UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ASSESMENT ON INDOOR AIR QUALITY ANALYSIS IN PORTABLE CABIN AND TRADITIONAL BUILDING CLASSROOM

This report is submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Refrigeration and Air-Conditioning System) (Hons.)

by

HAQEEM SHAH FIRDAUS BIN HJ. SHAMSUSAH

B071410475

950707105797

FACULTY OF ENGINEERING TECHNOLOGY

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DECLARATION

I hereby, declared this report entitled Assessment on Indoor Air Quality in Portable Cabin and Traditional Building Classroom is the result of my own research except as cited in references.

Signature	:	……
Author's name	:	HAQEEM SHAH FIRDAUS BIN HJ.SHAMSUSAH
Date	:	12 DECEMBER 2017

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirement for the degree of Bachelor of Engineering Technology (Refrigeration and Air Conditioning) (Hons.). The member of the supervisory is as follow:

DR. MOHAMMAD HAIDIR BIN MASLAN

(Project supervisor)

ABSTRAK

Kajian telah mendapati kadar kualiti udara dalaman (IAQ) mampu menjejaskan masalah kesihatan sama ada jangka pendek ataupun jangka panjang terutamanya di kalangan kanak-kanak dan warga tua. Kurangnya pemantauan dari pihak berkuasa tempatan berkaitan isu keselamatan dan kebajikan kesihatan persekitaran ruangan dalaman merupakan salah satu faktor yang menyumbang pada permasalahan ini terutamanya di sekolah. Kajian ini dijalankan untuk mengenalpasti status IAQ dalam bilik darjah mudah alih di Adni Bangi School serta membandingkan status IAQ dengan bilik darjah yang munggunakan batu bata serta simen sebagai struktur asas bangunan di Sekolah Kebangsaan Bukit Beruang. Antara parameter kualti udara yang diambil adalah suhu udara, kelembapan relatif (RH), karbon dioksida (CO_2), karbon monoksida (CO) serta bahan zarah (PM_{10}) diambil ketika waktu sesi persekolahan. Data kualti udara dalaman yang diambil kemudiannya dibandingkan dengan kod amalan industri tentang kualiti udara dalaman 2010 (ICOP IAQ 2010) dan didapati bahawa kepekatan CO_2 di bilik darjah Adni Bangi School menjangkaui had yang dibenarkan dengan kadar purata untuk 8 jam pendedahan sebanyak 1619.4 ppm. Sementara itu, bilik darjah di Sekolah Kebangsaan Bukit Beruang menunjukan suhu udara serta kelembapan relatif melebihi piawaian ICOP 2010 disebabkan oleh pengunaan sistem pengudaraan semulajadi yang bergantung kepada cuaca luar. Ini menunjukan bahawa sistem pengudaraan yang tidak mencukupi, susun atur bilik darjah yang kurang baik serta bilangan penghuni menjejaskan kadar kepekatan karbon dioksida di bilik darjah mudah alih. Diharapkan kajian ini dapat membantu penyelidik yang akan datang ataupun pemaju bangunan menjadikan kajian ini sebagai garis panduan untuk mengawal status IAQ untuk menyediakan suasana persekitaran dalaman yang lebih mesra serta mengurangkan risiko masalah kesihatan dalam kalangan penguni.

ABSTRACT

Studies have found that the quality of the indoor air affects the short term or long term health problem especially among children and elderly. Lack of supervision from local authorities regarding the safety and health welfare of indoor environment and quality become one of the main factor to this matter especially in schools. This study was carried out to determine the indoor air quality (IAQ) status for the portable cabin classroom in Adni Bangi School and compare the IAQ status with a classroom that use bricks and cement as the classroom structure in Sekolah Kebangsaan Bukit Beruang. IAQ parameters such as air temperature, relative humidity (RH), carbon dioxide (CO_2), carbon monoxide (CO) and particulate matter (PM_{10}) were measured during the assessment during the school hours. The IAQ results were compared with the industry code of practice (ICOP 2010) and it was found that the concentration of CO_2 in Adni Bangi School classroom exceed the allowable limit which the average mean for 8 hours exposure is 1619.4 ppm. Meanwhile the classroom in Sekolah Kebangsaan Bukit Beruang shows that the air temperature and RH is beyond the ICOP 2010 limits due to natural ventilation system that totally depends on the outside weather. It shows that inadequate ventilation system, poor classroom layout and number of occupants affects the concentration of CO_2 in the portable classroom. It is hope that the study will able help future researcher or building developer to use it as a guideline to control the IAQ status to provide friendlier indoor environment while reducing the risk of health problems among the occupants.

