Sick building syndrome: Assessment of school building air quality

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Abstract. Sick Building Syndrome is a term used to describe a situation in which occupants of a building have symptoms and discomfort. Sick Building Syndrome. The symptoms of SBS are shown in complaints that occur in occupants of the building as well as eye irritation, nonspecific symptoms, upper respiratory tract, lower respiratory tract, and skin irritation. SBS was also met on building buildings in schools which caused disruption of teaching and learning activities. The method of this study used a literature review which conducted on journals published in the last 10 years with the aim of producing references that are more focused on the development of the latest problems and solutions. The result of this review show that SBS occur because an environment factor, thermal factor, and psychosocial. Overall, this review provides an appropriate reference for further research by the specific factors about SBS and further symptoms related to SBS affect student learning outcomes.

1. Introduction
Sick Building Syndrome is a term used to describe a situation in which occupants of a building have a health symptoms and discomfort [1]. Sick Building Syndrome is also defined as a health problem caused by chemical and biological pollution in the room, temperature, and humidity, or other factors, which have been recognized as a problem in Western countries since 1970 [2]. Other factors that cause symptoms of Sick Building Syndrome are gender factors, a history of allergic disorders [3,4], and work stress psychosocial [5].

Health symptoms of Sick Building Syndrome such as: eye, nose, throat irritation, headaches, and disorders [2]. The specifications can be categorized into 5 SBS groups namely (1) Eye irritation: tired/tense eyes, dry eyes, itching/ irritation; (2) Nonspecific symptoms: headache, disturbance, drowsiness, stress, nervousness, difficulty in remembering things/ difficulties, dizziness, nausea; (3) Upper respiratory tract: sore throat/ dry throat, clogged nails/ runny nose, coughing, sneezing; (4) Lower respiratory tract: asthma; (5) Skin irritation: dry skin, rash [6-9].

Human spend up their lifetime about 80% inside workplace or in their own homes compared to outdoor [10]. And in a Norback study, 2009 also explained that people in industrialized countries spend about 90% of their lifetime in a room. A high percentage of people spend time indoors, has a high risk of experiencing SBS [11]. One of the risks of SBS experienced is due to air pollution in the room. Gusten and Strindehag (1995) ’s research about air quality that measured volatile organic compounds (TVOC) and CO2 in 185 schools in Sweden revealed that outdoor sources of contamination have an important role in influencing indoor air quality [12]. One of the outdoor contaminations is caused by high air
pollution, such as because an increase in of the vehicles, high population, and industrial practices [13]. Besides that, drastic climate change can also affect the air condition in the room, as a result the occupants in the room will be very at risk of experiencing Sick Building Syndrome, especially in the education environment which is usually in one classroom / building filled with many students.

Based on that, the objectives to be achieved in this literature review are about the ideal air quality for health, and how the results of measuring air conditions in the room in the school building.

2. Theoretical framework

2.1. Sick building syndrome
Sick Building Syndrome is a term used to describe a situation in which occupants of a building experience health symptoms and discomfort [1] Sick Building Syndrome is also defined as a health problem caused by chemical and biological pollution in the room, temperature, and humidity, or other factors, which have been recognized as a problem in Western countries since 1970 [14]. Other factors that cause symptoms of Sick Building Syndrome are gender factors, history of allergic disorders [3], and psychosocial work stress [5]. The following are symptoms that may occur due to SBS, such as: (1) throat irritation, (2) asthma, (3) hard of breathing, (4) flu, (5) allergies: sneezing, (6) dryness, rash, itchy skin, (7) headache, (8) dizziness, (9) difficulty concentrating, (10) forgetting, (11) fatigue, (12) anger, (13) nausea, (14) aches, (15) fever [15,16]. If someone has an allergy or respiratory disease, they may experience more severe symptoms when exposed to SBS [17]. For example, people who have a history of asthma might be at a higher risk of developing asthma because of SBS. The symptoms of SBS experienced by everyone is different. Some people may experience some of the symptoms described, some people may also not experience these symptoms. Some research conducted by experts states that factors that can affect the occurrence of SBS are based on thermal factors, such as: humidity, relative humidity, air velocity, indoor air quality, psychosocial (gender, age, asthma history, smoking habits, and rhinoconjunctivities) [1,2,4,6,11].

