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STUDENTS' RESPONSES AND PERCEPTION OF THE INDOOR ENVIRONMENT IN THE TEACHING AND LEARNING SPACES

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ABSTRACT

Poorly operated air conditioning and mechanical ventilation system might cause significant Sick Building Syndrome (SBS) symptoms and thermal discomfort in the hot and humid climate. Thermal comfort in educational building is the important criteria to be considered seriously. The issues related to the occupants' thermal comfort in work place/educational/residential buildings is given a great attention. However, thermal comfort in the educational building, especially the classroom is really significant to be considered seriously. Indoor environment is important since it affects the health and productivity of building occupants. It can affect the activities of occupants inside the room. The research was performed in the building of Pusat Asasi Sains University of Malaya (PASUM), Malaysia looking into classrooms and laboratories which are mechanically ventilated with air conditioning and ceiling-fans. A combination of both questionnaire surveys and experimental studies were carried out. An adopted questionnaire was distributed to respondents to understand their understandings with regards to the thermal comfort and the indoor environment of their learning spaces. Based on the findings, it was observed that the rooms (classrooms/ tutorial rooms) that incorporated air-conditioned system are more comfortable (temperature average of 25.2˚C) than the rooms (laboratories) which are using the ceiling fan (temperature average of 29.9˚C). The most significant conclusion which can be drawn from this research is that none of the learning spaces had thermal conditions falling within the comfort zone of ASHRAE standard 55. Students found temperature range beyond the comfort zone acceptable.

***Keywords**: Thermal Comfort, mechanical ventilation, ceiling fan.*

INTRODUCTION

Creating a shelter to secure the occupants against the environmental hazards is one of the most primary purposes in buildings during the human civilisation. Healthy and comfortable microclimate conditions are essential for any type of environment but, in particular, schools are a category of buildings in which a high level of environmental quality may considerably improve occupants' attention, concentration, learning, hearing and performances [1]. Definition of indoor comfort may have changed over the years, but some of the variables such as thermal comfort are seem to be accepted to date. According to ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) 55-74 Standard, thermal comfort is defined as "That condition of mind, which expresses satisfaction with the thermal environment." The existing thermal comfort standards, such as ASHRAE 55 [2] and ISO 7730 [3], are based on theoretical analysis of the human body heat exchange with the environment which predict the thermal environment and thermal comfort of human body in air-conditioned (AC) context [4].

In educational buildings, students as the major occupants of these buildings would be physically and mentally more sensitive to the environment conditions including thermal conditions. Malaysia faces hot and humid tropical condition which causes the high temperature, and low air flow distribution. This condition affects the thermal performance in indoor environment. As our sense of well-being and productivity are dependent on the indoor climate, it is important to equip these students with well-planned air-conditioning systems and to ensure that the building provides comfort specific to the comfort level of the occupants. Today, the thermal comfort complaints are common in many buildings. Thermal discomfort might affect the overall activities of the occupants. Son H. Ho [5] stated that "Thermal comfort has a great influence on the productivity and satisfaction of indoor building occupants." Thermal comfort might be achieved by installation air-conditioning system in the rooms since they could adjust the level of temperature when necessary. However, it is seen that in many classrooms, ceiling-fans are still being used.

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To obtain good thermal condition some basic measures must be put in place, such as: ensuring adequate ventilation, adequate heating, proper insulation and the reduction of excess moisture production, amongst others the indoor air quality (IAQ). According to Hanson and Burroughs [6], poor IAQ and discomfort in educational establishments have been attributed to deficiencies in ventilation systems. Some contaminants are not perceived by occupants and thereby do not cause complaints, but are still capable of causing various health effects that influence absenteeism, work performance, and some that include symptoms of allergies, asthma and respiratory illness [7-9]. According to ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality, acceptable IAQ is defined as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities, and which a substantial majority (80 % or more) of the people exposed do not express dissatisfaction" [10]. Classrooms can have higher occupant densities, typically four times as many occupants as office buildings for the same area of floor space (EPA, 2000). With a high building density in the urban environment, the Sick Building Syndrome (SBS) symptoms and thermal comfort level have become important concerns, from both the building operation and occupants' health/productivity points of view. Thus, this study is conducted to investigate on how the air-conditioning and ceiling-fan affects the room temperature in PASUM.

