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Assessment of Indoor Air Quality and Awareness of Sick Building Syndrome in Chulalongkorn University

การประเมินคุณภาพอากาศภายในอาคารและความตระหนักถึงโรคตึกเป็นพิษในจุฬาลงกรณ์มหาวิทยาลัย

Nattanon Sukkamnerd

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หัวข้อ	การประเมินคุณภาพอากาศภายในอาคารและความตระหนักถึงโรคตึกเป็นพิษใน จุฬาลงกรณ์มหาวิทยาลัย
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บทคัดย่อ

ผู้คนควรที่จะได้รับรู้ว่าพวกเขามีโอกาสที่จะสัมผัสกับอากาศภายในอาคารที่ไม่ดีและมีอาการของโรคตึกเป็นพิษเกิดขึ้นกับพวกเขา งานศึกษานี้จึงมีเป้าหมายที่จะประเมินคุณภาพอากาศภายในอาคารของห้องเรียนและสำรวจความตระหนักถึงโรคตึกเป็นพิษในหมู่นิสิตในห้องเรียนนั้น งานศึกษาได้วัดคุณภาพอากาศภายในอาคาร ระหว่างชั้นเรียน 10 คาบ ในห้องเรียน 201 ตึกมหามุฏ ณ จุฬาลงกรณ์มหาวิทยาลัย ตั้งแต่เวลา 13.00 ถึง 15.00 นาฬิกา โดยใช้เครื่องวัด SIRIUS ST-501 สำหรับค่าความเข้มข้นคาร์บอนไดออกไซด์ และ TM-4002 สำหรับค่าความชื้นสัมพัทธ์ อุณหภูมิ และ ความเร็วลม ในขณะเดียวกัน แบบสอบถามที่ดัดแปลงมาจากงานศึกษาก่อนได้ถูกใช้ในการสำรวจความตระหนักถึงโรคตึกเป็นพิษในหมู่นิสิต งานศึกษาพบว่า ค่าความเข้มข้นคาร์บอนไดออกไซด์ ความชื้นสัมพัทธ์ และ ความเร็วลม ไม่อยู่ในเกณฑ์ที่ยอมรับได้ตามร่างประกาศฯ ของกรมอนามัย กระทรวงสาธารณสุข มีเพียงแค่อุณหภูมิเท่านั้นที่อยู่ในเกณฑ์ ค่าสัมประสิทธิ์สหสัมพันธ์ระหว่างค่าความเข้มข้นคาร์บอนไดออกไซด์ กับ ความชื้นสัมพัทธ์ อุณหภูมิ และ ความเร็วลม เท่ากับ 0.108, – 0.209 และ 0.558 ตามลำดับ โดยที่ไม่มีนัยสำคัญ ($p>0.05$) ความตระหนักถึงโรคตึกเป็นพิษในแง่ของปัจจัยทางสิ่งแวดล้อมของนิสิตส่วนใหญ่อยู่ในระดับที่มาก ถึง ระดับมากที่สุด เมื่อพิจารณาจาก อุณภูมิห้อง การหมุนเวียนหรือระบายอากาศ แต่เมื่อพิจารณาจาก ความชื้นสัมพัทธ์ ความตระหนักอยู่ในระดับที่น้อยที่สุด ถึงระดับปานกลาง ความตระหนักถึงโรคตึกเป็นพิษในแง่ของอาการของนิสิตส่วนใหญ่อยู่ในระดับที่น้อยที่สุด ถึงระดับปานกลาง เมื่อพิจารณาจาก อาการทางตา ทางโพรงจมูก ทางผิวหนัง อาการปวด และอาการอื่นๆ มีเพียงแค่เมื่อพิจารณาจาก อาการทางลำคอและระบบทางเดินหายใจเท่านั้น ที่ความตระหนักอยู่ในระดับที่มาก ถึง ระดับมากที่สุด ความตระหนักถึงโรคตึกเป็นพิษในแง่ของกิจกรรมของนิสิตส่วนใหญ่อยู่ในระดับที่มาก ถึงระดับมากที่สุด เมื่อพิจารณาจาก การทำความสะอาดห้องเรียน และ การยืดกล้ามเนื้อ แต่เมื่อพิจารณาจาก

การบำรุงรักษาระบบปรับอากาศ และ ตำแหน่งที่นั่ง ความตระหนักอยู่ในระดับที่น้อยที่สุด ถึง ระดับปานกลาง งานศึกษานี้แสดงให้เห็นว่าคุณภาพอากาศภายในอาคารควรได้รับการปรับปรุงและ นิสิตควรได้รับการประชาสัมพันธ์เพื่อเสริมสร้างความรู้ความเข้าใจเกี่ยวกับโรคตึกเป็นพิษ นอกจากนี้ จำนวนของตัวอย่างต่างๆ ทั้งจำนวนครั้งในการเก็บวัดพารามิเตอร์คุณภาพอากาศภายในอาคารและจำนวนผู้ตอบแบบสอบถาม ควรมีจำนวนเพิ่มมากขึ้นในการศึกษาในอนาคต

คำสำคัญ: คุณภาพอากาศภายในอาคาร, ความตระหนัก, โรคตึกเป็นพิษ, ห้องเรียน

Project Title Assessment of Indoor Air Quality and Awareness of Sick Building Syndrome in Chulalongkorn University

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Abstract

It is important for the people, especially those who spend a lot of their time in building, to realize that they may expose to poor indoor air quality and Sick Building Syndrome can occur to themselves. Thus, this study aims to assess the indoor air quality and to explore the awareness of Sick Building Syndrome among students in the classroom. The study measured 4 indoor air quality parameters of classroom 201 in the Mahamakut building at Chulalongkorn University during the class in 10 sessions from 13.00 – 15.00 o'clock by using SIRIUS ST-501 for CO_2 Concentration and using TM-4002 for relative humidity, temperature and air velocity. Meanwhile, the questionnaires adapted from the previous were used to survey the awareness of Sick Building Syndrome in the students. In conclusion, 3 parameters including CO_2 concentration, relative humidity and air velocity were not complied with the acceptable standard. Only temperature parameter was complied. The Pearson correlation coefficient between CO_2 concentration and relative humidity, temperature and air velocity were 0.108, - 0.209 and 0.558 respectively but it was not significant ($p>0.05$). The majority of the respondents' level of awareness of Sick Building Syndrome in term of *environmental factors* considering room temperature and air circulation or ventilation was good or excellent. However, when considering room humidity, the level of awareness of the majority was very poor, poor or moderate. The majority's level of awareness in term of *symptoms* considering eye symptoms, nasal symptoms, skin problems, aches or pains and other symptoms was very poor, poor or moderate. Except when considering throat or respiratory tract symptoms, the level of awareness was good or excellent. The majority's level of awareness in term of *activities* considering classroom cleaning and muscle stretching was good or excellent. But when considering air conditioning system maintenance and sitting spot, the level of awareness was very poor, poor or moderate. The study suggests that the indoor air quality of the should be improved and the awareness of Sick Building Syndrome should be promoted more. Beside, this study recommends that the number of samples should be raised for the thorough study in the future.

Keywords: Indoor air quality, Awareness, Sick Building Syndrome, Classroom

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Nattanon Sukkamnerd

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CHAPTER I

INTRODUCTION

1.1 Introduction

People usually spend most of their time in an indoor space such as home, office and fitness center. So, the indoor environment is one of the important factors that might affect people's health (Norhidayah et al., 2013). This indoor environment can be assessed by indoor air quality. Therefore, activities causing distribution and accumulation of contaminants will contribute to poor indoor air quality. Exposure of people to this poor indoor air quality can affect their health.

Sick Building Syndrome (SBS) is a term described a phenomenon happened when the occupants of the building experience to either physical health effect or mental health effect, or even both, that associated with time spent in the building (Joshi, 2008). Sick Building Syndrome includes various nonspecific symptoms such as headache, dizziness, itchy skin, dry throat and nasal allergy. People that experienced health effect have these symptoms when they spend their time in the building.