2.2. Indoor Air Quality (IAQ)
Indoor air quality (IAQ) has been the subject of many studies due to scientists' increasing concern about the effects of indoor air pollution on health, especially for people who usually spend more time indoors than outside [18]. Indoor air pollution is a combination of contributions from outdoor sources and indoor sources. In some cases, air pollution can contribute to high-rise buildings located near highways or industrial estates [9]. Outside sources enter the building through windows, doors and ventilation systems, affecting indoor air quality. Studies by the US Environmental Protection Agency (EPA) (2006) reveal that the level of indoor pollutants can sometimes be more than 100 times higher than the external level. In addition, certain weather conditions can contribute to room pollution [19,20]. Educational facilities are one of the indoor places that are suspected of having high concentrations of pollutants, this is more serious than other categories of buildings, due to higher occupant density and increased student movement at rest and when changing classrooms. Schools that are directly adjacent to the highway can also affect air quality in the room if the air circulation system in the room is not good [3,21].

2.3. Tropical climate
In modern buildings Heating, ventilation and air conditioning (HVAC) systems have an important role to play in keeping people in them comfortable and healthy. To achieve this goal, HVAC is generally designed with many functions including providing air supply into the room, circulating air, filtering in and out air, and regulating the temperature of the room [22]. HVAC generally consists of blowers to move air, ducting systems to deliver air to each floor and room, and ventilation to distribute it. In addition, there is also an exhaust system, including an exhaust fan to remove dirty air from the room. The exhaust system is placed at a sufficient distance from the air supply system to accommodate good air circulation. In addition, HVAC can also be equipped with air conditioning and heating systems if needed [23].
3. Method

Literature review is conducted on journals published in the last 10 years with the aim of producing references that are more focused on the development of the latest problems and solutions. Various journals were collected through several well-known publications such as Google Scholar, Sage and ScienceDirect. Keywords used in journal search include: Sick Building Syndrome (SBS), Indoor Air Quality (IAQ), the symptom of SBS, the factor of SBS, indoor air pollution, the impact of thermal environment. Each of these journals will be reviewed about what part is studied, the scope of the problem under study, the focus of the research, and the results of the research. There is journal was found from several international journal providers.

Table 1. List of journals as a review literature.

| Source            | Total |
|-------------------|-------|
| Google Scholar    | 20    |
| Sage              | 12    |
| ScienceDirect     | 27    |
| **Total**         | **59**|

Journals obtained were selected based on abstracts, participants, published years, research findings and conclusions. There are 35 journals which have the potential to be studied.

Table 2. Journal reviewed in this study.

| Title                                                                 | Publication |
|----------------------------------------------------------------------|-------------|
| Indoor air quality & SBS in 3 selected Buildings                      | 2012        |
| Personal, Psychosocial, Environmental Factors related to SBS in Official Employees of Taiwan | 2017        |
| Indoor Air Pollution and Human Perception in Public Building in Tiajin China | 2015        |
| Comparing mixing and displacement ventilation in tutorial rooms : Students thermal comfort, SBS, and short-term performance | 2016        |
| Evaluation of indoor air quality and its symptoms in office building – A case study of Mashhad, Iran | 2018        |
| Survey datasets on SBS : causes and effects on selected public in Lagos, Nigeria | 2018        |
| Airbone bacteria levels in indoor environments : The influences of season and prevalence of SBS | 2014        |
| Impact of indoor environment quality of SBS in Indian LEED certified buildings | 2012        |
| Architectural evaluation of thermal comfort SBS symptoms in engineering laboratory | 2014        |
| Indoor Air Quality – A key element of the energy performance of the building | 2015        |
| Prevalence and risk factors of SBS among office workers               | 2013        |
| Outdoor air pollution, meteorological conditions and indoor factors in dwellings in relation to SBS among adult in China | 2016        |
| Office workers SBS and Indoor Carbon dioxide Concentration             | 2012        |
| Prevalence of SBS related symptoms among hospital workers in confined and open working space | 2015        |
| Prevalence and risk factors associated with nonspecific building symptoms in office employees in Japan : relationships between work environment, indoor air quality and occupational stress | 2014        |
| Sick Building Syndrome among junior high school student in Japan in relation to the home and school environment | 2015        |
| Sick Building Syndrome and Sick House Syndrome in relation to psychosocial stress at work in the Swedish workforce | 2012        |
| Work related symptoms in indoor environments : A puzzling problem for the occupational physician | 2014        |
| The prevalence and incidence of SBS in Chinese pupil in relation to the school environment : A two year follow up study | 2011        |
| An examination of factors affect healthy buildings : An empirical study in East China | 2017        |
| Comparative study on the indoor environment quality of green buildings in China with long term field measurement and investigation | 2014        |
| Living in an apartment                                               | 2015        |
| Indoor environmental quality, occupant perception, prevalence of SBS, sick leave in Green Mark Platinum – related vs non Green Mark – related building : A case study | 2015        |
| Physical quality of air and SBS in office employees of “X” company in Jakarta | 2014        |
| The significance of the psychosocial factors of the working environment in the development of SBS | 2014        |
Table 2. Cont.

