbing fixtures, contributing to indoor exposure.

b) Physical

Physical parameters are one of the important aspects of Indoor Environmental Quality (IEQ), which refers to the quality of the indoor environment in buildings and structures as it relates to the health and well-being of the occupants. Physical parameters of IEQ refer to the physical factors that can affect the quality of indoor air and the comfort of building occupants. These parameters include:

i) Temperature

The temperature of the interior environment can impact occupant comfort and well-being. Indoor temperatures should normally vary from 68 to 76 °F (20–24 °C) [11,12,18–22,24–28,30,44–46,49,60,61]. Buildings with inadequate heating or cooling systems may experience temperature extremes. In cold climates, insufficient heating can lead to discomfort and health issues, while in hot climates, poor cooling systems can result in overheating. Seasonal changes can impact the thermal conditions within a building. Inconsistent temperatures between seasons, such as insufficient cooling in summer or inadequate heating in winter, can contribute to SBS. In regions with significant temperature variations, buildings need to be equipped to handle both heating and cooling demands effectively.

ii) Relative Humidity:

The quantity of moisture in the air in comparison to the maximum amount of moisture the air can contain at a particular temperature is referred to as relative humidity. For interior situations, the ideal relative humidity range is generally 30–60 % [12,18–28,30,44,45,49,62]. Relative humidity influences thermal comfort. Extremely low or high humidity levels can lead to discomfort among occupants, affecting their overall well-being and productivity. Low humidity can cause dry skin, irritation of the eyes and throat, and an increased susceptibility to respiratory infections. High humidity can contribute to a feeling of stuffiness and discomfort. Relative humidity is closely tied to the growth of microorganisms such as mold and dust mites. High humidity levels provide an ideal environment for mold to thrive on surfaces like walls, ceilings, and damp materials. Mold spores and microbial volatile organic compounds (MVOCs) released by mold can trigger respiratory issues and allergic reactions among building occupants.

iii) Airflow and ventilation

Proper air movement and ventilation are critical for maintaining healthy indoor air quality and reducing pollutant accumulation. Inadequate airflow and ventilation can cause dangerous substances to accumulate and raise the risk of respiratory problems [11,12,16,21,25,42,43,52,63,64]. Buildings need a continuous supply of fresh outdoor air to dilute and remove pollutants. If the ventilation system is not designed or operated properly, there may be insufficient fresh air entering the indoor space. Lack of fresh air supply can contribute to elevated concentrations of pollutants, leading to irritation of the eyes, nose, and throat, as well as headaches and fatigue. Regular maintenance of ventilation systems is essential to ensure their proper functioning. Dirty filters, blocked air ducts, or malfunctioning components can compromise the efficiency of the ventilation system, leading to a decline in indoor air quality. Neglected ventilation systems may distribute pollutants rather than effectively removing them from the indoor environment.

iv) Lighting

Proper lighting is essential for a comfortable and healthy home environment. Inadequate illumination can cause eye strain, headaches, and other health issues [20,24,26,27,30,61,64]. The color temperature and spectrum of lighting can impact mood, alertness, and overall well-being. Cool white light with a higher color temperature may be perceived as harsh, while warm light with a lower color temperature might be considered more comfortable. Inconsistent or unnatural lighting may contribute to feelings of discomfort. Glare occurs when there is excessive contrast between bright and dark areas within the visual field. Glare from direct sunlight, bright artificial lighting, or reflective surfaces can cause discomfort, headaches, and visual disturbances among occupants.

v) Noise

Excessive noise levels can cause stress and discomfort for residents, as well as disrupt communication, focus, and productivity [20,26,28,30,64]. Buildings can be exposed to various sources of noise, both internal and external. Internal sources include office equipment, HVAC systems, footsteps, conversations, and other human activities. External sources might include traffic, construction, and other environmental noises. Prolonged exposure to high noise levels, especially if it's persistent and disruptive, can contribute to stress and discomfort among building occupants.

