SAVONIA

THESIS – **BACHELOR'S DEGREE PROGRAMME**
TECHNOLOGY, COMMUNICATION AND TRANSPORT

PERFORMANCE TESTS FOR A PORTABLE SOUNDPROOF MODULAR SPACE SYSTEM

- CO_2, TEMPERATURE, RELATIVE HUMIDITY, AIR FLOWRATE

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THESIS
Abstract

Field of Study Social Sciences, Business and Administration			
Degree Programme Double degree in Environmental Technology			
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Title of Thesis Performance tests for a portable soundproof modular space system - CO_2, temperature, relative humidity, air flowrate			
Date	20 May 2020	Pages/Appendices	27/1
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Client Organisation /Partners Savonia University of Applied Sciences - "Puu paremmaksi" project			

Abstract

The aim of this thesis was to test the various functional indicators and feasibility of a portable sound insulation device.

The module is called a box, and it was placed in the hall of Opistotie Campus,Savonia University of Applied Sciences.

The test began in 2020 at the spring break of Savonia UAS and lasted for two weeks. The test included a CO_2 content test inside the box, a noise test around the box and a temperature test inside and outside the box. All test equipment was provided by Savonia UAS and it was used to test the performance of the box. Then, the results were compared to the reference data to get the corresponding results.

As a result, it was found out that the air quality inside the box was good and the sound insulation effect was good. All in all, the box was a successful project and can be put into use.

Keywords
Indoor Air Quality, Modular Space, Carbon dioxide, Temperature, Humidity

CONTENTS

1 INTRODUCTION

People's lives nowadays are more and more social, and there are few spaces that are alone. Such modular spaces can provide people with a private space, and such spaces are becoming more and more popular. This thesis concerns a spatial box with certain functionality. In order to better promote the project, the box is experimentally studied, and the practicality of the box is judged from the indicators such as carbon dioxide, humidity, temperature and whether it is worth promoting or people and whether it is applicable.

2 THE SCOPE OF THE THESIS

In order to make the space of the box healthier and more convenient, experiments were conducted to study the air quality in the box. Indoor air quality determines people's comfort level. Whether they can rest, work or study in a small space better depends on indoor air quality.

3 REQUIREMENTS FOR INDOOR AIR CLASSIFICATION (Finland, China)

3.1 China indoor air classification

With the rapid development of China's national economy, a series of problems, such as air pollution and decoration pollution, threaten people's health and safety, especially people spend more than 80% of their lives indoors. After the promulgation of various regulations on healthy buildings in China, indoor air pollution can be mitigated from the source, which is the basic guarantee for achieving a healthy China. Today, China's indoor air quality can already reach the international average. (Indoor air quality in Chinese household, Hou Li'an,2019)

In recent years, with the continuous increase of environmental protection and ecological civilization construction in China, the air condition has been effectively improved (Fig 1). People began to pay more attention to indoor air quality. China Women's Magazine, China Women's Development Foundation, Liuxing Air Purification Technology (Hunan) Co., Ltd. jointly carried out "Survey on the Status of Chinese Household Indoor Air Quality Cognition". The respondents were mainly from large and medium-sized cities across the country. Among them, 80.4% of the respondents were from Beijing, Shanghai, Shijiazhuang, Zhengzhou, Xi'an, Chengdu, Taiyuan, and Jinan. Male respondents accounted for 59.9%, female respondents accounted for 40.1%. The average age of the respondents was 30 years old. (Report from: World.people.com)

