Effect of Different Ventilation Conditions on Indoor CO2 Levels

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Abstract

This paper describes a study on (Carbon Dioxide) CO2 levels based on different ventilation systems. Three main types of buildings were considered in the study, such as educational, office buildings and hospitals. The effect of different systems of natural ventilation systems on CO2 levels was studied. The measurements were taken by accommodating different situations in the open able condition of windows: fully opened, half opened and fully closed. It was found that, the size of windows, the number of windows and the positioning of windows have major impact on indoor air quality. CO2 measurements were taken in both naturally ventilated buildings and mechanically ventilated buildings. And a comparison was made between mechanically and naturally ventilated systems. In mechanically ventilated buildings two types of air conditioning systems namely cold water air conditioning system and spit type air conditioning system were considered for the comparison. Cold water air conditioning system was found to be good than the split type air conditioning system under improper maintenance conditions. From the experimental measurements we can conclude that the CO2 levels are higher in mechanically ventilated buildings which are not properly operated than in naturally ventilated buildings.

Key Words: Indoor air quality, Artificial ventilation, Natural Ventilation, Different air conditioners, Different types of building

1. Introduction

Indoor air quality represents the condition of the air inside a building. Proper ventilation design can create a healthier environment allowing clean air to circulate, but without it, the air in a building can actually be worse than the air outside. Since the people spend 80-90% of the time indoors, the indoor air quality affects the human health and work efficiency. The operating condition of the ventilation systems is very important for the occupants. The factors affecting indoor environment mainly include temperature, humidity, ventilation, gaseous pollutants, particle pollutants, volatile organic compounds (VOCs).[1] Although CO_2 is considered as non toxic, higher levels can cause health problems to the occupants such as drowsiness, headaches, lower efficiency and aggravated problems under long term exposure. Therefore this study has been focused on the effect of ventilation system on indoor CO_2 levels in different types of buildings. Since the study was conducted in Sri Lanka, tropical climate condition was considered in the study.

There are two main types of ventilation systems used in indoor spaces such as naturally ventilated and mechanically ventilated systems (air conditioners). Natural ventilation is widely used in tropical climates. With the natural ventilation, indoor comfort levels largely depend on the operating conditions of the provided doors and windows. However even in tropical climates mechanical ventilation has been introduced mainly in office environments, commercial and public buildings, due to the compact nature of indoor spaces.

Fresh air recharge of a mechanically ventilated space depends on the type of air conditioner used. Most of the buildings monitored in the study have higher CO_2 levels and poor operating conditions with respect to fresh air recharge. Several studies have been conducted on indoor CO_2 levels in artificially ventilated buildings and how to improve the conditions. [2], [3]

In order to see the effect of type of ventilation on indoor CO_2 levels, different ventilation systems and three main types of buildings were considered in the study. A comparison of indoor air quality level was done for the natural and artificial ventilation systems in the same building.

2. Objectives

This study was focused at the following objectives.

1. Determination of the effect of the ventilation system on indoor air quality levels.
2. Determination of the comfort levels of occupants under different ventilation systems.

3. Methodology

In order to achieve the above objectives, the following methodology has been adopted in the study.

- Three main types of buildings were selected such as educational, office space and hospitals.
- Measurements were taken for the indoor and outdoor CO_2 levels, temperature and humidity.[4]
- The type of indoor activity, occupant density and the type of ventilation were obtained for the entire sample.
- The sample of buildings was selected on random basis due to practical limitations of the study.
- Measurements were taken under different ventilation conditions by operating the windows in three different manners in naturally ventilated buildings. This included "100% opened", "50% opened" and "windows closed".
- Variation of CO_2 level, in natural and artificial environments, was monitored in the same building.
- All the measurements were taken for a period of 3 hour exposure levels.3 hours were chosen as the period of taking measurements due to the practical constrains. All the measurements were taken two times in one particular place in order to improve the accuracy.
- After collecting the data, on all the measurements: naturally ventilated systems and mechanically ventilated systems were compared.

