POST OCCUPANCY EVALUATION (POE) AND INDOOR ENVIRONMENTAL QUALITY (IEQ) ASSESSMENT: A CASE STUDY OF UTEM'S TECHNOLOGY CAMPUS

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Post Occupancy Evaluation (Poe) And Indoor Environmental Quality (IEQ) Assessment: A Case Study of UTeM's Technology Campus" is the result of my own work except as cited in references.

Signature :

Name : THAMARAI VATHANI ELANGKOVAN

Date : 20/7/2020

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :

Supervisor : DR TEE BOON TUAN

Date :

DEDICATION

To my beloved mother and father

ABSTRACT

Satisfaction and comfort level in a building is most demandable aspect by occupants that required to be concerned. Good management of indoor environmental quality can results enhancement towards health and well-being of occupants. Thus, by determining factors which involves in indoor environmental quality such as thermal comfort parameters and air quality parameters, various illness and unstable emotions of the occupants. This study of evaluating the indoor environmental quality works along the process of post occupancy evaluation which is to gather feedback performance of the building in use. The main objective of this research is to identify occupants' satisfaction and perception level on academic building in technology campus of UTEM especially in Faculty of Mechanical Engineering (FKM) and Faculty of Technology Management & Technopreneurship (FPTT). Thermal comfort analysis and indoor air quality analysis were conducted to appraise the indoor environmental quality of the buildings. Both analyses were conducted in the form of physical measurement and subjective assessment. Physical measurement in classroom were carried out with relevant instruments. Meanwhile, subjective assessment was carried out with distributing questionnaire in google form in order to obtain occupants' feedback. Followed by regression analysis which is to estimate the values of the dependent variables by using values of independent variables such as operative air temperature, PMV index, relative humidity, air velocity in order to identify their strength relationship. Based on the findings of this study, technical design improvisation are proposed with the goal to improve the indoor environmental quality in the buildings. This research will be helpful for those who endeavour to enrol research in this similar field.

ABSTRAK

Tahap kepuasan dan keselesaan di bangunan adalah aspek yang paling diperlukan oleh penghuni yang perlu diberi perhatian. Pengurusan kualiti persekitaran dalaman yang baik dapat menghasilkan peningkatan terhadap kesihatan dan kesejahteraan penghuni. Oleh itu, dengan menentukan faktor-faktor yang melibatkan kualiti persekitaran dalaman seperti parameter keselesaan termal dan parameter kualiti udara, pelbagai penyakit dan emosi penghuni yang tidak stabil. Kajian ini menilai kualiti persekitaran dalaman berfungsi sepanjang proses penilaian pasca penghunian iaitu untuk mengumpulkan prestasi maklum balas bangunan yang sedang digunakan. Objektif utama penyelidikan ini adalah untuk mengenal pasti tahap kepuasan dan persepsi penghuni terhadap bangunan akademik di kampus teknologi UTeM terutamanya di Fakulti Kejuruteraan Mekanikal (FKM) dan Fakulti Pengurusan Teknologi & Teknologi (FPTT). Analisis keselesaan termal dan analisis kualiti udara dalaman dilakukan untuk menilai kualiti persekitaran dalaman bangunan. Kedua-dua analisis dilakukan dalam bentuk pengukuran fizikal dan penilaian subjektif. Pengukuran fizikal di kelas dilakukan dengan instrumen yang relevan. Sementara itu, penilaian subjektif dilakukan dengan menyebarkan borang soal selidik dalam bentuk google untuk mendapatkan maklum balas penghuni. Diikuti dengan analisis regresi iaitu menganggarkan nilai pemboleh ubah bersandar dengan menggunakan nilai pemboleh ubah bebas seperti suhu udara operasi, indeks PMV, kelembapan relatif, halaju udara untuk mengenal pasti hubungan kekuatannya. Berdasarkan penemuan kajian ini, improvisasi reka bentuk teknikal dicadangkan dengan tujuan untuk meningkatkan kualiti persekitaran dalaman bangunan. Penyelidikan ini akan bermanfaat bagi mereka yang berusaha untuk mendaftar penyelidikan dalam bidang serupa ini.

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Moreover, I would also like to thank Mr. Asjufri bin Muhajir, assistant engineer for air-conditioning lab who taught me the procedure to utilise the relevant instruments to complete the physical measurements with very professional manner.

Furthermore, I would like to express special thanks to all the respondents in both buildings who reveal their feedback and perception on satisfaction level without any hesitation. Never forget to also thank my family and friends who have motivated me to complete the study.

Last but not least, my sincere thanks to all staffs of Faculty of Mechanical Engineering and Faculty of Technology Management & Technopreneurship (FPTT) for helping on arranging the schedules for physical measurement and storing instruments safely in place until the physical measurements are completed. I am grateful for all the contributions and appreciate all their kind assistance on completion of the research.

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SYMBOLS	DESCRIPTION
ºC	Degree Celcius
m	Metre
s	Seconds
%	Percentage
m/s	Velocity
ppm	Parts-per-million
cfm	Cubic feet per minute
R^2	Coefficient of determination

LIST OF ABBREVIATION

ABBREVIATION	DESCRIPTION
AV	Air Velocity
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
CO	Carbon Monoxide
CO_2	Carbon Dioxide
FKM	Faculty of Mechanical
FPTT	Faculty of Technology Management and Technopreneurship
IEQ	Indoor Environmental Quality
IAQ	Indoor Air Quality
LEED	Leadership in Energy and Environmental Design
MS	Malaysian Standard
PM	Particular Matter
POE	Post Occupancy Evaluation
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
RH	Relative Humidity
TSV	Thermal Sensation Vote
UTeM	Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.1 Background

In the era of rapid growing technology, people tend to chase after the term of satisfaction and comfort level in their respective occupied building. Aspects of comfortability to use and utilize serves as it must be fit for purpose as its demandable priority of occupants. The question is how efficient is the building performance that tally with occupants' satisfaction?

Post Occupancy Evaluation (POE) is the process of obtaining feedback performance in use. Being mandatory in majority of public buildings, it's rapidly recognised. This process also acts as a weapon in correcting past mistakes in terms of design where this is conducted after occupancy of occupants. In many cases, designed buildings' performance not up to the planning and expectation. These may bump on the results such as over costs and poor performance, occupant's wellbeing and business efficiency. Among the benefits from POE is it helps to identify successful design features to repeat (Watson,2003), identify problems to migrate or reduce, improve building environment performance (Vischer,2002; Hewitt et. al,2005).

Meanwhile. Indoor Environmental Quality (IEQ) encompasses the conditions inside a building—air quality, lighting, thermal conditions, ergonomics and their effects on occupants or residents. Strategies for addressing IEQ include those that protect human health, boost quality of life, and minimize stress and potential injuries. Better indoor environmental quality can enhance the lives of building occupants, increase the resale value of the building. Moreover, it also reduces liability for building owners.

The common endeavour of human being across the globe and through the timeline of human is to create a comfortable indoor environment at any circumstance to satisfy people. The overall comfort of indoor air environment constantly plays a critical role for human not only because of human comfort but also it has critical and major influence on human life (Costanza et al. 2007) There are several factors that influencing indoor environmental quality. There is thermal comfort, indoor air quality, lighting, acoustic condition and so on. By reviewing what occupants' experience and how they response to their needs by use and occupy building, information of building conditions can be collected.

In this research, the main elements that have focused are thermal comfort and indoor air quality in order to evaluate the indoor environmental quality in both buildings of Faculty of Mechanical and Faculty of Technology Management & Technopreneurship (FPTT) from UTeM's Technology Campus. According to the results obtained from the study, proactive measures to improve the indoor environmental quality will be recommended.

1.2 Problem Statement

Classrooms in each faculty plays a vital role in students' university life. These learning space must perfect in terms of the physical atmosphere where students' learning process can take place uninterruptedly. According to the previous observations, it is noticed that some of the students are being affected by health and also performance (Salleh et al., 2013). Some even felt hot and inconvenient while learning in classroom, where they tend to feel weak. Since there are several aspects may contribute to the impacts faced by the students it is best to conduct this research based on these questions to get a clear vision on this issue.

1. Do occupants satisfy with current indoor environmental quality of academic building in technology campus of UTeM.?
2. Do the learning process of students are being affected due to poor environmental conditions?
3. How to improve indoor environment quality in academic building and implement them in practical?

1.3 Objectives

1. To determine occupants' satisfaction and perception level on academic building in technology campus of UTeM.
2. To suggest and recommend ways to improve indoor environment quality in academic building.

1.4 Scope

Due to the rapid development of the university, the Technology Campus is utilised to accommodate the Faculty of Mechanical Engineering and the university's latest Faculty of Engineering Technology which was admitting its first batch of students in September 2011 and Faculty of Technology Management & Technopreneurship (FPTT).The premise has a land area of 119,200 sqm and was made as the industrial campus to sustain the increasing number of students. The industrial campus was equipped with laboratory facilities, library and a more organised administrative office. In this study, the focus of evaluating the indoor environmental quality is towards both Faculty of Mechanical Engineering and Faculty of Technology Management & Technopreneurship (FPTT) since it is the new building in UTeM's Technology campus. Sample of the classes are only air-conditioned classrooms and number of classrooms are 4. For Faculty of Mechanical Engineering classroom 4 have been taken as sample and for Faculty of Technology Management & Technopreneurship (FPTT) classroom 5, 8 and 11 were selected as sample. The measurement of data includes physical and subjective measurements. Physical measurement in classroom were carried out with relevant instruments. Meanwhile, subjective assessment was carried out with distributing questionnaire in google form in order to obtain occupants' feedback. The focus of the study is to evaluate the IEQ and suggest effective ways to improve them.

1.5 Significance of Research

There are multifarious benefits can be obtained by conducting this research of POE and IEQ in campus technology of UTeM. First and foremost, it is important to carry out this research in order to monitor satisfaction level of occupants especially students during lecture hours. By collecting the data, we can improve user requirements in terms of comfortability.

Furthermore, it is also work as a strategic space planning design by management as a tool to work on management procedures to improve design of building which contributes to positive and negative feedback from occupants. Thus, it is fundamental to conduct this research were all the data collected can be interpreted into table and carry out a comparison between lecture rooms. Upon submission of the data obtained and suggestion provided from the research management will have a clear idea to come up with various solution that currently exist.

According to the recommendation, management also can plan for the budget that needed to be spent to execute relevant actions. For example, collection of funds from

Government authority for building's performance required certain criteria where this research's outcome will play a fundamental role for preparation of documents.

Last but not least, by conducting this research not only improve the building performance but also discover a proper design guidelines and regulatory processes. This will enhance a significant way to apply maintenance and inspection to any individual building with POE and IEQ evaluations.

1.6 General Methodology

Initial Phase

1. Identify the problem

   Description that needs to be identified where it provides the context for the research study and generates the question which research aims to answer.

2. State the objectives

   Describe on what research aims to achieve.

Process Phase

1. Planning

   Identify the classes that will be inspected and the occupants that will be interviewed to obtain feedback and collect data.

2. Data analysis

   Measurements that have been collected must be analysed and transferred in the form of graph in order to identify the number of satisfied and unsatisfied occupants.

Recommendation Phase

1. Report writing

   From the data and feedback collected, it is important to come up with solution for the issues of the topic.

CHAPTER 2

LITERATURE REVIEW

This chapter comprises all the principles and theories that are related to Post Occupancy Evaluation (POE) and Indoor Environmental Quality (IEQ) of a building. In order to obtain a better understanding on all overall project, all these aspects such as indoor environmental quality, thermal comfort, indoor air quality are briefly explained. This chapter also includes journals which are relevant to branch of our study in terms of approach of research, building condition, methodology and overall result obtained for each journal respectively.

2.1 Post Occupancy Evaluation (POE)

After project completion, a survey taken to evaluate end users' level of satisfaction with the many factors of the new working environment, and in order to monitor on the performance against specifications of the systems that are main (Cotts 1999). Post occupancy evaluation is a term of pledge a method in providing opinion or feedback throughout a building's lifecycle. In order to improve in terms of technical performance of the building the outcomes of feedback may use in future. It is also a systematic way to figure out the current problem in a specific building, whereas allow us to come up with solutions to sort out the issues. By conducting POE in any building, researcher may able to discover the needs of the occupants of the building and can bring accountability of building performance by designers. Furthermore, results of POE also play a vital role by being a benchmark data which can be compared to other similar projects. One of the long-term benefits of POE is the overall improvement in design quality can be intensified. Once building is markedly occupied by occupants which is about after one year of period, POE will be carried out.

2.2 Indoor Environmental Quality (IEQ)

Aspects that are usually dealt in the term of POE are indoor environmental quality (IEQ), facilities, access and layout, control, operation, maintenance and so on. The indoor environmental quality (IEQ) contributes greatly for satisfaction and dissatisfaction of occupants.

Indoor Environmental Quality (IEQ) is defined as the quality of buildings' environment in accordance to health condition and well-being of occupants who occupied the specific building. IEQ covers several parameters in evaluation process. The parameters can be classified as thermal comfort, air quality, noise, light, humidity and so on.

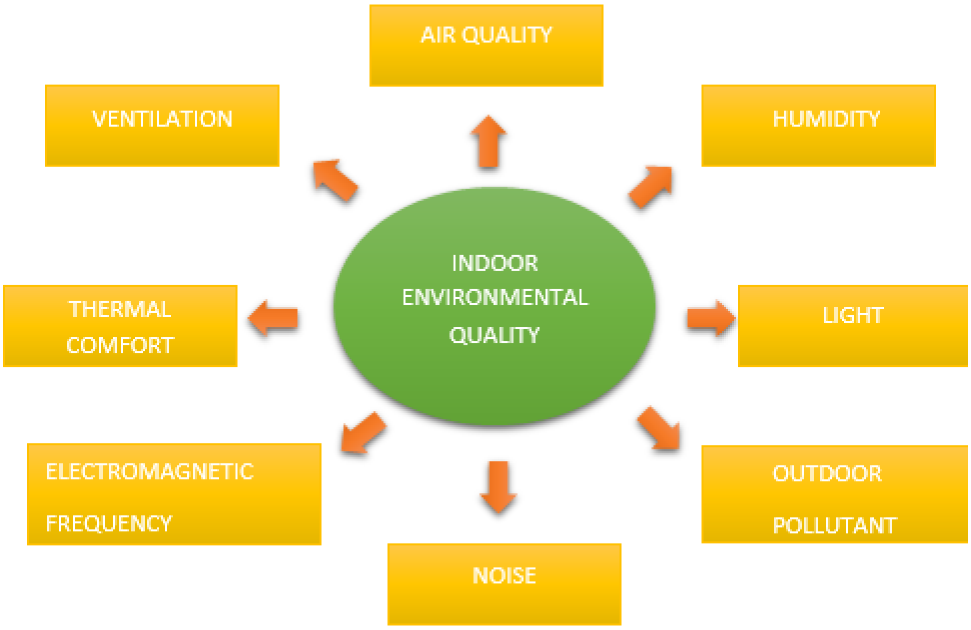


Figure 2.1: Factors of Indoor Environmental Quality (Muhammad Abdul Mujeebu et al., 2018)

2.2.1 Indoor Air Quality (IAQ)

Indoor Air Quality (IAQ) is the quality of air within and around structures and building. It is basically related to comfortability and health of occupants in building. Gases or pollutants in air such as carbon monoxide, carbon dioxide, particulates and so on can gradually affects the element of IAQ. Since it is part of IEQ, it is fundamental to monitor air quality because continuous exposure to pollutants can be hazardous to human health.

2.2.1.1 Carbon dioxide

Carbon dioxide, (CO_2), is a gas which is parameters of colourless which having a faint, strong odour and taste of sour. It is made from carbon-containing materials' combustion, fermentation, animals' respiration and released by plants during photosynthesis of carbohydrates. Some of the energy of radiant supplied to Earth from being returned to space due to presence of gas in atmosphere which leads to greenhouse effect. The amount of carbon dioxide deployed for each activity varies.

2.2.1.2 Carbon Monoxide

A colourless, odourless, and tasteless gas that is flammable and slightly less dense than air is known as Carbon monoxide (CO). It made up of one carbon atom and one oxygen atom, joint by a triple bond that has covalent bonds of two and as one covalent bond which is convergent. It is the uncomplicated oxo carbon and is isoelectronic with valence electrons of ten and triply-bonded molecules of diatomic. The partial oxidation of carbon-containing compounds produces carbon monoxide. When there is not enough oxygen to produce carbon dioxide (CO2), it is produced from it forms.

2.2.2 Thermal Comfort

Condition of mind that reflects satisfaction with the thermal environment is defined as thermal comfort (ANSI/ASHRAE Standard 55). Thermal discomfort of the body as a whole as expressed with the PMV and PPD indices may cause dissatisfaction, or unwanted cooling or heating of a particular part of the body also can be the reason for the cause. It is impractical to stipulate a thermal environment that will satisfy everybody because of individual differences. Thermal comfort needed to be always evaluated in terms of other factors of environmental and personal.

2.2.2.1 Temperature

A measure of how hot or cold the air is defined as air temperature. It is the most commonly measured weather parameter. Moreover, kinetic energy, or energy of motion, of the gases that make up air is described by temperature. Its unit is in terms of degrees Celsius (°C). As gas molecules move more rapidly, air temperature rises.

2.2.2.2 Radiant Temperature

The heat that radiates from a warm object is known as thermal radiation. If there are existence of heat sources in an environment, radiant heat may be appeared. The amount of heat lost or gain to the environment is definitely has more influence of radiant temperature as compared to air temperature.

2.2.2.3 Humidity

Humidity present when water is heated and it evaporates to the surrounding environment. The ratio between the exact water vapour amount in the air and the highest water vapour amount that the air can hold at that air temperature is defined as relative humidity. There will be negligence impact on thermal comfort if relative humidity between 40% and 70%. The indoor thermal environment influenced if relative humidity may be higher than 70% in workplaces which are not air conditioned, or where the weather conditions outdoors.

2.2.2.4 Clothing Insulation

Insulating effect of clothing on the wearer will affect the thermal comfort. As a control for it as we adapt to the climate in which we work, clothing plays potential cause and also thermal discomfort. Heat stress may come from wearing too much clothing or PPE although if the environment is not considered warm or hot. It is fundamental to detect on how the clothing chip in to thermal comfort or discomfort.

2.2.2.5 Metabolic Heat

Larger amount of heat produced when more physical work is done. Thermal comfort has critical effect of metabolic rate. When evaluating the thermal comfort, as factors such as their size and weight, age, fitness level and sex can all have an effect on what human experienced as an individual's physical characteristics should always been considered.

2.3 Standard

Standards are known as something that is evaluated by an authority or by general consent as a groundwork of comparison on an approved model. In order to recommend and suggest the thermal comfort and indoor air quality that can satisfy majority of occupants of a specific building. There are three standards involved in this research.

i. Malaysia Standard 1525: 2019

ii. ASHRAE Standard 55-2014

iii. ASHRAE Standard 62.1-2010

2.3.1 Malaysia Standard MS 1525:2019

A set of practice or standards involved in the aspect of energy efficiency and use of renewable energy for non-residential buildings is known as MS 1525 code. Technical Committee on Energy Efficiency in Buildings (Passive) under the officialdom of the Building, Construction and Civil Engineering has developed this Malaysian Standard 1525.

Previously, MS 1525:2014 was in the conduct. However, it is replaced by MS 1525:2019 as this Malaysian Standard has been resurrect. Purpose of this standard may apply in building envelope, coefficient of performance, cross ventilation, fenestration and so on.

The indoor design conditions of an air-conditioned space for comfort cooling recommended by MS 1525 as below:

i.	Recommended design dry bulb temperature	24°C - 26°C
ii.	Minimum dry bulb temperature	23°C
iii.	Recommended design relative humidity	50% - 70%
iv.	Recommended air movement	0.15 m/s – 0.50 m/s
v.	Maximum air movement	0.70 m/s

2.3.2 ASHRAE Standard 55-2017, Thermal Environmental Condition for Humans Occupancy

The goal of this standard is to particularize the indoor thermal environmental condition factors' condition that will supply most of the occupants' acceptable thermal environmental condition within the space.

The scope of the standard revolves where environmental factors such as temperature, thermal radiation, humidity and air speed will be addressed. Furthermore, thermal environmental conditions tolerable healthy individuals at atmospheric pressure equivalent to altitudes around 3000m in indoor spaces designed for human occupancy for periods not less than 15 minutes have been specified by this standard.

Satisfaction on thermal environment that are expressed is defined as thermal comfort. It's not similar for everyone to feel comfort with the environmental conditions. Due to individual differences, it's difficult to achieve an allowable thermal environment for all occupants in a specific space.

2.3.3 ASHRAE Standard 62.1 – 2010 and 62.2-2019, Ventilation for Acceptable Indoor Air Quality

ASHRAE Standard 62.1 plays vital role as a guide to improve indoor air quality in existing building. It is firstly published in the year 1973. For the first time since 2004, it has been fully revised to include three methods of ventilation design which are classified as he IAQ Procedure, the Ventilation Rate Procedure, and the Natural Ventilation.

As per ASHRAE Standard 62.1, new technology and latest findings, it enhances that several information means in standard helpful in achieving the goal. The updates as per 2019 in terms of scope are in order to eliminate commentary and to more specifically determine occupancies previously not covered, scope is changed. In addition, prohibition towards all air-cleaning devices that produce ozone.

Besides, ASHRAE recommended few indoor air contaminants that has its own concentration of interest as interpreted in the table below.

Table 2.1: Concentration of interest for few air contaminants recommended by (ASHRAE 62.1, 2010)

Contaminants type	Concentration of interest
Carbon Monoxide, CO	9 ppm
Nitrogen dioxide, NO_2	100 $\mu g/m^3$
Particles $PM_{2.5}$	15 $\mu g/m^3$
Particles PM_{10}	50 $\mu g/m^3$
Radon, Rn	4 pCi/L[a]
Sulphur Dioxide, SO_2	80 $\mu g/m^3$, 50 $\mu g/m^3$ if with PM

2.4 Study on IEQ in classroom by Jamaluddin et al. (2017)

Specifically, for educational oriented environment should prioritize good IEQ since it has potential of affecting students' learning performance. In order to evaluate the IEQ criteria, two methods have been individually chosen for this assessment which are classroom environment intervention and by set up of classroom measurement. For about two weeks the sampling devices were placed in certain chosen locations to see any difference on environment in the classroom of both situations. Set of questionnaires were distributed among the students to determine their satisfaction and the data of measurement in terms of thermal comfort and indoor air quality. The level of VOC was high which is (11.7ppm) in the findings for the survey in normal condition.

2.4.1 Methodology

This study was carried out by using quantitative analysis which was the field work in every designated area observing conducted. The detail of the calculated indoor environmental quality is listed in table below.

Table 2.2: Research Methods (Jamaluddin et al., 2017)

Method	**Questionnaire Survey**	**Fieldwork Monitoring**	
		Measurement Set Up	**Classroom Intervention**
Details	Questionnaire (based on elements of IEQ and current student's satisfaction level)	Sampling devices used to monitor the indoor environment of the classroom.	Classroom interventions in this research are mainly on application of landscape (potted plants) to reduce the level of TVOC, thermal comfort and relative humidity in the classroom.

2.4.2 Results

Response from the occupants based on questionnaires proved that the occupants' perceived learning productivity is not simply obstructed by any of the factors of indoor environment quality most likely due to students' young age. According to the fixed position (colour indicator in Figure 2.4 it can be summarized that the students perceived satisfaction on the thermal condition is due to the location in the classroom whether or not they are sitting near the air conditioner. Moreover, addition to this case, it was also monitored that only one air conditioner was operating in the classroom. Thus, the perceived level of satisfaction in terms of thermal comfort was not up to satisfactory.

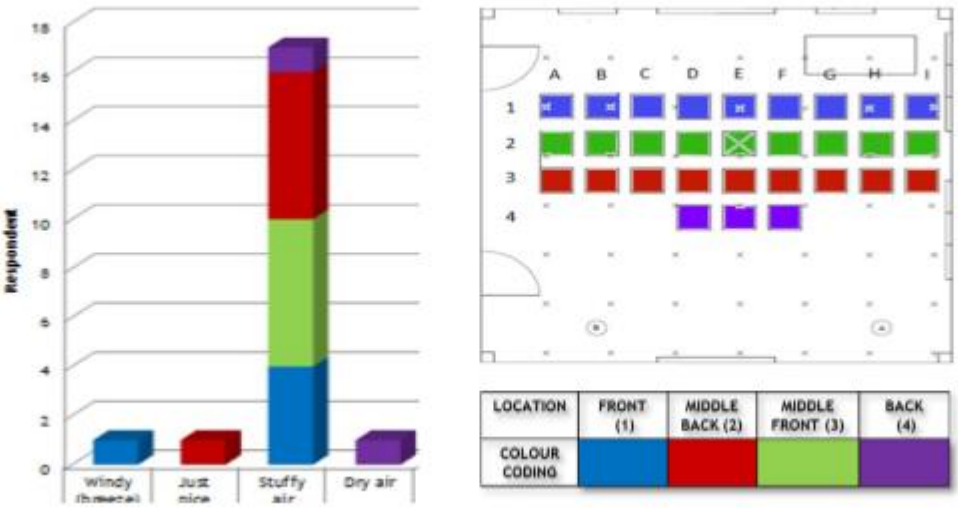


Figure 2.2: Students satisfaction level on the thermal condition (Nurul Malina Jamaluddin et al., 2017)

2.4.3 Conclusion

Common acknowledgement and IEQ level in the classroom of Pusat Asasi Sains University of Malaya is on average good. Although IEQ level is good, there were several issues found when observing the classroom such as:

- High concentration of TVOC that crossed the boundaries
- Significantly greater dissatisfaction on system of ventilation in the classroom.

To reduce indoor air pollution and improve air quality it is necessary to implement various ways. Rather than from minimizing gaseous air pollutants, study has proven that other parameters of IEQ can also be enhanced with indoor plants' commitment. Plant plays vital role as good biological filters for both indoor and outdoor plants. They contribute as part of the landscaping and supply physiological benefits to humans. The focus of this paper was to determine accurate tropical indoor plant in Malaysia with high efficiency in improving indoor air quality in educational building and also to come up with further awareness into how plants can minimize indoor pollution and enhance our health. Thus, many plants need to be examined, and a more standard environment is required.

2.5 Influence of Indoor Environmental Quality on Work Productivity in Green Office Buildings: A Review by Esfandiari et al. (2017)

This study reviews peer reviewed journal article and discussions to figure out aspect that shapes on IEQ and greenhouses work productivity. The results revealed that the occupants' productivity rapidly grows if the quality of IEQ parameters enhanced which will transform companies towards excellence. Simultaneously, the major goal of this research is to compare and examine the outcomes of energy related IEQ factors among various studies in the field of POE and BPE.

2.5.1 Methodology

Based on peer-reviewed journal articles and dissertations and analysis of published scientific literature which related to IEQ, POE and BFE have a bearing on occupants' health, comfort, and satisfaction, and work productivity, practical information provided by recent manuscript. In order to find out most similar variable of IEQ for the research. IEQ factors such as air quality index (IAQ), Acoustic Quality (AQ), Light Quality (LQ) and Thermal Condition (TC) have been listed from critical review of review papers. The greater number of samples. POE survey questionnaires and case studies is the reason behind for selection of these studies. Simultaneously, according to sequence of parameters from more dissatisfaction to less dissatisfaction were ranked among 1 to 4 which indicates that higher ranks reflects less dissatisfaction in the study. Statistical package for social science (SPSS) has been used to analyze collected data. Frequency analysis as main critical data analysis has been taken into account to present maximum frequency among dissatisfaction features of IEQ.

Table 2.3: Studies in the field of POE or BPE which analyzed IEQ factor (higher number means less dissatisfaction responded by occupants as 1=Extremely dissatisfied, 2=Highly dissatisfied 3=Slightly dissatisfied 4=Dissatisfied (Esfandiari et al., 2017)

No	Researcher	IEQ parameters' rank IAQ				AQ				LQ				TC				Description
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	Kim and Dear (2012)																	CBE occupants' database
2	Wong et al. (2008)																	293 occupants – Hong Kong
3	Pei et al. (2015)																	10 Green building –10 conventional building – over 1000 occupants
4	Amasyali and El-Gohary (2016)																	Over 600 valid respond of questionaries' of Green building
5	Ravindu et al. (2015)																	Case study of a LEED platinum certified factory
6	Woo (2014)																	POE in Green-rated high-rise office buildings
7	Liang et al. (2014)																	Certified Green office buildings in Taiwan
8	Frontczak et al. (2012)																	351 office building – 52980 occupants
9	Abbaszadeh et al. (2006)																	LEED rated green building (CBE Database)

2.5.2 Results

As shown in Figure 2.5, indoor air quality (IAQ) revealed more dissatisfaction frequency among other parameters which implicit that in selected green offices low attention was taken for evaluating the quality of indoor air. Thus, it brought many problems for occupants' so, based on the literature it is clearly foreseeable that dissatisfaction may lead to demotion in work productivity. Meanwhile, in second place of dissatisfaction scale, thermal condition and acoustic control stay together with same percentage. Moreover, light quality (LQ) stays in the hindmost line were occupants found that it impacts less in terms of comfort level.

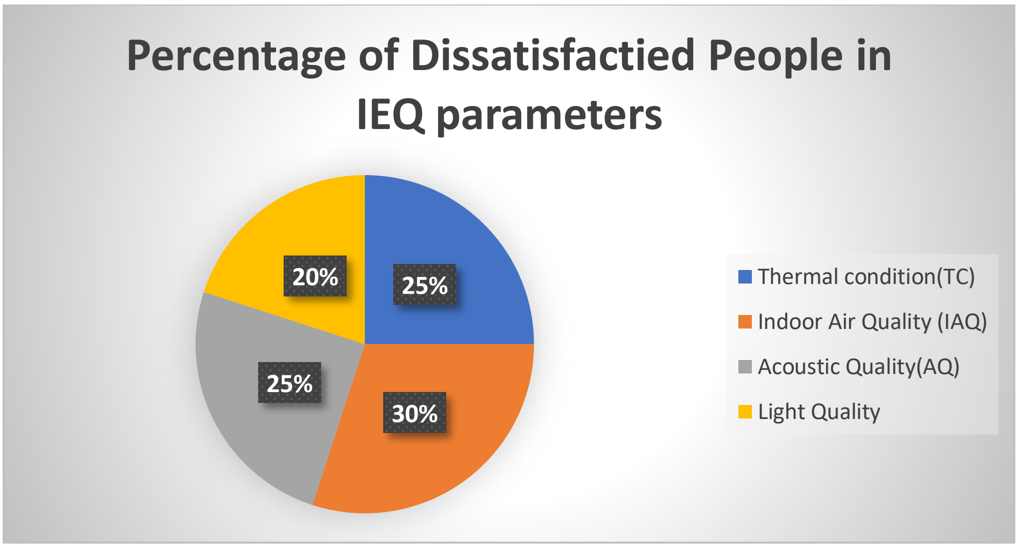


Figure 2.3: The percentage of dissatisfied people in common IEQ parameters (Esfandiari et al., 2017)

2.5.3 Conclusion

This research reviewed various studies and figure out that although the green buildings showed better IEQ rather than conventional buildings but there is still more dissatisfaction in IEQ parameters existed which requires enhancement. These parameters not only bring health and comfort for occupants, but also benefits company in terms of work productivity. Similarly, the suggestion of this study for designer and who involved in construction is that air quality should be prioritize rather than other elements. Furthermore, to clarify the sequence among them and determine which factor is causing more problem for occupants, this research extremely recommends more researches through the aspect of phycology of IEQ parameters.

2.6 IEQ Design for Advanced Occupants' Comfort -A Pre-POE of a Green – Certified Office Building by Elzeyadi et al. (2017)

This study reports on a longitudinal assessment of a commercial high-performance Leadership in Energy and Environmental Design, LEED double platinum retrofitted building. The problem statement of this research is whether a well-planned evaluation study with pre-post occupancy analysis of a retrofitted green-certified building could lead to more convincing discoveries relevant to the effects of green buildings and those with specific high IEQ on occupant's well-being, health, and productivity.

2.6.1 Methodology

For this study, the multi-method approach was used to analyze the results of the research. In both cases before and after green retrofitting the building, multi-comfort parameters and metrics with the thermal, visual, acoustical, and air quality environment were examined and evaluated. At the level of the building as well as the scale of the occupant work setting, instantaneous and long-term field measurements data of the physical environment and multi-comfort parameters were measured. Environmental sensors and data loggers measuring temperature, relative humidity, air velocity, and air movement graded across the various levels of floor in the buildings, were brought into play over the seasons of winter, spring and summer individually. In addition, approximately 15 liters of air was sampled for high performance liquid chromatography (HPLC) and mass spectrometry analyses as well as volatile organic compounds (VOCs) concentrations in order to analyze indoor air quality. Occupant's point of view and expectation was interpreted by applying a structured series and focus groups of open-ended. 10-15 employees entitled various job-levels and locations of workstation for each focus group. Physical measurements and survey responses were spatially tagged and numerically evaluated by using SPSS software. Moreover, data visualizations and multi-comfort parameters were enumerated using a suite of software that spatially evaluated the occupant's visual, thermal, acoustical and indoor air quality (IAQ) over different locations of the building.

2.6.2 Results

2.6.2.1 Thermal Condition

Pre-retrofit, thermal conditions vary from completely outside the comfort zone for perimeter workstations to partially within the comfort zones or in-between the comfort and adaptive zone for internal work zones. Meanwhile, majority of the thermal conditions after retrofit fit pleasantly within the thermal comfort area but supply enough differentiation to prevent taking place in thermal boredom conditions and still bounce back diversity in thermal conditions apt for occupants' various clothing and metabolic levels within the space in different times of the day.

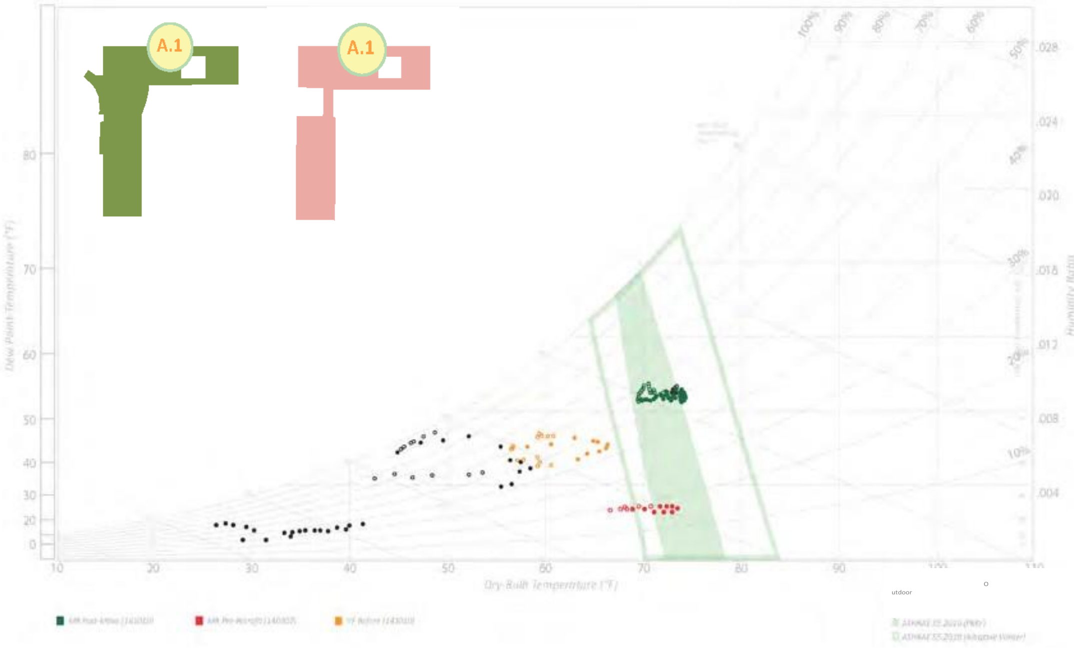


Figure 2.4: Comparative Analysis of Thermal Comfort Psychrometric Charts Spring Season of both Building Phases (green post-move/retrofit, red pre retrofit, orange move and black outdoor) (Elzeyadi et al., 2017)

2.6.2.2 Indoor Air Quality

Moreover, the samples of 15 litres of air with flow rate of 0.125 l/min were transmitted to an authorized laboratory for removal and analysis using high performance liquid chromatography (HPLC) in order to examine the indoor air quality. The results are portrayed in figure below.

