INDOOR AIR QUALITY ASSESSMENT – CASE STUDY AT MENARA KERJA RAYA KUALA LUMPUR

BY

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ABSTRACT

Indoor Air Quality (IAQ) generally may be defined as the nature of air that affects the health of the occupants in the building. Poor IAQ in the office buildings has been found to be associated with lower productivity, higher absenteeism, higher spending in health insurance, and a higher rate of a compensation claim. This research sought to investigate on Indoor Air Quality (IAQ) condition of the platinum Green Building Index (GBI) certified green buildings known as Menara Kerja Raya in Malaysia using post-occupancy evaluation. Comparison of the IAQ assessment parameter which refer to Industry Code of Practice (ICOP) 2010 with what prescribed in GBI guideline also been made. The methodology adopted in the study involves the on-site measurement of nine (9) IAQ parameter at eleven (11) floors and seventy-four (74) points of sampling. Nine IAQ (9) parameter investigated were Temperature, Relative Humidity, Air Flow, Carbon Dioxide (CO2), Carbon Monoxide (CO), Formaldehyde, Total Volatile Organic Compound (TVOC), Respirable Particulate, and Ozone. The data collection were analysed according to ICOP 2010 requirement. In general, the findings show that IAQ conditions varies across floor level, and office spaces layout, however, most of the floor meet the requirements of available standards ICOP 2010. This result was anticipated as Menara Kerja Raya was a new facility and designed to meet green building criteria especially on building material, system, office equipment, furniture and finishes. Finally, the findings show IAQ requirement presently prescribed in Malaysia's GBI was sufficient as the most prescription in GBI indicated that major IAQ element in ICOP 2010 had taken into account. Improvement of the GBI prescription in GBI scheme for IAQ section was been identified and highlighted so that IAQ condition in green building can give ultimate comfort and healthy environment to occupants.

خلاصة البحث

يمكن تعريف جودة الهواء الداخلي عموما كطبيعة الهواء الذي يؤثر على صحة شاغلي المبنى. وقد تبين أن رداءة جودة الهواء الداخلي في المباني المكتبية مقترنة بانخفاض الإنتاجية ، وارتفاع نسبة التغيب ، وارتفاع الإنفاق على التأمين الصحي، وارتفاع نسبة المطالبة بالتعويض. ويسعى هذا البحث إلى فحص جودة الهواء الداخلي وحالة البلاتين مؤشر المباني الخضراء (جي بي أي) المعروف في ماليزيا باسم برج العمل، من خلال التقييم بعد شَغل المباني الخضراء. ومقارنة تقييم عوامل جودة الهواء الداخلي التي يشير إليها قانون ممارسة الصناعة (ICOP) 2010 مع ما هو منصوص عليه في التوجيه المبدئي (جي بي أي). والمنهجية المتبعة في هذه الدراسة تتضمن قياس تسعة (9) معالم لجودة الهواء الداخلي في الطابق الحادي عشر (11)، و أربعة وسبعين (74) نقطة من العينات. ومعامل جودة الهواء الداخلي التسعة(9) لمؤشر المباني الخضراء التي تم فحصها هي درجة الحرارة، والرطوبة النسبية، وتدفق الهواء، وثاني أكسيد الكربون (CO_2)، و "أول أكسيد الكربون" (CO)، وفورمالدهايد، ومجموع العضوية المركبة المتطايرة (تبوك)، والجسيمات القابلة للاستنشاق، والأوزون. وتم تحليل البيانات المجمعة وفق شروط (ICOP) 2010. وأظهرت النتائج بصفة عامة، أن جودة الهواء الداخلي تختلف من طابق لطابق، وحسب تخطيط مساحات المكاتب، ومع ذلك فإن معظم الطوابق تفي بمتطلبات المعايير الموجودة في (ICOP)2010. وهذه النتيجة متوقعة لأن برج العمل يعتبر منشأة جديدة ومصمم لتلبية معايير المباني الخضراء خصوصا في مواد البناء ، والنظام، والأدوات المكتبية، والأثاث، والتشطيبات. وأخيراً، أوضحت النتائج أن جودة الهواء الداخلي تفي بالشرط المنصوص عليها في (جي بي أي) ماليزيا ، وتشير إلى أن معظم عناصر جودة الهواء الداخلي المذكورة في (ICOP)2010 قد أخذت في الاعتبار. وقد تم التعرف على تحسين (جي بي أي) المنصوص عليها في مخطط (جي بي أي)، وتم تسليط الضوء عليها من أجل أن يوفر الهواء الداخلي في المباني الخضراء الراحة القصوى ، والبيئة الصحية للموظفين.