4. Field Study

The field study included a questionnaire survey, and an experimental program. The questionnaire survey was focused at indoor comfort levels of occupants and the experimental program was focused in measuring indoor CO_2 level, temperature and humidity under different ventilation conditions.

4.1 Experimental programme

The summary of the study conducted including the type of the building, indoor activity, occupant density and the type of ventilation, is presented in Table 1.

Table 1: Deferent activity spaces considered in the experimental programme

Type Of Building	***Place/Location***	***Type of indoor activity***	***Occupant Density***	***Type of Ventilation***
Education Building 1	*Class Room 1*	*Lecture Class*	*100*	*Natural*
	Class Room 2	*Lecture Class*	*100*	*Natural*
	Laboratory 1	*Laboratory*	*5*	*Natural*
	Laboratory 2	*Laboratory*	*2*	*Air conditioned*
	Auditorium	*Lecture Class*	*90*	*Air conditioned*
	Seminar room	*Lecture class*	*70*	*Air conditioned*
Education Building 2	*Class Room 3*	*Lecture Class*	*20*	*Air conditioned*
	Office room 1	*Office room*	*10*	*Air conditioned*
	Office room 2	*Office room*	*4*	*Air conditioned*
Office Buildings	*Executive's office*	*Office room*	*5*	*Air conditioned*
	Executive's board room	*Office room*	*12*	*Air conditioned*
	Executive's room	*Office room*	*3*	*Air conditioned*
	Executive's quarters(4 trials)	*Rest house*	*5*	*Natural*
	Office Space 3	*Printing section*	*10*	*Natural*
	Office Space 4	*Printing section*	*10*	*Natural*
Hospital	*Hospital ward 1*	*Ward*	*30*	*Air conditioned*
	Hospital ward 2	*Ward*	*30*	*Natural*

4.2 Questionnaire survey

The questionnaire survey was conducted for the occupants in all the buildings considered. The main aspect included are the level of satisfaction for the indoor environment, exposure levels (the number of working hours), any health problem related to the indoor environment. [5]

Figure 1 indicates the level of satisfaction in naturally ventilated spaces in education buildings. The average condition was taken to summarize the results.

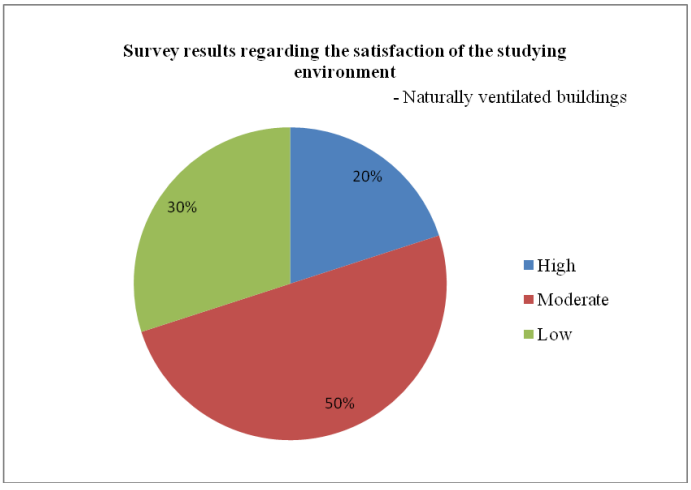

Figure:1 Survey results regarding the satisfaction of the occupants in naturally ventilated buildings

Figure 2 indicates the level of satisfaction in artificially ventilated spaces. From the results obtained it can be stated that in naturally ventilated spaces occupants are more comfortable than in the artificially ventilated spaces.