| Study                                                                 | Year |
|-----------------------------------------------------------------------|------|
| A comparison of the occupant comfort and satisfaction between a green building and conventional building | 2010 |
| A longitudinal investigation of work environment stressors on the performance on wellbeing of office workers | 2016 |
| The impact of the thermal environment on occupant IEQ perception and productivity | 2017 |
| Indoor air quality investigation in code for sustainable homes and passivhaus | 2015 |
| The effect of outdoor air supply rate on work performance during 8-h work period | 2011 |
| The impact of working in a green certified building on cognitive function and health | 2016 |
| Building related health symptoms and classroom indoor air quality: A survey of school teachers in New York State | 2015 |
| Decreased work ability associated to indoor air problems – An intervention (RCT) promote health behaviour | 2015 |
| Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong | 2009 |
| Assessment of school building air quality in a desert climate | 2015 |

4. Results and discussion

4.1. Air quality and health

The air on earth consists of various types of gases and forms a layer of the atmosphere. The pure air composition consists of 78% nitrogen, 21% oxygen, and other gases up to 100%. These various substances can be naturally present in the air (such as forest fires, volcanoes, microorganisms, and chemicals produced by animals and plants) and the results of human activities (exhaust emissions of motor vehicles, industry, even household activities) [20]. In 1976, 29 American Legion Convention participants died of a disease which was finally called Legionaries Disease and later it was discovered that the cause was Sick Building Syndrome. From the survey it is also known that 8,000-18,000 cases of Sick Building Syndrome occur annually in the United States. The high prevalence of SBS in many cases is caused by environmental factors, including: poor air circulation, lighting, high temperatures, cleanliness of the room, and time spent indoors [1, 24]. The most common symptom is headache and fatigue, these symptoms will subside as soon as they leave the room [9, 25, 26]. Paying attention to air quality is very important for health, especially in school buildings, poor air quality will cause SBS symptoms so that it will disrupt learning activities. Then there needs to be attention from various parties to overcome this by improving cleanliness, good flow of ventilation and adequate lighting [3, 27].

4.2. Indoor Air Quality (IAQ) testing

Air quality in a room is known as indoor air quality, which is a scientific field that refers to the quality of air in and around buildings, and is related to the health and comfort of building occupants [10]. There are eight types of indoor air pollutants that are dangerous. Five types of them have acute effects, namely CO, formaldehyde, organic vapors, particulates and microbes and three other types of chronic effects, namely asbestos, radon, and CO2 [28, 29]. However, it does not mean that pollutants other than the above types are not important because there are still adverse effects [25, 28]. Research conducted in Kuwait [13] shows 25 schools out of 46, or 54%, have a significant level of PM10 exceeding the permitted limit. The data clearly shows that PM10 is the main pollutant amid other parameters measured in this study. High levels of particulates can be found in Kuwait, this is due to the frequent sand storms in Kuwait. Based on the results of the average measurements carried out in the two office buildings in Kuwait it was noted that particulate levels were higher than the ASHRAE standard (1513 ppm and 1338 ppm). Among the various non-residential buildings, concentrations that were significantly lower than all pollutants (CO2: 672 ppm; PM2.5: 22.8 lg m 3 and VOC: 0.08 ppm) were recorded in the education building [30].
Table 3. Cited paper in this state of the art study.

