Indoor Air Quality Assessment of Campus Spaces with Carbon Dioxide (CO_2) as a Measure of Adverse Health Effects

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Abstract

Indoor air quality (IAQ) is referred to as "the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants" (US EPA, 2015). Indoor pollutant levels further determine the quality of indoor air, and one of the indicators used to measure IAQ is carbon dioxide (CO_2). Drawing on data collected from a classroom, auditorium, and gym setting in the Mount Royal University campus, the aim of this report is to determine if CO_2 levels present are within established margins substantial to result in adverse health effects.

1 Introduction

Indoor air quality (IAQ) is a frequent and relevant health and safety concern in many confined environments where human occupancy exists. IAQ is referred to as "the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants" (US EPA, 2015). As individuals spend approximately 90 percent of their time indoors (US EPA, 2015) it is important to recognize that adverse health effects can occur from poor air quality. Common indoor air pollutants include formaldehyde, molds, allergens, gas-burning furnaces and appliances, radon gas, and secondhand smoke (CDC, 2014).

This study aims to analyze the CO_2 levels in a variety of campus spaces: auditoriums, classrooms and a gym setting and to determine if the CO_2 concentrations exceed levels correlated to adverse health effects. Our main objectives are to analyze CO_2 in an outdoor setting as well as the Mount Royal University Recreation Center weight room during empty, peak and non-peak hours over a period of three days. We will also be analyzing the average CO_2 levels in an auditorium and a classroom setting when it is occupied with students and unoccupied over a period of three sessions.

2 Methodology

2.1 Collection of data

Colorimetric gas detection tubes (CO_2 300-5000 ppm) and a hand held pump were used to gather CO_2 concentrations in specified indoor spaces on MRU campus. The sampling occurred in a classroom, auditorium and a weight room in the fitness center for three separate days spaced out over a three-week time frame. For each specified classroom and auditorium setting, a baseline sample was taken at the beginning of the class session (prior to being occupied with students) with the doors closed. Another reading was taken after the class has ceased its session (before the students exited). For the weight room in the fitness center, a baseline sample was taken at opening hour (i.e. 06:00) prior to being occupied with students. Another reading obtained on the same day was taken at peak occupancy hour at 18:30. A non-peak occupancy was taken at closing hour (i.e. 23:00). A reading of the outdoor CO_2 levels was taken each day the indoor data was collected. Three days within a three-week time frame during the month of October and November were chosen for data collection. Locations were chosen based on varying room size and supplied air volume with varying occupancy load with the dates determined by convenience.

2.2 Data Analysis

The data obtained is referenced to established ASHRAE standards and the scientific literature.

3 Results

3.1 Assessment of parameters

Table 1: Detailed physical and numerical parameters of specific locations on MRU campus.

	Weight room	Auditorium	Classroom
Floor Area (m^2)	807.7	194.4	74.3
Supply Air (L/s)	7830	1320	426
Peak Student Count	32	50	24
Non-peak Student Count	23	/	/
Duration Occupied (hrs)	18	6	6

4 Discussion

4.1 Synthesis of key findings

The average indoor CO_2 concentrations detected in the selected indoor spaces were below the established 2500 ppm ASHRAE threshold levels; hence, it is not likely to pose any long term health risks to students. However, the average CO_2

levels at peak occupancy are above the 1000 ppm recommendation by ASHRAE guidelines for indoor comfort and within the range for short term effects (Satish et al, 2012). The results obtained in this study indicate that the ventilation rates in these specific locations are in compliance with the standards as the supply air is above the minimum ventilation rates in the breathing zone for acceptable indoor air quality. It is notable that supply air volumes are usually much higher due to ventilation (outdoor) air being mixed with room air (ASHRAE, 2013);

4.2 Hazardous effects corresponding to increased CO_2

67 percent of samples taken during the peak occupation had values greater than 1000 ppm CO_2 (Satish et al, 2012) which is has been identified as a threshold for cognitive effects. At these levels relative to the baseline data collected, it can be expected that there will be short-term mental impairments such as: task orientation, information usage and applied activity (Satish et al, 2012). Levels above baseline CO_2 levels may increase the prevalence of conditions such as headaches, lower respiratory issues and eye irritations (Apte, 2000). A more recent study suggests that in conjunction with the negative effects, the ability to concentrate on individual tasks increases with elevated CO_2 levels; peaking at 2500 ppm relative to the 600 ppm baseline (Satish et al, 2012).