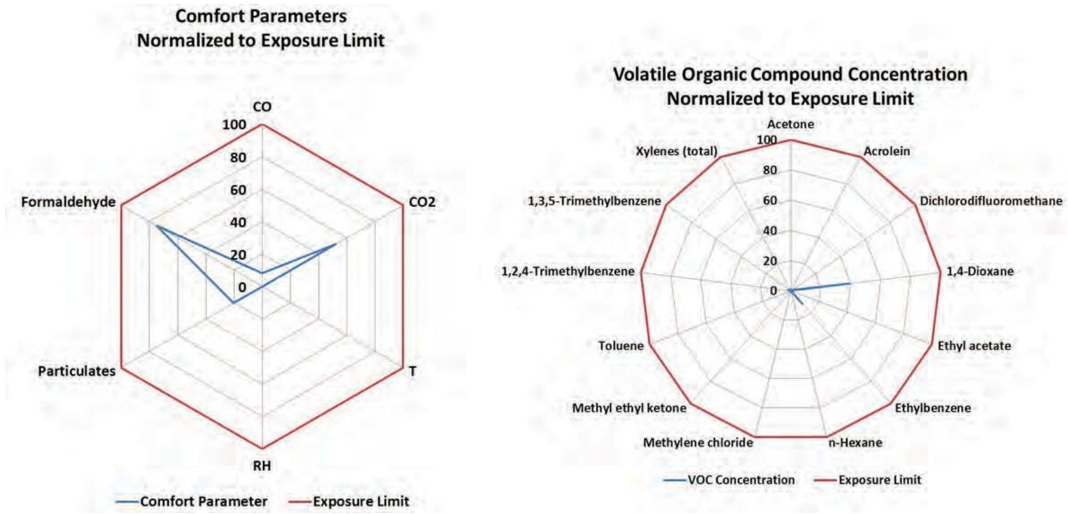


Figure 2.5: Comfort Parameters and Gas Concentrations (Elzeyadi et al., 2017)

2.6.2.3 Acoustic Comfort Analysis

Acoustic comfort mapping for spatial decay and distraction distance with STI is demonstrated in Figure 6. Results emphasized by the green lines shows that the expected distraction distance is achieved within 2 to 4 meters for majority of locations.

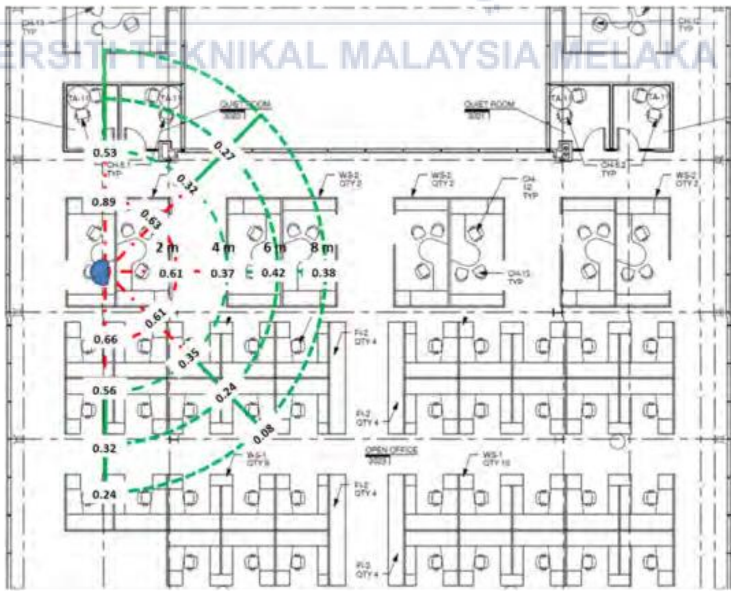


Figure 2.6: Acoustic Comfort Mapping for Spatial Decay with STI (Elzeyadi et al., 2017)

Introductory outcomes of the survey show high satisfaction of occupants with the environmental principles and green/LEED™ certification of the building. Approximately 75% of occupants in the retrofitted building accede about the significance to work in a building that is environmentally aware.

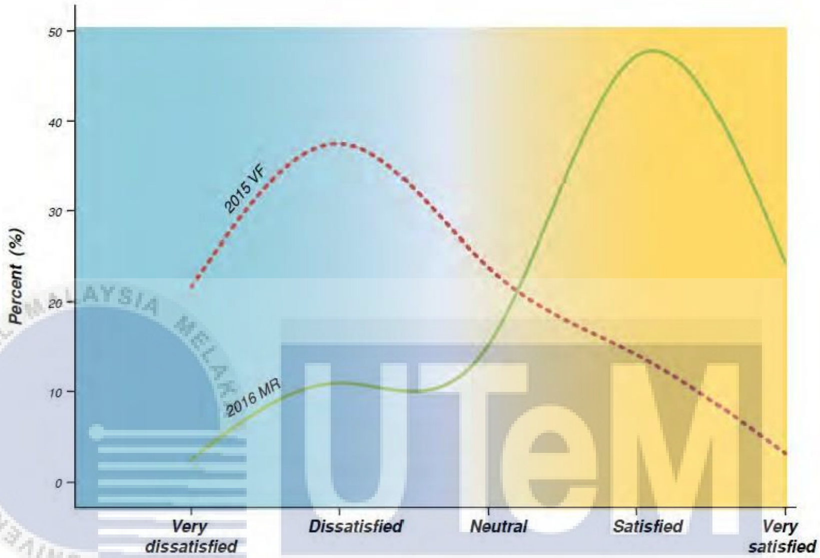


Figure 2.7: Occupant's Satisfaction Percentages from a POE Building Survey of Both Studied Building Phases (Elzeyadi et al., 2017)

2.6.3 Conclusion

The major goal of this research is to provide clear and context particular facts to judge IEQ inside green buildings from a comprehensive approach. By establishing a comparative approach between a traditional building pre-retrofit and its green retrofitted LEED certified platinum phase, the paper provides an evidence-based approach of green building design procedures that affect factors of IEQ.

2.7 POE of conventional-designed buildings by Akashah et al. (2015)

This paper reveals the how comfort and satisfaction impact the occupants' work rate in conventional-designed buildings. Five office buildings located in University of Malaya were chosen as the case studies. 278 questionnaires survey found to be benefited to form a database on the IEQ. In addition, using SPSS software, data collected were evaluated. Most of the respondents in conventional-designed building were slightly comfortable and satisfied about their IEQ comfort level which were indoor air quality, thermal, lighting, and noise comforts based on the results stated. Although, the design of conventional buildings did not count on sustainability designing, it still usefully well and provided comfort which cause to boost up productivity of employees. The associative test results that noteworthy correlation between symptom of illness and IEQ parameters. In variance with Faculty buildings, Admin buildings had more visible illness symptoms. It could be summarising that building occupants' productivity were minimally impacted by the conventional- design building.

2.7.1 Methodology

This research applied quantitative research technique, where a set of questionnaires was used to collect data and information regarding building occupants' comfort and satisfaction. As for case studies, five conventional-designed buildings were chosen. Those buildings named as Admin 1, Admin 2, Admin 3, Faculty 1 and Faculty 2 For the purpose of this paper. Building occupants/employees in those five building expressed their reaction and feedbacks as they fit the role of samples.

The questionnaires were classified into eleven sections which were the background, building overall, thermal comfort, IAQ, noise, lighting, respondent experience, personal control, workplace environment, knowledge, and response to problems. The question majorly used seven points of semantic differential scale from very low. A total of five hundred questionnaires were distributed randomly among the building occupants. Two hundred and seventy-eight respondents returned and could be used to form a database for analysis.

The total response rate of 55.6 percent was obtained. Moreover, in order to evaluate the raw data, a Statistical Package for Social Science (SPSS) software was utilized. Mean, mod, Kruskal Wallis, Mann-Whitney U and Spearman Correlation test. Mean score of 1.0 to 3.0 considered unsatisfied, 3.01 to 5.0 were fair and 5.01 to 7.0 considered satisfied as both descriptive and inferential data analyses techniques implemented.

2.7.2 Results

Spearman rank correlation coefficient included between 3 components of IEQ, which are the thermal comfort, lighting and noise characteristics on workers' illness symptoms. The outcome shown in Table 6. Humidity and temperature have high connection since most of the respondent tend to feel more sensitive towards temperature comfort than humidity. Admin 1, Admin 2 and Admin 3 had the minimal expected comfort for room temperature comfort than Faculty 1 and Faculty 2. Furthermore, in these building illness symptoms such as stuffy, tired or dry eye, dry skin and difficulty in concentration may found. There are significant affects not only in the case of employee's illness but also in absenteeism rate according to correlation findings. As what had stated by Sullivan et al. (2013), the measure of absenteeism is very likely to measure productivity while Ronald et al. (2003) states that identifying illness symptoms encountered by employees lead to obtaining their rate of absenteeism. It is understandable that how workplace environment comfort creates health issues and causes employees to absent themselves from work and indirectly affecting work productivity (Danielsson and Bodin, 2008). Based on the research, Admin 1, Admin 2 and

Admin 3 buildings had more recognizable illness symptoms as compared to Faculty 1 and Faculty 2 buildings.

Table 2.4: Spearman Correlation between Illness Symptom and IEQ Component (Akashah et al., 2015)

Illness Symptoms	IEQ Components for 5 Buildings														
	Admin 1			Admin 2			Admin 3			Faculty 1			Faculty 2		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Running nose	-.236	-.300	-.086	.165	.112	.322	-.420	-.363	-.243	.129	.162	.217	-.270	-.311	-.233
Stuffy	-.215	-.258	-.111	.317	.039	.363	**-.881****	.021	.002	.116	.179	.463	-.145	.062	.082
Tired or dry eye	.386	**-.569***	.159	.000	.074	.148	**-.602***	-.030	-.040	.019	.064	.044	-.301	-.129	-.140
Glare	.329	**-.611***	-.067	.048	.000	.380	-.345	-.217	-.437	.054	.101	.289	-.281	-.128	-.317
Blur vision	.189	**-.784****	-.102	.120	.000	.393	-.344	-.310	-.320	.151	.120	.493	-.187	-.251	-.217
Easily tired	.097	**-.785****	-.057	.337	-.076	.304	-.015	-.127	-.117	.247	-.156	.327	-.125	-.117	-.117
Headache	-.180	-.371	.318	.195	.193	.324	-.314	-.099	-.029	.159	.203	.154	-.112	-.083	-.089
Dizzy	.069	-.341	.347	.337	.154	.694*	-.403	-.171	-.211	.234	.045	**.494***	-.211	-.154	-.183
Dry skin	**-.504***	-.366	.194	**.466***	-.116	.324	-.156	-.285	-.255	.186	-.151	.424	-.056	-.183	-.081
Difficulty in concentration	.051	**-.566***	**.740***	.320	-.221	.295	**-.809****	-.364	-.314	.211	-.121	.295	-.207	-.181	-.038
Tension or stress	-.100	-.591	.292	-.398	-.175	.262	-.419	.108	.188	-.127	-.101	.262	-.211	.009	.098
Number of days absent	.056	**-.802****	-.095	**-.747***	-.037	-.332	**-.535***	.186	.096	-.217	-.037	-.332	-.237	.181	.206

2.7.3 Conclusion

Based on the survey, it could be summarised that the building occupants' comfort level was fair. Comfort parameters did not bring impacts to building occupants' productivity and health because their productivity and health were also fair. Similarly, working environment in conventional- designed buildings was great and comfort and they tally with working environment. The indoors environmental functionally well and provide comfort and satisfaction for the building occupants' productivity, although, conventional-designed buildings did not count in to sustainability aspect during construction stage. Moreover, with the further enhancement of the IEQ, which is indoor air quality, thermal comfort, acoustic comfort, and lighting comfort, these conventional-designed building were most likely had criteria to be awarded with green building status.

2.8 POE and IEQ of UTP Academic Complex by Khamidi et al. (2013)

As the goal to be certified as green building university, Universiti Teknologi Petronas are currently working hard with various initiatives for the development purpose of UTP. Hence, to accomplish the aim of the university to meet the requirement of GBI standard, this study determine and analyze the level of building performance according to occupants' satisfaction and indoor environmental quality analysis in accordance with Green Building Index (GBI) and Malaysian Standard MS1525. Lecturer, staff and students were selected as the sampling taken from the populations of UTP. In addition, three buildings which is Block 13, 14 and Pocket C were picked to represent the whole UTP new academic complex. Post Occupancy Evaluation (POE) and analysis field measurement of Indoor Environment Quality (IEQ) were both two methods which covers qualitative and quantitative aspects. POE determine the occupant's satisfaction level where the aspects need to achieve the severity index passing boundary. Similarly, six parameters of IEQ which are classified as temperature, relative air humidity, noise level, illumination level, CO_2 level and air velocity are measured in order to verify the result of POE.

2.8.1 Methodology

As for part of methodology in this research, AMI 300 Multifunction, Hygro-thermometer, sound level meter and solarimeter were used as shown table below with its function respectively for overall field measurement of research.

Table 2.5: Equipment used for field measurement (Khamidi et al., 2013)

Equipment	Function
AMI 300 Multifunction	To measure CO2 level, temperature and hygrometry
Vane probes	Measure air velocity and has an accuracy of ± 0.5ºC and ± 0.6% for temperature and relative humidity readings
Hygro- thermometer	To measure the relative humidity and temperature
Noise level meter	To measure internal noise level
Solarimeter	To determine illumination intensity for lighting

The results for each questionnaire are Post Occupancy Evaluation conducted to students and staff. A total of 80 respondents fulfilled the online survey which is 63 respondents are students and 17 are UTP staff. Moreover, by using online Google document data automatically collected and been inspected.

In addition, analysis Using Severity Index also utilised in the research. Relative index ranking technique is a non-parametric technique widely used by construction management researchers for analysing structured questionnaire response data involving ordinal measurement of attitudes AUDE (2006), Olomolaiye, P.O. et.al (1987), Holt, G.D (1997), Idrus, A. & M.Sodangi (2010). In order to compare the relative importance of the criteria under study severity index analysis which uses weighted percentage scores.

2.8.2 Results

Table 2.6: Overall Severity Index for all parameters (Mohd Faris Khamidi et al., 2013)

Parameter	Severity Index	Ranking
Air Quality	63.51	2
Temperature	49.76	4
Noise	55.89	3
Light	70.33	1
SI boundary	59.87	

All four parameter have been collected in the graph to reveal which of the parameter are most affects occupants" satisfaction on the building performance. From the table, light is in the top ranking which is 70.33% then air quality.

Noise and temperature are not passing the value since the SI boundary is 59.874%. Although, 79% of respondent satisfied with the indoor environmental quality of UTP building, POE does not meet the EQ16 of GBI standard. With accordance to that case, where when the survey results indicate that more than 20% of occupants/workers are dissatisfied with the overall comfort in the building UTP management need to come out with a plan for corrective movement.

2.8.3 Conclusion

In a nutshell, according to the findings from field measurement and post occupancy evaluation, it shows that some enhancements need to be implemented for the parameters which are not meeting the severity index passing boundary level and certified by indoor environmental quality assessment. In conclusion, Universiti Teknologi PETRONAS have great capability to achieve GBI certified level that will take university to towering level.

Furthermore, only noise level and light illumination level need improvement to achieve GBI requirement out of six parameters.

2.9 Summary of Previous Work

According to previous work by Nurul Malina Jamaluddin (2017), the perceived level of satisfaction in terms of thermal comfort was not up to satisfactory as compared to the results. In addition, based on the research by Masoud Esfandiari et al. (2017), although the green buildings showed better IEQ rather than conventional buildings but there is still more dissatisfaction in IEQ parameters existed which requires enhancement. Ihab Elzeyadi et al. (2017) stated that around 75% of occupants in retrofitted building about significance to work environmentally aware. Research by Farid Wajdi Akashah et al. (2015 in conventional-designed buildings resulted that Admin 1,2 and 3 has more recognizable illness compare to Faculty 1 and Faculty 2. Furthermore, Mohd Faris Khamidi et al. (2013) stated that Universiti Teknologi PETRONAS have great capability to achieve GBI certified level that will take university to towering level in his study. However, improvement to achieve GBI in terms of noise level and light illumination level needed to be focused.

Table 2.7: Summary of Previous Work

Researchers (year)	**Type of study**	**Building Type**	**Results**
Jamaluddin (2017)	Assessment	Classroom	Air Temperature=27.3°C Relative Humidity= 76.4% VOC (ppm)=11.7 Air Velocity=0.14
Esfandiari et al. (2017)	Review	Office Buildings	IAQ= 30% Thermal Comfort=25% Acoustic Quality=25% Light Quality=20%
Elzeyadi et al. (2017)	Pre-post Occupancy Evaluation	Green-certified Office Buildings	75% of occupants in retrofitted building about significance to work environmentally aware.
Akashah et al. (2015)	Post Occupancy Evaluation	Conventional-designed buildings (5)	Admin 1,2 and 3 has more recognizable illness compare to Faculty 1 and Faculty 2
Khamidi et al. (2013)	Case study	Academic complex building of UTP	Severity index Air Quality= 63.51 Temperature= 49.76 Noise= 55.89 Light= 70.33

CHAPTER 3

METHODOLOGY

This chapter encompasses methods and equipment used to evaluate thermal comfort and indoor air quality analysis. The function of each equipment, procedure on handling the equipment, survey questions questionnaire draft is briefly explained in this chapter. Furthermore, flow chart of overall steps also has been staged throughout this section.

3.1 Technology Campus of UTeM

Technology Campus of Universiti Teknikal Malaysia Melaka (UTeM) as shown in Figure 4.1 embrace of 3 main buildings. It can be classified as buildings of Faculty of Mechanical Engineering (FKM), Faculty of Engineering Technology of Mechanical and Manufacturing and Faculty of Engineering Technology in Electric & Electronics) and lastly Faculty of Technology Management and Technopreunership (FPTT). All these 3 faculties consist of several lecture rooms, laboratories, seminar halls, library and so on. FKM building can be recognized easily with its very own remarkable green colour building and it is also made of 7 floors as shown. The reason behind all these buildings are to supply student with comfortability while studying in lecture rooms, strategic learning environment and good platform to carry out their discussions. The plan for each FKM and FPTT building are shown in APPENDIX.

3.2 Selection of classroom in FKM and FPTT

According to the svcope of this study, in order to examine the indoor environmental quality of lecture rooms in Faculty of Mechanical Engineering Building AND Faculty of Technology Management and Technopreunership (FPTT), the analysis of both thermal comfort and air quality will be conducted. All the classrooms in each faculty are air conditioned. One huge classroom and one small classroom chosen to be samples in each faculty.

3.3 Physical Measurement

Physical measurement is one of the most fundamental concepts in engineering aspects. This is to investigate the actual condition of indoor environmental quality especially in chosen area. Anything that is measurable and displays the exact physical condition of a system is known as physical parameters. Physical parameters are classified into many types and it varies according to the method of investigation. The physical parameters which are involved in this study are listed in Table 4.1. The data of physical parameters also varies due to two different set of experiment sessions. First set of experiment involves two session which are (10am to 12pm) in the morning and (2pm to 5pm) in the afternoon. This is become the result will vary in these 2 different conditions as it has different weather criteria respectively in both morning and evening.

Similarly, the physical measurements will be calculated via two set of conditions which are with and without occupants in lecture rooms. A pilot test will be conducted in air-conditioning lab which leads to suitable lecture room selection for measurement of real parameters in this study.

Table 3.1: Physical parameters involved in this study

Physical Parameters	**Unit**
Indoor air temperature, T_a	Celsius
Air velocity, V_a	m/s
Relative Humidity, RH	%
CO_2 Concentration	Ppm
$PM_{2.5}$ Concentration	µg/m^3
$PM_{10.5}$ Concentration	µg/m^3
Predicted Mean Vote, PMV	-
Predicted Dissatisfied Percentage, PPD	%

3.3.1 Measurement Equipment for Thermal Comfort Parameters

In this research, the Delta Ohm Thermal Microclimate HD 32.1 as shown in Figure 4.4 is used to measure the thermal comfort parameters. Function of Delta Ohm Thermal Microclimate HD 32.1 is to study, measure and control the microclimate in specific chosen location. The microclimate is also defined as the parameters of environment that being cause for the heat exchange between a individual and spaces of surrounding. The equipment works in accordance with standards such as ISO 7726, ISO 7730, ISO 7243, ISO 7933, ISO 1. The equipment includes of eight inputs with SICRAM module. The range of operating temperature is from -5°C to 50°C, meanwhile the range of relative humidity is from 0% to 90%. The probes that are labelled is interpreted in Table 3.2 as shown below. All the probes are contoured with electric circuit and the instruments retained the settings of calibration, (Delta Ohm SRL, 2009).

Figure 3.1: Thermal Microclimate HD32.1 (Delta Ohm SRL,2009)

Table 3.2: Probes of Thermal Microclimate HD32.1

Probes	**Description**
1	Mean radian temperature measurement
2	Air velocity measurement
3	Relative humidity measurement
4	Carbon dioxide measurement

5	Natural ventilated wet bulb temperature
6	Radiant temperature measurement
7	Local thermal discomfort measurement

In this research, Program A: HD 32.1 Microclimate Analysis and Program B: HD 32.1 are the operating programs of the instrument. For the measurement of thermal parameters of indoor environmental probes that are involved are shown in Table 3.3.

Table 3.3: Probes used for this research

Thermal parameters	**Probes**
Sensors for wet bulb and dry bulb temperature	HP3217DM
Relative Humidity	HP3217
Globe temperature probe (150mm diameter)	TP3275
Air velocity (Omni directional hot- wire probe)	AP3203

General procedure to conduct thermal comfort analysis are:

1. Divide chosen lecture rooms into few measurement zones.
2. Thermal Microclimate HD32.1 is positioned and configured as shown in Figure 3.5 and Figure 3.6. 1.1 metre from floor level, the probes that used to obtain measurements are located.
3. By setting up the minimum interval of time to obtain data, firstly pilot measurement is carried out. Observation of the result will indicate how often and rapid the data changes within an hour. Next, actual measurement is carried out by set up of time interval to accumulate data for around 30 minutes at each zone.

4. For the case with occupants, the physical measurement is conducted from (10am to 12pm) as morning session and (2pm-5pm) as afternoon session respectively as shown in Figure.

Figure 3.2: Thermal Microclimate positioned in experimental zone for pilot test

3.3.2 Measurement Equipment for Indoor Air Quality Parameters

TSI IAQ-Calc Air Quality Meter 7545 and DustTrak II Aerosol Monitor as shown in Figure 3.3 and Figure 3.4. TSI's 7545 IAQ-CALC Meter is an first-rate equipment for examining and observing indoor air quality (IAQ). The 7545 model simultaneously calculates and data logs multiple parameters. CO, CO2, temperature, humidity; and calculations are dew point, wet bulb temperature, and % outside air are components of measurement parameters. The operating temperature is ranges from 0°C to 45°C. It requires 4 AA batteries or AC adapter to be operated.

In this study, IAQ-Calc Air Quality Meter 7545 is used to measure CO and CO_2 concentrations. The measurement is obtained as same procedure of Thermal Microclimate's and also same measuring zones which has been chosen.

Procedure of measurement with IAQ-Calc Air Quality Meter 7545:

1. Thermal Microclimate HD32.1 is positioned in divided measurement zones. From the floor level of 1.1 metre, the CO_2 concentration sensor is placed.

2. By setting up the minimum interval of time at 10seconds to obtain data, firstly pilot measurement is carried out. Then, the actual measurement will be conducted by adjusted time interval which changed from 10seconds if data shows trivial changes. The experiment will be conducted about 30minutes in each zone.

3. The physical measurement is conducted from (10am to 12pm) as morning session and (2pm-5pm) as afternoon session respectively as shown in Figure.

4. For both the cases with occupants and without occupants, the physical measurement is conducted from (10am to 12pm) as morning session and (2pm-5pm) as afternoon session respectively.

Figure 3.3: IAQ-Calc Air Quality Meter 7545

Meanwhile, DustTrak II Aerosol Monitor is utilised to measure concentration of aerosol be comparable to $PM_{2.5}$ and PM_{10} fraction of size. With gravimetric sampling, it provides real-time aerosol mass readings. This instrument majorly used for occupational hygiene, indoor air quality, outdoor environmental, emissions, remote monitoring and process monitoring.

Procedure of measurement with DustTrak II Aerosol Monitor:

1) DustTrak II Aerosol Monitor is positioned in divided measurement zones.
2) Before measurement begins, to get accurate results calibration required to be done.
3) By setting up the minimum interval of time at 1second to obtain data, firstly pilot measurement is carried out. Then, the actual measurement will be conducted by adjusted time interval which will be changed from 1seconds if data shows trivial

changes. The experiment will be conducted about 5 minutes in each zone to collect data concentration of $PM_{2.5}$ and PM_{10}.

4) The physical measurement is conducted from (10am to 12pm) as morning session and (2pm-5pm) as afternoon session respectively as shown in Figure 3.7:

Figure 3.4: DustTrak II Aerosol Monitor

3.4 Survey

For this study, questionnaire is used as a tool to measure the subjective measurement as shown in APPENDIX. It reflects the major overview on how occupants feel and express their satisfaction or dissatisfaction. The questionnaire consists of several elements such as occupants' feedback on thermal comfort during lecture hour in classrooms, clothing type of occupants, room air temperature, air velocity and indoor air quality. Survey Questionnaire is constructed and divided into 2 classifications.

i. Personal information on occupants’

It includes elements such as occupants’ gender, age, status occupation and also time spent in building, clothing type.

ii. Current environment condition

It consists of parameters in terms of air quality and thermal comfort. For air quality aspect, it includes occupants’ satisfaction level in air movement, air odour, air freshness and air humidity. Meanwhile, for thermal comfort involves parameters of temperature condition, temperature control and so on. The voting scales constructed in accordance with recommended ASHRAE standard which has seven-point scale.

3.4.1 Respondents selection

The questionnaire will be distributed in term of google form to the students who is having class session in selected classrooms during observation period of (10am-12pm) as morning session and (2pm-5pm) as afternoon session.

3.5 Result Analysis

There is several software that will be used to analyse the data obtained in each method. In this research, Delta Log_{10} Software and Minitab Statistical Software are used to analyse the thermal parameters. Meanwhile, for the analysis of indoor air quality parameters Microsoft Excel and Minitab Statistical Software is utilised. Lastly, Minitab Statistical software is used to evaluate results obtained for survey questionnaire. The analysis of outcomes is classified into few sections in this study.

3.5.1 Comparison of results between physical parameters measurement and standards.

In accordance with standards such as Malaysia Standard (MS 1525, ASHRAE55) the thermal comfort parameters which are air temperature, air velocity, relative humidity, PPD index and PMV index will be compared. Based on ASHRAE 62.1 standard, the indoor air quality parameters such as concentration of carbon dioxide, $PM_{2.5}$ and PM_{10} will be compared. Moreover, the results will be compared as well as with conditions of no occupants and with occupants to determine the impact of on occupants on each changes of parameter.

3.5.2 Analysis of occupants' votes according to questionnaire

Sensation vote of occupants is evaluated to study their feedback on the indoor condition of different sized lecture rooms. For occupants' thermal sensation vote and operative temperature, linear regression analysis will be performed.

3.5.3 Comparison of results between questionnaire and physical measurement

The feedback from survey questionnaire are crucial to compare with physical measurements. In order to figure out the strength of relationship between actual condition felt by respondents and physical measurement, linear regression analysis between both aspects needed to be done.

3.6 Recommendation on indoor environment quality improvement measures

By conducting thermal comfort analysis and indoor air quality analysis, the indoor environment condition can be discovered. In order to get to know on implementing improvements on concerned parameters, it is fundamental to analyse both measurement parameters as well as perception of occupants. Hence, appropriate measures and recommendations to improve environmental quality is suggested based on all these analysis comparisons.

3.7General Methodology

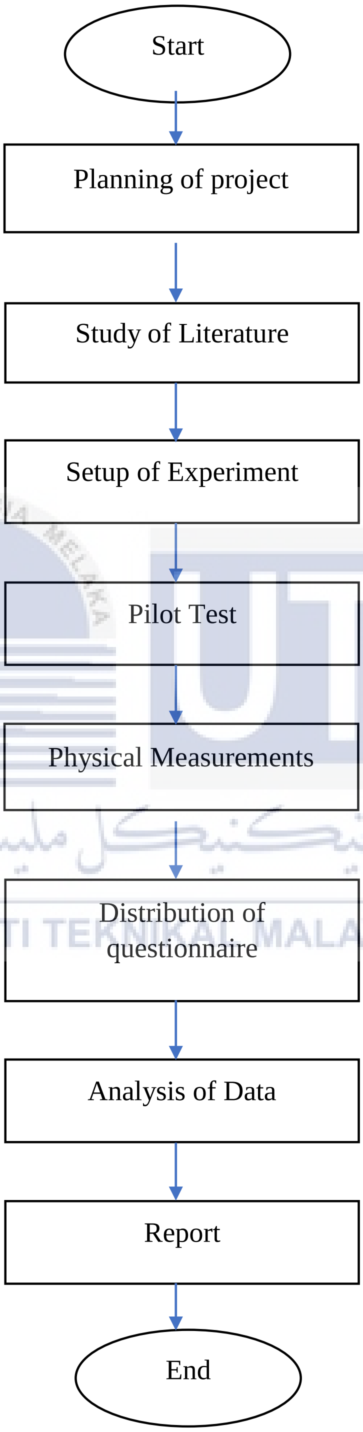


Figure 3.5: Flow chart of methodology

CHAPTER 4

RESULT AND ANALYSIS

This chapter portrays the data of measurements for occupancy conditions. Present and related standards have been utilized to analyse each data represent for each class. On the other hand, satisfaction of occupants also has been evaluated based on survey findings. Thus, all the outcomes from physical measurements and surveys have been wield in order to improve in terms of measure of Indoor Environmental Quality are proposed in the chapter.

4.1 Physical Measurement Results

Physical measurements are taken in the selected classes of Faculty of Mechanical Engineering (FKM) and Faculty of Technology Management & Technopreneurship (FPTT). All the measurements were conducted under the condition of with occupants.

The 2 sessions for physical measurements are from 10am to 12pm in the morning and 2pm to 5pm in the evening. The measurements were carried out from the date 20th February 2020 to 13th March 2020. Since the condition is with occupants, all the physical measurement was carried out during lecture hours.

Thermal comfort and indoor air quality which are the major pillars to identify the indoor environmental quality of classrooms are been focused. In order to measure human thermal comfort level and indoor air quality, the physical parameters such as air temperature

(Ta), relative humidity (RH), air velocity (Va) have been measured by using Thermal Microclimate HD32.1 instrument. The Predicted Mean Vote (PMV) index and Predicted Percentage of Dissatisfied (PPD) index also can be acquired from the instrument which is the key elements to analyse human thermal comfort level. Besides, parameters such as carbon dioxide level, concentration of particulate matter 2.5 and 10 which obtained from IAQ-Calc Air Quality Meter 7545 and Dust Trak II Aerosol Monitor respectively also have been taken in count by analysing in order to evaluate the indoor environmental quality.

4.1.1 Classrooms in FKM building

Measurements were taken in 2 zones of the classroom. Classroom was divided into 2 zones were first measurement was taken at the back of the classroom and middle of the classroom were students majorly sits. The parameters measured from Thermal Microclimate HD32.1 instrument such as air Temperature, relative humidity (RH) and air velocity (Va) are about the interval of 20 seconds with the duration of 30 minutes in each zone. Meanwhile, for the parameters of carbon dioxide level, data have been recorded for every 10 minutes about 1 minute of data measurements. Concentrations of PM 2.5 and 10 are about the duration of 30 minutes in each zone with interval time of 10.

Figure 4.1 and 4.2 shows the measurements that were recorded for air temperature in the classroom 4 of FKM in two different sessions which are morning and afternoon respectively. Each data of maximum, minimum and average of air temperature have tabulated in the graph in order to compare with MS 1525 standard. The maximum, minimum and average of air temperature are 26.9 ºC, 26.6ºC and 27.77ºC respectively for zone 1.

Meanwhile for zone 2, maximum, minimum and average of air temperature are 27.3ºC, 26.6ºC and 26.97ºC respectively.

Based on the graph below, as we compared with standard MS 1525, it shows that average air temperature for both the zones are not complying with the standard MS 1525. This is because, the minimum recommended air temperature by MS 1525 is from the range of 24ºC to 26ºC and the data that obtained are more than the recommended minimum air temperature.

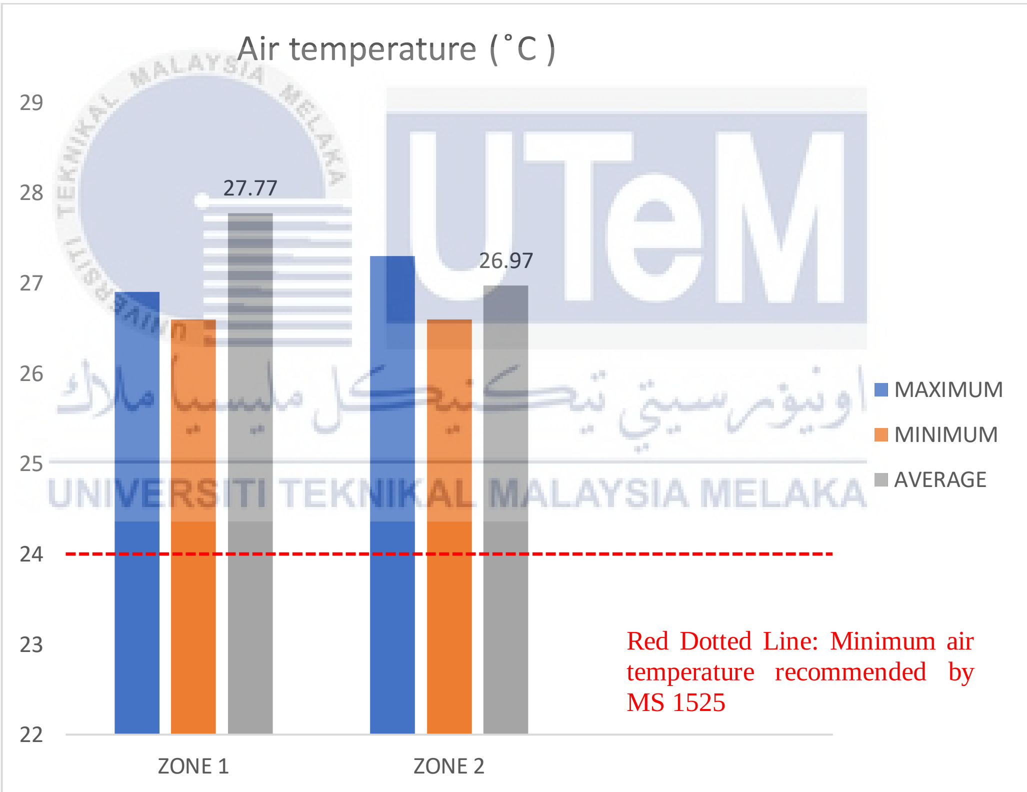


Figure 4.1: Indoor Air Temperature in Classroom 4 of FKM during morning

According to Figure 4.2, the maximum, mini mum and average of air temperature at zone 1 are 25.8ºC, 25.4ºC and 25.58ºC respectively with occupants' condition. Furthermore, the maximum, minimum and average of air temperature at zone 2 are 26.3ºC, 25.2ºC and 25.83ºC respectively.

As we compared with MS 1525 standard, it is clear that the data obtained are more than the recommended minimum air temperature suggested by MS 1525. Thus, the obtained data are complying with the standard.

