A Study on the Correlation between Indoor Carbon Dioxide Concentration and Air-Conditioner Working Efficiency

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Abstract

This study aims to investigate the correlation between carbon dioxide concentration, and air-conditioner power consumption under fixed air conditioner temperature. Data was collected using a carbon dioxide detector. After analyzing the data from small-scale experiments, it was found that if the daily average carbon dioxide concentration is high, the air conditioner unit must consume more energy to maintain the temperature, resulting in increased power consumption. Furthermore, there was moderately positive correlated between carbon dioxide concentration and air conditioner power consumption, although it was not significant. Nonetheless, it can still be observed that "when carbon dioxide concentration is high, power consumption increases", and the opposite trend can be seen when the concentration is low. The data obtained from this study will make the research results and inferences more complete, and a formula can be derived to increase the efficiency of air conditioner use, reduce carbon emissions from power plants, and achieve the goal of mitigating climate change.

Index Terms: **Indoor Carbon Dioxide Concentration**, **Air-Conditioner Working Efficiency**, **Climate Change**

I. Introduction

(I) Motivation

Climate change has grave consequences for human civilization, affecting not only living environments but also lifestyles. There are two categories of global measures to address climate change: "adaptation" and "mitigation." Adaptation means adjusting to its effects, while mitigation involves reducing carbon emissions and other activities that exacerbate climate change.

Air conditioner has become essential due to rising temperatures caused by climate change. Policies have encouraged installing air conditioner units in classrooms. However, students and teachers keep windows and doors closed to avoid air leakage and increased power consumption. Nevertheless, indoor carbon dioxide concentration increases due to human body radiation and breathing, affecting indoor temperatures and air conditioner power consumption.

Thermal power generation, the dominant electricity production method in Taiwan and many regions globally, emits greenhouse gases, including carbon dioxide, into the atmosphere, exacerbating climate change. Reducing air conditioner consumption can mitigate climate change by reducing carbon emissions.

This study aims to explore the relationship between air conditioner power consumption, indoor carbon dioxide concentration. It will collect data through environmental monitoring devices, analyze the data, and make recommendations to improve air conditioner efficiency and mitigate climate change's impact on society.

（II）Purpose

A. To understand the correlation between air conditioner temperature, carbon dioxide concentration, and air conditioner power consumption.

B. Reduce the improper use of air conditioner, in order to lower energy consumption and thus decrease carbon emissions.

（III）Literature review

A study conducted in Hong Kong found that even with only one person present in a room equipped with a split air conditioner system, the outdoor ventilation rate does not meet ASHRAE standards. While the outdoor ventilation rate for window-type air conditioner may be higher than that for split air conditioner, its effectiveness in controlling ventilation is still limited. Another research report from South Korea showed that the use of air conditioner in Seoul offices and the energy consumption of offices exceeded the assumptions of building energy consumption design predictions. The study also found a significant correlation between air conditioner energy consumption and the number of people indoors.

A CO2 study conducted in a primary and secondary school classroom showed that continuous monitoring data of CO2 in ten classrooms varied over time and with the entry of students into the classroom. CO2 levels rose at the beginning of class, decreased at the end of class, and reached equilibrium after a period of time. Approximately half of the classrooms had an average CO2 concentration exceeding 1000ppm, with two classrooms as high as 1929ppm and 2248ppm. Although air conditioner was installed, the ventilation rate inside and outside was insufficient. However, there was a trend of improvement after installing an exhaust fan. In a study of 54 elementary schools in the United States by

Shaughnessy R.J. (2006), there was a significant difference in ventilation rates and math learning outcomes in classrooms. Another study showed that increasing one exhaust fan could reduce indoor CO2 concentration by approximately 10.4%, and two exhaust fans could reduce it by approximately 17.3%.

II. Research materials and methods

（I）Research materials

A. Handheld Carbon Dioxide Monitors *2

B. Raspberry Pi Pico W+ environment sensors *1

（II）Research methods

This study uses handheld carbon dioxide monitors, Raspberry Pi Pico W, and environment sensors provided by MIT Media Lab to monitor the temperature and carbon dioxide concentration in the classroom. The daily air conditioner energy consumption is recorded using the on-campus air conditioner billing system. Finally, SPSS is used to analyze the data with Pearson correlation.

（III）Research assumptions

A. The classroom is a closed, homogeneous space with equal air composition.

B. Each person releases the same amount of carbon dioxide and infrared radiation.

C. Carbon dioxide concentration can absorbs infrared radiation, leading to an increase in indoor temperature.

（VI）Research architecture and background

This study divided the two monitored classes into an experimental group - Class A and a control group - Class B. The research team set the air conditioner temperature to 27°C and 26°C respectively.