The main objectives of this study are as follows:
(1) To find out the thermal conditions in classrooms via subjective and objective approach.
(2) To investigate occupants' perception of the level of thermal comfort in classrooms. In particular, thermal acceptability in classrooms shall be analysed using a vote based on the ASHRAE index. The evaluation had 7 levels from −3 to +3 sensation scale votes of preference and direct votes of acceptability (Table 1).

Table 1: Thermal sensation vote

Level	Thermal sensation
−3	Cold
−2	Cool
−1	Slightly cool
0	Neutral
+1	Slightly warm
+2	Warm
+3	Hot

MATERIALS AND METHODS

The aim of the study was to investigate the thermal environmental quality in a university classrooms and laboratories by means of both an objective and a subjective approach. The subjective approach was basically aimed at finding out the judgement about the perception of the thermal environment in terms of acceptability and preference of colder or warmer environments. While the objective approach was analysed by means of field measurement using the Thermal Environment Monitor QuestTemp°36 to monitor the temperatures, air velocity, and relative humidity level in the learning spaces. In the experimental investigation, monitoring of the indoor environment were carried from 8.00 am 5.00 pm daily in respective classrooms. This equipment was placed in each selected classrooms/ laboratories as illustrated in Figure 1.

(a)

(b)

Figure 1. The position of equipment for classroom (a) and laboratory (b) monitoring during occupancy.

The questionnaires were distributed to the students to measure the occupant's satisfaction level towards the indoor environment in the learning spaces. They were delivered and filled by the students while the measurements were going on. The answers to the questions concern the instantaneous assessment of

microclimatic conditions. In addition, a walkthrough observation was carried out in the selected rooms of PASUM building which consist of classrooms, laboratories, and offices.

PASUM was established in 1977 and they offer the science matriculation programs which has the purpose to prepare students with basic of science knowledge for entrance to universities with science-based courses. All the laboratories were equipped with ceiling fans. The windows in the laboratory are open most of the time to supply fresh air indoor and to have natural ventilation. On the other hand, all the tutorial rooms are equipped with air conditioning systems and windows in the rooms were closed at most of the time. The location of PASUM is illustrated in Figure 2.

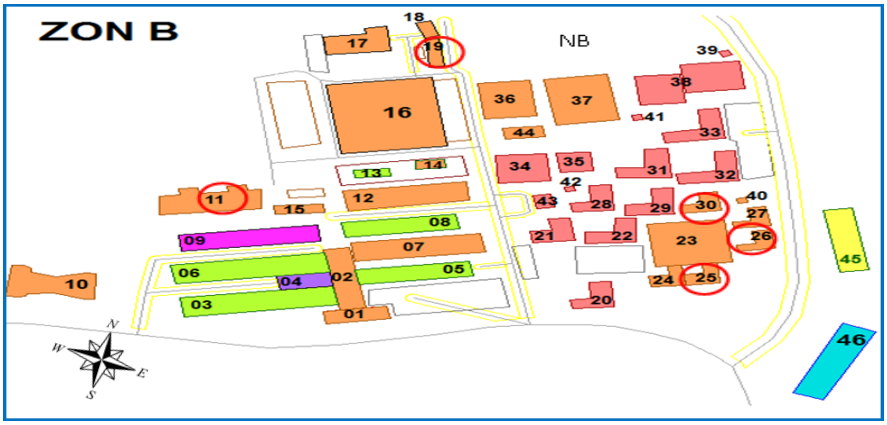

Figure 2: Site Plan of Pusat Asasi Sains University of Malaya (PASUM)

As displayed in the figure above, there are 6 locations of the case studies, which consist of:

NB – Biology Laboratory (New Building)
11 – Physic Laboratory
19 – Chemistry Laboratory
25 – Tutorial Room 1
26 – Tutorial Room 2
30 – Tutorial Room 3

RESULTS AND DISCUSSIONS

Basic information of the respondents

The questionnaire used in this research involves two major portions to address the issues on the indoor environmental quality and the thermal levels of the students learning spaces. In the onsite investigation, a total of 401 students including 208 females and 193 males, responded to the questionnaires. All of the respondents were below 20 years old and about 95 % of them were Malay-origins with the balance to be Chinese and Kadazan. The Malays, by virtue of being Muslims, tend to observe the Islamic dress code by wearing clothes that cover the majority of the body and the females are mostly wearing hijab.

