INDOOR AIR QUALITY AND RESPIRATORY HEALTH AMONG ACADEMIC STAFFS IN DEPARTMENT OF MECHANICAL ENGINEERING TECHNOLOGY, UTEM

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BACHELOR OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY (REFRIGERATION AND AIR CONDITIONING SYSTEM) WITH HONOURS

2023

Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical and Manufacturing Engineering Technology (Refrigeration and Air Conditioning System) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this Choose an item. entitled "Indoor Air Quality And Respiratory Health Among Academic Staffs In Department Of Mechanical Engineering Technology, UTeM" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Muhammad Akmal Bin Md Noor

Date : 11/1/2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Refrigeration and Air Conditioning system) with Honours.

Signature : AzwanAziz

Supervisor Name : Ts. Azwan Bin Aziz

Date : 27 January 2023

DEDICATION

I humbly dedicate this work to my loving parent, Mr Md Noor Bin Hamin and Mrs Sitee NoorHuda Binti Md Shariff, who has been my source of inspiration and given me enough strength to continue my journey in completing this research.

My family for their endless guidance and support, and my housemates who shared their advice and encouragement to keep going.

Lastly, alhamdulillah, I want to thank Allah SWT for giving me a chance to be in this place to complete the research.

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ABSTRACT

Indoor air quality (IAQ) has been the object of several studies due to its adverse health effects on humans. The rate of death and disease related to poor indoor air quality is very high and one of the significant threats to human health. Research on indoor air quality and its relation to respiratory health is essential to identify general symptoms related to indoor air pollutants and reduce the risk of respiratory health problems. A cross-sectional comparative study was carried out among academic staff in the Faculty of Mechanical and Manufacturing Engineering Technology, Univesity Teknikal Malaysia Melaka. The aim of the study was to determine indoor air quality and its association with respiratory health. A questionnaire was used to obtain an exposure history and respiratory symptoms of JTKM academic staff. The IAQ parameters obtained include the indoor concentration of particulate matter (PM), volatile organic compounds (VOCs), carbon dioxide (CO_2), temperature, and relative humidity (RH). The mean for $PM_{2.5}$ on the first floor (0.0063 ± 0.0055) is higher than on the ground floor (0.0008 ± 0.0008). Results show there is significant association between the concentration of $PM_{2.5}$ on the ground floor and first floor (P = 0.014) but not for CO_2, VOCs, temperature, and relative humidity. The ground floor has higher concentration of CO_2, and TVOC compared to first floor. However, the value of temperature and relative humidity is higher on first floor compared to ground floor. The statistical analysis cannot be done to associate the indoor air quality with respiratory symptom among academic staff due to limitiation on the data and research.

ABSTRAK

Kualiti udara dalaman (IAQ) telah menjadi objek beberapa kajian kerana kesan buruk kesihatannya terhadap manusia. Kadar kematian dan penyakit yang berkaitan dengan kualiti udara dalaman yang lemah adalah sangat tinggi dan merupakan salah satu ancaman besar kepada kesihatan manusia. Penyelidikan tentang kualiti udara dalaman dan kaitannya dengan kesihatan pernafasan adalah penting untuk mengenal pasti gejala umum yang berkaitan dengan bahan pencemar udara dalaman dan mengurangkan risiko masalah kesihatan pernafasan. Kajian perbandingan keratan rentas telah dilaksanakan dalam kalangan staf akademik di Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan, Univesiti Teknikal Malaysia Melaka. Matlamat kajian adalah untuk menentukan kualiti udara dalaman dan kaitannya dengan kesihatan pernafasan. Soal selidik telah digunakan untuk mendapatkan sejarah pendedahan dan gejala pernafasan staf akademik JTKM. Parameter IAQ yang diperolehi termasuk kepekatan dalaman bahan zarahan (PM), sebatian organik meruap (VOC), karbon dioksida (CO_2), suhu, dan kelembapan relatif (RH). Min untuk PM2.5 di tingkat satu (0.0063 ± 0.0055) adalah lebih tinggi daripada di tingkat bawah (0.0008 ± 0.0008). Keputusan menunjukkan terdapat perkaitan yang signifikan antara kepekatan PM2.5 di tingkat bawah dan tingkat satu (P = 0.014) tetapi tidak untuk CO_2, VOC, suhu, dan kelembapan relatif. Tingkat bawah mempunyai kepekatan CO_2 dan TVOC yang lebih tinggi berbanding tingkat pertama. Walau bagaimanapun, nilai suhu dan kelembapan relatif lebih tinggi di tingkat satu berbanding di tingkat bawah. Analisis statistik tidak boleh dilakukan untuk mengaitkan kualiti udara dalaman dengan simptom pernafasan di kalangan kakitangan akademik disebabkan oleh pengehadan data dan penyelidikan.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, praises and thanks to Allah for His showers of blessing throughout my research work to complete the research successfully. I finished my final year project research at University Technology Malaysia Malacca, Faculty of Mechanical and Engineering Technology (UTeM). I would like to express my sincere gratitude to my research supervisor, Ts Azwan bin Aziz, for his continuous support, patience and immense knowledge. His guidance helped me in completing this research and writing this thesis.

I am extremely grateful to my parents, Mr Md Noor Bin Hamin and Mrs Sitee NoorHuda Binti Md Shariff, for all the love, prayers and sacrifices that have been made since I was born until now. I am very thankful for my family and friends that have been pushing me and giving words of advice to pursue my degree.

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LIST OF SYMBOLS AND ABBREVIATIONS

WHO	-	World Health Organisation
%	-	Percentage
PM	-	Particulate Matter
CO	-	Carbon Oxide
CO_2	-	Carbon Dioxide
O_3	-	Ozone
NOx	-	Nitrogen Oxides
IAQ	-	Indoor Air Quality
VOCs	-	Volatile Organic Compound
AV	-	Air Velocity
%RH	-	Relative Humidity
JTKM	-	Jabatan Teknologi Kejuruteraan Mekanikal
UTeM	-	Universiti Teknikal Malaysia Melaka
µg	-	Microgram
m^3	-	Cubic metre
UV	-	Ultraviolet
IAP	-	Indoor Air Pollutant
SBS	-	Sick Building Syndrome
DOSH	-	Department of Safety and Health
HVAC	-	Heating, Ventilation, and Air Conditioning
URIs	-	Upper Respiratory Infections
ALRI	-	Acute Lower Respiratory Infections
COPD	-	Chronic Obstructive Pulmonary Disease
OSHA	-	Occupational Safety and Health Act
m^2	-	Metre Square
FTKMP	-	Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
ICOP	-	Industry Code of Practice on Indoor Air Quality (ICOP) 2010
SPSS	-	Statistical Package for Social Sciences
F3	-	Factory 3

95% CI	-	Confidence Interval
N	-	Sample Size
P	-	Significant

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CHAPTER 1

INTRODUCTION

1.1 Background

Air pollution is described as an alteration of air quality that chemical, biological or physical contaminants can measure in the atmosphere. As a result, air pollution refers to the undesired presence of contaminants or an abnormal increase in the quantity of certain atmospheric elements. It is divided into two categories: visible and invisible air pollution. The release of undesired contaminants in the atmosphere is detrimental to human health and the planet. Air pollution and its effect are often overlooked by human beings, which results in more pollution in this world. It is currently one of the most severe health and environmental issues and is one of the biggest threats to the environment and affects humans, animals, crops, cities and even aquatic ecosystems.

Every year, an estimated seven million people die due to air pollution around the world. According to World Health Organization (WHO) data, nearly all of the world's population (99%) breathes air that exceeds WHO guideline limits (figure 1.1) and contains high levels of pollutants, with low- and middle-income nations bearing the brunt of the burden. World Health Organization (WHO) is actively helping countries in combating air pollution.

Table 1.1 WHO Guideline Limits

Pollutant		WHO guidelines 2005	New WHO guidelines 2021
$PM_{2.5}$	Annual	10 µg/m³	5 µg/m³
	24-hour	25 g/m³	15 µg/m³
PM_{10}	Annual	20 µg/m³	15 µg/m³
	24-hour	50 µg/m³	45 µg/m³
O_3	Peak season (the six consecutive months of the year with the highest six-month running-average ozone concentration)	---	60 µg/m³
	8-hour	100 /m³	100 µg/m³
NO_2	Annual	40 µg/m³	10 µg/m³.
	24-hour	---	25 µg/m³
	1-hour	---	200 µg/m³
SO_2	24-hour	20 µg/m³	40. µg/m³
	10 min	---	500 µg/m³
CO	24-hour	---	4 mg/m³
	8-hour	---	10 mg/m³
	1-hour	---	35 mg/m³
	15 min	---	100 mg/m³

Meanwhile, Malaysia is one of many countries in the Southeast Asia region affected by air pollution problems. Malaysia ranked number 50 of 118 countries globally in air pollution. Malaysia's air quality is classified as moderately dangerous by the World Health Organization (WHO), according to the most recent data, the country's annual mean $PM_{2.5}$ concentration is 16 g/m^3, which is more than the recommended maximum of 10 g/m^3. Malaysia is a developing country with a strong emphasis on industry. In Malaysia, the predilection for private cars is widespread, resulting in haze and transboundary air pollution. As a result, air pollution has become a significant problem in Malaysia. Increases in hospital admissions and mortality have been linked to exposure to air pollutants coming from particles such as particulate matter (PM), carbon monoxide (CO), carbon dioxide (CO_2) and ozone (O_3).

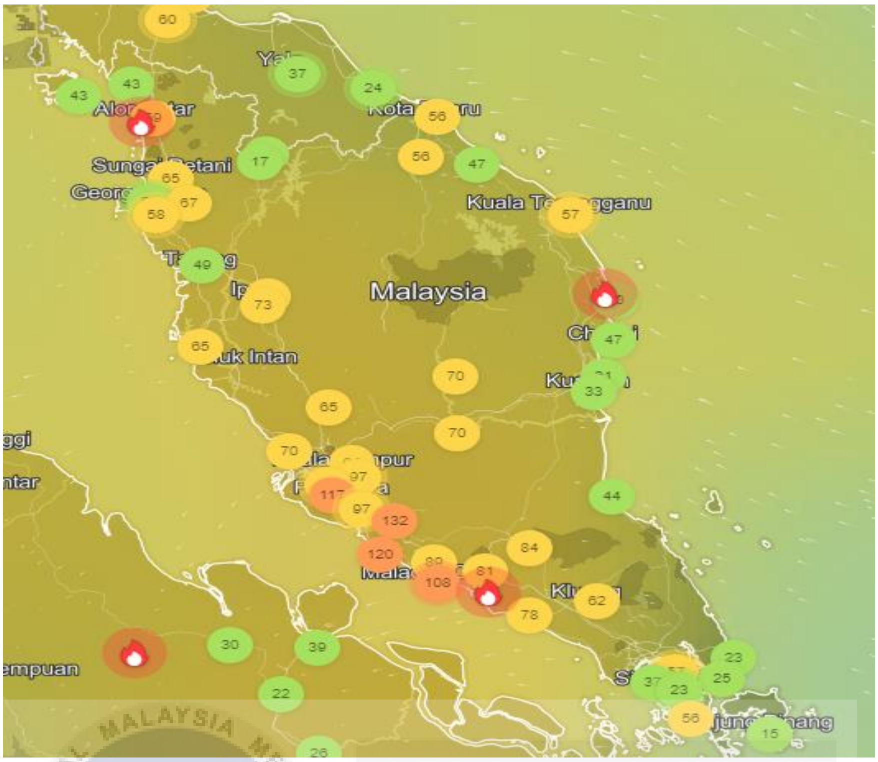


Figure 1.1 Malaysia's Air Quality's Map

Particulate matter (PM) refers to inhalable particles, composed of sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust or water. Carbon monoxide (CO) is a colourless, odourless, and tasteless poisonous gas created when carbonaceous fuels such as wood, petrol, charcoal, natural gas, and kerosene are burned incompletely. Meanwhile, carbon dioxide (CO_2) appears as a colourless, odourless gas at atmospheric temperatures and pressures. Relatively nontoxic and noncombustible. Lastly, ozone (O_3) is major component of smog. It is formed from photochemical reactions with pollutants such nitrogen oxides (NOx) emitted from vehicles, and industry.

All of the particle mentioned is a major particle of air pollution. In Malaysia, transboundary haze from other countries, industrial fuel burning, petroleum extraction and refining, rubber and palm oil processing, automobile emissions, and garbage burning are all factors that contribute to Malaysia's poor air quality. High amounts of air pollution can have a range of negative health consequences. Respiratory infections, heart problems, and lung cancer are all increased. Short and long-term exposure to air pollution has been linked to negative health outcomes. People who are already ill are subjected to more severe consequences.

Air pollution occurred not just in the open air, but also in enclosed spaces. Pollution inside the building is related to the indoor air quality (IAQ) that has been the object of several studies due to its adverse health effect on humans. Indoor air quality (IAQ) refers to the air quality inside and around buildings and structures, particularly as it relates to occupant health and comfort. Understanding and eliminating common indoor contaminants can assist to lower the chance of developing indoor health problems. Excessive contaminant particles in enclosed can affect to poor indoor air quality leading to respiratory health problems. Exposure to particle such as PM, CO, CO_2 and Ozone can cause difficulties in breathing, asthma, reduce lung function and even lead to lung cancer.

IAQ is influenced by various factors. Poor ventilation (lack of outside air), temperature control issues, high or low humidity, recent renovations, and other activities in or near a structure all can affect the amount of fresh air coming in. Specific contaminants such as construction or renovation dust, mold, cleaning supplies, pesticides, or other airborne chemicals (including small amounts of chemicals released as a gas over time) can sometimes lead to poor IAQ.

Indoor air quality (IAQ) is an essential factor that should be addressed as people nowadays tend to spend more time indoors rather than outdoors. Enclosed spaces, such as offices, schools, and workplaces, should have good indoor air quality since they are filled with workers or students who prioritize not just comfort but also good health condition, which must be taken care of.

Finally, air pollution inside the building must be reduced to avoid respiratory health problems among humans. Good ventilation is needed to improve the air quality inside the building as it is one of the important aspects of reducing the air pollution inside the building, other than creating awareness for people regarding the relation of indoor air quality with respiratory health issues.

1.2 Problem Statement

Unhealthy indoor air pollution brings many effects on health and has raised concern towards the indoor air quality inside every building as the majority of the world population is exposed to the risk of air pollutants even inside the building. Increasing cases of respiratory health among human reported every year proved that air pollutant is everywhere, and without proper studies regarding these issues, the good standard of indoor air quality inside of the building cannot be reached.

Inadequate ventilation is one of the main factors of poor quality of indoor air. Poorly ventilated offices and schools, for example, can have a negative impact on health, work, and academic performance. Controlled ventilation is particularly important in buildings that are substantially insulated and have little air exchange with the outside. Other than that, the infiltration process is also the factor of poor indoor air quality. Outdoor air enters buildings through cracks, joints, and openings in walls, floors, and ceilings, as well as around windows and doors during this process. Meanwhile, in natural ventilation, air travels through open windows and doors and also the differences in air temperature between indoors and outdoors, as well as wind, create air movement related with infiltration and natural ventilation.

In order to overcome this problem, the correlation between indoor air quality (IAQ) and respiratory health among human need to be studied as most people tend to stay indoors instead of outdoor in this pandemic era. An excessive amount of dangerous particles in the air brings a lot of harm to humans, and something needs to be done.

1.3 Research Objective

The main aim of this research is To determine the level of indoor air quality (IAQ) parameters and its association with respiratory health among Academic Staff in Department of Mechanical Engineering Technology, University Technical Malaysia Malacca. Specifically, the objectives are as follows:

a) To measure the level of indoor air pollutants such as PM, VOCs, CO_2 , Temperature, and Relative Humidity (%RH) in office room of JTKM academic staff.

b) To determine the symptom of respiratory health among Academic Staff in Department of Mechanical Engineering Technology, University Technical Malaysia Malacca.

c) To associate indoor air quality and respiratory health among Academic Staff in Department of Mechanical Engineering Technology, University Technical Malaysia Malacca.

1.4 Scope of Research

The scope of this research are as follows:

- Focuses on indoor air quality of lecturer's office room at Factory 3, Faculty of Mechanical and Manufacturing Engineering Technology, UTeM.
- Focuses on JTKM academic staff at Factory 3, Faculty of Mechanical and Manufacturing Engineering Technology, UTeM.
- Finding the relationship between indoor air quality and respiratory health of JTKM academic staff at Factory 3, Faculty of Mechanical and Manufacturing Engineering Technology, UTeM.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

People spend roughly 90% of their time indoors in various environments around the world. Indoor air quality and respiratory health have been raising issues, and several studies have been made. This chapter is a continuation of the prior research on the title. To gather the knowledge and data needed to validate this study of indoor air quality and respiratory health, literature reviews were necessary. The continuation of this chapter starts by focusing on air pollution, which is one of the main factors of indoor air quality. Also stated in this chapter is the correlation of health to IAQ, respiratory symptoms, IAQ and building occupants, the relation between IAQ and building occupants and lastly, IAQ effect on an office worker.

2.2 Air Pollution

Firstly, air pollution is the most serious environmental threat on the globe. According to WHO estimates, the combined impacts of ambient and home air pollution cause roughly 7 million deaths, mostly from noncommunicable illnesses (WHO, 2018). Similar worldwide studies of ambient air pollution alone show that there are between 4 million and 9 million fatalities and hundreds of millions of years of healthy life lost each year, with the highest illness burden attributed to low- and middle-income nations. (WHO, 2018). Air pollution occurs outdoor and indoors, which both bring harm to human health. More than 80% of people living in urban areas and roughly 91% of the world's population live in locations where air quality levels exceed WHO guidelines (Raj, 2020).

2.2.1 Outdoor Air Pollution

Outdoor air is known as ambient air. Outdoor air pollution is the presence of one or more undesired substances in the atmospheric air at high concentrations and above the duration of natural limits (Sweileh et al., 2018). Emissions from combustion processes in motor vehicles, solid fuel burning, and industry are the most frequent causes of outdoor air pollution. Other forms of pollution include wildfire smoke, windblown dust, and biogenic emissions from plants (pollen and mould spores). Particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), and sulphur (SO_2) are the most frequent air pollutants in ambient air. There are many serious risks to health from extensive exposure and exceeded guideline values based on World Health Organization (WHO) global guideline limits to the following gas emissions.

Table 2.1 Source of Pollutants

Pollutants	Source	Penetration into the respiratory system	Pathophysiology
TSP	Anthropogenic sources: street dust; road dust; agricultural activities; and construction activities. Natural sources: sea salt; pollen; spores; fungi; and volcanic ash.	Nose and throat	It impairs mucociliary and macrophage activity. It causes airway irritation. It induces oxidative stress and, consequently, pulmonary and systemic inflammation. Chronic exposure causes bronchial remodeling and COPD. It can be carcinogenic.
PM_{10}		Trachea, bronchi, and bronchioles	
$PM_{2.5}$	Burning of fossil fuels and biomass; thermoelectric power plants	Alveoli	
$PM_{0.1}$		Alveoli, lung tissue, and bloodstream	
O_3	It is not emitted directly into the atmosphere. It is produced by complex chemical reactions between volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of sunlight. Sunlight and temperature stimulate such reactions, so that, on hot sunny days, O_3 concentrations peak. The sources of VOC and NO_x emissions are vehicles, chemical industries, laundries, and activities that use solvents.	Trachea, bronchi, bronchioles, and alveoli	It is a photochemical oxidant that is extremely irritating. It induces respiratory tract mucosal inflammation. At high concentrations, it irritates the eyes, the nasal mucosa, and the oropharynx. It causes cough and chest discomfort. Exposure for several hours produces damage to the epithelium lining the airways. It induces inflammation and airway obstruction in the presence of stimuli such as cold and exercise.
NO_x, NO_2	Anthropogenic sources: nitric acid; sulfuric acid; and combustion engine industries (major source); fuel burning at high temperatures, in thermal power plants that use gas or incineration. Natural sources: electrical discharges in the atmosphere.	Trachea, bronchi, bronchiole, and alveoli	An irritant. It affects the mucosa of the eyes, nose, throat, and lower respiratory tract. It increases bronchial reactivity and increases susceptibility to infections and allergens. It is considered a good marker of vehicular pollution.
SO_2	Anthropogenic sources: petroleum refineries; diesel vehicles; furnaces; metallurgy; and papermaking. Natural sources: volcanic activity.	Upper airways, trachea, bronchi, and bronchioles	An irritant. It affects the mucosa of the eyes, nose, throat, and respiratory tract. It causes cough and increases bronchial reactivity, facilitating bronchoconstriction.
CO	Anthropogenic sources: forest fires; incomplete combustion of fossil fuels or other organic materials; and road transportation. Urban areas with heavy traffic are the major contributing source of CO emissions. Natural sources: volcanic eruptions and chlorophyll decomposition.	Alveoli and bloodstream	It binds to hemoglobin, interfering with oxygen transport. It causes headache, nausea, and dizziness. It has a deleterious effect on the fetus. It is associated with low birth weight neonates and fetal death.

2.2.1.1 Particulate Matter (PM)

Particulate matter (PM) is a widely used proxy measure of air pollution. It has the greatest impact on individuals of any contaminant. Sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral particles, and water are the main elements of PM. It is made up of a complex combination of organic and inorganic solids and liquid particles floating in the air. While particles with a diameter of 10 microns or less ($\leq PM_{10}$) may penetrate and lodge deep into the lungs, particles with a diameter of 2.5 microns or less ($\leq PM_{2.5}$) are much more harmful to one's health (WHO, 2018). $PM_{2.5}$ can get through the respiratory barrier and into the bloodstream. Chronic particle exposure increases the chance of developing cardiovascular and respiratory disorders, as well as lung cancer. Guideline values of fine particulate matter ($PM_{2.5}$) are 5 $\mu g/m^3$ for the annual mean and 15 $\mu g/m^3$ 24-hour mean.

2.2.1.2 Ozone (O_3)

Ozone (O_3) is an extremely high reactive gas that is made up of three oxygen atoms. It is both a natural and a man-made substance that occurs in the high atmosphere and lower atmosphere of the Earth. The high-level atmosphere is called stratosphere; meanwhile, lower-level atmosphere is called troposphere. Stratospheric ozone is created naturally when solar ultraviolet (UV) light interacts with molecular oxygen (O2). Tropospheric or ground-level ozone, which humans breathe, is principally produced by photochemical interactions between two primary types of air pollutants, volatile organic compounds (VOC) that are emitted from vehicles, solvent, industry, and nitrogen oxides (NOx) that come from vehicles and industry emissions (EPA, 2009). Ozone has different effects on life on Earth depending on where it resides in the atmosphere. Excessive ozone in the air can have serious consequences for human health. It can cause breathing issues, asthma attacks, reduced lung function, and lung disease. Guideline values for ozone are 100 $\mu g/m^3$ for 8-hour daily maximum and 60 $\mu g/m^3$ for 8-hour mean, peak season.

2.2.1.3 Nitrogen Dioxide (NO_2)

Nitrogen dioxide is the primary source of nitrate aerosols, which contribute significantly to $PM_{2.5}$ and, in the presence of UV light, ozone. The primary sources of anthropogenic NO_2 emissions are combustion activities (heating, power generation, and engines in vehicles and ships). Inhaling air with such a high concentration of Nitrogen dioxide might negatively affect the human respiratory system's airways. Short-term exposures can worsen respiratory diseases, notably asthma, resulting in respiratory symptoms (such as coughing, wheezing, or trouble breathing) and hospitalizations. Longer nitrogen dioxide exposure may contribute to the development of asthma and perhaps increase susceptibility to respiratory infections. People with asthma, children, and the elderly are all more vulnerable to the health impacts of nitrogen dioxide. Guideline values for nitrogen dioxide are 10 $\mu g/m^3$ for the annual mean of 25 $\mu g/m^3$ for the 24-hour mean. To protect the population from the health impacts of gaseous nitrogen dioxide, the current WHO guideline value of 10 g/m^3 (annual mean) was established.