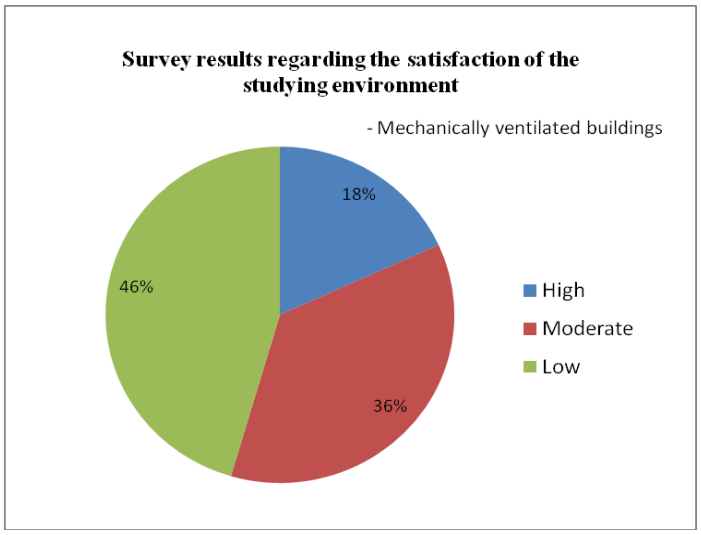

Figure:2 Survey results regarding the satisfaction of the occupants in artificially ventilated buildings

The Figure 3 and 4 shows the health symptoms in two places namely in Executive's office and in Aditorium.The health symptoms are the evidence for the quality of the air circulated throught the systems.[6][7]Because of that the occupants comfort levels in the Auditorium (cold water air conditioning system) and Executives's office (split type air conditioners) used to validate the importance of the type of the air conditioner.The air conditioner used in auditorium was cold water air conditioning system and in Executives office split type air conditioner was used. General complaint from the executives's office was the headaches caused when working for long hours. But none of the students complained that the auditorium was uncomfortable and no complaints for the sick building syndrome. But the problem identified was, sometimes the temperature went down considerably creating the environment too cold. Temperature could not be controlled. Comparatively cold watre air conditionning system is better than the split type air conditioning system.

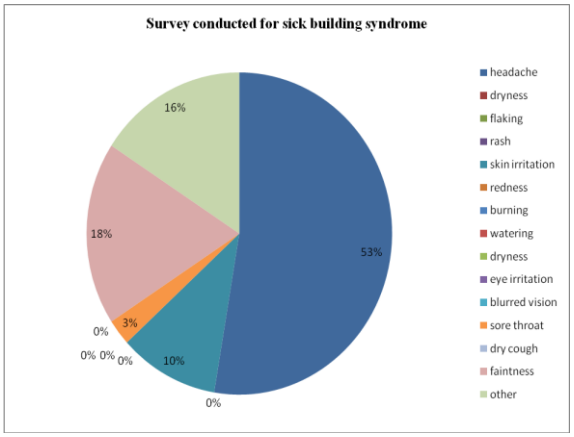

Figure:3 Health symptoms recorded in Executive's office

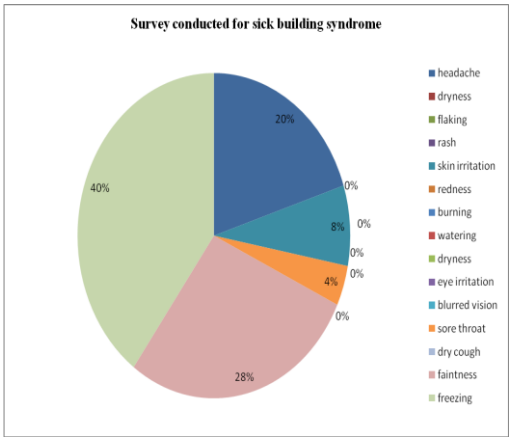

Figure:4 Health Symptoms inrecorded in Auditorium

5. Results

The air circulation rate directly relates to the indoor carbon dioxide levels in naturally ventilated buildings. Air circulation rate depends on number of factors as wind speed, amount of voids, and arrangement of the building. As shown in the Figure 5 it can be clearly stated that carbon dioxide level reduces with the increment of voids to wall ratio. Providing maximum possible voids will result in low levels of CO_2.