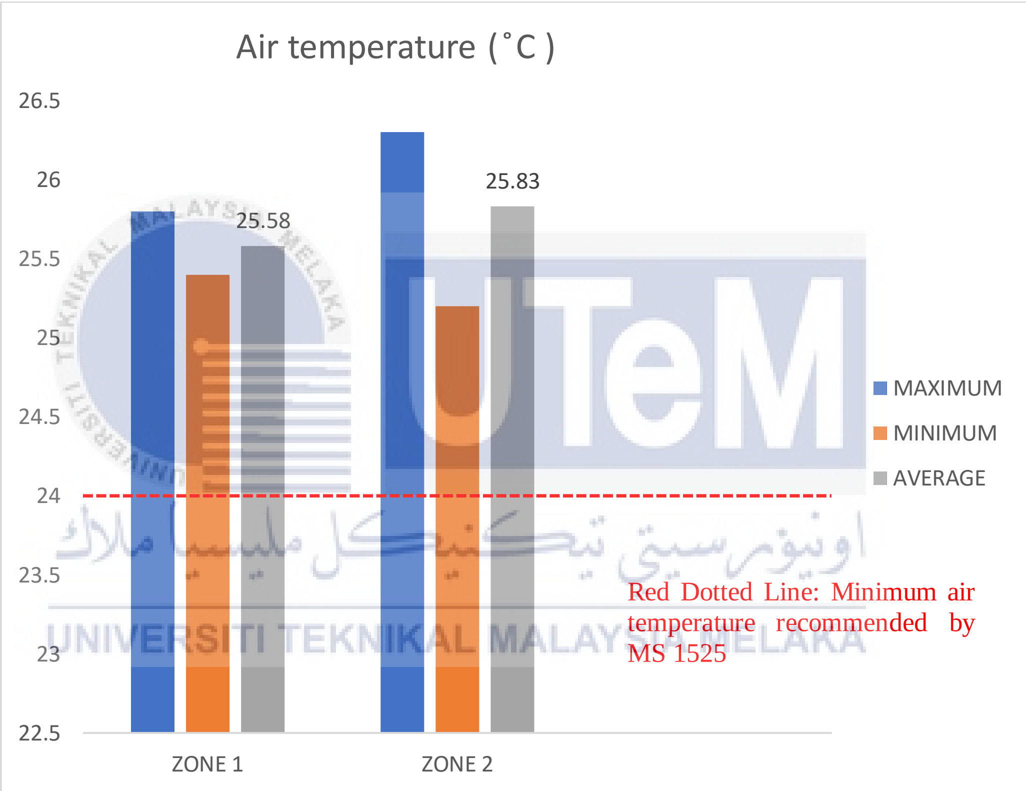


Figure 4.2: Indoor Air Temperature in Classroom 4 of FKM during afternoon

Based on Figure 4.3, the maximum, minimum and average of relative humidity among the zone 1 for occupancy are 120.5%, 82.3% and 120.05% respectively. While for zone 2, all three elements of maximum, minimum and average of relative humidity among the zone 1 for occupancy are similar which has the value of 120.5%.

According to the standard MS 1525, the recommended minimum relative humidity is between the ranges of 50% to 70%. Thus, the average values of both zone 1 and zone 2 during the morning session is complying with MS 1525 standard where it is more than the minimum value recommended.

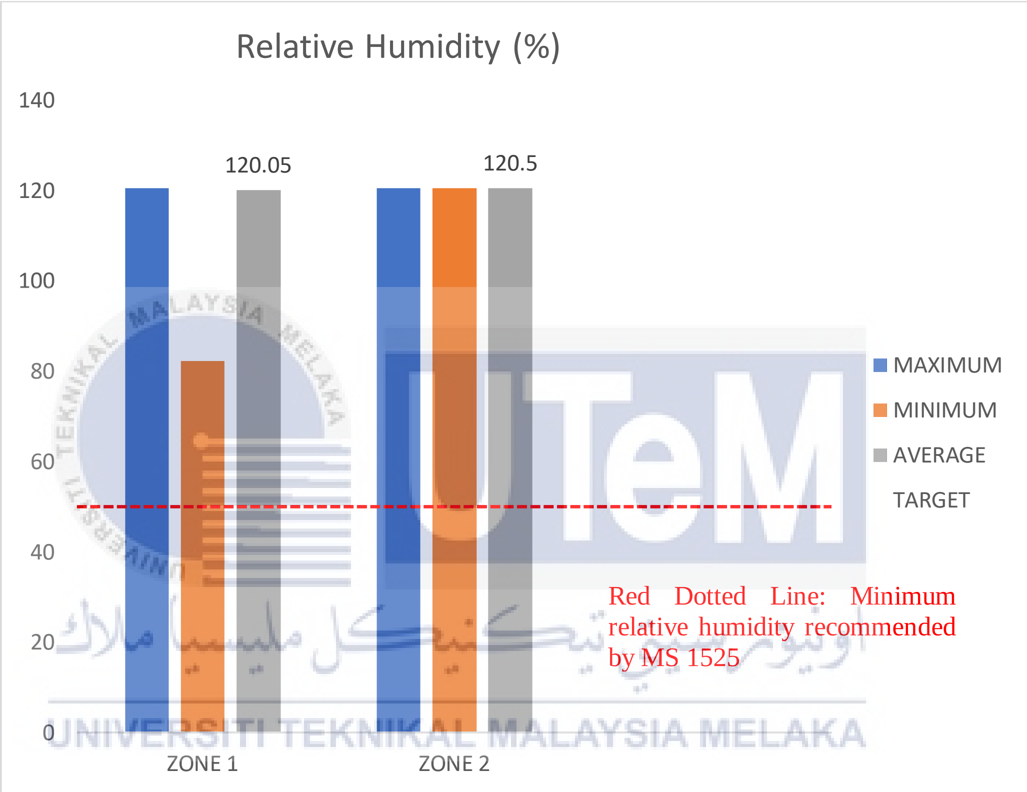


Figure 4.3: Relative humidity in Classroom 4 of FKM during morning

Relative humidity during the afternoon session for maximum, minimum and average are 82%, 80.8% and 81.56% respectively at zone 1. In addition, the maximum, minimum and average value of relative humidity in zone 2 are 80.7%, 78.7% and 79.67% respectively.

Hence, the overall average value for both zones are complying with recommended range by MS 1525 standard which is more than the minimum recommended value which is 50%.

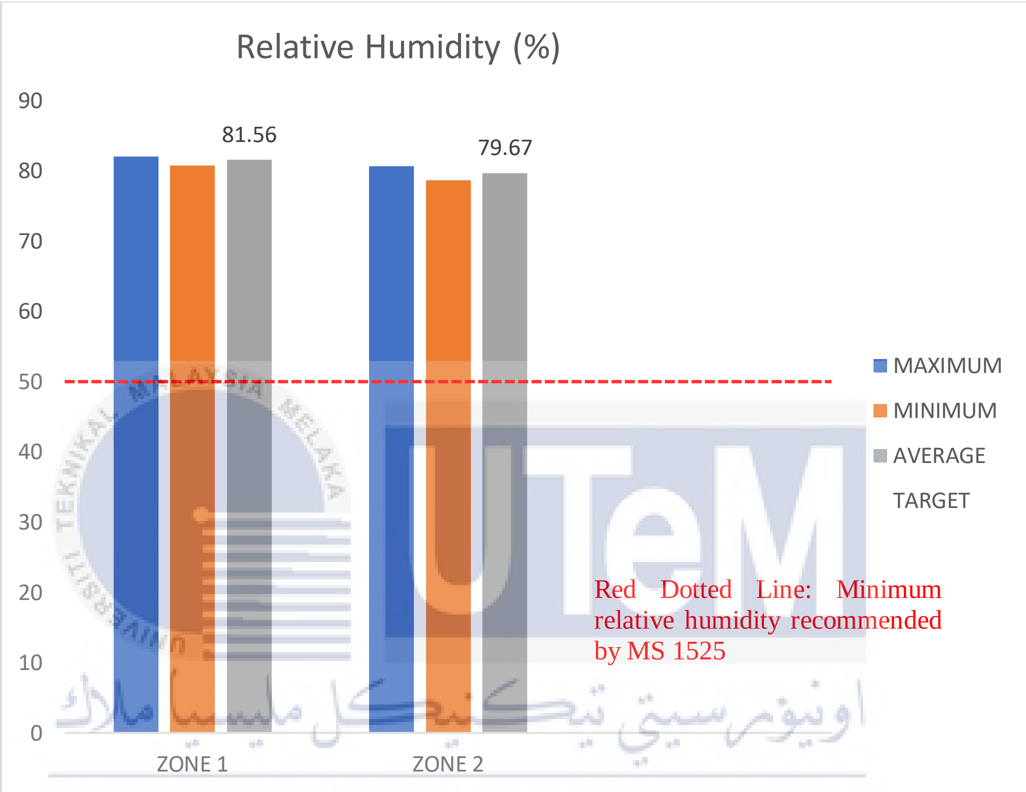


Figure 4.4: Relative Humidity in Classroom 4 of FKM during afternoon

Based on Malaysian Standard MS 1525, the suggested indoor air velocity ranges are from 0.15 m/s to 0.50 m/s. The indoor air velocity for both morning and afternoon session with occupants are tabulated in the Figure 4.5 and 4.6 respectively.

According to the figure 4.5, the maximum air velocity for both zones during morning are 0.31m/s. Meanwhile, the minimum air velocity for both zones during morning are 0 m/s and the average air velocity for both zone 1 and 2 are 0.13 m/s and 0.8 m/s respectively. As per compared to standard MS 1525, the average air velocity value for zone 1 and 2 not complying with the Malaysian Standard. This is because both the values are lower than the minimum recommended air velocity value by Malaysian Standard.

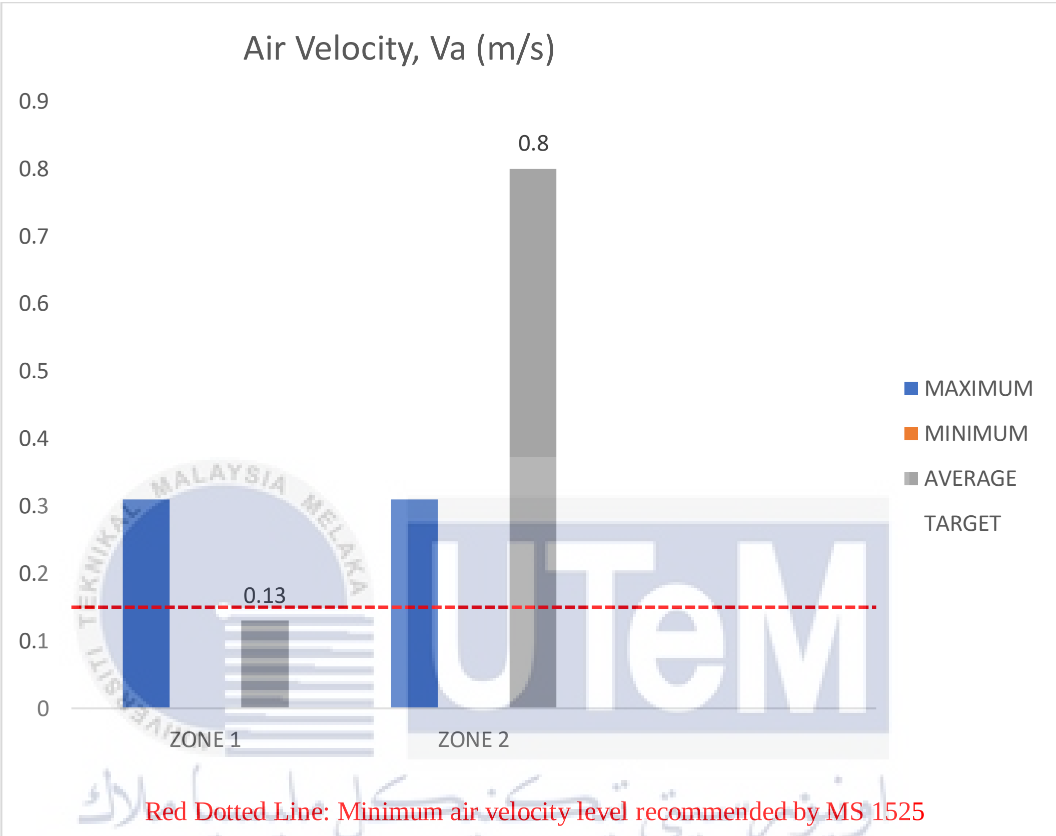


Figure 4.5: Air Velocity for Classroom 4 of FKM during morning

For the afternoon session, air velocity value with occupancy condition for maximum, minimum and average are 0.34 m/s, 0.03 m/s and 0.18 m/s respectively at zone 1. However, for zone 2, air velocity for maximum, minimum and average value are 0.28 m/s, 0m/s and 0.06m/s respectively.

Referring to Figure 4.6, the average air velocity value at zone 1 is complying with Malaysian Standard 1525. Meanwhile, the average air velocity at zone 2 which lower than the minimum air velocity recommended by MS 1525 does not achieve the minimum standard.

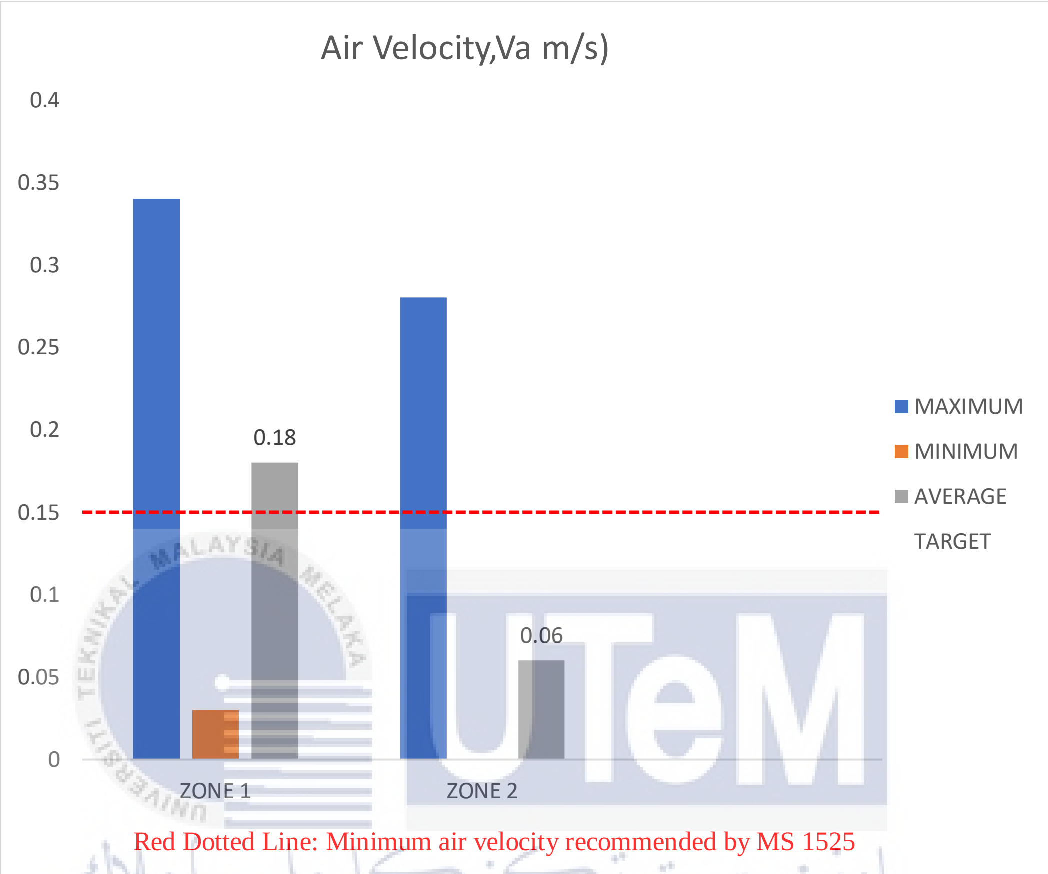


Figure 4.6: Air Velocity of Classroom 4 of FKM during afternoon.

Table 4.1: Carbon dioxide level in Classroom 4 of FKM during morning

Location	**Carbon dioxide level (ppm)**
Zone 1	1038
Zone 2	1261

Furthermore, during the morning session for occupancy condition carbon dioxide level have been measured in each zone of the classroom and tabulated into table. According to Table 4.1, it shows that the average carbon dioxide level at zone 1 and zone 2 are 1038 ppm and 1261 ppm respectively.

Based on ASHRAE Standard 62.1, carbon dioxide should not exceed 700ppm above outdoor air levels inside any buildings. Usually, carbon dioxide level at outdoor environment is within the range of 300ppm to 400 ppm. Thus, inside a building, the carbon dioxide level should not exceed the range of 1000ppm to 1100ppm.Due to the occupancy condition, the outcomes of the measurements in each zones during morning session are not complying with the standards. This is because, both measurements are lower than the minimum allowable carbon dioxide level recommended by ASHRAE Standard 62.1.

Table 4.2: Carbon dioxide level in Classroom 4 of FKM during afternoon

Location	**Carbon dioxide level (ppm)**
Zone 1	977
Zone 2	656

Meanwhile, measurement for afternoon session in zone 1 and zone 2 can be seen in Table 4.2. The average carbon dioxide level at zone 1 and zone 2 are 977ppm and 656ppm respectively. As compared by ASHRAE Standard 62.1, both the results obey the recommended minimum carbon dioxide level where lower than 1000ppm.

In Figure 4.7 and Figure 4.8, the measurements of average concentration of particulate matter 2.5 have been plotted for morning session and also afternoon session. Based on Figure 4.7, the average concentration of PM2.5 for zone 1 and zone 2 are $1.2\text{x}10^{-5}$ $\mu g/m^3$ and $7.1\text{x}10^{-5}$ $\mu g/m^3$ respectively. Since the maximum allowable concentration of PM 2.5 by ASHRAE Standard 62.1 is 15 $\mu g/m^3$, both conditions are far lower than the recommended value.

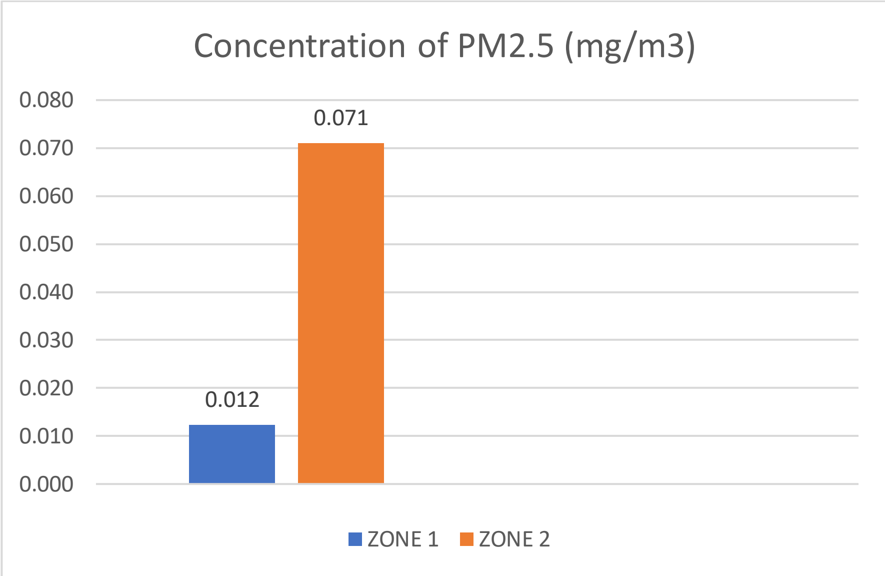


Figure 4.7: PM2.5 concentration in Classroom 4 of FKM during morning

Based on Figure 4.8, the average concentration of PM2.5 for zone 1 and zone 2 are 1.04×10^{-4} µg/m^3 and 1.42×10^{-4} µg/m^3 respectively. Both value in zone 1 and zone 2 are complying with ASHRAE Standard 62.1 as they lower than the maximum recommended value.

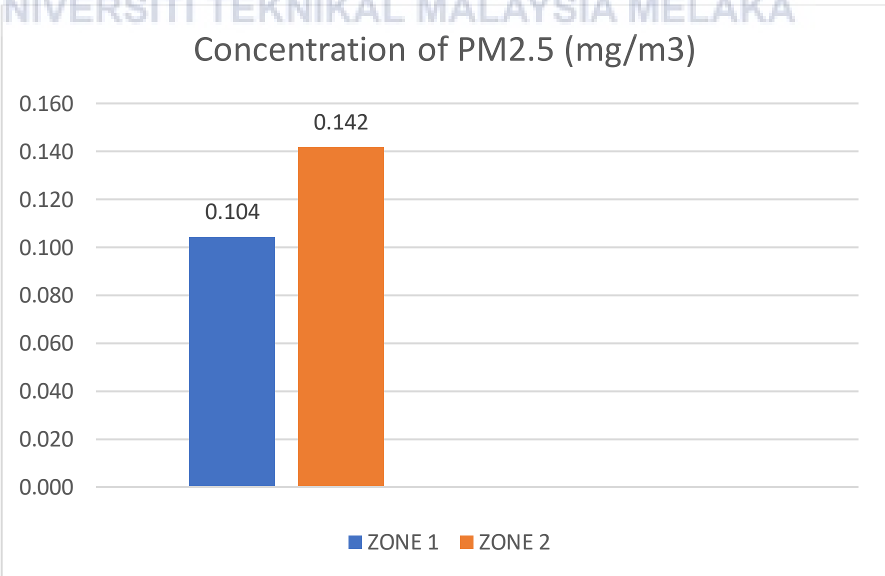


Figure 4.8: PM2.5 concentration in Classroom 4 of FKM during afternoon

Figure 4.9 and 4.10 shows the measurements of average concentration of particulate matter 10 for zone 1 and zone 2 during morning and afternoon. The average concentration for PM10 for both zones in the morning session based on Figure 4.9 are 1.8×10^{-5}µg/m^3 and 8.3×10^{-5}µg/m^3 respectively. According to ASHRAE Standard 62.1, it is within the allowable value of concentration of PM 10 which is 50 µg/m^3.

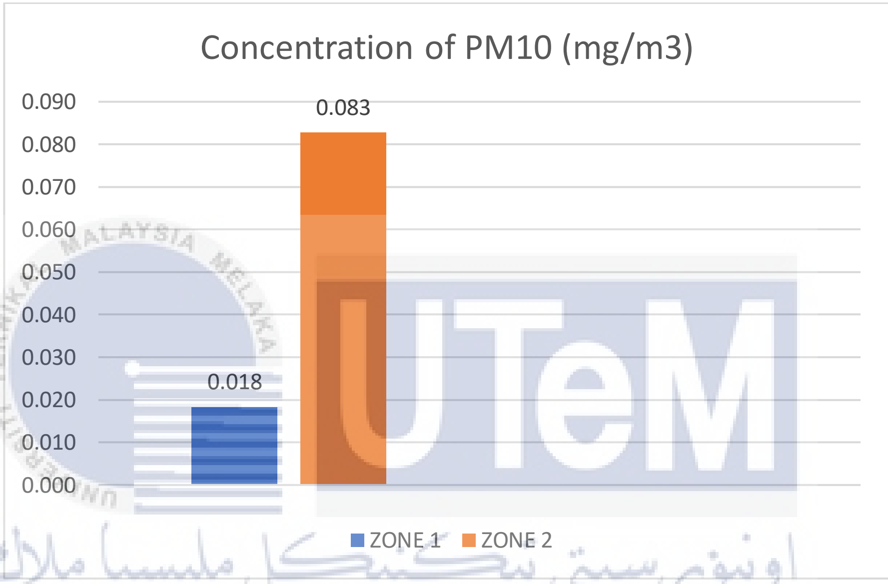


Figure 4.9: PM10 concentration in Classroom 4 of FKM during morning

As the result obtain for the concentration of PM 10 as 1.16×10^{-4} µg/m^3 and 1.46×10^{-4} µg/m^3 respectively for zone 1 and zone 2 respectively, it can be clearly seen that it complies with the ASHRAE Standard 62.1. This is because both have lower value than the recommended maximum value which is 50 µg/m^3.

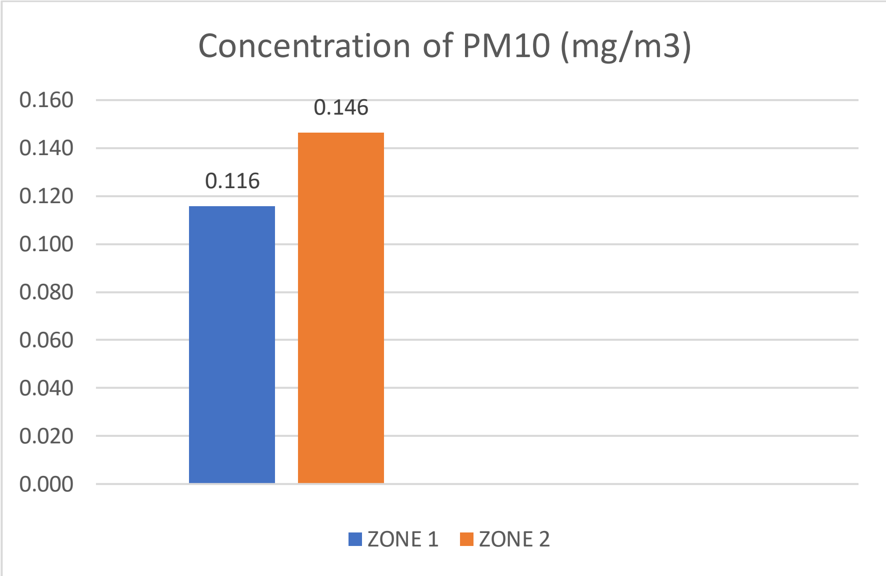


Figure 4.10: PM10 concentration in Classroom 4 of FKM during afternoon

4.1.2 Classroom 8 of FPTT building with occupants

Next, the measurements continued to be taken in 3 classes from FPTT building. These samples were given priority because it is a new building that required to be conduct evaluation on indoor environmental quality. As the same procedure in Classroom 4 of FKM, the parameters such as air temperature, relative humidity (RH) and air velocity (Va) were measured by using the instrument Thermal Microclimate HD32.1. Meanwhile, carbon dioxide level and concentration of PM2.5 and PM10 were measure using IAQ-Calc Indoor Air Quality Meter 7545 and Dust Trak II Aerosol Meter respectively.

Figure 4.11 and Figure 4.12 illustrate the indoor air temperature results for 2 different zones in the classroom 8 of FPTT building. Based on the Figure 4.11 during morning session, the maximum, minimum and average air temperature measured are 24.5º, 24.1º and 24.25º respectively at zone 1. This shows that, in this particular zone, it complies the MS 1525 Standard by achieving the minimum air temperature recommended. While for the zone 2, the maximum, minimum and average air temperature obtained are 24.1º, 23º and 23.58º respectively. Thus, at this point is does not achieve the minimum required air temperature. Condition zone 1 achieved the standard because it is located at back of the classroom meanwhile zone 2 is middle of classroom where more students occupies.

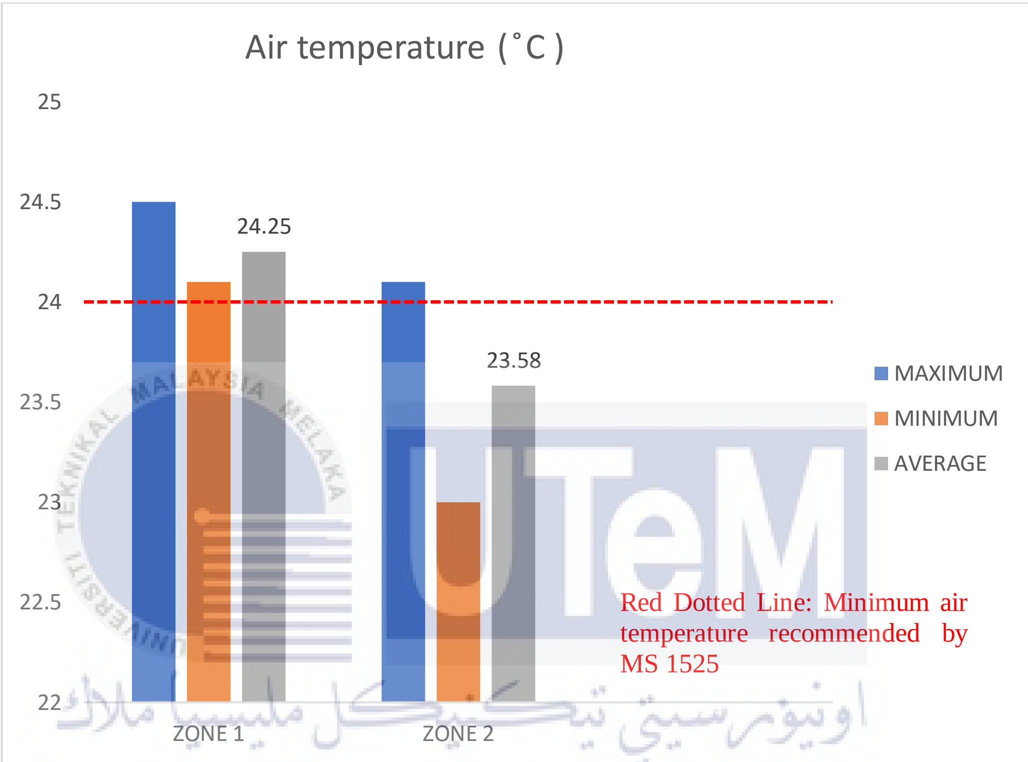


Figure 4.11: Indoor Air Temperature in Classroom 8 of FPTT during morning

According to Figure 4.12, the maximum, minimum and average temperature for zone 1 during afternoon session are 21.6º, 20.8º and 21.09º respectively. The result for zone 2 are 20.5º for maximum, 19.7º for minimum and 20.13º as the indoor average air temperature.

As compared to MS 1525 Standard, it is clear that both zones' values are not complying with the standard since both has not achieve the minimum recommended air temperature.

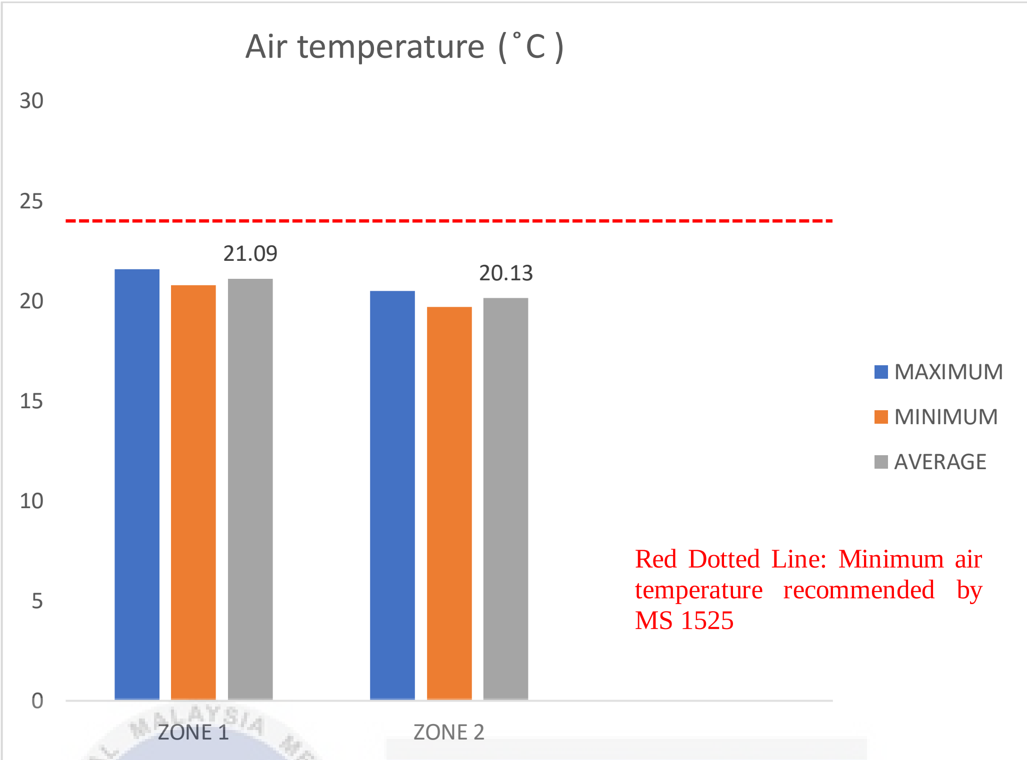


Figure 4.12: Indoor Air Temperature in Classroom 8 of FPTT during afternoon

Furthermore, Figure: 4.13 and 4.14 shows the outcomes of measurement for relative humidity in Classroom 8 at both zone in 2 different sessions. Based on the Figure 4.13, the average relative humidity for zone 1 and zone 2 are 62.72% and 63.52% respectively. Simultaneously as compared to Standard MS 1525, both conditions successfully achieved the minimum required relative humidity level during this morning session.

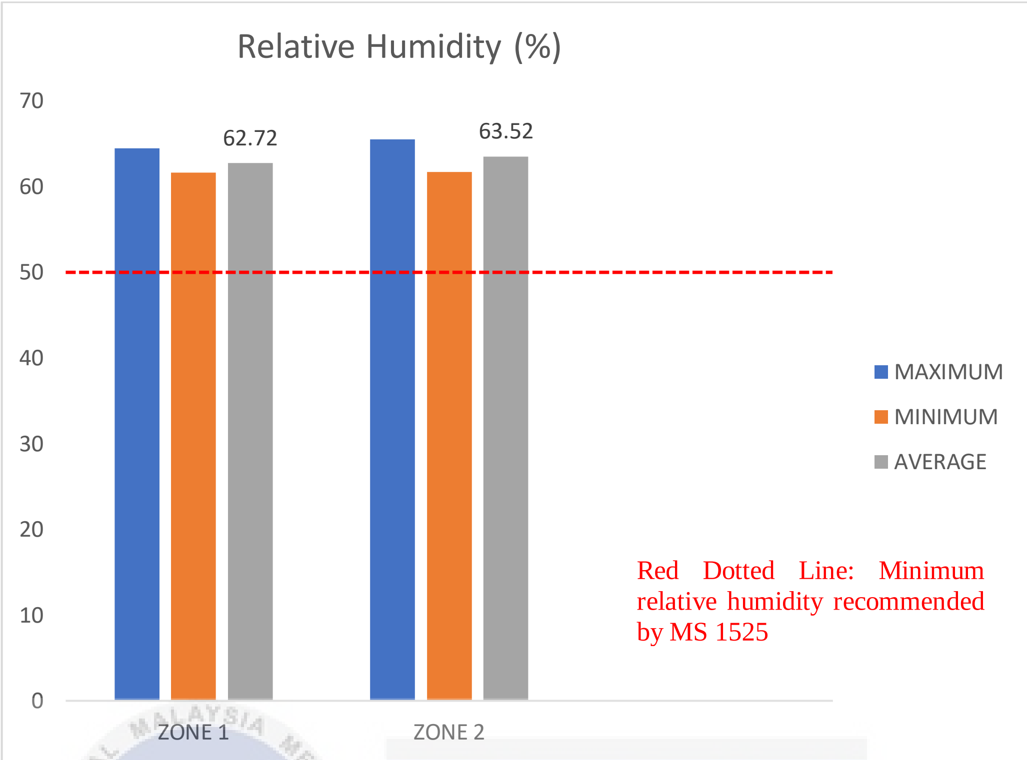


Figure 4.13: Relative humidity in Classroom 8 of FPTT during morning

Moreover, the average relative humidity for zone 1 and zone 2 during afternoon are 71.83% and 74.75% respectively. Thus, the Figure 4.14 clearly shows that both zone 1 and 2 are complying with MS 1525 Standard. This is because both average values are more than the minimum relative humidity recommended by Malaysian Standard.

