24th COBEM - 2017

24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-2466
CO_2 CONCENTRATION CONTROL SYSTEM IN TEACHING INSTITUTIONS

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Abstract. *Regarding air-conditioned environments that keep a large number of people for long periods, such as classrooms, the level of wholesomeness must be suitable to ensure the learning process and health. Therefore, air conditioning systems have to work not only on parameters such as temperature and relative humidity but also on air renovation and filtration to ensure that Inner Air Quality (IAQ) is always acceptable considering the accumulation of CO_2 produced by occupants respiration. Researches show that high concentrations of this non-biological contaminant can cause headaches, drowsiness and attention deficit, reducing student performance. In order to preserve the IAQ, the present work describes the development of an automated air renovation system for a classroom of an educational institution. The system was built with a CO_2 sensor, which is responsible for the measurement of CO_2 concentration in ppm (parts per million) inside the classroom; an Arduino, for data acquisition and control of the measured variable through the activation of an air blower and two overpressure dampers, to keep positive internal pressure but at acceptable levels. The CO_2 concentration reference used was 1000 ppm – maximum value for chemical contamination recommended by technical standards and sanitary surveillance agencies.*

Keywords: *Internal Air Quality, CO_2 Concentration, Learning, Educational Institutions, Automated System.*

1. INTRODUCTION

Currently, in air conditioning projects, IAQ must be considered due to its proven importance. This parameter has some indicators such as the air relative humidity, the thermal comfort and the presence of soiling, in which we classify the object of this study: CO_2 concentration.

Studies conducted by the Brazilian Association of Refrigeration, Air Conditioning, Ventilation and Heating (ABRAVA) - and other related entities - show that high concentrations of carbon dioxide in closed and air-conditioned environments can cause some effects on the occupant's body, such as eye irritation, headache, drowsiness and reduced performance.

In view of this, in order to ensure the well-being of those in environments that are conducive to such conditions, the World Health Organization (WHO) and the National Association of Sanitary Surveillance (ANVISA) have established standards to regulate the implementation of air systems conditioned in establishments according to aspects such as number of occupants, length of stay in the environment and flow and activity of people.

According to these guidelines, the Maximum Recommended Value for chemical contamination is 1000 parts per million (ppm) of carbon dioxide - (CO2), as an indicator of external air renewal, recommended for comfort and well-being.

The adequate Air Renewal Rate of air-conditioned environments should be at least 27 m^3 / hour / person, except in the specific case of environments with high turnover of people. In these cases, the minimum Air Renewal Rate will be 17 m^3 / hour / person, and it is not allowed in any situation that the environments have a CO2 concentration, higher or equal to that established. Assuming that the environment to be analyzed is a teaching institution classroom, the renewal rate of 27 m^3 / hour / person will be considered.

Starting from the premises admitted above, the aim of this paper is to validate the requirement of CO_2 concentration inside enclosure spaces through the built of an air renovation system control in order to comply with current regulations

declared by ANVISA. This study show the important is to ensure health and safety for those who attend the institution lessons. Moreover, it intends to offer an environment free of soiling, with comfort temperature, following the standard parameters.

2. PURPOSE

The purpose of this work is to validate the need to control CO2 concentration through the implementation of an air renewal system in order to comply with current regulations. This study aims to promote the practice of measures that guarantee the health and safety of those who attend the institution. More than that, to offer an environment free of impurities, with ideal temperature and mainly, within the established parameters.

3. INFLUENCE OF HIGH CONCENTRATION OF CO_2 ON STUDENTS' INCOME

When students are exposed for long periods in a conditioned environment with low air renewal they will be subject to symptoms such as drowsiness, headaches, distraction and difficulty to maintain concentration for long periods. Such effects are often caused by the high concentration of CO2 in the site.

When the balance of oxygen and carbon dioxide in the blood is out of the norm, with CO2 being in excess, acidosis of the same happens. The body's reaction to return to balance is yawn, characterized by deeper breathing, which in turn forces CO2 out of the blood. On the other hand, constant yawning also provides a higher frequency of mouth breathing, causing clinical and behavioral changes known as oral breathing syndrome. It is characterized by symptoms such as irritation, moodiness, drowsiness, restlessness, deconcentration, anxiety, impulsivity and consequently causes attention deficit.