World Health Organization (WHO) suggested that up to 30% of new and remodeled buildings worldwide may have problems involving Sick Building Syndrome associated with indoor air quality. Although this condition is temporary, there are long-term problems in some buildings. Furthermore, in 2009, WHO also conducted a report on Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks. The report said that some indoor air pollutants are responsible for the global burden of disease. A Large proportion of people presenting with indoor environmentally associated symptoms such as Sick Building Syndrome are infants and elders.

It is important for the people, especially those who spend a lot of their time in building such as students and office workers, to realize that they may expose to poor indoor air quality and Sick Building Syndrome can occur to themselves while doing their activity.

Hence, this study aims to assess the indoor air quality of the classroom and to explore the awareness of Sick Building Syndrome in terms of environmental factors, symptoms and activities among students who use the classroom.

1.2 Objectives

1.2.1 To assess the indoor air quality of classroom 201 in the Mahamakut building at Chulalongkorn University.

1.2.2 To assess correlations among CO_2 concentration, temperature, relative humidity and air movement.

1.2.3 To assess the awareness of sick building syndrome in the students using the classroom.

1.3 Hypotheses

1.3.1 The indoor air qualities of the selected classrooms are compiled to the acceptable standard from the Bureau of Environmental Health's criteria for monitoring indoor air quality 2016.

1.3.2 The students in the selected classrooms have a good awareness of sick building syndrome.

1.4 Expected Benefits

The Office of Physical Resource Management at Chulalongkorn University can use the study results as initial information on planning to improve the indoor air quality of the building and increase awareness of Sick Building Syndrome.

CHAPTER II

LITERATURE REVIEW

2.1 Parameters Affecting Sick Building Syndrome

2.1.1 CO_2 Concentration

In the present, about half of 22 studies of Sick Building Syndrome symptom in office buildings found that higher CO_2 concentration was associated with an increase in the prevalence of Sick Building Syndrome symptoms (Erdmann et al., 2002). It was also found that the primary source of CO_2 in office buildings is respiration of the building occupants. These Sick Building Syndrome symptoms consist of headache, eye irritation, nasal irritation, respiratory irritation and fatigue. A significant association between an increase in CO_2 concentration and Sick Building Syndrome symptoms was found in 70 percent of mechanically ventilated and air-conditioned buildings studies. The ventilation rate of a building was also associated with Sick Building Syndrome symptoms. In addition, there was an analysis of Building Assessment Survey and Evaluation (BASE) dataset in 1994-1996 that found dose-response relationships between CO_2 and symptoms which are sore throat, nasal irritation, tight chest, et cetera.

2.1.2 Temperature

Indoor temperature can affect thermal comfort, satisfaction with air quality and performance of occupants in the building. There was a study which an association of symptoms and complaints with mechanical ventilation and other indoor air factors, including temperature, was studied by Jaakkola, Heinonen, and Seppänen (1989). The study was conducted in a modern eight-floor office building with 2,150 workers. The variation of the room temperature was large (21 to 26°C), the average temperature was high at 23.3°C and the workers couldn't control the temperature. The result from the cross-sectional analysis showed that the room temperature was important indoor air parameter which affect Sick Building Syndrome symptoms and sensation of dryness. There was a linear correlation between the amount of Sick Building Syndrome symptoms, a sensation of dryness, and a rise in room temperature above 22°C. However, when the temperature was considered to be too cold and too warm, there was an excess of Sick Building Syndrome symptoms. It indicates that the symptoms can also be considered as workers' expression of general dissatisfaction with the temperature. In conclusion, individual control of room temperature will improve the thermal comfort and decrease the Sick Building Syndrome symptoms of workers.

2.1.3 Relative Humidity

Relative humidity is a ratio between the actual amount of water vapor in the air and the maximum amount of water vapor that the air can hold at that air temperature. In a high humidity environment, there is a lot of vapor in the air which prevents the evaporation of sweat from people's skin and this makes it hard for the body to cool down its temperature.

The research on the effect of air humidification on Sick Building Syndrome and perceived indoor air quality in hospitals was done by Nordström, Norbäck and Akselsson (1994). The objective of this study was to evaluate the effect of steam air humidification on Sick Building Syndrome and perceived air quality during the heating season. 104 Hospital employees working in four new and well-ventilated hospital units in southern Sweden are a dynamic population of this study. In Scandinavia, the indoor relative humidity in a well-ventilated building is usually in the range 10-35% in winter. Air humidification raised the relative air humidity to 40-45% in two units during a four-months-study period whereas the other two units served as controls with relative humidity from 25-35%. A questionnaire was used to measure symptoms and perceived indoor air quality both before and after the study period. The technical measurements include temperature, air humidity, static electricity, exhaust air flow, aerosols, microorganisms and volatile organic compounds in the air. The results of the humidification were a significant decrease in the sensation of air dryness, static electricity, and airway symptoms. After four months of air humidification during the heating season, 24% of respondents reported a weekly sensation of dryness in humidified units, compared with 73% in controls. No significant changes in symptoms of Sick Building Syndrome or perceived air quality over time were found in the control group. The room temperature was between 21-23°C in all units, and no significant effect of air humidification on the air concentration of aerosols and volatile organic compounds was found. No growth of microorganisms was found in the supply air ducts, and no Legionella bacteria were found in the supply water of the humidifier. However, air humidification significantly reduced personal exposure to static electricity. In conclusion, air humidification during the heating season in colder climates can decrease symptoms of Sick Building Syndrome and perception of dry air.

2.1.4 Air Movement

Air movement or air velocity is also one of important factors affecting thermal comfort because people can be sensitive to the feeling of the air on their skin. The speed of air that moves across a person's skin can help cool them down if it's cooler than the surrounding. The study of the association of Sick Building Syndrome with indoor air parameter was done (Jafari et al., 2015). The association between personal factors, environmental factors and Sick Building Syndrome symptoms was assessed by questionnaire. Indoor air parameters were measured using calibrated instruments. In conclusion, the results of this study showed the significant effect of air velocity on some symptoms which are cough and wheezing.

2.2 Review of Studies

Indoor Air Quality and Sick Building Syndrome in Three Selected Building

Indoor environmentally associated symptoms such as Sick Building Syndrome might be the result of exposing to poor indoor air quality. The objective of this study is to determine the association between indoor air quality parameters and Sick Building Syndrome symptoms in 3 selected building. The selection of buildings is considered by a long history of occupancy and age of buildings. Information from respondents was collected by structured questionnaire. In the meanwhile, Indoor air quality parameters were also measured in 3 selected building. The result found that 3 buildings have a similar prevalence of Sick Building Syndrome symptoms but no association between building type and Sick Building Syndrome occurrence was found. Most of indoor Air quality parameters in all 3 selected buildings complied with the Malaysia Standard of Indoor Air Quality except Air velocity. A significant difference between 3 buildings was found among air velocity, CO_2 concentration, temperature and relative humidity. In the other hand, significant difference was not found among CO concentration and fungal count. The study suggests that ventilation and accumulation of contaminants within an indoor environment are important factors causing Sick Building Syndrome. However, the study failed to achieve its objective which is to determine the association between indoor air quality parameters and Sick Building Syndrome symptoms in 3 selected building.

Awareness of Sick Building Syndrome (SBS): A Case Study of the Office Workers in Silom Area

People spend most of their time in an air-conditioned office building. So, they have chances to experience indoor environmentally associated symptoms which is Sick Building Syndrome. This Sick Building Syndrome refers to health effects associated with time spent in an indoor environment. The objective of this study was to explore the level of awareness of Sick Building Syndrome among office workers in the Silom area to assess their awareness of Sick Building Syndrome’s causes, symptoms and prevention. The respondents of this study were 100 full-time office workers working in air-conditioned buildings in the Silom area. The cross-sectional study was conducted in this study and the sample selection was done by snowball sampling method. Questionnaires consisted of questions and Likert Scale were used to explore the awareness of Sick Building Syndrome in office workers. The Statistical Package for Social Sciences (SPSS) version 15.0 was used for data analysis. The result shows that most of the respondents, more than half, were female workers and they were more likely to be aware of Sick Building Syndrome than male workers. Almost all respondents have had an uncomfortable experience working for long hours in offices, most of them had background knowledge of Sick Building Syndrome. The level of awareness of Sick Building Syndrome’s causes was very good and good. Poor ventilation was aware by most of the respondents. The level of awareness of the symptoms was good and moderate, a headache was the symptom awarded significantly by respondents. Furthermore, smoking restrictions for preventing of Sick Building Syndrome was the highest level of awareness.

