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Survey of Indoor Co2: Basis for Rapid Assessment of Office Workers' Level of Safety

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ABSTRACT

Most of the offices at LDCU main campus have air conditioning units that merely recirculate air thereby causing expected build-up of CO_2 during occupancy time which may affect workers' safety. Hence, a survey was conducted to determine the status of indoor CO_2 in select offices of its four buildings and to determine as well if there is a significant difference in the CO_2 levels across weeks. This study employed spot CO_2 determination using direct-reading instrument designed for rapid assessment. Out of the thirteen offices tested, six were found to have adequate ventilation. These include the offices of the College of Teacher Education, College of Criminology, College of Business and Accountancy, College of Engineering, Finance and Executive Offices. This result implied inadequacy of oxygen supply in the area resulting to health symptoms like drowsiness and headaches as reported by some employees during occupancy time. Recommendations included the installation of local exhaust to depressurize indoor air and allow oxygen to enter. Putting indoor plants for CO_2 absorption during photosynthesis. It is also considered that a local policy be made by the university to conduct periodic monitoring of CO_2 level which reflect the occupational health and safety of workers.

Keywords: Carbon dioxide, Indoor Air Quality, monitoring, worker safety

INTRODUCTION

Studies on CO2 levels have always been associated with ambient air quality. Few studies were attempted to focus on indoor air quality. While outdoor air quality is a determinant factor to human health and well-being, greater efforts should be geared on the indoor air, so much so that most people spend longer occupancy time in offices wherein airconditioning units merely recirculate air and producing continuous build-up of CO2 beyond normal levels.

Indoor CO2 then is considered a standard for ventilation (ASHRAE Std 62). And considering that ventilation may not be the same for different type of rooms, the occupant health may be at risk for some. An average person exhales about 35,000-50,000 ppm of CO2 yet ASHRAE standard 62.1 (2013) levels of CO2 are estimated at normal range of 200-700 ppm in a space area. WHO (2010) estimates the normal range at 350-1000 ppm. Air Indoor Quality (AIQ) asserts that normal level should be maintained at 1000 ppm in classrooms and 800 ppm in offices. The outdoor air is about 380 ppm, which means that it is a hundred times lower than the indoor level. This means that regardless of space of occupancy rates and volume occupied, this standard level should be maintained. IAQ (2000) reports that increased levels result in drowsiness, lethargy and a general sense that air is stale. Effects may be experienced right after exposure or after a long time. It is further asserted that there should be proper ventilation or natural flow and mixing of air to allow air levels to attain equilibrium that may be considered acceptable to human health as improper ventilation may predispose the occupants to adverse health effects.

Most air conditioning units in offices have nothing to do with oxygen levels in a room. They only control heat and humidity. These merely recirculate the available gas in the room. The moment doors are opened, only then can the CO2 inside be released and fresh air allowed to get inside. Also the higher pressure outside forces air into the room each time the door is opened. Therefore, if rooms are not opened for a long period, CO2 will continue to build up.

Recent studies have associated increased CO2 levels with lethargy and dizziness resulting to frequent sick leaves in offices and in extreme cases, to serious effects. The same may be considered as causal effect to cases of lethargy and dizziness inside classrooms especially in the congested ones and presumably may cause also the occupant to be out of focus on the work at hand. Basically, increased occupancy rate increases CO2 levels and conversely, O2 levels will decrease (EPA 2000).

Satish (2012) observed CO2 levels in association with impaired work performance, increased health symptoms and poor achievement. NCCH (2010) study also observed human health effects at very high CO2 levels. Daisy et al. (1999), collected CO2 data that strongly indicated inadequate ventilation in many classrooms.

Borghi (2017) stressed that air quality has a huge impact on life quality which is proven by the growing number of miniaturized monitors being developed because of their notable advantage. Chiu et al., (2015) even tried to monitor CO2 concentration within tour buses and real-time traffic conditions. Results revealed maximum concentrations of 3000 ppm and daily average concentrations of 2510.6 ppm and and 2646.9 ppm. These values exceeded the air quality standard Taiwan Environmental Protection Administration and as suggested, ventilation frequency should be increased to ensure travel safety. Even in hairdressing salons in Taipei, air quality was monitored by Chang et al (2017) and it was found out that 83% of the samples had levels higher than the standard regulated by Taiwan's IAQ Act. However, Smith and Pitt (2011) proved the reduction of CO2 level in two offices with plantscaping or introduction of plants which can lead to performance gains and reduce ill health effects on the work force.