Thus, it is observed that in addition to the observed direct symptoms, there is also a consequence, the reduction of student performance. Another extremely relevant point is that frequent exposure to such circumstances may in the long run cause a deterioration or reduction of nervous system functions, impairing the cognition of an individual.

A study by researchers at the Department of Psychiatry and Behavioral Sciences at the State University of New York in conjunction with the Department of Interior Environment at the Lawrence Berkeley National Laboratory examined the interference of high concentrations of CO2 in decision making and performance. To do this, three groups of people were arranged in three different environments: one with a low concentration of CO2 (600 ppm), the other with the recommended concentration (1000 ppm) and, finally, one with a high concentration (2500 ppm). Each of the groups responded to performance and decision-making tests and the result was:

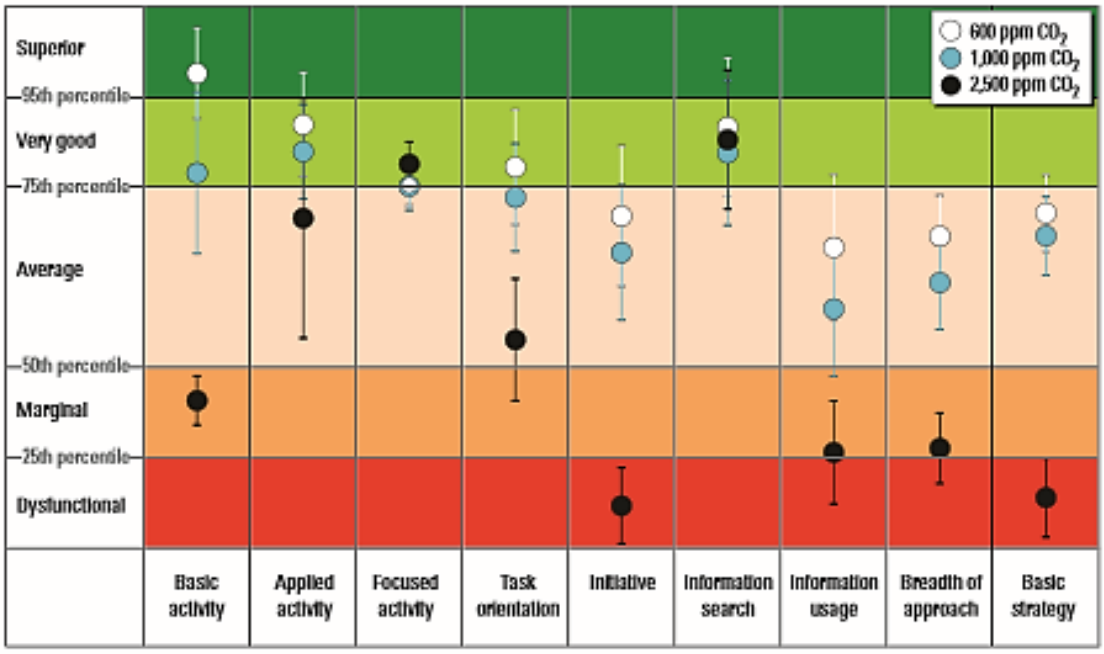


Figure 1. Impact of carbon dioxide on human performance for decision making.
Source: Article - "Is CO2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO2 Concentrations on Human Decision-Making Performance "

The colored bands represent a growing level (from red to green) of performance in decision making and the columns represent the type of activity, being: basic activity, applied activities, focused activity, task oriented, initiative, information search, use information, breadth of approach and basic strategy.

Colored dots represent the CO2 concentration of the environment in which people were exposed. It is noticeable that for most situations, the best yields were 600 ppm and the worst were 2500 ppm, while the 1,000 ppm group was intermediate. Only for focused activity and information search that the layout was different.

This research substantiates what has been addressed throughout this work: the fall in the income of people subjected to high concentrations of CO2. Evidence of the damage that students may have during their school life due to an inadequate system of air conditioning.

4. METHOGOLOGY

In order to enrich the research and highlight the necessityof the air renovation, measurements of carbon dioxide concentration were made inside a classroom of an educational institution with 127,5 m² located at the first floor. The equipment used was an air quality sensor equipped with CO_2concentration, relative humidity and ambient temperature sensors.

