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An Exploration Study on the CO_2 Concentration in Several Air-Conditioned Classrooms Located in Ho Chi Minh City

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Abstract. The South of Vietnam has a tropical humid climate: the temperature does not significantly vary in the year and there are only two seasons: the dry and the rainy one. The months with highest temperatures are usually from April to June, but the air temperature is rarely more than 35 °C. The rainy season is currently from June to November. During this season, the rains (usually occurring at the end of the afternoon) enable to refresh the ambient in the evening. Therefore, in general, the natural climatic conditions of the Southern of Vietnam are favorable for bio-climatic architectural designs, which are a basis for sustainable building. Vietnam's economic boom, however, went along with more resource-intensive lifestyles and changing demands of thermal comfort, particularly driven by the rapidly emerging urban middle class population. One consequence is that the use of air-conditioners has become increasingly popular in Vietnam. Also places of tertiary education get increasingly equipped with air conditioner units, which get equally used during dry and rainy season. This paper presents an exploration investigation on the CO_2 concentration in the air-conditioned classrooms at a University in Ho Chi Minh City, Vietnam. The measurement equipment used was by Testo® which could measure the air temperature, the air relative humidity and the CO2 concentration. The measurements could be performed during a long period of time with the data continuously recorded and sent to the cloud by Wifi. The results showed the high CO2 concentrations in the classrooms investigated, due to the high number of people within a closed space, without any aeration. The results obtained show the high relevance to take into account proper measures for air-conditioned spaces, to enhance the air-quality and the health of the students and teacher using classrooms in Vietnam.

Keywords: Air quality · CO2 concentration · Air-conditioned classrooms · Energy-efficient buildings

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1 Introduction

The Southern of Vietnam has a tropical humid climate in which only two seasons can be classified: the dry season and the rainy one. The temperature does not significantly vary in the year (Fig. 1). The months with highest temperatures are usually from April to June, but the air temperature is rarely more than 35 °C. The rainy season is currently from June to November. During this season, the rains (usually occurred at the end of the afternoon) enable to refresh the ambient in the evening. The dry season in the Southern of Vietnam extends from mid-November to April, where there is limited rainfall [1]. Following several preliminary studies basing on the psychrometric charts, the natural conditions of the Southern of Vietnam are favorable for the bio-climatic architectural designs [2], that is a sustainable approach. However, in the cities, especially in Ho Chi Minh City, the use of air-conditioners become the more than more permanent. In many buildings, the air-conditioners are necessarily used all months and all days.

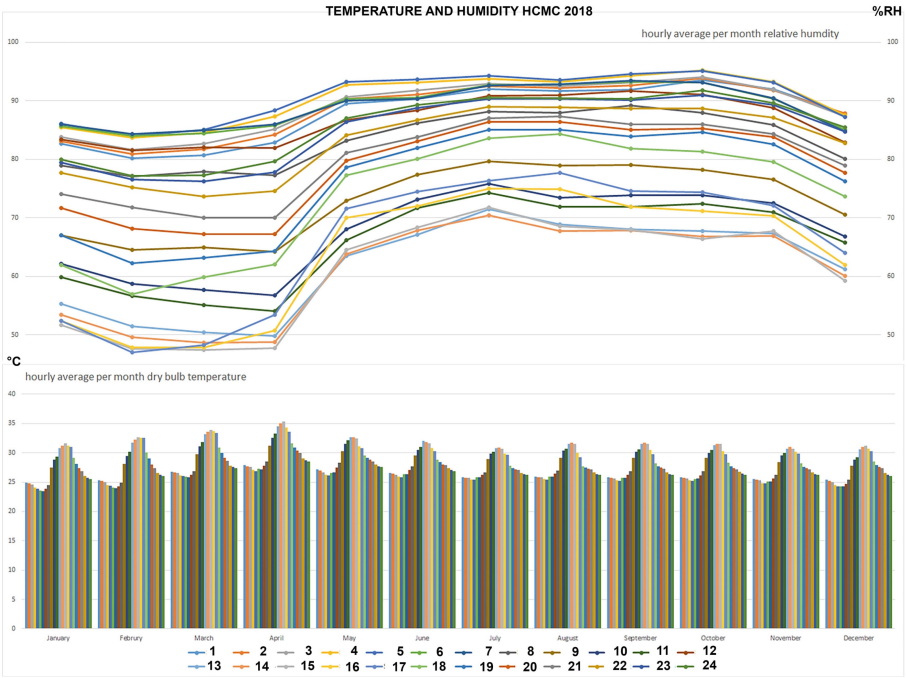


Fig. 1. Variation of the temperature of a typical year in Ho Chi Minh City.

