ASSESSMENT ON INDOOR ENVIRONMENTAL QUALITY (IEQ) WITH THE APPLICATION OF POTTED PLANTS IN THE CLASSROOM: CASE OF UNIVERSITY MALAYA

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ABSTRACT

Nowadays, the importance of the indoor environmental quality (IEQ) has become more serious as it is highly related to the satisfaction of the occupants. However, most building occupants are not normally aware of the importance of the Indoor Environmental Quality (IEQ). Good IEQ specifically for educational oriented environment should be focused on as it affects students' learning performance. Therefore, two methods have been specifically selected for this research. One is classroom environment intervention and the other is by classroom measurement set up. In both conditions, the sampling devices were placed for 2 weeks in certain selected locations to see any changes on environment in the classroom. Measurement of thermal comfort and indoor air quality were recorded and at the same time questionnaires were distributed among the students in order to identify their satisfaction. Results for the measurement in normal condition show that the level of VOC was high (11.7ppm). However, by placing the selected potted plants during the intervention, the action has decreased the level of relative humidity, level of CO_2 and TVOC.

Keywords: *Indoor Environment Quality (IEQ), Classroom, Intervention Setting, Measurement Set Up, Educational Building And Landscape.*

1. INTRODUCTION

Many researchers suggests that IEQ affect occupants' performance and exemplified in the work undertaken by Fisk, 2000 and Mendell et al., 2002 which show that poor indoor environment affects the student learning process in schools. Indoor environmental quality (IEQ) is defined as the building's environment quality related to health and wellbeing of building occupants (NIOSH, 2013). A further definition is given by Hill MC, 2009 who describes IEQ as a satisfactory condition of environment such as lighting, temperature, and space management which play important roles in improving students' satisfaction towards learning environments.

There are many factors of IEQ that may affect student's performance. It is down to the fact that different buildings would have different environmental qualities attached to it depending on the types of activities. Since the climate in Malaysia is classified as being hot and humid throughout the year, this might result in dissatisfaction among the building occupants regarding the IEQ issues of building, with particular emphasis on thermal comfort.

The study by Khadijah et al.(2013), were carried out in classrooms on the second floor at a local school in Bandar Baru, Selangor to assess the thermal condition during teaching lessons. This study was carried out for five consecutive days from 2pm to 6pm. The result shows that both students and teachers were not satisfied with the environment quality in their classrooms. They answered lack of ventilation as the main reason. Besides that, the layout plans of the classes need to be changed as the position of the students which were close to each and every table led to the discomfort of the students. As every human body produces heat transfer, by sitting close to each other, it contributes the feeling of thermal discomfort.

However, in general the occupants of the building do not give enough consideration on the effects of IEQ within their surroundings especially in the learning environment. Existing knowledge is still limited concerning the desirable levels of air quality, maintenance, and other factors affecting IEQ in Malaysian educational establishments. According to Turunen et al.(2014) poor IEQ will not only affect their health symptoms but also decrease the focus of students in the classrooms. Findings show correlation between headaches, dizziness, heavy head, tired, difficulties in concentrating, unpleasant odor, and high CO_2 concentrations with health symptoms that felt by the students due to poor environment quality. One way of preventing this is by using plants. The aim of using plants is to decrease the effects of IEQ especially for indoor air pollutants. However, according to Wood et al.(2006) the studies on the ability of potted-plants reducing air-borne contaminants in improving the air quality are still limited.

Other than that, ASHRAE, (2008) described that good IEQ can help and improve the learning process of students. Based on the basic space and function of educational buildings, where teaching and learning are the priorities, it is predicted that universities may also be facing similar problems with the IEQ in their classrooms. Therefore, this research is conducted to study the occupants' perception on how different environment gives different impacts on them.

EFFECTS OF IEQ TOWARDS LEARNING ENVIRONMENT PROCESS

Learning environment is the most critical environment because it relates to many actions in general (Higgins et al., 2005). According to Walinder, R., Gunnarsson, K., Runeson, R., Smedje, (2007), noise might cause headache and fatigue among students. Noise, light, color and temperature are the examples of physical variables in environment which give effects towards learning places as well as learning process. Previous researches conducted by Yuan et al., (1998), showed that the displacement ventilation leads to uncomfortable environment which was caused by the differences in the vertical temperature and the ventilation drafts which give poor quality environment towards the occupants.

Besides that, Turunen et al., (2014) assessed the IEQ in one of the elementary school buildings in Finnish. This research was conducted to find out how IEQ in school may affect the health and academic performance of students. In this study, the method used by the researchers was the "Indoor Environmental Quality and Academic Performance in Schools" which was based on Haverinen-Shaughnessy, et al (2012). They conducted mathematical test in random sample of 355 respondents of elementary schools in cooperation with the Finnish National Board of Education as a part of the national testing program. Health questionnaires were sent to the same schools in order to get responses from the students. Results showed that the most elements of IEQ factors that affect the condition of classroom were noise and poor IAQ.

IEQ IN CLASSROOM

A better IEQ can help improving learning process of students (ASHRAE, 2008). Generally, classroom been seen as a place for students to pursue their learning process. Thus, to get a quality environment in the classrooms, design comfort and the occupants' safety play important roles to prevent the occupants from any distractions. A good design of building will give a good influence on the building occupants' performance (NIOSH, 2013). Based on the previous research by Felix (2011), physical attributes could be classified into three categories.

The first category is the ambient environment, including attributes such as temperature, air quality, acoustics, lighting and daylight. The second category consists of attributes related to the spatial environment, such as classroom layout and furniture (Fu,2010) visibility and accessibility of sightline (Kenneth, 2000). Besides that, Yang (2007) explained that, the third category encompasses technology-related attributes including appropriate functions of high-tech hardware, ease of software use, and speed of internet transfers. These three types are related to the learning outcomes and student behavior which would turn into student satisfaction and performance.

IEQ has been found as to support but also as an obstruction to performance, comfort and satisfaction to people (Bako-biro, et al., 2012). Therefore, one proven method is by conducting a quantitative research method to the selected building to determine whether the IEQ elements may influence the environment of the building occupants. According to Corgnati, Ansaldi, & Filippi, (2009), educational building is classified as a building which needs a good environmental quality which results in occupant's performance. In the classroom, an evaluation of student's opinions and perceptions towards environment on their learning process is important in order to find out the impact on their performance.

INDOOR AIR POLLUTANTS

There is a risk that students in educational buildings will be exposed to many indoor or outdoor pollutant sources. According to Pegas, Nunes, Alves, Silva, Vieira, Caseiro (2012), pollutants inside the educational building may affect students' health, their learning performance and also attendance. Other than that, sources of indoor air pollutants are based on specific sources in the building such as furniture, chemical, building materials, food, water, smoking activity and also outdoor pollution. Besides that, according to Tucker, Brown, & Egan, (2008) most of indoor air pollutants are volatile organic compounds (VOC), formaldehyde, dust and other air borne particles. Therefore, by having good indoor air quality, it may prevent the effects of these pollutants on their health, performance and productivity.