The experimental group's instrument was placed on the computer cabinet next to the blackboard in the classroom where 36 people attended school for the first two days of measurement (9/29~9/30), and 4 people attended school for the next three days (10/1~10/3). The instrument for the control group, Class B, was also placed on the computer cabinet next to the blackboard in the classroom, with 40 people attending school every day, despite being diagnosed or under quarantine. The research team fix the air conditioner temperature at 27°C for the experimental group and 26°C for the control group.

The research team identified the following three variables:

A. Independent variable: Air conditioner temperature.

B. Controlled variables: Air conditioners settings (except temperature), the configuration of fans and windows.

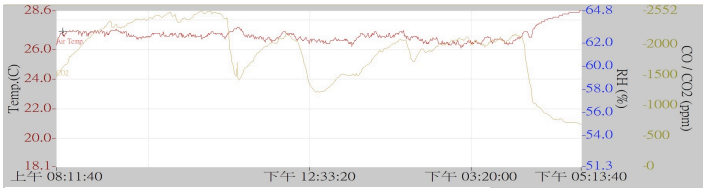
C. Dependent variables: Indoor temperature, carbon dioxide concentration, air conditioner power consumption.

III. Research results

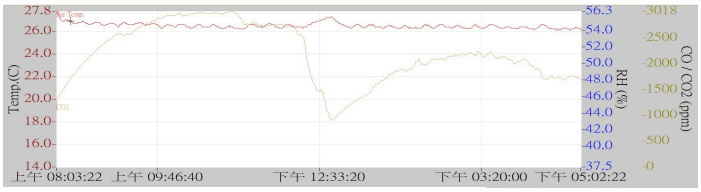
(I) Research results and data description

The following are the changes in indoor temperature and carbon dioxide concentration measured by the research team (from 9/29 to 9/30 and 10/3 to 10/5). Refer to Figure 2 for details.

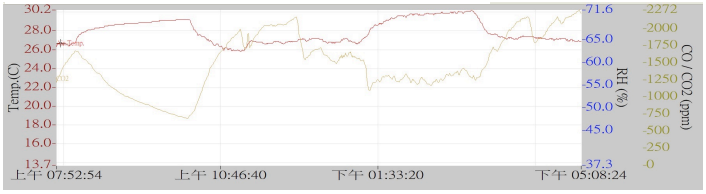
Control group (09/29)



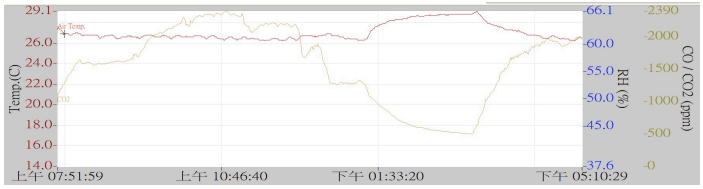
Experimental group (09/29)



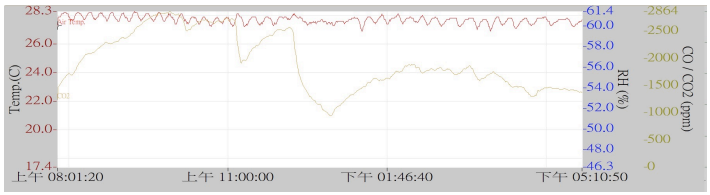
Control group (09/30)



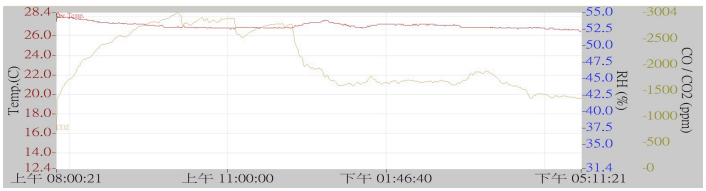
Experimental group (09/30)



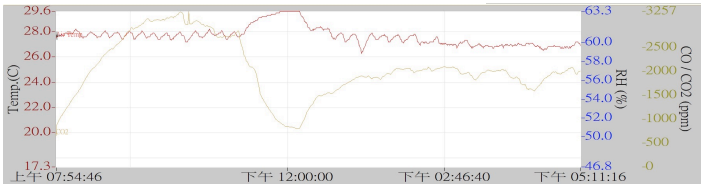
Control group (10/03)



