ASSESSMENT OF INDOOR AIR QUALITY AND SICK BUILDING SYNDROME IN NEW GOVERNMENT HEADQUARTERS BUILDING OF SELANGOR PUBLIC WORKS DEPARTMENT

BY

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ABSTRACT

In circumstantial “indoor generation”, 90% of the allotted time is spent in the building. While office workers spent 33.3% of their time indoors, giving an average of eight hours in the office building. It is vital for workers to preserve their health, comfort, and well-being, simultaneously optimizing work productivity and job performance in an office. This study aim to determine the indoor air quality (IAQ) condition and prevalence of sick building syndrome (SBS) in the new government headquarters building of Selangor State Public Works Department (PWD) in relation to the office environment and indoor air pollutants. The study investigates the building background, emphasizing the indoor air quality assessment strategies. Real-time measurement techniques were conducted in two-time slot sampling, morning and evening, at 11 sampling points. Indoor air quality measurement carried through identifies the indoor air quality's physical parameters i.e. temperature (^{o}C), relative humidity (% RH), and air movement (m/s), whereas chemical parameters i.e. carbon dioxide (ppm), carbon monoxide (ppm), the volatile organic compound (ppm), formaldehyde (ppm), ozone gas (ppm), and respirable particulates PM_{10} (mg/m^{3}). The physical parameters data findings were analyzed according to the Industrial Code of Practice on Indoor Air Quality (ICOP) 2010, and energy efficiency practice according to Malaysian Standard MS 1525:2019. The results show mean readings for temperature 23.5 ^{o}C, RH 59 %, and air movement 0.15 m/s. Thus, it identifies that the building experience temperature varies and inadequate ventilation. While the chemical parameters results show mean readings for, carbon dioxide 1.21 ppm, carbon monoxide 546 ppm, the volatile organic compounds 0.17 ppm, formaldehyde 0.04 ppm, ozone 0 ppm, and respirable particulates PM_{10} 0.07 mg/m^{3}. The chemical parameters were analyzed according to ICOP, and the results reach the standard requirements, shows the building is devoid of any harmful chemical contaminants. Furthermore, the sick building syndrome (SBS) study investigates the SBS symptoms among office workers associates with the building environment. There were 120 questionnaires distributed to the building occupants to acquire their perception of the building environment. Using SPSS analysis, the result indicates 15.3 % of the building occupants experience SBS symptoms. The analysis includes the potential people exposed to the SBS symptoms, female workers are 63.3 %, pregnant women are 1.3 %, senior citizen workers are 4 %, and workers with medical history like chronic asthma, sinus, and eczema are 21.4 %. Further analysis on SBS symptoms related to the building environment using the Pearson correlation test indicates the significant correlation is 0.001 (<0.01), showing that the building occupants' SBS symptoms are not allied with the building environment. Therefore, the study concludes that the headquarters building of Selangor State Public Works Department is classified as a non-SBS building.

