APPRAISAL OF WORKPLACE INDOOR ENVIRONMENTAL QUALITY (IEQ) IN OFFICE BUILDINGS AT PENANG ISLAND

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Abstract
As the weather is quite a big challenge to Malaysia, thus the Malaysians are tending to create the living environment as comfortable as we can. Workplace environment is very important as it ensure the health, activeness and productivity of workers who work in there. To ensure an optimum working environment, the indoor environmental quality, or frankly said, the HVAC system plays a big role. The objective if this paper is to determine the current indoor environmental quality of the selected offices in Penang Island. A few parameters were determined such as temperature, humidity, air velocity, air flor, noise level and lighting condition. Through indoor environmental quality measurement, it is found that most of the offices facing the lighting and noise problem.

Keywords: *Indoor air quality; temperature; noise level; HVAC; air velocity*

INTRODUCTION

There are many researches considered indoor environmental quality or indoor air quality as a factor that cause the sick building syndrome, although it is not ascertained yet. The high level of carbon dioxide, low ventilation rate and various other indoor air pollutants always been criticized as the main factors in indoor air quality to lead to serious health effect on human beings (Giddings et al., 2013). In this section, the parameters of indoor environmental quality will be explained in further.

In 2001, Hedge states that there are 6 factors that will affect the productivity of human beings in work. These including temperature, lighting, sound, vibration, indoor air quality and personal control. The imbalance or deficiency on above factors will cause the diseases such as sick building syndrome or even infectious diseases that thus decrease the human performance. In recent years, many philosophers are encouraged to study about workplace comfort level by using field studies. By this, they can study on various parameters within the workplace (Hassan et al., 2015). However, in many studies that the researcher hands on, the existing condition of indoor environment is obviously not good for humans to work in term of either physical work or mental work. To change the condition, standards recommending the various building indoor environmental quality optimum condition such as ASHRAE is being established.

When a person is wearing a normal amount of cloth, and he or she feels neither too cold nor too hot, the person is said that to be achieved a thermal comfort zone. It is essential for a person's great behavior and for his or her productivity on work. The thermal comfort normally refers to the air temperature and humidity, sometime including air movement too.

The temperature often becoming the most important factor to maintain the optimum indoor thermal comfort when the humidity is kept at around 50% with absent of air movement. Even though scholars prove the above statement, there is no one temperature that can satisfy everyone – if the office is too warm, the occupant will feel tired and drowsy. In contrast, if the office is too cold, they'll be easy to distract and may face to flu or other diseases. It is really very hard and essential to maintain constant and optimum thermal conditions in the offices as human beings are actually very sensitive to the thermal changes. Even minor deviation from comfort may be stressful and affect performance and safety for the workers.

In order to determine the indoor thermal comfort, questions regarding indoor temperature and humidity will be asked to the occupants. Besides, most of the studies require field test before asking for the occupants' opinions. According to ASHRAE Standard 55-2010, the optimum temperature for an office is 23℃ to 28℃, with humidity of 30%-65%. However, in tropical country like Singapore and Malaysia, majority of the occupants worked in offices equipped with air-conditioning system suggest that the 27℃ might be comfort enough. They think that 24℃ will create overcooling for the occupants (John, 2011). For humidity, little humidity will cause the dryness of the human skin. If the humidity in a room is high, the people will sweat and feel uncomfortable in this condition. Figure 1 shows the operative comfort temperature function of clothing and activity