CHAPTER III

METHODOLOGY

3.1 Study Scope

The study aimed to measure temperature, relative humidity, air movement and CO_2 concentration of classroom 201 in the Mahamakut Building at Chulalongkorn University to assess the indoor air quality. In the meanwhile, the survey of awareness of Sick Building Syndrome in those students using this classroom was done.

The study chose this classroom in the Mahamakut building to do research because the classroom was available for conducting research during the summer semester when the study was done.

3.2 Study Area

The study area of the study is classroom 201 in the Mahamakut building belonging to the Faculty of Science, Chulalongkorn University, where is located in Bangkok, Thailand. This classroom is used for the lecture. The dimension of the classrooms is proximate 18 m length × 14 m width × 2.8 m height. A total of 6 air conditioners are installed in the classroom and there are windows on 1 side of walls that allow the natural light to distribute to the room.

Figure 3.1 Classroom 201 at Mahamakut building

Figure 3.2 Classroom 201 at Mahamakut building

3.3 Study Framework

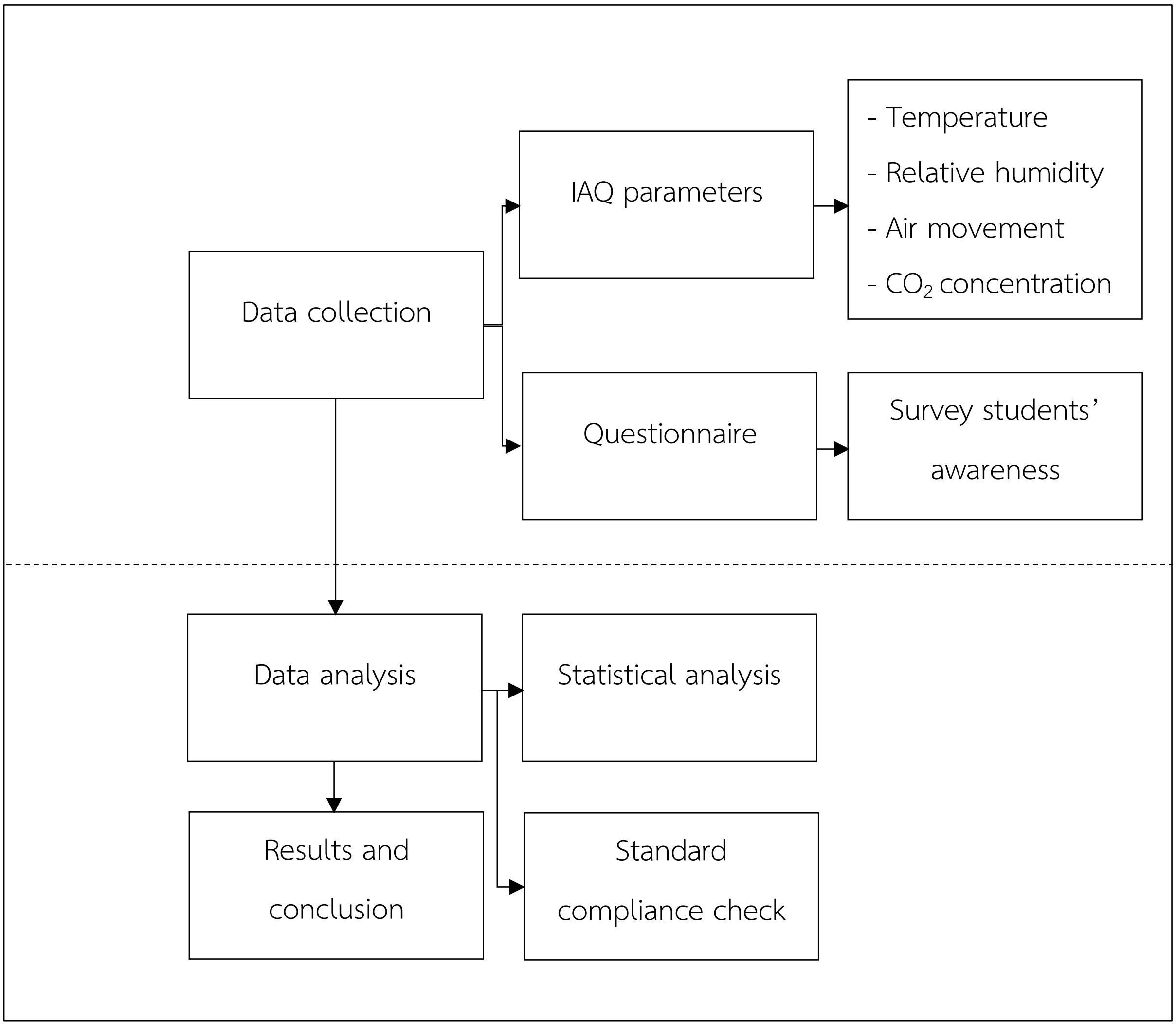

Figure 3.3 Framework of the study

The study framework in this study is adapted from the comprehensive indoor air quality audit methodology from the Bureau of Environmental Health, Department of Health, Ministry of Public Health, Thailand (The Bureau of Environmental Health, 2016).

3.4 Indoor Air Quality Measurements

The following parameters were measured together at the same time. After that, the collected data was used to assess indoor air quality according to an indoor air quality acceptable standard from the Department of Health, Thailand. The lecture was between 13.00 – 15.00 o'clock on Monday to Friday. A total of 10 sessions of sampling started on June 6, 2019 and ended on June 27, 2019.

3.4.1 CO_2 Concentration

SIRIUS Datalogger Detector Carbon Dioxide (CO_2) Meter (SIRIUS ST-501) (Appendix A) was used to measure CO_2 concentrations (ppm) in the selected classroom. It has a non-dispersive infrared (NDIR) gas sensor that detects the amount of infrared light absorbed by CO_2 molecules. This sensor type is widely used in an indoor air quality monitoring due to its high precision and accuracy (Bureau of Environmental Health, 2016). SIRIUS ST-501 was placed at the proper location, which would least interrupt the class activities and be nearest to the middle of the students seating area. It was set at between 75 - 120 centimeters from the ground as the breathing zone of sitting students. The sampling was done every 10 minutes during the lecture in classroom.

3.4.2 Air Movement, Temperature and Relative Humidity

TENMARS Hot-wire Air Velocity Meter (TM-4002) (Appendix A) was used to measure thermal comfort parameters of the selected classrooms, including temperature (°C), relative humidity (%) and air movement (m/s). It has a probe equipping with a sensor to detect heat transfer from the heated wire to the surrounding air. This sensor type is highly responsive and suitable for the spaces with low air movement. TM-4002's probe was placed near SIRIUS ST-501 with the sampling interval at 10 minutes as well.

Figure 3.4 TM-4002 and SIRIUS ST-501 measuring indoor air quality parameters in the middle of the class in classroom 201 at Mahamakut building

3.5 Awareness of Sick Building Syndrome

The questionnaires adapted from the previous study (Awareness of Sick Building Syndrome (SBS): A Case Study of the Office Workers in Silom Area) were used to survey the awareness of Sick Building Syndrome in the students after using the classroom. It consists of students' general information, environmental factors, symptoms and activities part. A total of 31 students was the study samples which was conducted by the systematic sampling from the population of 94 students.

