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Research paper

Indoor Air Quality (IAQ): Accuracy of Natural Ventilation for Temperature, Air Flow Rate and Relative Humidity (RH) in School Building Classrooms

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Abstract

Indoor Air Quality (IAQ) is an essential matter in achieving students' satisfaction for the learning process. Building's orientation is a factor that may encourage sufficient natural ventilation for the classroom occupants. Inadequate ventilation is an issue for most existing classrooms. The purpose of this paper is to analyze the accuracy of natural ventilation in classrooms. Therefore, experimental on 20 classrooms has been conducted by using Multipurpose Meter at secondary school buildings in Malaysia. The findings indicated that the accuracy of natural ventilation testing was below the permissible limits throughout the hours monitored, thus this may cause potential health hazards to the students. Temperature and air flow rates were lower than 23 °C and 0.15 m/s respectively, it fulfilled the basic requirements as a standard learning environment. However, measurements taken showed the overall relative humidity (RH) in the classrooms can be categorized as acceptable with 40% to 70% range. On the basis of these findings, it is evident that naturally ventilated classrooms are important especially due to energy efficiency, whereas mechanical ventilation should only be installed as an alternative under extremely hot weather conditions.

Keywords: *Air Flow, Classroom, Humidity, Natural Ventilation, Temperature*

1. Introduction

Schools are the main institutions of early education. Hence, it is important that they are able to provide comfortable conditions which also include occupants' health, both physically and psychologically [20]. School buildings are known as social environments, and to produce a positive classroom environment among students, the standard model of teaching and learning is an effective and interactive model to be used to evaluate the students' knowledge. Social skills such as discipline, behavior, and attitude are some main aspects influencing students' achievement in school. A positive classroom environment can also be built based on students' respect for each other and the spirit of helping each other academically. Teachers are able to develop students' skills more significantly during the teaching and learning process. Thus, classrooms should be planned and designed to meet the characteristics of education [17].

Classrooms need sufficient facilities to perform within a particular learning environment as they serve as the main spaces of a school building and provide a safe and health learning space for students. Ventilation and indoor air quality are among the comfort factors of a classroom environment in school buildings. Many researchers had found that there is a higher level of indoor pollutants than outdoor in the classroom environment since students and teachers spend more time indoors [18]. Therefore, poor indoor air quality is significantly connected to the ventilation quality, either natural or mechanical in a classroom. Satisfaction in terms of air ventilation and air quality in a classroom encourages students' learning ability and teachers and staff's productivity. Moreover, this will also reflect positively on students' development. Normally, evaluation on school building performance largely focuses on evaluating the quality of the indoor environment compared to other factors [10].

2. Ventilation

Ventilation is defined as the supply and removal of air by either passive or active actions. Passive ventilation means that the air movement is driven by wind and temperature differences through any openings such as windows and doors in a building. Active ventilation means that the air movement is supplied by mechanical methods such as fans and air-conditioning. Ventilation also functions to supply fresh air into rooms or spaces to provide healthy air to indoor building occupants. Normally, there are three parameters involved in evaluating building ventilation which are ventilation rate, airflow direction and air distribution or airflow pattern [3].

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2.1. Temperature, Air Flow Rate and Relative Humidity (RH)

Indoor Air Quality (IAQ) considers the natural ventilation comfort level in order to have effective energy efficiency or fresh air for occupants inside the building. However, this study focuses on classrooms in school buildings. Maintaining the IAQ is not only based on the number of people occupying a building, but also refers to the efficiency of natural ventilation itself. Some characteristics that can be significantly measured in the classroom space area include temperature, air flow rate and relative humidity (RH) as they directly contribute to quality ventilation, especially in educational buildings [15]. Therefore, the concept of building ventilation is necessary to produce sufficient air for breathing inside building areas that usually have different indoor-outdoor temperatures [5].

However, the air flow rate based on the requirement for the supply of fresh air in buildings has shown an acceptable indoor air quality level. The air flow rate can also be expressed as air changes at meter per second or meter per hour [13]. Relative humidity (RH) is defined as the uncontrolled moisture in buildings which can contribute to unacceptable indoor air quality and occupant discomfort. According to [8] the ASHRAE Standard recommends maintaining indoor relative humidity levels between 30 percent and 60 percent, as relative humidity (RH) of less than 30 percent may cause occupants' respiratory discomfort, while relative humidity (RH) of more than 70 percent can promote the growth of some forms of mould and fungi [4].