2.2.1.4 Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is a sulfur and oxygen-containing gaseous air pollutant. When sulphur-containing fuels such as coal, oil, or diesel are burnt, SO_2 is produced. Sulfur dioxide also transforms in the atmosphere into sulphates, which contribute significantly to fine particle pollution in the atmosphere. The combustion of fossil fuels by power plants and other industrial facilities is the major source of SO_2 in the atmosphere. Smaller sources of SO_2 emissions include industrial activities like mineral extraction, natural sources like volcanoes, railways, ships, and other vehicles and heavy equipment that consume sulfur-rich fuel. SO_2 can harm the respiratory system and lung functions, as well as irritate the eyes. Inflammation in the respiratory tract promotes coughing, mucus output, worsening of asthma and chronic bronchitis, and renders patients more susceptible to respiratory infections. On days with greater SO_2 levels, hospital admissions for heart illness and death rise. When SO_2

reacts with water, it produces sulfuric acid, which is the major component of acid rain, which causes deforestation. Guideline values for sulfur dioxide are 40 $\mu g/m^3$ 24-hour mean

2.2.1.5 Indoor Air Pollution

As outdoor air pollution has caused a lot of death and sickness to the population around the globe, indoor air pollution is responsible for over 3.8 million death each year. IAP can be produced within houses or buildings as a result of inhabitant activities such as cooking, smoking, using electronic appliances, using consumer items, or emission from building materials. Based on World Health Organization (WHO), around 2.6 billion people continue to cook with solid fuels (such as wood, agricultural wastes, charcoal, coal, and dung) and kerosene on open flames and inadequate stoves, resulting in high levels of air pollution (such as SO_2, NOx, CO, and PM). Worse, these air contaminants may develop in the interior environment if it is not properly vented (He et al., 2004) measured the effect of indoor sources on particle concentrations and emission rates from various indoor sources and activities, and the finding is that cooking-related activities may produce particulate matter during the process, increasing the particle number concentration in the house by 1.5 to 27 times. This practice brings so much impact on health. Among the 3.8 million casualties, pneumonia is responsible for 27% of it. 18% are victims of a stroke. Ischaemic heart disease affects 27% of the population. 20% died from chronic obstructive pulmonary disease (COPD), and 8% died from lung cancer (WHO, 2014). Table 2.2 shows the sources of numerous indoor air contaminants as well as their health implications.

Table 2.2 Source of Indoor Air Contaminants and Health Implications

Pollutants	Sources	Health Impacts
PM	Outdoor environment, cooking, combustion activities (burning of candles, use of fireplaces, heaters, stoves, fireplaces and chimneys, cigarette smoking), cleaning activities	Premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms
VOCs	Paints, stains, varnishes, solvents, pesticides, adhesives, wood preservatives, waxes, polishes, cleansers, lubricants, sealants, dyes, air fresheners, fuels, plastics, copy machines, printers, tobacco products, perfumes, dry-cleaned clothing, building materials and furnishings	- Eye, nose and throat irritation - Headaches, loss of coordination and nausea - Damage to liver, kidney and central nervous system - Some organics can cause cancer
NO_2	Gas-fueled cooking and heating appliances	- Enhanced asthmatic reactions - Respiratory damage leading to respiratory symptoms
O_3	Outdoor sources, photocopying, air purifying, disinfecting devices	DNA damage, lung damage, asthma, decreased respiratory functions
SO_2	Cooking stoves; fireplaces; outdoor air	- Impairment of respiratory function - Asthma, chronic obstructive pulmonary disease (COPD), and cardiovascular diseases
CO_x	Cooking stoves; tobacco smoking; fireplaces; generators and other gasoline powered equipment; outdoor air	Fatigue, chest pain, impaired vision, reduced brain function
Heavy metals	Pb, Cd, Zn, Cu, Cr, As, Ni, Hg, Mn, Fe Outdoor sources, fuel-consumption products, incense burning, smoking and building materials	- Cancers, brain damage - Mutagenic and carcinogenic effects: respiratory illnesses, cardiovascular deaths
Aerosols	Tobacco smoke, building materials, consumer products, incense burning, cleaning and cooking	Cardiovascular diseases, respiratory diseases, allergies, lung cancer, irritation and discomfort
Radon (Rn)	Soil gas, building materials, and tap water Outdoor air	Lung cancer
Pesticides	- Termiticides, insecticides, rodenticides, fungicides, disinfectants and herbicides - Building materials: carpet, textiles, and cushioned furniture - Outdoor environment	Irritation to eye, nose and throat; Damage to central nervous system and kidney; Increased risk of cancer
Biological allergens	House dust, pets, cockroaches, mold/dampness, pollens originating from animals, insects, mites, and plants	Asthma and allergies Respiratory infections, sensitization, respiratory allergic diseases and wheezing
Microorganism	Bacteria, viruses, and fungi are carried by people, animals, and soil and plants	Fever, digestive problems, infectious diseases, chronic respiratory illness

2.3 Indoor Air Quality

Indoor air quality is characterized by the presentation of pollutant concentrations and thermal conditions that may have a harmful impact on the health, comfort, and performance of occupants in a building (EPA, 2021). It can include but is not limited to temperature, humidity, mold, bacteria, inadequate ventilation, or exposure to other chemicals. Indoor air pollution has gotten less attention in the past than outside air pollution. It is currently a source of widespread concern, owing in part to the development of novel indoor air contaminants, the separation of the interior environment from the natural outdoor environment in well-sealed office buildings, and the examination of so-called Sick Building Syndrome (DOSH, 2010).

2.3.1 Factor of IAQ

To protect the individual from such contaminants, IAQ has emerged and grown as a study topic (Vinh, 2020). There are a lot of factors that are related to indoor air quality (IAQ) problems. It has been found that three key elements significantly influence IAQ in residential areas or buildings, which are outside air quality, human activities in buildings, and lastly, building and construction materials, equipment, and furniture. It is well recognized that outdoor pollutant concentrations and building airtightness have a significant impact on IAQ due to the probability of contaminants being transported from outdoors to the interior (Duckshin, 2020). An HVAC system is also one of the primary factors related to the IAQ problem as it is responsible for controlling existing air pollutants and maintaining thermal comfort (temperature and humidity levels that are comfortable for the majority of occupants). IAQ also can be influenced by a variety of substances, including gases like carbon monoxide, ozone, radon, volatile organic compounds (VOCs), particulate matter (PM) and fibers, organic and inorganic pollutants, and biological particles such as bacteria, fungus, and pollen (Allesandra, 2017).

2.3.1.1 Outdoor Source

Pollutants from the outside can infiltrate buildings through open doors, windows, ventilation systems, and structural defects. Some contaminants enter buildings through the foundations (Dennis, 2015). Contaminated outdoor air such as pollen, dust, fungal spores, industrial pollutants, and general vehicle exhaust easily enters the building through the door and ventilation system. Nearby source emissions, Soil gas like radon, pesticides, and leakage from underground storage tanks are also the outdoor source of air pollutants.

2.3.1.2 Indoor Source

Over the previous five decades, there have been significant developments in the products and building materials utilized indoors. These changes, together with changes in building operations, have resulted in various emission profiles for indoor pollutants. Building inhabitants' personal behaviors have also evolved over time (Klara & Simone, 2014). Human personal activities such as smoking, and cooking emit toxic combustion byproducts that can pollute the interior environment. Emissions from stores of supplies or waste, cleaning products and methods, usage of deodorizers and scents and airborne dust or dirt circulated by sweeping and vacuuming activities also contribute to indoor pollution (Vinh et al., 2020). Lastly, maintenance activities such as painting, remodeling, and pest control release a variety of pollutants, including volatile organic compounds, into the indoor air.

2.3.1.3 HVAC System

One of the most essential variables influencing indoor air quality is ventilation. Low ventilation rates, as well as CO_2 concentrations in indoor air, have been linked to health and perceived air quality outcomes (Seppänen et al., 1999). Poorly design and maintenance contribute to dust or dirt in ducting or other components, microbiological growth in drip pans, humidifiers, ductwork, and coils, poor combustion product venting, and refrigerant leaks according to (EPA. 2015)

2.3.2 Importance of IAQ

According to U.S. Environmental Protection Agency (EPA), people spend around 90% of their time indoors in various environments. Thus, the flow of good indoor air quality throughout a building is vital because indoor air quality (IAQ) is closely correlated to health and wellbeing. Indoor air quality brings so much impact on human health, and it is important to monitor and properly maintain the air quality inside the building or confined space.

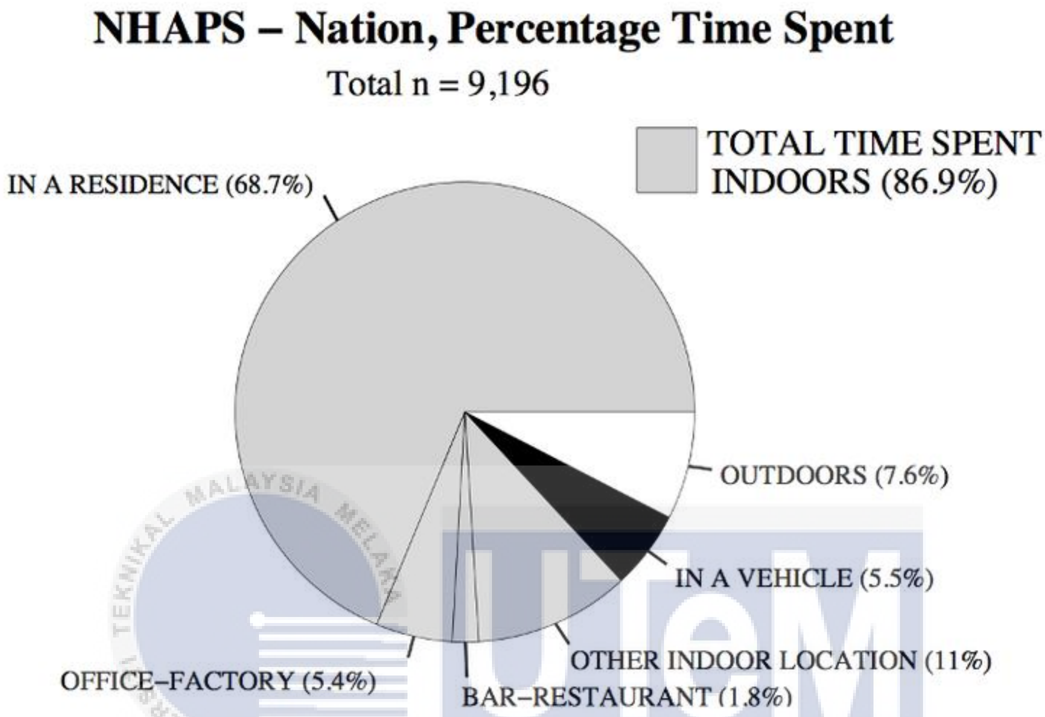


Figure 2.1 Pie Chart of Percentage Time Spent

2.4 Health Effect Related to IAQ

Indoor air quality (IAQ) has been the subject of various research due to its negative health impacts on humans (Juliana et al., 2014). Various symptoms and illnesses have been related to poor indoor air quality in buildings and houses throughout the last few decades. Indoor exposure to inorganic, chemical, physical, and biological pollutants is prevalent, pervasive, and long-lasting, even at low levels (Vinh et al., 2020). As a result, the negative consequences of IAP on human health have long piqued the public's interest and worry. Exposure to air pollution has a wide range of health consequences for people. When pollutants from the environment enter the body, they can affect a variety of organs and systems, not simply the respiratory system. Health effects related to indoor air quality can be classified as either short-term or long-term (Naziah et al., 2011)

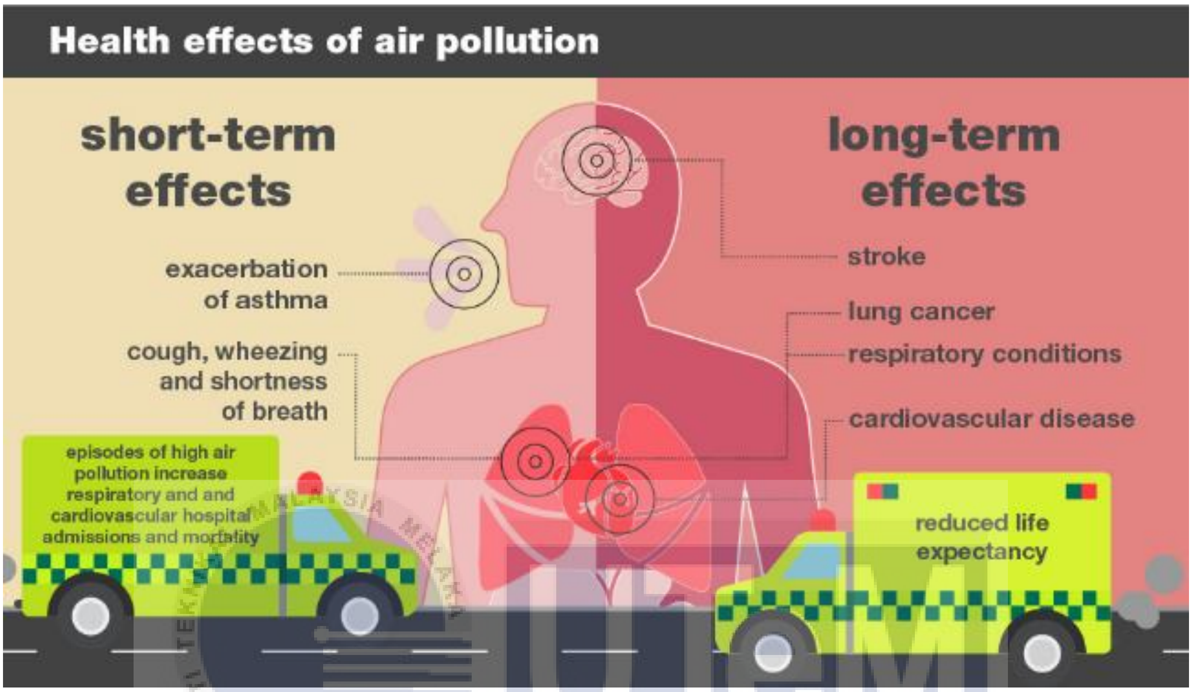


Figure 2.2 Health effect of air pollution

2.4.1 Short Term Effects

Some health impacts may appear soon after a single or recurrent exposure to a pollutant. These include eye, nose, and throat discomfort, headaches, dizziness, and tiredness (Anis et al., 2016). Such acute effects are often temporary and curable. If the source of the pollution can be determined, the treatment may consist of merely removing the person's exposure to it. Symptoms of some illnesses, such as asthma, may appear, be exacerbated, or deteriorate soon after exposure to some indoor air pollutants.

2.4.2 Long Term Effects

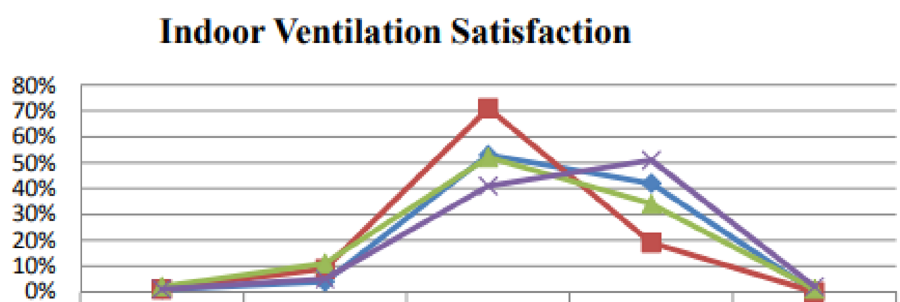
Other health problems may emerge years after exposure or only after prolonged or repeated periods of exposure. Air pollution's long-term impacts can continue for years or even a lifetime. Heart disease, lung cancer, and respiratory disorders such as emphysema are all long-term health consequences of air pollution. Air pollution can also harm people's nerves, brains, kidneys, liver, and other organs over time.

2.5 Respiratory Health

Respiratory health is important to be taken care of as it is one of the important aspects and integral to the human system. Respiratory is the most affected part when related to indoor air pollution. A few examples of diseases related to respiratory health is an acute respiratory infection, pulmonary disease, and cardiovascular diseases (CVDs). The respiratory system is frequently the primary target of IAP effects because pollutants often enter the human body through inhalation. Depending on the area of the affected respiratory tract, acute respiratory infections can be classified into acute lower respiratory infections (ALRIs) and upper respiratory infections (URIs). URIs are illnesses involving the upper respiratory with common symptoms, such as cough, sinusitis, and otitis media, and they are often mild in nature and caused by biological pollutants (viruses, bacteria, fungi, fungal spores, and mites). Meanwhile, ALRI, an acute infection of the lung, is caused by viruses or bacteria, resulting in lung inflammation (Vinh et al., 2020). Chronic obstructive pulmonary disease (COPD), asthma, and lung cancer are also health effects of poor indoor air quality. COPD diseases are defined by an increased chronic inflammatory response in the airways and lungs to harmful particulates or indoor air pollution, and its major risk factor is from cigarette smoke and fuel smoke combustion (Mahmood et al., 2017). Consequently, exposure to excessive contaminant particles in enclosed places causes difficulties in breathing, cough, asthma, decreased lung function, and chronic loss of pulmonary and lung cancer (OSHA, 2020)

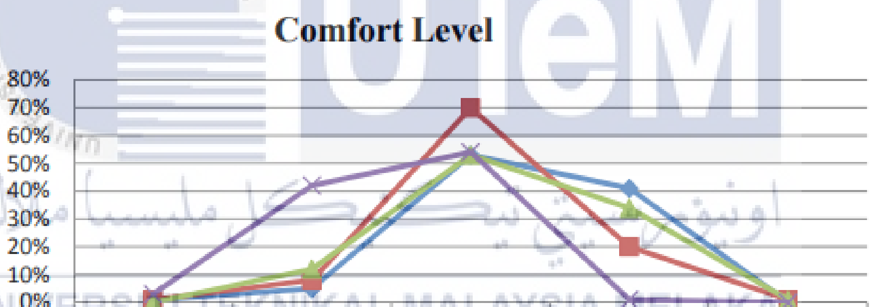
2.6 Correlation between IAQ and Building Occupant's

Indoor air quality brings an impact in many aspects to the occupant in the building, as poor indoor air quality can bring harm to the occupant's health. Not just that, polluted environments and poor indoor air quality will decrease occupant productivity. Both of these factors can result in poor health and physical condition, as well as poor work performance. The quality of outdoor air, as well as emissions from the internal environment and building inhabitants, has caused indoor air quality to be influenced by the kind and effectiveness of heating, air conditioning, and ventilation technologies (Jakola et al., 1994). High quantities of indoor air pollution have been demonstrated to impair diagnostic psychological test performance (Baelum et al., 1985). Indoor Air Quality has an impact on the psychology of office workers, as evidenced by the association between indoor ventilation satisfaction, air movement rate, comfort level, work productivity, and stress level. According to the study, the higher the occupants' satisfaction with the indoor air quality in the building, the higher their work productivity and the lower their stress level (Kamaruzzaman & Sabrani, 2011). Poor indoor air quality might decrease office work performance by 6-10% (David et al., 2005)



	Very Unsatisfied	Unsatisfied	Medium	Satisfied	Very Satisfied
Building 1	1%	4%	53%	42%	0%
Building 2	1%	9%	71%	19%	0%

Figure 2.3 Indoor Ventilation Satisfaction



	Very Uncomfortable	Uncomfortable	Medium	Comfortable	Very Comfortable
Building 1	1%	5%	53%	41%	0%
Building 2	1%	8%	70%	20%	1%
Building 3	0%	12%	53%	34%	1%
Building 4	3%	42%	54%	1%	0%

Figure 2.4 Comfort Level

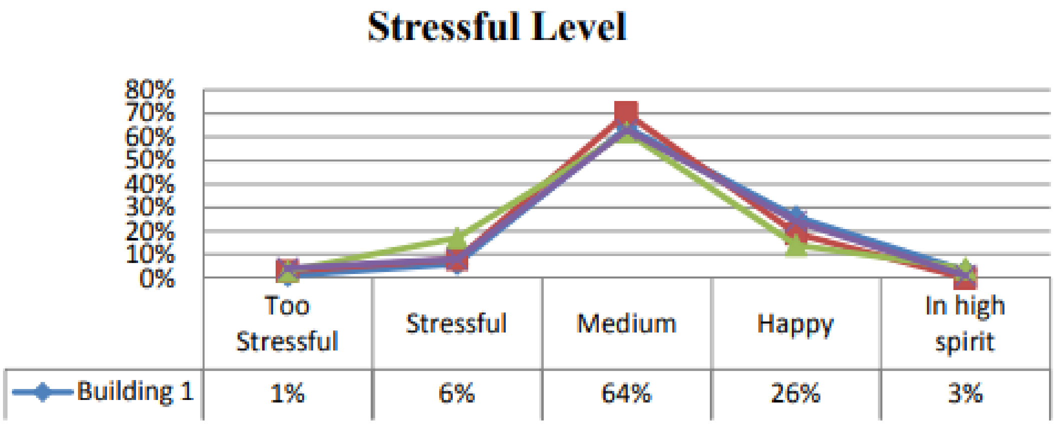


Figure 2.5 Stressful Level

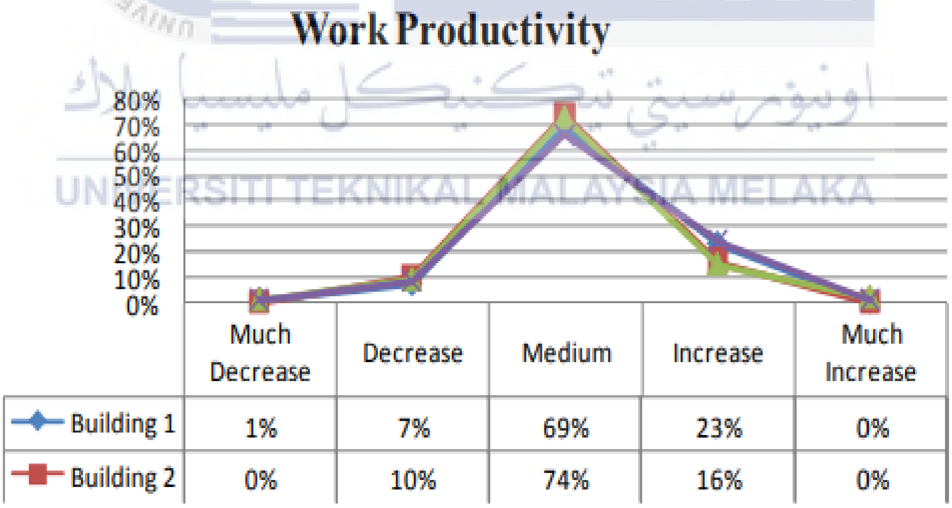


Figure 2.6 Work Productivity

2.7 IAQ Effect to Office Worker

Based on the study (Parmaksiz et al., 2021), 45 percent of the workforce in 100 US public buildings reported at least one health symptom connected to employment, and 20 percent reported symptoms in the following categories, which is mucosal irritation in the eyes, and upper airways. Low respiratory symptoms, for example, coughing. Central nervous system (neuropsychological) symptoms (CNS), for example, headache and lastly, tiredness (fatigue). Negative effects on general symptoms such as headache and concentration were complemented by negative effects on performance in the indoor environment (David & Pawel, 2005).