3.6 Data Analysis

First, descriptive statistics was used to describe characteristics of indoor air quality and awareness of Sick Building Syndrome datasets. Line graph was used to portray the distributions of CO_2 concentration, temperature, relative humidity and air velocity over time. The bar graph was used to illustrate the distribution of awareness of Sick Building Syndrome among the students in the classroom. And then, *t*-test was performed to determine compliance or non-compliance of indoor air quality for each classroom by comparing the sample means to the related acceptable standard in (Draft) Bureau of Environmental Health's criteria for monitoring indoor air quality 2016. The Pearson correlation coefficient was estimated to examine the correlations between CO_2 and air physical properties (temperature, relative humidity and air velocity). Finally, the Likert Scale was used to determine the level of awareness by using descriptive statistics presented by frequency and percentage.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Assessment of Indoor Air Quality

4.1.1 Characteristic of Classroom Air Quality

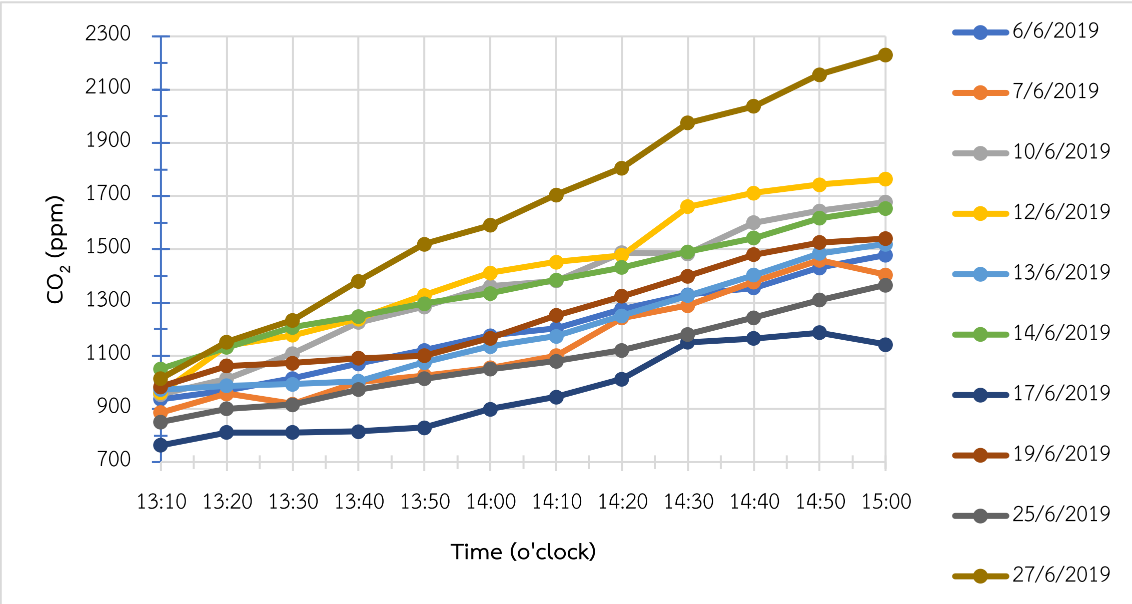

Figure 4.1 CO_2 concentration (ppm) in classroom 201 at Mahamakut building between 13.10 – 15.00 o'clock in 10 sessions of sampling

CO_2 concentration in classroom 201, Mahamakut building, increased dramatically over time. It started with an average of 937 ppm and went up to an average of 1577 ppm, which was an increase of 640 ppm within 2 hours. However, this increase of CO_2 concentration might be a result of low air velocity of this classroom (see figure 4.4) which caused a contamination of CO_2 gas in an enclosed space.

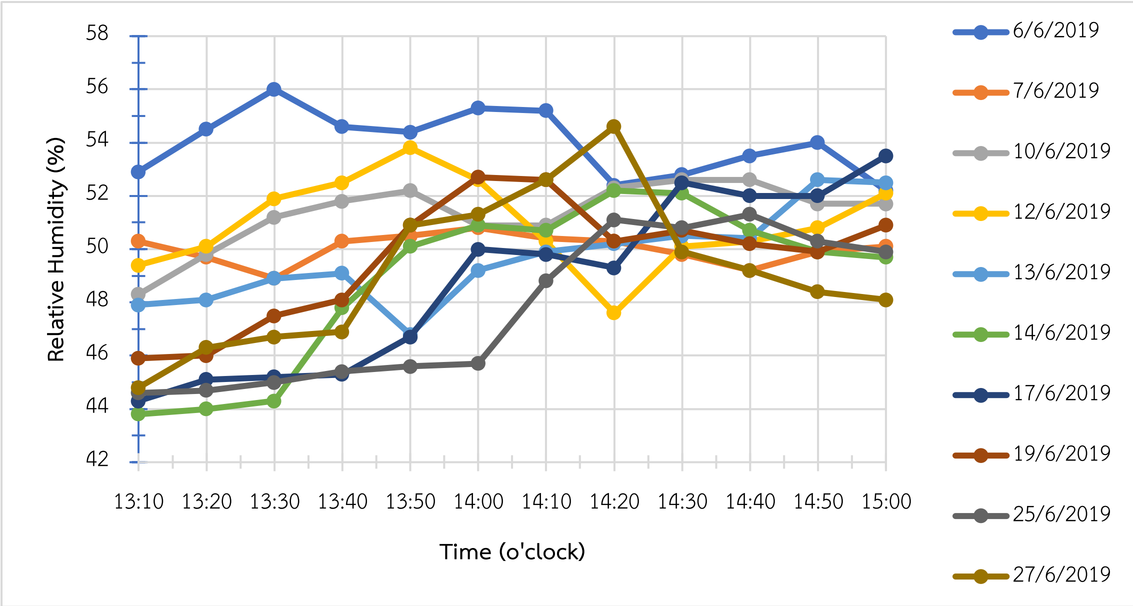

Figure 4.2 Relative humidity (%) of classroom 201 at Mahamakut building between 13.10 – 15.00 o'clock in 10 sessions of sampling

Relative humidity of the classroom started with an average of 47.2% and went up to an average of 51.0% at the end of session. There was a total increase of 3.8% of relative humidity within 2 hours. The relative humidity climbed to its peak in a middle of sampling session which was about 13.50 – 14.20 o'clock (50 – 80 minutes passed) before dropping slightly until the end of session.

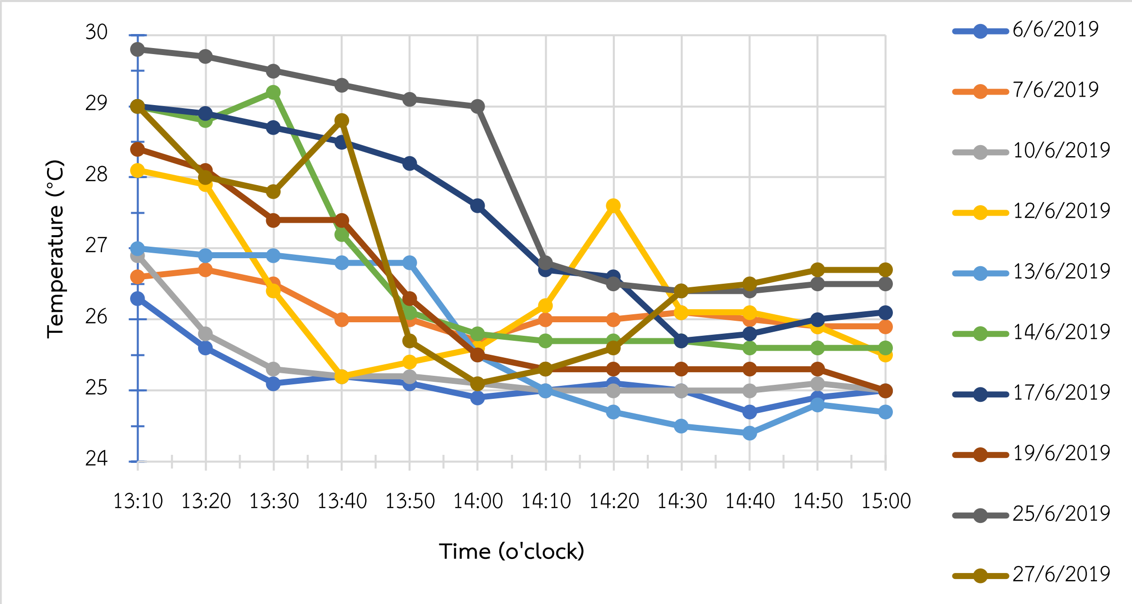

Figure 4.3 Temperature (°C) of classroom 201 at Mahamakut building between 13.10 – 15.00 o'clock in 10 sessions of sampling