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.

……..
Maisarah Ali
Supervisor

I certify that I have 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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Abdul Razak Sapian
Dean, Kulliyyah of Architecture
and Environmental Design

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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Signature ..... Date .....

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Signature Date

All praise be to Allah,

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Firstly, it is my utmost pleasure to dedicate this work to my dear parents Romlah binti Mamat and Ismail bin Hussein, my wife Adzriana binti Abd Aziz, my four little princess Irsya Arrania, Izzah Azzahra, Imani Annadwa, Imara Alleyah and all my family members, who granted me the gift of their unwavering belief in my ability to accomplish this goal: thank you for your support and patience.

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LIST OF ABBREVIATIONS

A/C	Air-Conditioning
ACMV	Air Conditioning and Mechanical Ventilation
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EQ	Environmental Quality
GBI	Green Building Index
IAQ	Indoor Air Quality
ICOP 2010	Industry Code of Practice of Indoor Air Quality 2010
IEQ	Indoor Environmental Quality
RH	Relative Humidity
TVOC	Total Volatile Organic Compound

LIST OF SYMBOLS

cfu/m^3	colony forming unit per cubic meter
mg/m^3	miligrams per cubic meter
^oC	degrees Celsius
ppm	parts per million
T	temperature

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Indoor Air Quality (IAQ) generally may be defined as the nature of air that affects the health and perceptions of the occupants. This definition incorporates the concept of health in the constitution of the World Health Organization (WHO): 'Health is a state of complete physical, mental, and social well-being, and not merely the absence of diseases of infirmity. Using ventilation to dilute contaminants, filtrations, and source control are the primary methods for improving indoor air quality in most buildings. In the early IAQ, where mechanical systems were not available to ventilate the buildings, man relied on natural ventilation to meet those needs. Caves with smoke exits, the castle with cleverly designed fireplace drafts, and the American Indian tepee were examples of early methods to control the indoor environment.

Since oil embargoes crisis of 1970's, there are concerns over the accessibility of supplies from the Middle East. Several factors have arisen to affect the way building are managed, cost of owning and operating of building increased, and shortage of fossil fuel products have repeatedly occurred in the United States and other high fuel usage countries. As a result of these factors, change in design and operation of the building have taken place throughout the world. Some of the changes have certainly been beneficial, such as reduced energy consumption and operating costs. Unfortunately, some of the changes have caused discomfort or had other adverse effects for the building occupant due to indoor contaminants. In 1981, IAQ concern for the health of the occupants in the construction was conveyed by National Research Council in 1981 report. Basic reason about IAQ are: Energy conservation

efforts have tended to reduce the amount ventilation to dilute contaminants, a technique for measuring occupant exposed to contaminants has improved, widespread sources of contaminants exist indoor and outdoor, awareness by the general public of the impact of IAQ on health has increased.

In the recent years, the green building concept is popular to reduce its environmental footprint because conventional buildings contribute more global greenhouse gas emissions, mainly due to the use of fossil fuels for energy generation. Green Building, also known as sustainable building, is a practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building cycle (US EPA 2014). Green building refers to the structures created using the principles and methodologies of sustainable construction, which aims to construct energy efficient, healthy and productive buildings that reduce the significant impact of buildings on urban life and the global environment. Pioneering work on green building certification was achieved in the 1990s in Europe and the United States. Following this development, many countries worldwide have joined the green building effort in the past decade and developed green building schemes adapted to their national economic and environmental conditions.

