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DETERMINATION OF INDOOR AIR QUALITY OF DIFFERENT LOCATIONS

Serden BASAK[1], Kazım Onur DEMIRARSLAN[2], Elif ISIK[3]

[1]Artvin Coruh University, Faculty of Health Sciences, Occupational Health and Safety Department, TR-08000, Artvin-Turkey

[2]Artvin Coruh University, Faculty of Engineering, Environmental Engineering Department, TR-08000, Artvin-Turkey

[3]Artvin Coruh University, Faculty of Health Sciences, Nursing Department, TR-08000 Artvin-Turkey

ABSTRACT

Generally, the peoples are spending 90% of their time, in closed environments; 70% business and 20% homes. The main factors, which makes peoples sick are, isolated buildings where there is no internal air circulation for energy saving, the use of unhealthy building materials and poor ventilation systems. Sick Building Syndrome (SBS)presents it self with symptoms of discomfort, such as headache, cough, hoarseness, dizziness, mental fatigue, nausea, some all ergicreactions, mouth and eye dryness, odorandtasteper version, chest tightness, watery eyes, it chingandredness. Various studies have been demonstrated, for comfort and productivity; clean air inhalation, 40 to 60% relative humidity and around 20 °C temperature are needed. 20% performance loss in humans have been observed when the temperature reaches 26 °C. Indoor air quality is a combination of different parameters such as; temperature, humidity, oxygen, carbon dioxide and has a direct impact on the social life of human. When there quests to the health are provider in the United States are analyzed, the indoor air quality and SBS related diseases are located in rank 4. With in creasing urbanization in recent years it must be taken various precautions, in over dependent the possible adversely effects on people' slives. Efficient and proper indoor ventilation, heat and moisture balance have great importance. In addition, maintenance of the ventilation system must be done periodically and accurate. The purpose of this research is to determine the quality of indoor air belonging to the spaces in which different occupational groups work. In this scope, a bank in Artvin Province, a Family Health Center and the Student Office of Health Sciences Faculty were elected. The amount of CO2 was measured during the hours of indoor air quality in three different locations. The result is compared with there late standard and various solution proposals are presented to the related places at the end of the work

Keywords: Indoor air quality, Employee, Health, CO2, SBS

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Introduction

One of the essential requirements of humanity is to maintain their life in a healthy and comfortable environment. This requirement is presented by structures with closed indoor spaces. However, nowadays, human beings who spend most of their lives indoors cannot fulfil the desired conditions indoors in terms of health and comfort because their direct connection with the natural external environment is cut and they are directly exposed to pollutants indoors [1].

Air is one of the most important life substances, even the most important one. All living creatures that consume oxygen to maintain their lives give off CO_2 to the environment. While an adult person needs two litres of water a day, he/she needs 20.000 litres of air on average [2]. The most important parameter recommended to check the indoor air quality is CO_2. Under normal conditions, 0.03% by volume of the atmosphere is CO_2. CO_2 in the outdoor air varies between 330 and 500 ppm according to environmental characteristics [3]. Nowadays, the carbon dioxide content in the atmosphere is around 380-390 ppm, and unfortunately, it increases by about 2 ppm every year [4].

The indoor air quality is related to the indoor air cleanliness and has a complex structure. It is difficult to draw or define precise limits for the indoor air quality because of different expectations of people of the air they are in and their different perceptions. Therefore, the term "acceptable indoor air quality" has emerged. In the ASHRAE 62–1989, 2001, and 2004 Standard, the acceptable indoor air quality is defined as "the air, in which known pollutants are not present at the level of harmful concentrations determined by the competent authorities, and 80% or more of the people breathing that air do not feel any dissatisfaction with the quality of the air" [3].