4.3 Human respiration

Respiration of indoor occupants is the primary source of elevated CO_2 in indoor settings (Seppänen, 1999; Apte, 2000), and the average adult breath respires about 35,000 to 50,000 ppm of CO_2 (Prill, 2000). Rooms that have poor ventilation can lead to concentrations of approximately 3000 ppm CO_2 solely from human respiration (Health Canada, 1989). Furthermore, it is advised that CO_2 levels do not exceed 700 ppm above outdoor ambient air,

4.4 Limitations

There are many compounding factors associated with this experiment that must be taken into account. Due to the nature of the experiment it was important to allow human movement in and out of the test locations in order to achieve a representative result. Having doors opened or closed within the indoor space would change the status of the system, therefore affecting the amount of air exchange between the room and hallways. This would result in varying air circulation rates over the course of the testing periods. Over a longer period with a greater number of samples, a representative average could be attained. With the limited number of samples (n=3) gathered for each room, coupled with the limited time frame, it is difficult to determine.

4.5 Future research recommendations

This study stipulates that there is a strong relationship between elevated indoor CO_2 levels with the number of occupants present in an indoor setting. Drawing from the results of this study, appropriate ventilation levels that would decrease the risk for adverse health effects can be indicated by the concentration of CO_2

in a fully occupied space. However, CO_2 is only one parameter to determine the quality of indoor air;

5 Conclusion

The results drawn from this study indicate that we can obtain a general illustration of CO2 levels in a variety of indoor spaces. Furthermore, fine-tuned adjustments can be made to the HVAC systems so as to increase the airflow in a confined indoor space. Other suggestions include using portable ventilation systems, ensuring that adequate maintenance is established, and retrofitting applicable indoor spaces where necessary.

6 Equations

$$e = mc^2 \tag{1}$$

$$(c + d)^2 = c^2 + 2cd + d^2 \tag{2}$$

$$log(xy) = log(x) + log(y) \tag{3}$$

References

[1] United States Environmental Protection Agency. Ventilation for Acceptable Indoor Air Quality. ANSI/ASHRAE Standard.**accessed Nov 28, 2015**. *http://www2.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality.*

[2] Yocom, J.E.; & MacCarthy S. M. Measuring indoor air quality: A particle guide. **1993**. *John Wiley and Sons.*

7 Appendix

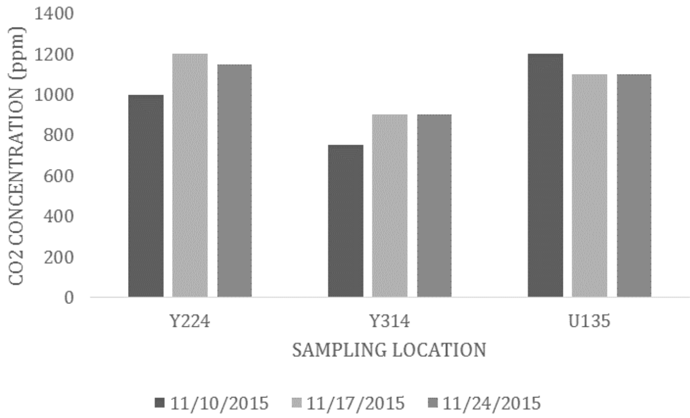

Figure 1: Peak CO_2 values for the selected locations on the days specified over a three week period

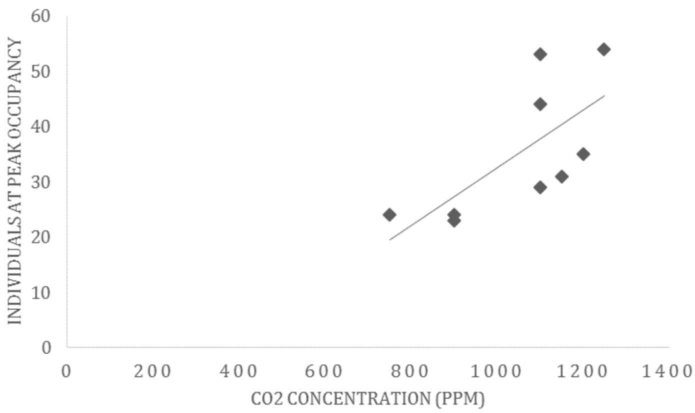

Figure 2: Plot of the relationship between the occupants in selected indoor spaces and the resulting CO_2 concentrations.

sitemap.png

	Baseline (ppm)	Peak Occupation (ppm)	Non-Peak Occupancy (ppm)	Peak Occupants	Non-Peak Occupants
Auditorium (Y224)					
Reading 1	700	1100	/	44	/
Reading 2	750	1100	/	53	/
Reading 3	600	1250	/	54	/
Classroom (Y314)					
Reading 1	700	750	/	24	/
Reading 2	650	900	/	23	/
Reading 3	750	900	/	24	/
Weight Room (U135)					
Reading 1	400	1150	750	31	18
Reading 2	450	1200	800	35	29
Reading 3	400	1100	900	29	22
Outdoors	300	300	300	/	/

Figure 3: The raw data recorded for various locations on MRU campus.