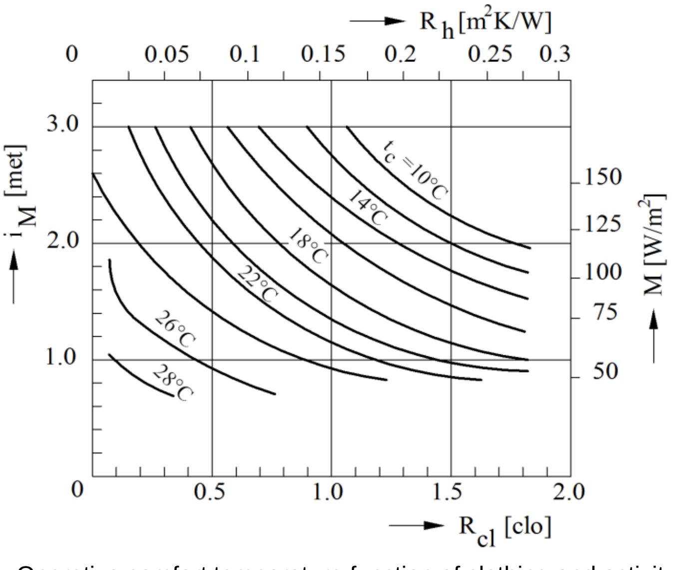

Figure 1. Operative comfort temperature function of clothing and activity (John, 2011)

Room temperature could influence productivity indirectly through its impact on prevalence of SBS symptoms or satisfaction with air quality. There are quite a number of studies that show the linkage between high temperatures and a higher prevalence of symptoms. Most of the studies show that high indoor air temperature in winter will like to cause more SBS symptoms compare to when the indoor air temperature is low.

The high humidity is present if the high amount of water is heated and evaporated to the surrounding environment. Relative humidity is the ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature. In some offices, humidity is usually kept between 40-70% because of computers even though the optimum is 30-60%. However, in workplaces without equipped with air conditional system, or where the tropical country where the outdoor air quality will indirectly affect the indoor thermal environment, the relative humidity could achieve more than 70%. High humidity environments have a lot of vapour in the air, which prevents the evaporation of sweat from the skin. When the room temperature is high, humidity is important to allow the evaporation of sweat from human body to prevent facing heatstroke unconsciously (Kariya et al., 2016). Humans are sensitive to humidity in the air as it will affect the evaporation cooling action that is used by human to control body temperature. Human will feel warmer when the relative humidity is high. However, if the relative humidity is higher than 80%, the sweat from human bodies is unable to be release due to the disturbance of osmosis gradient. Besides, a high relative humidity (greater than 60%) in an area supported with enough warmth will cultivate mould spore germination and growth. The mould will cause people to experience symptoms such as difficulty in breathing and skin and eyes allergy (Kenney, 1998). Figure 2 shows some common sick building symptoms distribution.

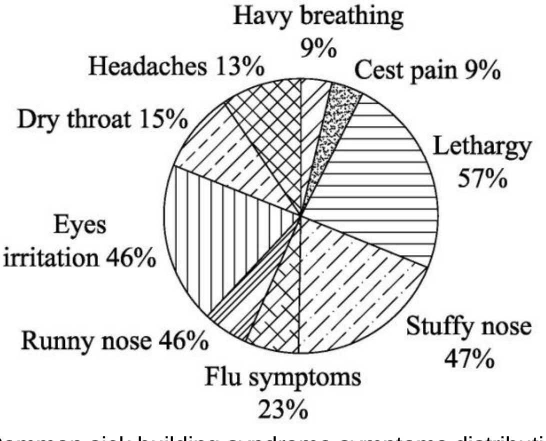

Figure 2. Common sick building syndrome symptoms distribution (Kenney, 1998)

Air movement will affect the human significantly by affecting the heat transfer. The higher the air velocity, the greater the rate of heat flow from the body through convection and evaporation. When the surrounding temperatures are within acceptable limits, the air velocity has no limitation on how fast or how slow it should be provided. The natural convection of air allows the continuous dissipation of body heat. When temperature increases, the natural air flow velocity will be no longer adequate. In this condition, the air velocity must be increased artificially, such as by the use of fans. Insufficient air velocity will cause stuffiness and air stratification. However, when air motion is too rapid, unpleasant drafts are felt by the room occupants (Nicol and Humphreys, 2002). In a study, the researcher states that the speed of air flowing across the worker and may help cool the worker if it is cooler than the environment temperature. Air velocity is a vital factor in thermal comfort because people are sensitive to it. If the air is still or stagnant in indoor environment which has artificial heat that is produced, the occupants will feel stuffy and it may also lead to build-up in odour, mostly mouldy smell. In contrast, moving air in warm or humid conditions can increase heat loss through convection for human bodies through sweating. Small air movement in cool or cold environments may be perceived as draught, which can cause skin dryness. The heat loss will be increase through convection if the room temperature is less than body temperature.