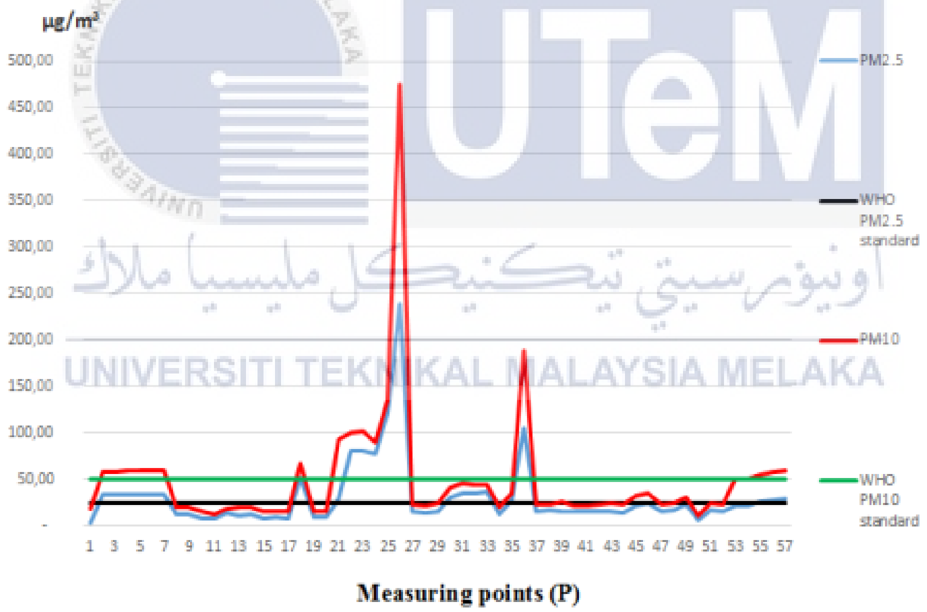


Figure 2.7 Measuring Points of Particulate Matters

2.8 Summary of Research Gap

Air pollution is one of the major environmental threats in this world, millions of deaths and illnesses reported every year according to World Health Organization (WHO). More than 90% of the worldwide population still inhale polluted air that exceeds WHO guideline, where low-and middle-income nation are affected the most. With indoor pollution contributing to over 3.8 million death every year, the number of building occupants that are still exposed to dangerous levels of household air pollution is worrisome. Since pollution is a serious issue to the environment and inhabitants, the research done is highly necessary to spread awareness and reduce the air pollution and improve indoor air quality for building occupants. Apparently, the correlation between indoor air quality and office workers is still minimal. Most published literature emphasizes the effect of poor indoor air quality towards general building occupants despite office workers who spend most of their time indoors rather than outdoor. The duration occupants spend inside the building or office contributes to how much effect of pollutants towards the occupant's health. The longer the occupant inhales poor indoor air quality, the worse it affects the occupant's health (Kamaruzzaman & Sabrani, 2011).

Poor indoor air quality not just affects the health of building occupants but also the quality of work as it relates to the psychology of workers in the office. Either non-serious diseases like irritation of the eyes, headache and dizziness or serious health problems like respiratory disease, heart disease and cancer, both are important to be taken care of. Indoor air quality is one of the factors that must be emphasized in every building or household in order to limit the number of deaths and diseases caused by air pollution. It is also vital to maintain the health and comfort of building inhabitants.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discussed the research approach and techniques used according to the specific objective. The method and equipment selection are crucial in data collection. Therefore, to fulfil the research of the study, the methodology section focuses on important parts such as method, study area, data collection, equipment used and data analysis. In addition, the usage of equipment and data acquired is critical to achieving the best potential research outcome.

3.2 Project Flowchart

A flowchart was used to represent the workflow of this chapter. This project's flow chart is shown in Figure 3.1.

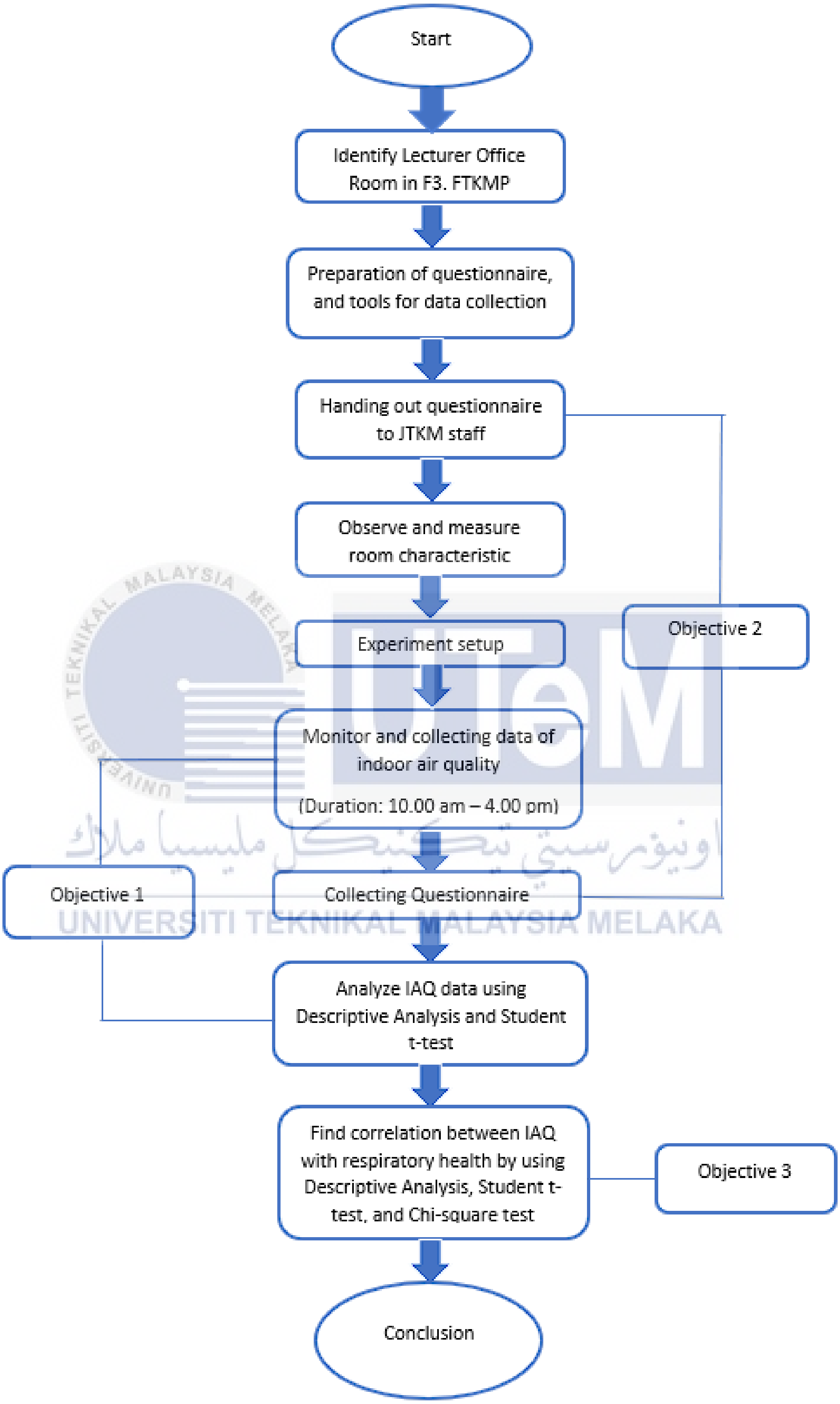


Figure 3.1 Project Flowchart

3.3 Study Design

The study design used in this research is a cross-sectional comparative study. In this study design, data were collected from many different individuals at a single time. The study has been carried out among academic staff in the Faculty of Mechanical and Manufacturing Engineering Technology. Male and female included. This research used a random sampling technique where data collection has been taken from random academic staff office room. The parameters assessed for this research are particulate matter, total volatile organic compound, carbon dioxide, temperature and relative humidity. Furthermore, universal sampling also used in this research, a questionnaire was used to determine the prevalence of respiratory symptoms and also descriptive analysis to identify the minimum value, maximum value, mean, and standard deviation of IAQ parameters.

3.3.1 Study Area

The study was conducted in Factory 3, Faculty of Mechanical and Manufacturing Engineering Technology, Univesity Teknikal Malaysia Melaka. It was located at Jalan TU 62, Taman Tasik Utama, 75450 Ayer Keroh, Melaka, Malaysia, with coordinates 2°16'41.7"N 102°16'22.8"E on the map. The study focuses on the lecturer's office room in the Factory 3 building of the Faculty of Mechanical and Manufacturing Engineering Technology.

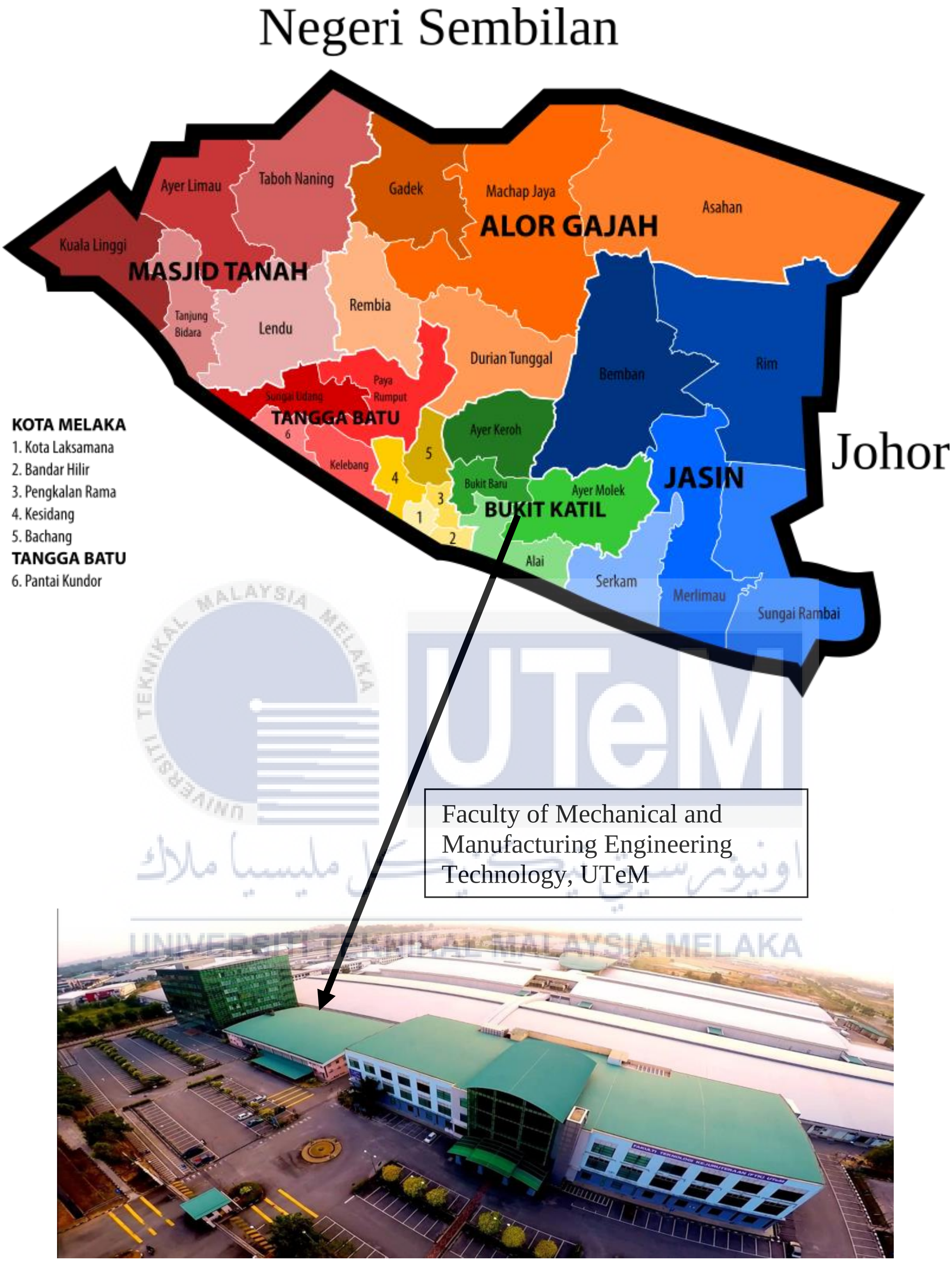


Figure 3.2 Location of the study area, FTKMP Building, University Teknikal Malaysia Melaka

3.3.2 Building and Room Layout

Figure 3.3 is the layout of Factory 3, where the study focuses on the lecturer's office room. The layout of the lecturer's office room is 3.6m in length and 3.6m in width. There are two different types of rooms which are with a window, and another one is no window. The ventilation of the room is dependent on the window and air conditioning. Room parameters were stated in table 3.1 The sample room follows guidelines according to the Department of Occupational Safety and Health (DOSH) indoor air quality standard.

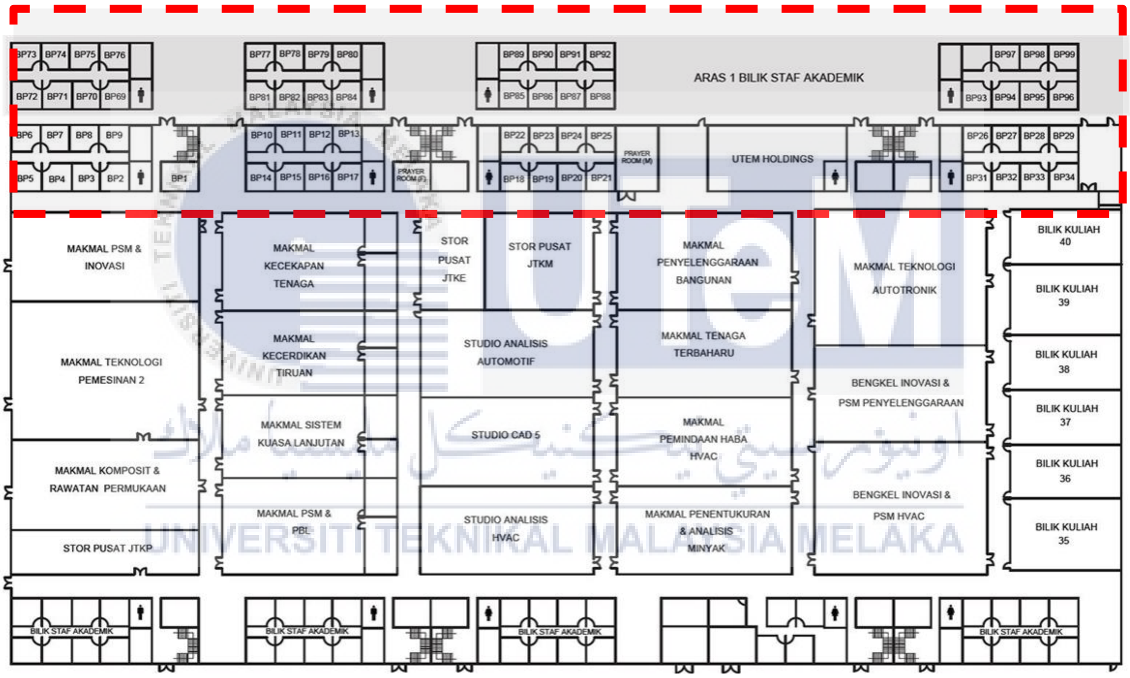


Figure 3.3 Factory 3 Building Layout

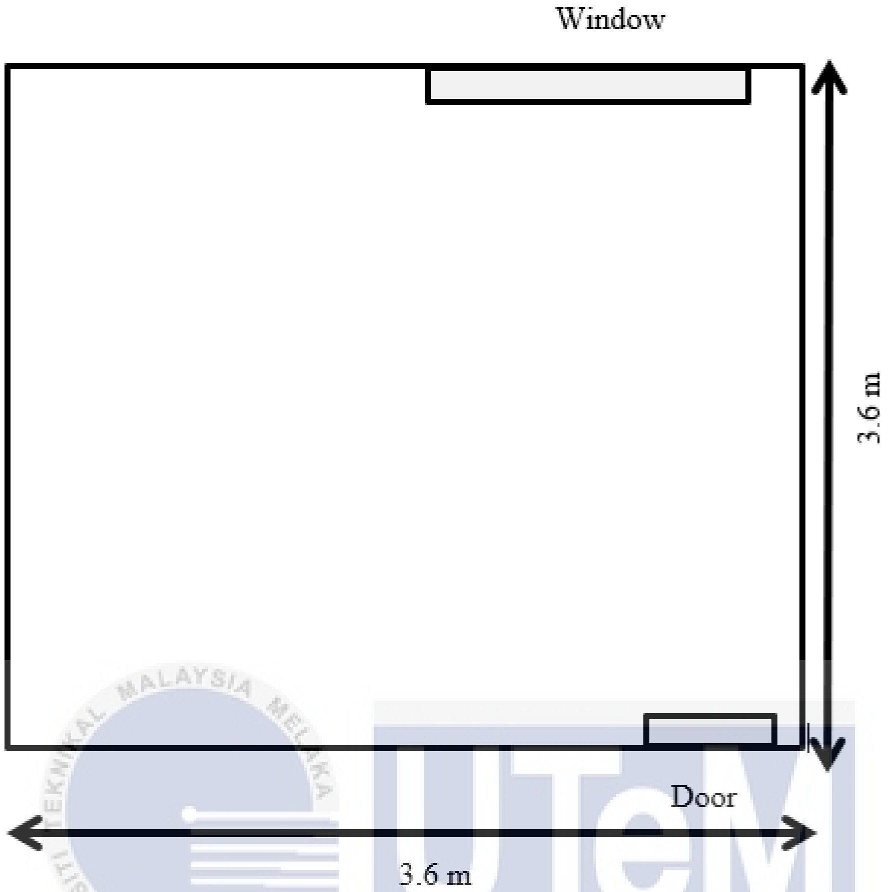


Figure 3.4 Measurement of lecturer's office room in factory 3 with window

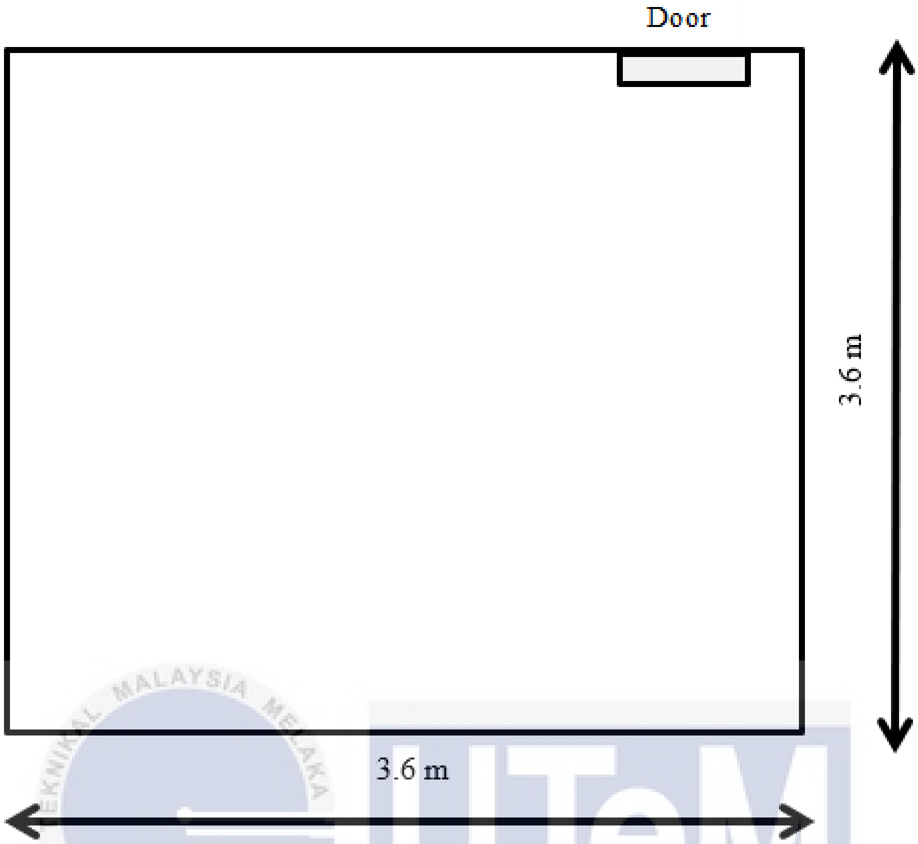


Figure 3.5 Measurement of lecturer's office room in factory 3 without window

Table 3.1 Room parameter

Room Size	3.6m x 3.6m
Room Area	$7.2m^2$
Floor Level	Ground & First floor
Ceiling material	Concrete
Floor material	Concrete
Wall type	Concrete & Partition
Window type	Glass
Window quantity	1
Door quantity	1
Lamp quantity	4

Table 3.2 Indoor air quality monitoring guideline by Department of Occupational Safety and Health (DOSH)

Total floor area	$2.2\ m^2$
Distance of instument from mechanical ventilation	1.4 m
Number of sampling points	1 (Area less than $3000\ m^2$ (DOSH))
Windows	Total = 2
Distance instrument from the ground	1 meter

3.3.3 Experiment setup

The study conducted at the lecturer's office room in Factory 3, FTKMP Building, was based on the random sampling method chosen. There are 16 room out of 64 room was chosen for data collection purpose. One room was selected for each row of the lecturer's office room. Both the ground floor and first floor was selected for comparison purpose. The room chosen was stated in table 3.3

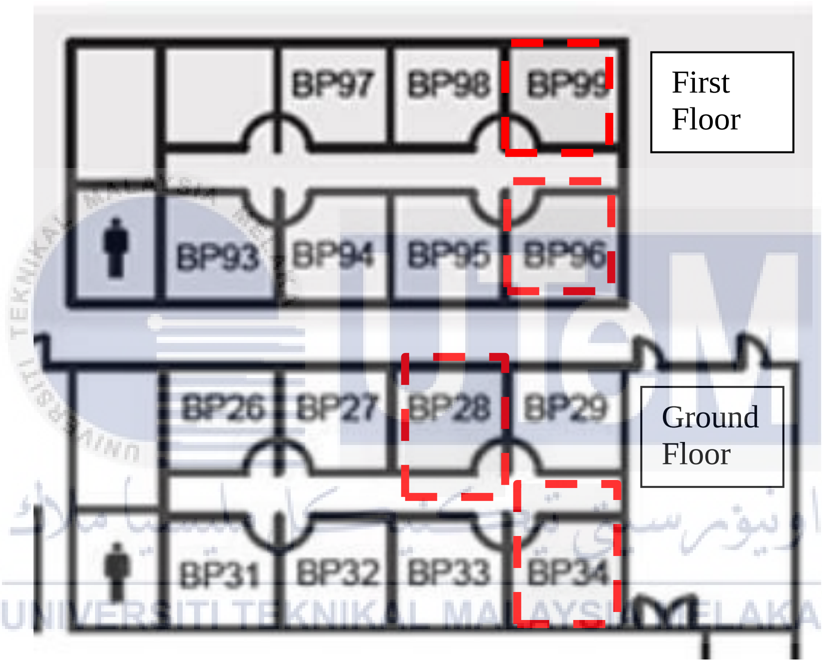


Figure 3.6 Room Sampling Selection

Table 3.3 List of room selected

Day	Office
Day 1	BP (3 & 70)
Day 2	BP (7 & 75)
Day 3	BP (13 & 77)
Day 4	BP (15 & 82)
Day 5	BP (21 & 88)
Day 6	BP (23 & 92)
Day 7	BP (29 & 95)
Day 8	BP (33 & 98)

Data collection was taken for 6 hours daily and took eight days to complete for 16 rooms. The time frame for data collection was from 10.00 a.m to 4.00 p.m. Presence of the study sample was needed during data collection. Hence, the time frame was chosen for this research.

