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Sick Building Syndrome Overview- UK'S Indoor Sick Building Syndrome Formation Analysis

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Abstract:- Building-related illnesses pose a critical risk to public health and have consistently been a source of concern. The illnesses are collectively referred to as Sick Building Syndrome (SBS) and are used to elaborate on a situation in which the occupants of a house experience headaches discomfort-related effects or symptoms of air borne diseases that seems to be connected to the time spent in houses. Symptoms are many, but in general, occupants may experience throat, eye, and nose discomfort, as well as fatigue and, on occasion, dizziness. The increased prevalence of this syndrome has prompted substantial research. Although there is no known specific cause of SBS, some experts have concluded that indoor pollutants have a significant role in exacerbating the illness. The sources of indoor pollutants include biological contaminants, chemical contaminants, and particulate matter. These contaminants include bacteria, volatile organic compounds (VOCs), and dust, respectively. This study will examine the role of indoor pollutants in Sick Building Syndrome symptoms, investigate the causes and effects, and recent progress in understanding and controlling SBS caused by these contaminants.And also outlines an overview of the UK's SBS issues.

I. INTRODUCTION

Indoor Pollutants and SBS The United States Environment Protection Agency refers to Indoor Air Quality (IAQ) as the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants (EPA, n.d.). There is a positive correlation between Indoor Air Quality (IAQ) and increased symptoms of Sick Building Syndrome. Indoor air quality can vary from building to building. The overall occupants' well-being and productivity are affected by increased SBS symptoms emanating from poor IAQ from indoor pollutants. The latter is a result of inadequate ventilation, volatile organic compounds (VOCs), biological contaminants, and particulate matter. These compounds can irritate the eyes, nose, and throat, headaches, and fatigue (Wolkoff et al., 2005). Formaldehyde, a common VOC found in building materials, has been particularly associated with respiratory and mucous membrane irritation (Mendell M, 1993). The COVID-19 pandemic era heightened concerns about IAQ as the need for extended indoor activity increased dramatically due to lockdowns and remote work arrangements. These remote and hybrid work arrangements have become more common post-pandemic era. The majority prefer these job patterns, which allow them to spend more time indoors. This clearly emphasises the urgent need for better ventilation systems and regular air quality monitoring to prevent SBS and promote indoor environmental health. The interactions of a multitude of factors, such as the site, climate, building system, construction materials, building dampness, contaminant sources, and activities of occupants, affect the quality of indoor air (Nag P, 2019). Research has shown that various indoor pollutants can contribute to the development of SBS symptoms. Poor indoor air quality poses negative impacts not only on the occupants' health but also their productivity. Over time, there has been an increase in the quantity of time people spend indoors. However, the quality of buildings that occupants spend time in is of greater concern. Some alternate between work and home thus increasing chances of intensifying SBS symptoms because they get exposed to higher concentrations of indoor pollutants from office equipment and materials. SBS has greater economic and social ramifications in addition to its effects on individual health. Increased healthcare expenditures, decreased productivity, and absenteeism due to illness are some of the repercussions. The overall impact on community health and well-being can be significant, affecting both societal functioning and economic stability. Therefore, there is a need for a more comprehensive approach to promoting healthy buildings. Government bodies and institutes must incorporate research and practice toward Indoor Air Environments.

II. METHODOLOGY

This study aims to analyse the relationship between Indoor Pollutants and Sick Building Syndrome and detail an overview of SBS studies in the United Kingdom. To accomplish this, an analysis and integration of previous studies on how indoor pollutants cause SBS will be examined. The systematic review of available academic journals extracted from abstracts and citation databases on PubMed, Scopus, ScienceDirect, and Google Scholar was done using keywords such as Indoor Pollutants, Sick Building Syndrome, SBS, Indoor Air Quality, and IAQ. The articles were chosen primarily on their relevance to the topic, publication date (ideally within the previous two decades), and trustworthiness of the authors. The key findings from selected papers were extracted, with an emphasis on different types of pollutants, for instance, biological, chemical, and particulate matter including documented effects on health relating to SBS for better understanding. With this understanding, an overview of the UK's Sick Building Syndrome studies will be outlined.