DEDICATION

This research work is dedicated to my beloved parents, Mrs. Mimi Asita Binti Abdul Hamid and Mr. Hj.Shamsusah Bin Zainal Abidin for their endless love, moral and financial support. May ALLAH always showered His blessing upon them.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

IAQ	-	Indoor Air Quality
IEQ	-	Indoor Environment Quality
DOSH	-	Department of Safety and Health
ICOP	-	Industry Code of Practice 2010
SBS	-	Sick Building Syndrome
VOC	-	Volatile Organic Compound
CO_2	-	Carbon dioxide
CO	-	Carbon monoxide
%RH	-	Relative humidity
PM_{10}	-	Particulate matter up to 10 micrometers in size
ASHRAE	-	American Society of Heating, Refrigerating and Air-Conditioning Engineers
HVAC	-	Heating, Ventilation and Air-Conditioning
ABS	-	Adni Bangi School
SKBB	-	Sekolah Kebangsaan Bukit Beruang
SBS	-	Sick Building Syndrome
UTeM	-	Universiti Teknikal Malaysia Melaka
ppm	-	parts per millions
mg/m^3	-	milligram per meter cube
°C	-	Degree Celsius
Max	-	Maximum
Min	-	Minimum
SD	-	Standard deviation
ERV	-	Energy Recovery Ventilator
TWA	-	Time weighted average

CHAPTER 1
INTRODUCTION

This section discuss the overall intention of the study. It serves as an orientation for readers to understand the detailed information in later sections. It includes the background of study, problem statement, objectives of the study, the scope and limitation of the study.

1.1 Background study

Indoor air pollution has been recognized as one of the most serious global environmental problems. Most individuals are not aware on status of indoor air quality, thus this may at certain extend affect towards their health and comfort. It is essential for human to receive clean environment and good air quality since we spend up to 90% of daily time indoors (Lee and Chang, 2000). Some of the building developers failed to follow the proper guidelines on design and installation work, maintenance and operations of ventilation system. The developers' primary objective besides completing the task is its cost effectiveness and maximizing profit regardless of the air quality outcome.

Moreover, the poor indoor air quality (IAQ) problem arise because of occupant activities within the building can lead environmental effect and make the matter worse. In July 2005, the Department of Occupational Safety and Health (DOSH) launched a code of practice on indoor air quality. One of the objectives of the code was to set maximum exposure limit for indoor air contaminant (DOSH, 2005). Lack of attention on IAQ can increase the long-term and short-term health problem. Recent study has found that indoor air quality affects human health especially children and elderly more compared to ambient atmospheric air (Marzuki Ismail, Nur Zafirah Mohd Sofian, 2010). Many factors affect the IAQ levels such humidity level,

temperature, ventilation rates and also the existence of indoor air pollutants including carbon dioxide (CO_2), carbon monoxide (CO), and volatile organic compound (VOC). All of this parameter will cause occupant discomfort and health problems if the level and concentration is not in the acceptable range. Building authorities should observe the parameters to ensure a healthy environment deliver to occupants.

However, there is still lack of concern on IAQ status in buildings especially in schools. A properly maintained mechanical ventilation system able to provide thermal comfort and healthier environment to occupants. Seppanen and Fisk (2002) claimed that air-conditioned or mechanical ventilation system in buildings will increase in prevalence of sick building syndrome (SBS) between 30% and 200% compared with natural ventilation systems. Although the building standards and guidelines may be met, the problem regarding the quality of indoor air still exists if the building used air-conditioned or mechanical ventilation system.

Majority of government schools in Malaysia used natural ventilation system since the installation and operating cost is much lower compared to mechanical ventilation systems. The numbers of private schools and institute have significantly increased throughout the year as the Malaysian government goal to increase number of preschool education as well as primary school. This encourages more private bodies to set up primary schools with various types of refurbished buildings (Salleh, 2010). Some schools authorities use portable cabins to build classrooms because they want to cut the cost and time to build the structure compare to the traditional building material such as brick and cement. Portable cabin known as versatile building structure because it suitable to use for any building proposes including offices, house, homestay, shops, classroom and etc.

Previous study on IAQ for the portable classroom found that there always problems regarding to the ventilation rates and high concentration of VOC's and indoor air pollutants within the portables. Although there are many studies have been conducted about IAQ in classroom, there is little information for IAQ in portable cabin classroom. This study aimed to determine the actual indoor air quality status for portable cabin and traditional building classroom and compare both IAQ statuses with existing IAQ standards.