1.2 PROBLEM STATEMENTS

Poor IAQ in the office buildings has been found (Singh 2010, Ries R 2006, Loftness 2006, Thatcher 2012) to be associated with lower productivity, higher absenteeism, higher spending in health insurance, and a higher rate of the compensation claim. Many causes contribute to the bad IAQ in the office building.

Poor IAQ can be due to a series of thermal discomfort (Frontczak and Wargocki, 2011). Many studies have found that most air- conditioned buildings with a

centralized system are often thermally too cold (Wong et. al., 2007 and Auliciems, 1972). According to Shaharon and Jalaludin (2012), recent developments in the field of thermal comfort have led to renewed interest in the issue of workers' comfort and workspace quality in office space by the Malaysia government. Hence conditions, where occupant feels too cold or too hot, will have a negative effect on such person thereby lowering their productivity with an adverse effect on economic and social indices.

Poor IAQ also can be due to indoor air contaminants that caused health effect to the occupants in the buildings. (Rahman 2014). Many studies have found that indoor air pollutants can cause health problems such as allergy, respiratory problem, eye irritation, severe headaches, skin rashes, dizziness, sinusitis, bronchitis, and pneumonia. (Ongwandee et al., 2009, Mahbob 2013, Wyon 2004, Kosonen 2004). Existing of indoor air pollutants indoor is due to that the modern office nowadays is surrounded by high technology equipment, artificial lighting, synthetic carpeting, wall coverings and air conditioning, which have influenced the indoor air quality in the buildings (Vitel, 2001).

Sick Building Syndrome is the name that has commonly been used for illnesses that occur among occupants as a result of poor IAQ. Hansen (1991) have found that office building can be categorized as sick building if at least 20 % of the occupants show symptoms of illness without apparent cause and the symptom will disappear once the occupant leaves the building. The symptoms of Sick Building is subsequently giving negative image to the owner of the building, lower the tenancy demand, and lower productivity at the workplace as people tend to get medical leave from time to time.

According to US Environmental Protection Agency (EPA), the trend of occupants spending 90% and more time indoor eventually has received increasing interest. A study also has revealed that stay in indoor is a no longer healthy environment where indoor air pollutants concentration is higher than outdoor (Chen Zhao 2011). Therefore the measurement of thermal comfort-related parameters and the levels of IAQ contaminants in the green building is crucial. This complied with the American Society of Heating, Refrigerating, and Air-conditioning Engineers, (ASHRAE) Standard 62-1989, where acceptable air quality is "Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and which a substantial majority (80% or more) of the people exposed do not express dissatisfaction, This definition implies compliances is required with both objective criteria (i.e., measured concentrations of contaminants) to prevent illness and subjective criteria such as individual perceptions and comfort.

A variety of green building certification systems worldwide has incorporated the IAQ as a category of evaluation. For example the Leadership in Energy and Environmental Design (LEED) of the US, the GREEN STAR of Australia and the Building Research Establishment Environmental Assessment Method (BREEAM) of the UK, and Green Building Index (GBI) of Malaysia. A study reveals that the global average contribution of IAQ in green building certification only represents 7.5% (W.Wei 2015) and contribution of indoor environmental quality is 21% of the criteria (GBI Organisation, 2010). This study shows that the certification for green building in many countries seems to target more on the lesser use of energy. As a matter of fact, the question of the schemes currently applied in green building certification fostering buildings of IAQ satisfying their occupants is remains an issue.

Therefore, the study for Menara Kerja Raya, the first government office building to receive platinum of Malaysia's Green Building Certificate was unique in that it presented a thorough evaluation on the IAQ of green buildings certified primarily to target a lesser use of energy. The post-occupancy evaluation employed in the study consist of walk-through survey and on-site measurements.

1.3 RESEARCH QUESTIONS

This research has the following questions which to be answered at the end of it.

i. What are the type of indoor air contaminants that exist and where are the sources?
ii. What are the conditions of IAQ in the building?
iii. Is the physical and chemical parameter found in line with GBI guideline?