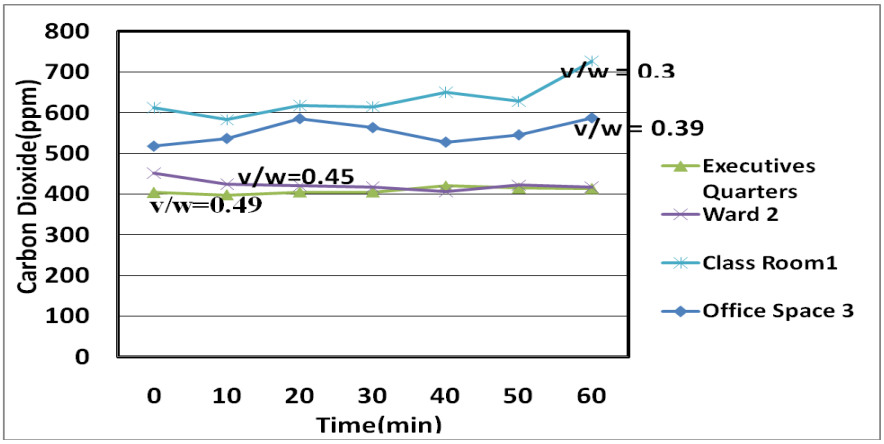

Figure:5 Carbon dioxide variation with void/wall Ratio

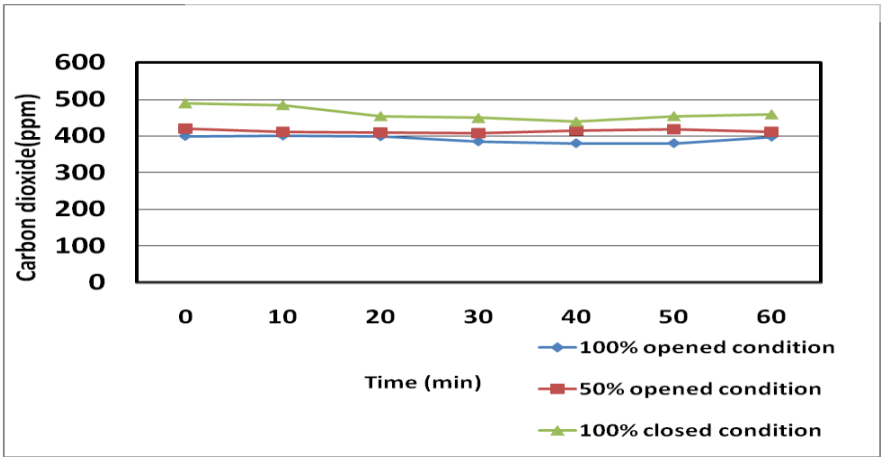

Figure:6 Carbon dioxide level variation with time in different operating conditions

Having enough void only doesn't allow the indoor air quality to be better but the operating level is also important in naturally ventilated buildings. According to the Figure 6 there is a very less difference in CO_2 levels in between 100% opened condition and 50% opened condition. But the above condition will be different when the number of people gets increased. [8]Because the occupancy level of the considered building for the above results was limited to 4 people. But when considered the

100% closed condition the CO_2 levels were considerably higher than the other two conditions. Above results prove the importance of providing proper maintenance for the building.

Only means of ventilating a building is not naturally ventilated system, but mechanically ventilated systems are also there. When concerning the indoor air quality comparison made on the naturally and mechanically ventilated system is vital. For the comparison the data collected from the hospital building was used. Two similar wards were selected for the experiment. One ward was naturally ventilated while the other one was air conditioned. Readings were taken for two hours continuously in each ward. The experiment period was limited to 120 minutes to avoid the inconvenience to the patients. To ensure the results, the experiment was carried out twice.