1.2 Problem statement

Indoor air quality always become problem for a building that using split unit air conditioning system or mechanical ventilation system. The problem become worse for portable cabin type building as ventilation is very poor. Now days, many people use portable cabin or shipping container as a building material because it is cheap and less time consuming to build. Children require good indoor environment since IAQ is very important for growth and wellbeing.

Poorly maintained building will lead to severe health problems including the sick building syndrome (SBS). This syndrome have tendency to increase absenteeism and reduce the performance of the students. For this research, the two main issues regarding the usage of portable cabins as classroom are poor ventilation systems and presence of organic material in the building.

During the first walkthrough survey in the selected private school, it was found that the portable cabin classroom does not have enough ventilation systems. Majority of the classroom located at the second floor of the portable cabin building. The entire classroom windows were sealed tight because the school authorities want to avoid accident or fatal occur because the children might try to climb over the window. Less fresh air intake will probably cause poor indoor air quality in the classroom as the air is circulated within the space. The only ventilation was the infiltration. This will increase the concentration of indoor contaminant including the carbon dioxide (CO_2) and volatile organic compound (VOC). During the second walkthrough inspection, there is no major problem regarding to the potential indicator of IAQ issue in the selected government school that uses bricks and cement as the classroom structure due to the usage of natural ventilation system.

This study was focused to reveal the status on IAQ in portable cabin and compare with existing classroom that use bricks and cement as the classroom structure. This study will help to increase awareness on the importance of maintaining good IAQ and provide healthier environment to the children.

1.3 Objectives

1.3.1 Main objective

To determine the Indoor Air Quality (IAQ) status for portable cabin and traditional building classrooms in selected primary school

1.3.2 Specific objectives

1) To measure the level of IAQ parameters including air temperature, relative humidity (RH), carbon dioxide (CO_2), carbon monoxide (CO), particulate matter (PM_{10}) and volatile organic compound (VOC)

2) To compare and analyze the IAQ status between portable cabin classroom and traditional building classroom

3) Asses the measured parameters by comparing with existing standard such as Industry Code of Practice on Indoor Air Quality 2010 (ICOP 2010)

1.4 Scope and Limitation of Study

A cross sectional study was carried out at private preschool, Adni Bangi School (ABS) located in Bangi, Selangor on September 2017 and at government school, Sekolah Kebangsaan Bukit Beruang (SKBB) situated in Ayer Keroh, Melaka on October 2017. This study involved the measurement of IAQ parameters in selected classroom. Five IAQ parameters were measured by using IAQ measuring instrument including:

- Air temperature
- Relative humidity (RH)
- Carbon dioxide (CO_2)
- Particulate matter (PM)
- Carbon monoxide (CO)

The outcomes of the sampling were compared with ICOP (2010). The standard specifies the minimum ventilation rates and measure for new and existing buildings to provide acceptable indoor air quality. There is limitation in this study. Volatile organic compound (VOC) was not measured due to equipment constraint.

CHAPTER 2

LITERATURE REVIEW

This section will be focusing on the theory and literature by the previous researcher that performed the similar case study. This section aim to provide understanding about this study and why this research need to be done. There are many study related have been conducted on indoor air quality (IAQ) for classroom in Malaysia and almost none in portable classroom. There are brief information on air conditioning systems, ventilation system, IAQ, IAQ parameters, relationship between rate of ventilation and IAQ, portable cabins, portable cabin as a classroom and method to improve IAQ in portable classroom.

2.1 Air Conditioning System

Air conditioning is a combined process that performs many function simultaneously by controlling the temperature, humidity, air movement, air cleanliness, sound level and pressure differential in a space within predetermine limits for the comfort and health of the occupants of the conditioned space or for the purpose of product processing (Wang, 2001). Almost all building use air conditioning to provide comfort and healthy environment to the occupants. A properly functioning air conditioning system will provide thermal comfort to occupants and remove odors and contaminants inside a building. Although air conditioning is widely use in improving thermal comfort but poor indoor air quality can lead to various health problem that cannot be avoided (Niu, 2004).

2.2 Ventilation system

To provide adequate amount of fresh and circulate air, ventilation system is required. Circulation of air in a building is important to dilute and remove odors, contaminant and keep the air consistence within the building. Based on the previous study on quality of indoor air, most of the researchers conclude that the biggest issue that promotes to poor indoor air quality is the inadequate ventilation system in the space. American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) have developed a ventilation standard for acceptable indoor air quality. The ventilation system plays a major role to improve the quality of the indoor air.