3.3.4 Monitoring Equipment

The equipment used for data collection is EVM-7-Environmental Monitor Series. Parameters that were measured by the monitoring equipment are total volatile organic compound, carbon dioxide, temperature, particulate matter and relative humidity. The equipment specification was shown in Table 3.4.

Table 3.4 Equipment Specification

EQUIPMENT SPECIFICATION	
Equipment Name	EVM-7-Environmental Monitor Series
Manufacturer	3M
Measurement	1. Total volatile organic compound 2. Carbon dioxide 3. Temperature 4. Relative Humidity 5. Particulate Matter
Instrument Range	1. Volatile Organic Compounds (VOCs) Gas Detector (PID Sensor) Range = 0.00 to 2,000 ppm or mg/m3 Resolution = 0.01 ppm Accuracy = +/-5% / 2%; (relative Isobutylene) at cal value 2. Carbon Dioxide Sensor Range = 0 to 5,000 ppm Resolution = 1 ppm Accuracy = +/-100 ppm@20ºC, 1 bar pressure at 2,000 ppm applied gas. 3. Relative Humidity Sensor

	Range = 0.0 to 100% Resolution = 0.1 Accuracy = +/- 5% RH signal between 10 – 90% 4. Temperature Sensor Range = ºC to 60.0 ºC Resolution = 0.1 Accuracy = +/- 1.1 ºC (+/- 2 ºF) +/- 2ºF 5. Particulate Sensor Range = 0.000- 200.0 mg /m3 Resolution = 0.001

3.3.5 Equipment Setup

Table 3.5 shows the equipment and experiment setup, before and during data collection process. The equipment setup was following the general guideline by Industry Code of Practice On Indoor Air Quality (ICOP) 2010.

Table 3.5 Equipment and Experiment setup

No	Description
	Equipment setup
1	The EVM-7 Monitoring Equipment was turned on
2	The log interval was set to 60 sec and averaging at 60 sec
3	PID sensor was turned on
4	Parameters unit was setup as following: 1) Temperature (Celcius (°C) 2) Particulate matter (µg/m3 (micrograms per cubic meter) 3) PID PPM/PPB (µg/m3)
5	Particulate pump, digital output, air velocity and analog out was enabled.
6	Lock/secure run was enable to ensure the session will not be stopped during data collection
	Experiment setup
1	Equipment was place height of 1.1 m above the floor and not within 2 metres of the door.
2	Placement of equipment is 0.5 away from windows, corners, walls, partitions and other vertical surfaces.
3	Equipment is situated away from air supply diffusers, induction units, floor fans and heaters.
4	Experiment was run by enter the auto-run mode on EVM-7 Equipment with 6 hours duration
5	Experiment was automatically stop after 6 hours
6	Data succesfully collected

3.4 Data Analysis

In this study, the analysis of data consists of 4 methods which are descriptive analysis, Student t-test, Chi-squre test, and questionnaire. Each method was used to achieved a different outcome with a different type of test. The outcome was presented in graph and table format. The analysis was done by using the SPSS software program.

3.4.1 Descriptive Analysis

Descriptive analysis was used to determine the mean, median, and standard deviation of indoor air quality parameters. Raw data were represented in graphs and tables form by using this method. The results was described based on the graph and table.

3.4.2 Student t-test

Student t-test was used to find the statistical significant and to compare the differences of indoor air quality between study areas. Study areas were divided into two zones which are the ground floor and the first floor. The results output was means value, standard deviation, 95% CI and P value.

3.4.3 Chi-square test

Chi-square is a statistical test used to compare observed results with expected results. As for this study, the Chi-square test was used to find the prevalence of respiratory symptoms among academic staff.

3.5 Relationship between Objective and Methodology

Table 3.6 Relationship Between Objective and Methodology

Objective	Methodology
a) To measure the level of indoor air pollutants such as PM, VOCs, CO_2, Temperature, and Relative Humidity (%HR)	• Study design • Data collection • Descriptive analysis • Student t-test
b) To determine the symptom of respiratory health among Academic Staff in Department of Mechanical Engineering Technology, University Technical Malaysia Malacca.	• Data analysis • Student t-test • Chi-square test • Questionnaire
c) To associate indoor air quality and respiratory health among Academic Staff in Department of Mechanical Engineering Technology, University Technical Malaysia Malacca.	• Descriptive analysis • Questionnaire

3.6 Summary

Finally, this chapter 3 describes the research approach. Begin by creating a flow chart to outline the research flow, approach, and conclusion. The study design described the technique, sample, and study area concerning the research objective. The experiment was set up as per the Industry Code of Practice on Indoor Air Quality (ICOP) 2010. The collected data were analysed using several methods, including the SPSS software programme, to determine the relationship between indoor air quality and the respiratory health of the research sample. This technique makes data collection and analysis more efficient.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the result and discussion of indoor air quality and its association with respiratory health. Data collection from both methods, which are indoor air quality assessment and questionnaire method, was to meet the objective of the research. The indoor air quality results for this research were taken from the data monitoring and data collection at the academic staff office room in Factory 3, FTKMP. The experiment was conducted on the ground floor and first floor with the same conditions where the academic staff's daily activity is as normal. Meanwhile, the data from the questionnaire that was handed out to all respondents were analyzed. The results were displayed in graphs and tables, both from data collection and the questionnaires.

4.2 Data of Questionnaire

This research used a questionnaire as one of the methods of collecting data. A questionnaire is a very practical tool for quickly gathering data from a large number of people. The questionnaire was developed by using the ICOP 2010 standard. Pretesting was done on the questionnaire, and the total number of respondents for the pretest was 10% of the sample size. A pretest was conducted to assess the survey's reliability. The questionnaire was handed out to all the respondents, which are Academic Staff in JTKM, Factory 3, FTKMP.

Initially, the questionnaire should be handed out to each academic staff office room which is in a total of 64 rooms. Then, the total respondent was narrowed down to 52 rooms due to some of the rooms were not occupied or no longer being used as academic staff rooms.

However, with a total of 52 questionnaires distributed, only 21 respondents participated. The questionnaire consists of several parts, such as the social demographic of the respondent, nature of the occupation, environmental condition, and respiratory health of the respondent.

4.2.1 Social Demographic of Respondent

Socio-demographics is a term that refers to the combination of social and demographic characteristics that identify persons within a particular group or community. Socio-demographic variables studied for this research were sex, age, and work.

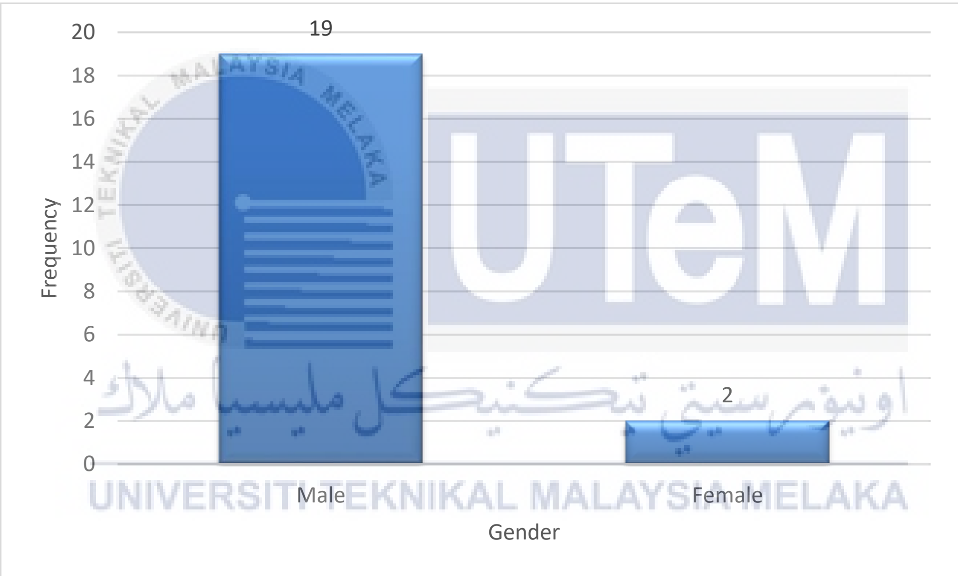


Figure 4.1 Frequency versus gender of respondent

Based on figure 4.1 above, the bar graph shows the gender of the respondent in this study. The respondent consists of 2 different genders, which are male and female. The majority of the respondent is male, with a total of 19 respondent. Meanwhile, there are only two females among the respondent.

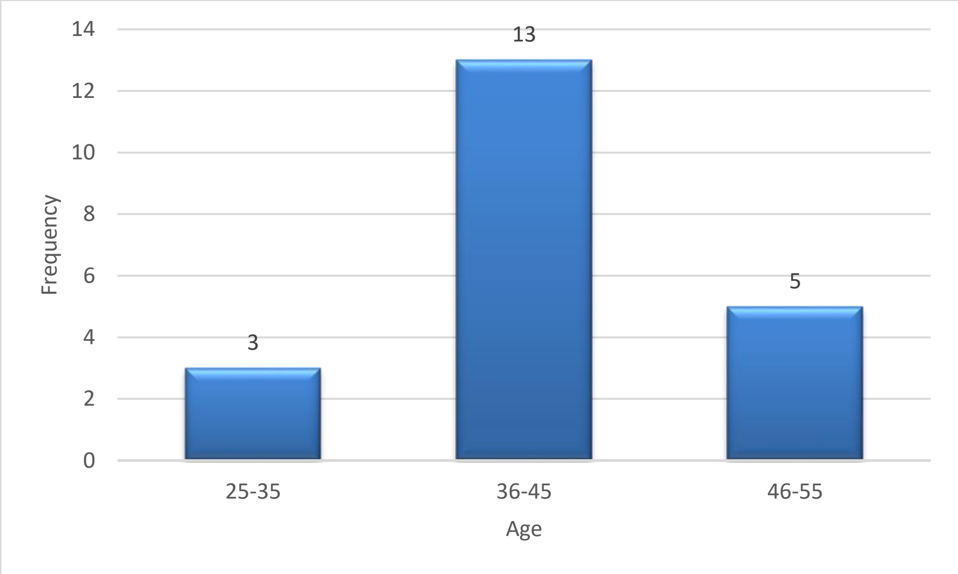


Figure 4.2 Frequency versus age of respondent

The bar graph above shows the age range of the respondent in this study. The highest group of age stated was in the range of 36 years old to 45 years old (n = 13). The second highest was in the age range of 46 years old to 55 years old (n = 5). The others are respondent with an age range of 25 years old to 35 years old

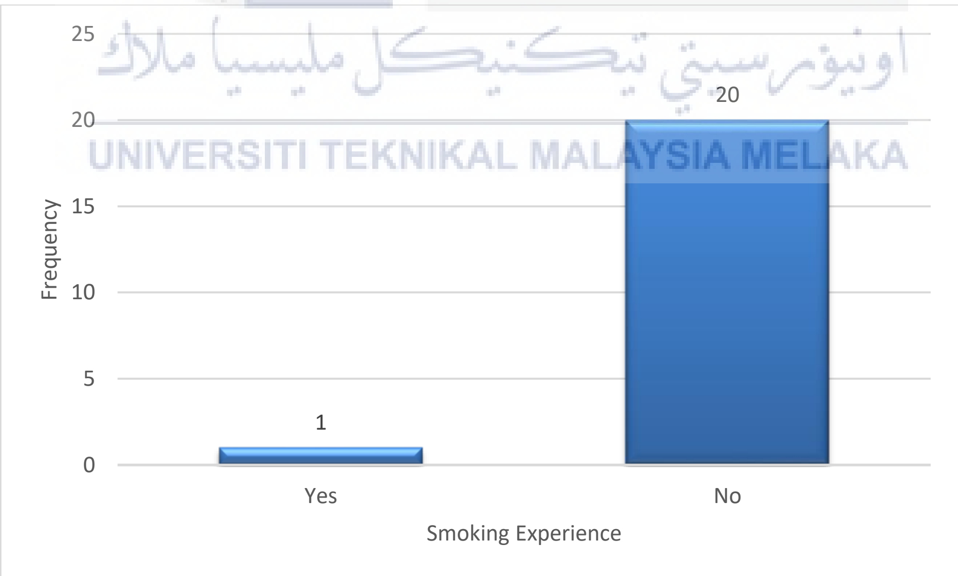


Figure 4.3 Frequency versus smoking experience

Based on figure 4.3 above, the bar graph states the amount of person who smokes among respondents. Out of 21 respondents, only one was smoking, while the others stated they never smoke.

4.2.2 Nature of Occupation

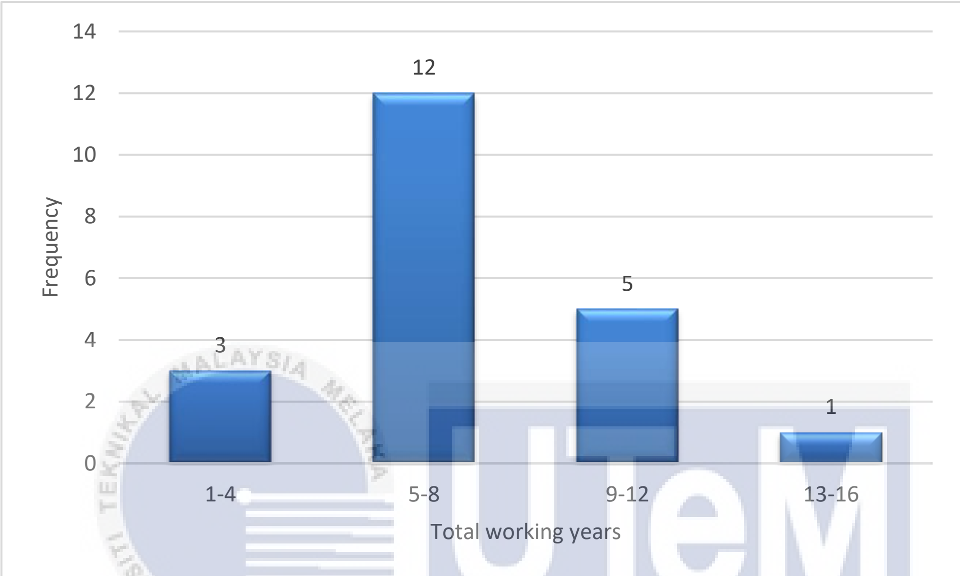


Figure 4.4 Frequency versus total working years

As for the nature of the occupation, the bar graph in figure 4.4 shows that out of 21 respondent, 12 respondent has been working for 5 to 8 years. The other five respondents have worked for 9 to 12 years, and three have worked for 1 to 4 years. Only one respondent has been working for 13 to 16 years at the same place.

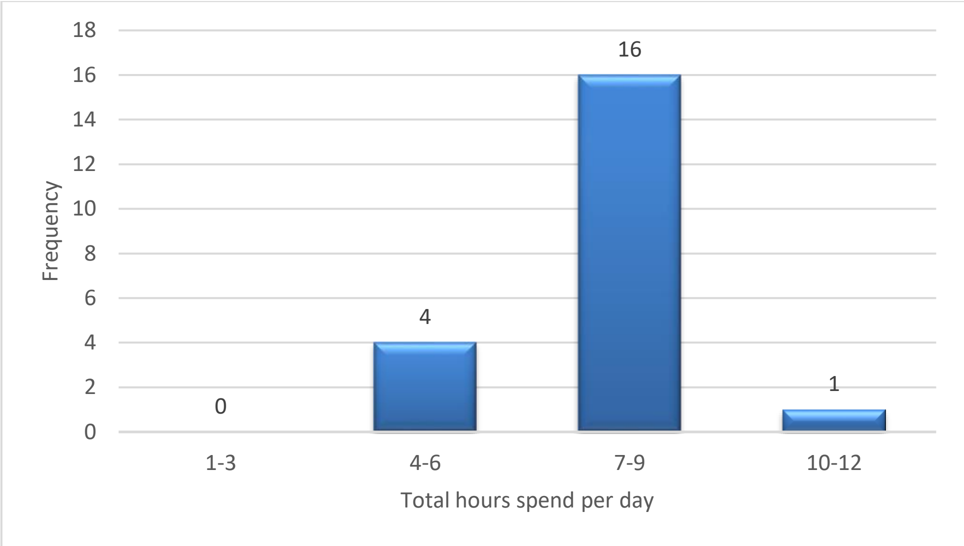


Figure 4.5 Frequency versus total hours spend per day

The bar graph above shows the total hours respondent spend per day at the workplace. The majority of the respondent, which is 16 respondents, spend 7 to 9 hours per day at the workplace. Only one respondent spends about 10 to 12 hours per day at the workplace, and the other four spend about 4 to 6 hours per day at the workplace.

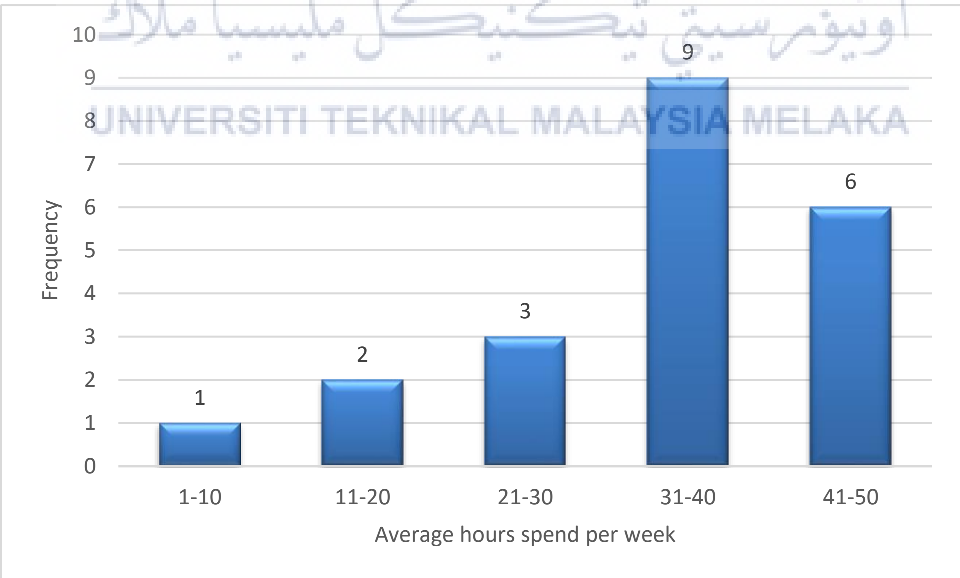


Figure 4.6 Frequency versus average hours spend per week

The bar graph in figure 4.6 above shows the average hours respondent spend per week at the workplace. A total of 9 respondents spend about 31 to 40 hours on average per week. Meanwhile, six respondents spend 41-50 hours per week at the workplace, three respondents spend 21 to 30 hours per week, two respondents spend 11 to 20 hours, and lastly, one respondent spends about 1 to 10 hours on average per week at the workplace. The total time and years spent at workplace may influence in the health of respondents and possible symptom occur.

4.2.3 Environmental Conditions

In this section, the questionnaire was used to find out the possible factor and environmental workplace conditions.

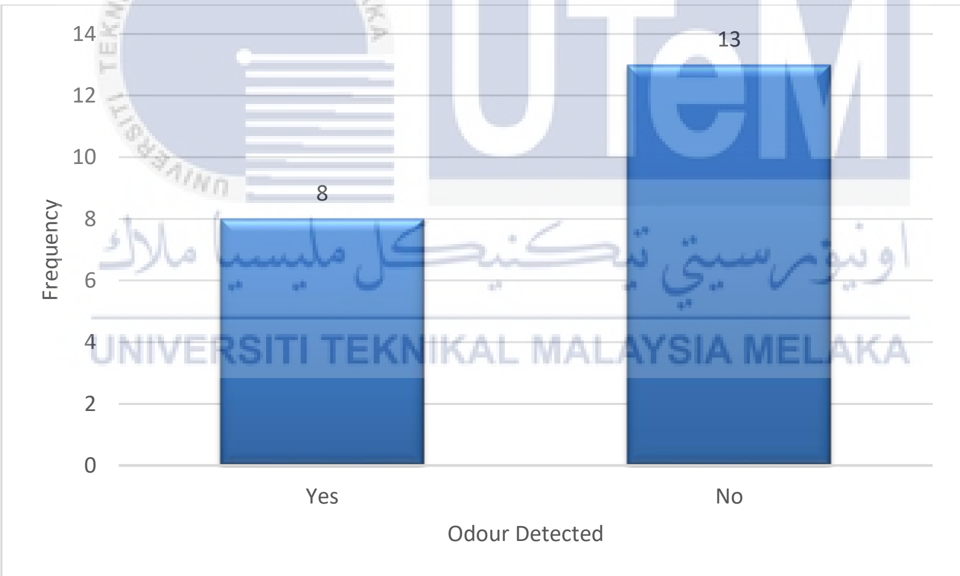


Figure 4.7 Frequency versus odour detected

The bar chart above shows the odour detection in the academic staff office room. More than half respondents answered that there was no odour detected in the office room. However, 8 of the respondents stated that there is a sense of odour in the room.

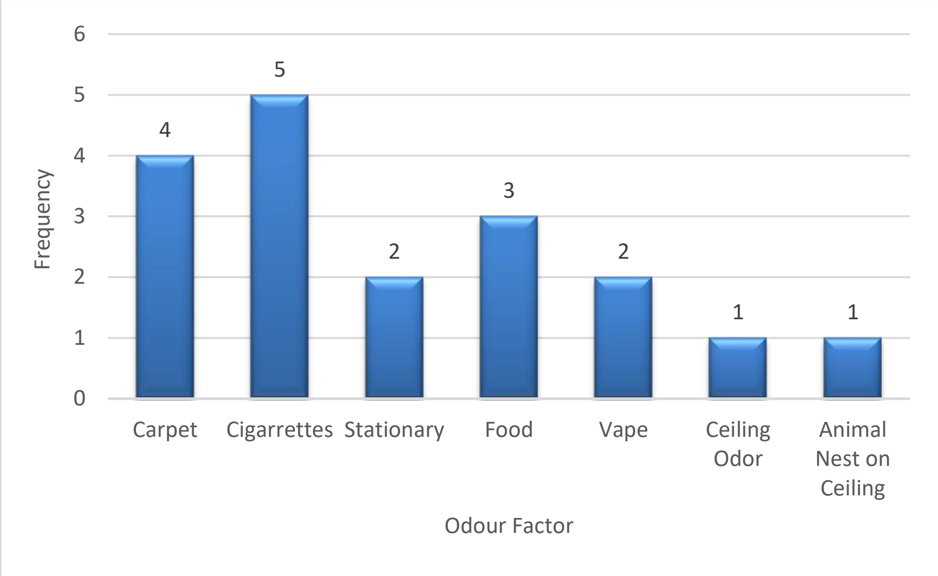


Figure 4.8 Frequency versus odour factor

Based on the graph in figure 4.7 and figure 4.8 above, the respondent that stated there was an odour in the office room believed that the odour was coming from many variables. Cigarettes and carpets are one of the main factors of odour in the office room. The respondent also believes that stationary, food, vape, and ceiling odour is one factor that contributes to odour in the surrounding. The respondent also stated that the animal nest on the ceiling was also a factor that contributed to odour in the office room.