Physical activity also increases air movement, so air velocity may be corrected to account for a person's level of physical activity.

In the early and mid-1900's, building ventilation standards called for approximately 15 cubic feet per minute (cfm) of outside air for each building occupant after dilution and removal of body odours. As a result of the 1973 oil embargo, however, national energy conservation measures called for a reduction in the amount of outdoor air provided for ventilation to 5cfm per occupant. In many cases these reduced outdoor air ventilation rates were found to be inadequate to maintain the health and comfort of building occupants. Inadequate ventilation, which may also occur if heating, ventilating, and air conditioning (HVAC) systems do not effectively distribute air to people in the building, is thought to be an important factor in SBS. In an effort to achieve acceptable IAQ while minimizing energy. Figure 3shows some common causes of sick building syndrome

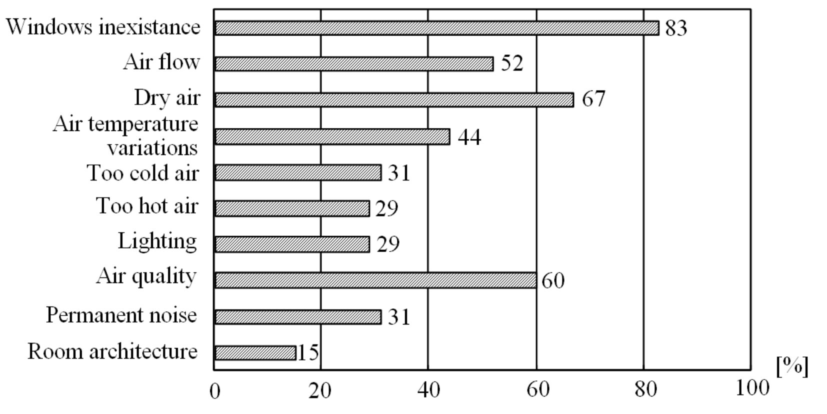

Figure 3. Common causes of sick building syndrome (Nicol and Humphreys, 2002)

Lighting is an important requirement for any places, especially in offices. The uniform illumination should be provided over the whole workplace. It is better if both natural and artificial lighting is provided in the same time. To save cost and to provide lighting for certain places that require, localized lighting may be provided. Good lighting helps us to see dangerous conditions. Optimum lighting can soothe the eye irritation and discomfort. Poor lighting will affect workers' performance and increase absentees. Besides, the poor lighting may cause dangerous condition as the visibility will be lesser, thus increases the opportunity to cause errors. Besides, natural working posture may not be possible under poor lighting, thus resulting in musculo-skeletal strain (Passarelli, 2009).

Artificial lighting is normally equipped when work especially during modern time, as most of the offices are using open plan design. Thus, general lighting and localized lighting are needed to suit different purposes. Normally, general lighting is like the fluorescent lights and is placed at the ceiling, it is designed for movement and casual work, such as filing (Pourzeynali and Jooei, 2013). Whereas localized lighting provides intense and central illumination at the workstations. It will illuminate only on specific work areas, like a desk. Natural lighting is good for health rather than artificial lighting. However, it is often undependable varies according to the weather conditions and even window spacing. Besides, it cannot provide enough illuminance to the occupants in the open plan office, and also it cannot provide the lighting during night time. Therefore, most of the modern offices are equipped with combining natural and artificial lighting. While for inadequate lighting condition, it may cause one to squint and cause eye irritation. A condition called backlighting will happen when one's body or a thing avoid the lighting from penetrate to the destination. It will cast the shadows on the destination and decrease the lighting level on the work place. The optimum lighting is 300-500 lux, but the least lighting level should not be lesser than 200 lux. In this research, the Light Meter Extech is being used to measure the indoor lighting level. While questions will be implemented in the questionnaire to ask the occupants about the satisfaction level and comment about the lighting system in the building in user perception