The temperature of the classroom started with an average of 28.0°C and went down to an average of 25.6°C at the end of sampling session, which was a total decrease of 2.4°C within 2 hours. The temperature declined dramatically from an early of session to a middle of session, reaching its bottom between 13.50 – 14.10 o'clock (50 – 70 minutes passed), then remained stable until the end of session. Considering a stable temperature, the air conditioning system of the classroom 201 at Mahamakut building was seemed to be efficient on controlling room temperature after 50 – 70 minutes passed.

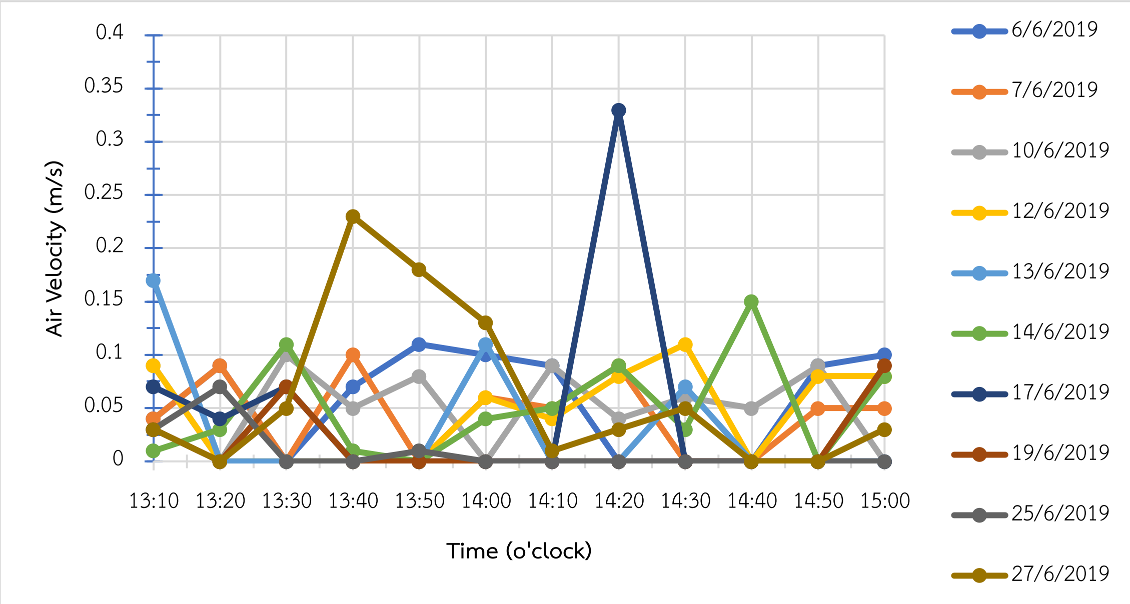

Figure 4.4 Air velocity (m/s) in classroom 201 at Mahamakut building between 13.10 – 15.00 o'clock in 10 sessions of sampling

In spite of a high efficiency on controlling room temperature of the air conditioning system of the classroom (see figure 4.3), the air conditioning system was not seemed to be much efficient on controlling stable air velocity. As seeing from the graph (figure 4.4), air velocity of the classroom over 2-hours sampling session is quite variant and there was no trend to be observed. This variant air velocity was a result of unsteady airflow came out from air conditioners. It was obvious that, regarding efficient room temperature control, this air conditioning system of the classroom 201 at Mahamakut building was not suitable for controlling stable air velocity.

Even though number of students attending each class was not counted and was considered the limitation of this study, human seemed to affect changes of indoor air quality. It is recommended that the future study should take this issue into consideration.

4.1.2 Indoor Air Quality Compliance

Table 4.1 Comparison between sampling average of each parameter and acceptable standard

Parameter	Sampling Average	Bureau of Environmental Health Acceptable Standard
CO_2 (ppm)	1,262	Less than 1,000
Relative humidity (%)	50.0	50 - 65
Temperature (°C)	26.4	24 – 26
Air Velocity (m/s)	0.04	0.10 – 0.30

Tests of Normality

Table 4.2 Normality test of indoor air quality parameter

Parameter	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
CO_2	0.132	10	0.200	0.973	10	0.920
RH	0.205	10	0.200	0.897	10	0.206
Temp	0.127	10	0.200	0.965	10	0.844
AirVelo	0.206	10	0.200	0.916	10	0.325

The test statistics are shown in the table. Here two tests for normality are run. For dataset small than 2000 elements, the Shapiro-Wilk test is usually used. otherwise, the Kolmogorov-Smirnov test is used. In this study, the Shapiro-Wilk test is used since each parameter has only 10 elements. The p-value of all 4 parameters is greater than 0.05 ($p>0.05$), the study can conclude that the data comes from a normal distribution. Thus, all 4 parameters can be used in *t*-test to determine indoor air quality compliance.

CO_2 Concentration

Table 4.3 One-sample statistics of CO_2 concentration

Parameter	N	Mean	Std. Deviation	Std. Error Mean
CO_2	10	1261.70	194.552	61.523

Table 4.4 One-sample test of CO_2 concentration

Parameter	Test Value = 1000					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
CO_2	4.254	9	0.002	261.700	122.53	400.87

The acceptable standard of CO_2 concentration is less than 1,000 ppm. Since p-value is less than 0.05 ($p < 0.05$), there is a significant difference in mean CO_2 concentration between the sample and the acceptable standard. And, the mean difference is 261.7 more than the acceptable standard. Therefore, this parameter of indoor air quality *was not complied* with the acceptable standard.

Relative humidity

Table 4.5 One-sample statistics of relative humidity

Parameter	N	Mean	Std. Deviation	Std. Error Mean
RH	10	50.020	1.7396	0.5501

Table 4.6 One-sample test of relative humidity

Parameter	Test Value = 50					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
RH	0.036	9	0.972	0.0200	-1.224	1.264

The acceptable standard of relative humidity is between 50 – 65 %. Although the mean difference is 0.02 more than 50, the p-value is more than 0.05 ($p > 0.05$). So, there is no significant difference in mean relative humidity between the sample and the acceptable standard. The study cannot conclude that the sample mean is between 50 – 65 %. This parameter of indoor air quality *was not complied* with the acceptable standard.

Temperature

Table 4.7 One-sample statistics of temperature

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Temp	10	26.360	0.8746	0.2766

Table 4.8 One-sample test of temperature

Parameter	Test Value = 24					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Temp	8.533	9	0.000	2.3600	1.734	2.986

Table 4.9 One-sample test of temperature

Parameter	Test Value = 26					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Temp	1.302	9	0.225	0.3600	-0.266	0.986

The acceptable standard of temperature is between 24 – 26 °C. Since p-value is less than 0.05 ($p < 0.05$) for the test value of 24, there is a significant difference in mean temperature between the sample and the test value. Meanwhile, the p-value for the test value of 26 is more than 0.05 ($p > 0.05$). So, the study can conclude that the sample mean is between 24 – 26 °C. This parameter of indoor air quality *was complied* with the acceptable standard.