According to Kim et al (2013), sources of formaldehyde emit from carpets, latex paint, cigarettes and building materials such as wood products and resins. This will lead to health problems such as respiratory tract irritation (asthma), allergy especially to the children and eye irritation. Besides that, Fantuzzi, et al. (1996) stated that the people are the most contributors of indoor dusts. Dust is made up of tiny particles carried by the air flow. Dust may come from formation of fracture process, such as grinding, crushing, or impacting. Industrial Code of Practice, (2010) stated that volatile organic compounds (VOC) are emitted from solvents during the maintenance or furnishing works. Some VOCs, including formaldehyde, in combination may under certain environmental and occupational conditions result in sensory irritation (Wolkoff et al, 2013). This will cause throat, eye and nose irritations, dizziness, headaches, cancers and others if the content exceeds 3 parts per million (ppm).

Carbon dioxide (CO_2) is one of the important indoor environmental parameters that must be controlled. Higher concentration levels of CO_2 may affect health, performance and productivity. Al-Rashidi et al. (2012), studied the concentration of carbon dioxide (CO_2) in the classrooms in Kuwait. He set up 10 classrooms in 3 schools which were occupied by the children of 6-10 years old. The indoor (air – conditioned phase) and outdoor (natural ventilation) concentration of CO_2 were measured in all classrooms.

In the natural ventilation phase, the windows and doors of the classrooms were opened in order to receive the airflow with high air change rate inside the classrooms for the comfort conditions. Compared to the air-conditioned phase, the windows and doors were closed to prevent any fresh 'air make up' and limit the natural ventilation which mainly rely on re-circulation of the room air. As a result, most of the classrooms show that there were lower CO_2 concentration levels (708ppm) in the natural ventilation compared to the classrooms with air conditioned which is 1596ppm.

Apart from that, Coley et al. (2007) conducted a study to find out the effect of low ventilation rates in the classroom using standardized and computerized tests. From the results obtained, there was a high level of CO_2 concentration in the classroom and this condition affected the students learning performance. Therefore, it can be proven that the comfort indoor concentration of carbon dioxide should not exceed 1000-1200ppm (background level 700ppm with typical outdoor carbon dioxide concentration ranges from 300-500ppm) (ASHRAE Standards 62-2001).

Thermal comfort is one of IEQ elements that may affect the building occupants' satisfaction. ASHRAE 55 (2004) describes there are six factors that affect the thermal comfort which are air temperature, air speed, mean radiant temperature, humidity, metabolic rate and also clothing levels. But Hensen, (1990) explained that building passive design structure, outdoor climate, occupants and Heating, Ventilation and Air Conditioning (HVAC) system as the factor influence in thermal condition. Based on (Seppanen, Fisk & Lei ,2006), indoor temperature may results in human behavior such as thermal comfort, Sick Building Syndrome System (SBS), perceived air quality and also work productivity.

In educational building, thermal comfort is given special attention because it might affect the overall activities of the building occupants. According to (Wong et al., 2003), high occupant density in the classroom may cause unsatisfactory thermal environment which will affect the students learning and performance. This is because thermal comfort is one of the elements that act as a significant role in teaching and learning lesson as it involves students' activities which may affect their performance in classroom (Wang et al., 2014). Therefore, based on Industrial Code of Practice (2010), indoor air temperature is standardized between 23^0 C to 26^0 C. This standard air temperature can be a guideline to others as well as give a comfortable environment for the occupants.

THE USE OF PLANTS TO IMPROVE INDOOR AIR QUALITY

Indoor air pollutant seems to be one of the factors that affect IEQ in the building. One of the examples of indoor air pollutants that is usually found is VOC. According to Aini Jasmin et al, (2012), VOC is one of the chemical compounds that able to affect the health of the building occupants. Previous researchers have suggested that plants can be used as an alternative to minimize the air pollution for better indoor air condition. According to Jim & Chen, (2008) plants can be used either indoor or outdoor as bio-filtering system.

During the process of photosynthesis, the plants absorb indoor air pollution into plant tissues through stomata together with the CO_2 while the O_2 is produced during the respiration process (Song et al., 2007). Next, the process of transfer of the pollutants in the tissues (Jim & Chen, 2008). According to National Aeronautics and Space Administration (NASA), the types of plants that are found to have the ability to improve indoor air quality are Peace Lily, Janet Craig, Spider Plant, Snake Plant, Golden Photos and many more. All of these plants have the ability to remove the air pollutants such as formaldehyde, carbon monoxide or other toxins or impurities.

2. MATERIALS AND METHODS

This research was conducted by using quantitative analysis which was the field work monitoring conducted at every designated area. The information of the measured indoor environmental quality is listed in Table 1.

Table 1: Research Methods

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.

CASE STUDY

Pusat Asasi Sains University of Malaya (PASUM) the centre of foundation studies in science was chosen as the case study. PASUM was established in 1977. The main objective of this foundation is to prepare the students to have comprehensive basic knowledge in all science-based subjects (mathematics, physics, biology, chemistry, etc.) in order to be competitive to enter critical science courses offered by the universities. The building is divided into two parts which are the new building and the old building which is also known as "Taman AsuhanJepun".

Figure1: Location Plan of Pusat Asasi Sains

Tutorial Room 7 (BT7) is one of the classrooms which is located at "Taman Asuhan Jepun". The classroom was built in 1977 which is almost 40 years ago. The classes are still being used even though the buildings can be categorized as one of the older buildings in University of Malaya. Figure 2.0 shows the overall condition of BT7. This classroom can occupy 20 to 30 students per time for tutorials or small group discussions. The classroom is only opened from 8a.m to 6p.m from Monday to Friday.

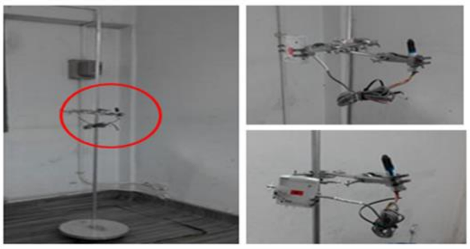
The classroom uses fully mechanical ventilation. There are two air conditioners placed in the classroom. However, one of the air conditioners that is located in front of the room is not functioning. Besides that, this classroom uses artificial lighting during learning process. This is because the classroom is dark even during daytime. There are also 6 tinted casement windows in this classroom. However, none of the window is opened during the learning process.