Out of the 401 responses, 201 respondents were located in the laboratories which uses the ceiling fan, while the remaining were in the classrooms equipped with air conditioning systems.

Indoor Thermal Conditions

Figure 3 shows the distributions of the respondents' thermal sensation votes (TSV) in both classrooms and laboratories. Based on the ASHRAE index, more than 50 % of the respondents in the laboratories stated that they were feeling hot at most of the time. About 25 % of the respondents considered the indoor thermal conditions to be hot (+3), 20 % of them responded that the indoor temperatures were warm (+2). Only 22 % of the respondents replied with neutral (0), slightly warm (+1, 14 %) or slightly cool (-1, 7 %). This value is noticeably lower than the value recommended by ASHRAE 55-2010 standard [10] which indicates that at least 80% of occupants should have thermal sensation between slightly cool (-1) and slightly warm (+1).

On the contrary, the majority of the respondents in the classrooms reported that they were feeling towards the cold sensation. However, there are still students who feel that the room should be cooler. It could be due to the building orientation where direct sunlight and insufficient insulation and shading devices on the ceiling/ wall to reduce the heat solar. Another possible reason is due to overcrowded. Number of occupancy is about 30 persons in a narrow space/class (56.25 m^2).

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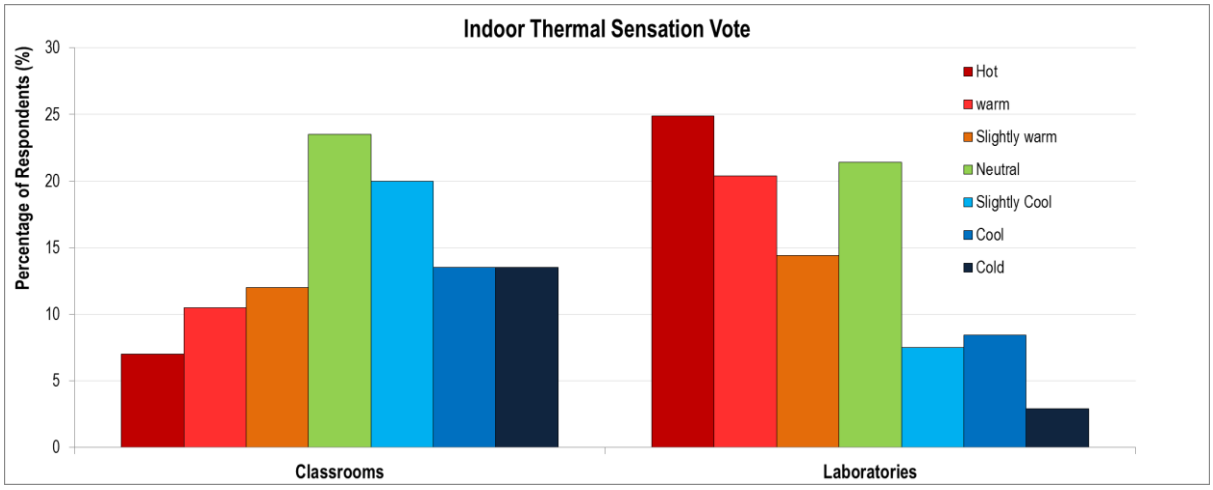

Figure 3: The Percentage of the Occupants' Satisfaction Level on the indoor thermal condition.

With regards to the satisfaction level of the students, similarly to the laboratories condition, the value recommended by ASHRAE as comfortable is clearly seen to be slightly lower than the satisfaction level with only 24 % of the respondents replied neutral (0), 20 % slightly cool (-1) and only 11 % slight warm (+1). Based on these findings, it is clearly observed that the conditions of the indoor thermal environment in the learning space are not satisfying.

As mentioned earlier, an objective approach which involves experimental monitoring was also carried out to investigate the values of indoor thermal condition in the selected learning spaces. Table 2 shows the overall measurements of the average indoor thermal environment in the selected learning spaces.