خلاصة البحث

في "التوليد الداخلي" الظرفية، يتم إنفاق 90٪ من الوقت المخصص في المبنى. بينما يقضي موظفو المكاتب 33.3٪ من وقتهم في الداخل، ويمنحون ثماني ساعات في المتوسط في مبنى المكاتب. من الأهمية بمكان أن يحافظ العمال على صحتهم وراحتهم ورفاهيتهم، مع تحسين إنتاجية العمل والأداء الوظيفي في نفس الوقت في المكتب. تهدف هذه الدراسة إلى تحديد حالة جودة الهواء الداخلي (IAQ) وانتشار متلازمة المباني المرضية (SBS) في مبنى المقر الحكومي الجديد لإدارة الأشغال العامة بولاية سيلانجور (PWD) فيما يتعلق ببيئة المكاتب وملوثات الهواء الداخلي. تبحث الدراسة في خلفية المبنى، مع التركيز على استراتيجيات تقييم جودة الهواء الداخلي. كما تم إجراء تقنيات القياس في الوقت الفعلي في أخذ العينات بفترتين، صباحًا ومساءً، في 11 نقطة أخذ عينات. يحدد قياس جودة الهواء الداخلي الذي يتم إجراؤه من خلال المعلمات الفيزيائية لجودة الهواء الداخلي، مثل درجة الحرارة (C) ، والرطوبة النسبية) ٪ (RH، وحركة الهواء (م/ث)، في حين أن المعلمات الكيميائية مثل ثاني أكسيد الكربون (جزء في المليون)، وأول أكسيد الكربون (جزء في المليون)، والمركب العضوي المتطاير (جزء في المليون)، والفورمالديهايد (جزء في المليون)، وغاز الأوزون (جزء في المليون)، والجسيمات القابلة للتنفس PM10. (mg/m^3)تم تحليل نتائج بيانات المعلمات الفيزيائية وفقًا لقانون الممارسة الصناعية لجودة الهواء الداخلي2010 (ICOP) ، وممارسات كفاءة الطاقة وفقًا للمعيار الماليزي MS. 2019 :1525أظهرت النتائج قراءات متوسطة لدرجة الحرارة 23.5 درجة مئوية، رطوبة نسبية 59٪ ، وحركة الهواء 0.15 م / ث. وبالتالي، فإنه يحدد أن درجة حرارة المبنى تتفاوت وأن التهوية غير كافية. بينما تظهر نتائج المعلمات الكيميائية متوسط قراءات لثاني أكسيد الكربون 1.21 جزء في المليون، وأول أكسيد الكربون 546 جزء في المليون، والمركبات العضوية المتطايرة 0.17 جزء في المليون، والفورمالديهايد 0.04 جزء في المليون، والأوزون 0 جزء في المليون، والجسيمات القابلة للتنفس 0.07 PM10 ملغ/م 3. تم تحليل المعلمات الكيميائية وفقًا لـ ICOP ، ووصلت النتائج إلى المتطلبات القياسية، وتبين أن المبنى خالٍ من أي ملوثات كيميائية ضارة. علاوة على ذلك، فإن دراسة متلازمة المبنى المريض (SBS) تحقق في أعراض SBS بين موظفي المكاتب المرتبطين ببيئة المبنى. تم توزيع 120 استبانة على شاغلي المبنى لمعرفة تصورهم لبيئة المبنى. باستخدام تحليل SPSS ، تشير النتيجة إلى أن 15.3٪ من شاغلي المبنى يعانون من أعراض SBS.يشمل التحليل الأشخاص المحتملين الذين تعرضوا لأعرا SBS، والعاملات 63.3٪، والنساء الحوامل 1.3٪، وكبار الموظفين 4٪، والعاملون الذين لديهم تاريخ طبي مثل الربو المزمن، والجيوب الأنفية، والأكزيما 21.4٪. يشير التحليل الإضافي لأعراض SBS المتعلقة ببيئة المبنى باستخدام اختبار ارتباط بيرسون إلى أن الارتباط المعنوي هو 0.001 (0.01>) ، مما يدل على أن أعراض SBS لشاغلي المبنى ليست متحالفة مع بيئة المبنى. لذلك، خلصت الدراسة إلى أن مبنى المقر الرئيس لإدارة الأشغال العامة بولاية سلانجور مصنف على أنه مبنى غير تابع لـSBS .

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Building Services Engineering.

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Shamzani Affendy bin Mohd Din
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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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Thank you Allah for blessing me much more than I deserve.

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LIST OF SYMBOLS

cfu/m^3	Colony Forming Units Per Cubic Meter
CO	Carbon Monoxide
CO_2	Carbon Dioxide
H_2S	Hydrogen Sulfide
HCFC	Hydrochlorofluorocarbon
mg/m^3	Milligrams Per Cubic Meter
NH_3	Ammonia
NO_2	Nitrogen Dioxide
O_3	Ozone
ppm	Parts Per Million
ppb	Parts Per Billion
SO_2	Sulfur Dioxide
VOCs	Volatile Organic Compounds

LIST OF ABBREVIATIONS

ACMV	Air Conditioning and Mechanical Ventilation
ETS	Tobacco Smoke
GBI	Green Building Index
IAQ	Indoor Air Quality
ICOP	Industry Code of Practice of Indoor Air Quality
IEQ	Indoor Environmental Quality
MS	Malaysian Standard
PM	Particulate Matter
VRF	Variable Refrigerant Flow

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

This research focuses on the Indoor Air Quality (IAQ) study of the new government headquarters building of Selangor State Public Works Department (PWD) in Seksyen 17, Shah Alam District. It is a study of indoor air quality assessment associated with indoor air contaminants' chemical parameters, the existence of the sources of indoor air contaminants in the building, and the prevalence of health symptoms related to indoor air quality (IAQ) and sick building syndrome (SBS). In addition, the study includes a discussion on the aspects of the impact on human health, work productivity and performance, and thermal comfort and well-being of building occupants.