Occurrence of the same cases were speculated by the researchers and therefore further exploration is deemed important to find out if proper ventilation is in place in building offices at LDCU campus for the purpose of assessing level of work safety, get immediate decisions concerning occupants' safety, and applying sustainable intervention for occupants to become productive.

FRAMEWORK

This study is anchored mainly on the concepts of Herwagen (2000), Hoseini et al. (2013), Sendimir (2013). Herwagen (2000) presented in his result that green buildings provides organizational success and occupant productivity. This is supported by Sendzimir (2003) who asserted that nature is the basis for green buildings. This means that green buildings are designed in a manner that is similar to nature and only then can the occupant who works comfortably, becomes successful and productive. The same can apply to a learning institution that provides an atmosphere that is conducive to doing office tasks.

Hoseini et al. (2013), stated that performance of green buildings have been transformed to a sensible and practical solution to alleviate CO2 levels. By saying this, he considers high levels of CO_2 as an impeding factor to building performance. Figure 1 illustrates the conceptual framework which underlies this paper and provides the basis along which the paper revolves in. In perspective, managing CO_2 levels impacts building performance which provides success and productivity to occupants.

Figure 1. Illustration of the conceptual framework that shows the relationship of the variables under study

The study area is the LDCU Main Campus. The buildings included consisted of the North Academic Cluster (NAC), South Academic Cluster, Heritage (HB) and Rodelsa Hall. The offices tested for CO_2 level at the NAC Building are the Publishing Office, Criminology and College of Teacher Education offices. In the South Academic Cluster building, the offices tested are the College of Engineering, College of Arts and Sciences and College of Business Administration. As for the Heritage building, the offices of the Vice-President for Academic Affairs (VPAA), the Research, Publication and Extension Office (RPEO), the Senior High School and Rehabilitation Science offices were tested. In the Rodelsa Hall, the offices included in the study are the Executive Office, Finance Office, and Student Personnel Services Office. The occupants of these offices are faculty, staff, and administrators.

The research design employed in this study is the descriptive type. It is most suited to describe the data on indoor air quality inside buildings of LDCU main campus and to come up with a reasonable and logical conclusion based on the CO_2 trend over a period of time.

The research material includes a CO_2 meter which will measure CO_2 levels indoor. It is the digital type of instrument based on infrared technology which is a direct reading instrument.

In this study, the researchers tested three (3) offices in each of the four (4) buildings, North Academic Cluster (NAC), South Academic Cluster (SAC), Heritage Building (HB), and Rodelsa Hall. Permission was sought from the administration before conducting the study.

During conduct of the study, the researcher followed standard precautions in handling the CO2 meter by properly calibrating the instrument prior to its usage.

The office occupants were asked about health symptoms they experienced duringtheir stay in the office. Spot measurements of CO2 concentrations in parts per million (ppm) both from indoor were carried out using CO2 meter once a day inthree representative offices of each buildings. The CO2 measurement was recorded in 3 different areas of the office and the average of the 3 measurements was recorded as the final result per office per period of sampling. The procedure was carried out for a period of 3 weeks, 4 days in a row per week. The average results were compared with standard measurements to identify the CO2 status of the offices that is, if the office has adequate ventilation or not. This study employed the use of F-test to determine if there is a significant difference in the data gathered across weeks.

OBJECTIVES OF THE SUDY

This tudy is aimed at generating baseline information on indoor air quality in selected offices of Liceo de Cagayan University main campus for sustainable intervention. Specifically, it aimed to (1) determine the status of indoor CO2 levels in the offices of North Academic Cluster (NAC), South Academic Cluster, (SAC), Heritage Building (HB), and Rodelsa Hall using CO2 meter and compare them with standards and (2) determine if there is a significant difference in the CO2 levels of offices across weeks.

RESULTS AND DISCUSSION

Objective 1. To determine the status of indoor CO2 levels in the offices in the North Academic Cluster, Heritage, Rodelsa Hall, and South Academic Cluster Buildings.