In order to make the experiments consistent, some factors were kept constant where applicable:

i. The wards under investigation were of similar size.
ii. Each had same amount of occupants.
iii. Temperature of the air-conditioner was set at 24◦C.
iv. Windows were opened wide where ever possible for natural ventilation.
vi. The measuring equipments were set up such that it can represent the whole building.

The following table gives the carbon dioxide levels of the two wards which were collected in 10minutes intervals.

Table 2 Carbon dioxide levels in two wards

Type of space	*Air conditioned room*	*Naturally ventilated room*
Reading	***Carbon dioxide levels(ppm)***	***Carbon dioxide levels(ppm)***
1	*1335*	*452*
2	*1360*	*424*
3	*1355*	*421*
4	*1380*	*417*
5	*1410*	*406*
6	*1455*	*422*
7	*1415*	*417*

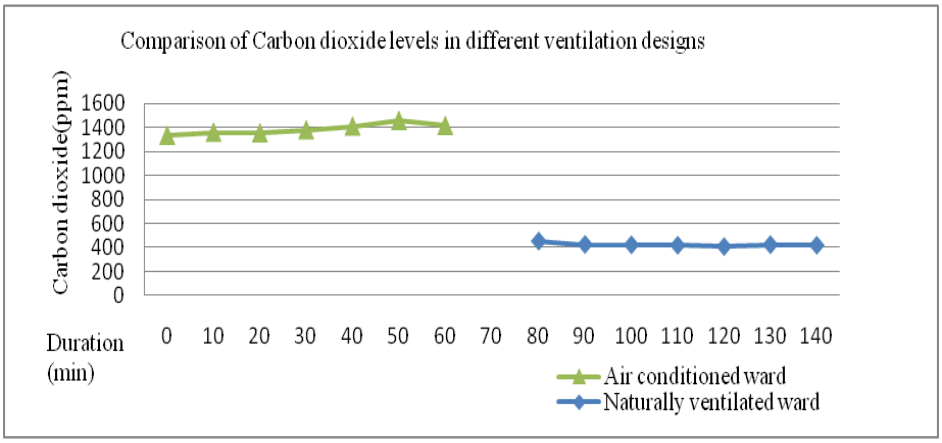

Figure: 7 Comparison of Carbon dioxide levels in different ventilation designs

The Figure 7 clearly shows the distinction between the carbon dioxide levels in different ventilation designs. The main contributor for the carbon dioxide concentration inside the building was, the rate of air circulation.

In the naturally ventilated buildings, the indoor air circulation velocity was considerably high when all the windows were fully opened and fans were switched on. Where in air conditioned building the air circulation rate was low.

To further validate the conclution made, another data set was used. The data collected from the auditorium which was artificially ventilated and the class room 1 which was naturally ventilated was chosen. The below Figure 8 shows the summary of the data collected. It's clearly shown on the graph that the CO_2 level gets increased in the Auditorium than in the class room 1 with the time. It's evident that the naturally ventilated system performs well by maintaining a good indoor air quality level inside the building.

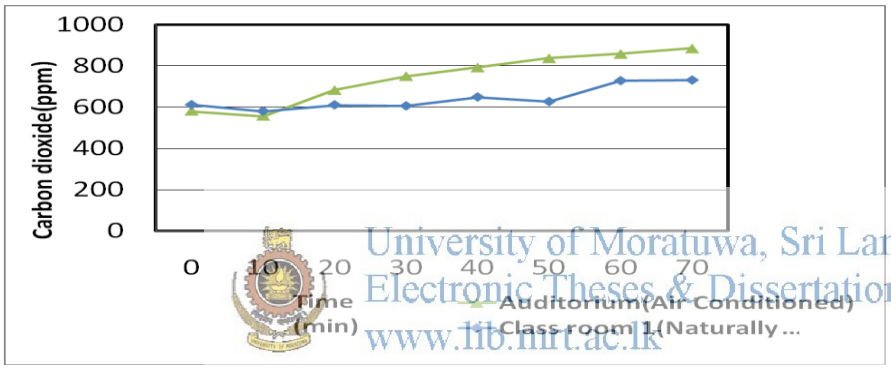

Figure:8 Comparison of different ventilation designs (Artificial and Natural)