Figure 2: Overall Condition of tutorial room 7

SAMPLING DEVICES AND TOOLS

The tools used in this research are YESAIR and YESDUST (Indoor Air Quality Monitoring), hobo data logger and outdoor weather station. The tools were placed in the selected tutorial classrooms with different environment settings. Each of the tools has its own purpose as in Table2.

Table 2: Sampling devices

No	Tools/ Devices		Purpose
1	YESAIR and YESDUST (Indoor Air Quality Monitoring)	 Figure 3: YESAIR and YESDUST	To measure and monitor the element of the indoor environment quality in the classrooms such as relative humidity, temperature, particle matters, carbon dioxide and concentration of VOC.
2	Outdoor weather station	 Figure 4: Outdoor Weather Station at rooftop of the faculty	To measure the outdoor environment such as wind speed, wind direction and temperature. Located approximately 1.5km from the selected classroom.
3	HOBO data logger and air velocity	 Figure 5: HOBO Data Logger	To measure and monitor the element of indoor environmental quality in the classrooms instead of using YESAIR such as relative humidity, temperature and light intensity

SAMPLING LOCATIONS

The locations of the YESAIR, YESDUST, outdoor weather station and HOBO data logger are located within the designated areas of the classroom. Table 3 shows the sampling location for each of the devices. The sampling devices are located for 2 weeks during the field measurement to record the actual and current condition of the classroom as well as during the period of the intervention environment setting.

Table 3: Sampling locations

Sampling Devices	Sampling Locations
YESAIR and YESDUST	Selected Tutorial Classroom
Outdoor Weather Station	Rooftop of the Faculty of Built Environment, University Malaya
HOBO Data Logger	Selected Tutorial Classroom

2.1 QUESTIONNAIRE SURVEY

20 questionnaires were distributed to all students in the classroom (Tutorial Room 7) to investigate their satisfaction level. The questionnaires were mainly related to IAQ, acoustic quality, visual comfort, thermal comfort and effects of IEQ to the students' learning performance. All data collected from the questionnaire survey were analyzed with a statistical method using Microsoft Excel.

2.2 FIELDWORK MONITORING

Measurement will focus on temperature, ventilation and relative humidity and TVOC in the selected areas which might be considered as factors that can contribute to poor indoor air quality. There are 2 types of measurements, which are the existing classroom as in Fig.6 and intervention classroom environment as in Fig. 7

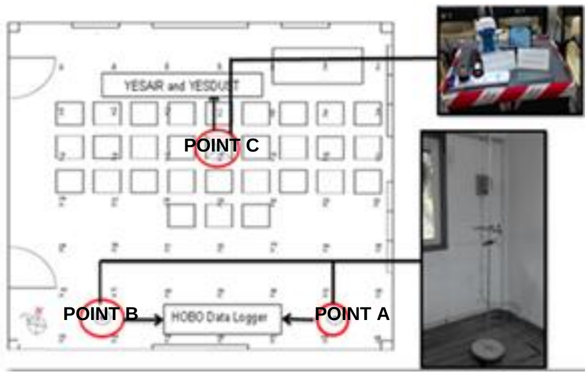


Figure 6: Classroom measurement set up

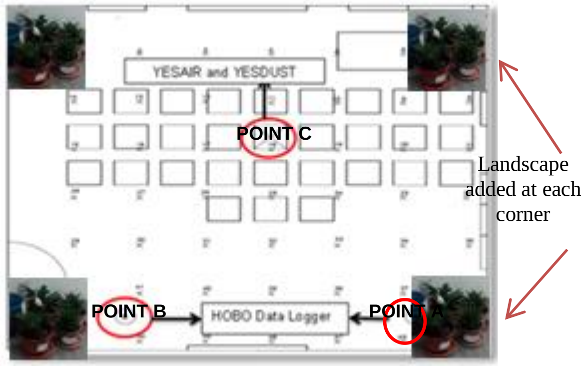


Figure 7: Intervention on the classroom environment

i. EXISTING CLASSROOM MEASUREMENT

Periodical monitoring on IEQ parameters which comprises of ventilation system and indoor air quality (IAQ) will be recorded. Different classroom environmental settings will be introduced, i.e. by adding plants to reduce the VOC levels in the classroom and the discussion will be based on the results of current IEQ condition in the classroom. This research will be conducted in Tutorial Room 7 (BT7) in the Centre for Foundation Studies in Science or also called as Pusat Asasi Sains, Universiti Malaya (PASUM). The area of the tutorial room is approximately 49m^2. The room mainly consisted of plastic furniture's which includes desks and chairs. Hence, the effects of fabrics that may absorb the contaminants and be released with time will not become a major issue in this study.

ii. CLASSROOM ENVIRONMENT INTERVENTION

The interventions of the environment will be designed to compare between the levels of IEQ in the classroom based on the current situation versus the measured level of the indoor environment – after the placement of the plants inside the classroom. The data collected during the existing condition of the classroom -shows that the rate of TVOC was significantly high which exceeded the standard threshold limit value (TLV). The potted plants are chosen in this intervention, as they are efficient in minimizing humidity and able to minimize the air pollutant in certain areas. The type of plants chosen for the purpose of this study is based on the suggestion by past studies which are (Orwell RL, 2004), (Orwell RL, 2006), (Wolverton, 1993), (Wolverton BC, 1989), (O. R. Wood RA, Tarran J, Torpy F, BurchettM, 2002) that reviewed on the ability of indoor plants to improve indoor air quality. Therefore, Peace Lily and Janet Craig have been selected in this research. Established studies pointed out that these plants were selected based on their effectiveness in removing indoor air pollutant, especially VOC. Besides that, the selection of plant to mitigate air pollution in a building does not only depend on their ability to clean the air but also on their growth habit, the ease of growing and maintaining them, their light requirement, and also their personal taste.

3. RESULTS AND DISCUSSIONS

3.1 Questionnaire Analysis

Figure 8 shows that the classroom is fully occupied with students from 1-3 hours on daily basis. Normal class session starts from 9.00 am daily and finishes at 5.00 pm. However, due to the varying time table schedules, most of the students spend less time in the classroom.