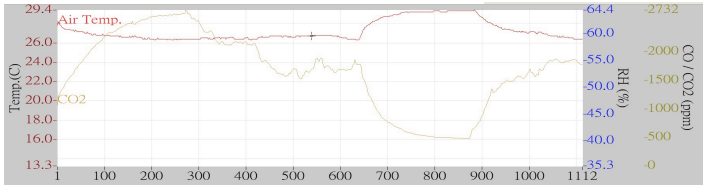
Experimental group (10/03)



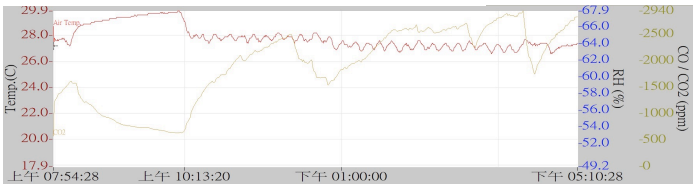
Control group (10/04)



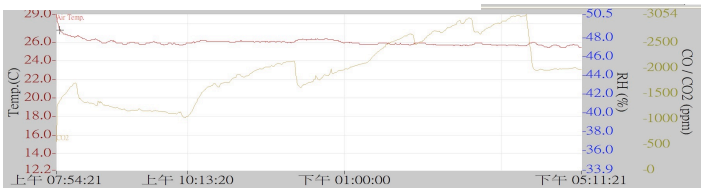
Experimental group (10/04)



Control group (10/05)



Experimental group (10/05)



The researchers then compiled the data into a table. From the table, it was found that regardless of whether it was the experimental group or the control group, the days with the highest average carbon dioxide concentration were also the days with the highest air

conditioner power consumption; conversely, the days with the lowest average carbon dioxide concentration were also the days with the lowest air conditioner power consumption.

	Group	09/29	09/30	10/03	10/04	10/05
Daily average concentration of CO_2 (ppm)	Experimental group	2196.01	1568.76	2081.62	1667.51	1975.62
	Control group	1888.04	1499.58	1933.38	2053.44	1912.12
Air conditioner power consumption (kWH)	Experimental group	38.20	34.36	48.83	38.71	46.41
	Control group	31.36	22.24	29.63	43.73	23.81

Table 1. Comparison of carbon dioxide concentration and air conditioner power consumption between experimental group and control group

This study used IBM SPSS statistical program and analyzed the data using Pearson correlation. The researcher adopted a more conservative two-tailed approach for the analysis. As shown in Table 2, the results of this study indicated a "moderately positive correlated with no significant difference" between carbon dioxide concentration and air conditioner power consumption.

		Daily average concentration of CO_2	Air conditioner power consumption
Daily average concentration of CO_2	Pearson Correlation	1	0.534
	Sig. (2-tailed)		0.112
	N	10	10
Air conditioner power consumption	Pearson Correlation	0.534	1
	Sig. (2-tailed)	0.112	
	N	10	10

Table 2. Pivot Table of Pearson Correlation Results.

V. Discussion

(I) Analyze

In addition to the long-term trends, we also analyzed the daily changes in carbon dioxide concentration and temperature inside the classroom in a one day scale. Below, we present four sets of data for illustration.

A. Experimental group (9/30)

From Figure 3, it can be observed that from 9 A.M. until before lunchtime, most students have left the classroom to buy lunches, resulting in higher carbon dioxide concentrations. During the entire day, except for off-site class, nap lead to lower respiratory rates, so the lowest point of carbon dioxide concentration occurs during the nap break.

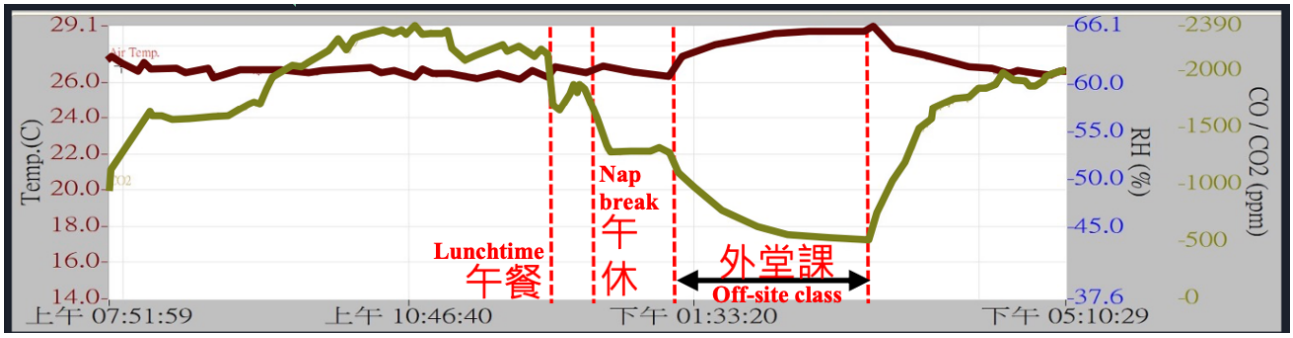


Figure 3. Experimental group (9/30)