Air Velocity

Table 4.10 One-sample statistics of air velocity

Parameter	N	Mean	Std. Deviation	Std. Error Mean
AirVelo	10	0.0410	0.01663	0.00526

Table 4.11 One-sample test of air velocity

Parameter	Test Value = 0.10					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
AirVelo	-11.217	9	0.000	-0.05900	-0.0709	-0.0471

The acceptable standard of air velocity is between 0.10 – 0.30 m/s. Since p-value is less than 0.05 ($p < 0.05$), there is a significant difference in mean air velocity between the sample and the acceptable standard. And, the mean difference is 0.059 less than the lower acceptable standard. The study can conclude that the sample mean is not between 0.10 – 0.30 m/s. This parameter of indoor air quality *was not complied* with the acceptable standard.

4.2 Correlation between CO_2 Concentration and Air Physical Properties

Table 4.12 Correlation between CO_2 and air physical properties

Parameter		RH	Temp	AirVelo
CO_2	Pearson Correlation	0.108	- 0.209	0.558
	Sig. (2-tailed)	0.767	0.563	0.093
	N	10	10	10

4.2.1 Correlation between CO_2 Concentration and Relative Humidity

The Pearson correlation coefficient between CO_2 concentration and relative humidity is 0.108, which indicates that there was only a very weak positive relationship between these 2 parameters using the guide that Evans (1996) suggests for the absolute value of r. It shows that, as CO_2 concentration increased, relative humidity increased in a small volume. However, the p-value is 0.767 which is greater than the significance level of 0.05, the study cannot conclude that the correlation is significant.

4.2.2 Correlation between CO_2 Concentration and Temperature

The Pearson correlation coefficient between CO_2 concentration and temperature is - 0.209. It indicates that there was only a weak negative relationship between these 2 parameters. So, as CO_2 concentration increased, temperature decreased at the same time in a small amount. However, the p-value is 0.563 which is greater than the significance level of 0.05, the study cannot conclude that there is a significant correlation.

4.2.3 Correlation between CO_2 Concentration and Air Velocity

The Pearson correlation coefficient between CO_2 concentration and air velocity is 0.558, which indicates that there was a moderate linear relationship between these 2 parameters. It shows that, as CO_2 concentration increased, air velocity increased. However, the p-value is 0.093 which is greater than the significance level of 0.05, the study cannot conclude that there is evidence about the significance of the association.

4.3 Awareness of Sick Building Syndrome

4.3.1 Demographic Information of the Respondents

A total of 31 students was the study samples which was conducted by the systematic sampling from the population of 94 students. 51.61% of the study population were female and 48.39% were male. The majority of study population (48.39%) was studying in fourth year at the time, followed by second year students (29.03%), third year students (9.68%), first year students (9.68%) and fifth year student (3.22%). Most study population was science students (61.29%) and about quarter were engineering students (25.81%), the other were allied health science students (9.68%). 1 of 31 students (3.22%) has unspecified for his faculty. Almost the whole proportion of the study population (96.78%) have not had any background knowledge of Sick Building Syndrome. There was only 1 out of 31 students (3.22%) that had a background knowledge, she specified the source of her background knowledge as she heard about it from her friends. 51.61% of the study population had an interest in learning further about Sick Building Syndrome and 48.39% had no interest.

4.3.2 The Level of Awareness of Sick Building Syndrome in Term of Environmental Factors

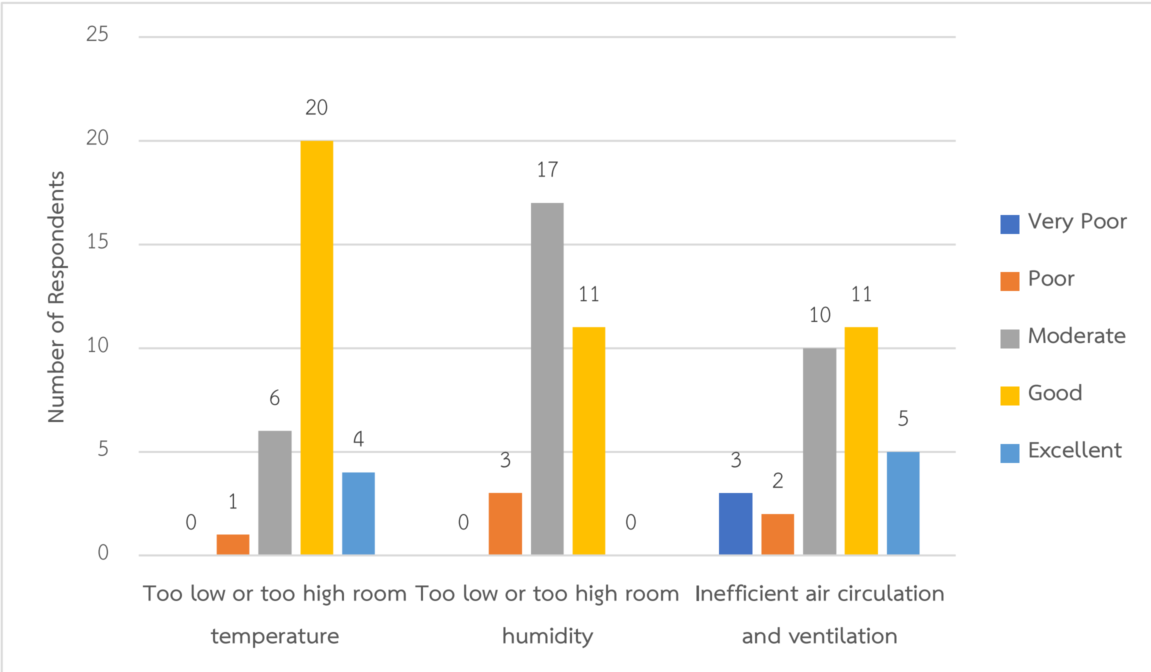

Figure 4.5 Number of respondents according to their understanding of how much they think each environmental factor is relevant to Sick Building Syndrome

Too low or too high room temperature

More than half of the respondents (64.52%) had a *good* awareness that too low or too high room temperature can contribute to Sick Building Syndrome. There was only a tiny proportion that had *very poor* and *poor* awareness (0% and 3.23%, respectively). Furthermore, the bar graph shows that 77.42% of the respondents had *good* or *excellent* awareness while other 22.58% had a *poor* or *moderate* awareness.

Too low or too high room humidity

Nearly half of the respondents (54.84%) had a *moderate* awareness that too low or too high room humidity results in Sick Building Syndrome. Furthermore, the bar graph shows that 64.52% of the respondents had *poor* or *moderate* awareness while 35.48% had *good* or *excellent* awareness.

Inefficient air circulation and ventilation

The proportion of the respondents who had *moderate* and *good* awareness that inefficient air circulation and ventilation can cause Sick Building Syndrome was almost at the same number (32.26% and 35.48%, respectively). However, the bar graph shows that 51.31% of the respondents had *good* or *excellent* awareness while only 48.39% had *very poor, poor* or *moderate* awareness.