Pollutants that disrupt the indoor air quality originate from the indoor and outdoor environment. People are at the forefront of indoor pollution sources. Besides, carpets, furniture, cleaning materials, cigarette smoke, stove smoke, and tools and devices used for various purposes in the indoor environment are other indoor pollutants. Furthermore, construction materials can also be important indoor pollutants and affect the indoor air quality. Outdoor pollutants can be dust, pollens, and car exhausts in the atmosphere and industrial pollutants. Pollutants present in the outdoor air adversely affect the indoor air quality, either by the outdoor air ventilated indoors or by the outdoor air leaking indoors [1].

People spend a considerable part of their time in buildings and indoor spaces. However, it cannot be said that the indoor air quality is generally high in buildings. The sufficient indoor air quality can be defined as the ventilation of the sufficient amount of sufficiently clean air indoors. One of the important aspects here is that the need for ventilation can be calculated more precisely, such as the heating and cooling needs of the building. In this context, there is a need to

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define the indoor air quality in order to improve the health, comfort, and working performance [4]. Depending on all these definitions, the occurrence of diseases in buildings can be gathered into two main groups:

a) Building Related Illnesses (BRIs) are factors related to the internal environment of the building. However, these are not the factors to be solved by ventilation, and they can be solved by eliminating the source [5].

b) Sick Building Syndrome (SBS) differs from building-related illnesses because the discomfort it causes is not easily noticeable and cannot be easily eliminated. The discomfort may pass when the building is abandoned. It is not possible to diagnose this discomfort [5].

The “Sick Building Syndrome”, which has recently entered the medical literature and can be encountered anywhere from business centres to hospitals, has threatened hundreds of thousands of people who spend 90% of their total time indoors, 70% at work and 20% athome. However, the reason for not paying enough attention to this problem is that the effects of air pollution in indoor environments usually emerge in the long term and do not threaten life directly or immediately [6].

According to the World Health Organization, the Sick Building Syndrome is defined as “the presence of at least one general, one mucosal, and one skin symptom every week in the last three months in a person” [7]. General symptoms are poor vision, shortness of breath, feeling of tightness in the chest, fever, drowsiness, fatigue, etc.; mucosal symptoms are burning-irritation, watering, redness in eyes, dry throat, dry cough, etc.; skin symptoms are dry skin, rash, and pruritus. SBS symptoms may depend on individual characteristics, as well as on outdoor causes or stress-related conditions [8].

In terms of the indoor air quality, ventilation according to the amount of CO_2 in the environment is best suited. Since the amount of oxygen consumed by humans will be too small for an environment with low density, it is not the main determinant for the fresh air need. CO_2 is considered to represent approximately all other pollutants and ventilation is performed according to the amount of CO_2 [9,10].

Although there is not a definite value for the limit CO_2 amount, the most accepted limit value for the amount of CO_2 is 1000 ppm. Therefore, 1000 ppm CO_2 concentration is considered as a basis for the indoor air quality. If the amount of CO_2 is lower than this level, the indoor air is of the acceptable indoor air quality. The amount of 1000 ppm CO_2 is also known as the Pettenkofer number [10,11].

The aim of this study is to determine the indoor air quality of places where people of different occupational groups work.

2. Material and Methods

The study was conducted between June and July 2017 by selecting three different places. One of the busiest banks in the city was selected as the first place. The bank consists of two floors with an area of approximately 100 square meters that are actively used. There is no central ventilation system, but ventilation and cooling are provided with different types of air conditioners located in various places on the floors. Project-out windows are available only in the director's room, and there are no project-out windows that can help to get fresh air from outside, apart from that room. It was informed that the maintenance of the air conditioners was performed annually by the maintenance team from the Head Office. Due to the increased internet banking, while the number of people who make transactions in the bank generally decreases, on the 15th-30th of every month, especially on the 15th-16th, there is density in banks. It has been reported that the number of people is below 50 on some days and over 500 on other days.

The second place where the measurement was performed is one of the busiest Family Health Centers (FHC). As a result of the information obtained in the selected FHC, the busiest day was determined to be Monday. The place has a wide corridor and two different types of rooms. The first type of rooms is those with street-front windows and a separate air conditioner. The second type of rooms is those with no window and air conditioner, with doors opening into the corridor. Rooms of the second type are connected to the central ventilation and ventilation has only the blowing function.