1.4 RESEARCH AIM AND OBJECTIVES

The aim of this study is to evaluate the IAQ condition of Menara Kerja Raya green buildings office which primarily to target a lesser use of energy, and determines the acceptable IAQ parameter conditions of the air condition office spaces. Problem statement and aim above led to the formulation of research objectives to achieve as follows:

i. To identify the sources of the indoor air contaminants.
ii. To investigate physical and chemical parameter of IAQ in the building.
iii. To compare the IAQ parameter assessed with what prescribed in Malaysia's GBI guideline.

1.5 OVERVIEW OF RESEARCH METHODOLOGY

In this dissertation, a comprehensive review of the previously work done by researchers regarding IAQ has been carried out. Toward achieving the objectives of this study, assessment has been conducted at the Menara Kerja Raya office spaces.

This study adopted a post occupancy assessment. A survey and experimental study have been performed at selected eleven (11) floors of central air- conditioned office spaces in the Menara Kerja Raya office building. From these floors, seventy-four (74) points were chosen based on Industry Code of Practice on Indoor Air Quality (ICOP 2010). At each points, the performance of the Menara Kerja Raya in IAQ was evaluated in the following parameters: Air Temperature, Relative Humidity, Air Flow, Carbon Dioxide (CO2), Carbon Monoxide (CO), Total Volatile Organic Compound (TVOC), Formaldehyde, Ozone, and Respirable Particulate by using portable monitoring equipment and devices.

Measurement and analysis of IAQ parameters were carried out according to the Industry Code of Practice on Indoor Air Quality 2010 (ICOP 2010). For the measurement, this code of practice gives further guidance on sampling strategy, sample position, sampling period, and sampling technique during the measurement. For results of data recorded, the analysis has been compared whether all parameters levels complied within the threshold and acceptable limit of IAQ parameter provided by this code of practice.

The assessment according to ICOP 2010 is compared with the Green Building Index (GBI) scheme and justify whether GBI currently applied in green building certification met the IAQ requirement and needs. Discussion on the findings were presented and recommendations of improvement of GBI made.

1.6 SIGNIFICANCE OF THE STUDY

The findings of this study helped in determining the actual condition of IAQ in Green Building Office at the post occupancy stages; thus to ensure occupants are protected from poor IAQ that could adversely affect their health and well-being, and thereby reduce their productivity. Consequently, the assessment will give the building owner the actual condition of the building regarding IAQ and if any contaminants detected, the urgent measures were provided for improvement of IAQ in the building.

IAQ parameters assessments found were compared with Malaysia's GBI certification. The study helped to justify whether GBI currently applied in green building certification met with IAQ requirement and needs. Recommendation of improvement of GBI made. This eventually gave future references to a new study of IAQ parameters of Green Building Office.

1.7 STRUCTURE OF THE THESIS

This thesis is divided into five chapters as shown in figure 1.1. These chapters include: 1. Introduction; 2. Literature review; 3. Methodology; 4. Result and discussion; 5. Conclusion and recommendations.

Chapter 1: Introduction. This chapter provides the study background, problem statements, research question, aim and objective, significance of study, structure of thesis and the summary.

Chapter 2: Literature review. The core part of the preliminary of the study which presents a review of the relevant literature on the indoor air quality, thermal comfort, contaminants, source and symptoms, green building and green building certification in Malaysia; which are basis for step by step investigation procedures and execution of the study.

Chapter 3: Research methodology. This chapter describes the methods applied in this research with an investigation and measurement. It commences with the survey building selection along with detailed descriptions of the building, as well as instruments, and measurement protocols.

Chapter 4: Results and Discussion. This chapter presents the data collected from the field study including the analysis. Results and discussions from the measurement examined and GBI requirement of the building observed with measurement during the field works.

Chapter 5: Conclusion and Recommendations. This chapter summarizes the research work and includes future study recommendations.

Figure 0-1: Structure of Thesis