There are two types of ventilation system; natural and mechanical ventilation. Cracks and fissures in building will allow air from the outside to penetrate to the building in a constants air flow. This air flow, together with air flow through the open doors or windows is known as natural ventilation. This type of ventilation depends on the temperature and pressure difference to control the airflow through the buildings. Unlike mechanical ventilation systems, natural ventilation system does not capable to control the humidity level in a space which is not a very effective ventilation system. But some of the occupants prefer to use natural ventilation since it is energy efficient and provide comfortable and healthier environment. Risk of getting sick building syndrome (SBS) is much higher in air conditioning building compared to those that are naturally ventilated (Wargocki, 2002). But natural ventilation can be dangerous to the occupant if the outdoor pollution is high.

Mechanical ventilation commonly known as the HVAC (Heating Ventilation and Air Conditioning) system. Mechanical ventilation forced or induced the airflow to circulate throughout the building and have the ability to remove odor and contaminant. The most common mechanical ventilation is the exhaust fan or the air handling unit system. Santamouris, M., & Allard, F. (1998) in his book states that many of the occupant complains about the mechanical ventilation system because it generate noisy sound when operate, promotes health problem such as sick building syndrome (SBS), require routine maintenance and consume energy.

2.3 What is Indoor Air Quality?

Most of the people spend 90% of their daily routine in indoor environment (Lee and Chang, 2000). Indoor environment give major impacts towards the occupant because it closely relates with human health and work efficiency. According to the ASHRAE (2011), indoor air quality is defined as the quality of air that relates to the level of contaminant that is closely related with human health, comfort and performance.

Hall et al. (1995) states that maintenance activity, presence of contaminant source, indoor humidity and temperature, rate of ventilation and seasons can give major impact on IAQ level. Previous researcher has identified many factors and contributor towards the quality of the indoor air. Number of occupant in a space and building material is one of the major contributors to the IAQ level besides the outdoor and indoor contaminant.

It is important to have good quality of indoor air to ensure the occupant stay healthy and comfortable. Occupants may experience short and long term health effect if the quality of indoor air is poor (Wargocki et al., 2002).

2.4 Indoor Air Quality Parameters

2.4.1 Volatile Organic Compound (VOC)

Usually source of volatile organic compound (VOC) emissions is from construction, renovations or from chemical and aerosol usage. Moreover, the new furnishing and building materials will produce off gassing chemical. Off gassing VOC emission is a type of colorless gas to the atmosphere and produce strong smelling odor. Kathleen Hess-Kosa (2011) believes that the total exposures of VOC's to the occupant are generally up to 10 to 100 times of non-industrial home and office environment. High concentration of VOC's emission is due to inadequate ventilation which will trap and recycled in the air within the space. There are many types of chemical found in indoor air quality but the most common indoor VOC is the Formaldehyde.

Formaldehyde is a colorless and strong smelling gas. It is a type of an organic compound that usually used in the home furnishing or office products. In most indoor air pollution, the existence of Formaldehyde is the main contributor to the poor quality of indoor air. This is due to the building materials that exist in the indoor environment such as particle board, plywood, wall panels and wood finish that will release off gas Formaldehyde. In office environment, some of the office equipment contains Formaldehyde containing product such as printers and photocopiers. Lee, C.W, Dai (2006) claims that the low quality of indoor air in office building because of the Formaldehyde emission during the operation of photocopiers and laser printers.

According to Carrer et al. (2002), the presence of VOC sources such as paints, cleaners, interior finish materials and furnishing has been quoted by The European Union authorized task force on Indoor Environment Quality (IEQ) in European schools. Previous study conducted by Poh, Jalaludin, Rahmawati & Mariah (2015), most of the preschool furniture made from pressed wood which may emitted Formaldehyde gases over a period of time. The concentration of VOC's is stronger if the new furniture product is added. High indoor temperature and humidity usually lead to the increasing of Formaldehyde from these products.

Children and elderly may become more easily sensitive to Formaldehyde which makes it more likely for them to become sick. People who suffering with breathing problems such as asthma is likely more sensitive towards Formaldehyde emission which will cause asthmatic attack. **Table 2.1** shows the health effect corresponds to the exposure level of Formaldehyde.