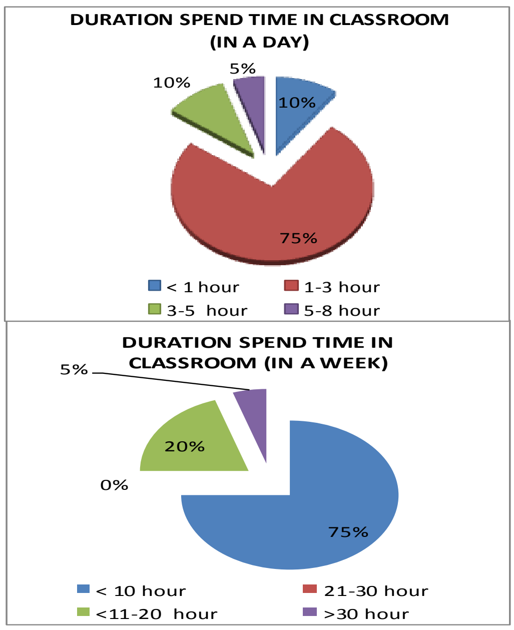


Figure 8: Daily and Weekly time duration spent in the classroom

Feedback from the questionnaires justified that the occupants' perceived learning productivity is not easily interfered by any of the elements of indoor environment quality probably due to the young age of the students. This explains that the respondents are neither easily affected by indoor environmental qualities nor susceptible to any health symptoms. Moreover, all possible health symptoms were found unnoticeable in the classroom (see Figure 9). However, there were a few health symptoms that have been identified such as stress, dry skin, itchy eye, blurred vision as well as tired eye.

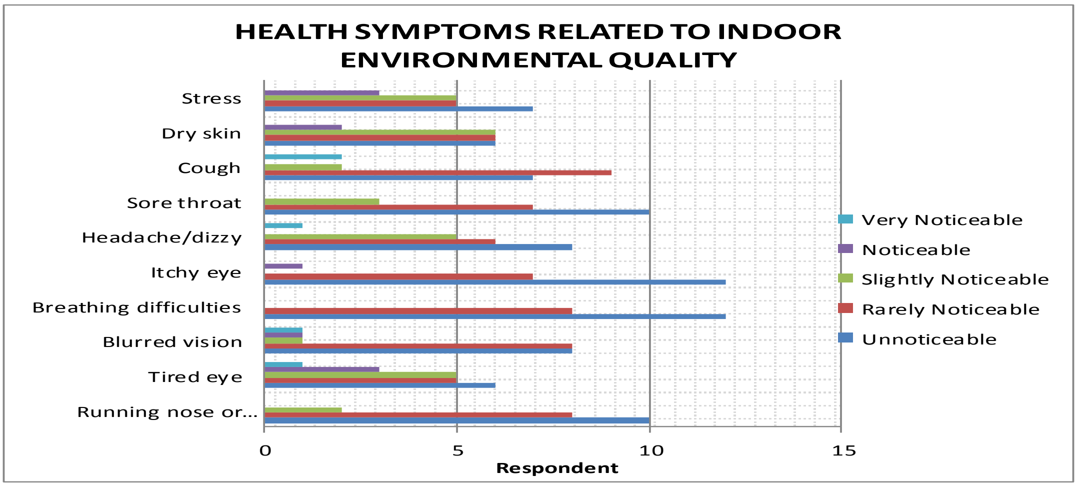


Figure 9: Health Symptoms Related to IEQ

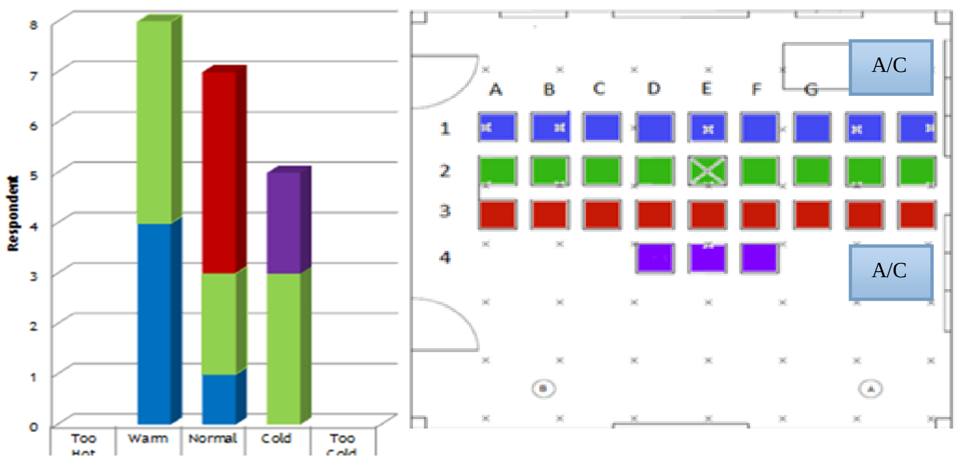
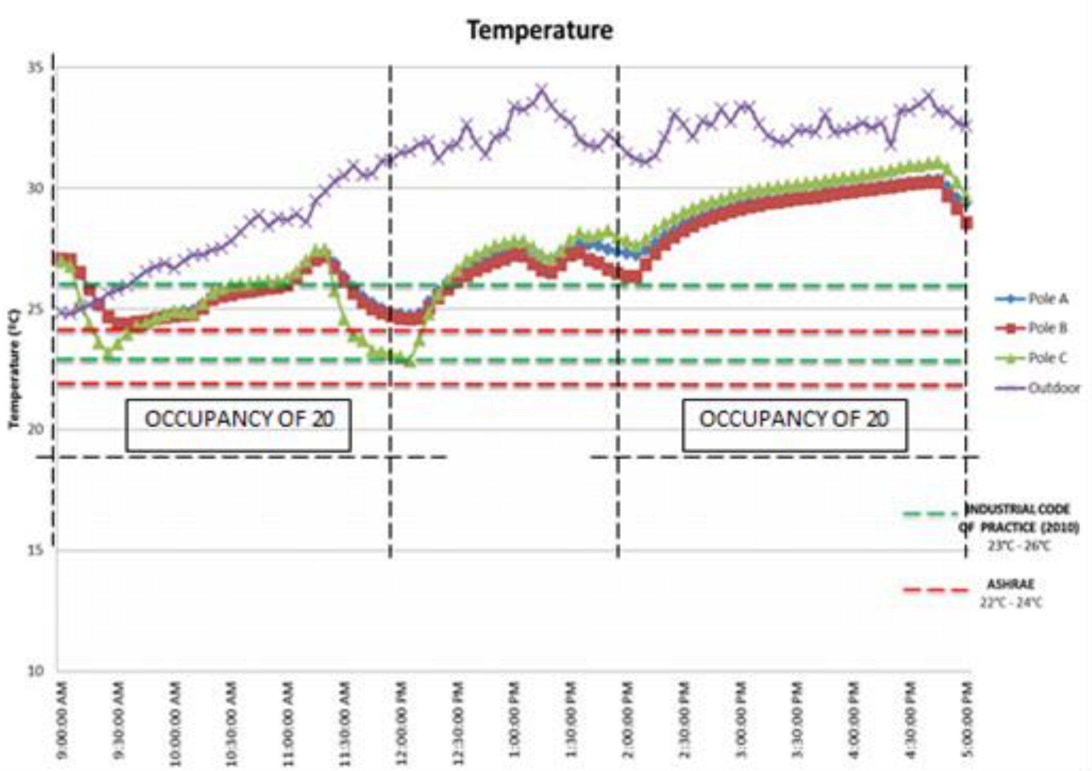


Figure 10: Students satisfaction level on the thermal condition

With regards to the thermal condition in the classroom, 8 respondents rated the classroom warm as illustrated in Figure. 10. This might be due to the heat transmission through the windows and lack of air circulation, which eventually reduces the ventilation rates in the classroom. It was observed that the classroom orientation with windows is towards Easts, which means that the classroom gain higher penetration from sunlight and this can cause heat gain in the classroom. However, there were few students rated it cold in the classroom. Based on the sitting position (colour indicator in Figure 10), it can be concluded 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. In addition to this, it was also observed that only one air conditioner was operating in the classroom. Hence, the perceived satisfaction level on the thermal comfort was not satisfactory.