B. Experimental Group (10/3)

From Figure 4, it can be observed that from 9 A.M. to lunchtime, most students have not left the classroom, resulting in higher carbon dioxide concentrations. The lower carbon dioxide concentration in the afternoon is due to the fact that students generally go to the school store in the afternoon, resulting in more people entering

and leaving the classroom, which facilitates the diffusion of carbon dioxide from the indoor classroom to the outdoor environment.

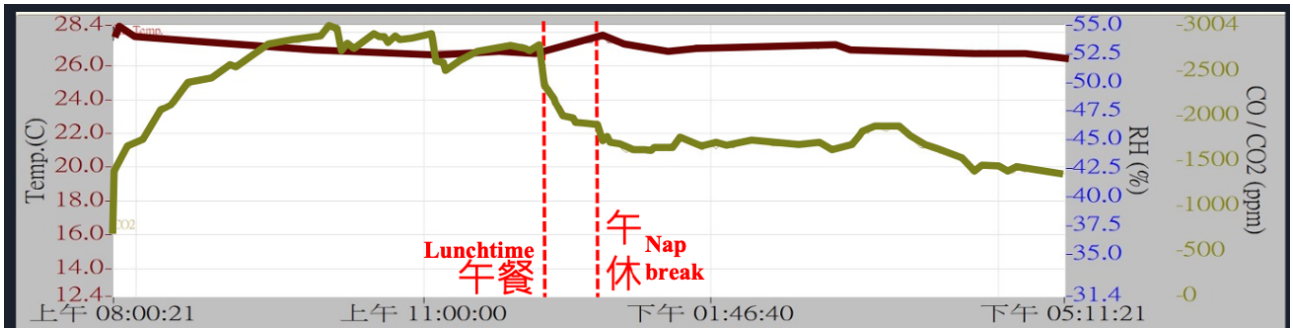


Figure 4. Experimental group (10/03)

C. Control Group (9/30)

From Figure 5, it can be observed that after the break between classes, students returned to the classroom, resulting in a rapid increase in indoor carbon dioxide levels. During lunchtime, most students went to the cooperative society to buy lunch, resulting in a decrease in indoor carbon dioxide levels. During the lunch break, carbon dioxide concentration continued to decrease due to the fact that people have lower respiratory rates during sleep.

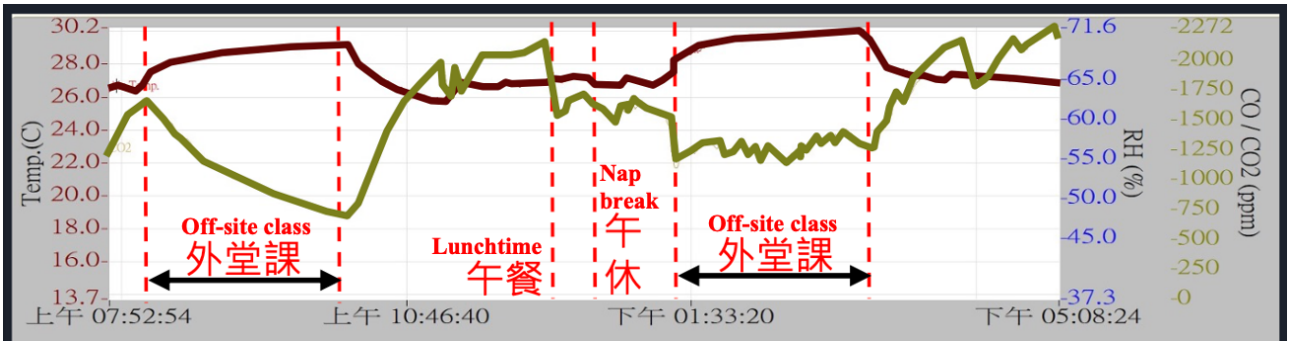


Figure 5. Control group (9/30)

D. Control Group (10/4)

From Figure 6, it can be observed that from 9 A.M. until before lunchtime, most students have left the classroom, resulting in higher carbon dioxide concentrations. The lower carbon dioxide concentration in the afternoon is due to the fact that students generally go to the cooperative society before the end of the three classes in the afternoon, resulting in more people entering and leaving the classroom, which facilitates the flow of carbon dioxide from the indoor to the outdoor environment.