Table 1: Indoor thermal condition in the learning spaces

INDICATORS MEASURED	THE AVERAGE OF THE EQUIPMENT MEASUREMENT DONE IN 3-TUTORIAL ROOMS AND 3-LABORATORIES					
	TR 1	TR 2	TR 3	BL	PL	CL
AIR VELOCITY	0.2 m/s	0.3 m/s	0.2 m/s	0.1 m/s	0.2 m/s	0.2 m/s
AIR TEMPERATURE (T_a)	23.8˚C	24.2˚C	25.0˚C	29.4˚C	29.9˚C	30.1˚C
GLOBE TEMPERATURE (T_g)	24.4˚C	25.4˚C	25.7˚C	29.5˚C	30.0˚C	30.7˚C
RELATIVE HUMIDITY	51.9 %	48.3 %	60.8 %	69.6 %	69.4 %	65.5 %
PREDICTED MEAN VOTE (PMV)	-0.91	-1.04	-0.98	1.45	1.30	1.30
PREDICTED PERCENTAGE DISSATISFIED (PPD)	21.9 %	27.9 %	25.0 %	50.5 %	41.5 %	41.5 %

TR – Tutorial Room BL – Biology Lab PL – Physics Lab CL – Chemistry Lab

Based on the PPD in table 2, it is noted that there is a correlation in results found between the objective approach and the subjective approach where the 80% of satisfaction level based on ASHRAE condition were not met. However, findings in the classrooms were quite minimal as compared to the laboratories where the percentage of occupants dissatisfaction is significantly high especially in BL (50 % of the occupants were not satisfied with the thermal condition of the room). Based on the observation carried out during the monitoring, it was found that numbers of occupancy were at most time higher (70 - 80 students) than that of the room capacity (65 nos). This would probably contribute to the increase of temperature in the laboratories.

Indoor Environmental Condition

With regards to the perceived indoor environment, respondents were asked about specific performance of their learning spaces. 4 specific perceived indoor environment criteria were asked: (1) noise, (2) disturbance of

sunlight (i.e. glare), (3) Unpleasant odour/ smelly and (4) air ventilation (dry air and stuffy air). As a result, figures 4 and 5 tabulate the frequencies of individual SBS symptoms. There were a high percentage of occupants who complained of wide varying SBS symptoms. Based on the individual symptom, most of them were of higher frequencies where these symptoms were faced by the occupant either always or sometimes except for glare and dust in classroom with approximately 30 % of respondents had never felt these symptoms.

However, on the contrary, in the laboratories, occupants responded that problems with glare (31 %), dust (34 %), noisy (37 %) and unpleasant odour (32 %) were always an issue in that learning spaces. These symptoms including stuffy air have exceeded the general guideline of more than 20% complains. This phenomenon might be due to the diversity of the individual respondent's expectations and sensitivities to indoor environments. It also highlights, to certain extent, the difficulty to satisfy everybody with different backgrounds and needs.

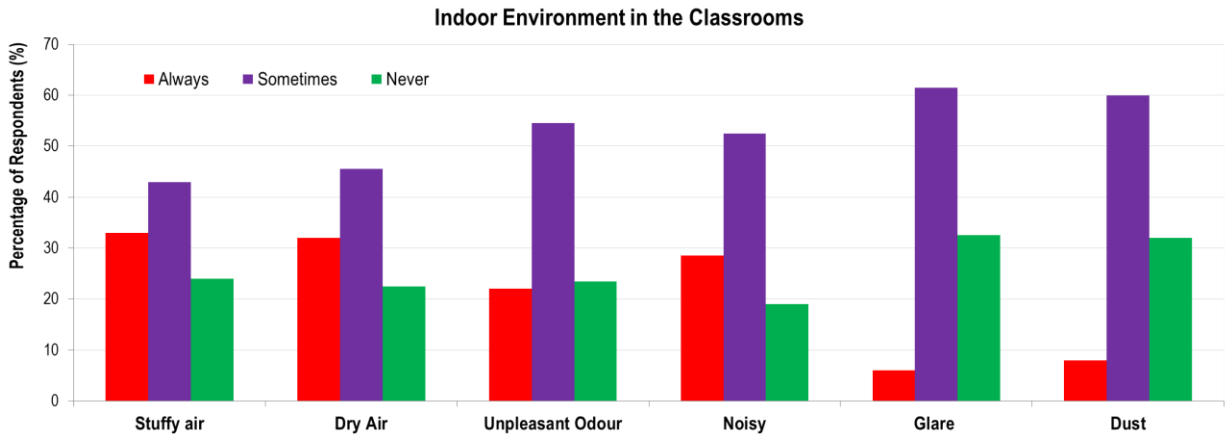

Figure 4: The percentage of occupants' satisfaction level on the indoor environmental quality of the classrooms.