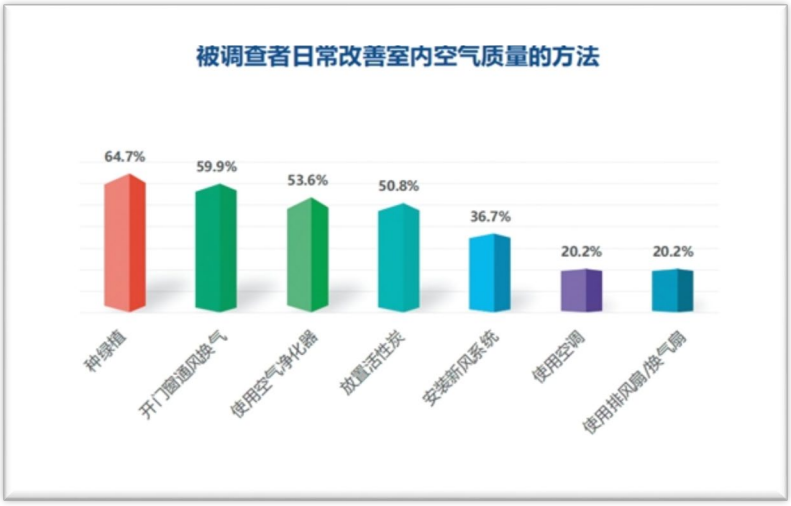

Figure 1: China indoor air classification

3.2 Finland indoor air classification

Regarding indoor air quality in Finland, as far as personal life in Finland is concerned, both indoor and outdoor air in Finland is very good. In the six months of living in Finland, I found that Finnish pay great attention to environmental health issues, so indoor air is also Very good. Compared to China, Finland is excellent in indoor air quality. (Personal feeling)

The Finnish Institute of Indoor Air Quality and Climate introduced the classification of indoor climate, building cleaning and decorative materials in 1995, and proposed to improve the indoor air quality of new buildings and reduce the emission of pollution from building materials. The S1, S2, and S3 categories in the Finnish Indoor Air Project are all in a better environment, and there is no disturbing odor in the environment. (Mervi Ahola, Jorma Sateri, Laura Sariola, 2018)

4 NEEDS AND WISHED FOR "BOXES"

I think the practicality of this kind of box of modular spaces is still relatively high, it takes up little space, but can play a lot of roles. For example, it provides a place for people to rest or chat. It provides a quiet place for others in a noisy place, you can talk about emergency matters, and can chat or call on the phone.

In my opinion, this box is very suitable for office workers and students. Because most office workers do not have their own independent office, most of them work together in a large shared office, if there is such a box, they can provide them with a more private and temporary resting place. Staff can take a short lunch break, listen to music, read books, or discuss more private topics with colleagues.

In schools, there are very few schools that provide students with a very private place. Especially in Chinese universities, students are in the public area no matter where they are in the school, and the dorms are generally for four or six people. If the school can place more such boxes, students will not affect or be influenced by others when they are studying or chatting with classmates.

Figure 2 Chinese "box" (ucmbar,2020)

In China, also have this kind of box as a way for singing, you can see it (Fig 2) also like a box. Such boxes are built in many places, such as shopping malls, movie theaters, restaurants, etc. For people to be bored while waiting for the meal, they can sing into the box, and the singing can not be heard outside the box. You can also relax yourself while consuming time.

Experimental part

5 DESCRIPTION OF BOX

A modular space, box is a place to work intensively, a place to be creative and inspired, and a place to rest (Figure 3). The space is easy to modify as a meeting room, work station, video conference room or a place to unwind. Box is a well-equipped product made with sustainable materials used in the product are environmentally friendly and the electricity consumption is as low as possible.

Box furniture measurements
Table height was 73,5 cm from the floor. CO2, Noise meter, etc. from this level.
Space from table top to the box roof 138,0 cm
Table width 53 cm, short side
Table width 70,8 cm long side

Table position:
Left edge 87cm from the left wall, right edge 89 cm from right wall. Quite in the middle and back a gainst the glass wall, as shown in your pictures.

Two seats with cushion:
77cm x 65 cm, height 43 cm

Figure 3 one type of box

6 MEASUREMENT PLAN AND PROCEDURE

First, I tested the noise of different setting (1,2,3) of the fan and the noise level within two meters outside the box and compared the noise level inside and outside the box to see if the quiet environment brought by this box is good.

Regarding to the test of air flow in the box, I have tested the air flow rate (m^3 / h) of fans with different setting several times and compared the data. In combination with noise, I can visually see the air flow frequency inside the box.

Next, under such fans with different setting, the door of the box was closed, and the carbon dioxide (CO_2) test in the space was performed. Each fan setting was measured four times and recorded every five minutes. The recorded data included the content of carbon dioxide (CO_2) concentration inside the box, the air temperature inside the box (°C), the normal room temperature (°C) outside the box, and the relative humidity (RH) inside the box. Of course, I measured the relevant data when there were no people in the box, one person in the box, and two people in the box, and tested them in two different time periods, Home study week and School day. The main goal of the test at this thesis is to feel the experience brought about by working and studying in this closed box and talking with people or taking a short break, whether there will be unsmooth air and whether the human body will not adapt.