The mechanical systems and equipment that provide thermal comfort to the occupants in office are often the risk factor that leads to noise problems. If they are at bad performance and with poor maintenance, they can create excessive noise that will cause the human health problem. Besides, rapid flow of air through ventilation ductwork can also transmit noise throughout a building. Additionally, beside HVAC system, equipment such as phones, computers; traffic noise; and people noise from conversation and argument also are the source of noise that will cause problem every day. Both high and low levels of noise can lead to SBS. According to the Academy of Otolaryngology, if the sound level is louder than 85 decibels (dBA), or similar to normal conversation sound level, it can affect irritate human's hearing and thus their health. While when the sound level is low, such as buzzing from fans or photocopy machine, it will cause headache and dizziness. However, the research also state that high frequency noises can actually mask the effects of low frequency noise. A study published in 1996 revealed that many occupants experienced the following symptoms: fatigue, headache, nausea, concentration difficulties, disorientation, seasickness, digestive disorders, cough, vision problems, and dizziness. After conducting the test on places, they discover the occupants have exposed to the low frequency noise of 7 Hz for long period. This study asserted that low frequency noise from the ventilation system was amplified in the tightly sealed rooms in long-term exposure will triggered a number of sick building syndrome symptoms (Passarelli, 2009). A study also states that comparing a quiet office, noisy offices will make their worker to have mood swing, particularly in negative mood. Besides, certain high or low level of noise can make a person to lost interest or unable to work well, eventually will bring stress to such worker. Once a person is in stress condition, the hormones will be imbalance: the long term release of epinephrine and norepinephrine found in urine and blood will cause people to feel even depressed. Besides, it will cause insulin resistance with the impact of memory lost. The noise range for an open plan office should be between 49-58dBA. In this research, the Sound Level Meter Extech is being used to measure the noise level within the office. While questions will be implemented in the questionnaire to ask the occupants about the satisfaction level and comment about the noise level in the building in user perception.

METHODOLOGY

Survey tests that are done within the case studies also provide useful primary data to this research. It can provide the most recent and precise information regarding various indoor air quality parameters that the offices possessed. Assessment of Indoor Environmental Quality (IEQ) of 6 buildings which referred as Building A, B, C, D, E and F were carried out conferring to the ASHRAE Standard 55-2010. The indoor environmental quality was measured by means of the Hygro Thermometer Clock which was used to measure the room temperature and relative humidity (%RH). In addition, hot Wire CFM Thermo-Anemometer was used to evaluate the air velocity and air flow in the case studies. Besides, the wide Range Light Meter was used to quantify the lighting level of the case studies. Lastly the Digital Sound Meter was used to assess the noise level in all 6 buildings.

RESULTS AND DISCUSSION

Temperature

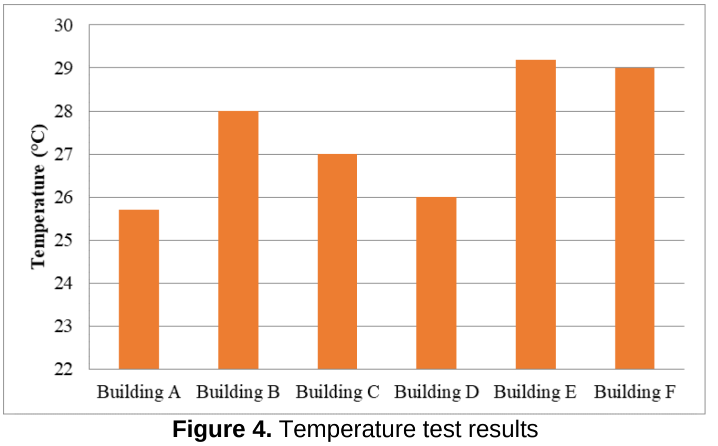

Figure 4. Temperature test results

Figure 4 shows the indoor temperature of each case study and also the acceptable highest and lowest indoor temperature for an office. There are two case studies exceed the optimum high temperature, they are Building E and Building F. While the Building B hit accurately on the optimum high temperature. Building A, Building C and Building D are within optimum temperature. The case studies tend to control the indoor temperature further high from the optimum low temperature. The analysis clearly indicated that in every case study, the occupants tend to control the indoor temperature further high from the optimum low temperature or more than the optimum temperature. The occupants disagreed with the ideal temperature, which is 24°C, which is suggested by ASHRAE. An air temperature of 27°C would make majority of the occupants satisfy with the working environment in their research