Furthermore, it is observed that the high level of humidity (.> 60%) in most of the learning spaces could contribute to the perspiration which leads to unpleasant odour. It is recommended that adequate ventilation system and proper maintenance might reduce the occurrence of SBS symptoms.

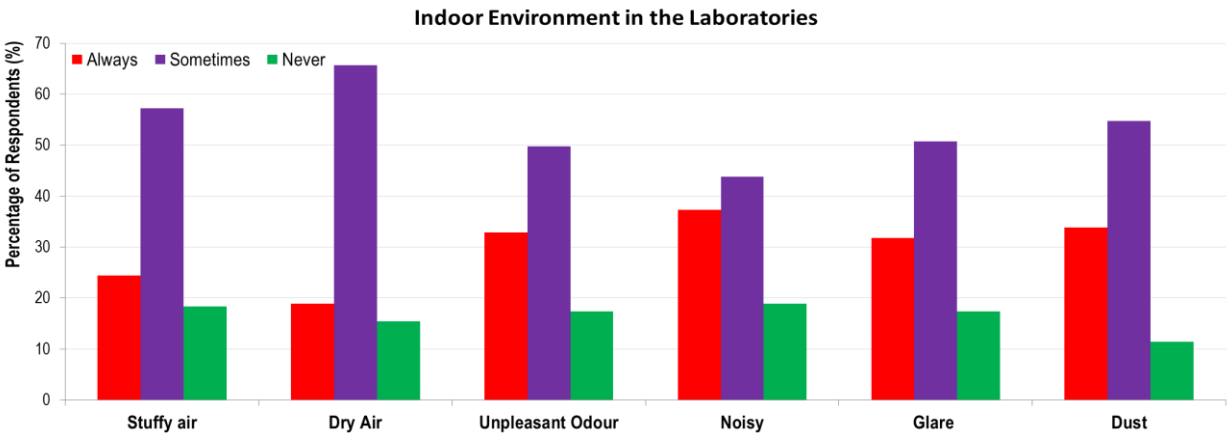

Figure 5: The percentage of occupants' satisfaction level on the indoor environmental quality of the laboratories.

With regards to the overall students feeling in their learning spaces, it was found that the majority of students are more comfortable in classrooms where the temperature are much lower than in the laboratories. As illustrated in figure 6, 64.5 % of respondents feel comfortable in the classrooms whereas, in the laboratories a significantly high percentage of students (55.2 %) are not comfortable with their learning space. The findings show that students prefer a cooler environment for better learning.

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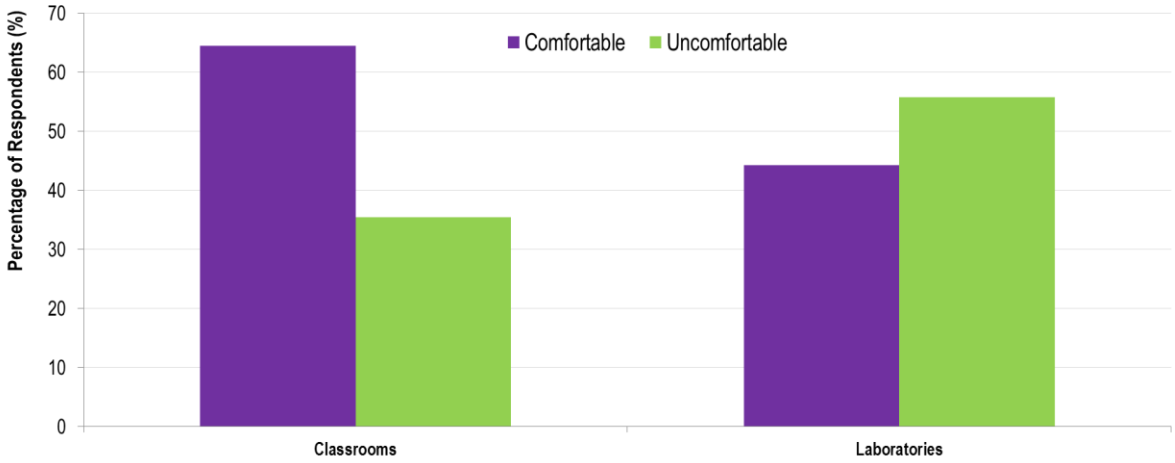