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III. LITERATURE REVIEW

Types of Indoor Pollutants Indoor Pollutants can be categorised into chemical, biological, and physical. The inhalation of polluted indoor air is hazardous and can cause harm to occupants' health. According to the World Health Organization, around 4.2 million people die prematurely due to indoor air pollution (WHO, 2022). Poor ventilation is one of the leading contributors to SBS. Certain architectural designs promote poor ventilation in buildings. Energy-efficient buildings frequently have poor ventilation to preserve energy. The downside of such architectural designs is the accumulation of indoor pollutants. Inadequate ventilation prevents indoor pollutants from being diluted and removed, which increases their concentration and exacerbates SBS symptoms. The interaction of various chemical pollutants can result in the production of new molecules that are potentially more toxic than the original chemicals. For example, ozone can combine with VOCs to generate formaldehyde, which is a recognized irritant. The length of time spent exposed to indoor pollutants and the degree of sensitivity of each person play a crucial role in the development of SBS. Continuous exposure to indoor pollutants, even at low levels, can have long-term health consequences. The symptoms are worsened especially when inhabitants have preexisting health problems or allergies.

- *Chemical Contaminants*

Chemical products contain different chemical compounds that are toxic and detrimental to the well-being of occupants in buildings. A wide range of health issues from minor irritations to severe respiratory problems, and long-term conditions like asthma and neurological systems are some of the effects of these chemicals. The lack of sufficient ventilation exacerbates these difficulties by allowing pollutants to collect to dangerous levels. The most common chemical compounds are Volatile Organic Compounds (VOCs). When VOCs are emitted into the air, they can cause SBS symptoms such as headaches, nausea, irritation of the eyes, nose, and throat, and other illnesses like kidney failure. These gases emanate from certain solids or liquids, including paints, cleaning supplies, pesticides, and office equipment. Formaldehyde is also a common VOC found in building materials and household products like glue, pressed wood, and insulation. In addition, this compound is particularly associated with respiratory and mucous membrane irritation (Adamova et al, 2020). Other chemicals like radon, a radioactive gas found in almost every soil and in some building materials, pose a great danger indoors because they cannot be diluted as quickly as outdoors (Tarakanov V, 2023). Prolonged inhalation of this chemical compound can cause lung cancer. Reactive gases generated by indoor air purifiers and printers also contribute to respiratory problems.

- *Biological Contaminants*

Mold, bacteria, dust mites, and pet dander are among the biological sources of indoor pollutants that contribute significantly to the development of SBS. These pollutants can thrive in places with inadequate ventilation and high humidity, triggering respiratory problems, allergic reactions, and other health issues (Douwes et al, 2023). Such environments foster the emission of allergens and chemicals, which degrade indoor air quality and exacerbate SBS in occupants. These contaminants can develop via ventilation systems, structural leaks, and human activities. Biological pollutants can cause allergic reactions like a runny or stuffy nose, skin rashes, itching, and irritated and watery eyes. Mold releases spores and mycotoxins that can cause allergic reactions and respiratory problems in vulnerable persons. Household dust contains dust mites and microscopic organisms that produce fecal particles and body fragments. These are strong allergens that cause sneezing, irritated eyes, and asthma flare-ups. Bacterial contamination in Heating, Ventilation, and Air Conditioning systems and stagnant water can cause the spread of hazardous bacteria, increasing SBS symptoms such as headaches, fatigue, and mucous membrane irritation. Pet dander, which comes from skin cells that are shed by animals with fur or feathers and consist of skin flakes, saliva, and urine proteins, also contributes to indoor allergen levels, causing symptoms in sensitive individuals (Mayo Clinic Staff, 2021).

- *Particulate Matter*

Particulate matter is a combination of solid particles and liquid droplets found in the atmosphere. These can substantially impact indoor air quality and health. It contributes to SBS by transporting dangerous substances such as chemicals, biological pollutants, and heavy metals. When inhaled, these particles can result in inflammation and irritation of the respiratory system, which are believed to cause the symptoms of SBS. These particles are divided into two categories based on their diameter, that is, PM10 (particles with a diameter of 10 micrometers or less) and PM2.5 (particles with a diameter of 2.5 micrometers or less). PM2.5 is the most dangerous because of its potential to penetrate deeply into the lungs and the bloodstream. When exposed to particulate matter, occupants can experience SBS symptoms such as fatigue, headaches, and shortness of breath. Larger particles (PM10) can also cause throat and nasal irritation, as well as coughing and sneezing (Seppänen et al, 1999).

- *Case Studies Reviews*

According to a study by (Fisk et al, 2007), which examined data from office buildings, symptoms of SBS such as headaches, dizziness, and respiratory problems were significantly influenced by high carbon dioxide (CO_2) and inadequate ventilation. The prevalence of SBS symptoms in an office environment is possible with a ventilation rate of up to 20-25 L/s per person (Seppänen et al, 2004). Air conditioning systems may increase the prevalence of SBS symptoms relative to natural ventilation if not clean.