Relative Humidity

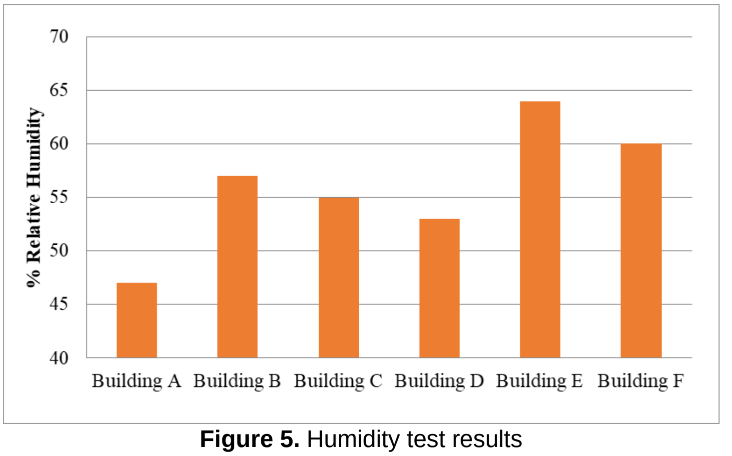

Figure 5. Humidity test results

Figure 5 shows the indoor humidity of each case study and also the optimum peak and valley indoor humidity for an office. The humidity of case studies are basically falls within the comfortable area. The only case study that has problem on humidity is Building E. It has humidity that is higher than optimum.

Air Velocity

Figure 6 shows the air velocity within each case study and also the optimum air velocity that should present in an office. The air velocity of case studies should not be higher than the optimum high value and also should not be lower than optimum low value. Building A has the air velocity that is lower than the optimum low value. While other case studies have indoor air velocities within the optimum range.

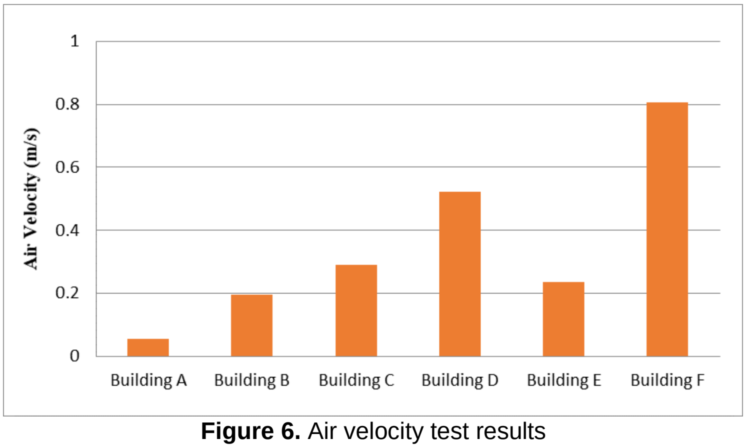

Figure 6. Air velocity test results

Air Flow

Figure 7 shows the air flow of each case study and also the optimum outdoor air flow within an office. The air flow of Building C and Building D did not achieve the minimum air flow that should be present in an office. Other case studies have optimum air flow. However, there is an outlier that fall far from the optimum which is Building F.