Table 1. Weekly CO2 Results of Offices at North Academic Cluster (NAC) Building

Offices	Week	Mean	Remarks
College of Teacher Education	1	826.5	Adequate ventilation
	2	786.7	
	3	914.0	
	Mean	842.4	
CRIMINOLOGY	1	961.3	Adequate ventilation
	2	831.7	
	3	778.0	
	Mean	857.0	
Publishing Office	1	1421.7	Inadequate ventilation
	2	1457.4	
	3	1246.9	
	Mean	1375.3	

LEGEND:

300-600 ppm = Ideal (I)
600-1000 = Normal (N)/Adequate Ventilation

1000-4000 = Moderate (M)

Table 1 presents the mean values of CO2 levels over a three-week period in sampled offices located at NAC Building and were contrasted to a range of values (ideal, normal, and moderate). Based on the results, two offices (CTE and Criminal Justice) had normal mean CO2 levels recorded at 842.4 ppm and 857.0 ppm respectively. This implies that there is adequate ventilation in this period of testing. On the other hand, the Publishing Office had a mean value of 1375.3 ppm, interpreted as moderate (tolerable level) and is further interpreted as inadequate ventilation. Therefore there is inadequate supply of O2 as asserted by EPA (2000). This may be attributed to the high occupancy rate in this office. Over a period of three weeks, only the CTE and Criminology Offices exhibited adequate ventilation.

Table 2. Weekly CO2 Results of Offices at HB Building

Offices	Week	Mean	Remarks
RPOE	1	1405.1	Inadequate ventilation
	2	1440.5	
	3	1228.0	
	Mean	1357.9	
VPAA	1	1112.4	Slightly inadequate ventilation
	2	1148.3	
	3	1016.3	
	Mean	1092.3	
SHS	1	1297.3	Inadequate ventilation
	2	1338.9	
	3	1044.8	
	Mean	1227.0	
RS	1	2036.2	Inadequate ventilation
	2	1773.3	
	3	1200.3	
	Mean	1669.9	

LEGEND:

300-600 ppm = Ideal (I)

600-1000 = Normal (N)

1000-4000 = Moderate (M)

Table 2 shows the mean values of CO2 over a three-week period in sampled offices located at HB Building. Based on the results, all offices (Research Publications and Extension Office, Vice-President for Academic Affairs Office, Senior High School, and Rehabilitation Science) had moderate mean CO2 levels computed at 1357.9, 1092.3, 1227.0, and 1669.9 ppm, respectively. Except for the VPAA Office, the increased levels may be due to the high occupancy rates in these offices. The PT Office however, had the highest value which may be caused by an average occupancy of 12 people, wherein the CO2 build up is higher and faster than its release. In regard to the VPAA office with only 2 regular occupants, the mean CO2 level is at moderate category but it is just slightly above normal. This is further interpreted as slightly inadequate ventilation. Except for VPAA Office with slightly inadequate ventilation, the rest had inadequate ventilation over a period of 3 weeks. Cases of occasional drowsiness and headaches were reported by some teachers in the Senior High and Rehabilitation Science offices. This is in consonance with the studies of Satish (2012) and Daisy et al. (1999)

whose results showed observed CO_2 levels which were associated with health symptoms and indicated inadequate ventilation.

Table 3. Weekly CO_2 Results of Offices at Rodelsa Building

Offices	Week	Mean (ppm)	Remarks
Finance	1	1132.2	Adequate Ventilation
	2	952.3	
	3	850.3	
	Mean	**978.3**	
SPS	1	1322.9	**Inadequate ventilation**
	2	1020.5	
	3	1066.3	
	Mean	**1136.6**	
Executive	1	986.5	**Adequate ventilation**
	2	934.8	
	3	883.4	
	Mean	**934.9**	

LEGEND:
300-600 ppm = Ideal (I)
600-1000 = Normal (N)
1000-4000 = Moderate (M)

Table 3 presents the mean values of CO_2 in sampled offices located at Rodelsa Building and were also contrasted to a range of values (ideal, normal, and moderate). Based on the results, the Finance and Executive offices obtained mean values (978.8 ppm and 934.9 ppm, respectively) which fall under the normal category and interpreted as having adequate ventilation. The SPS office had 1136.6 ppm which is verbally interpreted as moderate. It is beyond the normal level but is still considered tolerable yet inadequate ventilation. Health symptoms like dizziness and discomfort were reported by 3 employees at the time of occupancy. This is in agreement with the studies of Satish (2012) and Daisy et al. (1999) whose results showed observed CO_2 levels which were associated with health symptoms and indicated inadequate ventilation. This may be attributed to the small office area with an average number of 4-5 occupants.