In addition, in 2011, an extensive study carried out on 111 office workers in a sizeable, enclosed office building revealed a positive correlation between an increase in employee reports of SBS symptoms and higher concentrations of indoor carbon dioxide (CO_2) concentrations (Tsai et al, 2012). Again, poor ventilation was identified to be a significant contributing factor to the exacerbation of these symptoms.

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Researchers in Sweden examined the air quality at schools and discovered the respondents felt that the air is bad and dusty; unpleasant odors are extensive and comfort problems prevail in winter emanating from poor ventilation (Alsmo et al, 2013). These findings were accompanied by SBS symptoms complaints from staff and children.

According to the Opinion survey, over half of workers (52%) have heard of Sick Building Syndrome (SBS. With this definition in mind, nearly half (42%) believe that they have or may have suffered from SBS. Respondents believe the causes of SBS to be poor ventilation or poorly maintained air conditioning systems (60%), the release of toxic chemicals from poorly maintained air condition systems (46%), and poorly maintained sewage systems (33%) (OBeirne S, 2023).

A substantial study by (Sundell et al, 2011), which examined over 400 houses, discovered a strong relationship between biological pollutants such as dust mites and mold, formaldehyde, and volatile organic compounds (VOCs) and SBS symptoms. Meta-analysis suggests that building dampness and mold are associated with increases of 30–50% in a variety of respiratory and asthma-related health outcomes, and the associations are statistically significant in nearly all cases (Fisk et al, 2007). Moisture-damaged building materials can release volatile organic compounds or irritating airborne chemicals that may be associated with health problems (NIOSH, 2024).

Higher levels of CO_2 within the range found in typical indoor settings have been linked to slower work performance, more absences, perceptions of poor air quality, and an increased prevalence of acute health symptoms such as headaches, and mucosal irritation ((Erdmann et al, 2004); (Federspiel et al, 2004); (Milton et al, 2001); (Seppänen et al, 1999); (Shendell et al, 2004) and (Wargocki et al, 2000)). These findings have been supported by epidemiological and intervention research.

Burning wood or charcoal for cooking or heating causes indoor air pollution. In Mexico, this is a public health concern that affects women of reproductive age and children under five, particularly in the nation's underprivileged areas. In 1990, one in three Mexicans (91% of rural and 11% of urban residents) used wood for cooking; in 1993, 25.6 million people were estimated to use wood as household fuel; this number dropped to 17.2 million in 2000 (Maldonado et al, 2011). During wood combustion, several harmful pollutants including carbon monoxide (CO), volatile organic hydrocarbons (VOC), polycyclic aromatic hydrocarbons (PAH), PM10, and PM2.5 are released (Naeher et al, 2007).

➢ *UK'S SBS Sample Building Observations*

This study examines the relationship between Sick Building Syndrome (SBS) and residential buildings in the United Kingdom. Out of 117 recorded SBS buildings, 32 were selected for in-depth research and experimentation. Key Findings includes: A significant link exists between SBS and occupant health and the UK's SBS-prone building rate is moderate but approaching a critical level, with expectations of a surge in SBS cases if no action is taken. Some of the challenges and objectives are: Measuring and predicting SBS-prone buildings is a major challenge and also this study aims to develop a framework for testing SBS levels in residential buildings, focusing on design elements like orientation, roofing, and thermal floor masses. A primary goal is to create a measuring tool and SBS test software to help professionals identify SBS-prone buildings using direct interview software.

➢ *Causes of SBS in the UK*

Some of the causes are: Design faults and aging buildings contribute significantly to SBS issues and the common problems include:

- Inadequate ventilation
- Uneven heat distribution
- Lack of damp proofing in roof decks, walls, and foundations

This study seeks to address the critical issue of SBS in UK residential buildings by developing a measuring tool and test software to identify and mitigate SBS-prone buildings.

➢ *619 Respondents on their Encounter with SBS Buildings shown below:*

Table 1 619 Respondents on their Encounter with SBS Buildings

SBS BUILDINGS IN THE UNITED KINGDOM				
CITY	NO (RESPONDENT)	SEEN	LIVED	NEVER SEEN
SLOUGH	210	165	27	45
COVENTRY	95	72	16	23
PONTYPRIDD	104	89	22	35
LEEDS	210	176	52	34
TOTAL RESPONDENT	619	502	117	137

Source: Field Survey (2023)

➢ *Images of the Sample Case Study Buildings below:*

Fig 1 Case Study Building Samples

A survey of 619 respondents revealed that 502 had encountered a building with Sick Building Syndrome (SBS), while 117 had personally lived in such a building. Meanwhile, 137 respondents claimed to have never seen an SBS-affected building. Aging buildings are a significant factor in SBS, but even refurbishments can be ineffective if not done to a high standard. However, proper refurbishments can still mitigate or minimize SBS issues.