The Student Affairs Office of the Faculty of Health Sciences was selected as the third and final measurement site. There are 3 officers in the office. The room has two opening windows connected to the glass facade and a thermostat control unit that can perform heating/cooling functions depending on the central system. The density of the office varies by the time.

Data Collection: In the collection of the research data, three different devices were used for the measurements. The first one of these is the CO_2 measuring device (PCE-AC 3000) with the recording feature, the second one is the probe anemometer (PCE-423) for measuring the air flow rate, and the third one is the temperature and humidity measuring device (PCE-HT110) with the recording feature. By this means, measurements could be made with the devices placed in the environment during the working hours without getting involved in the environment and disturbing the employees. Furthermore, precise measurements were performed by the laser meter, and volume calculations were made in other places, except for the bank. The calibrations of the devices are new, and they were opened approximately 30 minutes before the start of the measurements at the measurement sites, and it was ensured that they met the ambient conditions. Necessary approvals were received from all the institutions before the start of the study.

3. Results

Measurements were performed on different days in three different places for the indoor air quality. Based on the preliminary negotiations, measurements were performed for two consecutive months at different times on the 15th day of the month, which is the busiest day of the bank. The bank has 18 employees. With the approval received, measuring devices were placed right behind the employees on the counter so that they were close to the employees and not influenced by incoming customers. The results of the measurements in the bank are presented in Tables 1 and 2. The air conditioner was not run all day on the day the first results were received. According to the results from the numerator, approximately 300 customers came to the bank on the same day.

Table 1: Bank, first measurement day(without air condition)

Measurement No.	*Time*	*CO_2 (ppm)*	*Temperature (^oC)*
1	09:30 (am)	1070	25.1
2	10:00	1000	25.3
3	10:30	951	25.2
4	11:00	1040	25.5
5	11:30	1095	25.6
6	12:00 (pm)	1285	25.6
7	12:30	1185	25.4
8	13:00	1105	25.4
9	13:30	1075	25.4
10	14:00	1365	25.5
11	14:30	1315	25.3

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12	15:00	1295	25.1
13	15:30	1185	25
14	16:00	1070	24.9
15	16:30	1135	25

According to the results of the measurements made in the bank, on the first measurement day when the air conditioner was off, the CO_2 concentration was found to be above the limit value of 1000 ppm, except for 10:30 am. During lunch break hours, a decrease was observed in the CO_2 rate with a decrease in the density of people, but it was found out that the concentration rose again when the bank started working again in the afternoon. The highest value was determined to be 1365 ppm at 14:00. According to the measurement performed one month later, it was recorded that the amount of CO_2 in the environment, which was quite low in the morning hours, increased during the day. However, the highest value was found to be 1355 ppm at 10:00 am.

On the day of the measurement performed for Table 2, air conditioners were mostly used actively. The officers in the bank counted customers and people who came with them and reported approximately 800 people.

Table 2: Bank, second measurement day (with air condition)

Measurement No.	*Time*	*CO_2 (ppm)*	*Temperature (^oC)*	*Moisture(%)*
1	09:00 (am)	684	25.9	41
2	09:30	839	26.3	40.1
3	10:00	1355	268	39.5
4	10:30	1280	26.3	39.7
5	11:00	1175	26.1	38.5
6	11:30	943	25.9	36.7
7	12:00 (pm)	896	25.8	36

8	12:30	820	25.8	33.7
9	13:00	858	25.9	36.3
10	13:30	1025	25.9	41.1
11	14:00	1045	25.8	43.6
12	14:30	1070	25.8	46.5
13	15:00	1065	25.8	48.8
14	15:30	1185	25.8	48.8
15	16:00	1050	25,6	48.8
16	16:30	831	24.8	48.6

On the 2nd day of the measurement, it was reported that the number of customers was higher. This shows that ventilation with air conditioners has a positive effect on the CO_2 concentration. The average of the 2nd measurement day was 1009 ppm.