6.1 Experimental measuring instruments

Measuring instruments are given in Table 1 and you will find photos of them in Figures 3-7.

Table 1. Measuring instruments

The name of instrument	Model number	component (unit)	valid range for meter
Sound Level Meter	TES 1352A	A dB	30dB – 130dB
Air Flow Meter	ALNOR APM150	Q m^3 /h	APM 150 METER
Carbon Dioxide Tester	VALLOX	CO_2 (ppm)	
Thermometer	FLUKE 50D	T（℃）	50S OR 50D
Hygro-/Thermo- / Flowmeter	VWR TH300	R.H（%） T（℃）	±0.1％ -25°C to 50°C

6.2 Measuring instruments procedure

Figure 4 Sound Level Meter

Sound level meter (Fig 4) measured the noise level (A) of different setting of the fan and the external noise level within two meters of the box

Figure 5 Air Flow Meter

Balometer (Fig 5) measures the flow rate of the two air outlets of the fan.

Figure 6 Carbon Dioxide Tester

Carbon Dioxide Tester (Fig 6) measures carbon dioxide concentration(ppm) inside the box.

Figure 7 Thermometer

Thermometer (Fig 7) detects the indoor temperature outside the box.

Figure 8 Hygro-/Thermo-/ Flowmeter

TH300(Fig 8) measures indoor air temperature and humidity inside the box

The instruments were located in the places shown in Figure 9 and Figure 10.

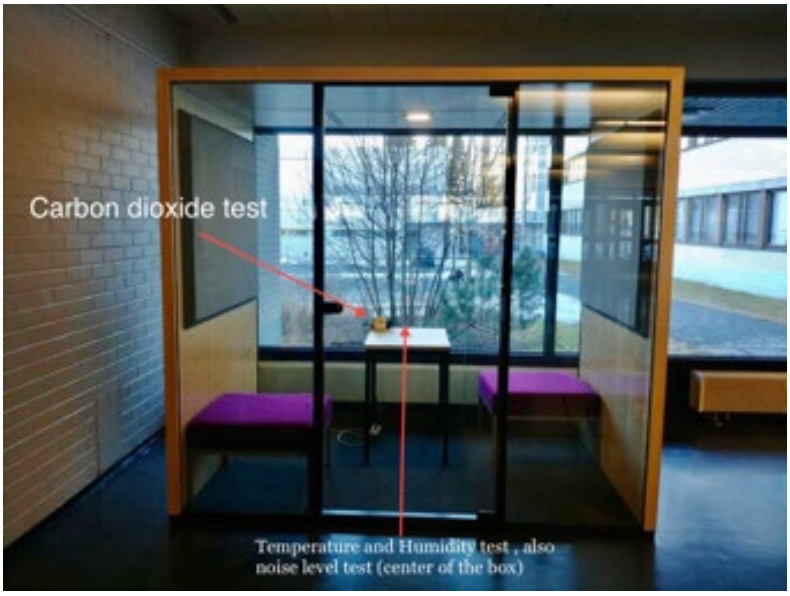

Figure 9 Carbon dioxide measuring instrument located on the table. Air temperature, humidity and noise meters were in the middle of the box.

Figure 10 Measure air flow from the fan's air outlet and noise level caused by changing fan settings

6.3 Experimental results

I divided the experiment into several parts (Table 2). First, I tested the indoor and outdoor temperatures, carbon dioxide content, and moisture corresponding to zero people, one person, and two people in the box at home study week (Figure 11,13,15). After these the plan was to test the same indicator data during school day (Figure 12,14,16) and compare the results.