4.2.4 Past and Present Disease

In this section, the questionnaire was used to find out the respondents' past and present diseases. The questionnaire was also used to determine whether the respondent experienced the symptom during working hours. This section is to determine the respiratory symptom of the respondent

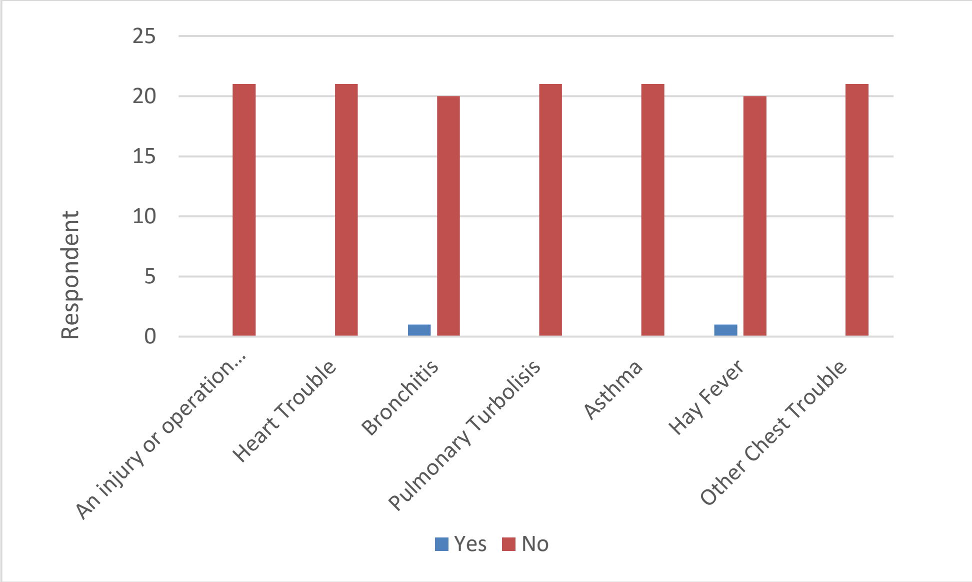


Figure 4.9 Past illnesses of respondent

Based on figure 4.9, the bar graph shows past illnesses for respondent. Disease that has been asked in this section is injury that affecting chest, heart trouble, bronchitis, pulmonary turbolisis, asthma, hay fever and other chest trouble. Based on the question, only two disease that has been experience by respondent which is bronchitis and hay fever. Both disease with one respondent each

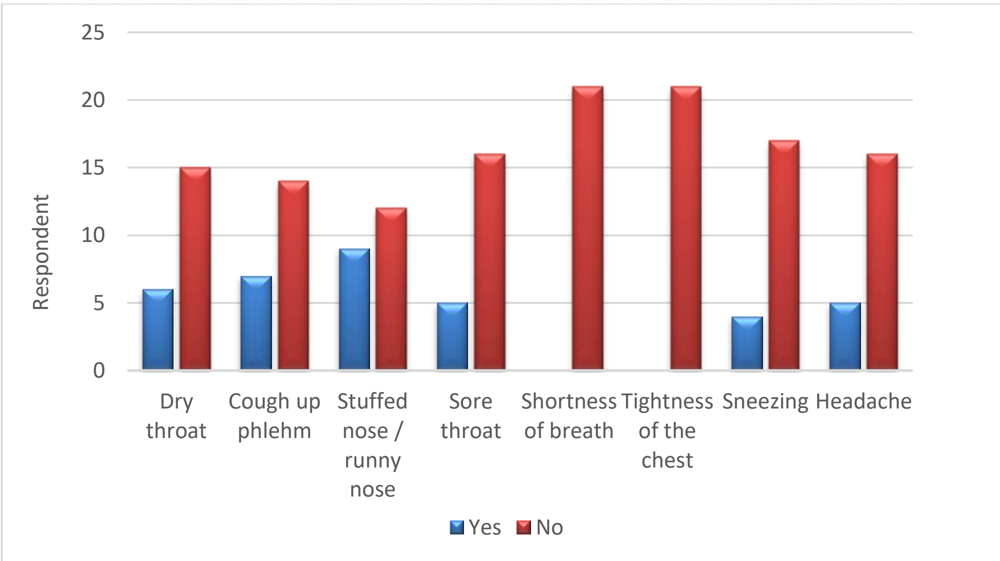


Figure 4.10 Symptom in previous weeks

The bar chart above shows the symptom that respondents experienced in the previous weeks. The symptoms are related to respiratory health. The highest symptom that affected the respondent was a stuffed nose / runny nose, with nine respondents had experienced the sickness. Only shortness of breath and tightness of the chest symptom did not occur during the past weeks among respondents.

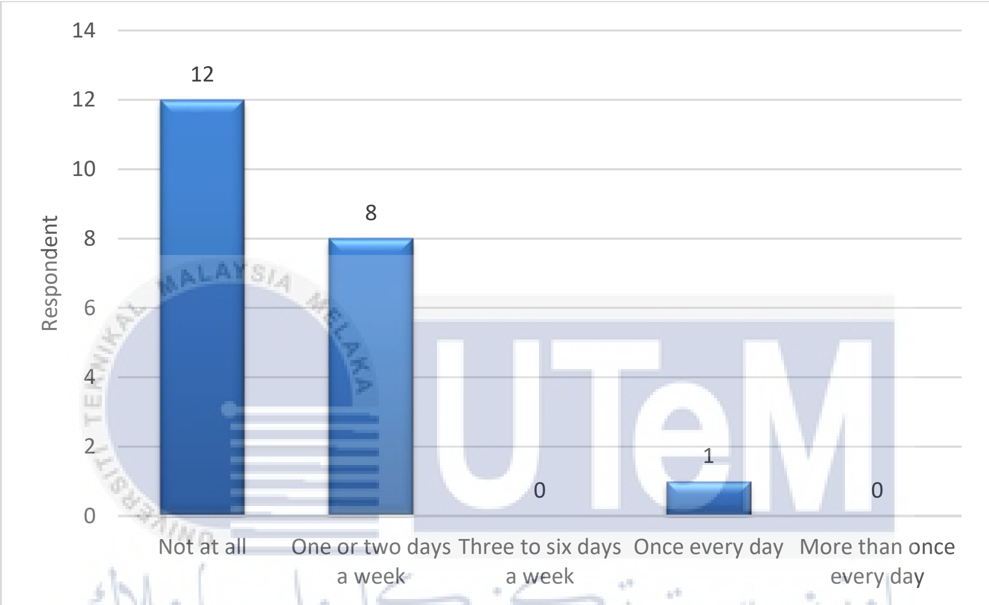


Figure 4.11 Frequency of symptom occur

Figure 4.11 illustrates the bar graph for the frequency of symptom occurrence in the past four weeks among respondents. A total of 8 respondents experienced the symptom one or two days a week. Only one respondent experienced the symptom once every day. Meanwhile, the other 12 respondents did not feel the symptom at all

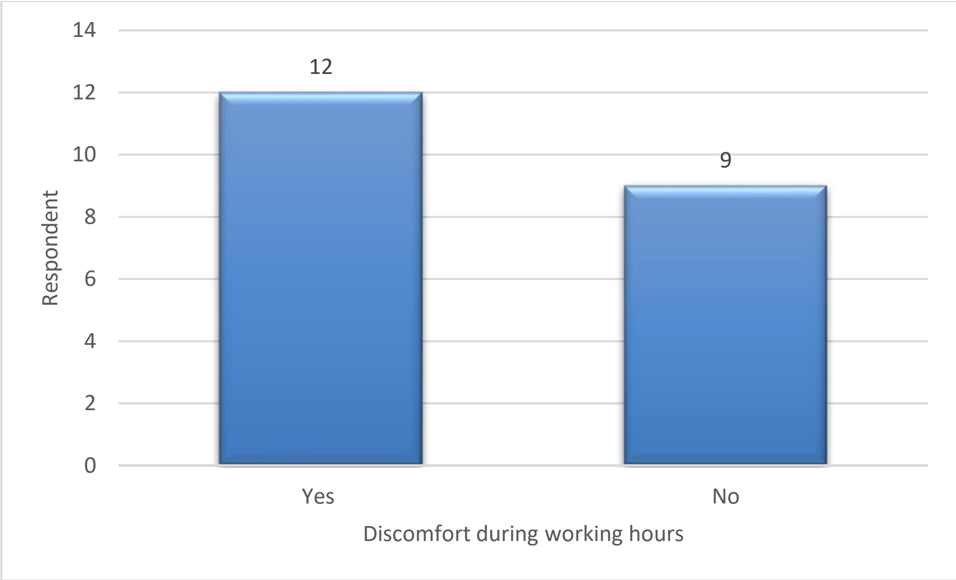


Figure 4.12 Discomfort during working hours

The bar graph in figure 4.12 above shows the respondent's answers for the time discomfort or symptom occurred. The total f the total respondent that felt discomfort happens during working hours was 12 respondent. Meanwhile, nine respondents stated that the discomfort did not occur during work.

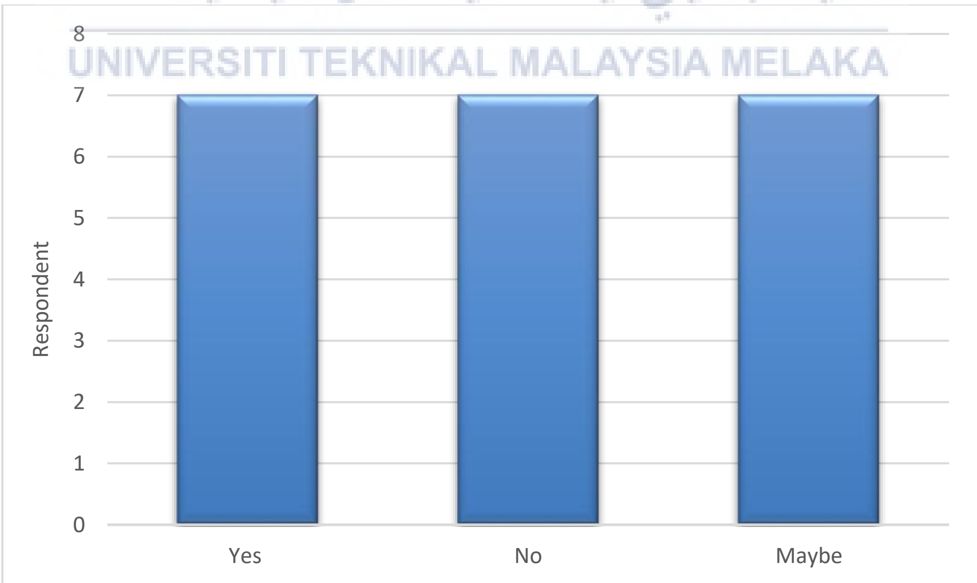


Figure 4.13 Source of discomfort from workplace

The bar graph in figure 4.13 illustrates the suggested answer from respondents about the cause of symptom and discomfort coming from bad IAQ condition at the workplace. The total respondent stated yes, no, and maybe as the answer is the same (n = 7, 33.3%)

4.3 Comparison of Office Room Characteristics

The study area selected was JTKM lecturer's office room in Factory 3, FTKMP, where the indoor air quality parameters data collection was conducted. The study area was divided into two zones, which are zone 1 on the ground floor, and zone 2 on the first floor. Data samples from these two zones were compared to find out about the office room characteristics. Both study areas, the ground floor and first floor, show the same characteristics. Room size for all rooms was 3.6m x 3.6m. The room area is 7.2m². The ceiling material and floor material is the same, using concrete. The wall type for all rooms are concrete, and partition between each room. All room has 1 door quantity. However, the window quantity is different for the lecturer's office room. The quantity of windows depends on the orientation of the room.

Based on figure 4.14, the room that was located at the end of the building wall and has direct sunlight was equipped with a window. Meanwhile, the room located on the opposite staff of the windowed room does not have a window as it is not required to have one. The ventilation of the room is dependent on the window and air conditioning. The academic staff office room was equipped with intake ducting and exhaust duct. All the academic staff office rooms use the same type of lamp, which is a fluorescent lamp and has the same amount of lamps which is 4 for each room. Each room also has one working table, chair, computer, and a bookshelf made up of pressed wood.

The orientation inside of the room is different, depending on the academic staff itself. There are rooms equipped with external items such as carpet, fan, air humidifier and personal accessories. The study area was located near with industrial area and had high traffic density. High possibility that pollution is coming from the vehicle and factories nearby.

4.4 Ground Floor Sampling Point Data

The results of IAQ parameters were illustrated in graph and table form. The sampling point represented the academic office room. The data collection was done for 16 sampling point out of 64 JTKM academic staff office room at Factory 3. The study area was divided into two zones which is ground floor and first floor with 8 sampling point for each zone. The data parameters taken in this research were to meet the objective, to measure the level of indoor air pollutants such as CO_2, VOCs, temperature, and relative humidity in the office room of JTKM academic staff.

Table 4.1 Ground floor IAQ data

Ground Floor Sampling point	IAQ Parameters				
Room	CO_2 (ppm)	TVOC (ppm)	$PM_{2.5}$ (mg/m^3)	Temperature (°C)	Relative Humidity (%)
1	258	4.426	0.00269	22.6	76.1
2	5	0	0.00012	24.2	71.41
3	1	0	0.00058	23.5	77.6
4	308	6.913	0.00077	19.8	79.4
5	328	4.871	0.001	23	75.9
6	17	0	0.0005	25.4	69.9
7	16	0	0.00015	22.49	75.3
8	332	7.107	0.00047	21.3	77.24
Mean	158.1	2.9	0.0008	22.8	75.4
Standard Deviation	160.3	3.2	0.0008	1.7	3.2
Acceptable limits/range	1000	3	0.15	23-26	40-70

Table 4.1 illustrated the IAQ parameters data collected for ground floor. Total room at ground floor is 8 room. The room is opposite to each other which some of the room is windowed and the others is non-window. The sampling point for each room is only one point as the total room area was less than 3000m², that recommended by DOSH guideline. The data collection was done for 6 hours, with interval of the data logged is every 1 minute. The data stated for each room and each parameter was the average value of the parameters. Other than that, the minimum value, maximum value, mean and acceptable limits/range by DOSH was also stated in the table 4.1. Graph on figure 4.15 until figure 4.24 was illustrated based on the table 4.1. The graph shows more details result of the data collection.

4.4.1 Result for Carbon Dioxide

This section stated the results for carbon dioxide on the ground floor. The results were divided and displayed into two different graphs, which are the value of each academic staff office room and another one is time series graph

4.4.1.1 Carbon Dioxide for Ground Floor Sampling Point

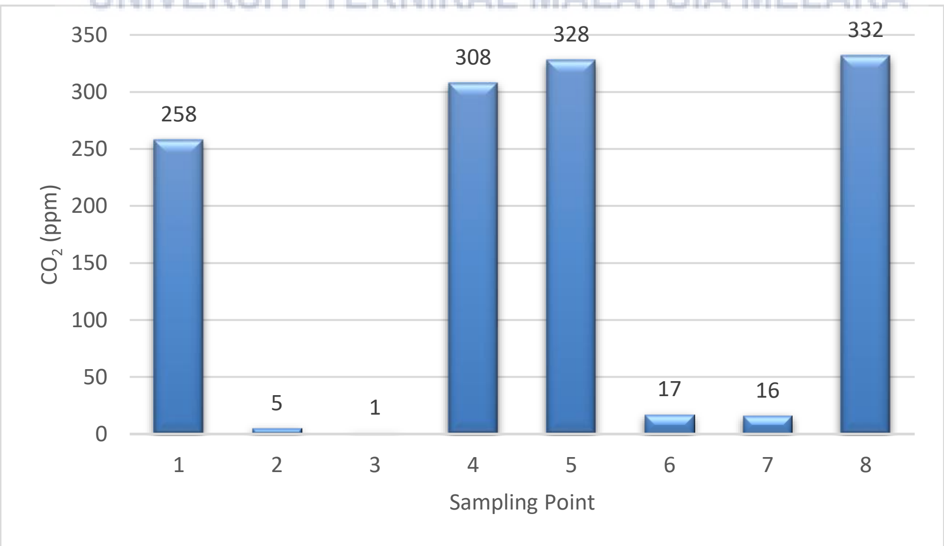


Figure 4.14 Graph of CO_2 versus Sampling Point

The line graph above illustrates the average value of CO_2 in each academic staff office room. The value of CO_2 is different for each room and shows big differences in minimum and maximum values of the graph. The minimum value stated is one ppm which is a relatively low value, in room 2. Meanwhile, the highest average value of CO_2 was in room 5 (328 ppm). The total average of the CO_2 for all rooms at ground level is 158.1 ppm. The acceptable limits by DOSH cannot be stated on the graph as the gap was too far, at 1000 ppm. The graph shows an upward and downward trend as it is not related to each other.

From the results on the average value of CO_2 in the ground floor lecturer's office room, it shows that all the office room was far below the acceptable limits by DOSH as the highest average value was 328 ppm. CO_2 usually comes from the burning of fossil fuels like coal, oil, and natural gas. All 8 room was in safe surrounding and safe from CO_2 emission in comparison of a total of CO_2 and the acceptable limits.

4.4.1.2 Carbon Dioxide for Every Hour

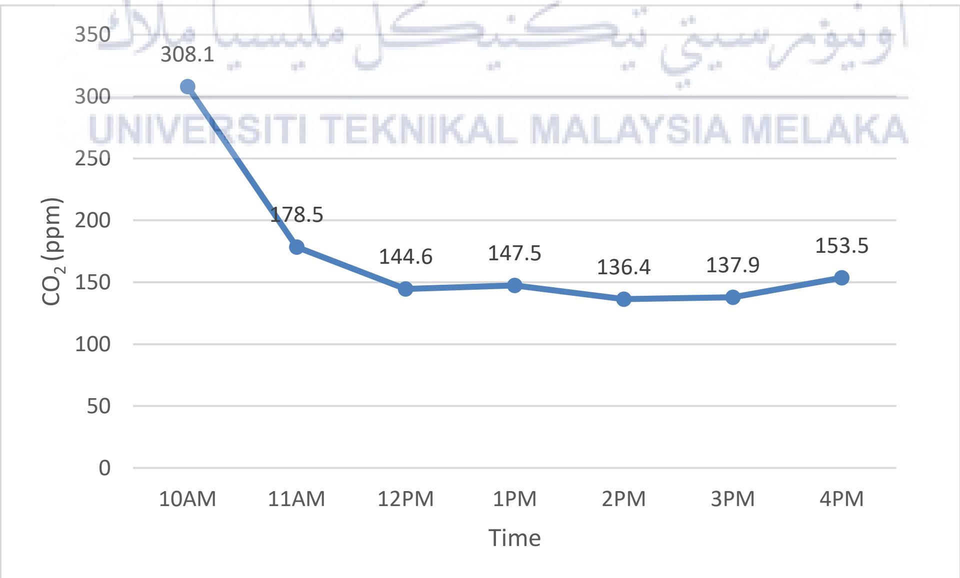


Figure 4.15 Graph of Carbon Dioxide vs Time

Based on figure 4.16, the line graph shows the value of CO_2 during the data collection. The data collection was done for 6 hours, which was from 10 am to 4 pm. The data interval for the data collection is 1 hour. The highest value recorded was at 10 am with 308.1 ppm. The value dropped to 178.5 ppm at 11 am and showed a stable trend for the rest of the data collection time. The last value recorded is 154.5 ppm at 4 pm.

4.4.2 Result for TVOC

The results for Total Volatile Organic Compound (TVOC) at ground level were presented in this section. The data were displayed in two different graphs.

4.4.2.1 TVOC for Ground Floor Sampling Point

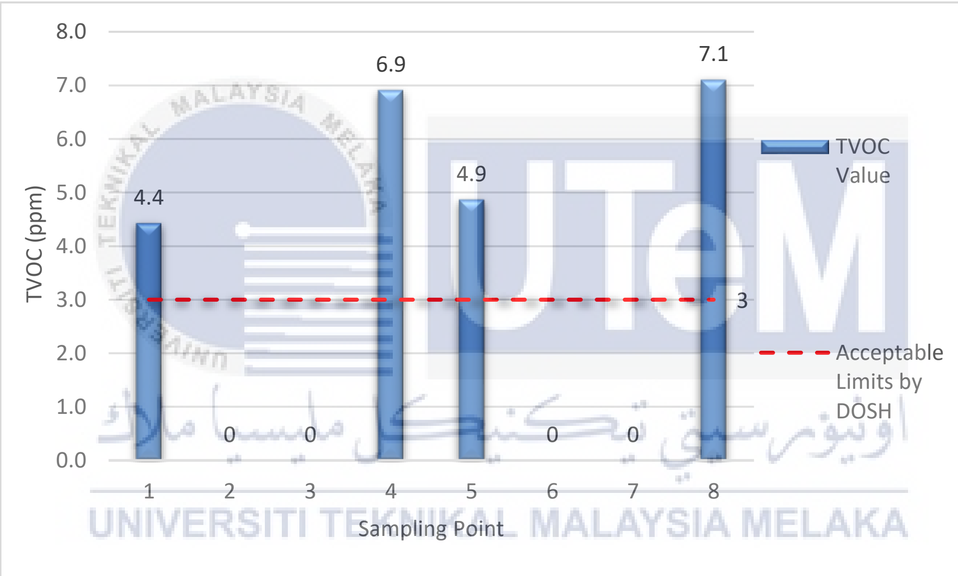


Figure 4.16 Graph of TVOC versus Sampling Point

The line graph above illustrates the average value of TVOC in the ground floor academic staff office room. The graph shows the same value in 4 different room, which is room 2, 3, 6, and 7. All four room shows the concentration of TVOC value of 0 ppm. The highest value of TVOC is 7.1 ppm, the value recorded in room number 8. Meanwhile, the acceptable limit by DOSH for TVOC shown in the graph is 3 ppm.

High levels of TVOC are considered hazardous to individuals since they have significant impact on their health. Upper respiratory infections, dizziness, allergic reactions, headaches, and swelling of the eyes, nose, and mouth are all possible side effects of TVOC exposure. Based on figure 4.17, the line graph shows half of the room recorded the value of TVOC, more than acceptable limits by DOSH. However, on average, the total value of TVOC is 2.9, which is still at acceptable limits.

4.4.2.2 TVOC for Every Hour

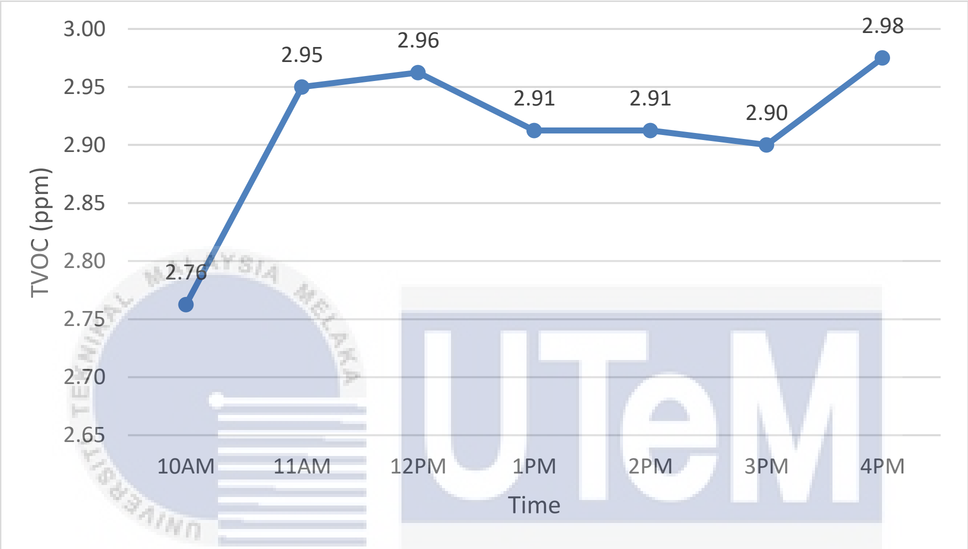


Figure 4.17 Graph of TVOC versus Time

The line graph above shows the value of TVOC versus time at ground floor sampling point. The minimum value recorded is at 10 am with value of 2.8 ppm. The value increasing to 2.95 ppm at 11 pm and constant at the range of 2.90 ppm to 3.0 ppm. The highest value recorded is at 4 pm, which is 2.98 pm.