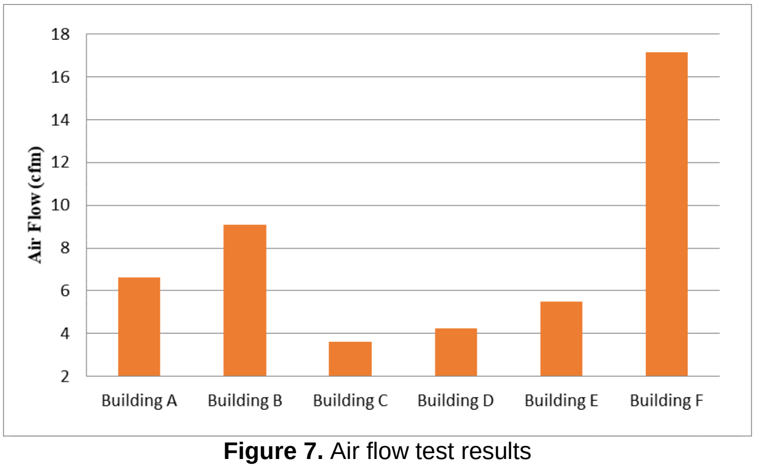

Figure 7. Air flow test results

Noise Level

Figure 8 shows the noise level of each case study and also the optimum noise level within an office. The condition divides into half-half. Half number of the case studies fall within the comfort zone, while half number of them has high noise level from optimum. Building A, Building B and Building E have optimum noise level within their office, while Building C has highest noise level within the six case studies.

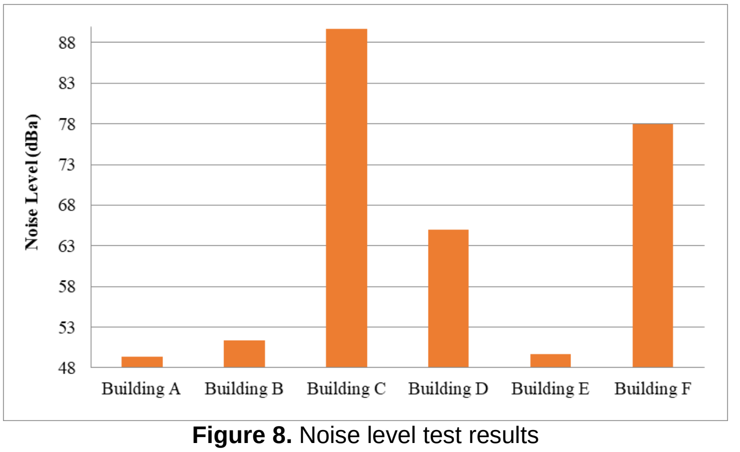

Figure 8. Noise level test results

Building F has the second highest noise level while Building D has slightly higher noise level than the optimum. High noise level from Building C is from the maintenance work of neighbour unit. The vibrations from the neighbourhood of buildings have always been indicated as a contributory factor for the increase of noise level.

Lighting

Figure 9 shows the lighting level (illuminance) of each case studies and also the optimum illuminance that an office should possess. Lighting is the most worried parameter among all as most case studies have problem regarding it. Only two case studies fall within the optimum condition, which are Building A and Building C. The others are all having low lighting level. The case studies that have the worst lighting condition are Building B and Building E.

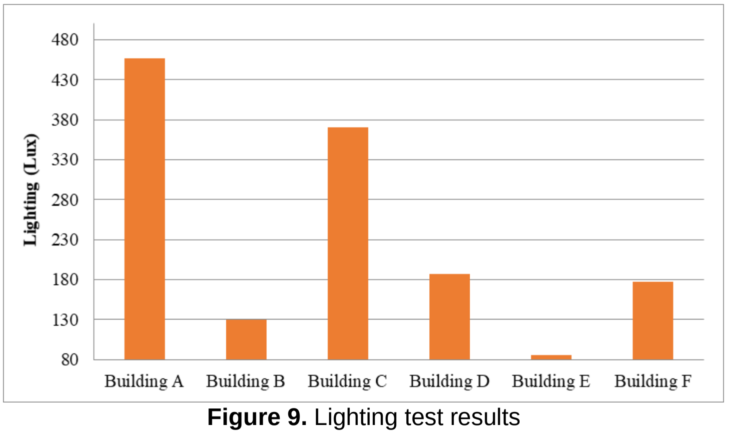

Figure 9. Lighting test results

CONCLUSION

The objective if this paper is to determine the current indoor environmental quality of the selected offices in Penang Island. This objective has been attained. Six case studies were selected according to office size. Permission and cooperation was given by the management department of all case studies to conduct some indoor environmental quality assessment within their premises. Through indoor environmental quality measurement, it is found that most of the offices facing the lighting and noise problem.

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