vi) Space geometry

Space geometry or the physical layout of indoor spaces, can be an indicator for the presence of SBS in indoor environments. Poor space geometry can contribute to the buildup of indoor pollutants, increase exposure to these pollutants, and exacerbate SBS symptoms [18,25,28,29,53,64]. The arrangement of rooms and partitions within a building can affect natural lighting and access to outdoor views. Poor access to natural light or outdoor views may contribute to feelings of discomfort and stress among occupants. Spaces that are poorly organized or overcrowded may impede the efficient flow of people and air, potentially leading to inadequate ventilation and increased exposure to indoor pollutants.

c) Biology

Biological parameters are an important aspect of Indoor Environmental Quality (IEQ), which refers to the quality of the indoor environment in buildings and structures as it relates to the health and well-being of the occupants. Biological parameters of IEQ refer to the presence and levels of biological contaminants in indoor environments that can affect the health and well-being of occupants. These parameters include:

i) Indoor Airborne Microorganisms

This refers to the presence of microorganisms such as bacteria, viruses, fungi, and mold spores in the indoor air. These microorganisms can be inhaled by occupants and can cause respiratory problems, allergies, and other health issues [16,43,49,65–67]. Microbes can enter indoor environments through various sources, including outdoor air, ventilation systems, contaminated water, building materials, and occupant activities. Poor ventilation, high humidity, and water damage can create favorable conditions for the growth and proliferation of microbes within a building.

ii) Bioaerosols

Bioaerosols are small particles that are released into the air from living organisms, such as bacteria, viruses, and fungi. These particles can be inhaled by occupants and can cause respiratory problems and other health issues [44]. Bioaerosols in indoor environments can originate from various sources, including occupants (skin flakes, respiratory droplets), outdoor air, ventilation systems, damp building materials (mold growth), and indoor plants. Poor ventilation and high humidity levels can contribute to the proliferation of bioaerosols.

3.5. Occupants

Based on Fig. 4(c), there are four sub-types of parameters under the Occupant's parameter to measure the SBS which are a) Health, b) Psychosocial, c) Behaviour, and d) Background. The most studied parameter is health with 17 papers, followed by psychosocial with 13 papers, behavior with 6 papers, and lastly background with only one paper.

a) Health

Human health is the state of human physical and physiology that is usually affected by their vicinity and behavior. Several human health parameters can be used to indicate Sick Building Syndrome (SBS). These include:

i) Respiratory rate

An increase in respiratory rate may indicate that an individual is having difficulty breathing due to poor indoor air quality [11,25,44,68]. Exposure to airborne pollutants, such as volatile organic compounds (VOCs), particulate matter, mold, and allergens, can irritate the respiratory system, leading to changes in respiratory rate. Individuals with pre-existing respiratory conditions like asthma or allergies may be more sensitive to these irritants, leading to an increase in respiratory rate. Certain individuals may be sensitive to specific chemicals present in building materials, cleaning products, or office equipment. This sensitivity can manifest as respiratory symptoms.

ii) Heart rate

An increase in heart rate may be a sign of stress or discomfort caused by SBS symptoms [11,25,46,69]. Poor indoor air quality, exposure to pollutants, or inadequate ventilation can lead to discomfort and stress among building occupants. Stress and discomfort, in turn, may contribute to physiological responses, including changes in heart rate. Elevated stress levels, whether caused by environmental factors or other workplace stressors, can lead to an increased heart rate. Other than that, Reduced oxygen levels or increased concentrations of pollutants may trigger stress responses in the body, potentially affecting heart rate.