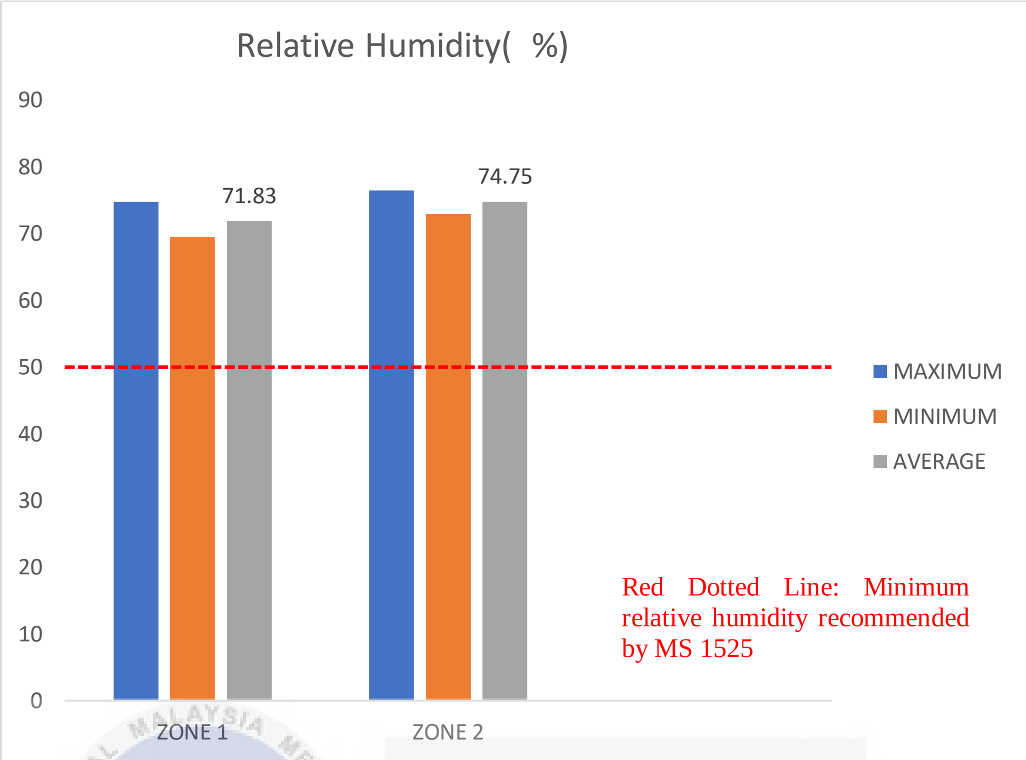


Figure 4.14: Relative humidity in Classroom 8 of FPTT during afternoon

Figure 4.15 and 4.16 portrays the graph for air velocity in the classroom 8 of FPTT during evening and afternoon session respectively. The recommended air velocity values suggested by MS 1525 Standard are within the range of 0.15m/s and 0.5m/s. Based on Figure 4.15, the average air velocity at zone 1 and zone 2 are 0.52m/s and 0.58m/s respectively. This shows that, during the morning session with occupancy condition, it does not comply to MS 1525 standard as it exceeded the required range of air velocity.

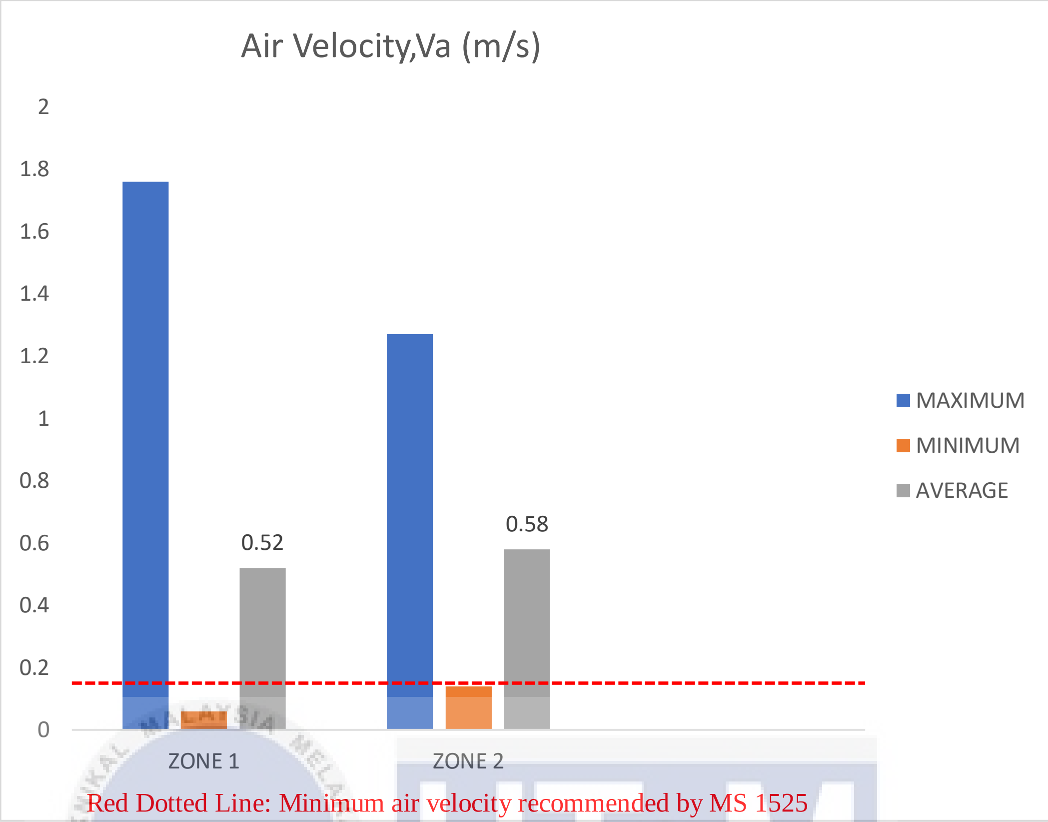


Figure 4.15: Air Velocity, Va in Classroom 8 of FPTT during morning

According to Figure 4.16, the average value of air velocity for both zones are 0.4m/s and 0.29m/s respectively. Thus, it can be concluded that both the average values for afternoon session are complying with Malaysian Standard as both are within the range of 0.15m/s and 50m/s.

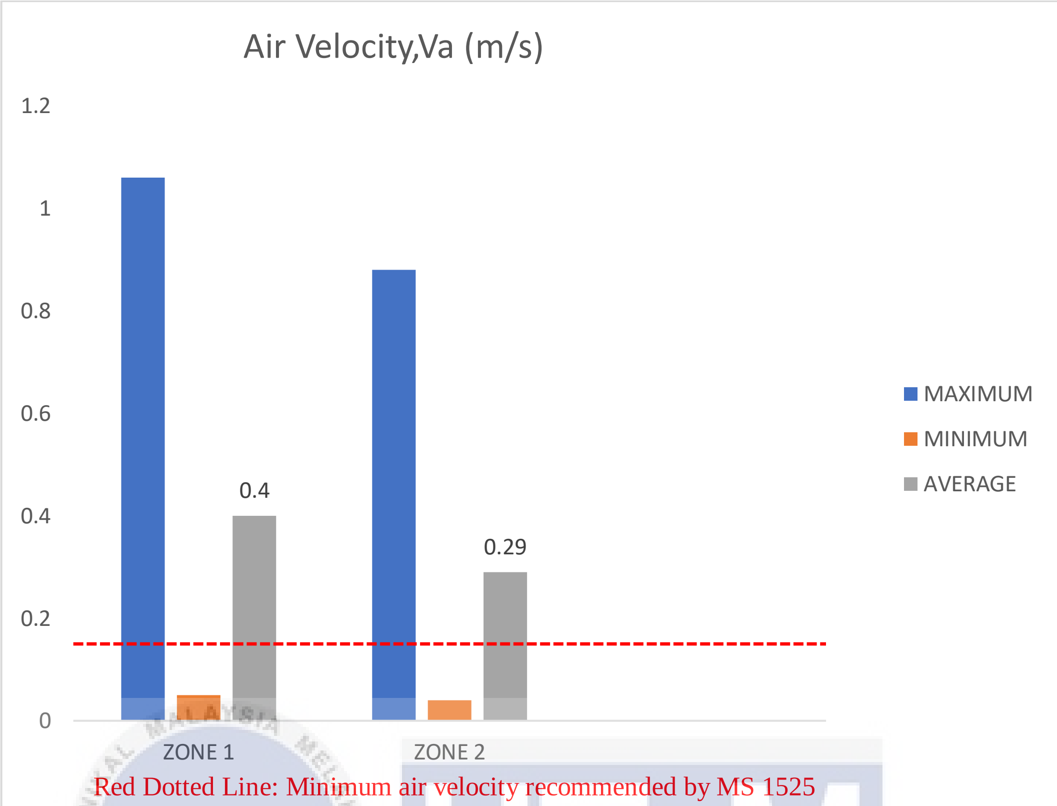


Figure 4.16: Air Velocity, Va in Classroom 8 of FPTT during afternoon

Table 4.3: Carbon Dioxide Level in Classroom 8 of FPTT during morning

Location	**Carbon dioxide level (ppm)**
Zone 1	2431
Zone 2	1914

Table 4.4: Carbon Dioxide Level in Classroom 8 of FPTT during afternoon

Location	**Carbon dioxide level (ppm)**
Zone 1	569
Zone 2	482

Table 4.3 and 4.4 shows the carbon dioxide level during afternoon and morning session in Classroom 8 of FPTT building. From Figure 4.19, it is known that the average carbon dioxide level for both zone 1 and 2 are 2431ppm and 1914ppm respectively. Carbon

dioxide level at outdoor environment is within the range of 300ppm to 400 ppm. Thus, inside a building, the carbon dioxide level should not exceed the range of 1000ppm to 1100ppm according to ASHRAE 62.1 Standard. By comparing to the standard, it is clear that both zones of occupancy condition not complying with standard as they are higher than the maximum carbon dioxide level that is been suggested.

Based on Table 4.4, the average carbon dioxide level for zone 1 and 2 during afternoon session are 569ppm and 482ppm respectively. Thus, these values are far lower than 1000ppm and achieve the criteria to achieve the standard of ASHRAE 62.1.

Figure 4.17 and 4.18 portrays the Concentration of PM2.5 for zone 1 and zone 2 during measurement of morning session. As refer to Figure 4.17, the average concentration of PM 2.5 value is 1.71×10^{-4} µg/m^3 for zone 1 and 2.65×10^{-4} µg/m^3 for zone 2. As compared to ASHRAE 62.1 Standard, the recommended maximum concentration of PM2.5 is 15 µg/m^3 where both these values obtained are far lower than the recommended value. Thus, it achieves the ASHRAE Standard.

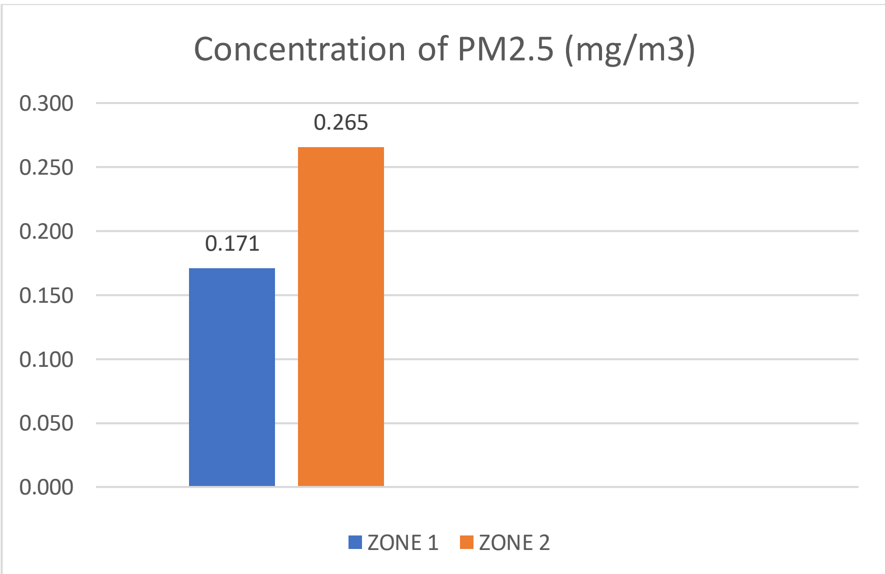


Figure 4.17: Concentration of PM 2.5 of Classroom 8 of FPTT during morning

In Figure 4.18, the average concentration of PM 2.5 during afternoon session of measurement is 2.12x10^{-4} µg/m^3 for zone 1 and 2.47x10^{-4} µg/m^3 respectively. Based on the Figure 4.18, it is known that the data complies with ASHRAE Standard as both values are smaller than the required concentration of PM 2.5.

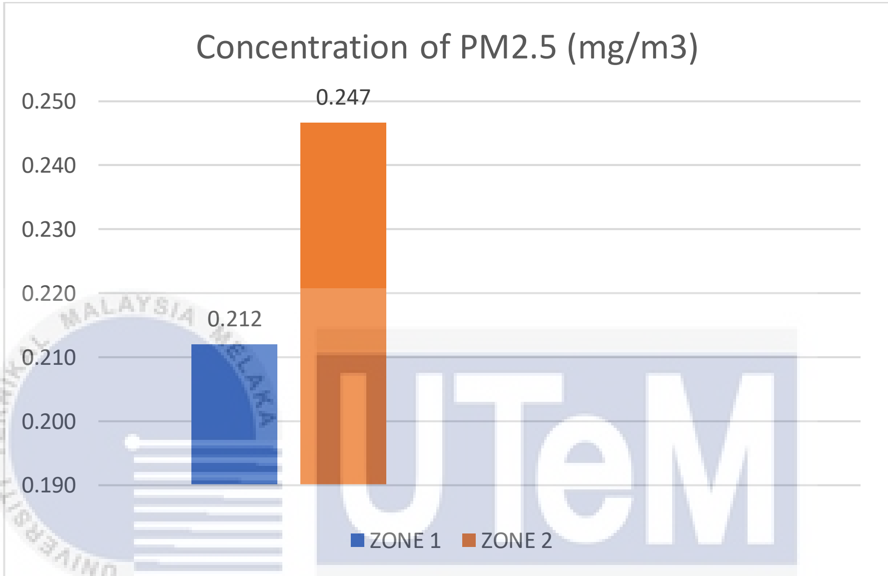


Figure 4.18: Concentration of PM 2.5 of Classroom 8 of FPTT during afternoon

Simultaneously, Figure 4.19 and 4.20 are plotted in order to show the concentration of PM 10 for each zone of Classroom 8 of FPTT during the session of morning and also afternoon.

Figure 4.19 have clearly showed the result obtained for average concentration of PM 10 values which are 2x10^{-4} µg/m^3 for zone 1 and 2.82x10^{-4} µg/m^3. According to the ASHRAE Standard 62.1, the recommended concentration of PM 10 is 50 µg/m^3. As compared to that specific value, it is clear that both average values are lower than the maximum value and obey to the ASHARE Standard.

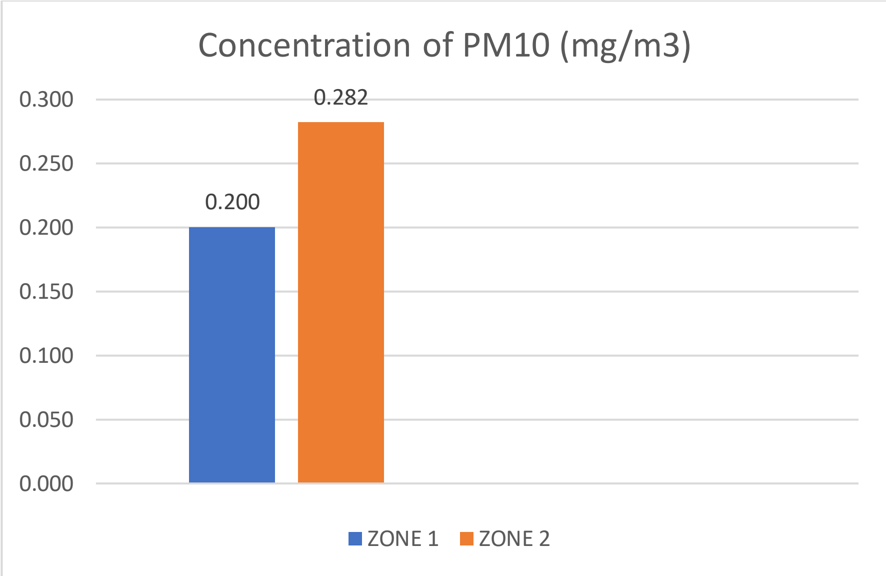


Figure 4.19: Concentration of PM 10 of Classroom 8 of FPTT during morning

According to Figure 4.20, the average concentration of PM 10 during afternoon with occupancy condition are $2.2\text{x}10^{-4}$ µg/m^3 at zone 1 and $2.64\text{x}10^{-4}$ µg/m^3 at zone 2 of FPTT classroom 8.This conclude that, the result obtained are lower than the maximum recommended average value for concentration of PM10. Hence, this condition obeys to the ASHRAE Standard 62.1.

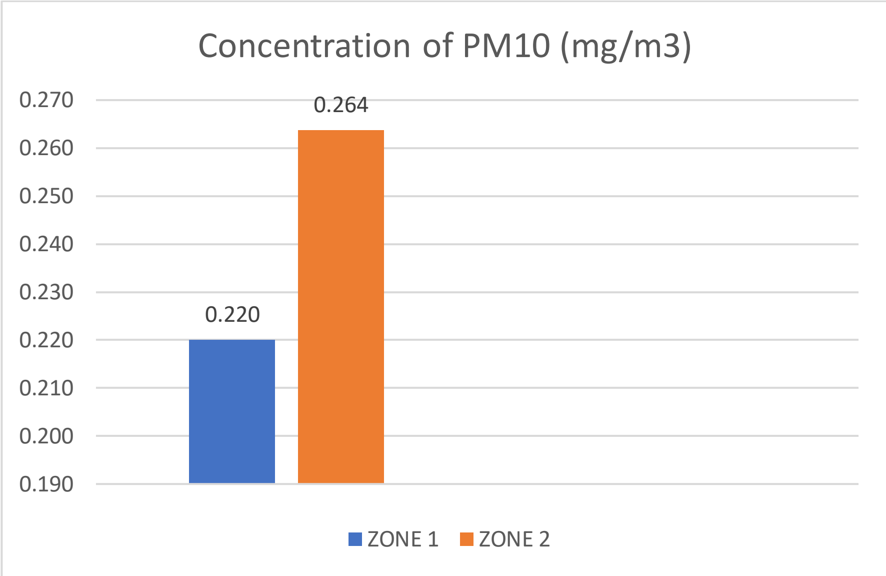


Figure 4.20: Concentration of PM 10 of Classroom 8 of FPTT during afternoon

4.1.3 Classroom 5 of FPTT building

Figure 4.21 and 4.22 represents the measurements for air temperature in the Classroom 5 of FPTT in two different sessions which are morning and afternoon respectively. In order to compare with MS 1525 standard. The data of maximum, minimum and average of air temperature have plotted in the graph in order to compare with MS 1525 standard. The maximum, minimum and average of air temperature are 23.7 ºC, 20.4ºC and 21.99ºC respectively for zone 1. Meanwhile for zone 2, maximum, minimum and average of air temperature are 23.4ºC, 21.5ºC and 22.38ºC respectively.

Based on comparison with standard MS 1525, it shows that average air temperature for both the zones are not complying with the standard MS 1525. This is because, the minimum recommended air temperature by MS 1525 is from the range of 24ºC to 26ºC and the data that obtained are not within the recommended minimum air temperature.

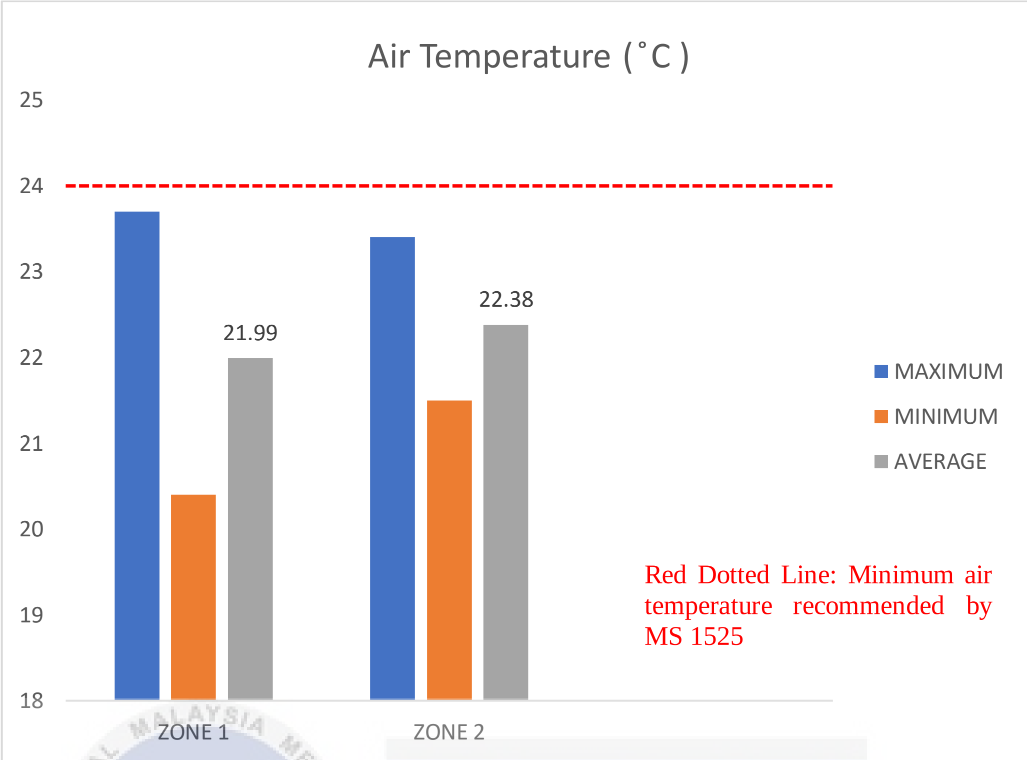


Figure 4.21: Indoor Air Temperature in Classroom 5 of FPTT during morning

According to Figure 4.22, the maximum, minimum and average of air temperature at zone 1 are 26.2ºC, 20.2ºC and 22.3ºC respectively with occupants' condition. Furthermore, the maximum, minimum and average of air temperature at zone 2 are 26.7ºC, 25.7ºC and 26.24ºC respectively.

Compared with MS 1525 standard, it is clear that the data obtained for zone 1 is below the recommended air temperature while air temperature at zone 2 is above the recommended air temperature range suggested by MS 1525. Thus, the obtained data are not complying with the standard.

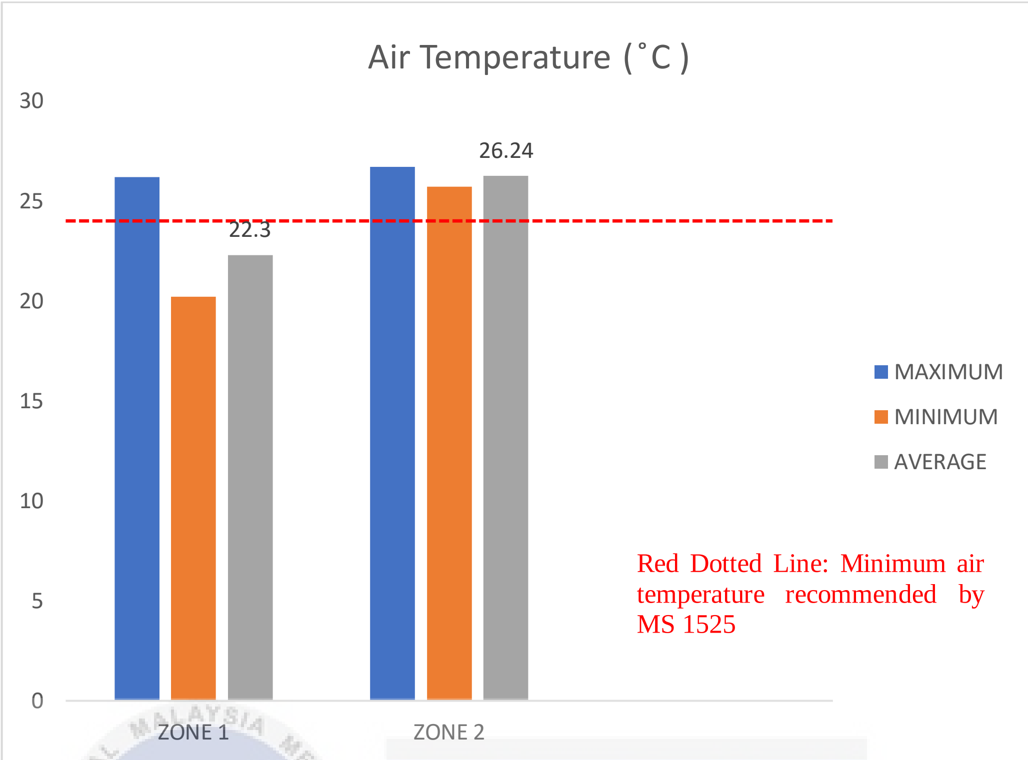


Figure 4.22: Indoor Air Temperature in Classroom 5 of FPTT during afternoon

Figure 4.23 and 4.24 shows the measurements for relative humidity in terms of percentage in each zone of classroom 5 of FPTT during occupancy condition. Based on Figure 4.27, the maximum, minimum and average of relative humidity among the zone 1 for occupancy are 75.5%, 61.3% and 68.84% respectively. While for zone 2, the maximum, minimum and average of relative humidity are 64%, 55.1% and 60.29% respectively.

According to MS 1525:2019 standard, the recommended minimum relative humidity is between the ranges of 50% to 70%. Thus, the average values of both zone 1 and zone 2 during the morning session is complying with MS 1525 standard where it is more than the minimum value recommended and less than the maximum humidity level recommended.

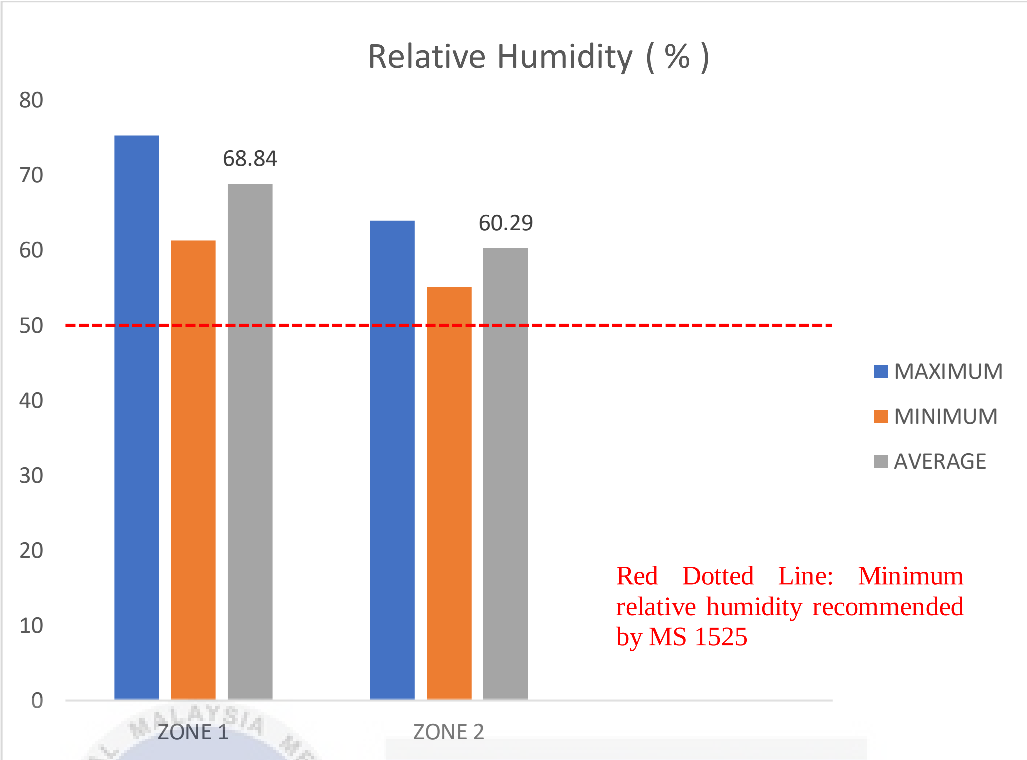


Figure 4.23: Relative humidity level in Classroom 5 of FPTT during morning

Relative humidity during the afternoon session for maximum, minimum and average are 73.7%, 57.1% and 63.44% respectively at zone 1. In addition, the maximum, minimum and average value of relative humidity in zone 2 are 54%, 51.9% and 52.56% respectively.

Hence, the overall average value for both zones are complying with recommended range by MS 1525 standard which is more than the minimum recommended value which is 50% to 70%.

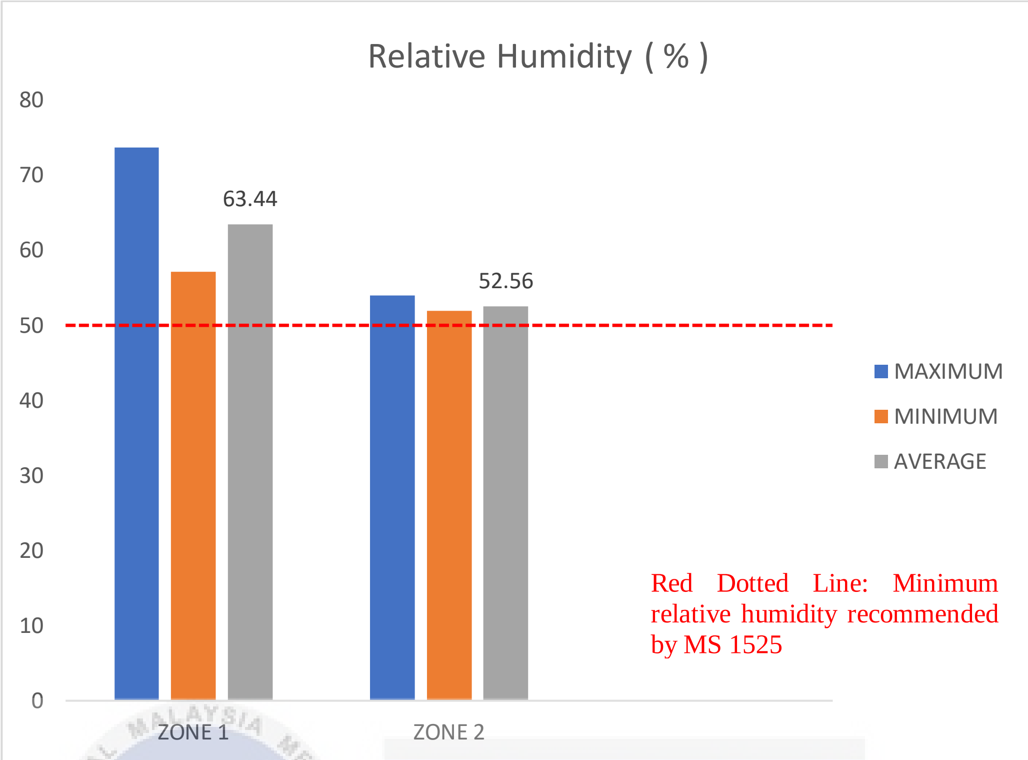


Figure 4.24: Relative Humidity in Classroom 5 of FPTT during afternoon

Based on MS 1525:2019, the suggested indoor air velocity ranges are from 0.15 m/s to 0.50 m/s. The indoor air velocity for both morning and afternoon session with occupants are tabulated in the Figure 4.25 and 4.26 respectively.

According to the figure 4.25, the maximum air velocity for zone 1 and 2 during morning are 1.17 m/s and 0.6 m/s. Meanwhile, the minimum air velocity for both zones during morning are 0.02 m/s and 0.01 m/s. Then, the average air velocity for both zone 1 and 2 are 0.3 m/s and 0.16 m/s respectively. As per compared to standard MS 1525, the average air velocity value for zone 1 and 2 are complying with the Malaysian Standard. This is because both the values are greater than the minimum recommended air velocity value by Malaysian Standard.

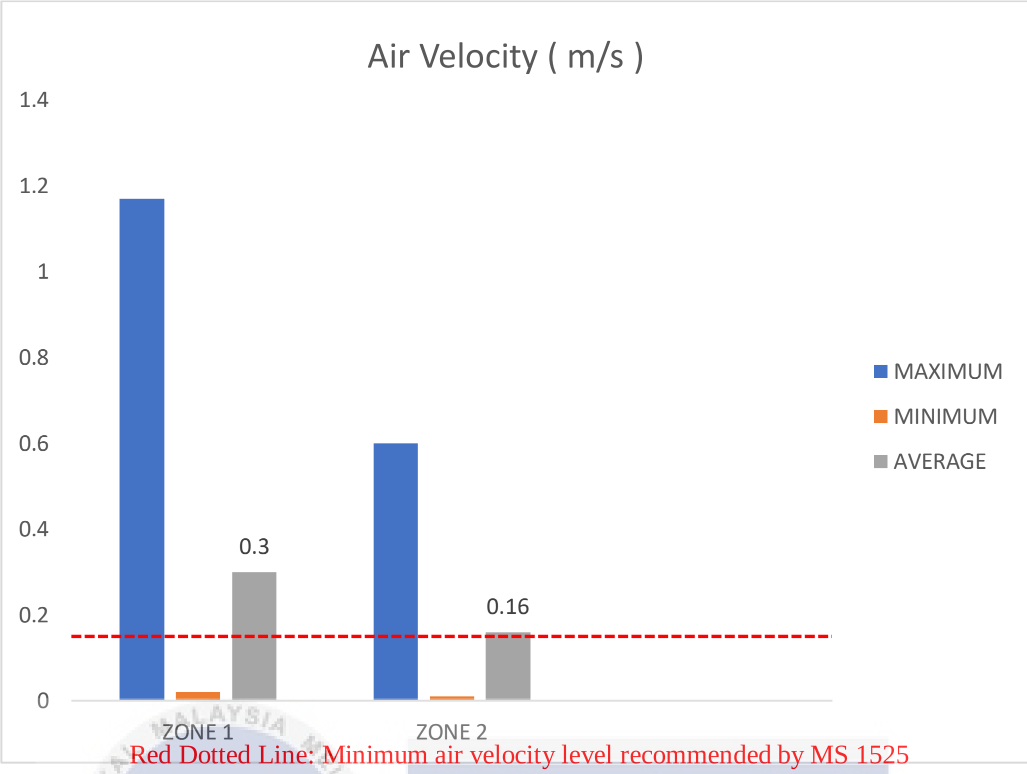


Figure 4.25: Air Velocity for Classroom 5 of FPTT during morning

For the afternoon session, air velocity value with occupancy condition for maximum, minimum and average are 1.65 m/s, 0 m/s and 0.18 m/s respectively at zone 1. However, for zone 2, air velocity for maximum, minimum and average value are 0.03 m/s, 0 m/s and 0 m/s respectively.

As referred to Figure 4.26, the average air velocity value at zone 1 is within the range of air velocity proposed by Malaysian Standard. However, the average air velocity at zone 2 which lower than the minimum air velocity recommended by MS 1525 does not achieve the minimum standard. Hence, it is concluded that the classroom during occupancy condition for afternoon doesn't comply with the Malaysian Standard 1525.

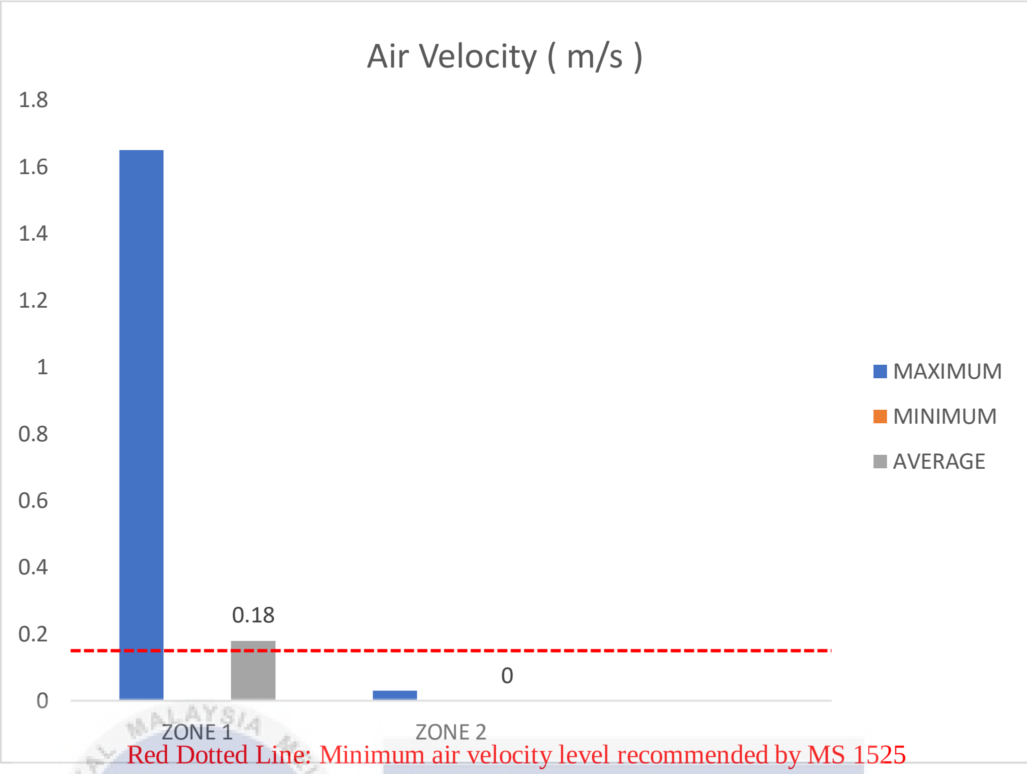


Figure 4.26: Air Velocity of Classroom 5 of FPTT during afternoon.