The dimensions of the FHC room with no windows are as follows: L:4.11m; W:3.82m; H:2.48m, A:15.68m^2,and V:38.84m^3. Table 3 shows the indoor air measurement results in this room.

Table 3:Measurement at FHC (roomwithoutwindows)

Measurement No.	*Time*	*CO_2 (ppm)*	*Temperature (°C)*	*Moisture (%)*
1	09:00 (am)	607	22.8	56.7
2	09:30	660	22.9	57.1
3	10:00	618	22.8	54.3
4	10:30	688	22.8	54.1
5	11:00	600	22.8	54
6	11:30	620	22.8	54.2
7	12:00 (pm)	600	22.8	54.1
8	12:30	681	22.8	54.7

9	13:00	743	22.8	55.3
10	13:30	699	22.6	55.1
11	14:00	556	22.5	54.9
12	14:30	546	22.6	54
13	15:00	525	22.6	53.5
14	15:30	604	22.9	54
15	16:00	629	22.6	53.6
16	16:30	521	23	52.3

According to the measurements performed in the FHC room without windows and on a less busy day, the highest concentration was found be 743 ppm at 13:00.

Table 4 shows the measurements of the room with windows in the FHC. During the measurements, the physician working in the room stated that he/she opened the window when the CO_2 rate on the device approached 1000 ppm.

Table 4.Measurement at FHC (roomwithwindows)

Measurement No.	*Time*	*CO_2 (ppm)*	*Temperature (^oC)*	*Moisture (%)*
1	09:00 (am)	681	24.1	53.5
2	09:30	659	24.1	49.1
3	10:00	748	24.1	49.5
4	10:30	920	24.1	48.5
5	11:00	835	24	48.5
6	11:30	736	24	49
7	12:00 (pm)	941	24	49
8	12:30	566	23.8	48.2
9	13:00	594	23.9	48.1
10	13:30	760	23.9	52.5

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11	14:00	759	23.9	53.4
12	14:30	701	23.8	54.5
13	15:00	742	23.9	54.5
14	15:30	711	23.9	56.2
15	16:00	690	23.9	55.5
16	16:30	669	24.3	55

Although the physician checked the measuring device and opened the window when the CO_2 rate approached 1000 ppm, the general average of the room with windows was found to be 732 ppm, which was 113 ppm higher than the other room, due to the lack of regular ventilation and the high number of patients on the busy working day.The dimensions of the Student Affairs Office are as follows: L:8.01m; W:5.69m; H:3.57m, A:45.62m^2, and V:162.77m^3. Table 5 and Table 6 show the indoor air measurement results performed in this room on different days and conditions.

Table 5:First measurement at Student Affairs Office(Windows closed, doorsometimesopen)

Measurement No.	*Time*	*CO_2 (ppm)*	*Temperature (°C)*	*Moisture (%)*
1	09:00 (am)	479	22.5	47
2	09:15	523	23.4	47
3	09:30	534	22.9	47.9
4	10:00	678	22.8	47.6
5	10:30	695	22.7	48.8
6	11:30	743	22.7	49

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7	13:30 (pm)	751	22.7	48.8
8	14:30	734	22.6	48.8
9	15:30	675	22.6	48.9
10	16:00	730	22.8	48.8

Table 6:First measurement at Student Affairs Office (Windows anddoorsometimesopen, busyday)

Measurement No.	*Time*	*CO_2 (ppm)*	*Temperature (°C)*	*Moisture (%)*
1	09:00 (am)	483	21	52.1
2	09:15	573	21.1	52.1
3	09:30	562	21.1	52.6
4	10:00	687	21.3	53.1
5	10:30	718	21.4	52.8
6	11:30	668	21.3	53.3
7	12:15 (pm)	907	22.2	52.6
8	13:30	790	21.9	52.7
9	14:30	916	21.8	54.3
10	15:30	889	21.9	54.1

In the measurements performed in the Student Affairs Office, the average on the busy day when windows were opened at intervals was found to be 719 ppm, and it was found to be 654 ppm on the not busy day when windows were closed.