iii) Skin conductance

An increase in skin conductance, or the ability of the skin to conduct electricity, may indicate increased sweating or other physiological responses to SBS symptoms [44,46,50,60,69]. High levels of stress or discomfort experienced by occupants in a building may be reflected in changes in skin conductance. Unpleasant environmental conditions, such as poor air quality, inadequate ventilation, or uncomfortable temperatures, can contribute to stress responses and physiological discomfort. Certain aspects of indoor environments, such as high levels of pollutants, poor air circulation, or uncomfortable temperatures, can contribute to stress and discomfort among occupants. Skin conductance measurements may capture variations in physiological responses to these environmental stressors.

iv) Cognitive function

SBS can also affect cognitive function, such as memory and attention [18,70]. Poor indoor air quality, including elevated levels of pollutants such as volatile organic compounds (VOCs), can have adverse effects on cognitive function. Exposure to indoor pollutants has been associated with a decline in attention, memory, and decision-making skills. Studies have shown that higher levels of indoor pollutants are linked to decreased cognitive performance among occupants.

v) Subjective symptoms

Finally, subjective symptoms reported by individuals, such as headaches, fatigue, and irritation of the eyes, nose, or throat, can be used to indicate SBS [11,25,28,30,44,50,60,69–71].

b) Psychosocial

Psychosocial refers to the interrelationship between psychological and social factors that influence an individual's overall well-being. In addition to the physical symptoms, Sick Building Syndrome (SBS) can also affect the psychosocial well-being of occupants. Here are some of the psychosocial parameters that are associated with SBS:

i) Stress

Occupants may experience increased levels of stress due to the discomfort and uncertainty caused by the symptoms of SBS. The stress can further exacerbate the physical symptoms, creating a vicious cycle [22,45,51,61,68]. Stress can make individuals more sensitive to environmental factors, potentially amplifying their perception of discomfort or symptoms related to indoor air quality. Even if the building conditions meet acceptable standards, stressed individuals may be more prone to attribute their discomfort to the environment.

ii) Anxiety

SBS can cause anxiety in occupants, particularly if they are unsure about the cause of their symptoms or if they are concerned about the long-term health effects of exposure to the indoor environment [12,51,61]. Individuals may experience anxiety when they perceive environmental stressors within a building, even if those stressors are not objectively harmful. For example, concerns about air quality, noise levels, or the presence of allergens can contribute to heightened anxiety.

iii) Social Isolation

SBS can also lead to social isolation, as occupants may avoid social interactions due to their symptoms or fear of exposure to the indoor environment [24,45,51]. Prolonged periods spent in indoor environments, especially those characterized by poor design, lack of natural light, or limited social interaction spaces, can contribute to feelings of isolation and stress among occupants. The psychological impact of social isolation can manifest in various ways, potentially influencing overall well-being and job satisfaction.

iv) Frustration

Occupants may become frustrated due to the lack of a clear diagnosis or solution for their symptoms, leading to feelings of helplessness and hopelessness [68,72]. Poor indoor air quality, uncomfortable temperatures, inadequate lighting, and excessive noise are common environmental stressors in buildings. These factors can lead to frustration among occupants. For example, a lack of proper ventilation or persistent unpleasant odors can create discomfort, contributing to frustration and dissatisfaction.

v) Anger

Some occupants may become angry if they feel that their symptoms are being dismissed or not taken seriously by others [49,68,72]. Factors contributing to SBS, such as inadequate ventilation, high levels of pollutants (including VOCs), and the presence of allergens, can affect the overall comfort and well-being of occupants. Extensive exposure to poor IAQ may contribute to stress and frustration, which could potentially manifest as anger.

c) Behavior

Human behavior is the potential and expressed capacity (mentally, physically, and socially) of human individuals or groups to respond to internal and external stimuli throughout their lives. Human behavior parameters can also be used to indicate Sick Building Syndrome (SBS). These parameters refer to the actions and behaviors of individuals in response to SBS symptoms, such as:

i) Productivity

SBS can also impact occupant productivity, such as decreased work output or increased errors [11,19,26,27,45,51,61]. Symptoms associated with Sick Building Syndrome, such as headaches, fatigue, and irritation of the eyes, nose, or throat, can significantly impact an individual's ability to focus and perform tasks effectively. Persistent health issues may lead to increased absenteeism, reduced work hours, or a decline in overall work performance.