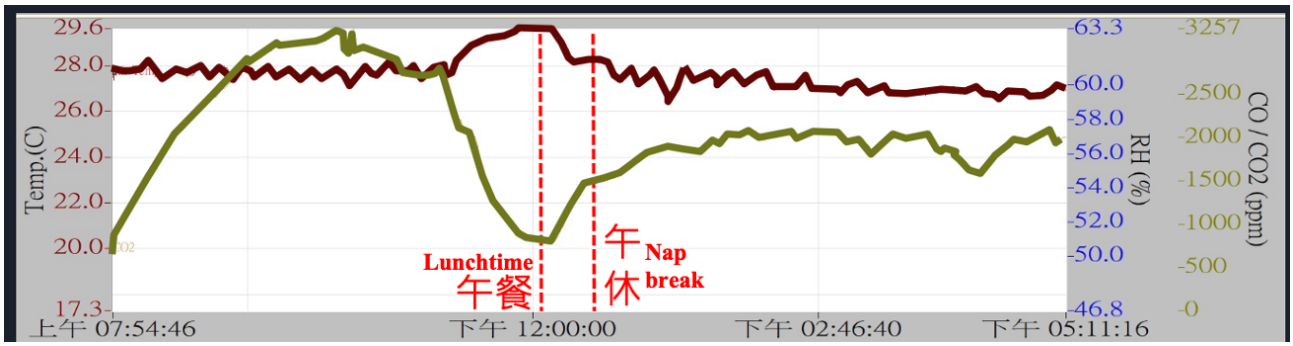


Figure 6. Control group (10/4)

(II) Summary

Moderate use of ventilation equipment can help slow down the decrease in indoor carbon dioxide concentration when there are many people present, thereby reducing air conditioner power consumption and ultimately reducing carbon emissions from power generation.

IV. Research conclusion and limitation

(I) Research conclusions

The aim of this study is to explore the correlation between temperature, indoor carbon dioxide concentration, and air conditioner power consumption. Firstly, literature review

was conducted to understand the standards for indoor carbon dioxide, the recommended temperature for air conditioner by Taiwan Power Company, and the relationship between carbon dioxide and learning performance. Then, observations were made, data was collected and analyzed.

The relationship between temperature, indoor carbon dioxide concentration, and air conditioner power consumption is the focus of this study. Based on the results and analysis, the following conclusions were drawn and discussed by the researchers:

A. There is a moderate positive correlation between indoor carbon dioxide concentration and air conditioner power consumption that has not reached a significant difference. However, there is still a trend of "the higher the carbon dioxide concentration, the higher the power consumption". If the research data is sufficient, a significant positive correlation may be obtained.

b. When the carbon dioxide concentration is high, the mental state of the people in the classroom is significantly poor, which may be one of the reasons why students fall asleep in class.

（II）Research limitations

After the above discussions, the research team believes that some factors may have caused deviations in the results of this study, as follows:

A. The amount of data collected may not be sufficient.

B. The equipment may produced bias due to lack of calibration.

C. The classroom is not a closed ideal system.

D. The amount of carbon dioxide and infrared radiation emitted by each person is not equal.

E. The temperature inside the classroom may be affected by external environmental radiation.

V. Reference

Geun Young Yun, Hyo Joo Kong, and Jeong Tai Kim, A Field Survey of Occupancy and Air-Conditioner Use Patterns in Open Plan Offices, *Sage Journals*, Volume 20, Issue 1, https://.doi.org/10.1177/1420326X10388883

Michael A. McNeil, and Virginie E. Letschert.(2008), Future Air Conditioner Energy Consumption in Developing Countries and what can be done about it: The Potential of Efficiency in the Residential Sector.

Shaughnessy RJ., Haverinen-Shaughnessy U., Nevalainen A., Moschandreas D.(2006). *Europe PMC*,16(6),465-468. doi:10.1111/j.1600-0668.2006.00440.x

Zhongping Lin, Shiming Deng, The outdoor air ventilation rate in high-rise residences employing room air conditioners, *Building and Environment*, Volume 38, Issue 12, 2003, Pages 1389-1399, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2003.07.001.

王愛傑，建置空氣品質無線監測系統暨室內二氧化碳濃度預測模型，碩士論文，臺北科技大學環境工程與管理研究所，臺北，2012。

粘金傳(2011)，室內二氧化碳濃度偵測分析研究-以彰化縣國民中小學電腦教室為例，大葉大學工學院，碩士論文。