| Study                                                                 | Participant                                                                 | Method                                                                                                                                   | Basic Finding                                                                                                                                                                                                 |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Indoor Air Quality and Sick Building Syndrome in Three Selected Buildings [10] | 44 people, 6 people and 13 people who worked at the Pahang Lay Library Association, the Bukit Fraser Progress Comparisons and the Pahang Museum of Art. | A set of structured questionnaires was adopted from ICOP 2010 and later, shared to study the population. The questionnaire included weekly social work, job position, SBS occurrence and air quality in the building. | The PKBF building shows the highest percentage (55.55%) of respondents reporting confirmed symptoms of SBS and can be defined as sick buildings. The second highest is the PPAP Building with 35.25% and then followed by PMA buildings with 20% of the total respondents. Comparison of the prevalence of SBS between the three buildings was done through Chi-square tests. |
| Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong [31] | 100 people, 41 women and 51 men. (Ages 18–29 consisting of 13 people, 30–39 consisting of 23 people, 40–49 consisting of 22 people, 50-59 consist of 19 people, 60–69 consist of 12 people and over 70 consist of 11 people) | To study the relationship between SBS and IEQ perceptions, a self-administered questionnaire (in Chinese), based on SBS and the IEQ literature, was designed to (1) identify symptoms of SBS occupants in apartment buildings and (2) assess occupants perceptions of specific IEQ components and overall IEQ. | Of the 748 households living in Hong Kong, it was found that: (1) upper respiratory symptoms were the most common symptom of SBS even though there was no central ventilation system in the apartment building; (2) noise which is the main problem of IEQ. |
| Assessment of school building air quality in a desert climate [13] | 46 schools selected by gender, in Kuwait.                                    | Indoor air quality tests (IAQ), with measurement points, were carried out for 7 months from October 2012 to May 2013. Testing measured nine parameters, namely nitrogen dioxide (NO2), nitrogen oxide (NO), carbon monoxide (CO), sulfur dioxide (SO2), hydrogen sulfide (H2S), volatile organic compounds (VOC), formaldehyde, carbon dioxide (CO2), and particulate matter (PM10). The daily operational studies for selected schools take between 3.5 and 4 hours during regular school hours. | The results of this study indicate that PM10 concentrations were 54% and CO2 by 24%, which means that the concentrations of both exceeded the standards allowed during school hours which might cause potential health hazards for exposed residents. Other pollution parameters measured in this study are in accordance with the standards. The results of the questionnaire given to students showed a significant correlation between PM10 in the room and the concentration of CO2 and some health symptoms suffered by the students. |
| Building related health symptoms and classroom indoor air quality: A survey of school teachers in New York State [32] | 501 teachers in New York (elementary and junior high school teachers randomly selected) | Questionnaire Survey                                                                                                                     | In this study many class that have the potential to experience symptoms of SBS are related to indoor air quality. And more than 40% of students report at least one health symptom associated with the building every day. Most of the class characteristics that are detrimental are dust, paint odor, mold. Based on the results of the study it is known that green buildings in China have a significantly higher level of satisfaction compared to conventional buildings in the aspects of thermal, visual, acoustic, IAQ and environment. |
| Comparative study on the indoor environment quality of green buildings in China with long term field measurement and investigation [33] | 101 green office buildings built after 2008 located in Beijing, Tianjin and Shanghai | Case study of buildings, measurement of physical parameters.                                                                               |                                                                                                                                                                                                             |
5. Conclusion
One of the problems with Sick Building Syndrome (SBS) is very vulnerable to occur in a room where there are many people at one time. Based on several studies this happens because HVAC systems (Heating, Ventilation and Air-Conditioning) are not routinely checked and maintained. The use of electronic devices with high electromagnetic radiation in a room, including the use of smartphones. The condition of the psycho-social environment is not good, especially in the school or campus environment.

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