The classrooms in Vietnam are classically designed following the "open approach", that means the doors and windows are open and the suspended fans are used. However, since several years, the air-cooling has been used in many classrooms, from the primary schools to the universities. Our study will show that the over-use of electrical air-cooling does not only increase the energy consumption, but also reduce the indoor air quality. It is worth mentioning that on one hand, the low air quality can influence on the health

and the efficiency of the occupants, and on the other hand, the bad ventilation and the low rate of air refreshing can rise the risk of transmission of certain viruses such as new-Corona virus (Covid-19) [3].

The upper limit of indoor CO_2 concentrations is usually recommended at 1000 ppm [4]. This limit can differ in some other countries, but in general this limit is higher than 1500 ppm [5].

An investigation about the thermal comfort in the air-conditioned classrooms was caried out in Hong Kong [6]. A field survey was conducted in several classrooms of a University. The results indicated that students in light clothing (0.42 clo) had the preferred temperature of approximately 24 °C, while the comfort range was between 21.5 °C and 26.7 °C. However, the CO_2 concentration was not mentioned in the study. Another study on the indoor temperature, relative humidity and CO_2 levels in academic buildings has been performed in Pakistan [7]. The results showed that for the air-conditioned buildings investigated, the CO_2 concentration was much higher than that in the buildings with natural ventilation, but the excess was not very high, the maximum CO_2 concentration was 1545 ppm in the buildings investigated.

Another study has been carried out on the indoor environmental quality and thermal comfort in a primary school in Ho Chi Minh City, Vietnam [8]. The study was performed within classrooms with ceiling fans. The relative humidity was in the range of 60% to 70%, and the average air velocity was of 0.56 m/s. With these parameters, the current temperature in the classroom was 29.4 °C. The CO_2 concentration was lower than 1000 ppm, which showed the relevancy of the ventilation by the ceiling fans for the CO_2 evacuation.

In the present paper, a study on the CO_2 concentration in the air-conditioned classrooms of a university in Ho Chi Minh City will be presented. The equipment used monitored the air temperature, the air relative humidity and the CO_2 concentration. It will be shown that results can be useful for the choice of active or passive architectural design for the classrooms in the Southern of Vietnam.

2 Experiments in the Classrooms

2.1 Device Used

In the present study, the device used for the measurements was the Testo® box (Fig. 2). It can measure the air temperature (in °C), the air relative humidity (in %RH), the CO_2 concentration (in ppm), the air pressure (in mbar), the dewpoint temperature (in °C td) and the absolute humidity (in g/m^3). On the device screen, the air temperature and the CO_2 concentration are permanently shown. The Testo® box is portable and easy to use. The measurements can be performed for long periods, the data are recorded and get sent to the cloud by means of a Wifi connection. The device had been calibrated by the sale company before the testing period. The accuracy of the device was ±2%RH, ±0.5 °C, and ±50 ppm.

2.2 Description of the Classrooms Investigated

The classrooms investigated in the present study are located in various buildings of Ton Duc Thang University (TDTU), at the Ho Chi Minh City campus in District 7. Six rooms

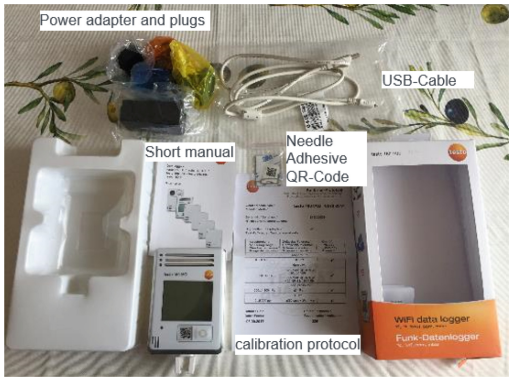


Fig. 2. The device used by Testo®.

with different sizes have been measured: B409, B408, B302 (6.5 m × 8 m), F412 (6 m × 6 m), D305 (8 m × 10.5 m) and B404 (6 m × 14 m), see also Fig. 3. All classrooms have two doors and the sliding windows on two parallel walls. The doors and windows are composed of aluminum frames and glass. The walls are in masonry of clay burnt bricks and finished by cement plaster and water paint. The classrooms have the air conditioners installed on the ceiling or on the top of the walls. The air-conditioning is common in all classrooms of TDTU campus.

At TDTU, there are 4 sections of teaching in a day: 2 sections in the morning and 2 other sections in the afternoon. In the present study, the measurements have mainly been performed in the section 2 (9h30-12h) and the section 3 (12h45-15h15), only one measurement was performed in the section 4 (15h30-18h00). The measurement device was placed on the lecturer's office during the measurement (Fig. 3). The number of students in these classrooms was about 35. The air conditioner units were turned on at the beginning of each teaching section. In general, the classrooms are closed during the teaching section. However, in the present, to investigate influences of the door opening or window opening on the CO_2 concentration, several scenarios have been investigated:

- Scenario #1: Standard scenario with doors and the windows being closed (as the current usual situation).
- Scenario #2: The doors are opened before the teaching section.
- Scenario #3: The windows are opened (about 20 cm) during the teaching break.