The primary causes of SBS, such as mold formation on walls and roofs, are often due to moisture buildup resulting from poor ventilation in internal spaces like bathrooms and bedrooms. Notably, living rooms were rarely found to have mold formation, indicating that SBS is not primarily a building material issue, but rather a result of incorrect orientation, inadequate roof insulation, and thermal floor mass.

To reduce or prevent SBS, it is crucial to ensure proper ventilation and lighting in rooms and bathrooms. Furthermore, roof decking systems can absorb moisture over time, leading to mold formation and SBS. Therefore, addressing these design and ventilation issues is essential to preventing SBS."

- *According to the Studies, the most affected areas by Sick Building Syndrome (SBS) are:*

✓ Bathrooms
✓ Bedrooms

These areas are more prone to moisture buildup due to poor ventilation, leading to mold formation and SBS issues. In contrast, living rooms were rarely found to have mold formation, suggesting that SBS is more likely to occur in areas with higher humidity and poorer ventilation.

In the United Kingdom, numerous cases of Sick Building Syndrome (SBS) have gone unreported due to landlord negligence and unclear policies. A recent online questionnaire and field research study revealed a disturbingly high number of buildings with SBS-related issues. This is largely attributed to the lack of policies governing private building maintenance, leading to neglect by owners who often don't reside in these buildings. Many of these properties are rented to foreigners and students, exacerbating the issue. Statistical analysis estimates that at least 52 housing units, including apartment buildings and bungalows, are affected by severe cases of SBS.

➢ *Statistical Analysis of Respondents in Contact with SBS Buildings*

Table 2 Statistical Analysis of Respondents in Contact with SBS Buildings

SICKNESS BUILDING SYNDROME SPREAD			
		Type of Apartment	
Total Respondents	Area	Flats	Others
165	SLOUGH	87	78
72	COVENTRY	55	17
89	PONTYPRIDD	36	53
176	LEEDS	109	67
502			

Source: Field Survey (2023)

This study revealed that when shown images of buildings exhibiting Sick Building Syndrome (SBS) characteristics, respondents acknowledged experiencing or witnessing SBS-related issues in varying degrees. However, many individuals were unaware of the causes of their SBS-related symptoms, and a significant number of building occupants suffered from health issues directly linked to SBS. During the field study, inspections were conducted in four UK cities, revealing that a quarter of respondents' SBS symptoms were directly attributed to the poor condition of the buildings. Notably, some respondents reported improved health when away from the building for an extended period. Unfortunately, many respondents were either unaware of the root causes of their symptoms or underestimated the severity of their situation, assuming it posed no significant threat to their well-being.

Fig 2 Sample Case Study
Source: Field Survey (2023)

A case study was conducted on a residence located near Slough, United Kingdom, where the occupant, Miss H, has been living for nine months. During her tenure, she has been experiencing recurring health issues, including severe intermittent headaches, sore throat, and chest pain, which have persisted for four months. Additionally, Miss H has consistently noticed a moldy odor in her room and has occasionally suffered from flu-like symptoms, such as coughing, shortness of breath, and a runny nose, as confirmed by medical reports from the hospital.

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➢ *SBS effect on Dwellers of the sample Case Study Building*

Table 3 SBS effect on Dwellers of the sample Case Study Building

TABLE SHOWING CASE STUDY RESULT							
						Frequency of SBS Symptoms	
Case Study No	**Location**	**Respondent Name**	**SBS Symptoms**	**No of years as End User**	**Hospital Visit**	**Often**	**Sometimes**
C	Slough	Miss H	Headache/Flu	9 Months	Yes	Yes	-

This house was built in around 1974 and contains three bedrooms and a sitting room with one toilet and bath. This particular house under study was refurbished with wall painting re-done by the current owner, due to aging and some damping issues, the SBS effects and developments still continued after a while. The occupant of this building has encountered several SBS related ailments during the time of residing in this apartment. The walls are construction with bricks with cement finishes but has inadequate wall insulation with the wall paints already showing signs of wearing. The mold formation on the bathroom walls are clearly visible.