Table 4.5: Carbon dioxide level of Classroom 5 of FPTT during morning.

Location	**Carbon dioxide level (ppm)**
Zone 1	1412
Zone 2	2710

Table 4.6: Carbon dioxide level of Classroom 5 of FPTT during afternoon.

Location	**Carbon dioxide level (ppm)**
Zone 1	1778
Zone 2	2804

According to Table 4.5 and 4.6 stated from IAQ equipment is to identify the carbon dioxide level in terms of average, as a parameter of classroom 5 in morning session. At zone 1 shows 1412 ppm and for zone 2 shows that 2710 ppm.

Next, in Table 4.6 shows the same parameter in afternoon session where zone 1 is 1778ppm and in zone 2 as 2804ppm during the occupancy condition. According to ASHRAE Standard 62.1, the classroom does not comply with recommended standard as it exceeded the in terms of ppm value.

Figure 4.27 and 4.28 shows the measurements for the average concentration of particulate matter 2.5 respectively for morning and afternoon session. Based on Figure 4.27, the average concentration of PM2.5 for zone 1 and zone 2 are 1.39×10^{-4} µg/m^3 and 2.05×10^{-4} µg/m^3 and based on figure 4.10 the average concentration of PM2.5 for zone 1 and 2 are 2.14×10^{-4} µg/m^3 and 2.29×10^{-4} µg/m^3 respectively. According to these data, the concentration of PM2.5 are complying with ASHRAE Standard 62.1 because both zone's PM concentration are far lower than the maximum allowable standard value which is 15 µg/m^3.

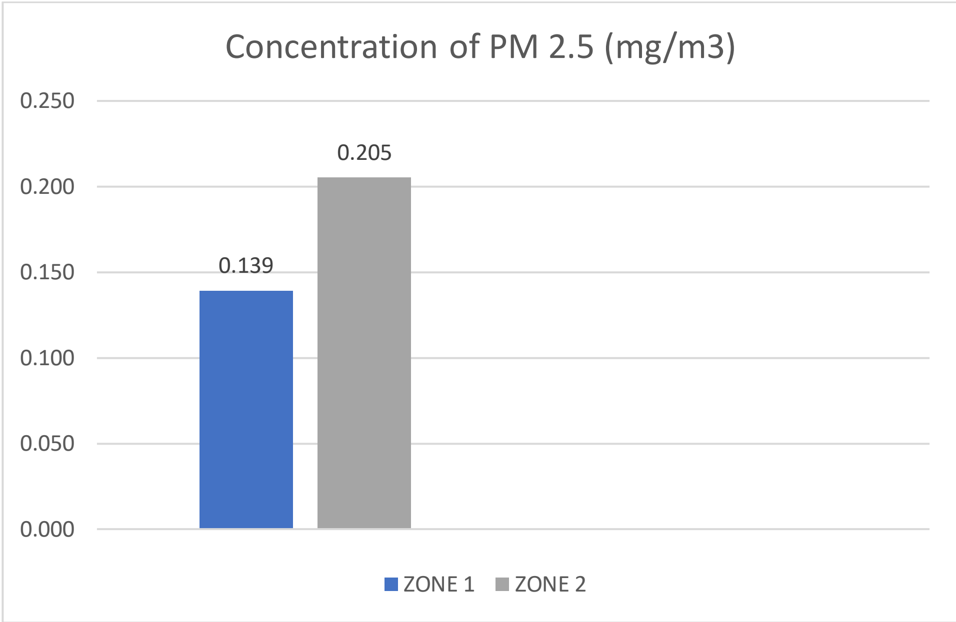


Figure 4.27: Concentration of PM 2.5 of the classroom 5 of FPTT during morning.

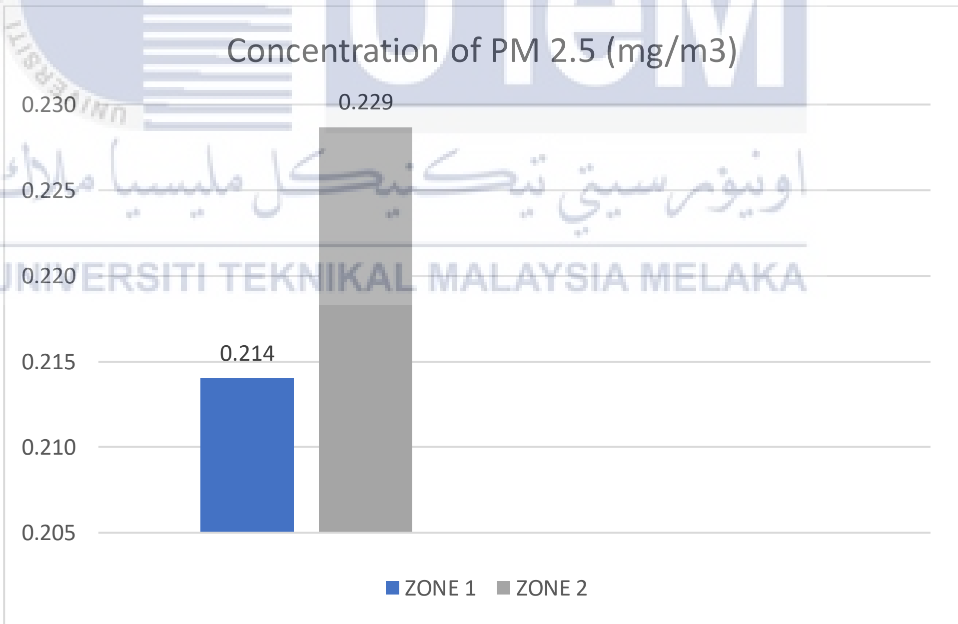


Figure 4.28: Concentration of PM 2.5 of the classroom 5 of FPTT during afternoon.

Figure 4.29 and 4.30 shows the measurements for the average concentration of particulate matter 10 respectively for morning and afternoon session. According to Figure 4.29, the average concentration of PM10 for zone 1 and 2 are 1.56×10^{-4} µg/m^3 and 2.1×10^{-4} µg/m^3.

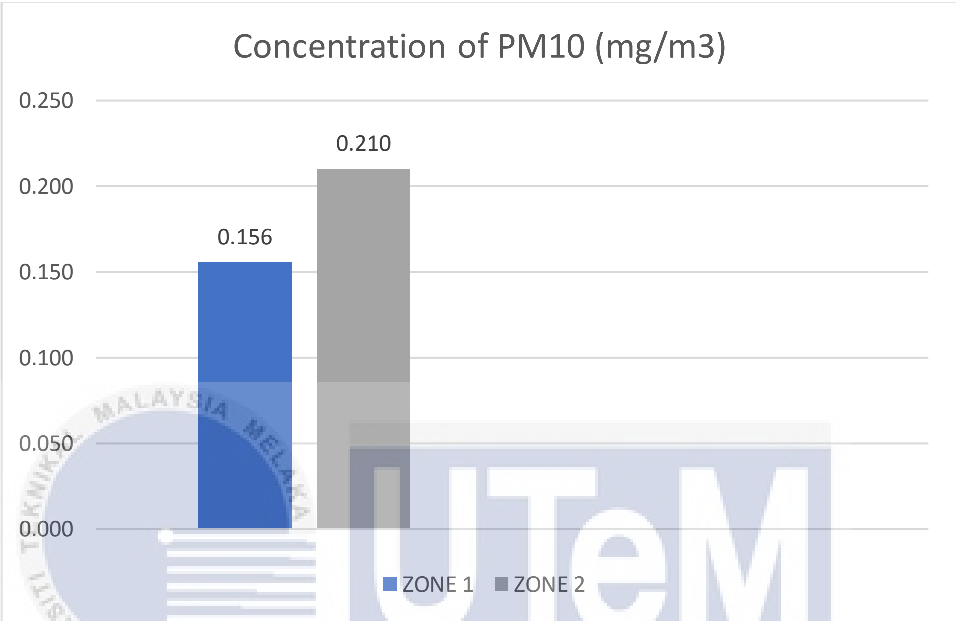


Figure 4.29: Concentration of PM 10 of the classroom 5 of FPTT during morning

Simultaneously, on Figure 4.36 the average concentration of PM10 for zone 1 and 2 are 2.23×10^{-4} µg/m^3 and 2.4×10^{-4} µg/m^3 respectively. According to these data, the concentration of PM10 are complying with ASHRAE Standard 62.1 as the allowable standard value is 50 µg/m^3 for both afternoon and morning session.

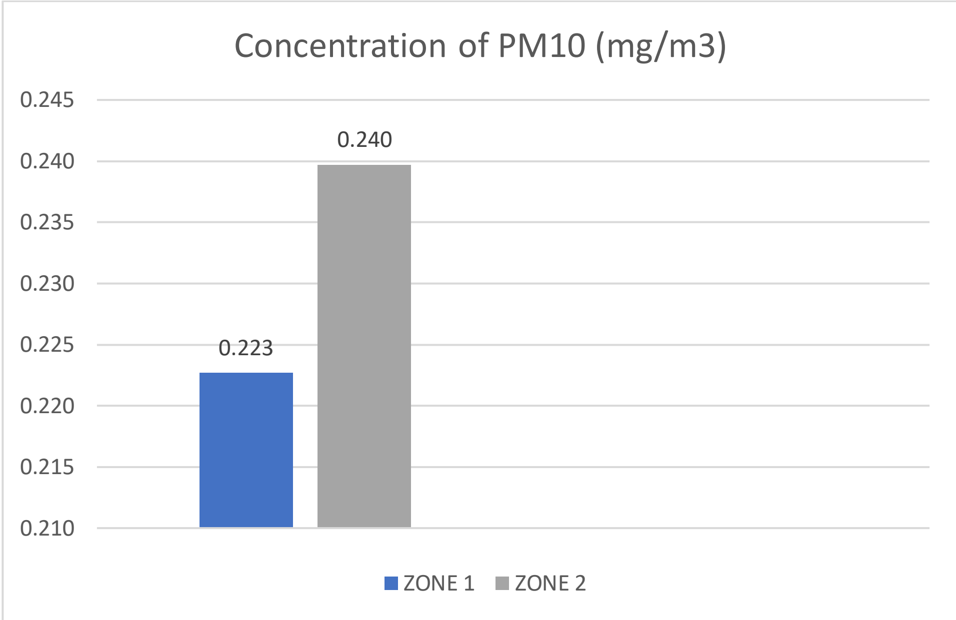


Figure 4.30: Concentration of PM 10 of the classroom 5 of FPTT during afternoon.

4.1.4 Classroom 11 of FPTT building with occupants

Figure 4.31 and 4.32 shows the measurements that were recorded for air temperature in the classroom 11 of FPTT. The maximum, minimum and average of air temperature are 23.7 ºC, 23.4ºC and 23.59ºC respectively for zone 1. Meanwhile for zone 2, maximum, minimum and average of air temperature are 23.7ºC, 23.5ºC and 23.63ºC respectively. As compared to the Malaysian Standard, it is clear that both zones are not complying with the range of air temperature but acceptable.

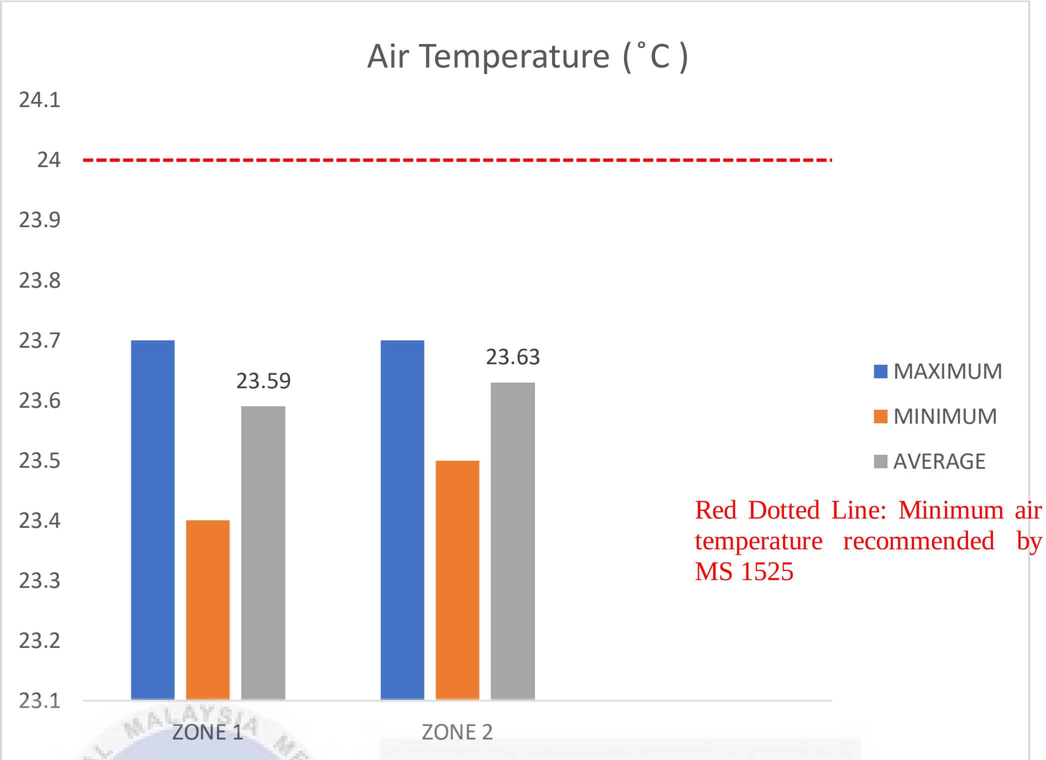


Figure 4.31: Indoor Air temperature of Classroom 11 of FPTT during morning.

However, the maximum, minimum and average of air temperature for afternoon session are 23.2 ºC, 22.8ºC and 22.96ºC respectively for zone 1. Meanwhile for zone 2, maximum, minimum and average of air temperature are 23.4ºC, 23.2ºC and 23.32ºC respectively. As we compared Figure 4.32 with standard MS 1525, it shows that average air temperature for both the zones are not complying with the standard MS 1525. This is because, the minimum recommended air temperature by MS 1525 is from the range of 24ºC to 26ºC and the obtained data are less than the recommended air temperature.

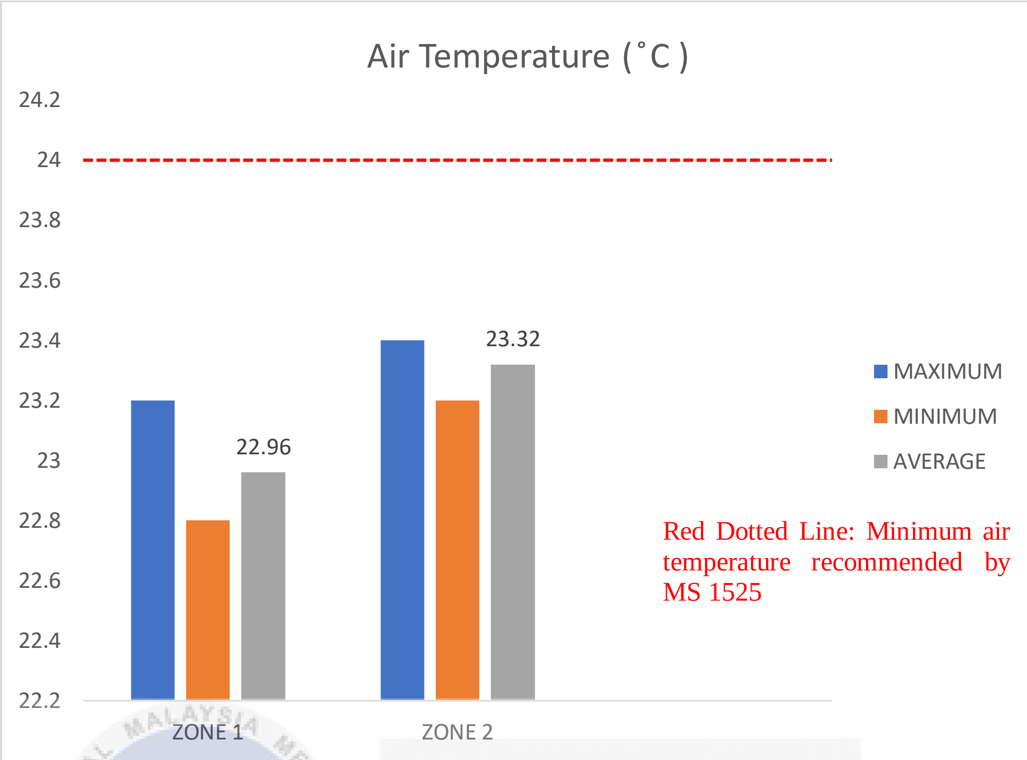


Figure 4.32: Air temperature of Classroom 11 of FPTT during afternoon.

Based on Figure 4.33, the maximum, minimum and average of relative humidity among the zone 1 and zone 2 for occupancy are similar in both afternoon and morning session with 120.1%. According to the standard MS 1525, the recommended minimum relative humidity is between the ranges of 50% to 70%. Thus, the average values of both zone 1 and zone 2 during the morning session is not complying with MS 1525 standard where it is more than the minimum value recommended.

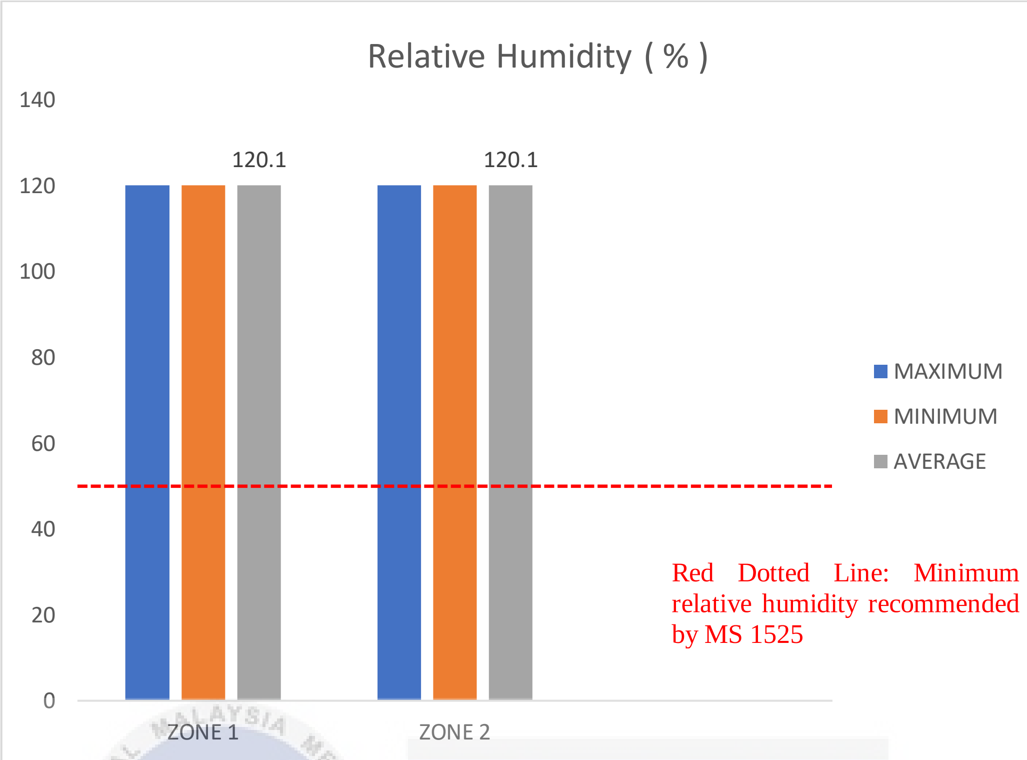


Figure 4.33: Relative humidity of Classroom 11 of FPTT during morning.

Figure 4.34 shows for maximum, minimum and average are 74%, 72.9% and 73.38% respectively at zone 1. Moreover, the maximum, minimum and average value of relative humidity in zone 2 are 72.9%, 72% and 72.47% respectively. In conjunction with it, the overall average value for both zones are not complying with recommended range by MS 1525 standard.

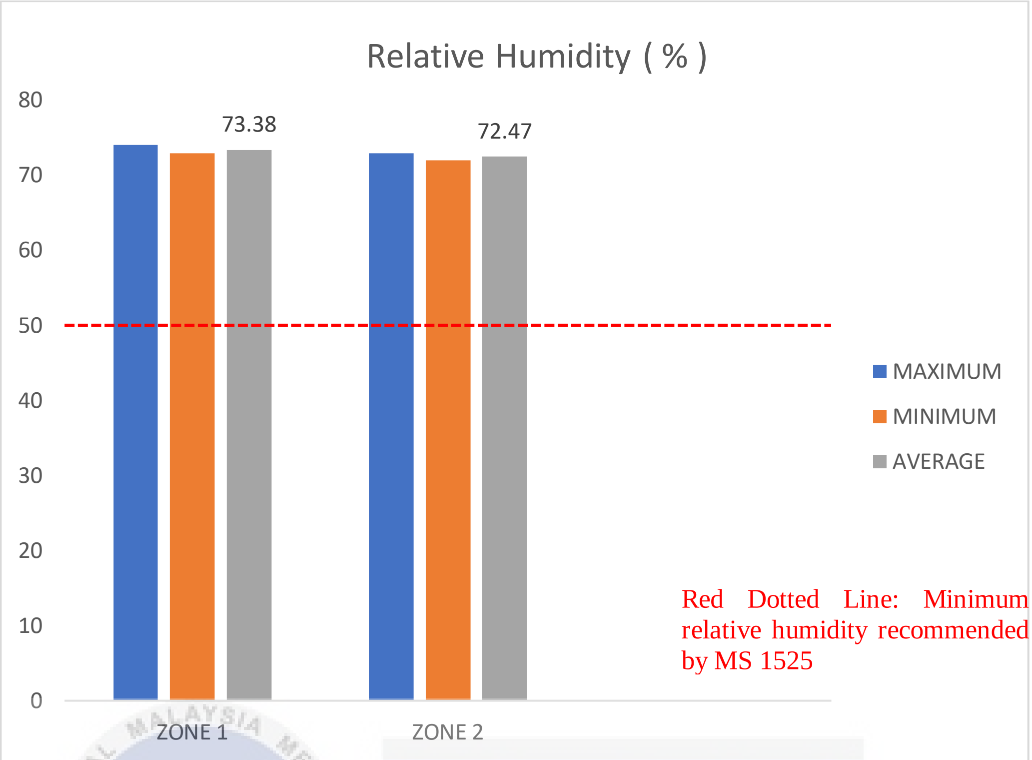
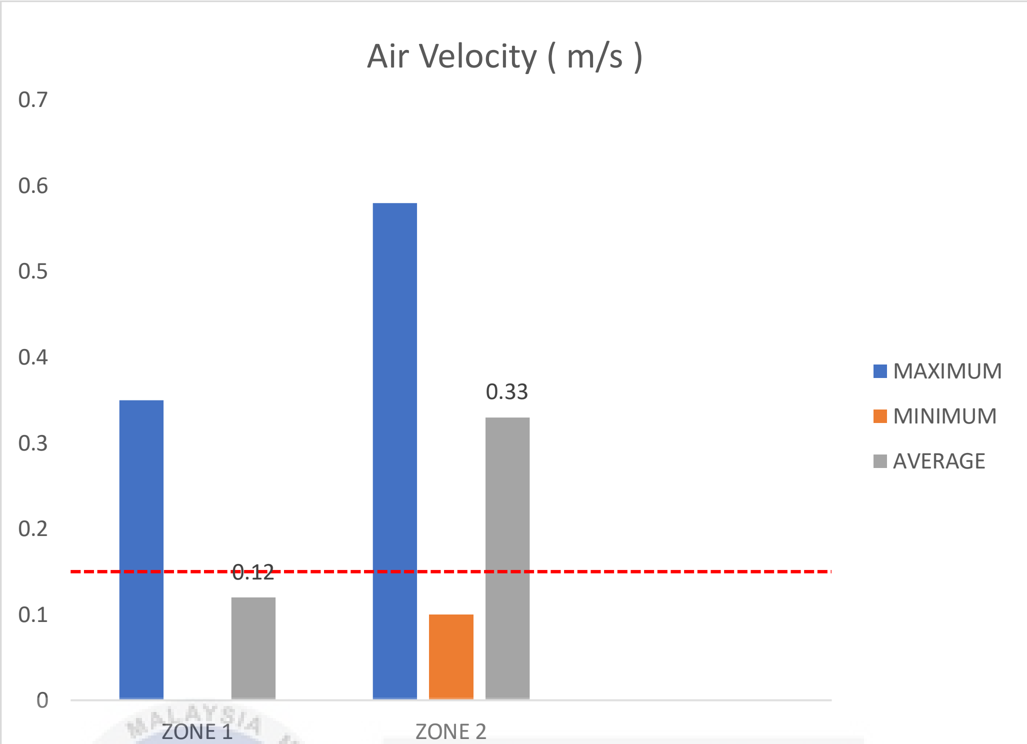


Figure 4.34: Relative humidity of Classroom 11 of FPTT during afternoon.

Figure 4.35 and 4.36 represents the air velocity level in both session during occupancy condition in Classroom 11 of FPTT. As referred to Figure 4.35 the maximum, minimum and average of air velocity for zone 1 during morning are 0.35 m/s, 0 m/s and 0.12 m/s and in zone 2 during morning are maximum, minimum and average are 0.58 m/s, 0.1 m/s and 0.33 m/s respectively. As compared to Malaysian Standard one of the zones which is zone 1 is not complying as it is below the minimum allowable air velocity level which is 0.15m/s.



Red Dotted Line: Minimum air velocity level recommended by MS 1525

Figure 4.35: Air Velocity of Classroom 11 of FPTT during morning.

Figure 4.36 also shows the parameter of air velocity in zone 1 afternoon session 0.36 m/s, 0m/s and 0.11 m/s and in zone 2 as 0.53 m/s, 0.06 m/s and 0.3m/s. In addition, these outcomes are not complying with recommended MS1525 standard as only one of the zones are within the recommended range.

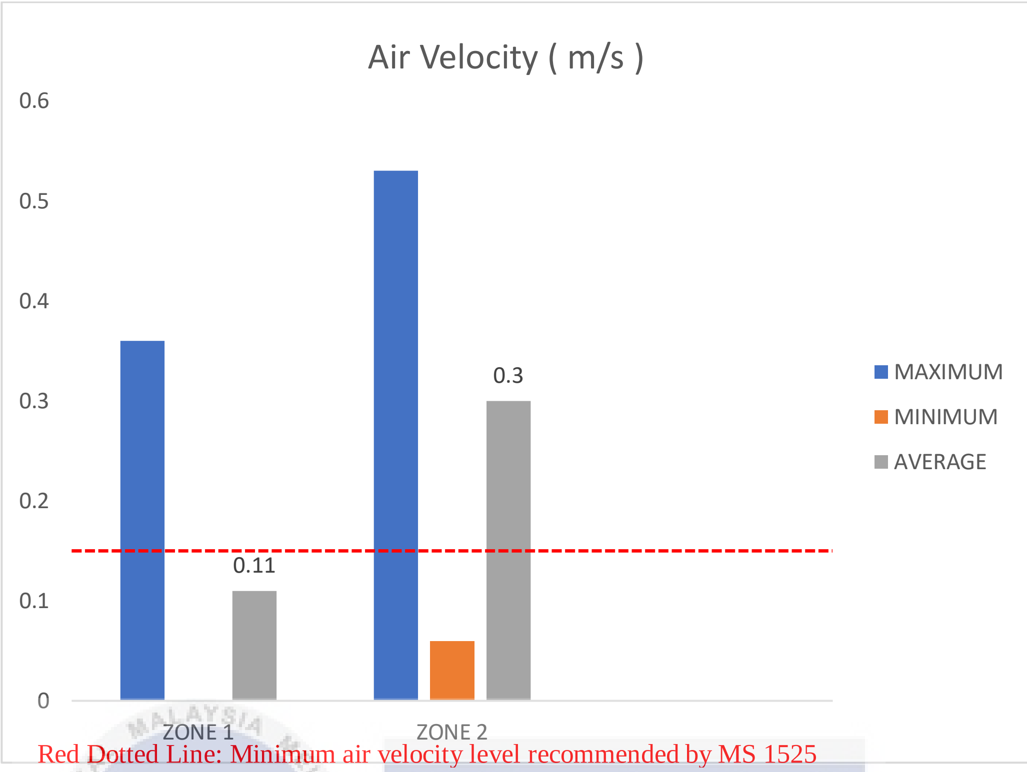


Figure 4.36: Air Velocity of Classroom 11 of FPTT during afternoon.

Table 4.7: Carbon dioxide level of Classroom 11 of FPTT during morning

Location	**Carbon dioxide level (ppm)**
Zone 1	631
Zone 2	754

Table 4.8: Carbon dioxide level of Classroom 11 of FPTT during afternoon

Location	**Carbon dioxide level (ppm)**
Zone 1	863
Zone 2	877

Next, Table 4.7 and 4.8 shows the average values for carbon dioxide level in classroom 11 of FPTT especially in morning and afternoon. Measurements at zone 1 shows 631ppm and for zone 2 shows that 754ppm.

Then, in Table 4.8 shows the same parameter in afternoon session, zone 1 as 863ppm and in zone 2 as 877ppm. It is clear that, both session's measurements are complying with the allowable standard of carbon dioxide level as they don't exceed 1000ppm.

Figure 4.37 and 4.38 shows the measurements of average concentration of particulate matter 2.5 shows the data of morning and afternoon session of classroom 11. Based on Figure 4.37, the average concentration of PM2.5 for zone 1 and zone 2 are 4.5x10^{-5} µg/m^{3} and 1.12x10^{-4} µg/m^{3} and based on figure 4.38 the average concentration of PM2.5 for zone 1 and 2 are 1.13x10^{-4} µg/m^{3} and 1.55x10^{-4} µg/m^{3} respectively. According to these data, the concentration of PM 2.5 are complying with ASHRAE Standard 62.1 because the standard value is 15 µg/m^{3}.

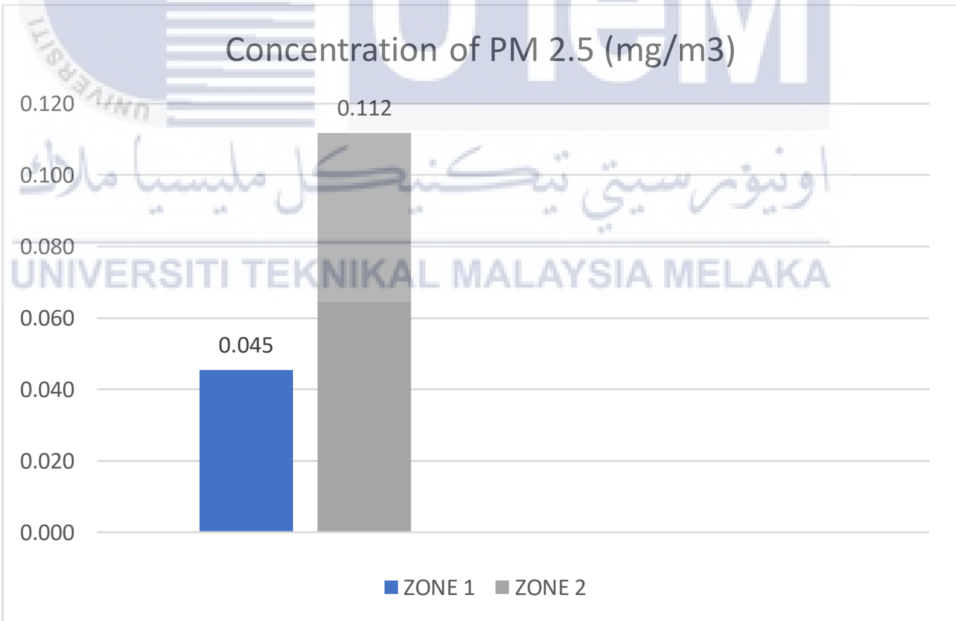


Figure 4.37: Concentration of PM 2.5 of the classroom 11 of FPTT during morning.

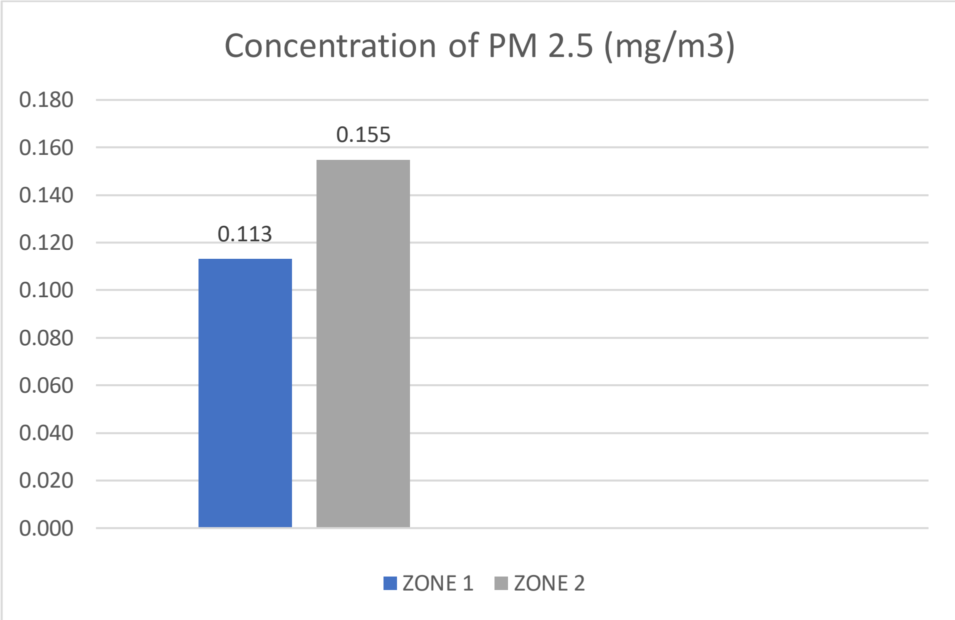


Figure 4.38: Concentration of PM 2.5 of the classroom 11 of FPTT during afternoon.

Figure 4.39 and 4.40 portrays the average concentration of PM10 for zone 1 and 2 during occupancy condition. The average value of concentration PM10 are $5.5x10^{-5}$ µg/m^3 and $1.23x10^{-4}$ µg/m^3.