The difference between the teaching section 2 and teaching section 3 were also noted, because normally before the section 2, the doors are opened, however, the between the section 2 and section 3, the doors are usually not opened. In fact, between the teaching section 2 and the teaching section 3, the students have the lunch break, so the air conditioners are turned off during this period. However, the classrooms are usually remained closed during this break time.

In total, 17 measurements have been carried out in the classrooms, with different scenarios. During the measurements, the device was placed on the lecturer's table (Fig. 3).

Fig. 3. Classrooms investigated.

3 Results and Discussion

The typical results of a measurement are illustrated in Fig. 4, in which 6 parameters measured are presented: the CO_2 concentration (in ppm, red line), the indoor temperature (in °C, cyan line), the relative humidity (in %RH, purple line), the air pressure (in mbar, green line), the dewpoint temperature (in °C td, yellow line) and the absolute humidity (in g/m3, blue line). In the present paper, the attention is paid for the three parameters: the CO_2 concentration, the indoor temperature and the relative humidity.

First, the CO_2 concentration in Fig. 4 (red line) is analysed: at the beginning of the teaching Sect. 2 (at 9h30), the CO_2 concentration was about 500 ppm, which was the current value for an outdoor ambient of an aerated space [5]. When the teaching section started, the classroom was filled by the students and the lecturer, the air-conditioners were turned on, the doors and the windows were closed, the CO_2 concentration increased until 2200 ppm at 10h45 when there was a beak until 11h00. During the break, the students went out, the doors were opened and the windows was opened just 20 cm to ventilate the classroom. That was why the CO_2 concentration dropped to 1800 ppm at 11h00. Then, when the teaching continued after the break, the doors and the windows were closed, the CO_2 concentration continued to increase until 2800 ppm at 11h50, when the teaching finished.

It is important noting that after the teaching section 2 (which finished at 11h50 that day), the measurement device was taken out with the lecturer. Therefore, the data from 11h50 to 12h45 was not that measured in the classroom. During this lunch break, the doors and the windows of the classroom were still closed, therefore the air could not be renewed.

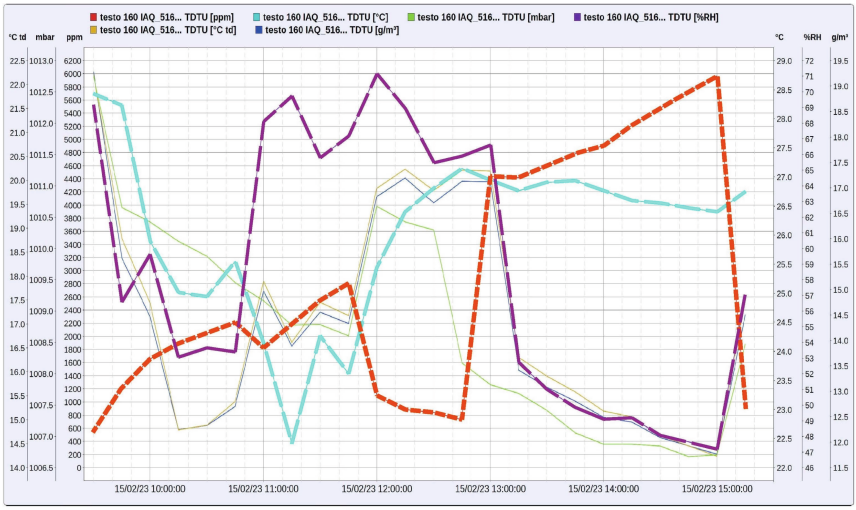


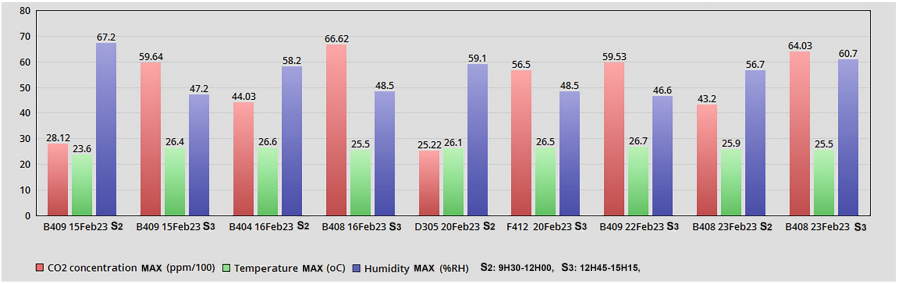
Fig. 4. A result obtained in the air-conditioned classroom B408, from 9h30 to15h15.