Table 4. Weekly CO2 Results of Offices at SAC Building

Offices	Week	Mean	Remarks
CAS	1	956.6	Slightly inadequate ventilation
	2	1193.1	
	3	931.0	
	Mean	**1026.9**	
CBA	1	1046.1	Adequate Ventilation
	2	977.3	
	3	925.8	
	Mean	**983.0**	
COE	1	1128.8	Adequate ventilation
	2	988.6	
	3	786.6	
	Mean	**968.0**	

LEGEND:

300-600 ppm = Ideal (I)

600-1000 = Normal (N)

1000-4000 = Moderate (M)

Table 4 reveals the mean values of CO2 in sampled offices located at the Building and were also contrasted to a range of values. Based on the results, the COE and CBA obtained mean values (983.0 ppm and 968.0 ppm, respectively) which fall under the normal category and interpreted as having adequate ventilation. The CAS office on the other hand had 1026.9 ppm which is considered as moderate but interpreted as having slightly inadequate ventilation. It is slightly above the normal level yet is still considered tolerable but the fact remains that inadequate ventilation means lack of O2 in an occupied room or office. The highest increase in the CO2 levels was obtained in week 2 which was during the peak enrolment period. No cases of health symptoms were generated during the interview with the office occupants at the time of testing.

The trend of values in different offices is further illustrated in figures 1- 3.

Figure 1. The CO_2 trends across weeks in the offices of RPEO, VPAA, Senior High School and Rehabilitation Science

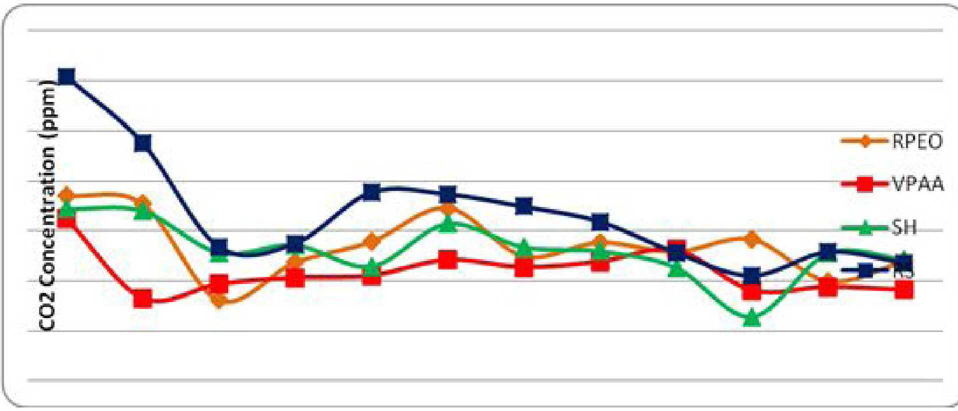

Figure 1 shows the CO_2 trend across weeks of the RPEO, VPAA, Senior High School and Rehabilitation Science Offices. It is illustrated further that these offices had values which were above normal and with Rehabilitation Science having obtained the highest values especially in the first and second week. As for the first three offices, the values are not consistent since these are frequented byvisitors consisting mainly of students in varying numbers across the study period. The VPAA office however had values indicating slightly inadequate ventilation and less frequented by visitors which are mostly faculty and some staff.