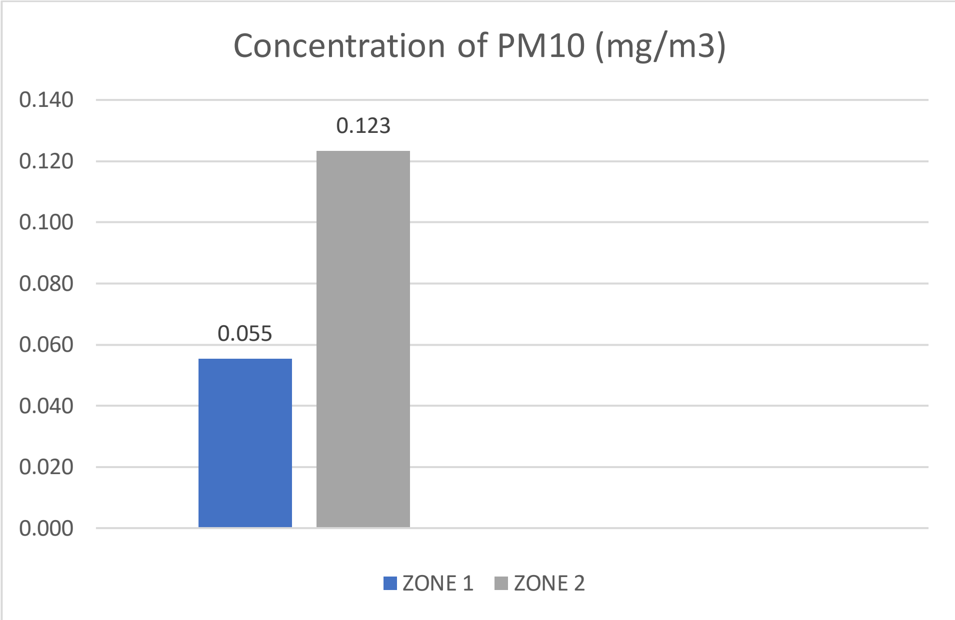


Figure 4.39: Concentration of PM 10 of the classroom 11 of FPTT during morning.

Similarly, based on Figure 4.39 and 4.40 the average concentration of PM10 for zone 1 and 2 are 1.25×10^{-4} µg/m^3 and 1.61×10^{-4} µg/m^3 respectively. According to these data, the concentration of PM10 for both sessions are complying with ASHRAE Standard 62.1 as the standard value 50 µg/m^3.

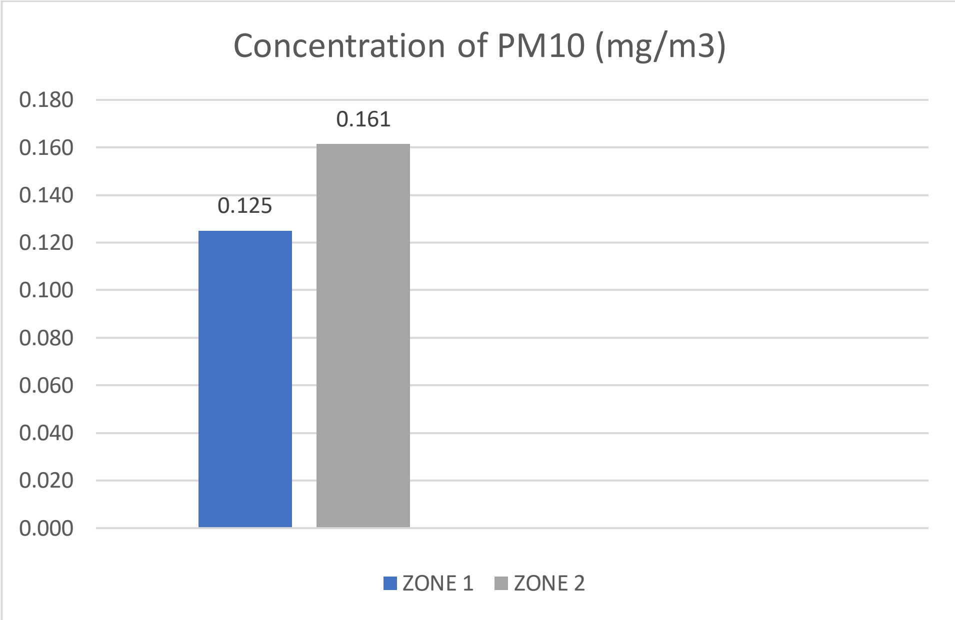


Figure 4.40: Concentration of PM 10 of the classroom 11 of FPTT during afternoon.

4.1.5 Overall Physical Measurement Results.

This study will clearly explain the compliance of the average values of parameters with the relevant standards which are MS 1525 and ASHRAE 62.1 Standard.

Table 4.9: Summary of Physical measurements in Classroom 4 of FKM

Parameters	Classroom 4 of FKM	
	With Occupants	Comment
Indoor Air Temperature, Ta (°C)	M: 27.37°C A: 25.71°C	Not comply with MS 1525
Relative Humidity (%)	M: 120.28% A: 80.62%	Not comply with MS 1525
Air Velocity, Va (m/s)	M: 0.47m/s A: 0.12 m/s	Not comply with MS 1525 but acceptable

Predicted Mean Vote (PMV)	M: 0.31 to 0.5 A: -0.78 to -0.3	Not Comply with ASHRAE 55
Predicted Percentage Dissatisfied (PPD)	M: 7.97 to 10.87 A: 7.43 to 19.54	Not Comply with ASHRAE 55
Carbon Dioxide Level (ppm)	M: 1149.5ppm A: 816.5ppm	Not Comply with ASHRAE 62.1
Concentration of PM2.5 (µg/m3)	M: $4.15x10^{-5}$ µg/m^3 A: $1.23x10^{-4}$ µg/m^3	Comply with ASHRAE 62.1
Concentration of PM10 (µg/m3)	M: $5.05x10^{-5}$ µg/m^3 A: $1.31x10^{-4}$ µg/m^3	Comply with ASHRAE 62.1

*M: Morning

*A: Afternoon

Table 4.10: Summary of Physical measurements in Classroom 8 of FPTT

Parameters	Classroom 8 of FPTT	
	With Occupants	Comment
Indoor Air Temperature Ta(°C)	M: 23.92°C A: 20.61°C	Not comply with MS 1525 but acceptable
Relative Humidity (%)	M: 63.12% A: 73.29%	Comply with MS 1525 but acceptable
Air Velocity, Va (m/s)	M: 0.55m/s A: 0.35m/s	Not comply with MS 1525 but acceptable
Predicted Mean Vote (PMV)	M: -3.35 to -2.56 A:-3.54 to -3.4	Comply with ASHRAE 55
Predicted Percentage Dissatisfied (PPD)	M: 68.7 to 96.75 A: 94.2 to 97.8	Not comply with ASHRAE 55
Carbon Dioxide Level (ppm)	M: 2172.7ppm A: 525.5ppm	Not comply with ASHRAE 62.1
Concentration of PM2.5 (µg/m3)	M: $2.18x10^{-4}$ µg/m^3 A: $2.3x10^{-4}$ µg/m^3	Comply with ASHRAE 62.1

Concentration of PM10 (µg/m3)	M: 2.41x10^{-4} µg/m^3 A: 2.42x10^{-4} µg/m^3	Comply with ASHRAE 62.1

*M: Morning

*A: Afternoon

Table 4.11: Summary of Physical measurements in Classroom 5 of FPTT

Parameters	Classroom 5 of FPTT	
	With Occupants	Comment
Indoor Air Temperature Ta(°C)	M: 22.19 ºC A: 24.27 ºC	Not comply with MS 1525
Relative Humidity (%)	M: 64.57% A: 58%	Comply with MS 1525
Air Velocity, Va (m/s)	M: 0.23m/s A: 0.09 m/s	Not comply with MS 1525
Predicted Mean Vote (PMV)	M:-3.08 to -2 A:-2.14 to -0.16	Comply with ASHRAE 55
Predicted Percentage Dissatisfied (PPD)	M: 71.75 to 91.87 A: 5.77 to 73.75	Not Comply with ASHRAE 55
Carbon Dioxide Level (ppm)	M: 2061ppm A: 2291ppm	Not Comply with ASHRAE 62.1
Concentration of PM2.5 (µg/m3)	M: 1.72x10^{-4} µg/m^3 A: 2.22x10^{-4} µg/m^3	Comply with ASHRAE 62.1
Concentration of PM10 (µg/m3)	M:1.83x10^{-4} µg/m^3 A: 2.3x10^{-4} µg/m^3	Comply with ASHRAE 62.1

*M: Morning

*A: Afternoon

Table 4.12: Summary of Physical measurements in Classroom 11 of FPTT

Parameters	Classroom 11 of FPTT	
	With Occupants	Comment
Indoor Air Temperature Ta(°C)	M: 23.61 ºC A: 23.14 ºC	Not comply with MS 1525
Relative Humidity (%)	M: 120.1% A: 120.1%	Not comply with MS 1525
Air Velocity, Va (m/s)	M: 0.23m/s A: 0.21 m/s	Comply with MS 1525
Predicted Mean Vote (PMV)	M:-2.2 to -1.31 A: -2.49 to -1.84	Comply with ASHRAE 55
Predicted Percentage Dissatisfied (PPD)	M: 41.06 to 80.63 A: 67.24 to 87.71	Not Comply with ASHRAE 55
Carbon Dioxide Level (ppm)	M: 692.5ppm A: 870ppm	Comply with ASHRAE 62.1
Concentration of PM2.5 (µg/m3)	M: $7.85\text{x}10^{-5}$ µg/m^3 A: $1.34\text{x}10^{-4}$ µg/m^3	Comply with ASHRAE 62.1
Concentration of PM10 (µg/m3)	M: $8.9\text{x}10^{-5}$ µg/m^3 A: $1.43\text{x}10^{-4}$ µg/m^3	Comply with ASHRAE 62.1

*M: Morning

*A: Afternoon

Indoor air temperature plays an important key role human’s satisfaction level in terms of thermal comfort. A human being’s thermal sensation of surrounding atmosphere is known as thermal comfort where it reflects satisfaction level of occupants in any buildings. In order to manifest thermal balance, human body coverts heat via heat conduction mechanism. Through 30% convection,40% radiation 20% evaporation and 10% respiration, the metabolic heat formed by the body is eliminated (Ceylan,2011). Based on the Table 4.9, 4.10, 4.11 and 4.12, the indoor air temperature is not complying with the recommended range by Malaysian Standard 1525. This is because body temperature varies based on hours of measurement, sex, age and so on for each individual. A person's body temperature differs in the morning as well as evening. Thus, these factors contribute to affect the indoor air temperature of any occupied space. If the average radiance temperature tend to increase, the body temperature also will be increased (Atmaca and Yigit:2005).

Relative humidity is the amount of water vapour present in air to amount of water vapour an air can withstand. Simultaneously, for the case of relative humidity, FKM classrooms and FPTT classrooms are not complying with the standard MS 1525 except for classroom 5 and 8 of FPTT as refer to Table 4.9, 4.10, 4.11 and 4.12. This rise up since there is closer relationship between temperature and relative humidity. If the temperature decreases, the relative humidity will be increases. The hike in relative humidity level will boost fungal growth or mold. In addition, even if the relative humidity is too low, individuals may experience health issues such as allergies and irritation of eye. Another reason that contributes to the relative humidity is due to the excess water vapour caused by breathing. Sweating of occupants also one of the reasons for relative humidity to be differ. Since the indoor air temperature is not within the range, thus it somehow effects the relative humidity criteria directly.

However, another parameter which is the air velocity is defined as basically air moving speed around humans. According to the (The Government of The Hong Kong Special Administrative Region Indoor Air Quality Management Group, 2003), clearly stated that higher hot air and lower cool air contribute to effects on ventilation and convection currents. As we compared the air velocity in classrooms of FKM and FPTT, the average air velocity level in all the classrooms not complying with the ASHARE Standard 62.1 except for classroom 11 of FPTT. This is because classroom 11 is comparatively bigger in terms of area measurement (m^2) as compared to classroom 4 of FKM and classroom 5 and 8 of FPTT. This makes this classroom provide with wider space. Although the classroom is wider, number of occupants were around students while for other classes there were student above 40. Thus, this makes the heat dissipation to the atmosphere and occupants around in that classroom to be lower. As the heat dissipation is lower, level of air velocity is also lower and within the required range proposed by ASHRAE 62.1 Standard.

Moreover, it is also important to combine all the parameters such indoor air temperature, relative humidity, air velocity which have their individual contribution towards indoor air quality. Thus, by combining all these elements in the PMV and PPD measurements in order to evaluate occupants' sensitivity towards thermal discomfort and comfort. The man who found these theories Mr. Povl Ole Fanger where he stated that if we able to balance up the factor of skin temperature and sweat secretion that will bring up to a comfortable condition for occupants. PMV is used to in companion with the seven-point thermal sensation scale in order to determine the mean value votes within a set of occupants. In contrast, the PPD is an index which is known as predicted percentage of dissatisfied. Fanger developed this theory with the aim to enhance the measurement for thermally dissatisfied occupants in terms of quantitative predictions. The acceptable thermal environment standard for PMV index in order to achieve comfort condition is from the range of -5 to 5, which recommended by ASHRAE 55. Nonetheless, the recommended value of PPD index is lower than 10%.

As referred to Table 4.9 and 4.10, the classroom 4 of FKM are not complying with ASHRAE 55 standard. However, for classroom 5, 8 and 11 of FPTT are complying with ASHRAE 55 standard. As for the case of PPD index, none of the classroom are complying with the ASHRAE 55 standard as their PPD index are above 10%. This is because all 4 classrooms' have not achieved the minimum recommended indoor air temperature due personal factors such metabolic rate and also clothing insulation rates.

Based on theory of Hays et al. (1995), carbon dioxide is known as an asphyxiant gas, which is classified in terms of element such as colourless and odourless. As we compare with ASHRAE 62.1 standard, it should not exceed 700ppm above outdoor air levels. However, when it comes to inside the building condition it should not be higher than 1000ppm as it causes severe health issues to occupants. According to the 4 tables above, classrooms 4 of FKM and classroom 5 and 8 of FPTT not complying with ASHRAE 62.1 standard. Again, classroom 11 of FPTT achieved the allowable range of carbon dioxide level. Some people tend to have effects in terms of physical such as tiredness during lecture. These impacts have close relationship with carbon dioxide level. As mentioned above, the number of students in class 11 of FPTT is lower where the number of occupants present being one of the reason behind the indoor carbon dioxide hike. The large number of students in other 3 classes in both morning and afternoon session boost the average carbon dioxide level which make them to not comply with required standard.

Furthermore, similarly as the concentration of carbon dioxide, concentration of particulate matter 2.5 and 10 also are major component that required to be analysed in indoor air quality. PM 2.5's exposure for a longer period of time may affect people who undergoing health issues especially in lungs and heart. Meanwhile, for the case of PM 10, the short-term exposure may bring various difficulties in breathing or respiratory system of humans. Based on Table 4.1, 4.2, 4.3 and 4.4, all the classrooms are complying with ASHRAE 62.1 standard. This is because all 4 classes are below the maximum allowable range for both particulate matter 2.5 and 10 which is $15\mu g/m^3$ and $50\mu g/m^3$ respectively. Hence, this will prevents health effects such as respiratory problems, infection on lungs and so on. Not only have that, this condition boosted up the level of comfortability for the occupants to study during lecture hours.

4.2 Subjective Assessment

In this subjective assessment, questionnaire were distributed via google form during the objective measurements in classrooms of FKM and FPTT. The survey carried out on 5th March 2020, 7th March 2020, 25th March 2020 and also 27th March 2020. There are total of 30 respondents in each session of morning and afternoon. Thus, the total number of respondents represent FKM building and FPTT building are 60 respondents respectively. The result of thermal sensation votes for both classrooms were tabulated in Table 4.5.

Table 4.13: Occupant's thermal sensation vote for FKM and FPTT classrooms

ASHRAE SCALE		Classroom of FKM			Classroom of FPTT		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Hot	+3	1	1	2	2	2	4
Warm	+2	7	7	14	0	3	3
Slightly warm	+1	7	7	14	2	6	8
Neutral	0	7	10	17	16	8	24
Slightly cool	-1	7	5	12	2	4	6
Cool	-2	1	0	1	5	4	9
Cold	-3	0	0	0	3	3	6
Total				60			60

ASHRAE seven-point scale are used to carry out this survey questionnaire in order to identify their satisfaction level and insight towards the indoor environment of the classrooms. It is considered to be acceptable if 80% of the occupants voted for the interval (-1,1) based on ASHRAE Standard 55. The PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied people) are the main thermal comfort indexes that required to be considered. This is because according to the study conducted by Fanger and others there are convoluted relationship between personal and environmental parameters. According to Fanger's Therory, it stated that thermal environment is acceptable if the votes for interval (-1,1). Meanwhile, environment is not acceptable if the votes for interval (-3,-2) and (+2, +3).In Figure 4, it clearly shows the frequency distribution of occupants/ thermal sensation based on ASHRAE-7 point scale. The majority of the respondents in both FKM classroom and FPTT classrooms have voted for neutral which are 28.33% and 40% respectively. There is no respondent voted for cold in FKM classrooms. The outcomes of the results shows that there is no respondents exceeded 80% of votes for the central three categories which are slightly cool. Neutral and slightly warm conditions. Thus, it indicates that both faculty's classroom has not achieved the thermal acceptable conditions.

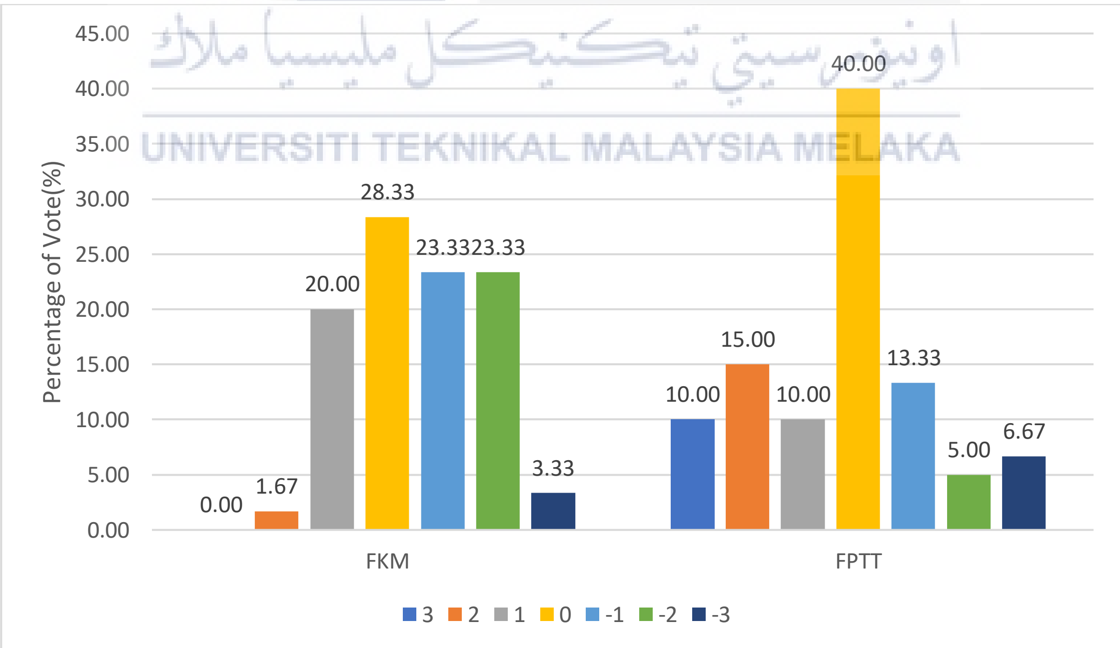


Figure 4.41: Frequency Distribution of occupants' thermal sensation according to ASHRAE 7-point scale

Table 4.14: Relative humidity sensation vote of occupants in FKM and FPTT classrooms

ASHRAE SCALE		Classroom of FKM			Classroom of FPTT		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Very dry	+3	1	0	1	1	0	1
Dry	+2	7	1	8	5	1	6
Slightly dry	+1	7	11	18	4	6	10
Neutral	0	7	9	16	11	10	21
Slightly humid	-1	7	7	14	9	7	16
Moderately Humid	-2	1	1	2	0	5	5
Humid	-3	0	1	1	0	1	1
Total				60			60

Data in Table 4.14 have been plotted into graph in Figure 4.42 to have a clear picture on relative humidity sensation vote of occupants in FKM and FPTT classrooms. For FKM classrooms, the highest vote is for slightly humid condition which is 30%. The vote for neutral condition are 26.67% and 23.33% for slightly dry condition. In the other hand, the majority vote is for neutral, slightly humid and slightly dry condition is 35%, 26.67% and 16.67% respectively. As referred to the figure, majority of the respondents cast their vote for interval (-1, 0, 1) for both faculty classrooms which are 80% and 78.34% respectively.

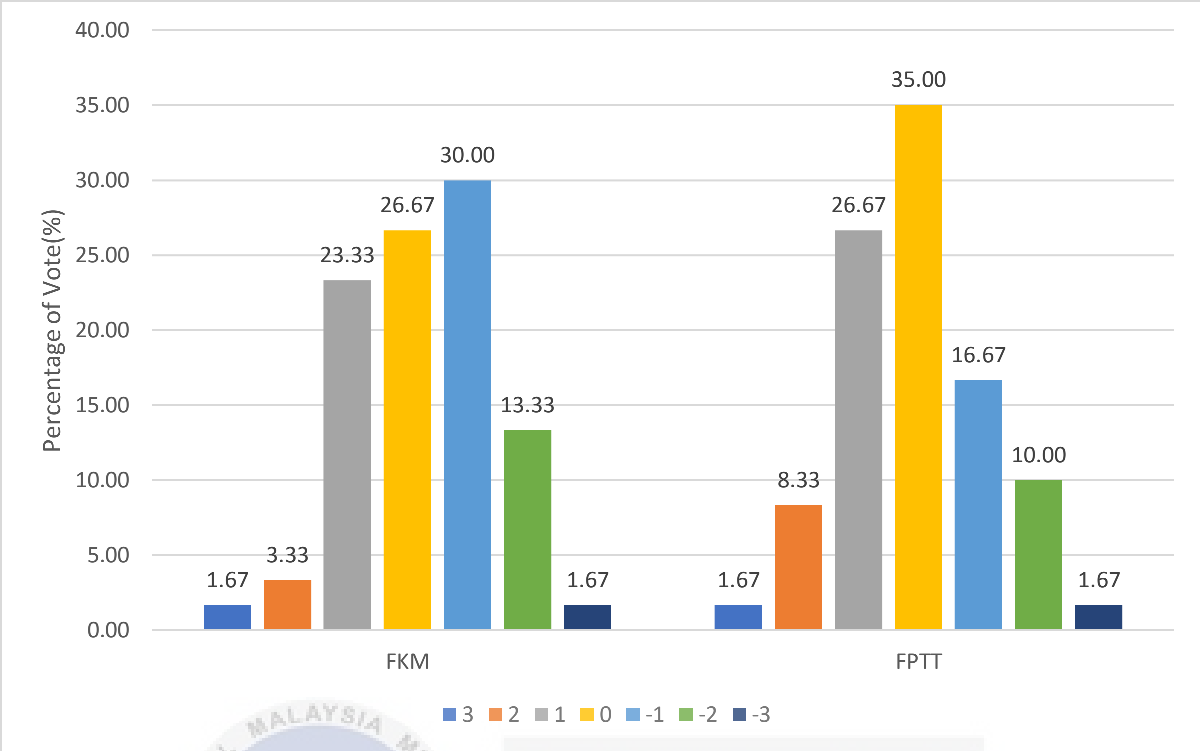


Figure 4.42: Frequency Distribution of occupants' relative humidity sensation according to ASHRAE 7-point scale

Table 4.15: Air velocity sensation vote of occupants for both FKM and FPTT classrooms

ASHRAE SCALE		Classroom of FKM			Classroom of FPTT		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Very still	+3	0	1	1	1	4	5
Moderately still	+2	7	6	13	7	12	19
Slightly still	+1	5	9	14	8	9	17
Neutral	0	11	8	19	9	4	13
Slightly draughty	-1	6	3	9	2	0	2
Moderately draughty	-2	1	3	4	1	0	1
Very draughty	-3	0	0	0	2	1	3
Total				60			60

Based on Figure 4.43, the highest vote is for neutral condition in FKM classroom with percentage of 31.67%. Moreover, the vote percentage for slightly still, moderately still and slightly draughty for FKM are 23.33%, 21.67 and 15% respectively. While for vote for very still and moderately draughty are only about 1.67% and 6.67% respectively. There is no vote for very draughty condition by occupants. However, for the case of FPTT, the highest vote is for moderately still condition with percentage of 31.67%. The value of percentage for slightly still, neutral and very still are 28.33%, 21.67% and 8.33% respectively. The vote percentage for slightly draughty, moderately draughty and very draughty are only about 3.33%, 1.67% and 5% individually.

According to the results obtained, it shows that less than 80% of respondents voted for interval (-1, 0, 1) which makes the FKM classrooms to not achieve thermal acceptable condition. Nevertheless, more than 80% of the respondents voted for interval (-1, 0, 1). Thus, it shows that air velocity condition in FPTT classrooms is considered acceptable.

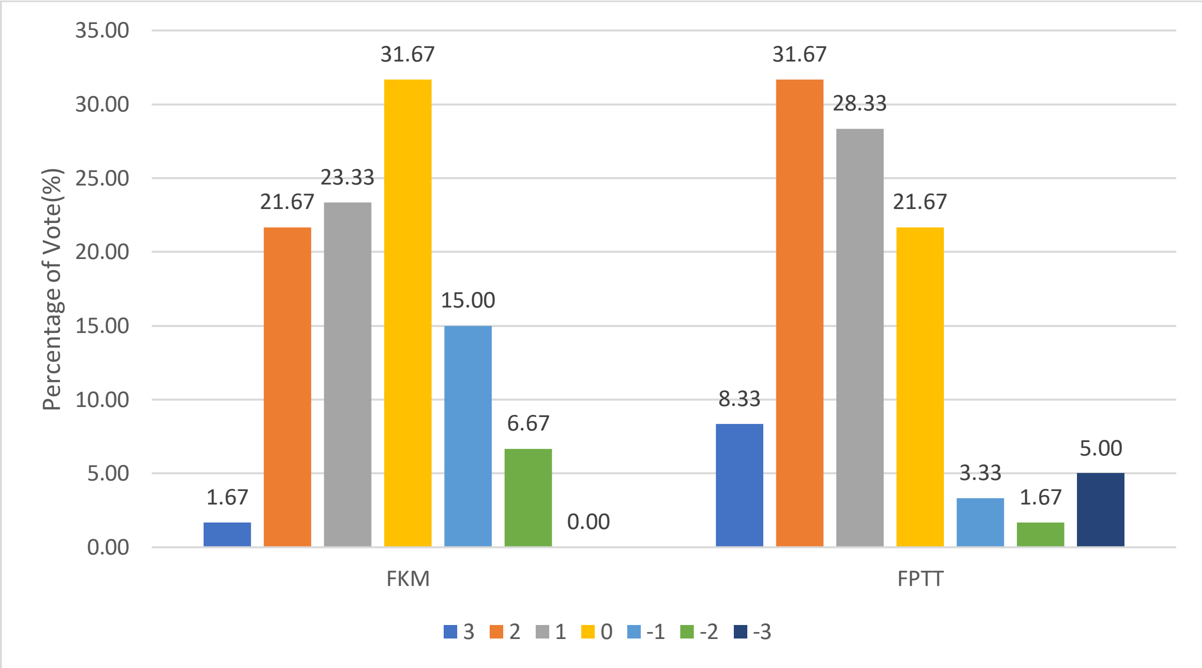


Figure 4.43: Frequency Distribution of occupants' air velocity sensation according to ASHRAE 7-point scale

Table 4.16: Odour perception vote of occupants for both FKM and FPTT classrooms

ASHRAE SCALE		Classroom of FKM			Classroom of FPTT		
		Morning	Afternoon	Total	Morning	Afternoon	Total
No odour	+3	2	2	4	3	9	12
Very weak odour	+2	9	5	14	9	11	20
Weak odour	+1	5	9	14	5	2	7
Moderately weak odour	0	6	8	14	11	5	16
Moderately strong odour	-1	7	5	12	0	1	1
Strong odour	-2	1	1	2	1	2	3
Very strong odour	-3	0	0	0	1	0	1
Total				60			60

Based on Figure 4.44, the percentage of vote are similar which are 23.33% for all three moderately weak odour, moderately strong and strong odour. Occupants voted about 20%, 6.67% and 3.33% for weak odour, very strong odour and very weak odour respectively. It is shown that no respondent voted for no odour in FKM classroom. However, for FPTT classroom, the highest percentage of vote is for strong odour 33.33%. The vote percentage for neutral is 26.67%. As referred to the Figure 4.44, it indicates that the central 3 categories for both faculties are 66.66% and 40.01% respectively.

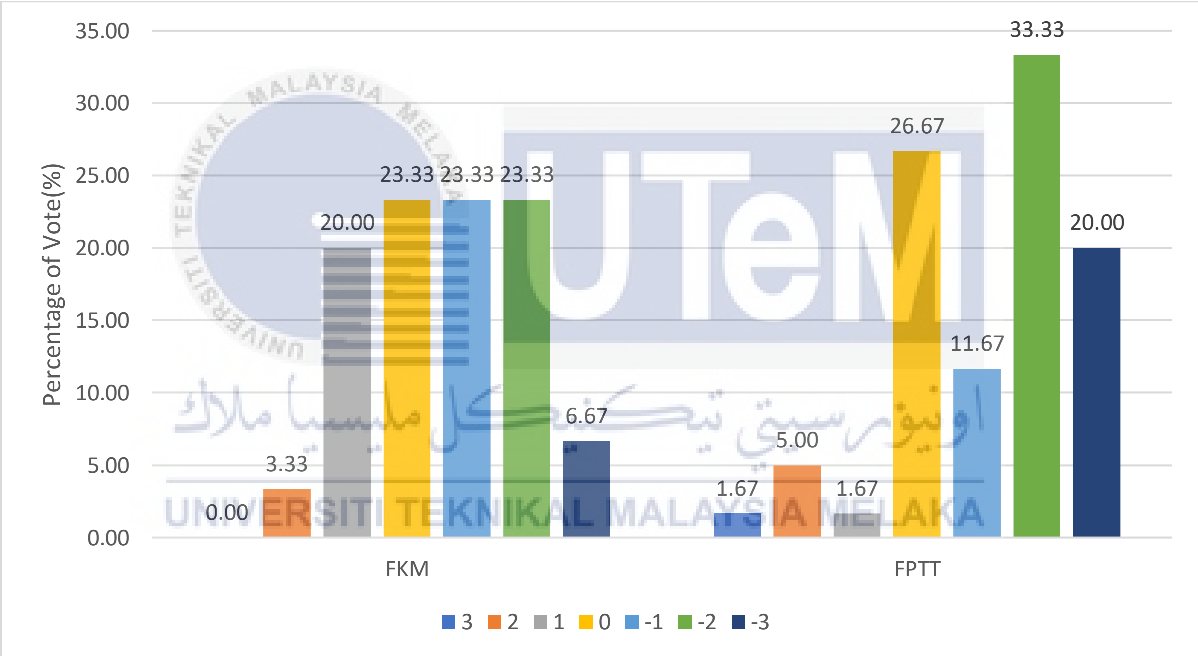


Figure 4.44: Frequency distribution of occupants' odour perception.

Table 4.17: Occupants’ satisfaction on air temperature in FKM and FPTT classrooms

Scale		Classroom of FKM			Classroom of FPTT		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Entirely satisfy	+3	0	1	1	0	4	4
Mostly satisfy	+2	5	6	11	5	4	9
Somewhat satisfy	+1	8	9	17	8	9	17
Neither satisfy nor not satisfy	0	6	5	11	12	8	20
Somewhat not satisfy	-1	6	4	10	2	5	7
Mostly not satisfy	-2	1	4	5	0	0	0
Entirely not satisfy	-3	4	1	5	3	0	3
Total				60			60

For the aspect of satisfaction level, the similar 7-point scale concept have been used with the classification of satisfy, neutral and not satisfy category. The sum of percentage of vote for interval (-3,-2,-1) indicates the non-satisfaction level, while interval (1, 2, 3) indicates satisfaction level and scale 4 is for neutral.

Figure 4.45 determines the occupants’ satisfaction on air temperature in FKM classroom and FPTT classroom. For the case of FKM classrooms, the respondents expressed highest vote for somewhat not satisfied with the air temperature which is 28.33%. The respondent also voted for mostly not satisfied and entirely not satisfied with the percentage of 18.33% and 1.67% respectively. Furthermore, the percentage vote for somewhat satisfied and neutral are 16.67%, and 18.33% respectively. The vote for both entirely satisfy and mostly satisfy are same which is 8.33%. This indicates that the total satisfaction level in classroom of FKM on air temperature is 48.33% and around 33.33% of respondents not satisfied with the current air temperature in classrooms. On other contrary, measurements on

FPTT classrooms shows that majority the students cast vote for neutral condition with percentage of 33.33%. It is shown that the total percentage for not satisfy condition of air temperature is 16.67% and 50% of the respondents are satisfied with the air temperature in FPTT classrooms. Thus, this shows that the respondents both faculty's classrooms are satisfied with current air temperature.

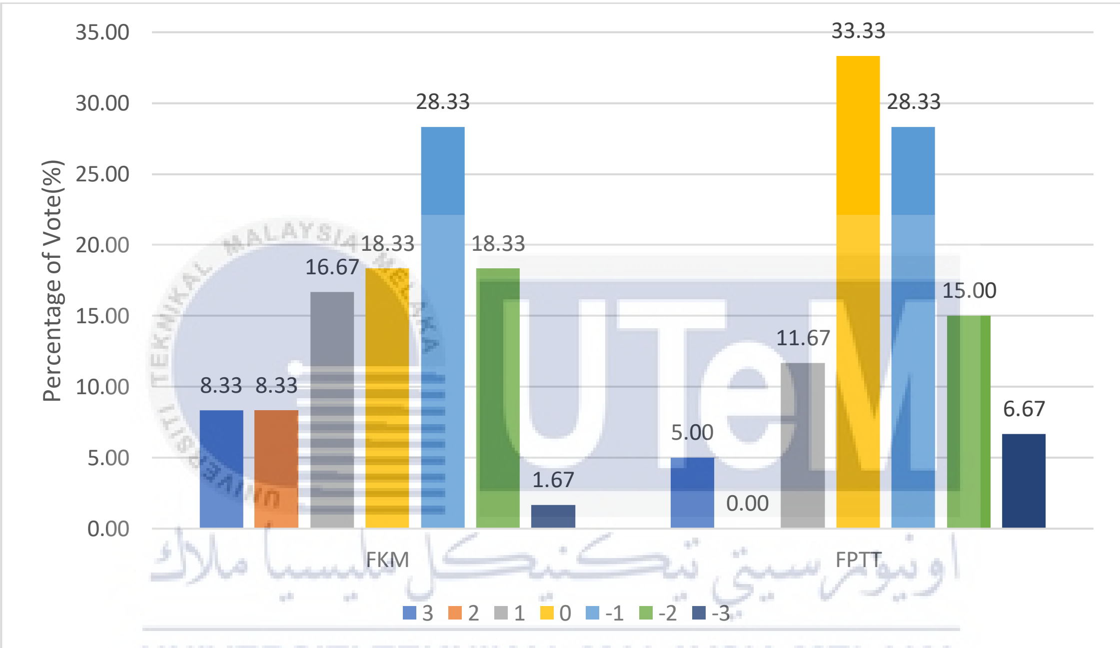


Figure 4.45: Occupants' satisfaction on air temperature in FKM classroom and FPTT classroom

Table 4.18: Occupant's overall comfort level on FKM and FPTT classrooms

Scale		Classroom of FKM			Classroom of FPTT		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Entirely satisfy	+3	2	1	3	0	2	2
Mostly satisfy	+2	6	5	11	3	6	9
Somewhat satisfy	+1	5	12	17	13	14	27

Neither satisfy nor not satisfy	0	11	4	15	11	4	15
Somewhat not satisfy	-1	4	7	11	2	2	4
Mostly not satisfy	-2	2	0	2	0	1	1
Entirely not satisfy	-3	0	1	1	1	1	2
Total				60			60

Figure 4.46 portrays the frequency distribution of occupant's overall comfort perception in FKM and FPTT classrooms. According to the figure, the majority of respondents in FKM have expressed their vote for 28.33% which is for the somewhat satisfy element. The percentage of vote for mostly satisfy and entirely satisfy are 15% and 3.33% respectively. Hence, it brings the total satisfaction level for overall comfort perception is 51.66% meanwhile 23.33% of respondents not satisfied with the overall comfort. Diversely, for the case of FPTT classrooms, 45% of respondents voted for somewhat satisfy element. Next, the mostly satisfy and entirely satisfy elements have the percentage of 15% and 3.33% respectively. Thus, this bring in a total of 63.33% of respondents are satisfied with the overall indoor environment and comfort. Responses from both faculty respondents have clearly shows that they are satisfied with the overall indoor environment.