4.3.3 The Level of Awareness of Sick Building Syndrome in Term of Symptoms

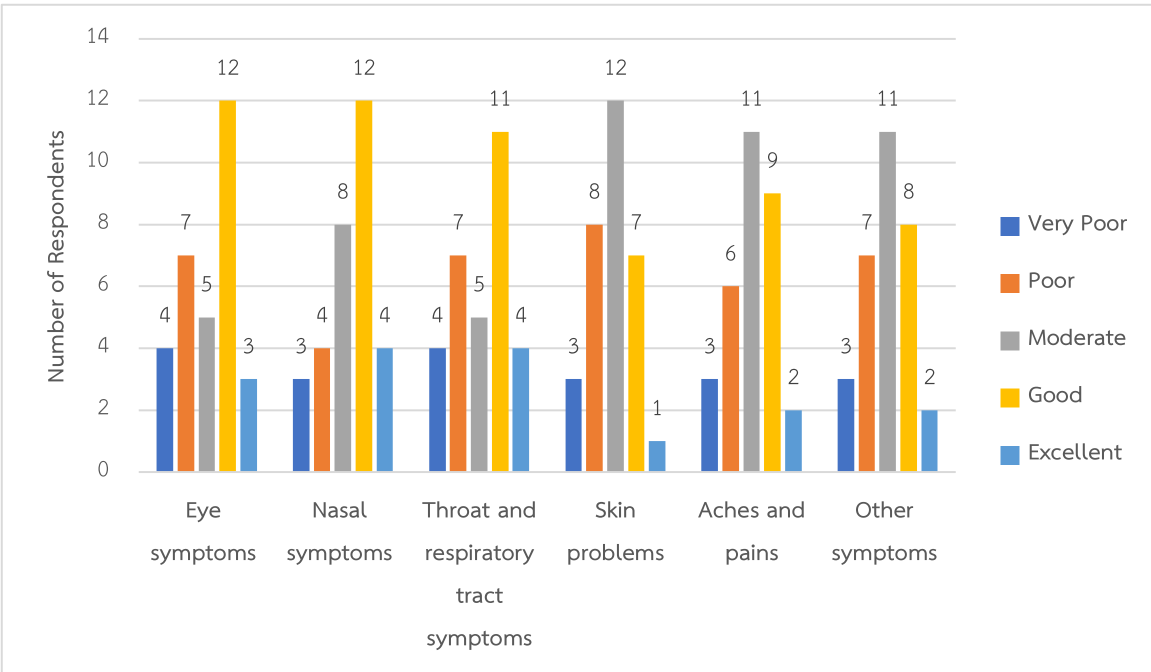

Figure 4.6 Number of respondents according to their understanding of how much they think each symptom is relevant to Sick Building Syndrome

Eye symptoms

Many of the respondents (38.71%) had a *good* awareness that eye symptoms were some of the effects of Sick Building Syndrome. However, the bar graph shows that 51.61% of the respondents had *very poor, poor* or *moderate* awareness while only 48.39% had *good* or *excellent* awareness.

Nasal symptoms

A lot of respondents (38.71%) had a *good* awareness that nasal symptoms were result of Sick Building Syndrome. Furthermore, the bar graph shows that 51.61% of the respondents had *good* or *excellent* awareness while other 22.58% had a *poor* or *moderate* awareness.

Throat and respiratory tract symptoms

The majority of the respondents (35.48%) had a *good* awareness that Sick Building Syndrome accounts for throat and respiratory tract symptoms. However, the bar graph shows that 51.61% of the respondents had *very poor, poor* or *moderate* awareness while only 48.39% had *good* or *excellent* awareness.

Skin problems

38.71% of the respondents had a *moderate* awareness that Sick Building Syndrome causes some skin problems. Furthermore, the bar graph shows that 74.20% of the respondents had *very poor, poor* or *moderate* awareness while other 25.80% had *good* or *excellent* awareness.

Aches and pains

Nearly one-third of the respondents (35.48%) had a *moderate* awareness that Sick Building Syndrome is responsible for aches and pains. Furthermore, the bar graph shows that 64.52% of the respondents had *very poor, poor* or *moderate* awareness while other 35.48% had *good* or *excellent* awareness.

Other symptoms

A large proportion of respondents (35.48%) had a *moderate* awareness that some symptoms such as nausea, dizziness and loss of concentration were the effect of Sick Building Syndrome. Furthermore, the bar graph shows that 67.74% of the respondents had *very poor, poor* or *moderate* awareness while other 32.26% had *good* or *excellent* awareness.

4.3.4 The Level of Awareness of Sick Building Syndrome in Term of Activities

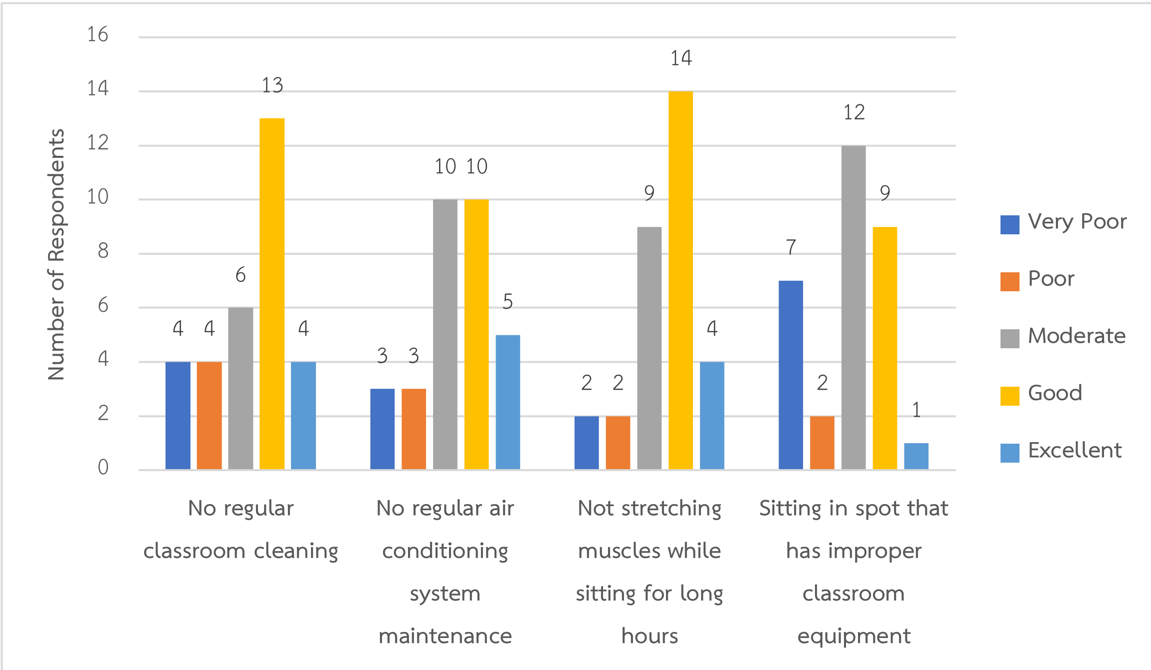

Figure 4.7 Number of respondents according to their understanding of how much they think each activity is relevant to Sick Building Syndrome

No regular classroom cleaning

41.94% of the respondents had a *good* awareness that no regular classroom cleaning can causes Sick Building Syndrome. Furthermore, the bar graph shows that 54.84% of the respondents had *good* or *excellent* awareness while other 45.15% had a *very poor, poor* or *moderate* awareness.

No regular air conditioning system maintenance

The proportion of the respondents who had *moderate* and *good* awareness that this activity lead to Sick Building Syndrome was at the same at 32.26%. However, the bar graph shows that 51.61% of the respondents had *very poor, poor* or *moderate* awareness while other 48.39% had *good* or *excellent* awareness.

Not stretching muscles while sitting for long hours

Nearly half of the respondents (45.16%) had a *good* awareness that not stretching muscles while sitting for long hours is the cause of Sick Building Syndrome. Furthermore, the bar graph shows that 58.06% of the respondents had *good* or *excellent* awareness while other 41.94% had a *very poor, poor* or *moderate* awareness.

Sitting in spot that has improper classroom equipment

Most of the respondents (38.71%) had a *moderate* awareness that sitting in spot that has improper classroom equipment can result in Sick Building Syndrome. Furthermore, the bar graph shows that 67.74% of the respondents had *very poor, poor* or *moderate* awareness while other 32.26% had *good* or *excellent* awareness.

CHAPTER V

CONCLUSIONS

The indoor air quality parameters of the classroom 201 at Mahamakut building including CO_2 concentration, relative humidity and air velocity were not complied with the acceptable standard. Only one parameter was complied which was temperature.

The Pearson correlation coefficient between CO_2 concentration and relative humidity, temperature and air velocity is 0.108, - 0.209 and 0.558 respectively. However, the p-value of all these 3 correlations is greater than the significance level of 0.05, so the correlation is not significant.