➢ *The Influence of Different Building Elements on Building*

Table 4 The Influence of Different Building Elements on Building

BUILDING ELEMENENT	VENTILATION	LIGHTING	HEAT	SBS SYNDROMS
ORIENTATION	✔	✔	✔	Dry or sore throat, heat wave, head ache, drowsiness, running nose
ROOFING	---	---	✔	Head ache, Drowsiness, Running Nose
THERMAL MASS	---	✔	✔	Cancer, rapid Loss/gain of Temperature

From this study also, additional plans for air movement or circulation is needed in the bathroom to deal with damping issues thus minimizing SBS effect and development especially during the winter season. When additional ventilation mechanism is installed, it will lower if not completely the build-up of moisture within the space thereby discouraging the SBS formation in the building. Further studies are required where the dwellers of this buildings will be used as references.

IV. MITIGATION STRATEGIES

There is a need for proactive measures in building design and maintenance. Advanced technological research has brought forward mitigation strategies to combat SBS. Enhancing ventilation is one of the most effective strategies to reduce indoor pollutant levels and mitigate SBS. In the UK, where dampness and high humidity levels are common, ventilation plays a crucial role in preventing the conditions conducive to mold growth, a contributor to SBS (VENTI, 2023).

(Mousavi et al, 2020) analysed the impact of air purifiers in conjunction with mechanical ventilation in a temporary plastic anteroom, with a special focus on air purifiers. The study demonstrates that while air purifiers favourably enhance indoor air quality by reducing Total Volatile Organic Compounds (TVOC) and Particulate Matter (PM 2.5), mechanical ventilation has a higher impact on the dilution of contaminants.

In order to effectively reduce the spread of harmful microbes in indoor spaces, (Sodiq et al, 2023) study of air purifiers in combination with HVAC operations dynamics recommends using innovative solutions like the integration of Ultraviolet Germicidal Irradiation (UGVI) that is used simultaneously with a nonporous air filter. Adsorption and photocatalytic oxidation are the current approaches for the removal of VOCs and PM2.5 with high efficiency (Yue et al, 2021). Air purifiers and indoor plants can improve air quality. High Efficiency Particulate Air [filter] (HEPA) is a type of pleated mechanical air filter that can theoretically remove at least 99.97% of any airborne particles with a size of 0.3 microns (µm), which can include dust, pollen, mold, and bacteria (UMASS, n.d.).

(Seppänen et al, 2002) discovered that improved ventilation decreased the prevalence of SBS symptoms. (Mendell M, 2003) further demonstrated the relationship between VOCs and SBS, emphasising the significance of indoor air quality control. Improved air quality enhances ventilation and lowers levels of volatile organic compounds and particulate matter (PM2.5) thus lessening SBS symptoms. Minimizing indoor pollutants largely reduces SBS in buildings. Regular cleaning and maintenance can prevent pollutant buildup; this can be achieved by fixing leaks, using dehumidifiers to prevent mold growth, and using non-toxic cleaning products.

Amongst the many mitigation strategies to reduce indoor pollutants buildup and SBS are the technology-driven solutions. To combat SBS, smart building solutions are essential. Green buildings mitigate SBS by improving indoor air quality through the incorporation of sustainable design concepts (WGBC, n.d.). Modern ventilation systems, non-toxic building materials, and enhanced access to natural environments also alleviate SBS. The use of energy-efficient systems improves indoor air quality. Internet of Things (IoT) sensors integrated with Building Management Systems (BMS) enable dynamic control of comfort parameters (temperature, humidity, air quality, etc.) tailored to occupants' needs for personalised comfort (Mathé C, 2023).

V. CONCLUSION

It is critical that we evaluate not just how sick buildings are, but also how healthy buildings can be. Indoor Air Quality (IAQ) is crucial for the health and comfort of building occupants, and it is positively correlated with increased symptoms of SBS. Poor IAQ triggered by indoor pollutants such as volatile organic compounds (VOCs), biological contaminants, and particulate matter play a key role in exacerbating Sick Building Syndrome. Sick Building Syndrome (SBS) is a public health concern involving acute health or comfort-related effects linked to time spent in a building. Symptoms include discomfort, fatigue, and dizziness. SBS has significant economic and social repercussions, including increased healthcare expenditures, decreased productivity, and absenteeism due to illness. Proactive measures in building design and maintenance are crucial to combat SBS. Advanced technological research has shown that improving ventilation is an effective strategy to reduce indoor pollutant levels. Air purifiers, combined with mechanical ventilation improve indoor air quality by reducing Total Volatile Organic Compounds (TVOC) and Particulate Matter (PM 2.5). Innovative solutions like Ultraviolet Germicidal Irradiation (UGVI) and nonporous air filters can effectively reduce the spread of harmful microbes. Regular cleaning and maintenance are among the many ways of preventing pollutant buildup. Technology-driven solutions, such as green buildings, modern ventilation systems, non-toxic materials, and energy-efficient systems can be implemented to combat SBS.

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