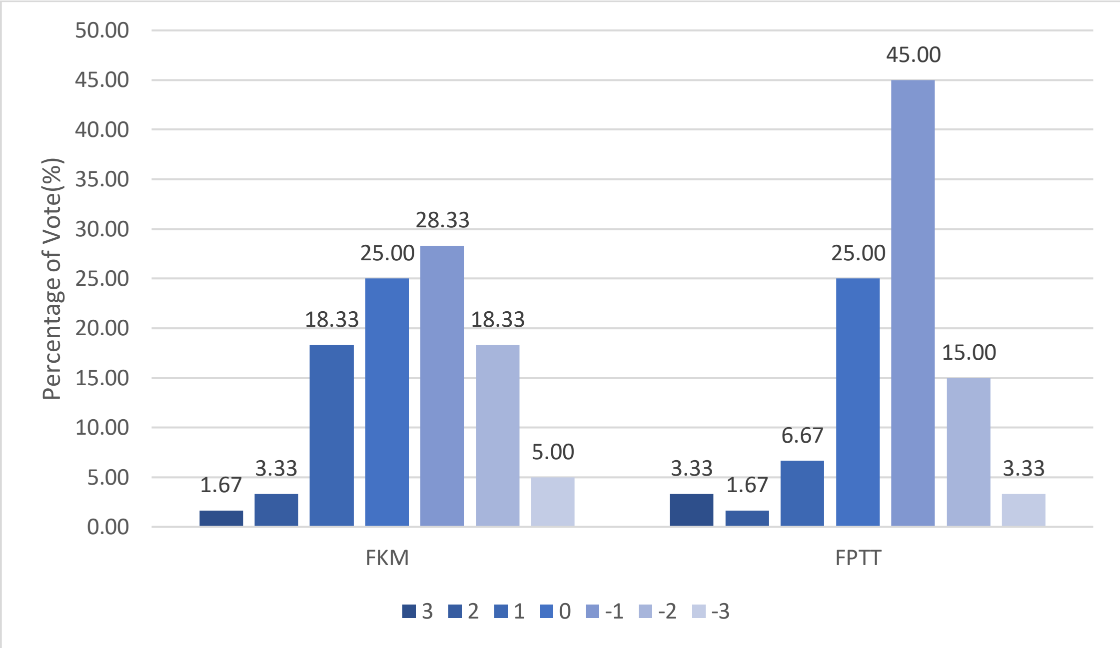


Figure 4.46: Frequency Distribution of occupant's overall comfort perception in FKM and FPTT classrooms

4.3 REGRESSION ANALYSIS

Regression analysis gives the estimation of values of the dependent variables by using values of independent variables. By using the method of regression analysis. It plays a vital role in identifying the strength of relationship between the parameters that have been focused in the research. The regression approach is utilised in order to obtain the neutral values from the data collected. R-squared which widely known as determination coefficient or variance proportion in terms of percentage (%). These R-squared values which are obtained from regression analysis are used to evaluate the strength of relationship any two parameters involved. In this study, the comparison between parameters are shown in Table 4.19.

Table 4.19: Variables involved in regression analysis.

Dependent variable (y-axis)	Independent variable (x-axis)
Thermal Sensation Vote (TSV)	Operative Temperature, T_{op}
Predicted Mean Vote (PMV)	Operative Temperature, T_{op}
Predicted Mean Vote (PMV)	Relative Humidity (RH)
Predicted Mean Vote (PMV)	Air Velocity, AV
Carbon Dioxide, CO_2	Particulate Matter 2.5 (PM)
Carbon Dioxide, CO_2	Particulate Matter 10 (PM)

In order to evaluate the strength of relationship between these variables, it is necessary to apply the rule of thumb based in R-squared values as listed in Table 4.20.

Table 4.20: R-squared Value Classification (Zikmund & William et al., 2000)

Range of R-squared value	Strength of relationship
$R^2 < 0.3$	Very weak effect size
$0.3 < R^2 < 0.5$	Low effect size
$0.5 < R^2 < 0.7$	Moderate effect size
$R^2 > 0.7$	Strong effect size

4.3.1 Regression analysis in FKM

In Figure 4.47, the regression between Thermal Sensation Vote, TSV and operative temperature, T_{op} is showed that coefficient of determination, R^2 is about 0.89 which will fall under the condition of very strong effect size. Thus, this shows that the relationship is very strong between both the variables. Based on the TSV regression line, the neutral temperature is 34.69 °C.

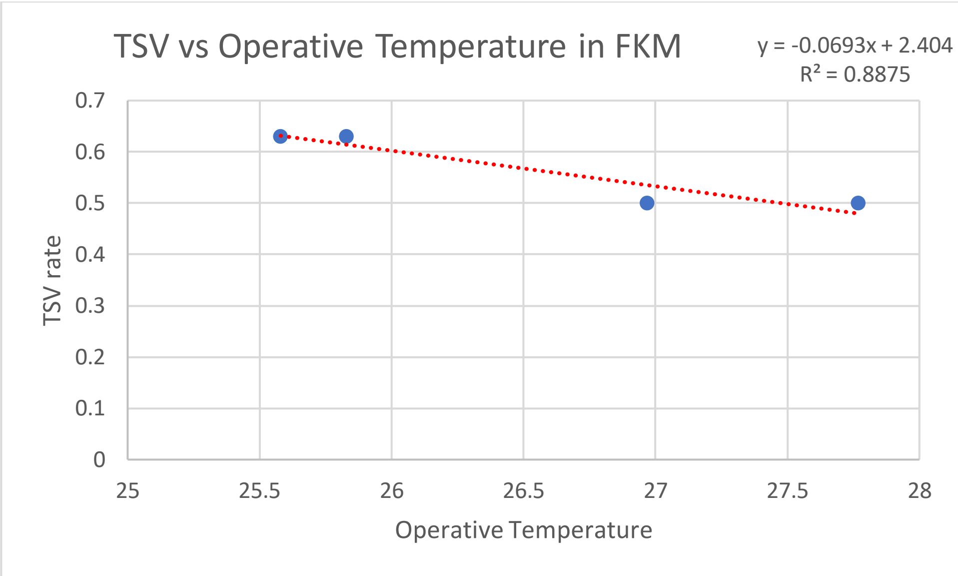


Figure 4.47: Regression of Thermal Sensation Vote versus Operative Temperature in FKM

Factors of thermal comfort and predicted mean votes via seven-point scale relates one another as suggested by ASHRAE55 Standard. Based on Figure 4.48, the regression analysis between PMV and operative temperature shows that the coefficient of determination, R^2 is 0.81 represents for FKM. This reflects that the relationship is very strong and around 81% of the data of variations showed by linear relationship between PMV and operative temperature (°C). From the PMV regression, the predicted neutral temperature is 26.85°C.

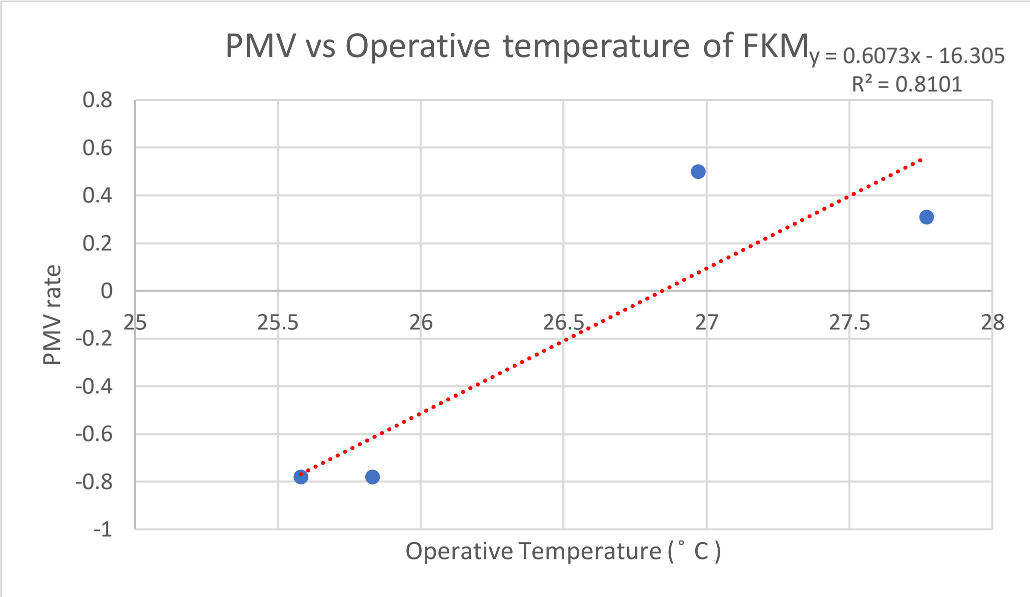


Figure 4.48: Regression of PMV versus operative temperature in FKM

In contrast, for the case of regression of PMV and relative humidity with PMV and air velocity, the coefficient of determination, R^2 are 0.99 and 0.45 respectively. Based on Figure 4.49, it portrays that the relationship between PMV and relative humidity is very strong with strong effect size. Meanwhile, based on Figure 4.50, it indicates that relationship between PMV and air velocity is weak with weak effect size. This means that, not even half of variations can be explained by this relationship.

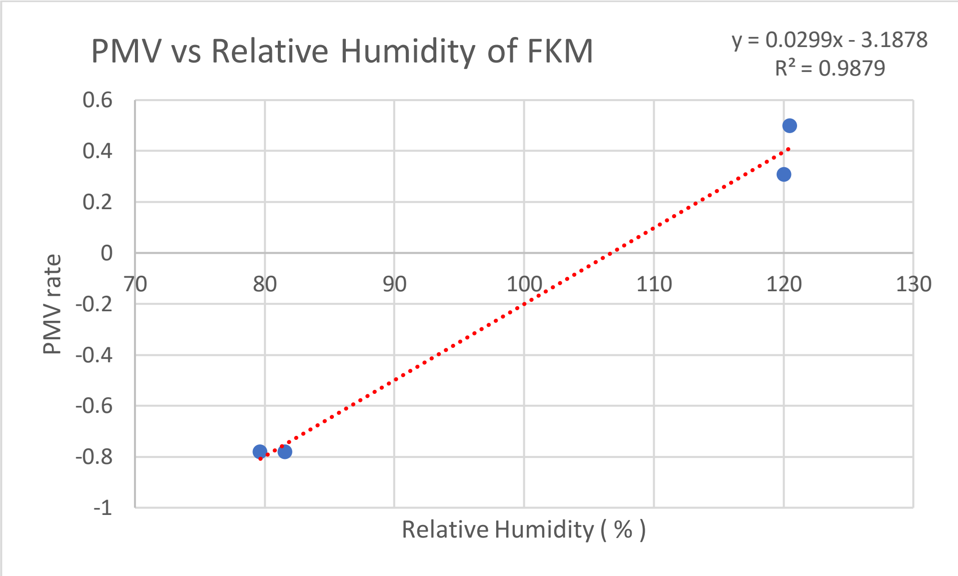


Figure 4.49: Regression of PMV versus relative humidity in FKM

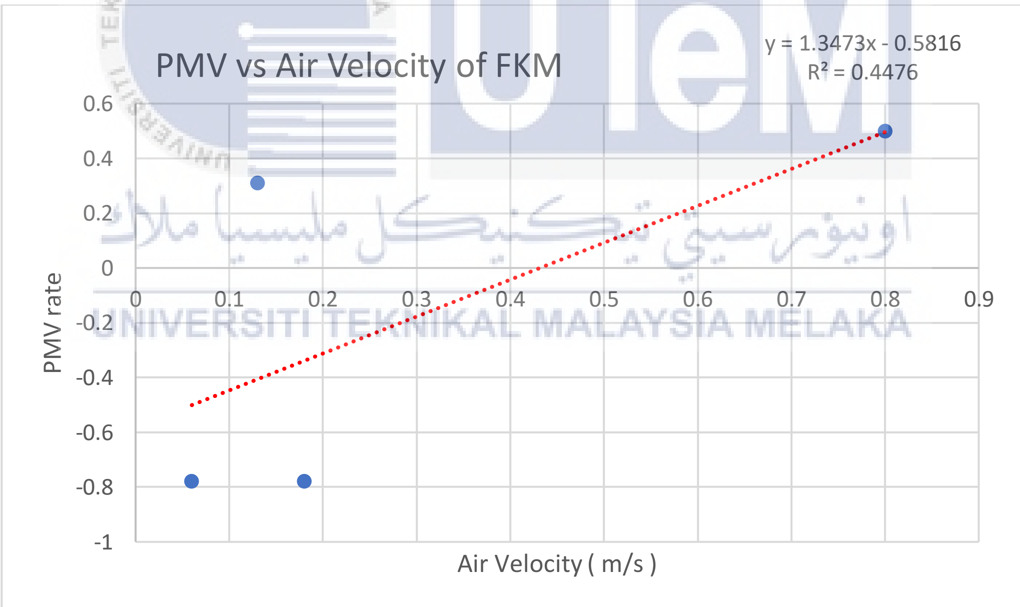


Figure 4.50: Regression of PMV versus air velocity in FKM

In addition, Figure 4.51 and Figure 4.52 shows the regression of carbon dioxide with particulate matter 2.5 and 10 respectively. As referred to Figure 4.51, coefficient of determination, R^2 is 0.42. Moreover, based on Figure 4.52, the coefficient of determination,

R^2 is only about 0.35. As referred to both the values, it clearly tells that both strength of relationship between carbon dioxide with PM 2.5 and PM 10 is weak or lower effect size respectively.

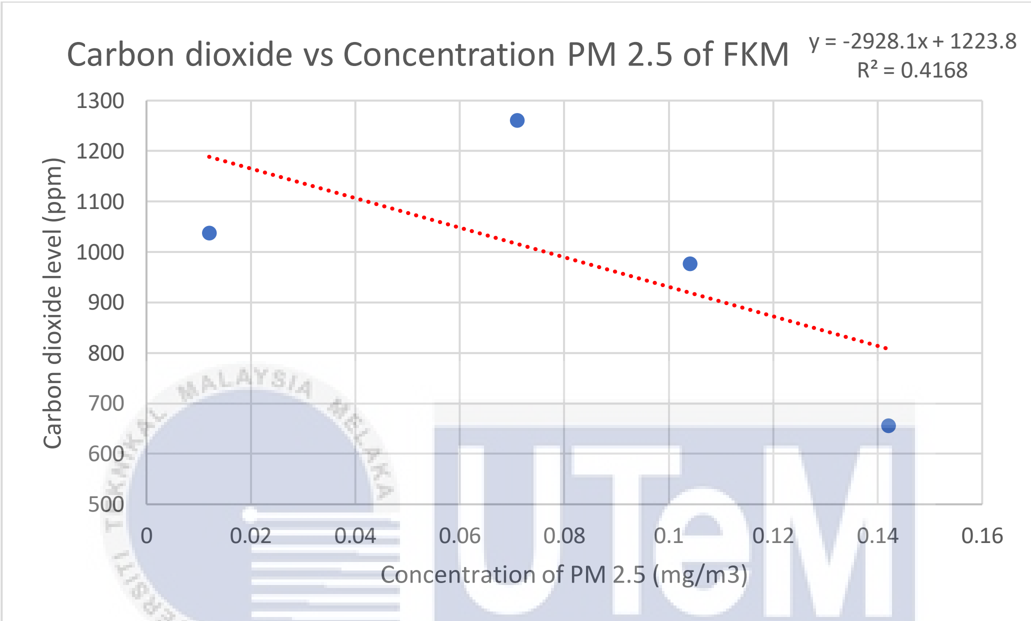


Figure 4.51: Regression of carbon dioxide versus PM 2.5 in FKM

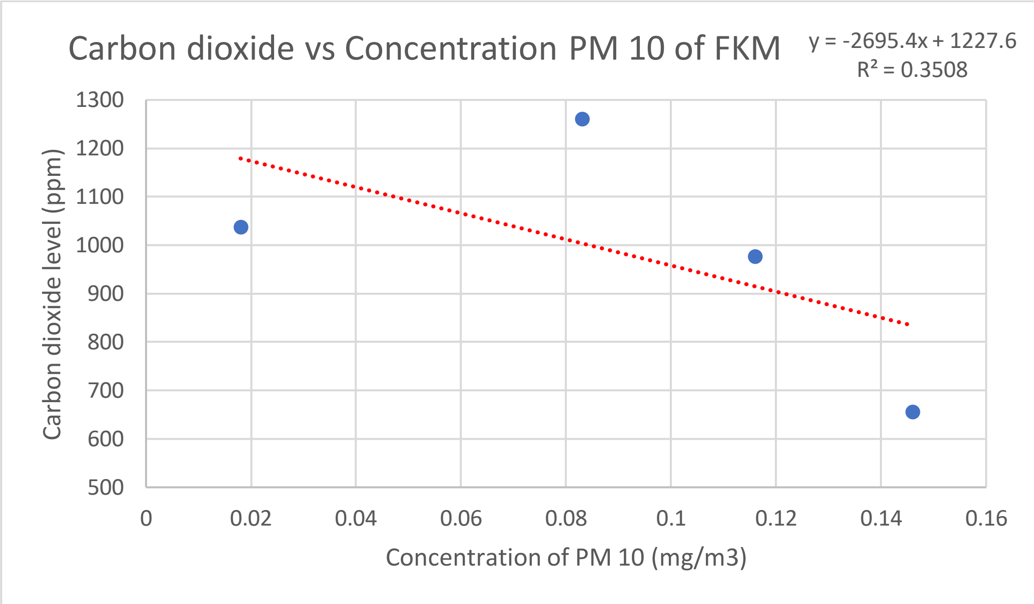


Figure 4.52: Regression of carbon dioxide versus PM 10 in FKM

4.3.2 Regression analysis in FPTT

The linear regression between TSV and operative temperature in FPTT classrooms are tabulated in Figure 4.53. It results that coefficient of determination, R^2 is 0.04. This is shows that the strength of relationship between TSV and operative temperature is very weak. The neutral temperature obtained is 10.1°C.

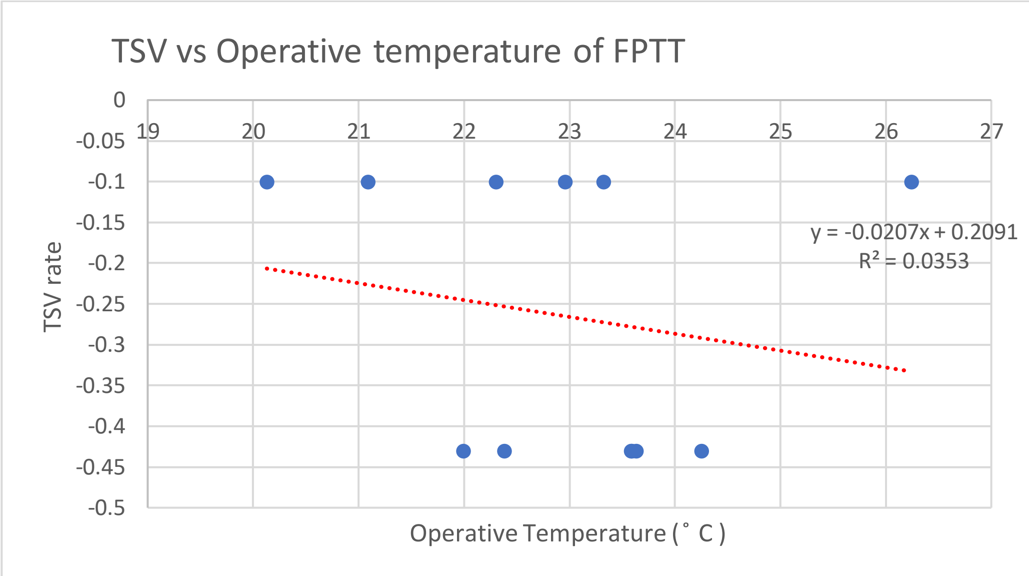


Figure 4.53: Regression of TSV and operative temperature in FPTT

Based on Figure 4.54, the regression analysis between PMV and operative temperature shows that the coefficient of determination, R^2 is 0.57 represents for FPTT. This reflects that the relationship is moderate and around 57% of the data of variations showed by linear relationship between PMV and operative temperature (°C). From the PMV regression, the predicted neutral temperature is 27.93°C.

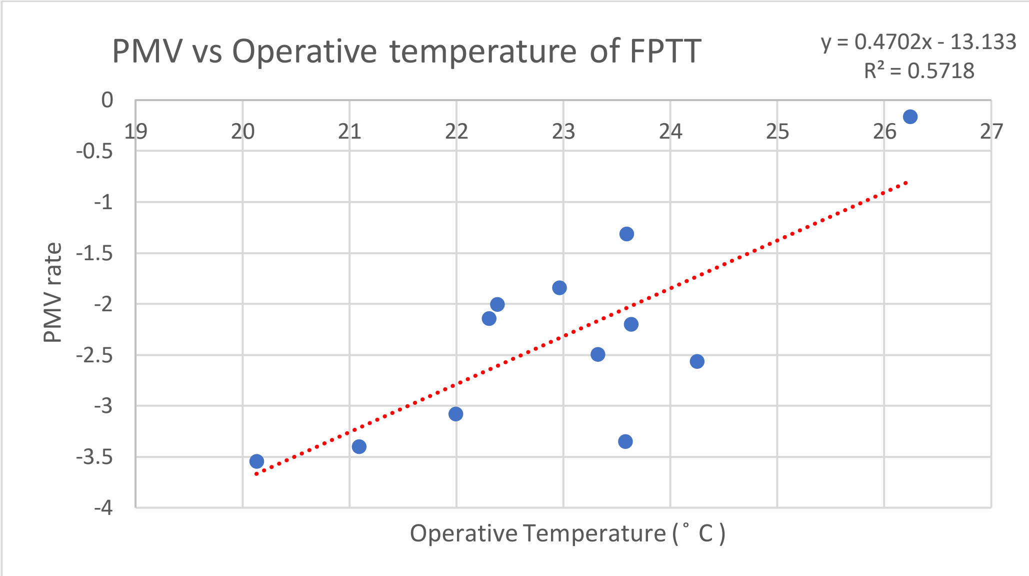


Figure 4.54: Regression of PMV and operative temperature in FPTT

Pre contra, for the case of regression of PMV and relative humidity with PMV and air velocity, the coefficient of determination, R^2 are 0 and 0.6 respectively. Based on Figure 4.55, it portrays that the relationship between PMV and relative humidity is very weak with weakest effect size. Meanwhile, based on Figure 4.56, it indicates that relationship between PMV and air velocity is moderate. This means that, more than half of variations can be explained by this relationship for air velocity as variable. Thus, it also indicates that the relationship is a negative between PMV and air velocity which mean the more the air velocity, the lower the PMV value.

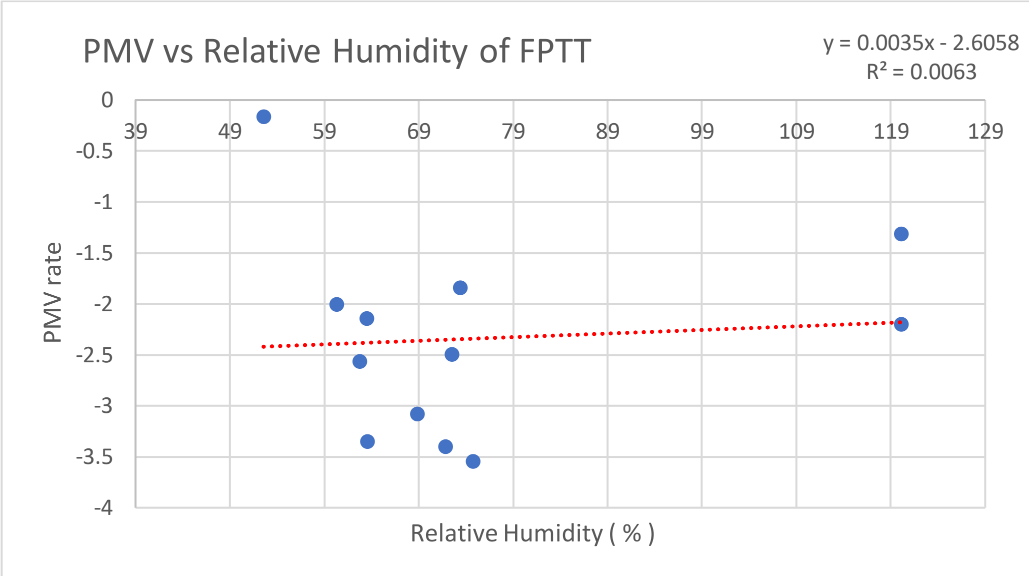


Figure 4.55: Regression of PMV and relative humidity in FPTT

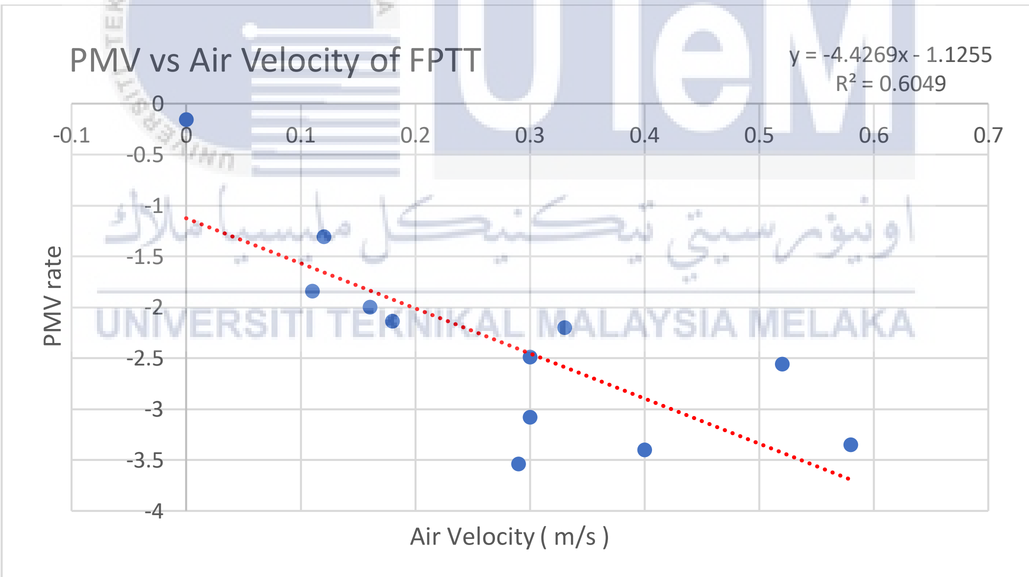


Figure 4.56: Regression of PMV and air velocity in FPTT

Nonetheless, Figure 4.57 and Figure 4.58 shows the regression of carbon dioxide with particulate matter 2.5 and 10 respectively. As referred to Figure 4.65, coefficient of determination, R^2 is 0.18. Moreover, based on Figure 4.66, the coefficient of determination,

R^2 is only about 0.19. As referred to both the values, it clearly tells that both strength of relationship between carbon dioxide with PM 2.5 and PM 10 is very weak or lowest effect size respectively.

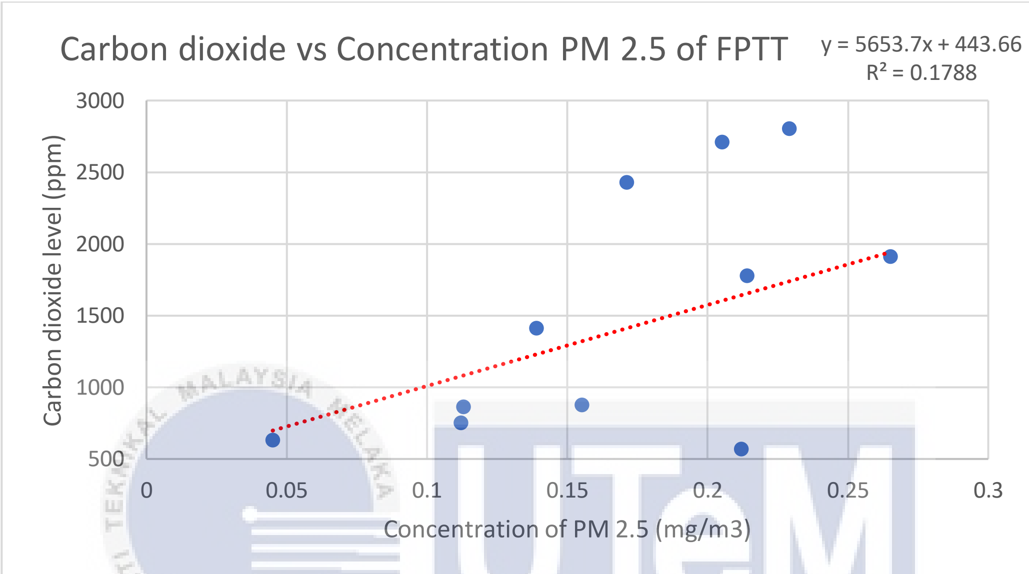


Figure 4.57: Regression of carbon dioxide versus PM 2.5 in FPTT

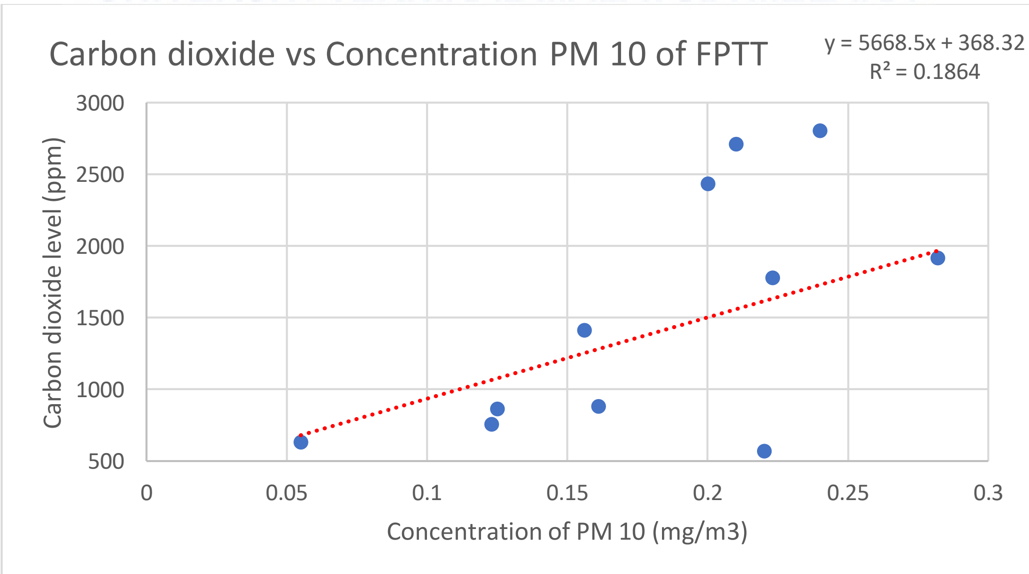


Figure 4.58: Regression of carbon dioxide versus PM 10 in FPTT

4.3.3 Summary of Result

Thus, this leads to the importance of how thermal comfort is been affected by various factors. In Table 4.21 shows the whole summary of regression between parameters and their strength of relationship which have been tabulated. Compared to the regressions of both TSV and operative temperature and PMV and operative temperature in FKM for both have very strong relationship with one another. This is because one of the main aspect influencing the relationship is the number occupants in each classrooms. Both TSV and PMV have provided a strong relationship with operative temperature since both have contributed equally during the subjective assessment and physical measurement. The number of occupants who corporate to do the survey was around 30 in each session during physical measurement.

Meanwhile, in FPTT, the relationship between TSV and operative temperature is slightly lower than the relationship between PMV and operative temperature. This might be due to the limitation of data provided for thermal sensation in FPTT classrooms. Each session came with uncontrollable number of occupants who expressed vote.

According to Fanger's theory, the European Standard ISO stated that PMV's neutral condition will be zero. In contrast, via three stages, an human body may obtain capacity to adapt so the neutral temperature differs for TSV and PMV (Nastase et.,al; 2016, Zhang 2007). The neutral temperature obtained in regression of TSV and operative temperature in FKM is 34.69 ºC. However, the neutral temperature obtained in regression of PMV and operative temperature in FKM is 26.85 ºC.

Compared to the research by Hwang (2006) stated that the study fields in tropics in Taiwan resulted in neutral operative temperature of 25.6ºC. Furthermore, based on another research in lecture hall of university of Malaya, the neutral operative temperature is 24.6 ºC from the regression between PMV and operative temperature. The neutral temperature obtained from PMV regression is more compatible with other researches compare to neutral operative temperature from TSV regression. Although the neutral temperature is 34.69 ºC, majority of 28.33% people voted for neutral condition.

In FPTT, the neutral operative temperature obtained from regression of TSV is 10.1 ºC. Meanwhile, neutral operative temperature obtained from regression of PMV and operative temperature is 27.93 ºC. The neutral temperature obtained from PMV is higher than in the actual vote. As similar to FKM, respondents in FPTT expressed voted to neutral condition was higher with 40%. As compared to previous research, Karyono conducted an experiment in Jakarta at an air-conditioned office building. From the research, it was detected that majority of occupants were comfortable with the temperature from 26.7 ºC to 28.6 ºC where the neutral temperature 26.7 ºC. Based on this result, the neutral operative temperature from regression of PMV shows more compatibility than from regression of TSV.

In addition, the strength of relationship between PMV and relative humidity is stronger in FKM as compared to FPTT. However, the relationship strength between PMV and air velocity in FPTT is greater than in FKM. Moreover, in this study, the relationship between carbon dioxide with both PM 2.5 and Pm10 is considered to be weak respectively.

Table 4.21: Summary of regressions results and strength of relationship for both faculties.

D/I Variables	FKM		FPTT	
	R^2	Strength of relationship	R^2	Strength of relationship
TSV/ T_{op}	0.89	Strong	0.04	Very weak
PMV/ T_{op}	0.81	Strong	0.57	Moderate
PMV/ RH	0.99	Strong	0	None

PMV/ AV	0.45	Weak	0.60	Moderate
CO_2/ PM2.5	0.42	Weak	0.18	Very weak
CO_2/ PM10	0.35	Weak	0.19	Very weak

4.4 Improvisation Measures

4.4.1 Improvement Measures in Faculty Mechanical Engineering

1. Replacement of return air vent or diffuser

Upon conducting thermal comfort analysis, it is resulted that the average temperature in FKM classroom do not comply with the Malaysian Standard 1525. In contrast, around 63.33% of respondents are satisfied with the average air temperature in classroom of FKM. Hence, the neutral operative temperature obtained from regression of PMV was 26.85°C. As referred to that outcomes, the first suggestion is installing the suitable return air vent or return air diffuser within suitable distance. This is important because when return air vent is closer to supply register, it will be lacking in time for the air to circulate properly. As if the supply register is just right after, the air may just elapse without even cooling the room. For a proper process returning air to air conditioning system which includes heating or cooling element, it is fundamental to have return air vent which actually monitors the air circulations. The air which is already exist within the internal surrounding required to be expelled. Hence, return air vent will be expelling the specific air in order for the conditioned air released to the indoor.

It is important to also clean the vents and make sure the vents are not closed. This is to ensure that no harmful impurities get sucked in to the system in order to prolong the lifespan of the air conditioning system. If the dust or impurities stacked between vents, it also may cause blockage in ductwork. The number of vent required is depends on the room size.

2. Installation of Ventilator

Next, based on perception of occupants from questionnaire, it is revealed that 70% of the respondents voted for interval of (-1, 0, 1) which shows their satisfaction level in FKM classroom 4. The classroom does not come up with a recommended average air velocity value by not complying with MS 1525 standard according to the physical measurement. Hence, it is compulsory to improve ventilation system of the respective classroom. Ventilation not only prevents airborne pollutants from entering indoor atmosphere while it also plays important role in controlling indoor temperature.

In order to improve the air quality, proactive measures must be taken via main two classifications for classroom. First classification is through spot ventilation and followed by natural ventilation. Most common element in the element of spot ventilation is installation exhaust fan. Nevertheless, exhaust fan must be installed based on the volume of a classrooms with corresponding to the cfm value which is known as cubic feet per minute airflow. CFM value needed to be found in both actual criteria and also standardised criteria based on ASHRAE 62.1 standard.