The measurement procedure is shown in Table 2. The corresponding experimental data can be seen in Appendix 1-7

Table 2 measurement procedure (few: home study week, some/many: school day)

Date	Fan set	number of people in the box	test time with each fan set	number of the people in the hall
6.3.2020	1,2,3	0	20 min	Few
11.3.2020	1,2,3	0	20 min	Some
6.3.2020	1,2,3	1	20 min	Few
11.3.2020	1,2,3	1	20 min	Some
5.3.2020	1,2,3	2	20 min	Few
9.3.2020	1,2,3	2	20 min	Many

7 RESULTS AND DISCUSSIONS

7.1 Results of case a and b

Comparing the two sets of data (Fig 11 and Fig 12), when there is no one in the box, the fluctuation of carbon dioxide concentration is not large. The temperature inside and outside is also very stable, and the humidity inside the box is gradually decreasing. The results indicate that at this time, there is no significant difference between the inside and outside of the box, whether it is in home study week or school day. The number of people in the main entry hall does not effect on the experimental results.

Case a: empty box (home study week)

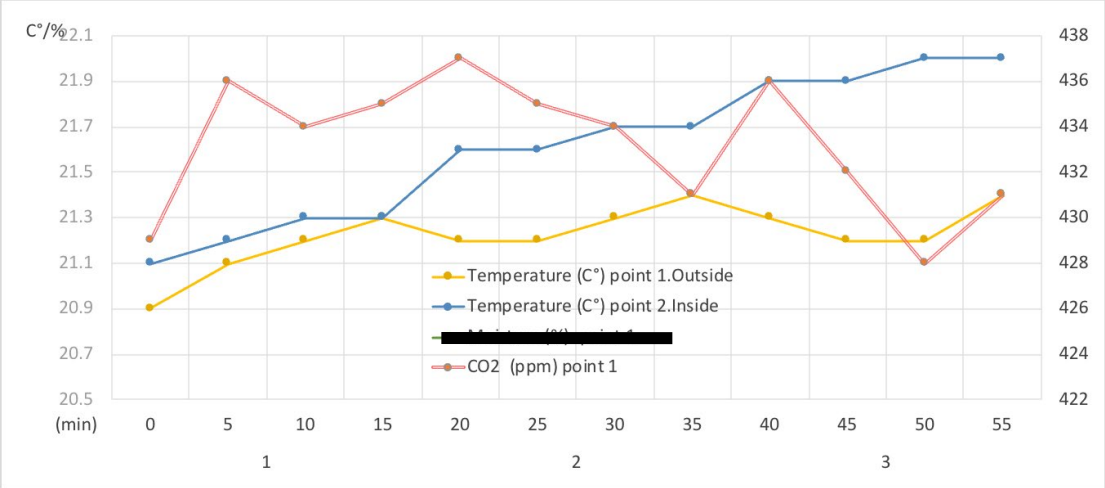

Figure 11 Two line graphs of results in case of empty box during home study week

Case b: empty box during school day

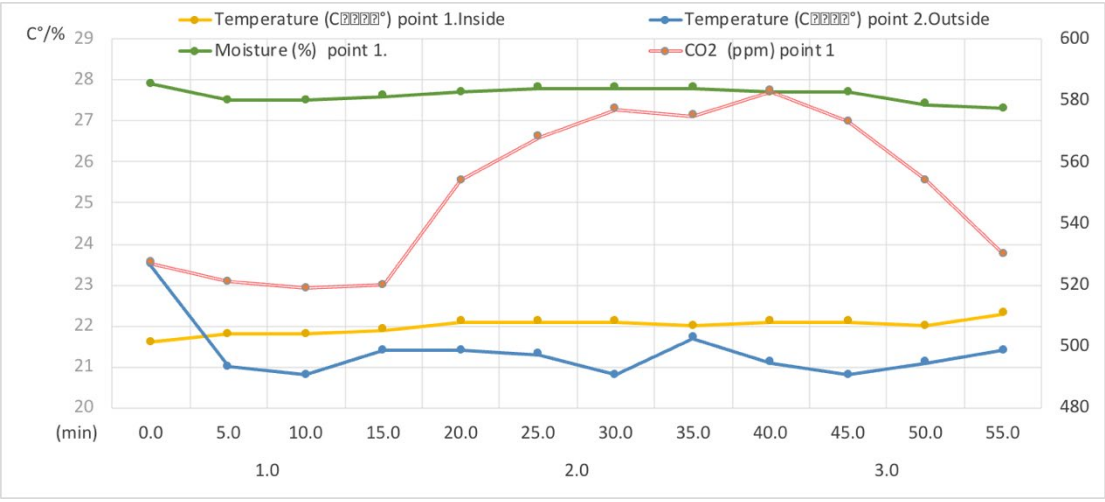

Figure 12 Line graph of results in case of empty box during school day

7.2 Results of case c and d

When a person continues to stay in the box for data testing, the experimental data between the two sets of results begins to differ significantly (Fig 13 and Fig 14).