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The distribution of the results of the CO_2 measurement in the bank by time is comparatively presented in Figure 1.

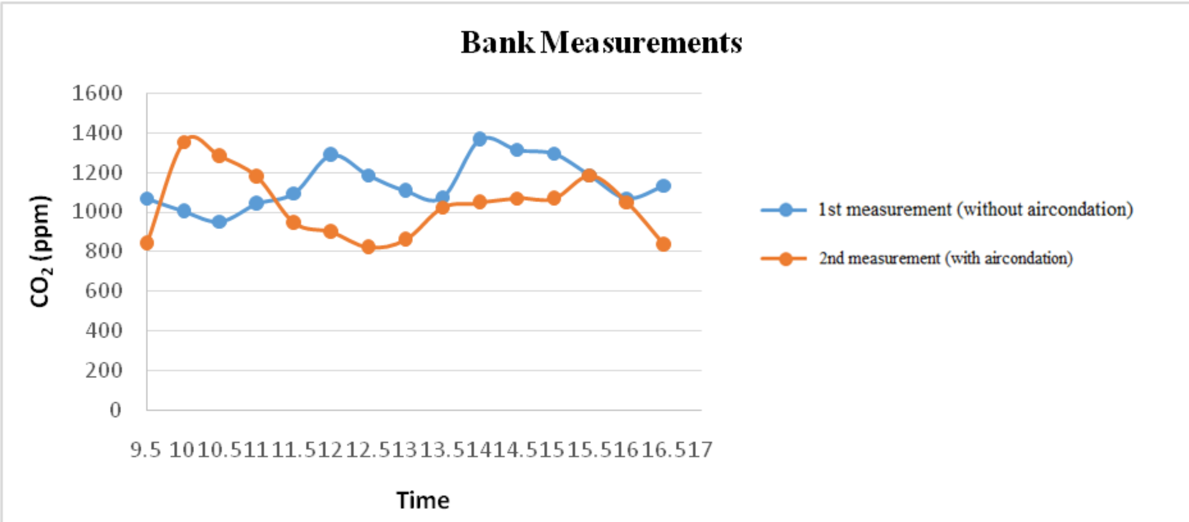

Figure1:. Results of the CO_2 measurement in the bank by time

The distribution of the results of the CO_2 measurement in the FHC by time is comparatively presented in Figure 2.

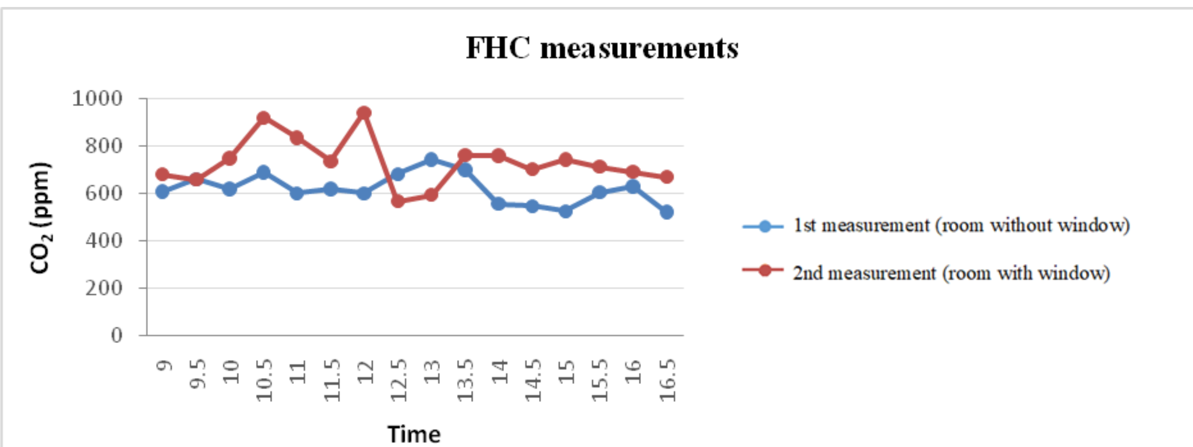

Figure 2: Results of the CO_2 measurement in the FHC by time

The distribution of the results of the CO_2 measurement in the student affairs officeby time is comparatively presented in Figure 3.