3.2 Fieldwork Monitoring –Thermal Comfort, Ventilation and Indoor Air Quality

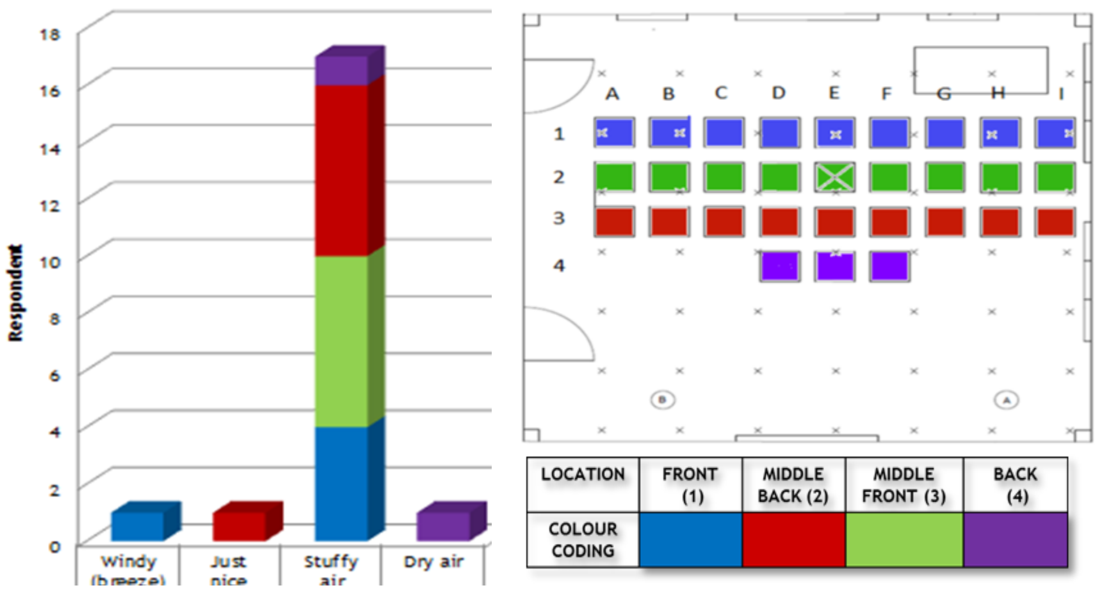
The measurement taken in the classroom is to identify the elements of indoor air quality that contribute to the environment quality in the classroom which includes temperature, relative humidity, volatile organic compound (VOC) and concentration of carbon dioxide (CO_2). Figure 11 shows the collected data on indoor temperature at Tutorial Room 7 (BT7). The temperature was compared with ASHRAE, 2010 as well as Industrial Code of Practice (2010). The ASHRAE recommended that the suitable indoor temperature for good indoor air quality is within 23^{o}C to 26^{o}C.



A/C Temperature setting	Average Indoor Temperature Throughout the Day	Average Outdoor Temperature Throughout the Day	Average Indoor Temperature when Occupancy	Average Indoor Temperature when Non Occupancy
23°C	27.3 °C	28.3 ° C	27.41° C	26.66° C

Figure 11: Profile of air temperature in the classroom during normal conditions

Based on the graph, the measured air temperature in the classroom is in the range of 23°C to 30.9°C. This result supported the findings from the questionnaire where almost majority (about 40%) of the students feel warm in the classroom (see Figure 10). The indoor air temperature pattern was observed to be influenced by the outdoor air temperature. However, it was noted that from 9.00 am to 2.00 pm, the difference between indoor and outdoor temperature was slightly lower. Yet the temperature levels were above the standard range set by ASHRAE and Industrial Code of Practice (dotted lines) as illustrated in Figure 11.



Air Velocity (Average Reading)	Min	0.14 m/s	0.12 m/s
	Max		0.17 m/s
World Health Organization (WHO)		0.25 m/s	

Figure 12: Perceived satisfaction on the air movement in the classroom

With regards to the air circulation in the classroom, it was noted that the average reading for air velocity was only 0.14 m/s as illustrated in Figure 12. This value is below the threshold limit value (TLV) set by World Health Organization (WHO). Air velocity level that is below 0.25 m/s is considered as stale air. Due to this, it can be concluded that the air movement in the classroom is very low. This finding is supported further by the students' perceived satisfaction level on the air movement based on the responses from the questionnaire.

Majority of the students feel that the air in the classroom is quite stuffy. This is probably due to the enclosed classroom where the doors and the windows are closed at most of the time when the room is occupied. It is also due to the operation of only one air conditioning system, which further reduces the ventilation rates of the classroom. It was observed that there were two exhaust fans above the door, but are not functioning to allow the exchange of air.