ii) Sick leave rates

An increase in sick leave rates among occupants may also indicate that SBS is present in the building [19,25,51]. SBS symptoms, such as headaches, respiratory issues, eye irritation, and fatigue, may lead employees to take sick leave more frequently. A higher-than-normal rate of absenteeism, especially if it is concentrated within a specific building or office space, may raise concerns about the indoor environment contributing to employee health issues.

iii) Occupant complaints

One of the primary indicators of SBS is occupant complaints, such as reporting symptoms of discomfort or poor air quality [29,43,68]. Occupants experiencing symptoms such as headaches, dizziness, fatigue, irritation of the eyes, nose, or throat, and respiratory issues may report these complaints. The range of symptoms is diverse and can vary from person to person, making it challenging to attribute them to a specific cause.

iv) Building vacancy rates

Higher than usual building vacancy rates may indicate that occupants are avoiding the building due to SBS symptoms [28,29,43]. Vacant buildings may not receive regular maintenance and attention. Lack of upkeep can lead to issues such as water leaks, mold growth, and pest infestations, all of which can contribute to poor indoor air quality and health problems.

v) Behavior modification

Finally, occupant behavior modification can also be an indicator of SBS. For example, if occupants are opening windows or using personal air purifiers in response to SBS symptoms, this may indicate that the building's ventilation system is not working properly [43,73].

d) Background

Personal background parameters can also be used to indicate Sick Building Syndrome (SBS). These parameters refer to the individual characteristics of building occupants, such as:

i) Age

SBS symptoms may be more common in certain age groups, such as young children or elderly individuals [29]. Children may have developing immune systems, and elderly individuals may have weakened immune systems. Both age groups may be more susceptible to the effects of indoor pollutants, including allergens and irritants.

ii) Gender

Some studies have suggested that females may be more sensitive to SBS symptoms than males [29]. Occupations may have different gender distributions, and some occupations may be more prone to indoor air quality issues than others. For example, offices, healthcare facilities, and educational institutions may have different gender compositions, and the nature of the work or exposure to specific substances can vary.

iii) Health status

Individuals with pre-existing respiratory conditions, such as asthma or allergies, may be more susceptible to SBS symptoms [29]. Regular health surveys and assessments among building occupants can help identify patterns of symptoms associated with SBS. Occupational health professionals may conduct surveys to collect data on the prevalence and severity of symptoms, helping to establish a correlation between building occupancy and health status.

iv) Smoking status

Smoking can exacerbate SBS symptoms and increase the risk of developing respiratory illnesses [29]. Smoking indoors is a major contributor to poor indoor air quality. Tobacco smoke contains a complex mixture of harmful chemicals, including particulate matter, volatile organic compounds (VOCs), carbon monoxide, and numerous carcinogens. Second-hand smoke, also known as passive smoke or environmental tobacco smoke, lingers in the air and can persist in indoor environments, affecting both smokers and non-smokers.

v) Medication use

Some medications, such as beta-blockers or antihistamines, can impact an individual's response to SBS symptoms [29].

vi) Sensitivity to environmental factors

Some individuals may be more sensitive to environmental factors, such as changes in temperature or humidity, which can exacerbate SBS symptoms [29].

4. Discussions

4.1. The Parameter for the Sick Building Syndrome: the current practice and progress

The IEQ state of the building is the most commonly used criterion to measure the SBS. The IEQ is divided into three key categories: chemical, physical, and biological. One of the key reasons for this predicament, according to Ganesh et al. [74], is the amount of time individuals spend indoors. People spend a significant amount of time indoors, particularly in office buildings, schools, and residential areas [75]. The longer people are exposed to unhealthy indoor environmental conditions, the more likely they are to develop Sick Building Syndrome [76]. Aside from that, poor indoor air quality can lead to the accumulation of indoor contaminants such as VOCs, formaldehyde, radon, and mold spores. These contaminants are frequently generated by construction materials, furniture, and cleaning goods. People who breathe in these contaminants over time may develop respiratory disorders, allergies, and other health problems [77].