The majority of the respondents' level of awareness of Sick Building Syndrome in term of *environmental factors* considering room temperature and air circulation or ventilation was good or excellent. However, when considering room humidity, the level of awareness of the majority was very poor, poor or moderate.

The majority's level of awareness in term of *symptoms* considering eye symptoms, nasal symptoms, skin problems, aches or pains and other symptoms was very poor, poor or moderate. Except when considering throat or respiratory tract symptoms, the level of awareness was good or excellent.

The majority's level of awareness in term of *activities* considering classroom cleaning and muscle stretching was good or excellent. But when considering air conditioning system maintenance and sitting spot, the level of awareness was very poor, poor or moderate.

In conclusion, this study suggests that the indoor air quality of the classroom 201 at Mahamakut building should be improve by adjusting air conditioning system. And, the awareness of Sick Building Syndrome should be promoted more to the students. Beside, this study recommends that the number of samples should be raised for the thorough study in the future.

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APPENDIX A

Indoor Air Quality Instruments

The thermal comfort (temperature, relative humidity and air movement) and indoor air contaminant (Carbon dioxide) parameters of concern in the study were measured by the following instruments:

1. SIRIUS Datalogger Detector Carbon Dioxide (CO_2) Meter (SIRIUS ST-501)

Specifications

- CO_2 sensor: GE Dual Beam Absorption Infrared™

- Temperature/humidity sensors

- Measurement range: 0 to 5,000 ppm display

- Display resolution: ±1 ppm

- Accuracy: ±75 ppm or 10% of reading

- Datalogging: 50,000 records

Figure A.1 SIRIUS ST-501

2. TENMARS Hot-wire Air Velocity Meter (TM-4002)

Specifications

- Air velocity measurement range: 0.01 to 40.00 m/s

- Air flow measurement range: 0 to 9999 CMM

- Temperature measurement range: -20 to 50 °C

- Humidity measurement range: 20 to 80 %RH

Figure A.2 TENMARS TM-4002

APPENDIX B

แบบสำรวจความรู้ความเข้าใจเกี่ยวกับโรคตึกเป็นพิษ (Sick Building Syndrome)

แบบสำรวจนี้เป็นส่วนหนึ่งของการศึกษาในรายวิชา 2308499 โครงงานวิทยาศาสตร์ (Senior Project) หลักสูตรวิทยาศาสตรบัณฑิต สาขาวิชาวิทยาศาสตร์สิ่งแวดล้อม คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ปีการศึกษา 2561 ซึ่งมีจุดประสงค์เพื่อสำรวจระดับความรู้ความเข้าใจเกี่ยวกับโรคตึกเป็นพิษของนิสิตจุฬาลงกรณ์มหาวิทยาลัย ดังนั้น จึงขอความร่วมมือในการกรอกข้อมูลให้ครบถ้วน ถูกต้อง และเป็นจริง โดยข้อมูลที่กรอกทั้งหมดจะเป็นความลับ และใช้ประโยชน์เพื่อการศึกษาเท่านั้น

คำชี้แจง: โปรดทำเครื่องหมาย ✓ ลงในช่อง ☐ หรือเติมข้อความลงในช่องว่างให้ตรงกับความเป็นจริง

1.) เพศ ☐ หญิง ☐ ชาย ☐ ไม่ต้องการระบุ

2.) ชั้นปีที่__________ภาควิชา________________________คณะ_________________________

3.) ท่านเคยได้รับข้อมูลข่าวสารเกี่ยวกับโรคตึกเป็นพิษ (Sick Building Syndrome) หรือไม่ ?

☐ ไม่เคย ☐ เคย (โปรดระบุแหล่งข้อมูลข่าวสาร:_____________________________________)

4.) ท่านคิดว่าปัจจัยสภาพแวดล้อม กลุ่มอาการ และกิจกรรมต่อไปนี้เกี่ยวข้องกับโรคตึกเป็นพิษมากน้อยเพียงใด?	มากที่สุด (5)	มาก (4)	ปานกลาง (3)	น้อย (2)	น้อยที่สุด (1)
ปัจจัยสภาพแวดล้อม					
☐มีอุณหภูมิภายในห้องเรียนที่สูงหรือต่ำเกินไป					
☐มีความชื้นภายในห้องเรียนที่สูงหรือต่ำเกินไป					
☐มีการหมุนเวียนและระบายอากาศภายในห้องเรียนที่ไม่ดี					
กลุ่มอาการ					
☐ทางตา เช่น เคืองตา ตาแห้ง แสบตา ตาแดง ภาพมัว					
☐ทางโพรงจมูก เช่น น้ำมูกไหล คัดจมูก จาม					
☐ทางลำคอและระบบทางเดินหายใจ เช่น คอแห้ง ไอแห้ง เจ็บคอ หายใจลำบาก					
☐ทางผิวหนัง เช่น ผิวแห้ง คัน ผื่นแดง					
☐อาการปวด เช่น ปวดหัว ปวดหลัง ปวดกล้ามเนื้อ					
☐อาการอื่น ๆ เช่น วิงเวียน คลื่นไส้ สูญเสียสมาธิ					
กิจกรรม					
☐ไม่มีการทำความสะอาดห้องเรียนเป็นประจำ					
☐ไม่มีการซ่อมบำรุงระบบปรับและระบายอากาศภายในห้องเรียนเป็นประจำ					
☐ไม่มีการยืดเส้นยืดสายเมื่อนั่งเรียนเป็นระยะเวลานาน					
☐เลือกที่นั่งเรียนในบริเวณที่มีการชำรุดเสียหายของวัสดุประจำห้องเรียน					

5.) ท่านมีความสนใจที่จะเรียนรู้เพิ่มเติมเกี่ยวกับโรคตึกเป็นพิษหรือไม่ ?

☐ ไม่สนใจ ☐ สนใจ

Questionnaire of awareness of Sick Building Syndrome[1]

This questionnaire is a part of the study submitted in partial fulfillment of the requirement for the Degree of Bachelor of Science program in Environmental Science, Faculty of Science, Chulalongkorn University academic year 2018. It is aimed to survey the level of awareness of Sick Building Syndrome of the students in Chulalongkorn University. All information provided will be treated confidentially, to be used for academic and research purposes only. Your cooperation and assistance in this matter is greatly appreciated.

Caution: please mark a symbol ✓ in the frame ☐ or fill the information according to the truth.

1.) Gender ☐ Female ☐ Male ☐ Unspecified

2.) Year_________department___________________faculty______________________

3.) Do you have any background knowledge of Sick Building Syndrome?

☐ No ☐ Yes (please specify the source:___________________________________)

4.) How much do you think that these environmental factors, symptoms and activities are relevant to Sick Building Syndrome?	Excellent (5)	Good (4)	Moderate (3)	Poor (2)	Very Poor (1)
Environmental Factors					
☐ Too low or too high room temperature					
☐ Too low or too high room humidity					
☐ Inefficient air circulation and ventilation					
Symptoms					
☐ *Eye symptoms* e.g. eye irritation, dry eyes, burning, redness and blurred vision					
☐ *Nasal symptoms* e.g. runny nose, congestion and sneezing					
☐ *Throat and respiratory tract symptoms* e.g. dry throat, dry cough, sore throat and breathing difficulties					
☐ *Skin problems* e.g. dry skin, itchy skin and skin rashes					
☐ *Aches and pains* e.g. Headache, Backache and Muscle pain					
☐ *Other symptoms* e.g. nausea, dizziness and loss of concentration					
Activities					
☐ No regular classroom cleaning					
☐ No regular air conditioning system maintenance					
☐ Not stretching muscles while sitting for long hours					
☐ Sitting in spot that has improper classroom equipment					

5.) Are you interested in learning further about Sick Building Syndrome?

☐ No ☐ Yes

[1] Adapted from Mahawong, J. (2009). *Awareness of sick building syndrome (SBS): a case study of the office workers in Silom area* (Master's Thesis, Thammasat University). Retrieved from http://digi.library.tu.ac.th/thesis/lg/0388/01TITLE.pdf

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