Table 2.1: Formaldehyde exposure level and reported health effect (Kathleen Hess-Kosa 2011)

Exposure Level (ppm)	Health Effects
0.05-1.0	pungent odor
0.01-2.0	eye irritation
1.0-3.0	irritation of eyes, nose, respiratory tract, throat and upper respiratory tract
4.0-5.0	unable to tolerate prolonged exposure
10.0-20.0	severe respiratory symptoms and difficulty breathing
>50	serious injury to the threshold

2.4.2 Carbon Dioxide (CO_2)

Sometimes a person may have difficulties to breath or maybe feel stuffy when entering a room that has low ventilation rates. The possible factor for the problem to arise is due to less amount of oxygen but high concentration of carbon dioxide in the confined space. Carbon dioxide is chemical compounds that have colorless and odorless characteristics. Usually the product of carbon dioxide is from combustion or respiratory process of living beings. Insufficient dilution of air contaminant or inadequate amount of fresh air will increase the carbon dioxide in a space. Carbon dioxide measurements are commonly used to access the adequacy of ventilation within indoor environment (Kathleen Hess-Kosa, 2011).

The main source of carbon dioxide in indoor air is from through human respiratory process. Human absorb oxygen and expelled carbon dioxide. Besides that, other sources of carbon dioxide are from by-products of combustions such as vehicle exhaust, gas cooking appliance, heaters and tobacco smoke.

A great part of existing literature claims the positive relationship between absenteeism and carbon dioxide concentrations in office building located in Boston (Myatt et al., 2002). This statement is also supported by another researcher, Shendell (2004) in his review states that the increase of carbon dioxide level will decrease the attendance. The study shows that excess carbon dioxide will cause a significant impact on human health. According to ASHRAE, if the level of carbon

dioxide exceeds 1000 ppm, it indicates that the space has low rate of air exchange. Concentration beyond the recommended level will create stiffness in building. If the occupant exposed to carbon dioxide that has high concentration, usually a person may experience headache and feeling fatigue.

2.4.3 Carbon Monoxide (CO)

Carbon monoxide (CO) is type of harmful gas that is produced when fuel is burned. It is a colorless, tasteless, odorless toxic gas. According to Journal of the American Medical Association (2002), more than 1700 suicides and over 500 unintentional death reported every year in United States that caused by poisoning death due to excessive exposure of the carbon monoxide. The toxic gas has the greater ability to displace the oxygen-to blood transfer in the lungs. The carbon monoxide exists in the blood will prevents the distribution of oxygen throughout the human body. The person may receive inadequate oxygen supply that will cause the person to fainting, severe lung, brain damage and eventually may lead to death. The minimum value of carbon monoxide exposure to human is 10 ppm for 8 hours exposure (DOSH, 2005).

A recent review on indoor air quality for non-industrial place conducted by Siti Hamimah, Baba, & Abd Mutalib (2010) states that carbon monoxide is part of combustion product and indicates the infiltration issue in the indoor environment. Carbon monoxide poisoning can occur anywhere and anytime if there is existence by product combustion such motorize vehicle exhaust, tobacco smoke, heating systems and cooking appliances.

Most recent evidence reveals that the concentration of carbon monoxide is higher in capital city compared to the suburban area due to high populated city with more heavy traffic and less greenery (Tezara, C., Adam, N. M., Juliana, J., Mariani, M & Siregar, 2013). Case study of IAQ in 3 primary school in Malaysia reveals that the source of carbon monoxide emission is from attach garage, nearby roads and parking area (M.Ismail et. al, 2010). **Table 2.2** shows the carbon monoxide exposure level and health effect. Hess-Kosa (2011) in his book listed down several sources of high

level of carbon monoxide and other combustion by product are encountered in one or combination of the following scenarios;

i. Vehicle exhaust in a building (e.g., air intake to a building located a street level in a busy alley or an automobile left running in a garage)
ii. Poorly vented gas-fired hot water heater
iii. Air from a leaking exhaust duct or furnace flue
iv. Combustion by-products vented close to an air intake for a building
v. Poorly sealed wood-burning gas stove
vi. An insufficient amount of oxygen supplied to a gas operated space heater
vii. Poorly turned forklift trucks
viii. Poorly vented and insufficient replacement air in building with natural gas and wood burning fireplace (e.g., tight building with little or no air coming from outside to replace to the air discharger through chimney)
ix. Gas-fired heaters in air handling unit
x. Industrial combustion gases from an associated building

Table 2.2: Carbon monoxide exposure level and health effects
(Source: http://www.detectcarbonmonoxide.com/co-health-risks/)

Concentration (ppm)	Health effects
35	Headache and dizziness within six to eight hours of constant exposure
100	Slight headache in two to three hours
200	Slight headache within two to three hours
400	Frontal headache within one to two hours
1600	Dizziness, nausea, and convulsions within 45 minutes. Insensible within two hours.
3200	Headache, dizziness and nausea in five to ten minutes. Death within 30 minutes.
6400	Headache and dizziness in one to two minutes. Death in less than 20 minutes
12800	Unconsciousness after 2-3 breaths. Death in less than three minutes.