According to Oh et al. [78], IEQ status has an impact on the inhabitants' health and comfort. Human health and comfort are directly affected by IEQ variables. Inadequate ventilation and excessive humidity levels, for example, can increase mold and bacterium growth, resulting in respiratory issues and allergic responses [79]. Uncomfortable temperatures and inadequate illumination can result in headaches, weariness, and decreased productivity. Building owners and facility managers have some control over the interior environment [80]. Improving ventilation systems, utilizing low-emission building materials, and implementing suitable lighting solutions are only a few of the ways that can improve IEQ and lower the risk of Sick Building Syndrome [81].

A combination of poor IEQ characteristics can cause Sick Building Syndrome. Inadequate ventilation, for example, can produce a buildup of indoor pollutants, and poor illumination can induce eye strain and headaches [77]. Addressing various IEQ indicators may result in a more thorough treatment of health conditions. Many nations have created norms and regulations for indoor air quality, thermal comfort, lighting, and acoustics in buildings, according to Elnaklah et al. [82]. Compliance with these criteria contributes to a better interior environment for inhabitants while also lowering the incidence of Sick Building Syndrome [83].

4.2. The Parameter for the Sick Building Syndrome: The challenges and limitations

In examining and evaluating the SBS, the occupant factor is just as significant as the building's IEQ condition. However, there is a scarcity of studies and research that focus on the occupier [84]. One of the explanations, according to McWhirter et al. [85], is the subjectivity of symptoms reported by the inhabitants. SBS symptoms are frequently subjective and vary from person to person. They can include, among other things, headaches, tiredness, respiratory difficulties, dizziness, and skin irritation [86]. Multiple occupants complain of headaches, but one person might attribute it to a stressful day at work, another to lack of sleep, and another to the indoor environment. Without specific, consistent symptoms, it's challenging to pinpoint the cause. Since these symptoms can be induced by a variety of causes that are not always connected to the building environment, it is difficult to assign them purely to SBS. SBS symptoms might be similar to those of other health issues or illnesses, making it difficult to distinguish between SBS and other causes. This can result in SBS misdiagnosis or underreporting [87].

The latency duration of a symptom, on the other hand, will postpone the urgent essential reaction for the afflicted inhabitants [88]. For example, employees move into a newly renovated office space, and a month later, several complain of respiratory issues. The delay in symptoms makes it challenging to link them directly to the renovation and raises questions about other potential causes. In other circumstances, symptoms may not show right away, and there may be a delay between being exposed to poor indoor environmental conditions and experiencing symptoms [17]. This delay makes it more difficult to attribute the symptoms to the building environment. Indoor environmental elements are not the only contributors to SBS symptoms, according to Thach et al. [83]. Other factors that can play a role include psychological stress, work-related stress, personal health issues, and lifestyle choices [89]. To determine the precise etiology of the symptoms, all relevant contributing variables must be carefully considered [86].

SBS symptoms might change with the seasons. Some symptoms, for example, maybe more evident during the winter when buildings are sealed and less ventilated, whilst others may be more prominent during the pollen season when allergies are increased [77]. Several employees report feeling unwell during the winter months. It might be tempting to attribute this to poor ventilation or heating issues, but some symptoms could also be related to seasonal illnesses like the flu or increased indoor exposure due to colder outdoor temperatures. Furthermore, various persons have different sensitivity to indoor environmental elements. Some people may be more sensitive to specific contaminants or environmental circumstances, whereas others may not suffer any negative effects under the same settings [90]. A group of employees works in an environment with a known level of a particular indoor pollutant. While most show no adverse effects, one individual with a heightened sensitivity experiences symptom. The challenge lies in understanding why this person reacts differently than others. Indoor environmental parameters frequently interact with one another, making it difficult to isolate the influence of a single component, according to Al Horr et al. [91]. Poor ventilation, for example, can amplify the impacts of indoor pollutants, and inadequate illumination can cause eye strain and discomfort (Jafari et al., 2015 [92]). Finally, SBS symptoms are usually transient and improve or vanish as people leave the building. Because of their ephemeral character, it might be challenging to undertake regular and uniform examinations [17].