Figure 2. The CO_2 trends across weeks in the Finance, SPS and Executive Offices

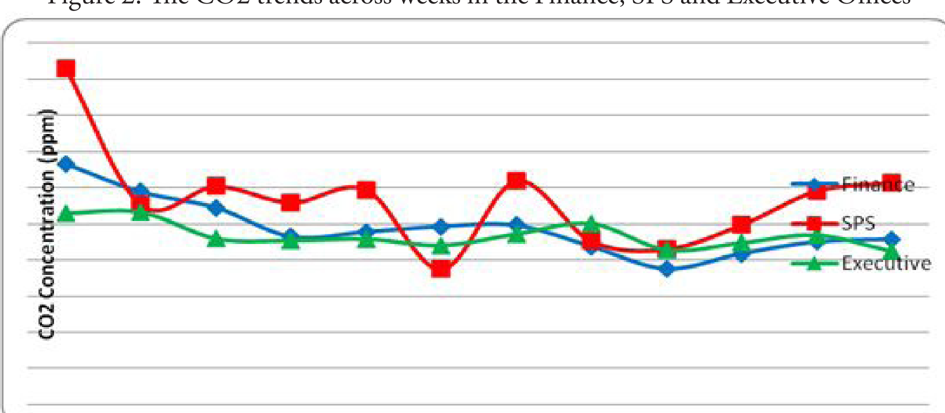

Figure 2 shows the trend of values for CO2 in the Finance, SPS, and Executive Offices. Higher values were obtained by SPS and Finance offices. Generally low and within normal values were recorded for the Executive office.

Figure 3. The CO2 trends across weeks in the offices of CTE, Criminology, and Publishing

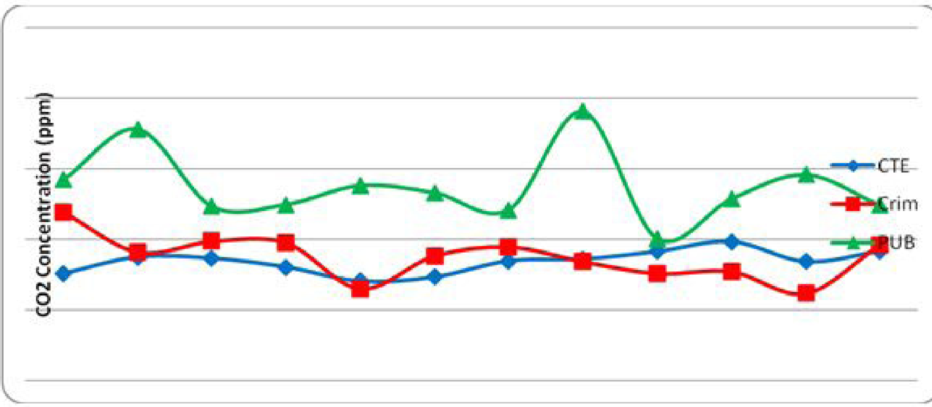

Figure 3 illustrates the trend of values for CTE, Criminology, and Publishing Offices across a three-week period. CO2 values for CTE and Criminology offices were generally low and of normal category while those of Publishing Office were rather high with peak values in the first and second week.

Figure 4. The CO2 trends across weeks in the offices of CAS, CBA, and COE

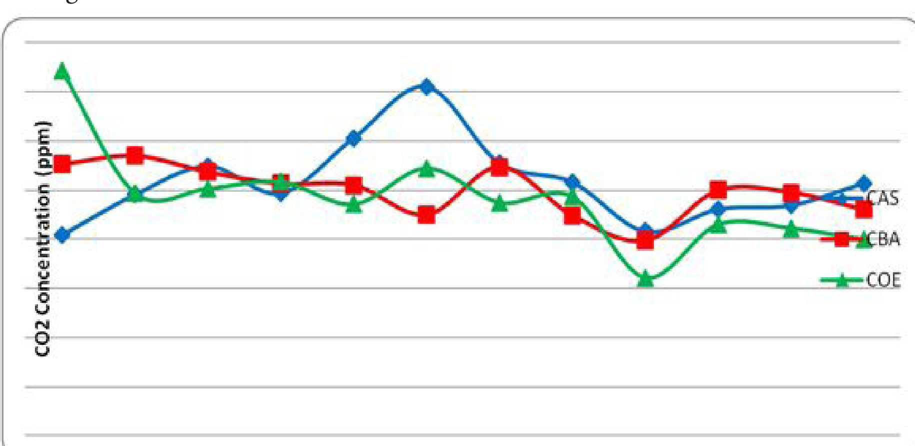

Figure 4 illustrates the trend of values for CAS, CBA, and COE Offices across a three-week period. CO_2 values for CBA and COE offices were generally low and of normal category while those of CAS were rather high with peak values in second week.