Actual ventilation rate:

(Volume of room x ACH rate) / 60 minutes = CFM

Volume of room = length x width x height

Note: To find out the CFM, the volume of the classroom measurement must be in feet.

Standard ventilation rate:

$V_{bz} = (R_p \times P_z) + (R_a \times A_z)$

R_p = Outdoor air flow rate from table ASHRAE

R_a = Outdoor air flow rate required per unit area from table ASHRAE

P_z = number of people in the area

A_z = zone floor area

Table 4.22: Ventilation rate and breathing zone outdoor airflow, V_{bz}

FKM Classroom	Actual ventilation rate	Breathing air outdoor airflow, V_{bz}
Classroom 4	545.69 CFM	360.21 CFM

The installation of exhaust fan is requiring appropriate position as its aim is to remove moisture contents, odours and contaminants by boosting the level of indoor air quality. In consequence, the suggestion of exhaust fan based on calculation of breathing air outdoor airflow, V_{bz} have been tabulated in Table 4.16. Although the ventilation rate is not within the ventilation range recommended, yet it is still acceptable as the actual ventilation rate is higher than the breathing air outdoor airflow, V_{bz} value.

Table 4.23: Specification of exhaust fan

Type/ Model	Ceiling or Wall Mount Utility Ventilator w/ Grill 400 CFM Variable Speed FF400

	
Brand	Soler & Palau
Size	Width: 23-1/4" Depth: 14" Height: 11-3/4"
Capacity	400 CFM

4.4.2 Improvement Measures in FPTT

1. Installation of exhaust fan

Simultaneously by referring to physical assessment in FPTT classroom, either none of the classroom's average temperature comply with Malaysian Standard 1525. However, according to the subjective assessment also 73.33% of respondents voted as satisfied with the average air temperature.

Table 4.24: Ventilation rate and breathing zone outdoor airflow, V_{bz}

FPTT Classroom	Actual ventilation rate	Breathing air outdoor airflow, V_{bz}
Classroom 5	585.93 CFM	449.84 CFM
Classroom 8	598.63 CFM	410.64 CFM
Classroom 11	971.73 CFM	358.29 CFM

Based on the table 4.25, it resulted that the actual ventilation rate at FPTT classroom 11 is higher compare to classroom 5 and 8 individually. Classroom 11's carbon dioxide level also compatible with the ASHRAE standard 62.1 as it was within the range for both morning and afternoon session. However, the relative humidity level for both session do not comply with ASHRAE standard 62.1.Thus, it is required to enhance adequate humidity level in classroom as it may also lead to illness, trigger allergic reactions. Based on ventilation rate a proper exhaust fan required to be mounted in classroom BK 11. It is acceptable condition, as the breathing air outdoor airflow is still less than the actual ventilation rate obtained. Similarly, for classroom 5 and 8 of FPTT, the carbon dioxide level doesn't achieve the minimum requirement of carbon dioxide value suggested by ASHRAE standard 62.1. The breathing air outdoor airflow is also less than the actual ventilation rate obtained for classroom 5 and 8 respectively which lead to the ability to the acceptance. Overall, all 3 classroom required to install exhaust fan to promote with good air circulation. The exhaust fan that is recommended based on actual ventilation rate is axial flow fan which comes with range of 50 cfm to 1500 cfm. This exhaust fan is suitable not only to all 3 classroom of FPTT but within breathing air outdoor airflow, V_{bz} which is 1500cfm. This exhaust is highly recommended to the space which necessarily required to improve ventilation. It is also a simple structure and convenient to install as well as to maintain well.

Table 4.25: Specification of exhaust fan

Type/ Model	Axial flow fan

	
Brand	Everon
Size	Minimum 32” inches
Capacity	50-1500 CFM

2. Installation of air purifier

Next, another way to improve the indoor air quality is by enhancing the utilization of wall mounted air purifier in into the classroom walls. The main goal of air purifier is to eliminate contaminants or impurities to supply with clean air to the surrounding. The air purifier must be mounted to the wall of each classroom. The air purifier also comes with display screen where it will show the particulate matter 2.5 and 10 values with also odour level of that particular room.

Table 4.26: Specification of air purifier

Type/ Model	AeraMax PRO AM 4 PC Air Purifier 120V

	
Brand	Fellowes Brands
Size	19.50 x 37.00 x 9.50 (inches)
Capacity	600 to 1400 square feet

4.4.3 Improvement measures in overall building of FKM and FPTT

1. Installation of automated shading system

In order to improve the overall indoor environmental quality, factors that influencing them needed to be prioritized such improving in terms of thermal comfort and indoor air quality. This can be initiated from the existing natural ventilation which includes the operable window. It is best to install the automatically operable window with shading in the side walls of the classroom. It is required to be positioned at least 2 metres or higher from the level of floor. This is because the shading which installed on window, can eliminate the heat gain towards the building. In order to prevent heat from hitting the window, this shading will block the sunlight. Automated shading system will help in increasing thermal comfort by lowering the temperature of surface of existing window wall. It usually comes with remote controller or Wi-Fi system in order to control its operation as per individual preference.

Figure 4.59: Automated shading system

2. Installation of cool roof system

In addition, the modification can be done to both buildings' roof for a better enhancement in improvisation of indoor environmental quality. Roof act as one of the most important aspect that covers up the building. Its main aim is to provide security, privacy or safety to the individual who occupy any building. Instead of using most common roof types such as thermoplastic roof membrane, modified bitumen roofing and so on, the roof can be replaced with cool roof. This roofing system by utilizing cool roofs have the capability promote greater reflectance of solar from the sun. This means that the roofing system will reflect back either visible or invisible wavelength from sun. Cool roofs are usually come in the colour of white or lighter colours. Typically, the roofing system in Malaysia is in darker shade of colour which absorb more heat. Hence, the absorbed heat will be dissipated and makes the internal building even warmer or hotter. Cool roof not only decreases cooling load of buildings, but eventually will lower the utility bills as well. It will be great way to even prevent 'heat island effect' from this solution. Since cool roof reduces internal air temperature of building without even utilizing air conditioning system, the energy will be saved even drastically. If less energy is been used, the indoor environment quality will be developed and improved.

Figure 4.60: Cool roof system by BMI Group

3. Maintenance of Heat, Air Ventilation, and Cooling system

Moreover, proper maintenance of HVAC system is compulsory to be concerned. This can be done through scheduled inspection in HVAC system. For example, the evaporator coil of air conditioner will be collecting dirt and contaminant for every bit of months. In order to protect the coil, it is necessary to include air filter. Although, coils are protected by air filters, the dirt will still present. Hence, inspecting the evaporator annually or whenever necessary will protect the whole system by not causing blockage to the airflow. It is important to eliminate the debris by at least 2 feet will promote good air flow throughout condenser.

Furthermore, as mentioned earlier it is important to also clean or replace air filter routinely. The efficiency of system will be effected if there is dirt present as it leads to blockage of airflow. Hence, if there is contaminants, it will be trapped by air filters in order to distribute clean air to the surrounding.

4. Installation of plasterboard.

The neutral operative temperature obtained for both buildings are 26.85 ºC and 27.93 ºC from regression of PMV and operative temperature respectively. Hence, installation of "Gyproc Thermaline" thermal plasterboard to the wall of the building can make the temperature to improved and be within the recommended range by Malaysian Standard 1525. This is because the thermal plasterboard is laminated with heat insulation materials. It can be mounted in wall lining and also ceiling applications. It even can lowers the utilization of air conditioning system inside the building as comes with great heat protection. Thermal plasterboard also does not contains any harmful substance. Moreover, the plasterboard which is known "ACTIV'AIR" uses special technology in order to remove harmful gases such as formaldehyde. Formaldehyde have a possible link to severe diseases such as cancer which death threatening for human beings. Hence, by installing "ACTIV'AIR" plasterboard, those formaldehyde will be converted into compound of inert by absorbing them around 70 %. This is one of the way to improve the indoor environmental quality of the buildings.

Figure 4.61 : Activ'Air Plasterboard by Gyproc Saint-Gobain

Figure 4.62 : Gyproc Thermaline Plasterboard by Gyproc Saint-Gobain

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As a conclusion, Post Occupancy Evaluation (POE) is conducted in this study to evaluate the indoor environmental quality of FKM and FPTT buildings especially in terms of thermal comfort and indoor air quality parameter. As per the outcomes from the physical measurement it resulted that indoor air temperature in FKM is not complying with the Malaysian Standard 1525:2019. Meanwhile, the air temperature of FPTT classrooms also not complying with Malaysian Standard 1525:2019. Furthermore, the PMV and PPD index of FKM classroom not complying with ASHRAE Standard 55. However, for FPTT classroom the PMV index value is complying with the ASHRAE Standard 55 but the PPD index not within the recommended range. The carbon dioxide level is not within the recommended range by ASHRAE Standard 62.1 for both faculty classes except for classroom 11 of FPTT. Simultaneously, the concentration of particulate matter 2.5 and 10 is within the recommended range where the values are much lower from the maximum allowable range by ASHRAE Standard 62.1.

In contrast, observation through subjective assessment resulted that that there are no respondents exceeded 80% of votes for the central three categories which are slightly cool, neutral and slightly warm conditions. Thus, it indicates that both faculty's classroom has not achieved the thermal acceptable conditions in terms of thermal sensation. Moreover, for the case of relative humidity, majority of the occupants expressed more satisfaction level in FKM classroom compare to FPTT classroom. Nevertheless, more than 80% of the respondents voted for interval (-1, 0, 1). Thus, it shows that air velocity condition in FPTT classrooms is considered acceptable. Majority of the occupants also expressed higher satisfaction level towards overall comfort perception in FPTT.

According regression analysis, the neutral operative temperature for FKM and FPTT are 26.85ºC and 27.93ºC respectively from PMV regression. The neutral temperature obtained from PMV regression is more compatible with other researches compare to neutral operative temperature from TSV regression in both FKM and FPTT.

Upon conducting this study, it is identified that analysis in the form of physical measurement, subjective analysis and regression analysis between parameters are fundamental in order to improve the indoor environmental quality. Proactive solutions can be given based on analysis to make the obtained values to be achievable as per recommended by relevant standard such as Malaysian standard 1525, ASHRAE Standard 55 and ASHRAE Standard 62.1. According to the whole outcome, it is best to work on improvisation of the ventilation system as it will help to boost to good thermal comfort and indoor air quality. Hence, good thermal comfort criteria and indoor air quality brings to excellent overall indoor environmental quality of the building. Eventually, this improvised indoor environmental quality in practical in both faculty will enhance students' performance.

5.2 Recommendation

In this study, the result for regression analysis between the measurement parameters and sensation vote of occupants shows not so strong relationship. This is because the sample classroom that were chosen are with random number of occupants which varies from each classroom. Consequently, for future research, researchers should focus on greater number of occupants during both physical measurement and subjective assessment. Moreover, number of classrooms chosen as sample also required to be equal for a better outcome of results. This is because, the sample for FKM were one while sample represents FPTT building were three. Particularly, the higher target towards FPTT building in this research as it is a new building and required to conduct Post Occupancy Evaluation to evaluate the indoor environmental quality.

In order to strengthen indoor environmental quality in both faculties, the best initiative is through improvising the ventilation system. This ventilation recommendation was given based on the calculation of ventilation rate according to ASHRAE Standard. The selection of exhaust fan for both faculties were purely from calculation of the air flow in term of cubic feet per minute. However, future researchers recommended to choose the ventilator by including additional parameters such as simulation and loudness limit. Within limited time, the suggestions of ventilators have been given. To enhance better accuracy and suitability of suggestion, sound or noise generated by the fan also required to be concerned as it may causes disruption for students' performance in classroom.

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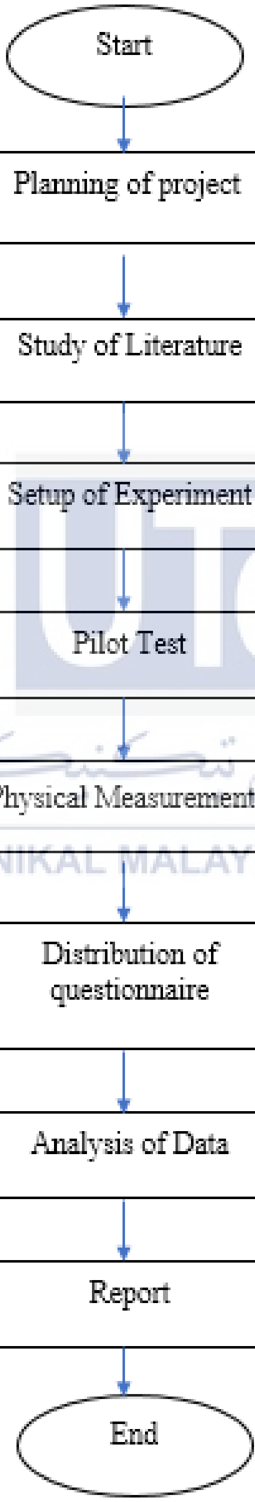
APPENDIX A

Flow Chart of Final Year Project



APPENDIX B

Gantt Chart of PSM 1

TASK	**WEEK**																
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**17**	**18**
TOPIC SELECTION								**MID SEMESTER BREAK**									
PROJECT PLANNING																	
PREPARATION OF CHAPTER 1																	
LITERATURE STUDY																	
PREPARATION OF CHAPTER 2																	
PROGRESS REPORT																	
PREPARATION OF CHAPTER 3																	
PSM 1 REPORT																	
PSM PRESENTATION																	
DATA MEASUREMENT																	

APPENDIX C

Gantt Chart of PSM 2

TASK	WEEK														
DATA MEASUREMENT								MID SEMESTER BREAK							
QUESTIONNAIRE DISTRIBUTION															
ANALYSIS OF OBJECTIVE MEASUREMENT															
ANALYSIS OF SUBJECTIVE MEASUREMENT															
SUGGEST IMPROVEMENT															
PSM 2 REPORT															
PSM 2 PRESENTATION															

APPENDIX D

Plan of Faculty of Technology Management & Technopreneurship (FPTT)

APPENDIX E

Questionnaire for Faculty of Mechanical

SURVEY ON "OCCUPANTS' SATISFACTION TOWARDS INDOOR ENVIRONMENTAL QUALITY OF CAMPUS TECHNOLOGY BUILDING(FKM-MORNING)"

Hi everyone!!

This survey is for Final Year Project with the aim to study occupants' satisfaction on indoor environmental quality of campus technology buildings in Universiti Teknikal Malaysia Melaka.This is part of Post Occupancy Evaluation(POE) that conducted to identify the performance of the building based on occupants response.

Your kind feedback in completing this questionnaire is highly appreciated.

Thank you.
THAMARAI VATHANI ELANGKOVAN
Final Year, Mechanical Engineering
Universiti Teknikal Malaysia Melaka.

*Required

SECTION A : BACKGROUND

1. Gender. *

- Male
- Female

2. Occupation *

- Student
- Staff
- Other

3. Status *

- Full time
- Part time

4. Age *

- Below 18
- 18-23
- 24-50

5. Time spent in building *

- less than 1 hour
- 1-2 hours
- 3-4 hours
- 5-6 hours
- 7-8hours
- more than 8 hours

Section B: Air Quality

1. Does the quality of air in this part of building have any negative effect on your performance? *

	1	2	3	4	5	6	7	
Not significant	○	○	○	○	○	○	○	Very significant

2. Is the air humid or dry? *

	1	2	3	4	5	6	7	
Too humid	○	○	○	○	○	○	○	Too dry

3. Air fresh or stale? *

	1	2	3	4	5	6	7	
Stale	○	○	○	○	○	○	○	Fresh

4. Does air have any odour? *

	1	2	3	4	5	6	7	
Very Strong Odour	○	○	○	○	○	○	○	No Odour

5. Is there air movement? *

	1	2	3	4	5	6	7	
Very Draughty	○	○	○	○	○	○	○	Very Still

6. Do you have control over ventilation? *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

SECTION C: TEMPERATURE

1. Does the temperature in this part of building causes negative effect on your performance? *

	1	2	3	4	5	6	7	
Not significant	○	○	○	○	○	○	○	Very Significant

2. The temperature is too cold or hot? *

	1	2	3	4	5	6	7	
Too cold	○	○	○	○	○	○	○	Too hot

3. Do you have control over the temperature? *

	1	2	3	4	5	6	7	
No control	○	○	○	○	○	○	○	Full control

4. Do you sweat during lecture hours which leads to uncomfortability? *

	1	2	3	4	5	6	7	
Not significant	○	○	○	○	○	○	○	Very significant

5. How do you rate the overall acceptability of thermal environment at this moment? *

	1	2	3	4	5	6	7	
Too bad	○	○	○	○	○	○	○	Too good

6. Are you satisfied with the current temperature in your classroom? *

	1	2	3	4	5	6	7	
Not satisfied	○	○	○	○	○	○	○	Very satisfied

SECTION D: SUGGESTIONS

1. Are you satisfied with the overall indoor environmental quality of the technology campus in Utem?

	1	2	3	4	5	6	7	
Not satisfied	○	○	○	○	○	○	○	Very satisfied

2. Suggest improvements that can be made to improve the quality of indoor environment for campus technology buildings. * *

Your answer

Thank you so much for your co-operation and time.

APPENDIX F

Questionnaire for Faculty of Technology Management and Technopreneurship

SURVEY ON "OCCUPANTS' SATISFACTION TOWARDS INDOOR ENVIRONMENTAL QUALITY OF CAMPUS TECHNOLOGY BUILDING(FPTT-MORNING)"

Hi everyone!!

This survey is for Final Year Project with the aim to study occupants' satisfaction on indoor environmental quality of campus technology buildings in Universiti Teknikal Malaysia Melaka.This is part of Post Occupancy Evaluation(POE) that conducted to identify the performance of the building based on occupants response.

Your kind feedback in completing this questionnaire is highly appreciated.

Thank you.
THAMARAI VATHANI ELANGKOVAN
Final Year, Mechanical Engineering
Universiti Teknikal Malaysia Melaka.

*Required

SECTION A : BACKGROUND

1. Gender. *

- Male
- Female

2. Occupation *

- Student
- Staff
- Other

3. Status *

- Full time
- Part time

4. Age *

- Below 18
- 18-23
- 24-50

5. Time spent in building *

- less than 1 hour
- 1-2 hours
- 3-4 hours
- 5-6 hours
- 7-8hours
- more than 8 hours

Section B: Air Quality

1. Does the quality of air in this part of building have any negative effect on your performance? *

	1	2	3	4	5	6	7	
Not significant	○	○	○	○	○	○	○	Very significant

2. Is the air humid or dry? *

	1	2	3	4	5	6	7	
Too humid	○	○	○	○	○	○	○	Too dry

3. Air fresh or stale? *

	1	2	3	4	5	6	7	
Stale	○	○	○	○	○	○	○	Fresh

4. Does air have any odour? *

	1	2	3	4	5	6	7	
Very Strong Odour	○	○	○	○	○	○	○	No Odour

5. Is there air movement? *

	1	2	3	4	5	6	7	
Very Draughty	○	○	○	○	○	○	○	Very Still

6. Do you have control over ventilation? *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

SECTION C: TEMPERATURE

1. Does the temperature in this part of building causes negative effect on your performance? *

	1	2	3	4	5	6	7	
Not significant	○	○	○	○	○	○	○	Very Significant

2. The temperature is too cold or hot? *

	1	2	3	4	5	6	7	
Too cold	○	○	○	○	○	○	○	Too hot

3. Do you have control over the temperature? *

	1	2	3	4	5	6	7	
No control	○	○	○	○	○	○	○	Full control

4. Do you sweat during lecture hours which leads to uncomfortability? *

	1	2	3	4	5	6	7	
Not significant	○	○	○	○	○	○	○	Very significant

5. How do you rate the overall acceptability of thermal environment at this moment? *

	1	2	3	4	5	6	7	
Too bad	○	○	○	○	○	○	○	Too good

6. Are you satisfied with the current temperature in your classroom? *

	1	2	3	4	5	6	7	
Not satisfied	○	○	○	○	○	○	○	Very satisfied

SECTION D: SUGGESTIONS

1. Are you satisfied with the overall indoor environmental quality of the technology campus in Utem?

	1	2	3	4	5	6	7	
Not satisfied	○	○	○	○	○	○	○	Very satisfied

2. Suggest improvements that can be made to improve the quality of indoor environment for campus technology buildings. * *

Your answer

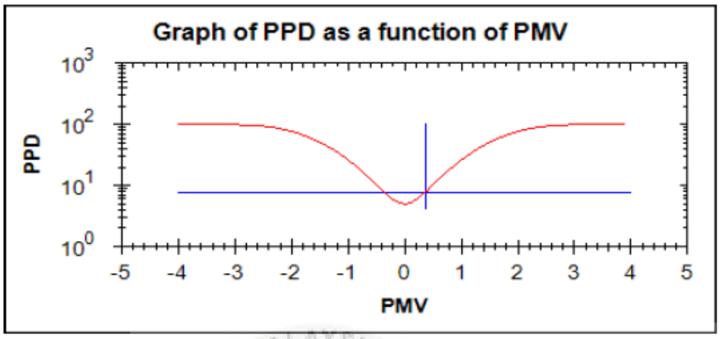
Thank you so much for your co-operation and time.

APPENDIX G

Graphs of PPD as a function of PMV for Faculty of Mechanical

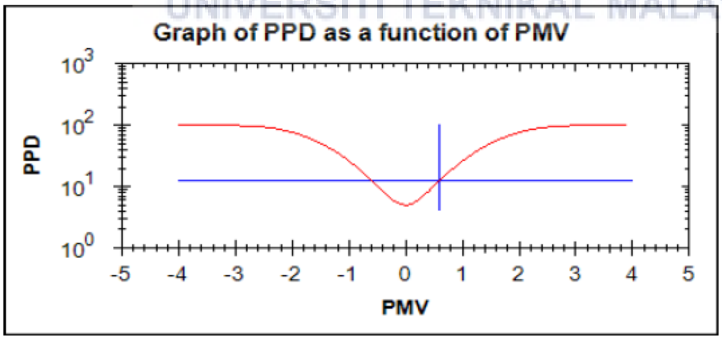
Morning Session (10am to 12pm)

Overall result:	
Predicted Mean Vote PMV	0.31
Predicted Percentage of Dissatisfied - PPD	7.97



Zone 1

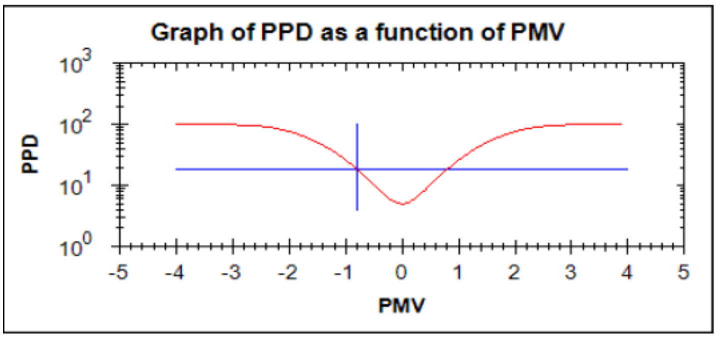
Overall result:	
Predicted Mean Vote PMV	0.5
Predicted Percentage of Dissatisfied - PPD	10.87



Zone 2

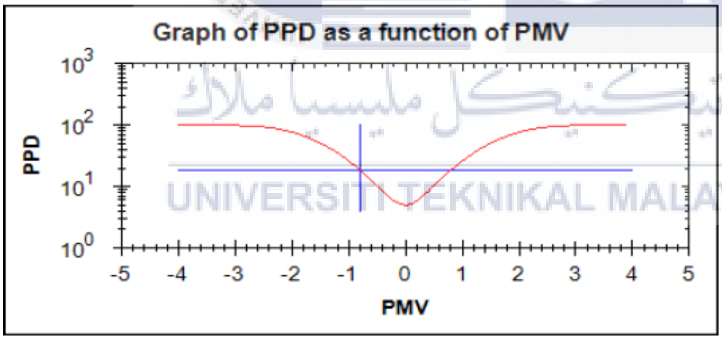
Afternoon session (2pm-5pm)

Overall result:	
Predicted Mean Vote PMV	-0.78
Predicted Percentage of Dissatisfied - PPD	19.54



Zone 1

Overall result:	
Predicted Mean Vote PMV	-0.78
Predicted Percentage of Dissatisfied - PPD	19.54



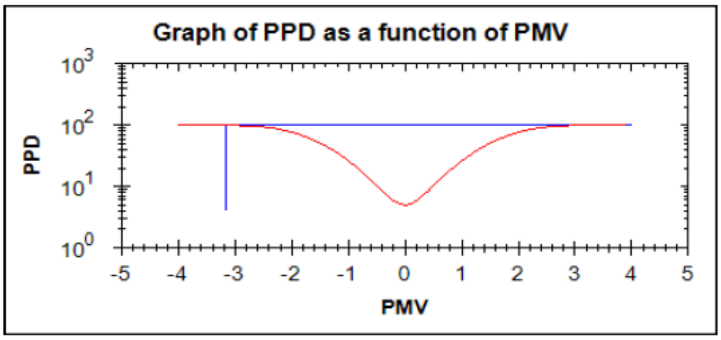
Zone 2

APPENDIX H

Graphs of PPD as a function of PMV for Faculty of Technology Management and Technopreunership (FPTT)

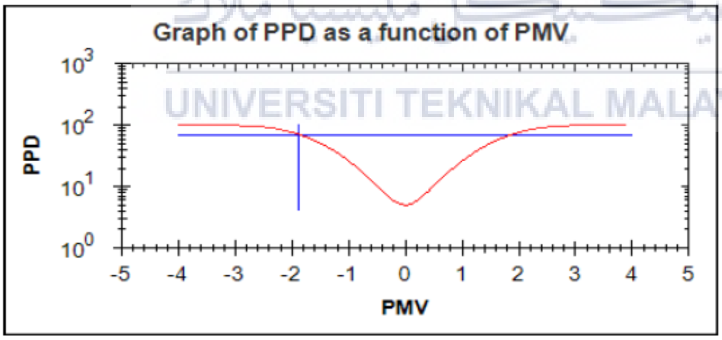
Morning session (10am to 12pm) of BK 5

Overall result:	
Predicted Mean Vote PMV	-3.08
Predicted Percentage of Dissatisfied - PPD	91.87



Zone 1

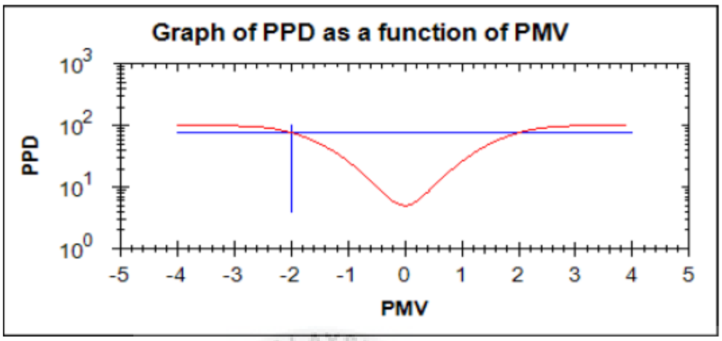
Overall result:	
Predicted Mean Vote PMV	-2
Predicted Percentage of Dissatisfied - PPD	71.75



Zone 2

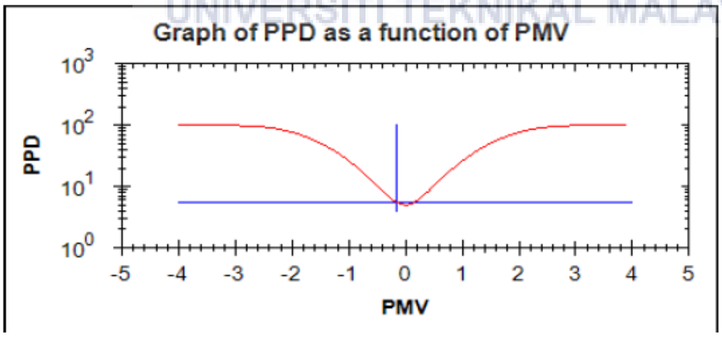
Afternoon session (10am to 12pm) of BK 5

Overall result:	
Predicted Mean Vote PMV	-2.14
Predicted Percentage of Dissatisfied - PPD	73.75



Zone 1

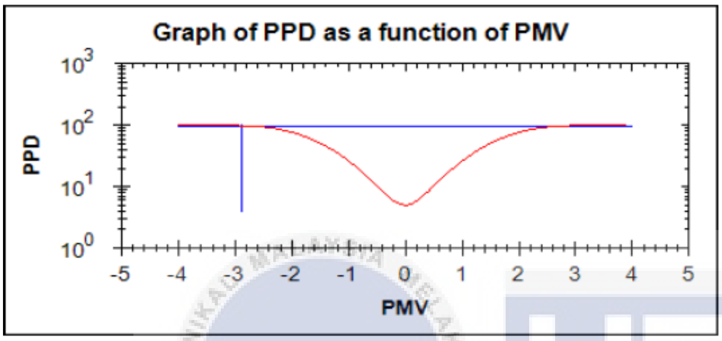
Overall result:	
Predicted Mean Vote PMV	-0.16
Predicted Percentage of Dissatisfied - PPD	5.77



Zone 2

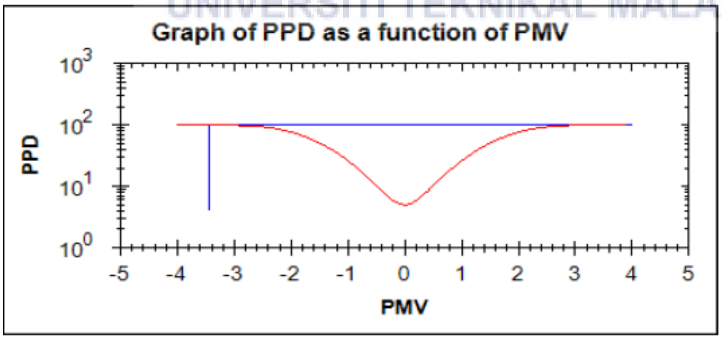
Morning session (10am to 12pm) of BK 8

Overall result:	
Predicted Mean Vote PMV	-2.56
Predicted Percentage of Dissatisfied - PPD	68.7



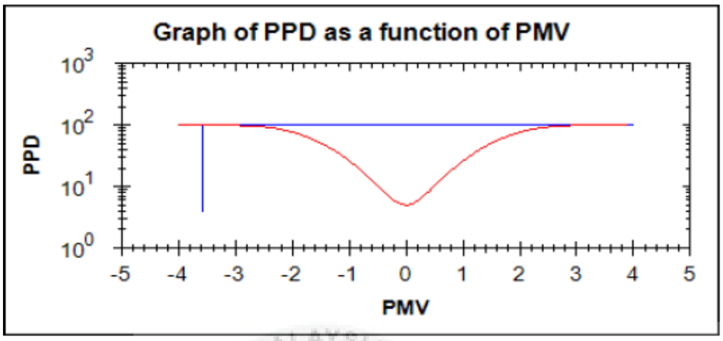
Zone 1

Overall result:	
Predicted Mean Vote PMV	-3.35
Predicted Percentage of Dissatisfied - PPD	96.75



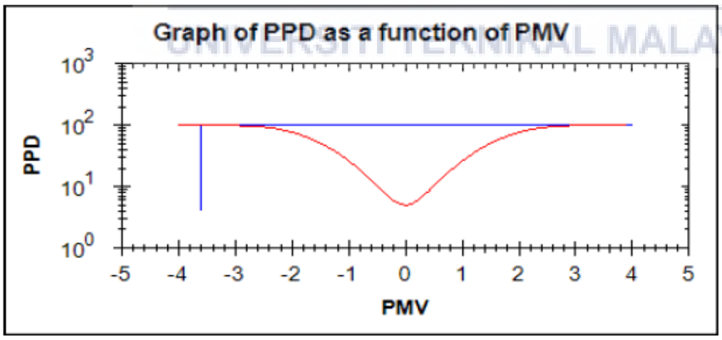
Afternoon session (2pm to 5pm) of BK 8

Overall result:	
Predicted Mean Vote PMV	-3.4
Predicted Percentage of Dissatisfied - PPD	94.2



Zone 1

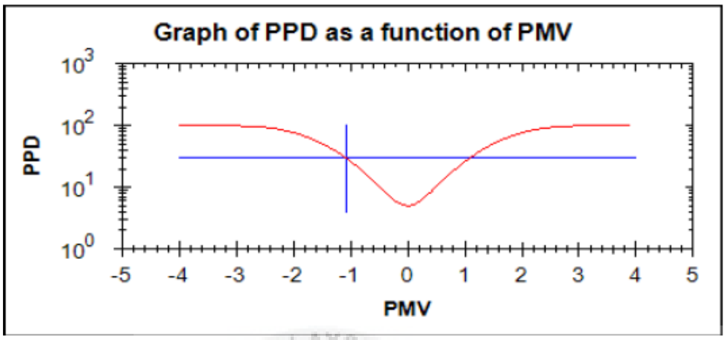
Overall result:	
Predicted Mean Vote PMV	-3.54
Predicted Percentage of Dissatisfied - PPD	97.8



Zone 2

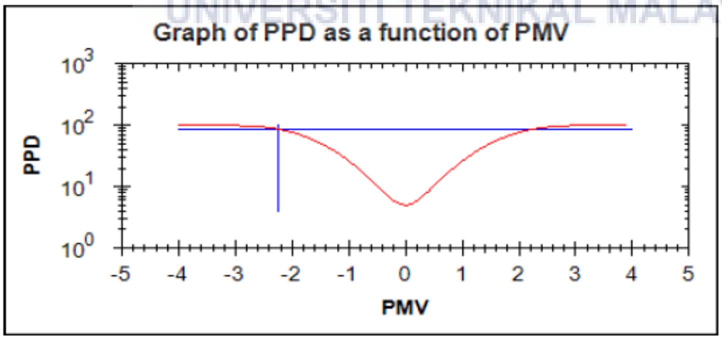
Morning session (10am to 12pm) of BK 11

Overall result:	
Predicted Mean Vote PMV	-1.31
Predicted Percentage of Dissatisfied - PPD	41.06



Zone 1

Overall result:	
Predicted Mean Vote PMV	-2.2
Predicted Percentage of Dissatisfied - PPD	80.63

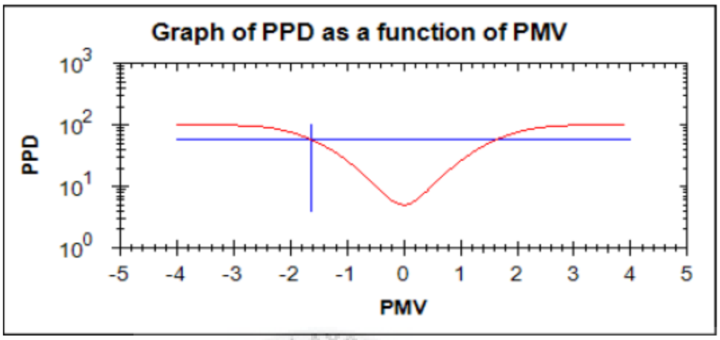


Zone 2

Afternoon session (2pm to 5pm) of BK 11

Overall result:

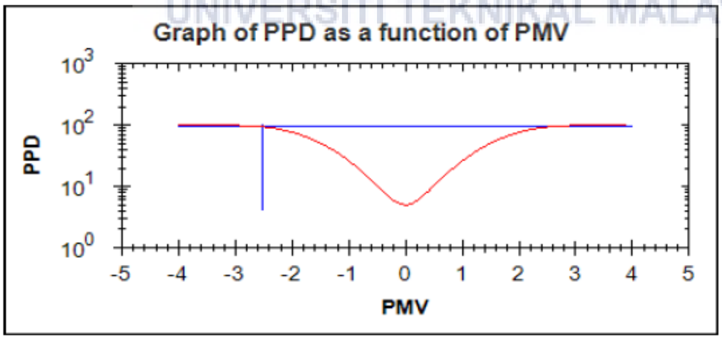
Predicted Mean Vote PMV	-1.84
Predicted Percentage of Dissatisfied - PPD	67.24



Zone 1

Overall result:

Predicted Mean Vote PMV	-2.49
Predicted Percentage of Dissatisfied - PPD	87.71



Zone 2

APPENDIX I

Pictures of Physical Measurement


FKM
12