First, during the home study week, there were very few people in the main entry hall, almost no one, and the outdoor temperature was very stable. The indoor temperature gradually increases, the humidity gradually decreases, and the carbon dioxide concentration has increased relative to the initial value. But when the fan settings 1, 2, 3 are changed, the amount of carbon dioxide increase becomes smaller, indicating that the change in fan settings can effectively accelerate the box air circulation inside.

During school day, the number of people in the main entry hall was so great that the carbon dioxide concentration before closing the door, that is, the initial carbon dioxide content was high, and gradually decreased after closing the door. It remains stable at a certain value. After the reduction, the humidity in the box is much higher than when there is no one, and the fluctuation is not large.

Case c: one people inside during home study week

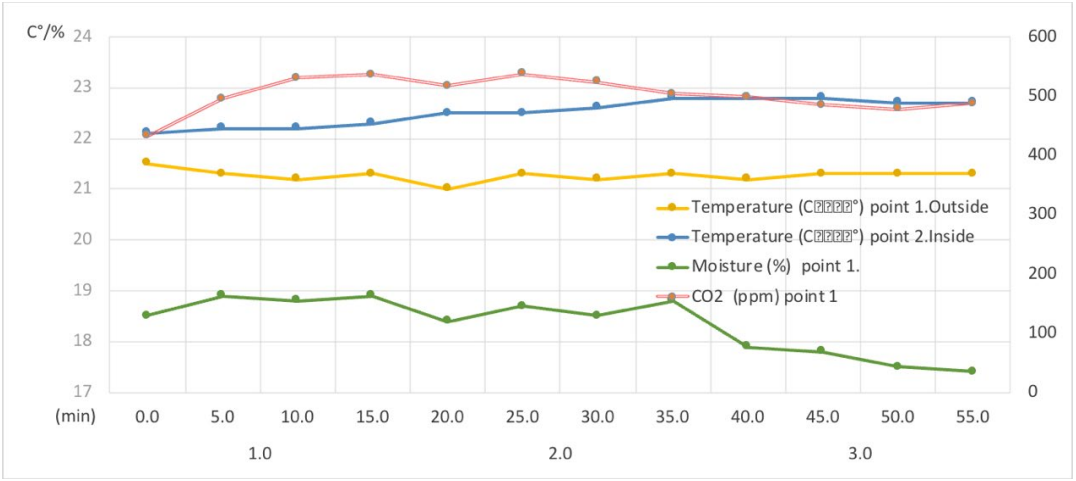

Figure 13 line graph of result in case of one people inside the box during home study week

Case d: one people inside during school day

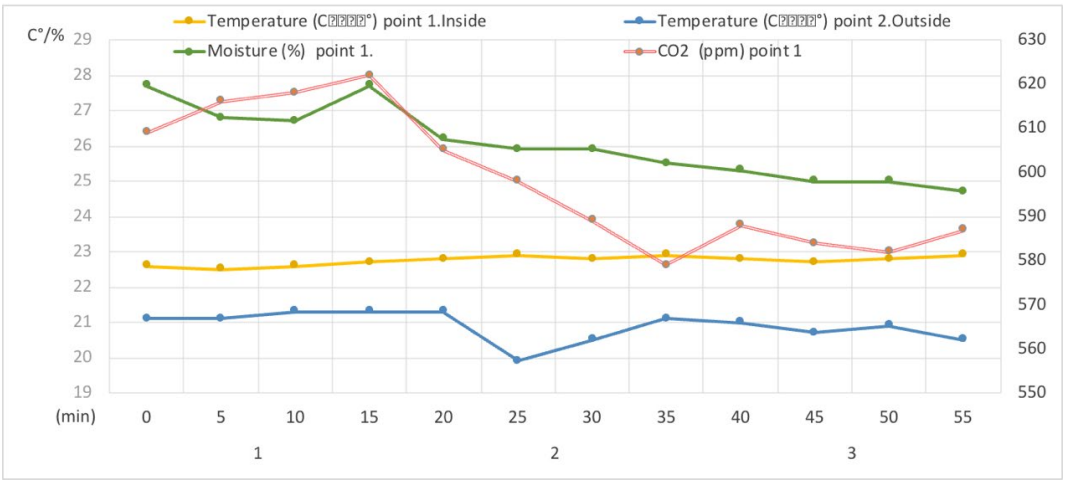

Figure 14 Line graph of results in case of one people inside the box during school day