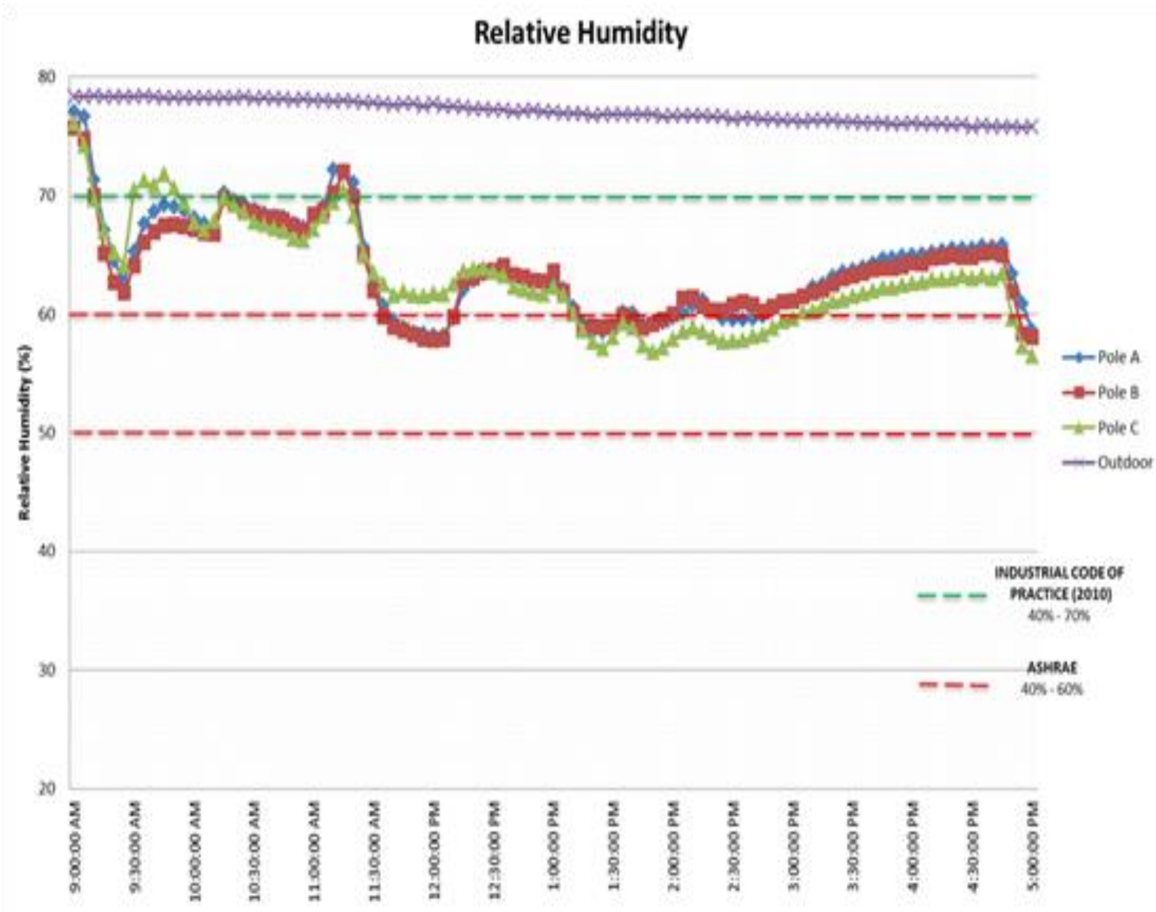


Figure 13: Relative humidity in the normal condition classroom

Figure 13 on the other hand shows data collected ogn the relative humidity in the classroom. From the graph, it shows that the relative humidity in the classroom is in the range of 53.12 % to 78.2 %. At certain time of the day, the RH level was noted to go beyond the TLV (above 60% set by ASHRAE).

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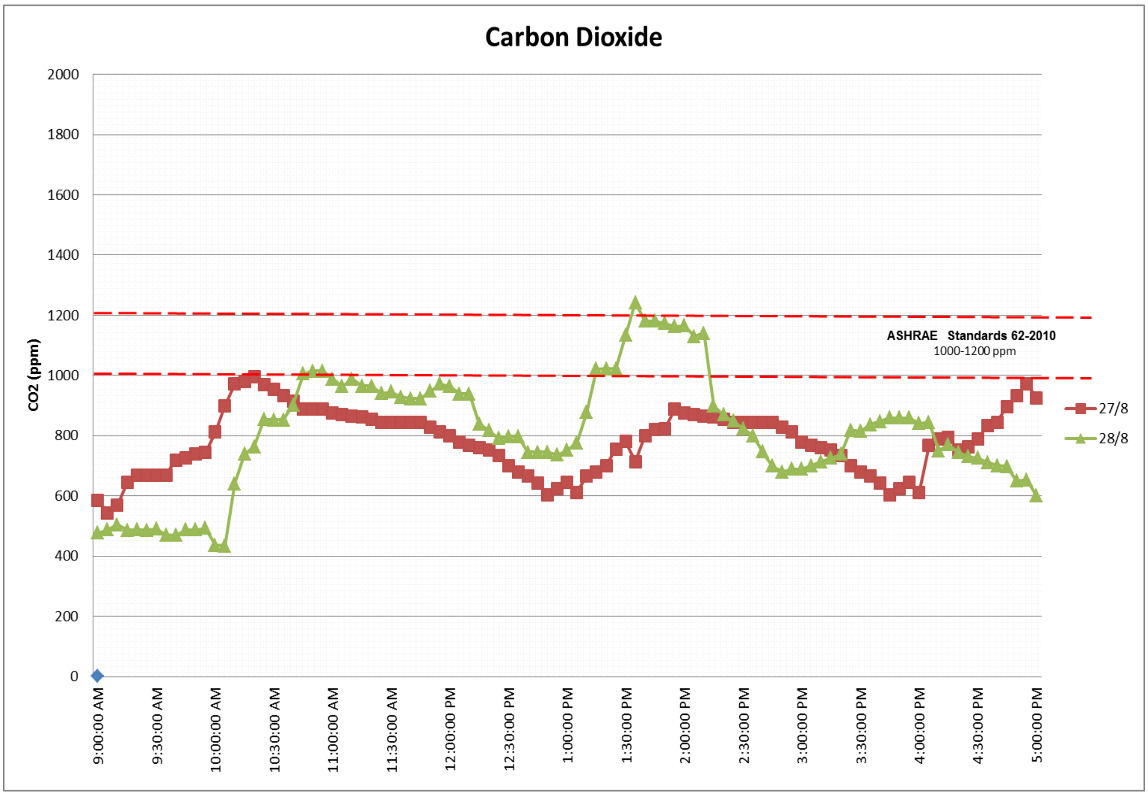

Figure 14: Concentration level of CO_2 in the normal condition classroom

In addition to RH, CO_2 was also measured (Fig. 14). Results of the CO_2 concentration level in the classroom is within the acceptable standards for the CO_2 that should be 700ppm above the outdoor concentration i.e., approximately 1000ppm. Similar to CO_2, there was no serious issues regarding dust particles (PM_{10}) in the classroom.