Figure 6: The percentage of occupants' satisfaction level on the indoor environmental quality of the laboratories.

CONCLUSIONS

The characteristics of thermal comfort and indoor environmental quality in learning spaces and students' perceptions are studies in this paper. The developed investigations, performed during the learning hours in classrooms and laboratories in Pusat Asasi Sais University of Malaya, highlighted the key findings as follow:

- It was found out, a good agreement between the measured PPD based on the objective approach and percentage of dissatisfied from the questionnaires (subjective approach) when people voting for the thermal sensation vote. Both the results showed that none of the learning spaces had thermal conditions falling within the comfort zone of ASHRAE standard 55. Occupants found temperature range beyond the comfort zone acceptable.
- It was found that in both classroom and laboratories, the rate of satisfaction level in the students' learning spaces were below the recommended value. In classrooms the predicted percentage of dissatisfied (PPD) was at the range of 21.9 % and 27.9 % which quite marginal. However, in the laboratories which were equipped with ceiling fans, the PPD obtained were significantly high with the range of 41.5 % to 50.5 % of students not satisfied with the learning spaces condition.
- The majority of students in the classrooms feel that the air is stuffy and dry most of the time which may be due to the air conditioning systems. However, the relative humidity measured in the classrooms were within the range of acceptable values of 30% - 60%. On the contrary, the relative humidity level in the laboratories was above the recommended range with approximately 65.5 % - 69.5 % RH. This finding coincides with the students' perception in the questionnaire.
- It was found that students are more comfortable in classrooms where the indoor thermal environment is much cooler than that of laboratories.

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REFERENCES

[1] Clements-Croome, D.J., et al., *Ventilation rates in schools.* Building and Environment, 2008. **43**(3): p. 362-367.
[2] ANSI/ASHRAE55-1994, *ASHRAE standard: thermal environmental conditions for human occupancy*. 1994: Atlanta (USA): American Society of Heating, Refrigerating and Air-conditioning Engineers Inc.
[3] ISO7730, *Moderate thermal environments-determination of the PMV and PPD indices and specification of the conditions for thermal comfort.* , I.S. Organization, Editor. 1984: Geneva.
[4] de Dear RJ, B.G., *Developing an adaptive model of thermal comfort and preference.* ASHRAE Trans 1998. **4**(1): p. 145–67.
[5] Son H. Ho, L.R., Muhammad M. Rahman., *Thermal comfort enhancement by using a ceiling fan.* Applied Thermal Engineering, 2008. **University of South Florida.**

[6] Burroughs, H.E. and S.J. Hansen, *Managing Indoor Air Quality*. 2004, 3rd ed, Lilburn, GA: Fairmont Press.
[7] Coley, D.A. and R. Greeves, *The Effect of Low Ventilation Rates on the Cognitive Function of a Primary School Class*, in *Report R102 for DfES*. 2004.
[8] Shendell, D.G., et al., *Evidence of inadequate ventilation in portable classrooms: results of a pilot study in Los Angeles County.* Indoor Air, 2004. **14**(3): p. 154-158.
[9] Fisk, W.J., *Health and Productivity gains from better indoor environments and their relationship with building energy efficiency.* Annual Reviews of Energy and the Environment 2000. **25**: p. 537 - 566.
[10] ASHRAE, *Ventilation for Acceptable Indoor Air Quality* 2010, Atlanta, USA. American Society of Heating, Refrigeration and Air-Conditioning Engineers ANSI/ASHRAE 62.1, 2010. p. .

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