Table 1: Acceptable Ranges for Indoor Air Quality (IAQ) Parameters

Indoor Air Quality (IAQ) Parameter	Acceptable Range	Unit
(a) Temperature	23 – 26	°C
(b) Air Flow Rate	0.15 – 0.50	m/s
(c) Relative Humidity (RH)	40 – 70	%

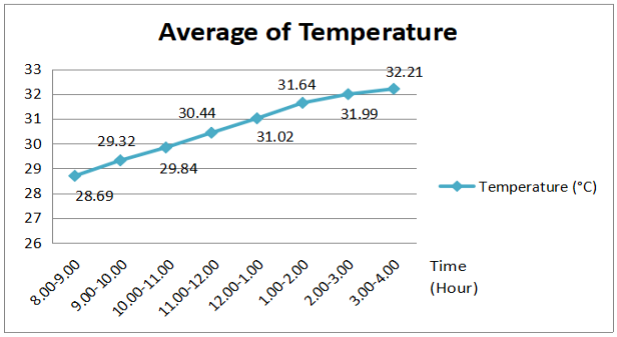
Source:Department of Health and Safety (2010)

3. Methodology

To achieve the purpose of this study, twenty (20) classrooms were selected from secondary school buildings in Selangor, Malaysia which consist of a mix of school buildings from the urban and rural areas. This is to ensure that the experiment is conducted fairly. The main aspects considered in the school building selection are its physical environment, size of population and building age. The buildings chosen were in the range of 16 to 42 years as according to [1] buildings in this age range should be evaluated more in order to check their comfort level for the comfort of the occupants. Three (3) indoor air characteristics related to natural ventilation were measured by using a 4 IN 1 Multipurpose Meter; air flow rate, relative humidity and temperature. This equipment was calibrated to traceable international standards (ISO 9001 Quality Management System) produced by Lutron Electronic Enterprise.

Fig. 1: Lutron LM-800A
(4 in 1 multipurpose meter of indoor air quality)

4. Results and Discussion



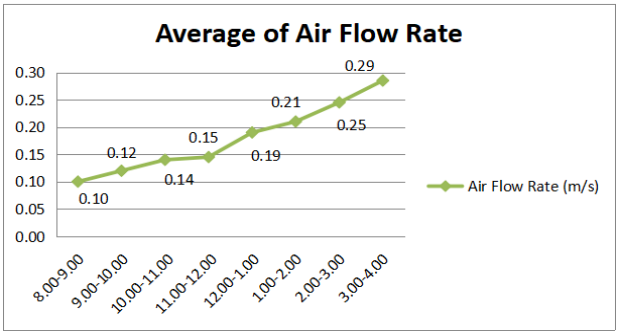


Fig. 3: Average air flow rate in the classrooms

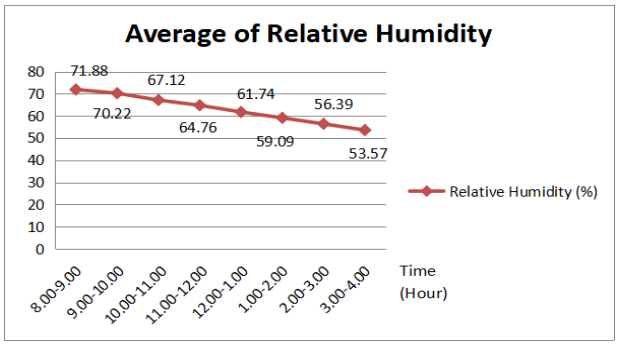


Fig. 4: Average relative humidity in the classrooms

Descriptive statistics shows the data collected from the experiments conducted in twenty (20) classrooms at secondary school buildings during the weekdays where 85% of the experiment duration was occupied by students. Measurements of Indoor Air Quality (IA) in the classrooms included temperature (°C), air flow rate (m/s) and relative humidity (%) as the main parameters in this study. The data showed that ten (10) out of twenty (20) classrooms (CS) recorded a 0.0 m/s air flow rate, which means that there was no circulation of air. Air flow rate is based on the existence of controlled openings such as windows and doors. Unfortunately, wrong building orientation has contributed to an overall poor IAQ performance. However, only 20% of the classrooms have wrong building orientations as evidenced by the recurrence of 0.0 m/s air flow rate measurement more than once. To provide comfortable air circulation in building spaces, new buildings should be designed to have an optimal wrong building orientation [12].

4.1. Temperature

The average temperature in the classrooms had not decreased much throughout the experiment period with a range of 28.69 to 32.21°C.As we can see in Fig. 2, the differences of temperature between each hour are on a small scale. According to Jamaluddin (2017) from the Malaysian Meteorological Department, Malaysia's climate is categorized as an equatorial or tropical maritime

climate with uniform temperature, and is hot and humid throughout the year. The average temperature for this country is normally 27 °C. However, the El-Nino Southern Oscillation Index (ENSO) that happened in year 2017 had enhanced the temperature to be more than the average value. Therefore, the temperature values recorded during the experiment showed higher values than the average. This usually influences the students' comfort during the teaching and learning process [3]. Besides, too hot or too cold of a temperature in a classroom environment may negatively affect students' concentration as they may feel uncomfortable. Hence, the hot and humidity levels in school classrooms should always be simultaneously controlled [14].