4.3. The Parameter for the Sick Building Syndrome: Addressing research gap and future trends

Despite progress, several research gaps persist in our understanding of SBS parameters. Firstly, there remains a lack of consensus on standardized diagnostic criteria for SBS, leading to variability in reported prevalence rates and hindering effective comparison between studies. Secondly, the complex interplay between various parameters and their cumulative effects on occupant health requires further investigation. Additionally, there is a need for longitudinal studies to assess the long-term impacts of SBS on occupant health and productivity. Furthermore, emerging factors such as climate change and building design trends introduce new complexities that warrant exploration.

Addressing the research gaps in SBS parameters requires a multi-faceted approach. Future trends in SBS research may include: a) advanced sensor technology, which the development of wearable sensors and real-time monitoring systems can provide valuable data on indoor environmental quality and occupant health, allowing for more precise identification of SBS parameters. b) integration of building design and health which incorporating principles of biophilic design, sustainable materials, and enhanced ventilation systems into building design can mitigate SBS risk factors and promote occupant well-being. c) leveraging big data analytics techniques can enable researchers to analyze vast amounts of data collected from various sources, facilitating comprehensive studies on SBS parameters and their interactions. d) interdisciplinary collaboration between architects, engineers, environmental scientists, and medical professionals is essential for holistic approaches to addressing SBS, considering both environmental and human factors. e) Strengthening regulations and standards related to indoor air quality and building design can incentivize the adoption of SBS mitigation strategies and promote healthier indoor environments.

5. Conclusion

After a systematic and careful screening procedure, a total of 55 publications were evaluated to research and find the factors that have been utilized to assess or quantify Sick Building Syndrome (SBS). For the first goal, this survey discovered a considerable rise in interest in the study of SBS among academics and researchers. The spatial distribution pattern, on the other hand, revealed that the Sick Building Syndrome research was spread over 26 nations, with the majority of articles originating from the United States and China. In terms of context, the majority of the selected publications employed the survey approach to investigate SBS parameters. Aside from that, the most researched form of building is the business building. Through the thematic analysis, there were two main parameters to measure the SBS, namely: a) Indoor Environmental Quality and b) Occupants. For the first theme, there are three sub-themes, which are a) Chemistry, b) Physical, and c) Biology. For the second theme, there are four sub-themes, which are a) Health, b) Psychosocial, c) Behaviour, and d) Background. All these discoveries show that this study has succeeded in filling the gap and answering the questions raised earlier. It also opens a new dimension for research and discovery in the study of Sick Building Syndrome.

This study reveals that the parameter used to calculate the SBS has various limits and obstacles. For starters, there is a scarcity of studies that include both types of criteria in their research. Second, the indoor environmental quality, particularly for the chemical and physical characteristics, dominated the SBS investigations. Finally, there is a shortage of research from other nations, particularly those in Asia and Latin America. For future investigations, we urge that scientists and researchers investigate the occupant aspect to quantify the SBS. Furthermore, it would be more intriguing if researchers could incorporate both indoor environmental quality and occupant factors into a study, resulting in more holistic conclusions. Furthermore, there is an urgent need for nations in Asia and the Americas to perform more studies in SBS so that a wide range of discoveries may be uncovered.

Ethics approval and consent to participate

Not Applicable.

Data availability statement

Not Applicable.

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CRediT authorship contribution statement

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Declaration of competing interest

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