7.3 Results of case e

When two people are in the box (Fig 15), I think this is the most typical situation. Open the box door every 20 minutes for ventilation. It can be clearly seen that when the fan is set to 1, the increase of carbon dioxide content is very large, and the indoor temperature, too. Relative humidity also increases. When the fan is set to 2, the carbon dioxide still increases, but it increases slowly compared to the setting 1, and at the setting 3 it increases even more slowly, indicating that the fan setting can change the air circulation inside the box, and the effect is obvious. This allows people to make appropriate adjustments in different situations to be more comfortable when inside the box.

Case e :two people inside during home study week

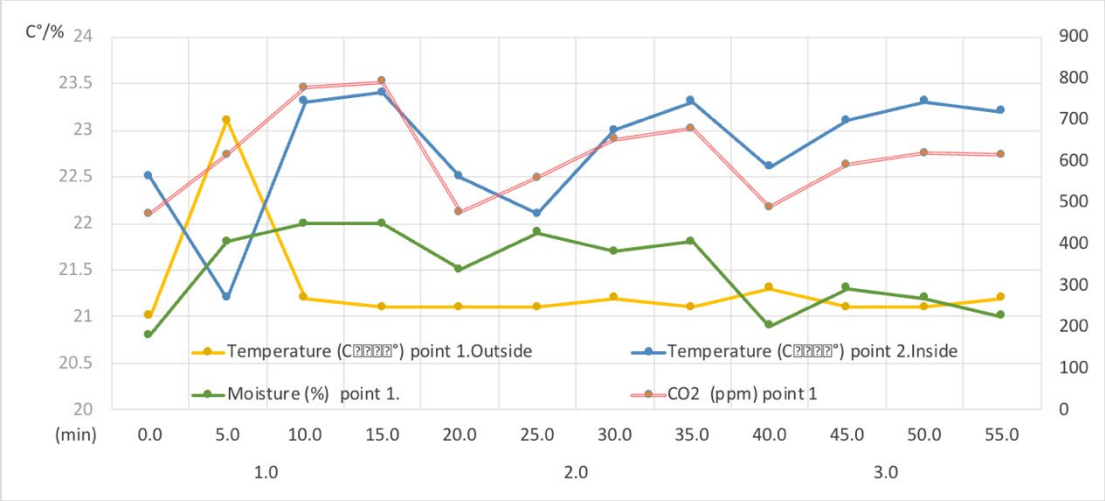

Figure 15 Line graph of results in case two people inside the box during home study week

7.4 Results of case f

On school day (Fig 16), you can more clearly see the changes in carbon dioxide concentration and the increase of carbon dioxide when the fan settings are changed, which is similar to the home study week. However, because the number of people in the main entry hall is large, the initial value of carbon dioxide will be higher, the outdoor temperature will decrease, and the indoor temperature increases but the fluctuation is small, and the humidity is decreasing.