4.4.3 Result for Particulate Matter

Particulate matter $_{2.5}$ ($PM_{2.5}$) refers to tiny particles or droplets in the air with a width of two and a half microns or less. Short-term health consequences from exposure to small particles include irritation of the eyes, nose, throat, and lungs, coughing, sneezing, runny nose, and shortness of breath. The results of $PM_{2.5}$ for the ground floor are illustrated in the graph below.

4.4.3.1 Particulate Matter for Ground Floor Sampling Point

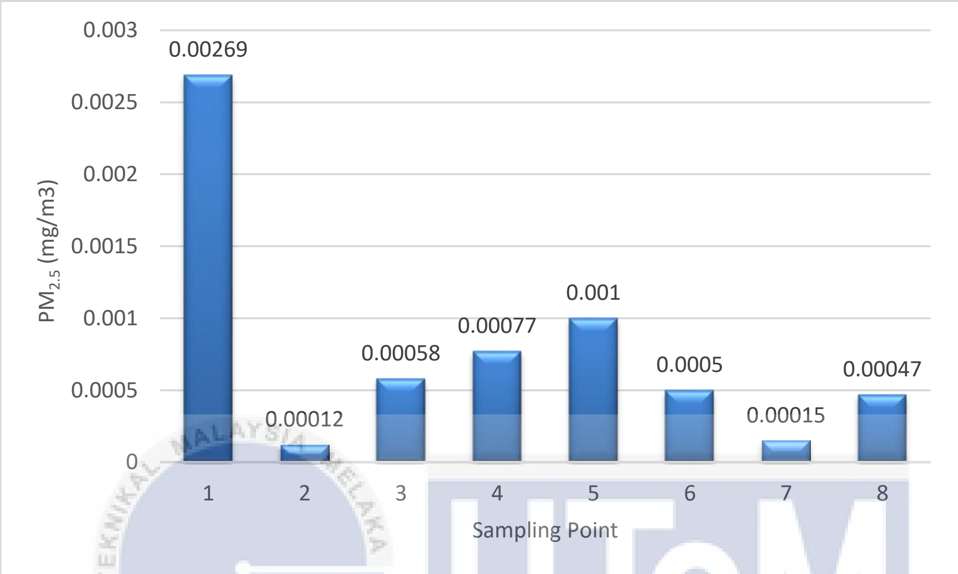


Figure 4.18 Graph of $PM_{2.5}$ versus Sampling Point

Figure 4.19 shows the bar graph of average value of $PM_{2.5}$ at ground floor lecturer's office room. The graph shows the average value of $PM_{2.5}$ for each room is relatively low. All the value was below than 0.03 (mg/m^3). The highest value recorded was at room 6 with 0.00269 (mg/m^3). The acceptable limit by DOSH is 0.05 (mg/m^3)

Based on the graph above, the total dust at lecturer's office room at ground floor is in safe zone. There is significant amount of total average of $PM_{2.5}$ compared with the acceptable limits. The value of $PM_{2.5}$'s total average is 0.0008 (mg/m^3). Thus, the condition inside the lecturer's office room is good and comply with DOSH standard.

4.4.3.2 Particulate Matter for Every Hour

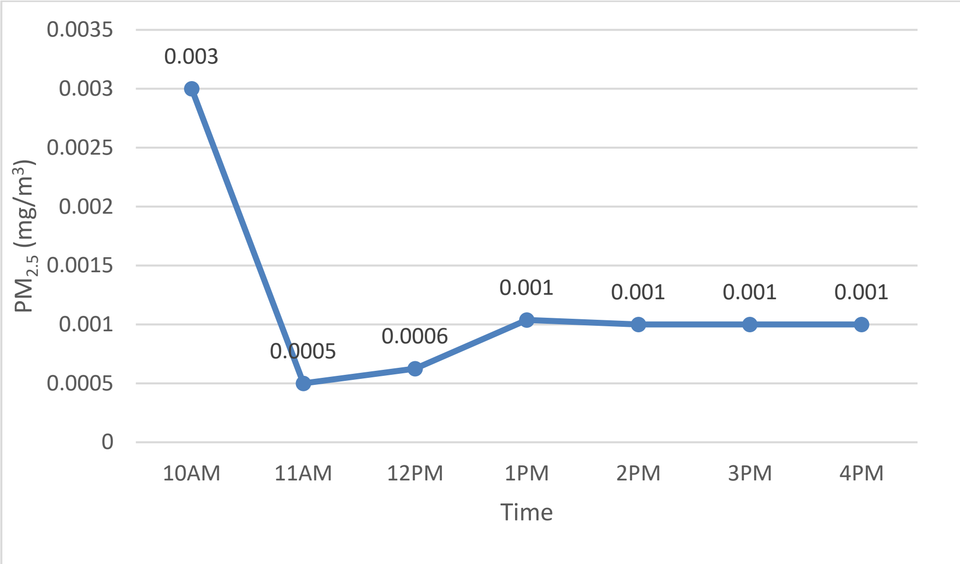


Figure 4.19 Graph of $PM_{2.5}$ versus Time

Time series graph above shows particulate matter $_{2.5}$ for 6 hours with 1-hour intervals. The PM $_{2.5}$ value is at the peak at 10 am, where the value is 0.003 mg/m^3. The value drops to 0.0005 mg/m^3 after one hour. The value increases the next hour to 0.0006 mg/m^3 and stays constant from 1 pm to 4 pm. The starting value is a bit high due to the start-up process of data collection. The movement of the researcher during the start-up process might cause particulate dust that the equipment detects.

4.4.4 Result for Temperature

The result of temperature for the ground floor was shown in 2 graphs below. The temperature should be in the same range of value as all the sampling rooms using a centralized air-conditioner.

4.4.4.1 Temperature for Ground Floor Sampling Point

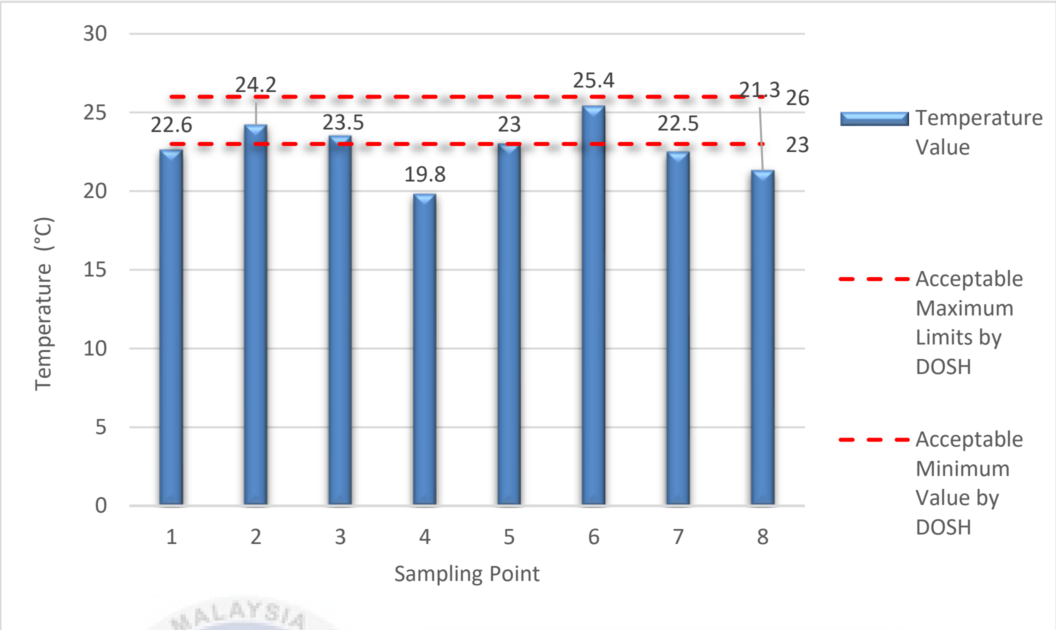


Figure 4.20 Graph of Temperature versus Sampling Point

Figure 4.21 above illustrates the line graph of the average value of temperature in the academic staff office room on the ground floor. The comfortable standard by DOSH is between 23 °c to 26 °c. A total of 4 rooms are within comfortable limits, which the highest temperature recorded at room 6 at 25.4 °c. Meanwhile, there are 4 rooms that are below the minimum temperature limits, which is room 1, room 4, room 7, and room 8, with value of 22.6 °c, 19.8 °c, 22.5 °c and 23 °c respectively. Room 7 is the lowest value of temperature amongst all 8 rooms. The temperature of the room is very important as it is one of the factors of comfort for a person. Too high a temperature may bring discomfort and can lead to heat stress.

Meanwhile, too low a temperature also bring discomfort a person. However, the level of comfort depends on the person itself. Recommended temperature value by DOSH is just in general, but the different thermal comfort of the person is different with others. Based on the graph, the value is not significant for each room. As for room 7, the low temperature recorded might be cause by activities in the room or the staff is not in the room for few hours.

4.4.4.2 Temperature for Every Hour

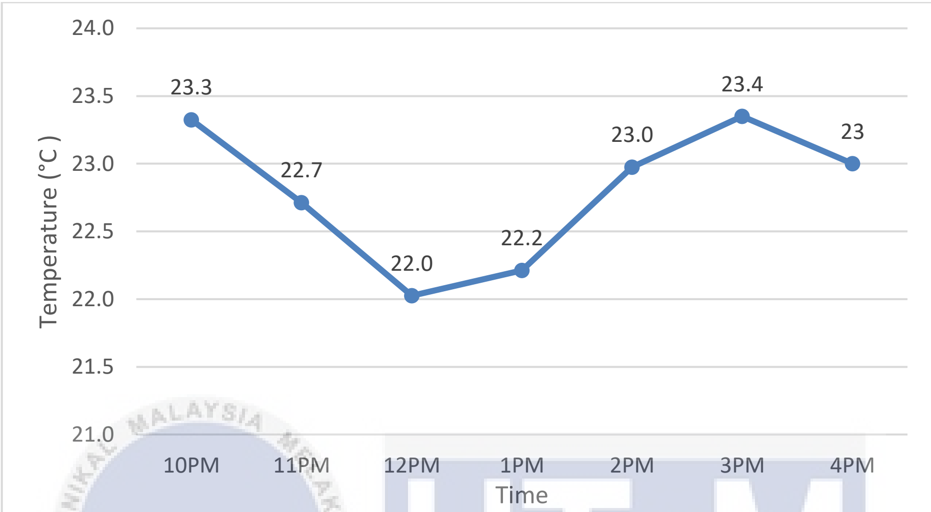


Figure 4.21 Graph of Temperature versus Time

The line graph in figure 4.22 above shows the temperature value recorded on the ground floor sampling point every hour from 10 am to 4 pm. The highest value recorded is between 10 am and 3 pm, with 23.3 °C and 23.4 °C, respectively. Meanwhile, the lowest temperature recorded is from 12 pm to 1 pm. The occupants not in the room are one of the reason the temperature is at the lowest value, as 12 pm to 1 pm is the usual break time for academic staff. The presence of occupants is one factor that influences the temperature value.

4.4.5 Result for Relative Humidity

The relative humidity is one of the important aspects of IAQ. The ability to monitor and manage RH not only assists in maintaining a comfortable climate within a building but also in optimising the HVAC system efficiency. The relative humidity results are shown in the bar graph and line graph below.

4.4.5.1 Relative Humidity for Ground Floor Sampling Point

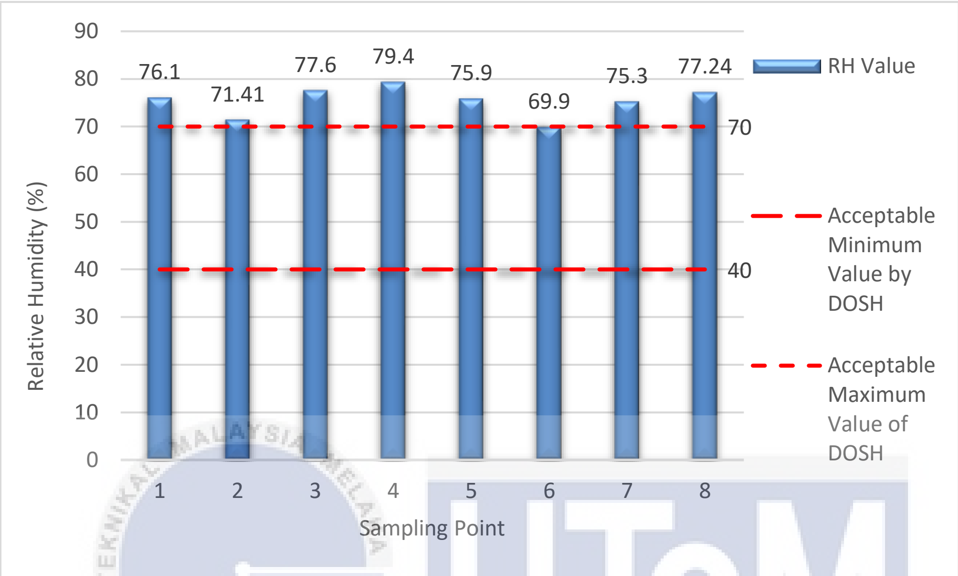


Figure 4.22 Graph of RH versus Sampling Point

The bar graph in figure 4.23 shows the average value of RH in the academic staff office room on the ground floor. The lowest relative humidity recorded was at room number 6, with 69.9 % of relative humidity. Room number 4 recorded the highest percentage of relative humidity, with 79.4 %. The minimum and maximum acceptable limits ranged from 40 % to 70 %. All the rooms recorded the percentage of RH over the maximum acceptable limits by DOSH except for room number 6, which is on par with the minimum limits.

Relative humidity (RH) refers to the amount of water vapor in the atmosphere. The relative humidity will decrease when the temperature increases, making the air drier. When the temperatures drop, the air will get wet, increasing relative humidity. Humidity and temperature are inversely proportional. The total average relative humidity value in the academic staff office room on the ground floor is 76.21 %. The average is slightly higher than the maximum acceptable limits by DOSH.

4.4.5.2 Relative Humidity for Every Hour

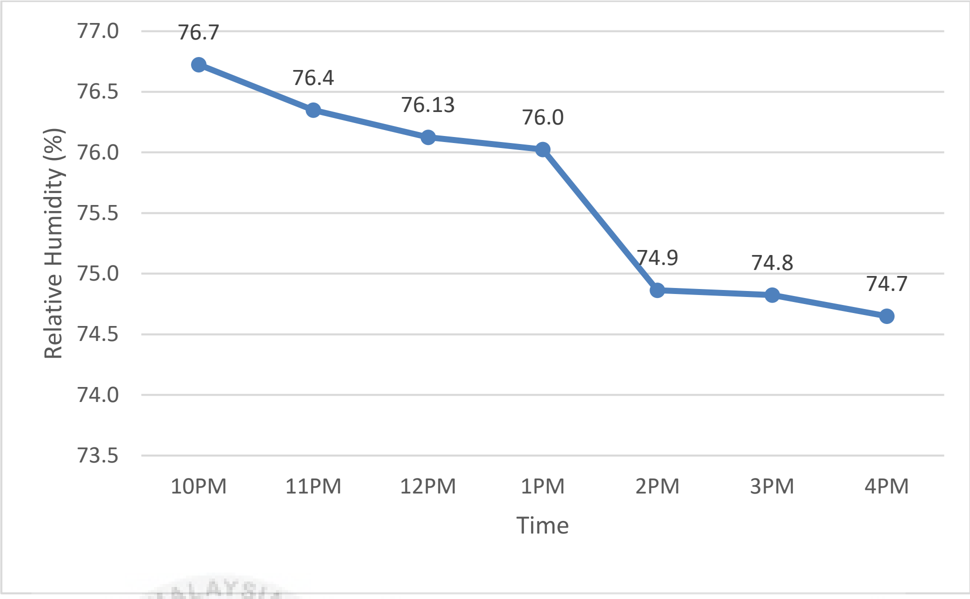


Figure 4.23 Graph of RH versus Time

The line graph above shows the relative humidity value for ground floor from 10 am to 4 pm. The value of relative humidity is decreasing by time. The highest value of relative humidity recorded is 76.7 % at 10 am. Meanwhile, the lowest value recorded is 74.7 %. The trend of the graph is decreasing.

From the result of relative humidity vs time, it shows that the relative humidity is highest in the morning, this is usually because the low temperature in the morning. With the temperature is increasing during the day, the value of relative humidity is decreasing.

4.5 First Floor Sampling Point Result

Table 4.2 First Floor Sampling Point Data

First Floor Sampling point	IAQ Parameters				
Room	CO_2 (ppm)	TVOC (ppm)	$PM_{2.5}$ (mg/m^3)	Temperature (°C)	Relative Humidity (%)
1	219	3.2	0.00454	22.6	76.1
2	0	0.0	0.0026	24	70.4
3	1	0.0	0.0013	23.5	77.6
4	183	5.8	0.00369	22.1	80.8
5	55	4.6	0.007	24.2	82.4
6	0	0.0	0.0017	24.6	79.8
7	225	5.6	0.01458	21.43	82.7
8	0	0.0	0.01473	23.54	78.4
Mean	97.6	2.7	0.0051	23.2	78.5
Standard Deviation	106.8	2.7	0.0046	1.2	4.3
Acceptable limits/range	1000	3	0.15	23-26	40-70

Table 4.2 illustrates the IAQ parameters data collected for the first floor. The total sampling point on the first floor is the same as the ground floor, which is 8 sampling points, and the room's orientation is the same as the ground floor. The data stated for each room and each parameter was the average value of the parameters. The minimum value, maximum value, mean and acceptable limits/range by DOSH were also stated in table 4.2. Graph from figure 4.20 until figure 4.29 was illustrated based on table 4.2. The graph shows more details results of the data collection

4.5.1 Result for Carbon Dioxide

The Carbon Dioxide results for first floor is stated in this section. The results were displayed into 2 different graph which is value of for each academic staff office room, and another one is time series graph.

4.5.1.1 Carbon Dioxide versus Sampling Point

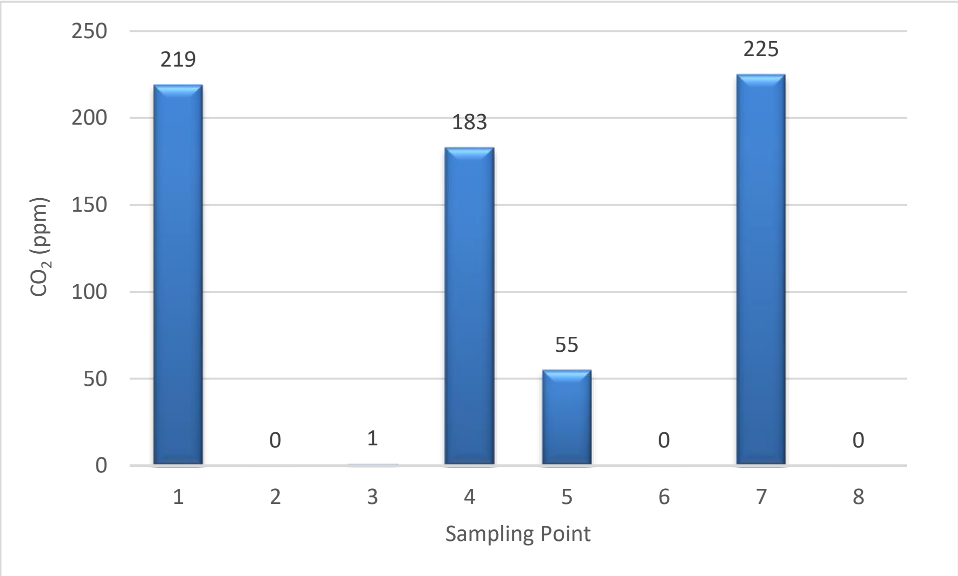


Figure 4.24 Graph of Carbon Dioxide versus Sampling Point

The line graph above illustrates the average value of CO_2 in each lecturer's office room on the first floor. The graph shows that the value of CO_2 is different for each room except for room number 2, room number 6, and room number 8 where all rooms recorded a 0-ppm value. Thus, it is the minimum value of CO_2 for the first floor. Meanwhile, the highest average value of CO_2 was in room 7, with 225 ppm. Room number 1 and room number 4 show a high amount of CO_2 near the maximum value of the graph, with 219 ppm and 183 ppm, respectively. The total average CO_2 for all rooms on the first floor is 112.88 ppm.

Based on the line graph above, the results of the average value of CO_2 in the ground floor lecturer's office room shows that all the office room was far from over the acceptable limits by DOSH as the average value was 112.88 ppm. Meanwhile, the acceptable limit is 1000 ppm. All the room on the first floor can be marked safe from the danger of CO_2 emissions as the results is under acceptable limits.

4.5.1.2 Carbon Dioxide for Every Hour

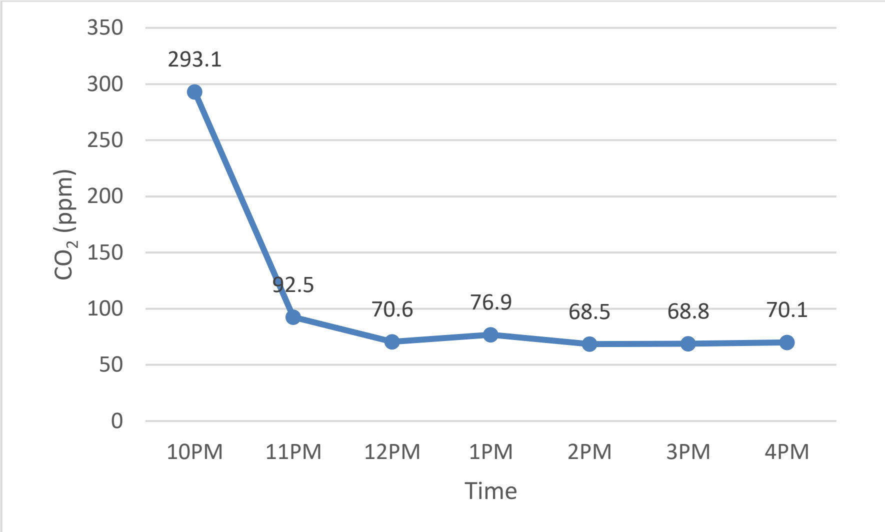


Figure 4.25 Graph of Carbon Dioxide versus Time

The line graph in figure 4.26 shows the value of carbon dioxide at the first-floor sampling point for 6 hours. The starting value at 10 am is 293.1 ppm which is a little high compared to the rest of the hours. This occurs due to the apparatus needing adjustment before becoming stable. The result from 11 am to 4 pm shows a stable trend in the range of 68 ppm to 92 ppm.