4.2. Air Flow Rate

Circulation of air inside a classroom basically refers to the natural ventilation or wind that ensures the occupants' comfort without the need for any mechanical ventilation mediums such as fan or air-conditioning. We can see that the air flow rate in Fig. 3 was measured in meter per second for the8 hours of experiment (8.00 am to 4.00 pm). However, the average air flow rate in the 20 classrooms was clarified at 0.1 m/s for the lower air flow rate and 0.29 m/s for the higher air flow rate. However, 0.4 m/s was counted as the optimal air flow rate of the overall sample. This illustrates that the air flow rate is still in an acceptable range (0.15 – 0.5 m/s) of the IAQ parameter, where it can produce the satisfaction of building performance and health for learning environments [6].

4.3. Relative Humidity (RH)

Relative Humidity (RH) is generally the control of water moisture, and should be approximately under 70% to be classified as the comfortable level [8]. Fig. 4 shows the average relative humidity (RH) of the 20 classrooms experimented on. It can be summarized that the highest rate of RH was 71.88% (8.00 am to 9.00 am) and the lowest rate of RH was 53.57% (3.00 pm to 4.00 pm). This clearly shows that the rate of RH rose steadily throughout the 8 hours of experiment. Therefore, it can be said that the level of RH in the classrooms in this study is under the acceptable range; whereby the only measurement above 70% was recorded in the early morning (8.00 am to 9.00 am) due to Malaysia's humid climate as a tropical country [4]. In fact, exposure to too low or high relative humidity (RH) levels in a classroom will commonly affect the occupants' health performance and lead to problems such as nasal congestion, irritated eyes, skin problem and other infections. Commonly, better achievement of students or employees is linked to their health performance, which is usually related with current IAQ conditions [19].

4.4. Relationship between Temperature and Relative Humidity (RH)

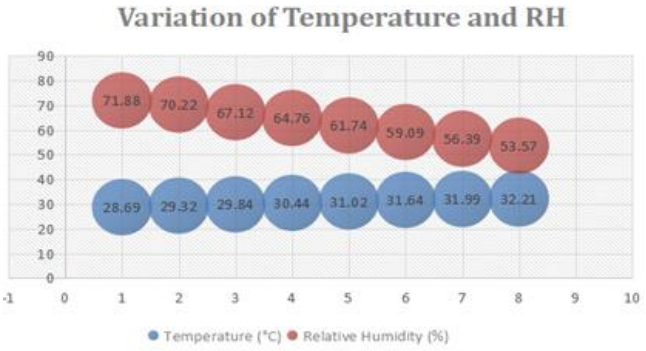


Fig. 5: Variation of Average Temperature and Relative Humidity in the Classrooms

More than 80% of the experiment period had involved occupied classrooms due to the double shift schooling session in all of the school buildings which increased the duration of students' occupancy. In fact, the amount of students in a classroom will balance the humidity level caused by the environment and humans' respiration processes [2]. Humphreys (1932) mentioned that if the temperature rises, RH should fall and when the temperature falls, RH should rise. This is to produce constant moisture content in the specific space. As showed in Fig. 5, the levels of temperature and RH rose steadily and fell steadily respectively throughout this experiment in the different classrooms. However, it is important to note that the percentage of relative humidity is parallel to the temperature level in the classrooms where the study was conducted.

5. Conclusion

Overall, the investigation found that the accuracy of IAQ specifically for natural ventilation in the classrooms in terms of air flow rate and relative humidity (RH) is in an acceptable range. However, the temperature recorded was not in the acceptable range due to the hot weather conditions present at the area of investigation. Approximately 85% of the classrooms still showed satisfactory comfort levels due to the effects of air flow rate and relative humidity (RH) which become apparent at high temperature levels. Thus, it can concluded that even when the temperature is higher than the expected range (23– 26 °C), the classrooms' comfort level will depend on the classrooms' location i.e. orientation in the school building design. The location of the classrooms is really significant to ensure the sufficiency of natural ventilation which is usually based on the effective air flow rate flowing into the classroom. Poor IAQ levels in the classroom not only will affect the comfort level but also the health condition of students and teachers, thus reducing students' concentration, attendance and performance. This situation should be addressed early so that several actions can be taken by the occupants, school management and parents to produce better IAQ levels in the classroom environment.

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