Case f: two people inside during school day

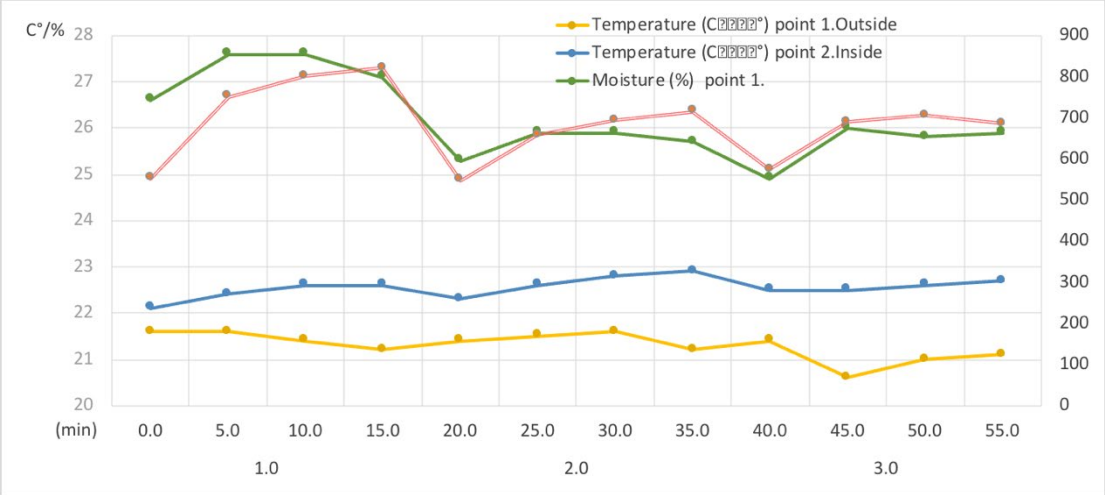

Figure 16 Line graph of results in case two people inside during school day

7.5 Results of case g

The average value of the fan's air flow rate during home study week or school day is almost the same. It can be clearly seen in the Figure 17 that when the fan is set to 1, the air flow rate is the smallest, and when set to 3, the air flow rate is the largest, of course, This is because different setting values have different air output, so you can also know the change in noise level.

Case g: air flow rate during home study week and school day

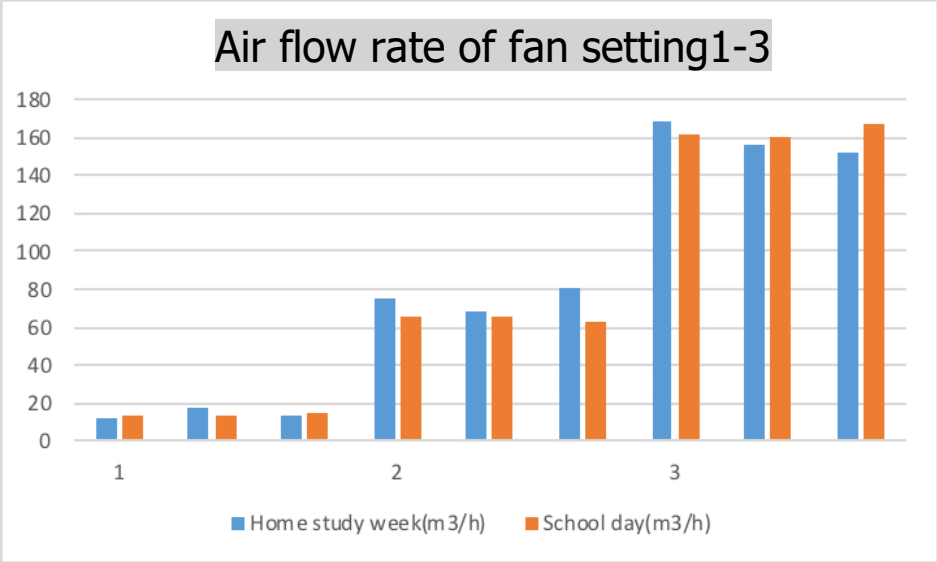

Figure 17 Air flow rate comparison histogram

8 CONCLUSIONS

8.1 CO_2 concentration

Carbon dioxide concentration is an important data for this experiment. The air quality inside the box can be seen intuitively for reference.

Experimental data shows that when no one is in the box, close the door or open the door, the carbon dioxide concentration is normal.

But when there are one or two people in the box, the carbon dioxide content starts to rise, especially when two people, the growth is very rapid. But this problem can be solved. The fan setting inside the box can effectively enhance the air circulation inside the box, by adjusting different settings, it corresponds to the required air quality.

So it is feasible to stay in the box for a long time.

8.2 Indoor air temperature and relative humidity RH

Throughout the experiment, the data shows that the difference between the indoor temperature value in the main entry hall and the initial value is not much, basically tends to be equal.

The indoor air temperature has signs of rising in every case. If someone is in the box, the rising trend is more obvious, but by adjusting the fan settings, you can control the temperature inside the box not to keep rising, which is great.