1.2 BACKGROUND OF THE STUDY

According to the World Health Organization (2010), Indoor Air Quality (IAQ) defines air quality inside buildings. For example, homes, offices, schools, daycare centers, healthcare centers, or other public buildings where people spend most of their time and activities inside the building and the nature of the air that can determine the person's health and well-being. In addition, indoor air quality can be described as a property of air inside a building consisting of contaminants and thermal concentration that affects occupants' health, comfort, and production (Kamaruzzaman & Razak, 2011). Whereas, according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) defines the acceptable indoor air quality as:

"Air in which there are no known contaminants at harmful concentrations, as determined by cognizant authorities, and with which a substantial majority (80 % or more) of the people exposed do not express dissatisfaction" (ASHRAE 62.1, 2019, p.3).

The primary concern regarding indoor air quality is because most people are currently spending 90 % of their time inside the building either working or being at home (EPA, 2019). While, in the nowadays twenty-first-century community spends 80 % to 90 % of their time indoors either at their workplace or residence (Adebayo et al., 2018; Lu et al., 2015; Profile, 2012). In addition, employed people spend their time from 20 to 60 hours per week in the office which means 3 to 9 hours per day (Wargocki, 2011). A study in Canada reveals that 88.9 % of Canadians spend their time indoors, whereas 5.8 % spend their time outdoors, and the other 5.3 % spend their time in vehicles, which also consider a closed space. The seasonal climate, gender, and age have become the factors contributing to their indoors time (Matz et al., 2014).

Further, indoor air quality in the office environment becomes one of the public concerns as the time spent by an employee in the building is quite long. In developed countries, adults spend about 8 to 10 hours in an office building as part of their work responsibilities. A previous study showed that USA adults spend 18.2 % of their time indoors in office buildings, which means they spend around 5 hours per day in an office building. In comparison, adults in European countries spend about 28 % of their time in an office building, about 7 hours a day. Even though the percentage represents were low, people in the office building are much higher than in other places like homes and schools. Indoor pollutants in office buildings are mainly related to outdoor sources like traffic emission, industrial emission, and construction activities which infiltrate through the building's gaps and openings like doors, windows, and buildings structures. What makes the matter worse is these outdoor emissions are generated during the daytime,

which is happening during working hours. Indoor pollutants in office buildings contribute to human activities and office equipment such as computers, printers, and photocopiers. The building condition may impact work performance among the staff and poor ventilation rates adding to the uncomfortable environment as most office buildings are well equipped with air conditioning and mechanical ventilation systems (Ioar et al., 2019). In addition, providing a pleasing working environment to the employee shall be the main characteristic to improve work efficiency and boost satisfaction. Thus, exposure to indoor air is more significant to control than outdoor air (Kamaruzzaman & Sabrani, 2011).

There are many reasons indoor air can contaminate. The sources might come from outdoor contaminated air associated with vehicle emissions and smoke from industrial activities that can enter the building through infiltration by natural ventilation such as a louvered window or between building gap and mechanical air-conditioning and ventilation system. Besides, indoor air also can be contaminated by building occupant's activities, for example, through combustion activities such as burning fuels, coal, tobacco products, and candles, gas emissions from building materials and furnishings, electronics appliances, household cleaning products, and pets (Leung, 2015). However, the most encountered causes of contaminated indoor air are lack of maintenance and inadequate air-conditioning and ventilation systems. For example, insufficient fresh air intake into the buildings will lead to the humidity problem (Kamaruzzaman & Razak, 2011; Norhidayah et al., 2013).

Consequently, this contaminated air inhaled by our body enters our lungs and finally into the bloodstream. Poor indoor air quality effects include irritated eyes, nose, sinus, and throat (ASHRAE, 2019). Other examples of poor indoor air quality are cough, tight chest, wheeze, or difficulty in breathing (Norhidayah et al., 2013).

Therefore, the term SBS explains circumstances in which building occupants experience discomfort and severe health because of the time spent in the buildings. The common complaints regarding the SBS symptoms from the building occupant include headache, irritation of throat and skin, and dry cough. However, those symptoms will soon get relief after leaving the workplace. The previous study reported that 20-30 % of the building occupants experienced sick building syndrome symptoms in office buildings. It is an important issue to highlight in occupational medical studies since 50 % of the entire workers in industrial countries spend their time working in office buildings (Fauzan et al., 2016).