The measurements were done at different times and classes in order to evaluate the different conditions of the internal air quality. For the measurements method, the meter was positioned at a height of approximately 1.5 meters of the floor and at the middle of the classroom.

As in many other cases, the environment in question is conditioned but does not present any form of ventilation in order to maintain exchanges with the outside environment for an Internal Air Quality control. Therefore, as expected, the values of the presence of CO2 were discrepantly outside the standards referenced by ANVISA.

Furthermore, an Arduino was programmedto control the air blower based on a maximum CO_2 concentration of 1000ppm and an ambient CO_2 sensor is responsible for the data acquisition, the range of the sensor is up to 2000 ppm. Figure 2 shows the system control diagram.

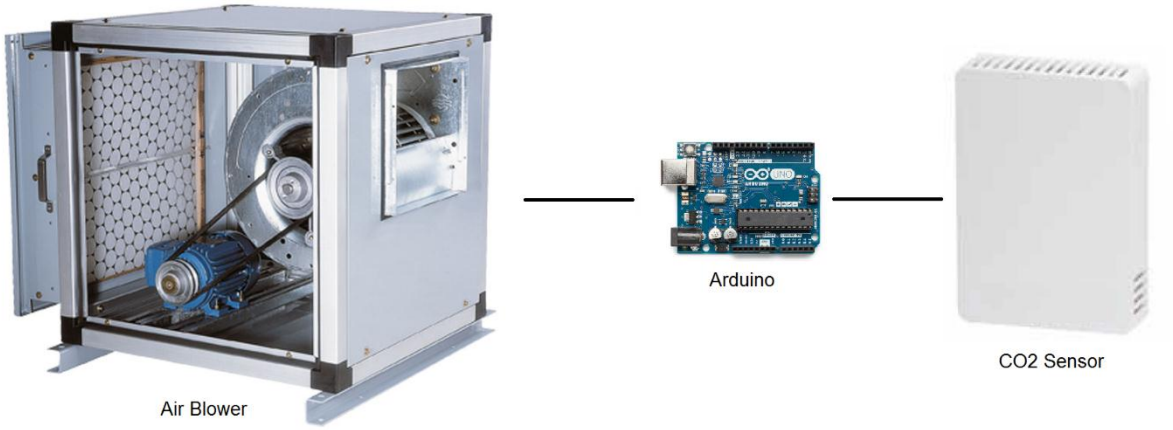


Figure 2. System control diagram with air blower, Arduino controller and CO_2 sensor.

5. DISCUSSION AND RESULTS

N measurements were performed, in different situations, but always in the same room. The measurement numbers, the start and end times for each one, the number of occupants and the date of measurement are detailed below.

Table 1. Information on start and end time, number of students in the room and date for each of the measurements.

Measurement	hs	hf	occupants	day
1	11:10	12:20	47	09/mar
2	15:25	16:40	100	09/mar
3	13:30	15:05	33	16/mar
4	17:30	18:30	23	16/mar
5	17:25	18:30	15	17/mar

The table below shows the CO2 concentrations in ppm for each of these measurements. Labeling was done within five minutes for all samples. The amount of values marked varied according to the beginning and end of the class, which were different for each case.