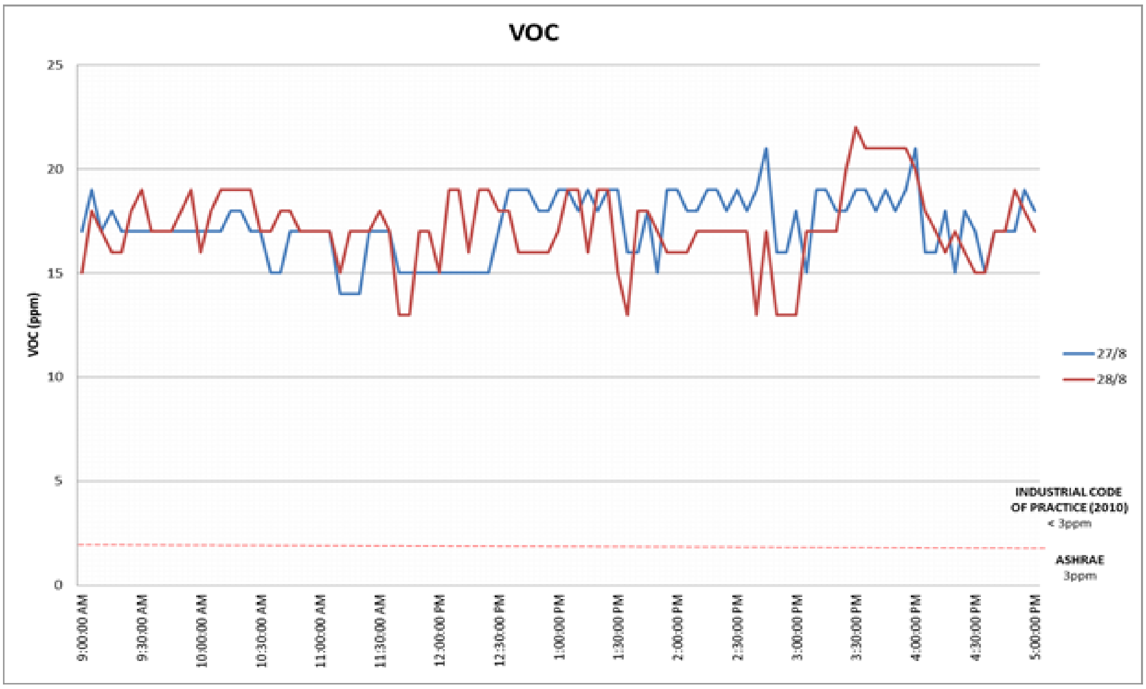

Figure 15: TVOC concentration in the normal condition classroom

On the other hand, TVOC concentration on both monitoring days shows a significantly high value beyond the TLV set (3ppm) as illustrated in Figure 15. The sources of TVOC were probably from cleaning chemicals, which are used by the cleaners during break time (1-2 pm) every day. It can also be from the perfumes that are used by the students in the classroom as well as the marker pens used by the lecturers during learning process.

3.3 Summary of Normal Condition Classroom

Table 4 shows the summary for current condition in the classroom. Most of the elements in the classroom were not in compliance with the standard TLV. The level of TVOC in the classroom was significantly higher with an average concentration of 11.7 ppm compared to 3 ppm as set in the standard TLV. According to Jim and Chen (2008), one of the pollutants that are widely found indoors is TVOC, which could contribute to dissatisfaction of the building occupants It could lead to distraction in students learning performance and focus during lectures.

Table 4: Summary of IEQ Measurements in a Natural Condition Classroom

Element		Average		TLV (Threshold Limit Value)		Remarks
Temperature (°C)	Occupancy	27.3°C	26.17°C	22°C-26°C	Code of Practice on Indoor Air Quality (DOSH 2010)	Above TLV
	Non-occupancy		26.66°C			
Relative Humidity (%)		76.4%		40%-70%	Code of Practice on Indoor Air Quality (DOSH 2010)	Above TLV
VOC (ppm)		11.7ppm		3ppm	Code of Practice on Indoor Air Quality (DOSH 2010)	Above TLV
Particulate matter (PM10)		$0.11mg/m^3$		$0.15mg/m^3$	Code of Practice on Indoor Air Quality (DOSH 2010)	Compliance
Air velocity (m/s)	Min	0.14m/s	0.12m/s	0.25m/s	World Health Organization (WHO)	Below TLV
	Max		0.17m/s			

3.4 Comparative Analysis of Total Volatile Organic Compound (TVOC) with Application of Plants

Figure 19 shows comparison of TVOC concentration between normal condition and intervention classroom. Based on the graphs, it is observed that there was a sharp decline in the TVOC concentration when plants were placed in the classroom. Therefore, it is proven that plants could reduce the air pollutants especially TVOC inside the classroom.

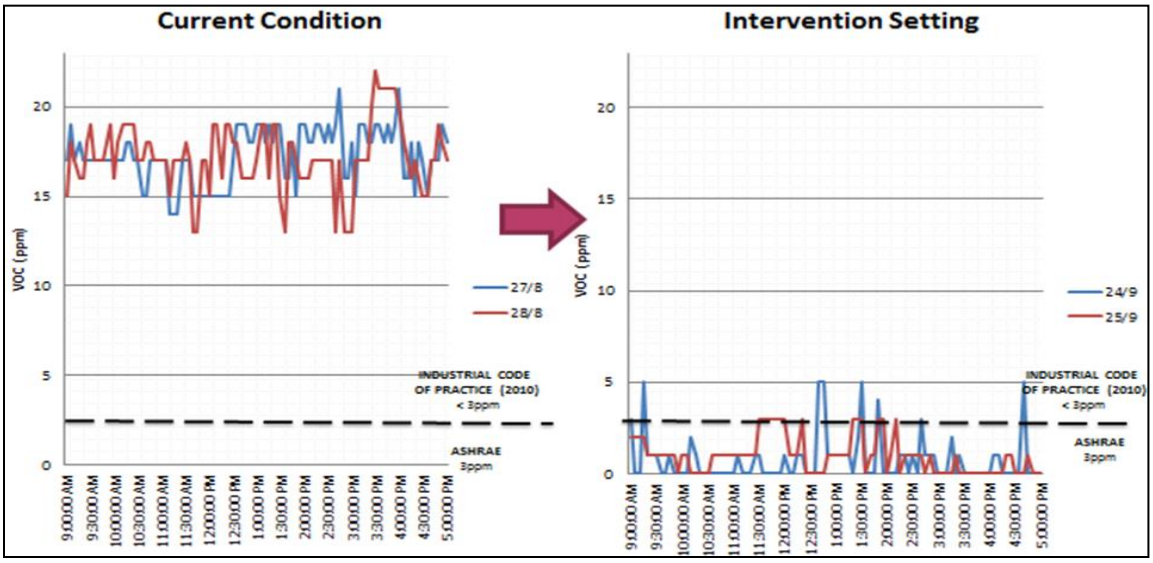

Figure 19: Comparison of TVOC concentration level between normal condition and intervention settings.

3.5 Comparative Analysis of Relative Humidity (RH) with Application of Plants

Similar to TVOC, a significant reduction was observed in RH level when plants were placed. (Figure. 20) A significan reduction in RH level was found in sampling device located in point A and B, which were near to the plants. However, sampling point C has no significant impact based on the indoor outdoor ratio of the relative humidity. This finding gives further evidence that the air in the classroom is not flowing well as discussed in the earlier section. However, the number of plants in the room should be considered in the future to prevent further reduction of RH value.