4.5.2 TVOC for First Floor Sampling Point

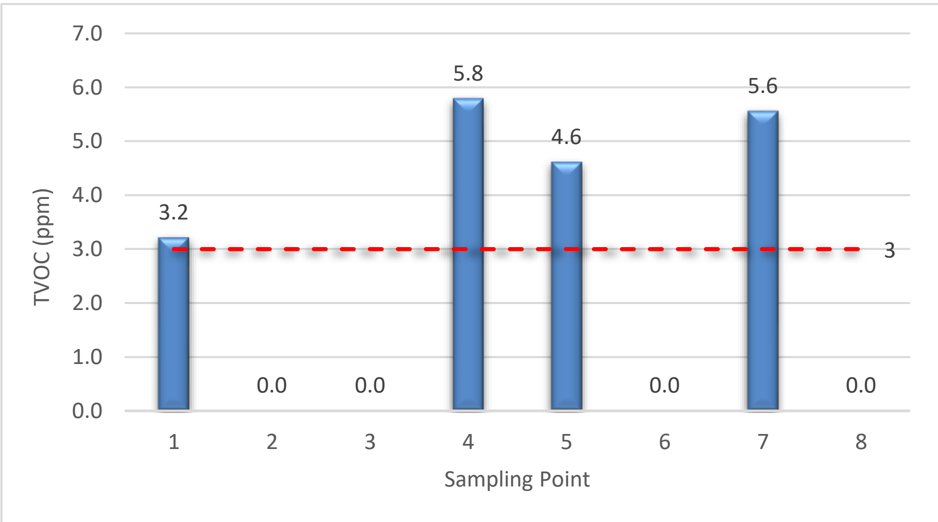


Figure 4.26 Graph of TVOC versus Sampling Point

The line graph above illustrates the average value of TVOC in the first-floor lecturer's office room. The graph shows that room numbers 2, 3, 6, and 8 all recorded the same value of TVOC, which is 0 ppm. The highest value of TVOC was recorded in room number 4, with a value of 5.8 ppm and room number 7 is close to the highest value, with 5.6 ppm. Meanwhile, the acceptable limit by DOSH for TVOC shown in the graph is 3 ppm.

Based on figure 4.27, the line graph shows half of the room recorded the value of TVOC that is slightly higher than the acceptable limit by DOSH. However, the total average value of TVOC is still under the acceptable limit, with a value of 2.7 ppm.

4.5.2.1 TVOC for Every Hour

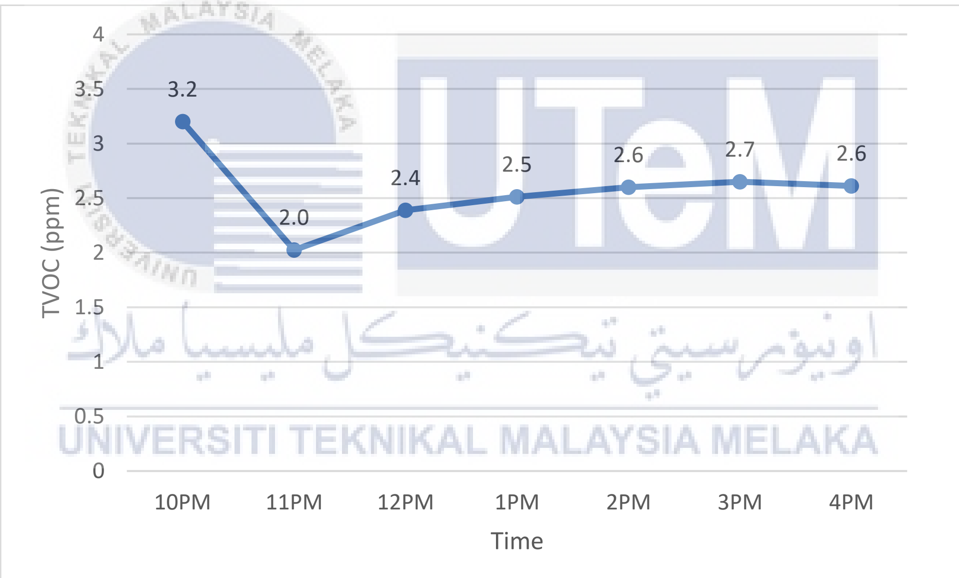


Figure 4.27 Graph of TVOC versus Time

The line graph above shows the total volatile organic compound value of first floor for every hour. The highest value recorded is 3.2 ppm at 10 am, meanwhile the lowest is 2.0 ppm at 11 am. The range value of TVOC is not significant between each hour.

4.5.3 Result for Particulate Matter

The result of particulate matter was illustrated by two different graphs, which are a bar graph for the sampling point and a line graph for the time series. The graph in figure 4.29 and figure 4.30 below represents the particulate matter results for the first floor.

4.5.3.1 Particulate Matter for First Floor Sampling Point

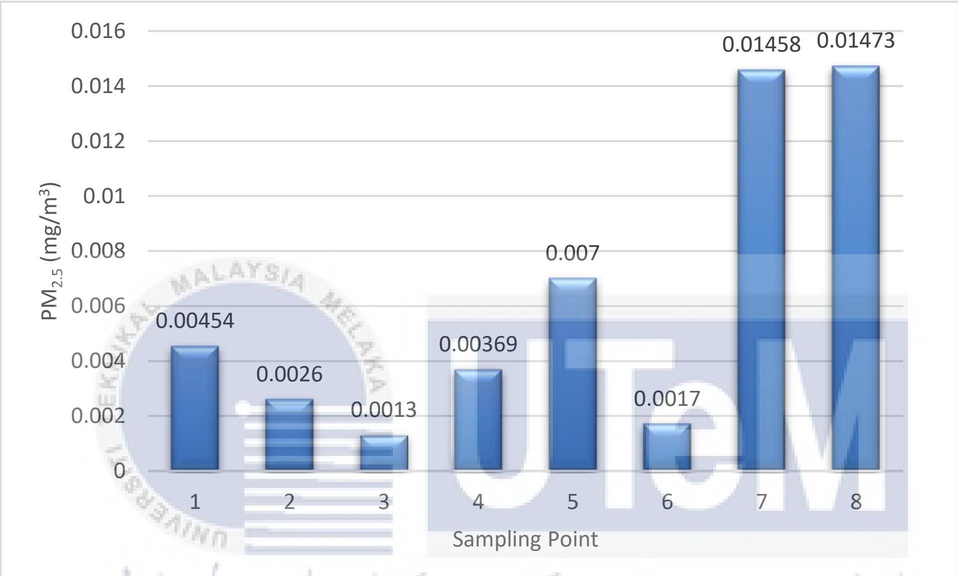


Figure 4.28 Graph of Particulate Matter versus Sampling Point

The line graph above illustrates the average value of $PM_{2.5}$ in the first-floor academic staff office room. The graph shows that the lowest average value recorded was at room number 3, 0.0013 (mg/m^3). The highest value recorded was in room 8, with 0.01473 (mg/m^3). Room number 7 recorded a similar value of particulate matter to room number 8, with a value of 0.01458 mg/m^3. The acceptable limit by DOSH is 0.15 mg/m^3

Based on the graph above, the average $PM_{2.5}$ in academic staff office room on the first floor is below the acceptable limits by DOSH. The value of $PM_{2.5}$ total average is 0.0063 mg/m^3. The range of the average value of $PM_{2.5}$ is far significant compared to the acceptable limits. Therefore, the condition in the academic office room is low in terms of dust particles.

4.5.3.2 Particulate Matter for Every Hour

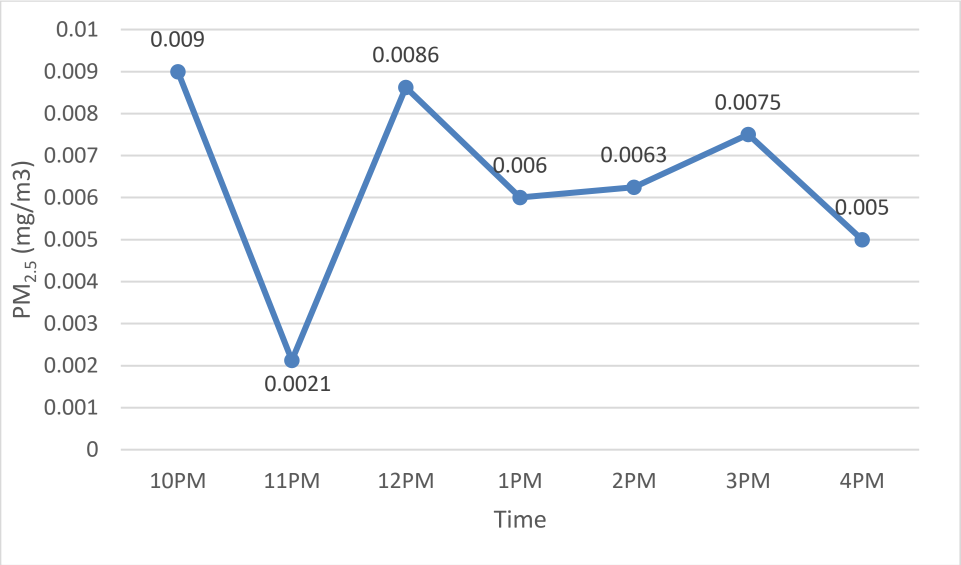


Figure 4.29 Graph of Particulate Matter versus Time

Figure 4.30 above represents a line graph of particulate matter versus time for the first-floor sampling point. The graph shows an upward and downward trend. The first value at 10 am is 0.009 mg/m^3 and drops to 0.0021 mg/m^3 an hour later. The value increases to 0.0086 mg/m^3 at noon and drops again to 0.006 mg/m^3 at 1 pm. The reason is due to the room's occupant activity in the sampling point room. The particulate matter value changes with common indoor activities such as smoking, vaping, or dust from room cleaning.

4.5.4 Result for Temperature

The temperature for the first-floor sampling point was recorded and illustrated in the graph below. Surrounding outside the building may influence the temperature value inside the lecturer's office room. However, the range must not be far between each room because of the type of HVAC system used.

4.5.4.1 Temperature for First Floor Sampling Point

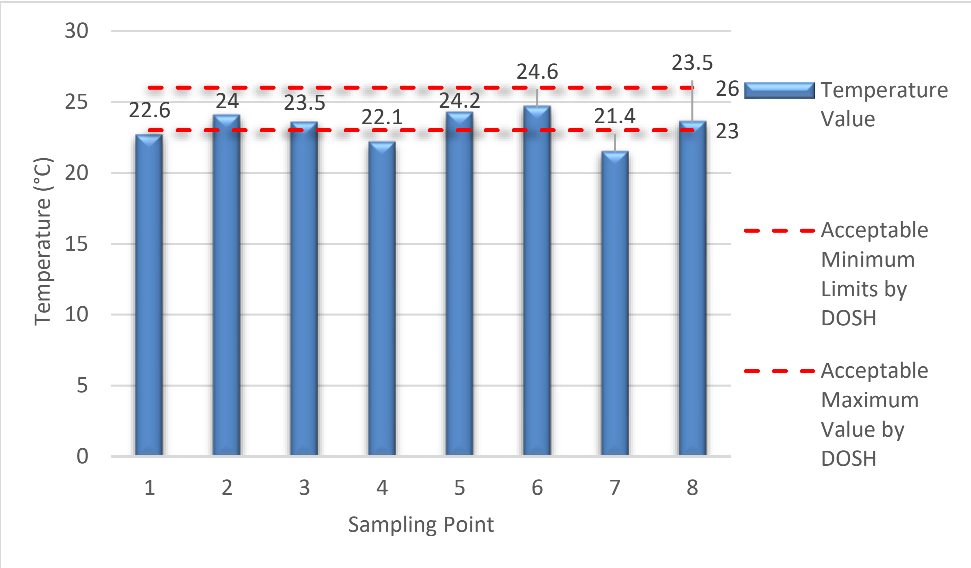


Figure 4.30 Graph of Temperature versus Sampling Point

Figure 4.31 above illustrates the line graph of the average temperature value at the lecturer's office room on the ground floor. The comfortable standard by DOSH is between 23 °C to 26 °C. The value of temperature between all the rooms on the first floor is between 21 °C to 25 °C. The graph stated the highest average temperature recorded was at room number 6, with a value of 24.6 °C. Meanwhile, the lowest temperature value recorded was 21.4 °C in room number 7.

Based on the graph from figure 4.31, the total average value for the lecturer's office room on the first floor is 23.2 °C. It shows that, on average, the value of temperature in the first-floor office room is at the minimum recommendation by DOSH. The equipment, total of people in the room, and outside surrounding are one of the factor values of temperature.

4.5.4.2 Temperature for Every Hour.

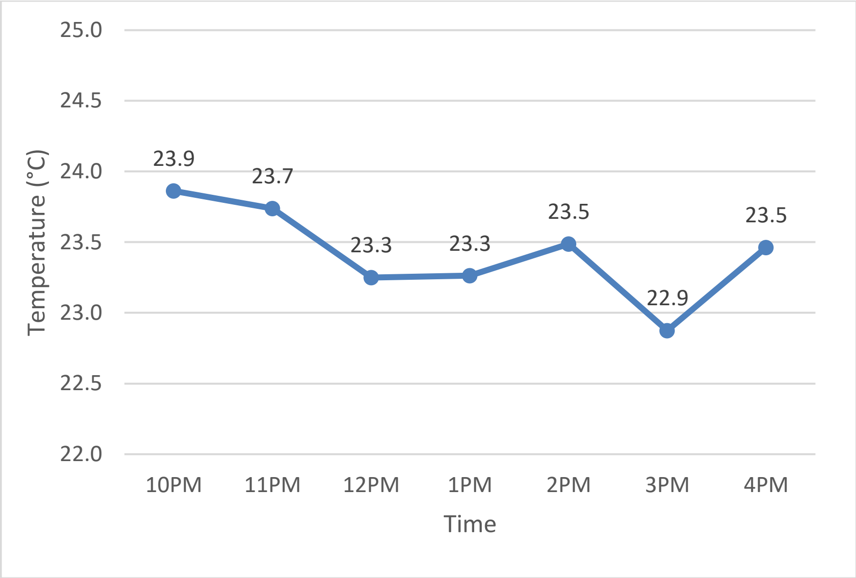


Figure 4.31 Temperature versus Time

The line graph above shows the temperature of the first-floor sampling point and the time recorded. The highest temperature recorded is 23.9 °C at 10 am. During 12 pm and 1 pm, the value recorded is the same, with 23.3 °C for both times. The lowest temperature is at 3 pm, at 22.9 °C. The temperature results show no significant changes during the 6 hours of data collection.

4.5.5 Result for Relative Humidity

This section stated the result for relative humidity for the first-floor sampling point. The results were displayed in two graphs below, which are a bar graph that represents the relative humidity for each sampling point and a line graph that represents the relative humidity for 6 hours.

4.5.5.1 Relative Humidity for First Floor Sampling Point

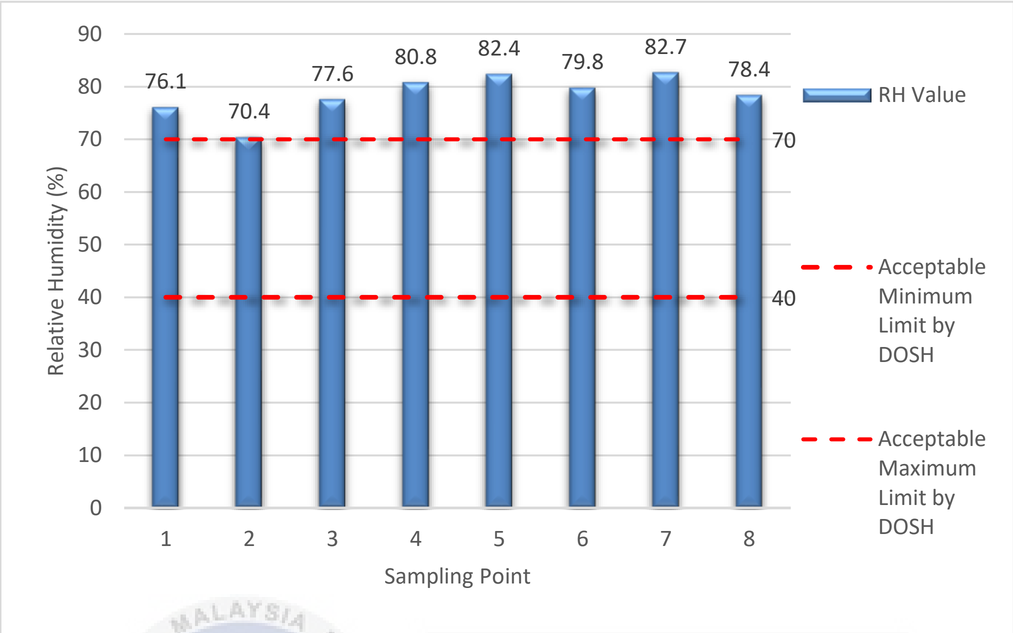


Figure 4.32 Relative Humidity versus Sampling Point

The line graph in figure 4.33 shows the average relative humidity value in the academic office room on the first floor. The highest relative humidity recorded was at room number 7, with 82.7 % of relative humidity. Room number 2 recorded the lowest percentage of relative humidity, with 70.4 %. The minimum and maximum acceptable limits ranged from 40 % to 70 %. All the lecturer's office rooms on the first floor recorded the percentage of RH over the maximum acceptable limits by DOSH.

Based on the table and graph above, the total average relative humidity value at the lecturer's office room on the ground floor is 78.5 %. The average is slightly higher than the maximum acceptable limits by DOSH. Thus, the air in the office room might feel warmer. A fresh air intake duct was needed to keep the humidity in the room within acceptable limits and comfortable.

4.5.5.2 Relative Humidity for Every Hour.

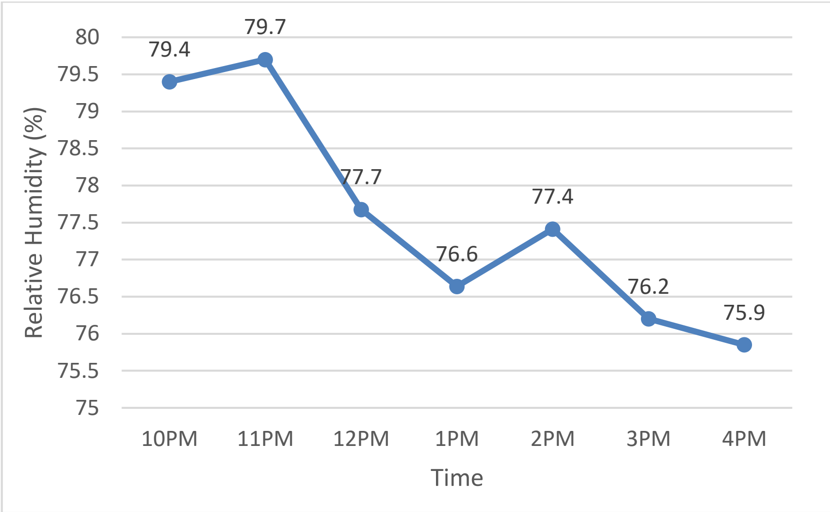


Figure 4.33 Relative Humidity versus Time

Line graph 4.34 above shows the relative humidity value for each hour, from 10 am to 4 pm. The graph shows an upward and downward trend. The highest relative humidity value (79.7%) recorded is at 11 am. Meanwhile, the lowest value for relative humidity (75.9%) is at 4 pm. There is a similar trend with the ground floor graph, where the morning humidity is higher than during the day.

4.5 Comparisons of Indoor Air Quality between Study Areas.

Table 4.3 Comparisons of indoor air quality between study areas

Variable	Ground Floor (n = 8)	First Floor (n=8)	df	95% CI	P value
	Mean±SD				
CO_2 (ppm)	158.1 ± 160.3	85.4 ± 104.7	67.7 (14)	-72.43 - 217.93	0.301
TVOC (ppm)	2.9 ± 3.2	2.4 ± 2.7	1.4 (14)	-2.68 - 3.71	0.735
$PM_{2.5}$ (mg/m3)	0.0008 ± 0.0008	0.0063 ± 0.0055	0.002 (14)	-0.01 - (-0.001)	**0.014***
Temperature(°C)	22.8 ± 1.7	23.2 ± 1.1	0.72 (14)	-2.01 - 1.11	0.530
RH (%)	75.5 ± 3.2	78.5 ± 4	1.81 (14)	-7.04 - 0.71	0.102

*Significant at P <0.05, N = 16
CI = 95% confidence interval

Table 4.3 shows the comparisons of indoor air quality between the ground floor and the first-floor sampling point. Based on table 4.3 above, the mean of CO_2 on the ground floor (158.1 ± 160.3) was higher than on the first floor (85.4 ± 104.7). Student t-test found that the means CO_2 of the ground floor and first floor are not significantly different (P = 0.301). Therefore, there is no significant association between the level of CO_2 on both the ground floor and the first floor.

The mean total volatile organic compounds (TVOC) on the ground floor (2.9 ± 3.2) were found to be higher compared to the first floor (2.4 ± 2.7). Results show no statistically significant differences between TVOC levels on the ground floor and first floor (P = 0.735). The means for particulate matter $_{2.5}$ on the first floor (0.0063 ± 0.0055) is higher than on the ground floor (0.0008 ± 0.0008).

The means $PM_{2.5}$ of the two groups are statistically significant (P = 0.014). Therefore, there is significant association between the level of $PM_{2.5}$ in both study areas. As for physical parameters, the means for temperature shows that the first floor (23.2 ± 1.1) is higher compared to the ground floor (22.8 ± 1.7). Based on the means, there are no significant differences between temperatures on the ground floor and the first floor (P = 0.53).

Meanwhile, the average relative humidity on the first level is higher than on the first floor (75.5 ± 3.2). Based on the P value (P = 0.102), there are no significant differences in relative humidity in the two study areas.

In this research, indoor air quality parameters were measured in 16 academic staff office rooms. The F3 JTKM academic staff room on the ground floor had the highest quantities of CO_2 and TVOC. In-room number 8 on the first floor, the highest levels of $PM_{2.5}$ were measured. Temperature and relative humidity are also higher on the first floor than on the ground. Between 23 and 26 degrees Celsius (°C) is the optimal temperature range for building occupants' comfort. The average temperature (23.1 °C) in the office room of academic employees was within the Department of Occupational Safety and Health's guidelines (DOSH).

As for relative humidity, the recommended percentage by DOSH should be between 40 and 70% for optimum comfort level. However, the percentage of RH (76.7%) for study areas is slightly over the recommended. Individuals may notice that their skin feels dry and static-filled in an environment with low humidity, while sticky skin results from an environment with high humidity. This research's average concentration of CO_2 (121.8 ppm) complies with the DOSH standard. The location of study areas influences the concentration of CO_2 as the study areas have a high volume of road traffic and industrial activities nearby.

Based on statistical analysis, there is no significant difference between VOCs levels between the first floor and the ground floor. As for average, the VOCs levels (2.7 ppm) follow DOSH acceptable limits. The presence of VOCs is due to a building characteristic. The academic staff office rooms' walls were made of concrete and partitions. One of the factors contributing to the prevalence of VOCs is the use of concrete. Office equipment such as photocopiers and printers are also a source of volatile organic compounds (VOCs) and is utilised daily by academic staff. Properly maintained exhaust and air intake systems can lower VOCs in the office space of academic personnel.