Over the three-week period, the trend in CO_2 detection shows that the office of the Rehabilitation Science had the highest values above normal while those with normal values are the COE, CTE, and Executive Offices.

Objective 2. To determine if there is a significant difference in the CO_2 levels of offices across weeks.

Building	Office	Level of Significance	P-value	F-value	Result
NAC	CTE	0.05	0.057	4.01	No Difference across the weeks
	CRIM	0.05	0.0688	3.66	No Difference across the weeks
	PUB	0.05	0.4893	0.77	No Difference across the weeks
HB	RPEO	0.05	0.6282	0.49	No Difference across the weeks
	VPAA	0.05	0.723	0.34	No Difference across the weeks
	SENIOR	0.05	0.0682	3.67	No Difference across the weeks
	RT/PT	0.05	0.0974	3.05	No Difference across the weeks
RODELSA	Finance	0.05	0.0171	6.61	**Difference between W1 and W3**
	SPS	0.05	0.2745	1.5	No Difference across the weeks
	Executive	0.05	0.117	2.75	No Difference across the weeks
SAC	CAS	0.05	0.0345	5.01	**Difference between W2 and W3**
	CBA	0.05	0.0615	3.86	No Difference across the weeks
	COE	0.05	0.0357	4.94	**Difference between W1 and W3**

Table 5 reveals the results on the test of significant difference in the mean CO2 levels in the representative offices of each building. The p values for the NAC offices (CTE-0,057, Crim, 0.0688, and Publishing Office -0.4893) are greater than alpha at 0.05 indicating no significant difference across weeks. This implies no significant variations and exhibiting consistency of mean CO2 levels across the three-week sampling period.

Similarly, the offices in HB Building, the p-values (RPEO-0.6282, VPAA-0.723, Senior High-0.0682, and RT/PT-0.0974) which are also greater than alpha at 0.05 indicated no significant difference on the mean CO2 levels across weeks implying consistency in the obtained values. With Rodelsa Hall only the Finance Office showed a significant difference in CO2 levels (1132.2 and 850.0 ppm respectively) between week 1 and 3. Week 1 had significantly higher CO2 levels than week 3 which may be due to an increase of visitors going into the office. This time of sampling was during the onset of the summer enrolment period which was at its peak. The other two offices (SPS and Executive offices) had p-values (0.2745 and 0.117, respectively) which are greater than alpha at 0.05 indicating no significant difference in their mean CO2 levels across weeks. This implies that the values showed consistency in the three-week period.

In the SAC building, both CAS and COE had significant difference across weeks in their values as shown in the results (p-values 0.0345 and 0.0357, respectively) which are less than alpha at 0.05. For the CAS office, the difference is between week 2 and 3 with the former having a significantly higher mean value but may be due to the enrolment period wherein students frequented the office most of the time.

CONCLUSION

Out of the thirteen (13) offices tested for indoor CO2 levels, only six (6) were found to have adequate ventilation. These are the offices of College Teacher Education, Criminology, College of Business and Accountancy, College of Engineering, Finance Office, and Executive office. The rest have slightly inadequate to inadequate ventilation which means that there is insufficient supply of O2 getting into the office resulting to health symptoms like drowsiness and headaches as reported by some employees which occurred during occupancy time. Those with Inadequate ventilations may compromise the health, comfort, and productivity of occupants.

RECOMMENDATIONS

1. Most air conditioning units in offices merely function to recirculate available air and therefore there will be a continued buildup of CO2 during the long hours that offices are occupied. It is therefore recommended that the management shall advice to install local exhaust especially in offices with inadequate ventilation. This will depressurized the room by releasing gas and allowing the entry of fresh air.

2. The putting of indoor plants is also hereby recommended to at least help reduce the level of CO2 since it is also utilized by them during the process of photosynthesis.

3. It should be made a local policy of any institution to periodically monitor the status of indoor CO2 in offices as basis for determining occupational health and safety of workers.

4. This research should be extended to a greater range of classrooms within the campus with more extensive monitoring.

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