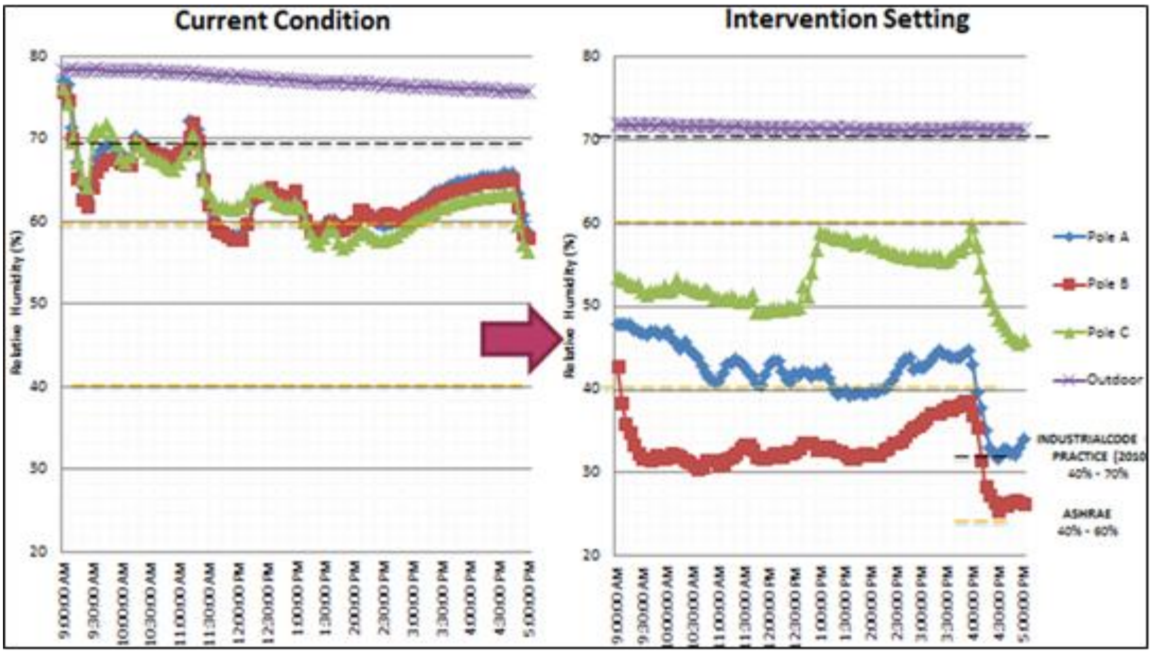

Figure 20: Comparison of Relative Humidity level between normal condition and intervention settings

3.6 Summary of IEQ Measurements Comparison between Normal Condition and Intervention Settings

Based on Table 5, it can be summarized that most of the elements show reduction in the percentage. However, the temperature shows some increment due to the increase of outdoor temperature during data monitoring. Therefore, it can be assumed that most of the elements are complied with threshold limit value and guidelines when landscaping is intervened.

Table 5: Summary of IEQ Measurements in a Natural Condition Classroom and Intervention Settings

Element		Average (9am- 5pm) Current Condition	Intervention Setting	Findings	
Temperature (°C)	Outdoor	28.3	33.3		
	Indoor	27.9	29.7	6.45% increment (difference of 1.8°C- due to different readings of outdoor temperature during both measurements	
Relative Humidity (%)	Outdoor	61.6	43.8		
	Indoor	76.4	71.5		6.41% reduction (Difference of 4.9%)
CO_2 (ppm)	9am-5pm	1084	781.89		27.87% reduction (difference of 302.11ppm)
	8pm-7am	443.65	429.22		3.25% reduction (difference of 14.43ppm)
VOC (ppm)		11.7	1.5		87.18% reduction (difference of 10.2ppm)
Particulate Matter (mg/m^3)		0.11	0.12	9.09% increment (difference of 0.01mg/m^3)	

Based on the findings, the results show decrement in the concentration of VOC and concentration of relative humidity. According to (Lohr,1992), plants can increase indoor relative humidity by releasing moisture into the air. Plants with large leaf surface area emit more water vapour during photosynthesis, and thus increase the humidity level in a space. Relative humidity can affect temperature. It gets warmer if the relative humidity increases (Swanson, 2006). According to Zhang et al. (2007), temperature is one of the environmental parameters that influences VOC emissions from building materials, together with air velocity and humidity (Wolkoff, 1998). Bremer et al. (1993), Cox et al. (2005) and Yang (1999) reported that the emitted substances were temperature dependant. Therefore, the use of plants is not only to filter the air but can help maintain a good relative humidity and temperature to control airborne pollutants.

4. CONCLUSION AND RECOMMENDATIONS

General perception and level of IEQ in the classroom of Pusat Asasi Sains University of Malaya is on average good. However, there were several key issues found when monitoring the classroom such as:

a) High concentration of TVOC that exceeds the limits
b) Significantly higher dissatisfaction on ventilation system in the classroom.

However, based on the questionnaire, the students were neither easily interfered in terms of perceived productivity nor susceptible to any health symptoms and their performance. Based on the findings it is recommended that the air circulation in the classroom should be improved to remove heat as well as to increase the level of air velocity. Therefore, the exhaust fan and the air conditioning systems should be fixed and maintained. Besides that, the usage of cleaning agent that consists of high VOC should be minimized.

There are various ways to reduce indoor air pollution and improve air quality. Apart from reducing gaseous air pollutants, research has shown that other aspects of IEQ can also be improved with the help of indoor plants. Plants have always been good biological filters for both indoor and outdoor. They do not only serve as part of the landscaping, but also bring physiological benefits to humans. The focus of this study was to identify which tropical indoor plant in Malaysia has better efficiency in improving indoor air quality in educational building. The selection of plant to mitigate air pollution in a building does not only depend on their ability to clean the air but also on their growth habit, the ease of growing and maintaining them, their light requirement, and also their personal taste. Therefore, Peace Lily and Janet Craig are good examples of indoor plant that should be considered for indoor landscaping in improving indoor air quality. To provide further insights into how plants can reduce indoor pollution and improve our health, more plants need to be tested, and a more controlled environment is needed as well.

ABBREVIATION AND ACRONYMS

ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
CIBSE	Chartered Institution of Building Services Engineers
CO_2	Carbon Dioxide
IEQ	Indoor environmental quality
IAQ	Indoor air quality
MOE	Ministry of Education NIOSH National Institute of Safety and Health
NIOSH	National Institute of Safety and Health
PM10	Particulate Matter 10
PPM	Part Per Million
RH	Relative Humidity
VOC	Volatile Organic Compound

ACKNOWLEDGEMENT

The authors gratefully acknowledge the cooperation extended by Department of Development and Estate Maintenance and Centre of Foundation Studies in Science at the University of Malaya for granting access to their facilities to conduct this research.

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