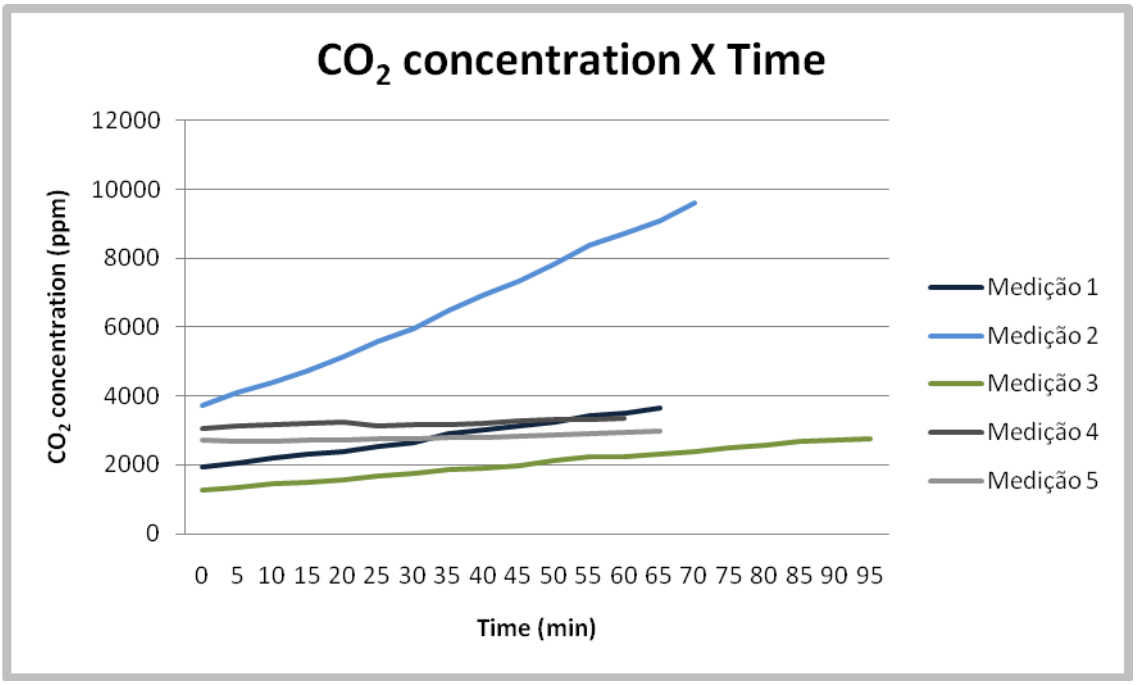
Table 2. Carbon dioxide concentrations for each measurement

Time	**CO_2 concentration (ppm)**				
	1	**2**	**3**	**4**	**5**
0	1926	3730	1272	3045	2715
5	2040	4100	1361	3120	2697
10	2195	4416	1444	3152	2705
15	2320	4730	1508	3190	2735
20	2385	5130	1578	3260	2739
25	2530	5586	1668	3129	2765
30	2646	5940	1758	3158	2775
35	2893	6484	1850	3168	2796
40	3015	6916	1919	3190	2816
45	3144	7315	1990	3266	2847
50	3255	7817	2115	3305	2872
55	3410	8362	2220	3308	2921
60	3517	8715	2248	3363	2943
65	3654	9090	2315		2979
70		9594	2395		
75			2485		
80			2570		
85			2703		
90			2739		
95			2759		

Some small swings in concentration measures are perceptible. This is due to the fact that there is a flow of people coming and going, even if it is low. For the measurements made with a smaller number of students, the interference was greater.

Another point to note is the variation of the first measured concentration for each of the measurements without following a logical standard in relation to the other samples. This happens because in some cases already had a class for another class, in the same place, so in those cases, the initial concentration was higher.

Through this data, it was possible to plot the following graph:



Graph 1. Carbon dioxide concentration present inside the room over time

As already predicted, the marked concentrations increased with time, after all, the high concentrations occur due to the accumulation of CO2 as a byproduct of the students' breathing. In addition, the inclinations presented by the curves were larger for the measurements made in classes with larger numbers of students.

6. CONCLUSION

Measurements of carbon dioxide concentration have proven what was already supposed: the presence of CO2 exceeds the values recommended by ANVISA. This circumstance did not cause strangeness due to the inadequate conditions of air conditioning of the room whose system prioritizes only the temperature. Therefore, the other indicators of Indoor Air Quality that are also extremely relevant, such as CO2 concentration, are neglected.

Thats values exposing the critical condition that the students face frequently. Such a situation presupposes that these occupants are susceptible to the symptoms shown in this paper.

Faced with the alarming figures and exposed premises, the renewal of air becomes a caution that should have been adopted before there was even a case study about the room. This is because in any case, it is expected that educational institutions always offer the most favorable environment possible for the optimal performance of their student body. Hence, renewal of air to control CO2 concentration becomes a problem that every educational institution should pay attention to.

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8. RESPONSIBILITY NOTICE

The authors Camilla de Sousa Silva, Leandro Mota Carvalho and Luís Gabriel Guanabara Keler Gesteira are the only responsible for the printed material included in this paper.