The device continued the measurements in the classroom at 12h45 when the lecturer entered to the teaching section 3. It is clearly observed in Fig. 4 that the CO_2 concentration in the afternoon was much higher than that in the morning. The highest CO_2 concentration was 6000 ppm at the end of the teaching section 3 (which finished at 15h00 that day). When compared to the recommended value (which is 1000–1500 ppm), the CO_2 concentration in the air-conditioned classroom investigated was very high, which have influences on the concentration and the effectiveness of the students in class.

The teaching section 3 (from 12h45 to 15h15) is analyzed in detail, because in this section, the windows were not opened during the break. It is observed that when the air-conditioners were turned on, the relative humidity (purple line) decreased.

From this figure, it is also suggested that the preferred temperature for the students were around of 26 °C.

The synthesis of the results obtained on other classes at other teaching sections is illustrated in Fig. 5, in which the maximum CO_2 concentration, the maximum temperature and the maximum relative humidity are presented. It is observed that for the classrooms measured, the maximum CO_2 concentrations varied from 2360 to 6913 ppm, which depended on several parameters: the dimensions of the classroom, the number of students in the teaching section, the teaching section (2, or 3 or 4). It is shown that in general, the CO_2 concentration of the teaching section 2 (in the morning) was lower than that of the section 3 or 4 (in the afternoon). Before the section 2, the classrooms were not air-conditioned (following the University's regulation), so the CO_2 concentration corresponded to a well-aerated space. From the section 2, the air-conditioner were turned on, the doors and the windows were closed, which increased the CO_2 concentration. During the break between the section 2 and 3, the doors and the windows were not opened, so the CO_2 accumulated to the section 3 and 4. This result shows the necessary to ventilate the classrooms, especially during the breaks.



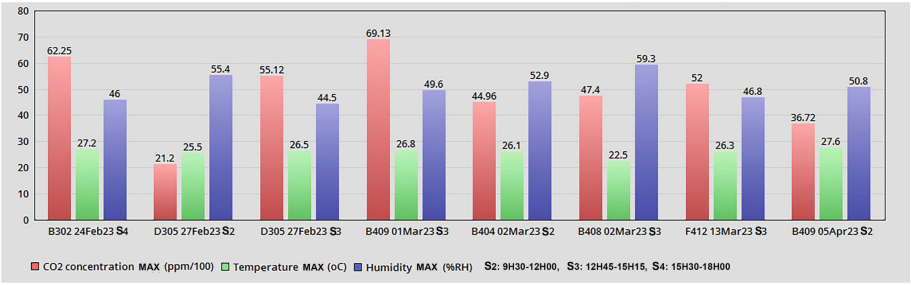


Fig. 5. Synthesis of the results obtained for different measurement periods: maximum CO_2 concentration, maximum temperature, maximum relative humidity. *Note: the CO2 concentration results should be multiplied by 100.*

The maximum relative humidities were in the range from 45 to 67%. In a tropical climate like Ho Chi Minh City, the use of air-conditioners clearly decreased the air humidity. It is also observed that in general, the classrooms were cooled less than 27 °C, which was in a current thermal comfort zone [2].

4 Conclusions and Outlooks

The use of air-cooling systems is constantly increasing in Vietnam and in Asia, including in the spaces which were traditionally operated with fans and natural ventilations, such as the classrooms. On one hand, the use of air-conditioners can create the cool spaces with the temperatures in the comfort zones, which can enhance the comfort of the occupants. The results showed that the use of air-conditioners reduced the humidity in the classrooms, which was also a positive aspect in a tropical climate. However, on the other hand, to reduce the energy consumption, the air-conditioned spaces are usually closed, which can reduce the air-quality, especially the increase of the CO_2 concentration. The present paper showed that, when the ventilation is absent or inefficient, the CO_2 concentration in the air-conditioned classrooms can be higher several times than the limits recommended by the standards. The high CO_2 concentration in the classroom can therefore directly influence on the concentration of the students, the relevancy of the courses in the classes.

From the results in this explorative study, it is suggested that the air-conditioned classrooms (and in general the air-conditioned spaces with high number of users) should

be equipped with suitable air-extraction system. In regard of the classrooms where the air-extraction is not available, the doors and/or the windows should be opened at some periods (for example between the teaching sections or at the breaks) to renew the air in the closed space. These openings may increase the energy consumption but it is necessary to have a better air quality and to ensure health of the students and teachers.

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