Regarding the indoor humidity, in any case, the indoor humidity is decreasing. The evaporation of water is a normal phenomenon, and when the inside of the box is closed, the air is exchanged with the outside through the adjustment of the fan, so the humidity will be reduced, But it is not obviously, it is within the normal range.

8.3 Air flow rate versus Air condition

In the experiment, I tested the air flow changes when the fans were set to 1, 2, and 3. Of course, setting 1 is the smallest, then setting 2, and the largest is setting 3.

The average value of fan setting 1 is 14m^3/h, the average value of 2 is 70m^3/h, and the average value of 3 is 160m^3/h.

The change in air volume can be clearly felt at the air outlet, and the different air flow also indicates the frequency of air circulation between the box and the outside world.

The larger the air flow value is, the slower the growth rate of carbon dioxide concentration is. Therefore, the fan settings can be adjusted according to the situation.

8.4 Conclusions

The purpose of the whole experiment is to test whether this kind of box is suitable for wide application in life. The experimental tests were carried out in box, which was set up in the main entrance hall of Opistotie campus, Savonia University of Applied Sciences.

The indicators of carbon dioxide concentration, indoor air temperature, humidity and air quality show that the box can be used as a good quiet private space for study, work or private phone. The fan setting inside the box is very effective to control the growth of carbon dioxide, avoiding the lack of oxygen and chest tightness caused by staying in the box for a long time.

For me personally, what needs to be improved is the air humidity inside the box. There will be thirst and dryness in the box for a long time, but it is within the acceptable range.

8.5 Destination of Finland or China

As we all know, Finland is a country with a large area and a small population. It is very rich in resources and is located in the north of the globe. Such a box is very suitable in Finland. Whether it is in an office building, school or even a shopping mall, it is a good choice. It is a very suitable box, but in China, which has a total population of 1.4 billion, and the crowd is very dense, especially in places such as school malls and ordinary office buildings. I think that putting this box in these places is not a feasible way. Because of the frequent use, it is easy to update the box. The boxes of this size cannot be placed in large quantities in these places in China, so this common situation is not applicable. However, there are some schools in China, where the number is small, and it is feasible. There are also some office buildings of foreign companies that also need such boxes. People need a quiet place to deal with more private issues. Therefore, compared with Finland, China is not widely applicable, but there are also places that are in great need.

9 PERSONAL SUGGESTIONS AND FEELINGS

Through personal experiments, for me personally, I think such a box is very practical, no matter where it is placed, it can give everyone a small private space. In all people's life and study, they would like to have a period of self-time, make a private phone call, take a short 10-minute break or have a private conversation with others, etc. This box is a very good choice.

I stayed in the box for a long time. Personally, I felt pretty good. If possible, I should add a curtain and a switch to control the brightness of the electric lamp. If it for rest, the brightness of the electric lamp can be reduced.

Also, there should be a reminder sign outside the door. If there are people inside the box, people outside will know that they are not allowed to open the door and walk in.

This box is suitable for many places, such as schools, office buildings, large shopping malls, large coffee shops and so on. Students and staff who work for the day should be in great need of such boxes for short breaks and study work.

10 PEOPLE'S OPINION

According to my survey, I found that many people like this kind of box very much. There are two interviews blow.

A 19 years old university student said: The box was good for university student, I wander that if we have such a box in our school library, I can study in there and without any noise. Chinese libraries are very crowded because the large students, so when I studied in library every time, it is always noisy. I really want to have a box like this.

A teacher about 30 years old said: Such a box is suitable for being placed in a teacher's office building, preferably with curtains, so that the teacher can communicate privately with students or handle personal affairs by phone. Not only protect the privacy of students but also protect the privacy of teachers. If the school has such a box, I think anyone will like it.

REFERENCES

Indoor air quality in Chinese household, Hou Li'an,2019 [Accessed on April 2020]

Report of Chinese environmental protection and ecological construction, Available from: http://world.people.com.cn/n1/2019/0724/c190970-31254058.html [Accessed April 2020]

Ucmbai,2020, Available from: http://www.ucmbar.com/ [Accessed May 2020]

Mervi Ahola, Jorma Sateri, Laura Sariola, Revised Finnish classification of indoor climate, 2018 [Accessed June 2020]

APPENDIX DATA SHEETS (ONLY FOR THE CUSTOMER)