Even though with the proven results, the building designers use air conditioning systems. Even with porven results using central air conditioning system will not be feasible in certain cases. So we'll be forced to go for the option of split type air conditioner which is only suitable for the small and medium office buildings. In such cases the proper maintenance will give better indoor air quality.Small experiment was conducted in office room 1 which was air conditioned with split type air conditioner to understand the behaviour of the system. The measurements were taken by simulating the condition of opening the windows in the morning for 30 minutes and then switching on the air conditioner after closing the windows.The secound set of measurements were taken by not opening the windows in the morning. The results obtained clearly shows the difference in the indoor pollutant levels when it's maintained properly and when it's not maintained properly.

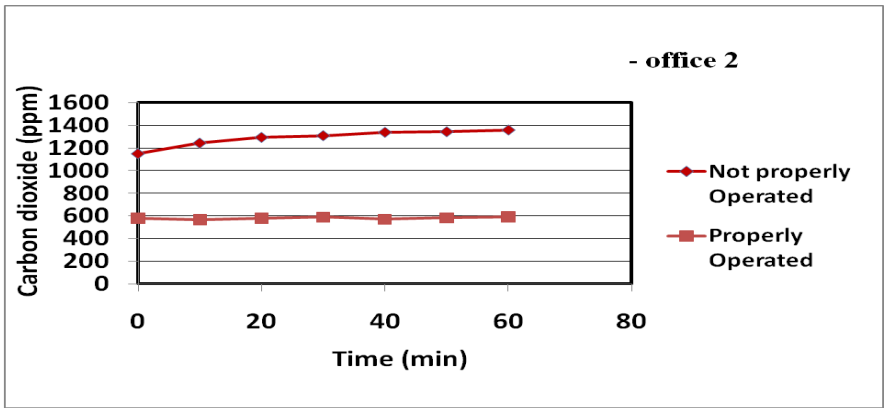

Figure:9 Comparison of CO2 level variation with time with the operating condition

The indoor carbon dioxide levels in the air conditioned buildings which were not mantained properly were in 900 and 1000 ppm levels. But the above office room recorded very low levels of carbondioxide when compared to the other air conditioned buildings which were not maintained properly.

Average Carbon dioxide values from the whole research experimental data.

Naturally ventilated buildings: 570 ppm

Artificially ventilated buildings: 916 ppm

6. Conclusions

The results obtained from the experiments clearly state that the architects or other leading design professionals can take proactive actions in addressing IAQ concerns by their proper building design. The properly designed building should reduce occupant exposure to harmful or annoying substances and should enhance the indoor comfort among the occupants.

In the naturally ventilated buildings IAQ can be manipulated by using the openable area and locations of windows. As showed in the results the openable percentage of the windows improves the air circulation in the building. This is one of the major a factor which contributes to the indoor carbon dioxide level.

In the air conditioned buildings, proper maintenance should be practiced to minimize the indoor carbon dioxide levels. Few air-conditioning types do not allow fresh air circulation inside the building. In such cases carbon dioxide level is increased. So that necessary steps should be taken to allow fresh air movement inside the building. Exhaust fans, opening windows regularly in the morning for few times will result in reducing the problem with the air conditioners.

When comparing the two systems the better results for the carbon dioxide levels were obtained from the naturally ventilated buildings. And the building occupants can be satisfied with the natural

ventilated buildings with the provision of adequate wind speed and the comfort temperature. The temperature can be controlled by adopting passive features into the building. [9] Creating micro climate around the building will enhance the thermal comfort of the building occupant. [10]

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