The acceptable standard for indoor $PM_{2.5}$ concentration was 0.05 mg/m^3. The average concentration of $PM_{2.5}$ was below the recommended standard (2.7 ± 2.9) mg/m^3. Motor vehicles and pollution from nearby industrial activities were believed to be the primary sources of $PM_{2.5}$. Other than that, human activities and room surrounding affect the concentration of $PM_{2.5}$. The carpet in the room, curtains, and dust from return ducting was the source of pollutants in the academic staff's office room.

4.6 Prevalence of Respiratory Symptoms Among Respondents

Table 4.4 Prevalence of respiratory symptoms among respondent

Variable	Ground Floor (n = 8)	First Floor (n=13)	$\chi 2$ value	P value
	Total (%)			
Cough				
Yes	2 (25)	5 (38.5)	0.4	0.525
No	6 (75)	8 (61.5)		
Phlegm				
Yes	2 (25)	5 (38.5)	0.4	0.525
No	6 (75)	8 (61.5)		
Wheezing				
Yes	3 (37.5)	6 (46.2)	0.15	0.7
No	5 (62.5)	7 (53.8)		
Chest Tightness				
Yes	0 (0)	0 (0)	-	-
No	8 (100%)	13 (100%)		

*Significant at P <0.05, N = 21

The results from table 4.4 above show the prevalence of respiratory symptoms among academic staff on the ground floor and first floor. Academic staffs from the first floor have a higher prevalence of cough (n = 5, 38.5%) compared to the ground floor (n = 2, 25%). Statistical results from the Chi-square test showed that the prevalence of cough between academic staff on the ground floor and first floor are not significantly different (P = 0.525). Therefore, there is no significant association between cough and academic staff. Meanwhile, results for phlegm are the same with cough, where academic staff from the first floor have a higher prevalence of than the ground floor, and there is no prevalence between phlegm and academic staff. As for wheezing, the Chi-square test showed no significant difference among academic staff with wheezing ($\chi 2$ = 0.15, P = 0.7). The results show the academic staff from the first floor have a higher prevalence of wheezing (46.2%) as compared to academic staff from the ground floor (37.5%). Table 4.4 shows, the academic staffs did not experience any symptom of chest tightness, thus the significance cannot be calculated.

4.7 Association between Indoor Air Quality and Respiratory Symptoms

Table 4.5 Association between Indoor Air Quality and Respiratory Symptoms

Floor / Parameter	Respiratory Symptom			Mean (SD)
	Cough	Phlegm	Wheezing	
	Yes / No	Yes / No	Yes / No	
Ground Floor				
CO_2				158.1 ± 160.3
TVOC				2.9 ± 3.2
$PM_{2.5}$	2 (25) / 6 (75)	2 (25) / 6 (75)	3 (37.5) / 5 (62.5)	0.0008 ± 0.0008
Temperature				22.8 ± 1.7
RH				75.5 ± 3.2
First Floor				
CO_2				85.4 ± 104.7
TVOC				2.4 ± 2.7
$PM_{2.5}$	5 (38.5) / 8 (61.5)	5 (38.5) / 8 (61.5)	6 (46.2) / 7 (53.8)	0.0063 ± 0.0055
Temperature				23.2 ± 1.1
RH				78.5 ± 4

N = 21

Table 4.5 above shows the association between Indoor Air Quality and Respiratory Symptoms. A descriptive analysis was conducted to assess the association between indoor air quality and respiratory symptoms among academic staff. Based on table 4.5, the academic staff whose experienced coughing had higher CO_2 concentrations on the ground floor (158.1 ± 160.3) compared to the first floor (85.4 ± 104.7). The ground floor recorded a higher VOCs value (2.9 ± 3.2) than the first floor (2.4 ± 2.7). However, there is no significant between the two study areas.

Meanwhile, $PM_{2.5}$ shows there is a statistically significant between study areas. The staff coughing related to the concentration of $PM_{2.5}$ that was higher on the ground floor (0.0063 ± 0.0055) compared to the ground floor (0.0008 ± 0.0008). As for temperature and relative humidity, both variables show higher mean values on the first floor (23.2 ± 1.1) and (78.5 ± 4.0).

The academic staff on both floor experience phlegm, where the ground floor shows a higher value of CO_2 (158.1 ± 160.3) than the first floor (85.4 ± 104.7). The means of VOCs show a higher concentration on the ground floor (2.9 ± 3.2) compared to the first floor (2.4 ± 2.7). Even so, the total means for both study areas were close to recommended limits by DOSH. Thus, there is no significant between VOCs and phlegm.

The concentration of $PM_{2.5}$ indicates there is significant association between the two study areas. The academic staff whose experience phlegm had higher concentrations of $PM_{2.5}$ on the first floor (0.0063 ± 0.0055) compared to the ground floor (0.0008 ± 0.0008). The mean temperature on the first floor is higher (23.2 ± 1.1) compared to the ground floor (22.8 ± 1.7). The means of RH is slightly higher than the acceptable limits by DOSH. However, there is not statistically significant between RH and phlegm symptom

The prevalence of academic staff (n = 9) experience wheezing symptom had higher CO2 concentrations on the ground floor (158.1 ± 160.3) compared to the first floor (85.4 ±

104.7). The wheezing symptom is not associate to the VOCs as there is no statistic significant between VOCs and symptom. $PM_{2.5}$ shows statistically significant between means value and study areas. However, there is not statistically significant between $PM_{2.5}$ with wheezing. As for academic staff whose experience wheezing had higher temperature and relative humidity, both variables show higher mean values on the first floor (23.2 ± 1.1) and (78.5 ± 4.0). The chest tightness symptom was not shown as no academic staff was affected by the symptom.

There is no association between indoor air quality and respiratory symptom among JTKM academic staff in F3, FTKMP as the analysis was done by descriptive analysis method only. The statistical analysis cannot be done due to limitation of the research such as sample data respondent and equipment.

4.8 Chapter Conclusion

This chapter presented the result of the IAQ parameter measured, the symptom of respiratory health among staff, the analysis of IAQ parameters, and the associations between the parameters and respiratory symptoms among academic staff in F3, JTKM building, FTKMP. Next, the parameters CO_2, VOCs, $PM_{2.5}$, temperature, and relative humidity were analysed using various techniques, including descriptive analysis, student t-test, time series analysis, and chi-square test. According to the analysis results, CO2, VOCs, temperature, and relative humidity have no significant association with the study areas. The chi-square test indicates that there is a statistically significant association between the means of particulate matter2.5 and academic staff office room. Next, the data demonstrates that academic staff encountered respiratory health symptoms at work or during work hours. However, the correlation between indoor air pollution concentration and respiratory symptoms among academic employees at F3, JTKM, and FTKMP is not statistically significant. Every IAQ parameter is within the acceptable range established by the Department of Occupational Safety and Health (DOSH), except for the relative humidity, which is slightly above the acceptable limits.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, indoor air pollution remains a major environmental health hazard for building occupants. A different indoor pollutant can lead to respiratory health symptoms, even with low concentration. The amount of time the building occupants spending time in the workplace makes the respiratory health effect more serious.

This research was done to measure indoor air quality parameters such as carbon dioxide (CO_2), the total volatile organic compound (TVOC), particulate matter 2.5 ($PM_{2.5}$), temperature, and relative humidity (RH). The finding is only Particulate Matter $_{2.5}$ is statistically significant between the ground floor and first floor of study areas. However, the concentration of $PM_{2.5}$ in the academic staff room is under acceptable limits. All the parameters complied with DOSH recommended standard except for relative humidity, which was slightly higher than the acceptable limit.

To fulfil the first objective, the symptom of respiratory health among JTKM academic staff was assessed. This study found there is a symptom of respiratory health experienced by academic staff at the workplace or during working hours. Higher exposure to $PM_{2.5}$ may increase respiratory symptoms amongst academic staff. The furniture, like carpet, and the dust from the improperly maintained exhaust duct contribute to the concentration of $PM_{2.5}$. Besides, the study location is near a high volume of road traffic and industrial activities that contribute to higher pollutants nearby. Proper ventilation system maintenance is necessary to reduce pollution inside the academic staff's room. The other IAQ parameters show no prevalence between the study areas. Hence there is no association between IAQ and respiratory symptoms of academic staff.

Lastly, to fulfil the third objective, the association between indoor air quality and respiratory symptoms was done by using descriptive analysis as there is the limitation to doing statistical analysis, such as the total equipment for research, calibration of equipment, and total respondent. The results show the differences of means at the descriptive analysis stage only. However, the results is not significant.

5.2 Recommendations

The recommendations to further improve the present research are summarized below.

i) Data collection for indoor air quality can be done in two different factory or building for comparison purpose.

ii) Conduct the lung function test among respondent by using Spirometer to get more accurate data for respiratory symptoms.

iii) Calibrate and add more measuring equipment to make sure data collection can be done widely. Results taken at simultaneous time is better to reduce uncontrollable external factor such as surrounding weather.

REFERENCES

American Society for Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)., ASHRAE Standard 62.1-2019: Ventilation for acceptable indoor air quality. ASHRAE, Inc. U.S.

Arbex, M. A., Santos, U. P., Martins, L. C., Saldiva, P. H., Pereira, L. A., and Braga, A. L. 2012. Air pollution and the respiratory system. *Jornal brasileiro de pneumologia : publicacao oficial da Sociedade Brasileira de Pneumologia e Tisilogia*, 38(5), pp. 643–655.

Argunhan, Z., and Avci, A. S., 2018. Statistical Evaluation of Indoor Air Quality Parameters in Classrooms of a University. *Advances in Meteorology,* 2018, pp. 1–10.

Baelum, J., Andersen, I. B., Lundqvist, G. R., Mølhave, L., Pedersen, O. F., Vaeth, M., and Wyon, D. P. (1985). Response of solvent-exposed printers and unexposed controls to six-hour toluene exposure. *Scandinavian journal of work, environment & health,* 11(4), pp. 271–280.

Choo, P. C., Jalaludin, J., Hamedon, T. R., and Adam, N. M., 2015. Indoor Air Quality Assessment and Lung Functions among Children in Preschool at Selangor, Malaysia. *Advances in Environmental Biology*. 9(9), pp. 1-9.

Choo, C. P., Jalaludin, J., and Hashim, Z., 2014. School's Indoor Air Quality and Respiratory Health Implications among Children. *Advances in Environmental Biology*. 8(14) pp. 112-121.

Cincinelli, A., and Martellini, T., 2017. Indoor Air Quality and Health. *International Journal of Environmental Research and Public Health,* 14(11), 1286.

Cionita, T., Jalaludin, J., Adam, N. M., and Siregar, J. P., 2014. Assessment of Children's Health and Indoor Air Contaminants of Day Care Centre in Industrial Area. *Iranian J Publ Health,* 43, pp. 81-88.

Colligan, M. J., 1981. The psychological effects of indoor air pollution. *Bulletin of the New York Academy of Medicine*, *57*(10), pp. 1014–1026.

Department of Occupational Safety and Health (DOSH)., 2010. Questionnaire for building occupants. *Industry Code of Practice on Indoor Air Quality 2010*.

Fritz, G. J., and Herbarth, O., 2001. Pulmonary function and urban air pollution in preschool children. *International Journal of Hygiene and Environmental Health,* 203(3), pp. 235–244.

Hulin, M., Simoni, M., Viegi, G., and Annesi-Maesano, I., 2012. Respiratory health and indoor air pollutants based on quantitative exposure assessments. *European Respiratory Journal*, 40(4), pp. 1033-1045.

Jaakkola, J. J., Tuomaala, P., and Seppänen, O., 1994. Air recirculation and sick building syndrome: a blinded crossover trial. *American Journal of Public Health*, 84(3), pp. 422–428.

Kamaruzzaman, S. N., and Sabrani, N. A., 2011. The Effect of Indoor Air Quality (IAQ) Towards Occupants' Psychological Performance in Office Buildings. *Journal Design + Built*, 4.

Kamaruddin, A. S., Jalaludin, J., and Hamedon, T., 2016. Exposure to Industrial Air Pollutants and Respiratory Health School and Home Exposure among Primary School Children in Kemaman, Terengganu. *International Journal of Applied Chemistry*. 12(1), pp. 45-50.

Kumar, R., 2020. Air pollution and respiratory health. *J Adv Pediatr Child Health*, 3, pp. 032-037.

Langkulsen, U., Jinsart, W., Karita, K., and Yano, E., 2006. Respiratory symptoms and lung function in Bangkok school children. *European Journal of Public Health,* 16(6), pp. 676–681.

Leung, D. Y. C., 2015. Outdoor-indoor air pollution in urban environment: challenges and opportunity. *Frontiers in Environmental Science,* 2.

Li, S., Xu, J., Jiang, Z., Luo, Y., Yang, Y., and Yu, J., 2019. Correlation between indoor air pollution and adult respiratory health in Zunyi City in Southwest China: situation in two different seasons. *BMC Public Health*, 19(1).

Padilla, R. P., Schilmann, A., and Rodriguez, H. R., 2010. Respiratory health effects of indoor air pollution. *The International Journal of Tuberculosis and Lung Disease*, 14(9), pp, 1079-1086.

Parmaksız, K., Dogan, T. R., and Yeşilnacar, M. I., 2021. Exposure of Indoor Air Quality in Office Environment to Workers and its Relationship to Health. *El-Cezeri*, 8(1) , pp. 231-244.

Rawi, N. A. M. N., Jalaludin, J., and Chua, P. C., 2015. Indoor Air Quality and Respiratory Health among Malay Preschool Children in Selangor. *BioMed Research International*, 2015, pp. 1–8.

Roh, T., Moreno-Rangel, A., Baek, J., Obeng, A., Hasan, N.T., and Carrillo, G., 2021. Indoor Air Quality and Health Outcomes in Employees Working from Home during the COVID-19 Pandemic: A Pilot Study. *Atmosphere*, 12, 1665.

Salleh, N. M., Kamaruzzaman, S. N., Sulaiman, R., and Mahbob, N. S., 2011. Indoor Air Quality at School: Ventilation Rates and It Impacts Towards Children- A review. *Proceedings of the 2nd International Conference on Environmental Science and Technology*, 6.

Seppanen, O. A., Fisk, W. J., and Mendell, M. J., 1999. Association of Ventilation Rates and CO2 Concentrations with Health andOther Responses in Commercial and Institutional Buildings. *Indoor Air*, 9(4), pp. 226–252.

Slezakova, K., Morais, S., and Carmo Pereir, M. Do., 2012. Indoor Air Pollutants: Relevant Aspects and Health Impacts. *Environmental Health - Emerging Issues and Practice.*

Sweileh, W. M., Al-Jabi, S. W., Zyoud, S. H., and Sawalha, A. F., 2018. Outdoor air pollution and respiratory health: a bibliometric analysis of publications in peer-reviewed journals (1900 – 2017). *Multidisciplinary Respiratory Medicine*, 13(1)

Tran, V. V., Park, D., and Lee, Y.-C., 2020. Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality. *International Journal of Environmental Research and Public Health*, 17(8), 2927.

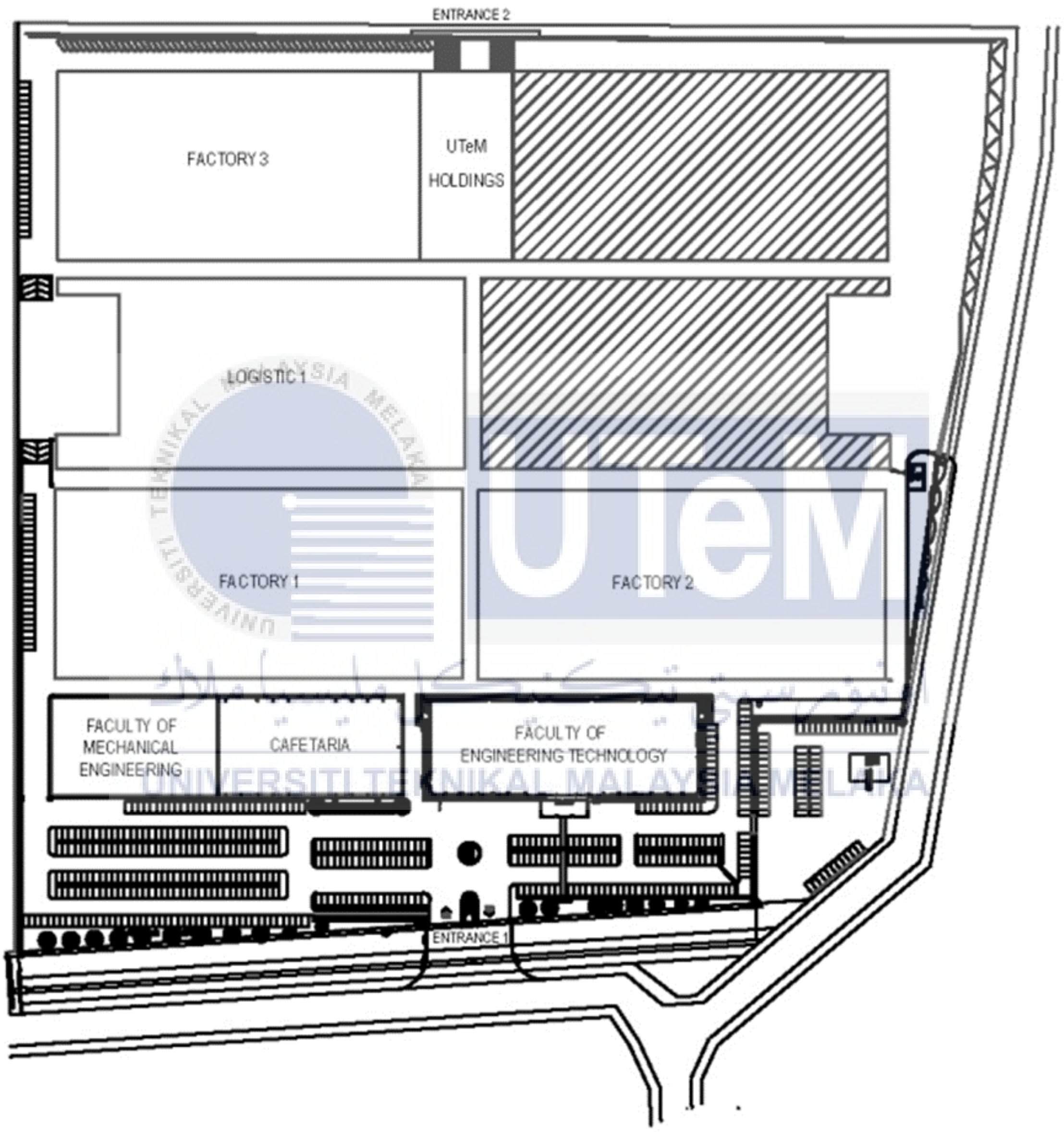
United States Environmental Protection Agency (EPA)., 2021. Human health effect associated with indoor air pollutants. EPA.

World Health Organization., 2021. Air quality guidelines. Global update 2021. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. WHO.

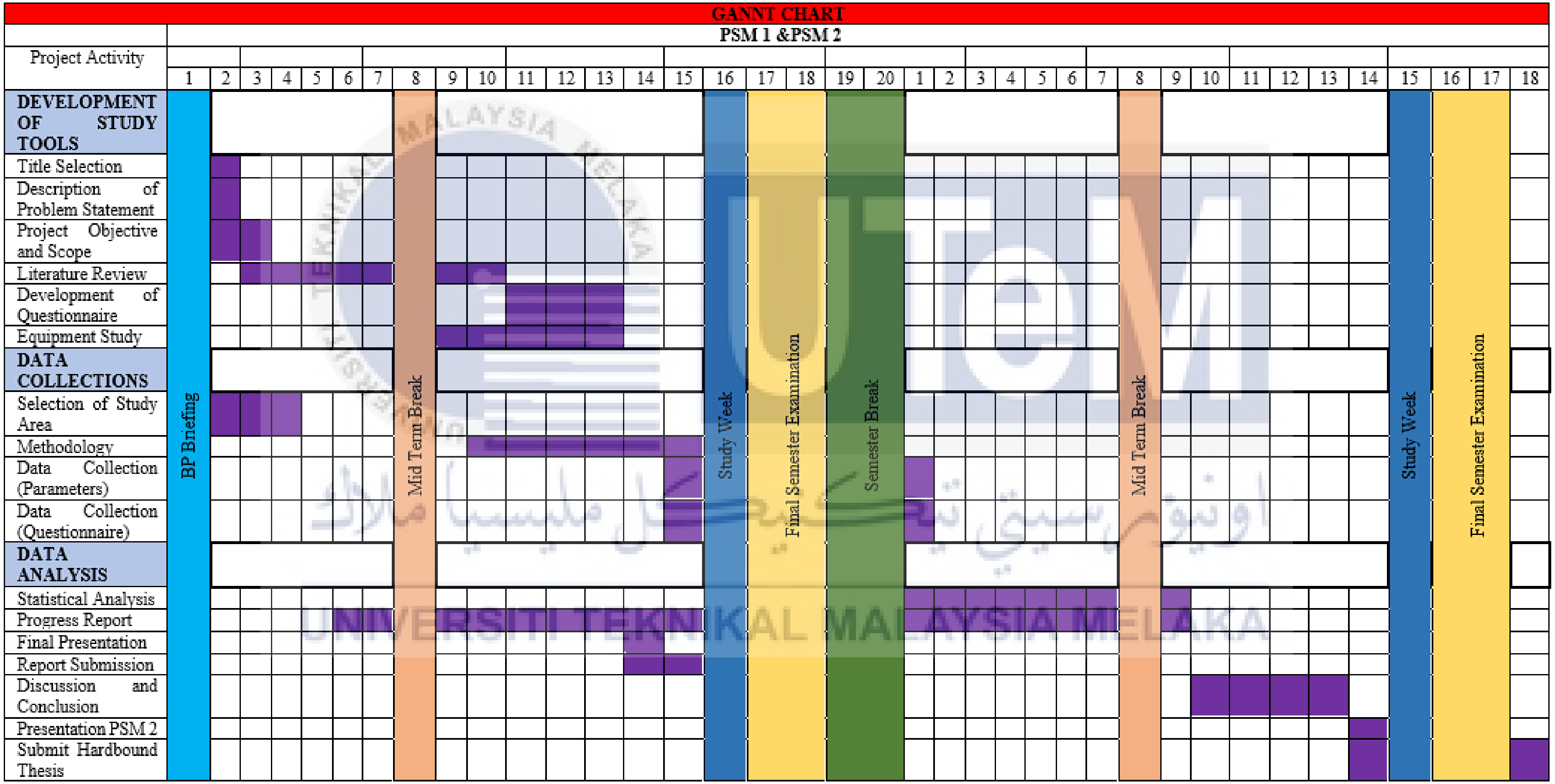
Wyon, D. P., and Wargocki, P., 2006. Indoor air quality effects on office work. *Creating the Productive Workplace*, 2, pp. 193-205.

APPENDICES

Appendix A Overall Layout of FTKMP Faculty



Appendix B Research Gannt Chart



Appendix C Data collection at sampling point

Appendix D Possible factor of Particulate Matter ($PM_{2.5}$)

Appendix E Sampling point at study area

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Dengan segala hormatnya merujuk kepada perkara di atas.

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Nama pelajar: MUHAMMAD AKMAL BIN MD NOOR
Tajuk Tesis: INDOOR AIR QUALITY AND RESPIRATORY HEALTH AMONG ACADEMIC STAFFS IN DEPARTMENT OF MECHANICAL ENGINEERING TECHNOLOGY, UTeM

3. Hal ini adalah kerana IANYA MERUPAKAN PROJEK YANG DITAJA OLEH SYARIKAT LUAR DAN HASIL KAJIANNYA ADALAH SULIT.

Sekian, terima kasih.

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