Further, inadequate ventilation varies in temperature and humidity. Therefore, chemical and biological contaminants in the office building could cause discomfort, lower work efficiency (Abdel-Hamid et al., 2013), and reflect economic losses (Gou & Siu-Yu Lau, 2012). According to the United States, Environmental Protection Agency, the financial implication of poor indoor air quality and SBS associated with discomfort, illness, and low employee productivity in office buildings could cause an approximate loss of the USA $10 billion in a year. On the other hand, by improving the indoor air environment, it is estimated that the United States could have productivity gain and potential annual savings by the USA $29 to $168 billion. In addition, the reduction of employee absenteeism could have a net savings of USA $400 per employee per year. In Europe, improving productivity due to indoor quality could benefit EUR 330 per year for each employee (Wargocki, 2011).

Indoor air quality and SBS issues have been highly reported in office buildings fully equipped with centralized air conditioning and mechanical ventilation systems (Zamani et al., 2013). Hence, controlling the inflow and outflow of air into the building provides a comfortable and safe working environment to the employee, who becomes

the main factor in increasing work productivity and employee satisfaction index (Shin et al., 2018).

Thus, the international standard and guidelines in indoor air quality and sick building syndrome have been produced and used widely around the globe to look after the welfare of the employees or building occupants. The listed standards and guidelines are World Health Organization (WHO) of Guidelines for Indoor Air Quality, ASHRAE Standard (American Society of Heating, Refrigerating and Air-Conditioning Engineers), and National Ambient Air Quality Standards (NAAQS) by the United States Environmental Protection Agency.

Adapted to the Malaysian climate and perspectives, the Industrial Code of Practice on Indoor Air Quality (ICOP) (2010) has been published by the Department of Occupational Safety and Health Malaysia (DOSH). The code proposed the selected indoor air quality parameters and their acceptable limits to prevent the building occupant from the prevalence of symptoms from Sick Building Syndrome (SBS). Further, a guideline by the Public Work Department of Malaysia (PWD) on Indoor Environmental Quality (IEQ) for Government Office Building (2013) was implemented widely in Malaysia to provides comfort and prevent the occurrence of health problems to the building occupant, especially to government office buildings.

1.3 PROBLEM STATEMENTS

Poor indoor air quality can have a negative impact on occupant health (Billionnet et al., 2012; Mitchell et al., 2015; Sakellaris et al., 2021; Wolkoff, 2018). A previous study found that specific health effects of poor indoor air quality in buildings are cancer, respiratory illness, and cardiovascular disease (Hoskins, 2010; Maynard, 2019; Seppänen & Fisk, 2006). This effect is due to the concentration of air pollution in the

building's environment. The air pollutants in the indoor space come from industrially produced substances, chemical products, bacteria, mould, radon, dander, pollen, and smoke. In 2020, the world was outbreak by the virus called Covic-19, which is one of the viruses from the class of biological pollutants from the wide-ranging category of indoor air pollutants. Hence, it makes the indoor environment more polluted than the outside air (D'Antonio, 2021). Indoor air pollutants such as respirable particulate, carbon monoxide, ozone gases, and volatile organic compounds at higher concentrations can be more dangerous than the outside air. These pollutants can significantly affect the building occupants (Cheek et al., 2021). Thus, many studies say that prolonged exposure to indoor air is more life-threatening than outside Saini et al., 2020). The previous research also claimed poor indoor air quality could cause higher absentees to the workplace due to health problems (Singh et al., 2010; Thatcher & Milner, 2012). Absentees or sick leave could cause losses to the employer to cover health expenses and deductions to the operations (Tham et al., 2015).

In addition, poor indoor air quality in an office building can reduce works productivity, performance, comfort, and well-being (Al horr et al., 2016). For the past 30 years, studies have proved that indoor air pollutants could significantly impact building occupants, including comfort, wellness, and work performance (Tham, 2016). Furthermore, indoor air quality issues vary with the air pollutants, either indoor or outdoor air, which impact building occupants in terms of comfort and performance, leading the organizations to fall (Ibrahim, 2015). Hence, much contemplation is given to indoor air quality issues in office buildings as a deep concern of employee well-being and work productivity. Moreover, the study proved that the employees' productivity always depends on employee satisfaction towards their work environment and comfortable workspace. Thus, a better building environment and workspace would