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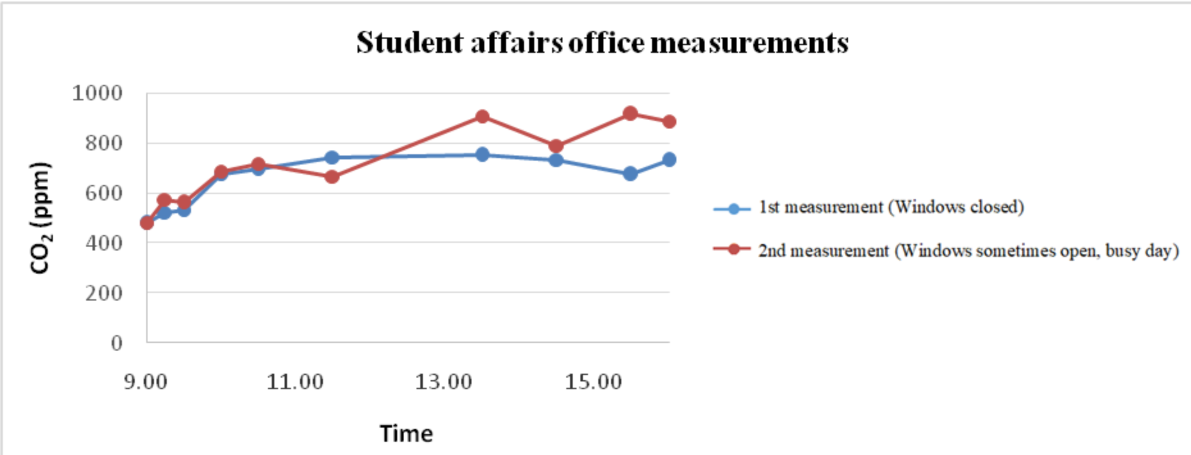

Figure 3: Results of the CO_2 measurement in the student affairs office by time

4. Discussion

Many studies have been conducted especially in various countries on the indoor air quality and its effect on the social life, and standards in relation to the subject have been developed. According to a study conducted in the USA, the work performances of 20% of employees working in skyscrapers are affected, 7-10% have serious problems such as fatigue, nasal obstruction, headache, respiratory distress, and eye irritation, those who work in offices that are ventilated with 12 liters/second of outdoor air use 35% more sick leave than those who work in offices that are ventilated with 24 liters/second of air. It is estimated that 20-30% of buildings in the USA have properties that will cause SBS. According to the American Environmental Protection Agency (EPA) data, SBS is in the 4th rank among the top 10 health problems to be dealt with. As another example, in a study conducted on 3507 people in Denmark, SBS-related general symptoms such as eye, nose, or throat irritation were detected in 27% of the subjects, and headache, fatigue, and weakness were detected in 36% of the subjects [6].

In the report published by the European Commission in 1989, the presence of at least 5 characteristic symptoms of the sick building syndrome was indicated in 20% of 600 office workers in a study conducted in the United States of America and in 29% of 4373 employees working in 46 buildings in a study conducted in the UK [8]. In a study conducted in workplaces in Singapore in 1998, it was shown that the typical symptoms of the Sick Building Syndrome were found in approximately 19.6% of 2856 people [12]. From the group of chemical pollutants that cause indoor air pollution, construction materials are one of the most important factors of SBS. It is very important for the health to know the health effects of buildings where the largest part of the day is spent and to take precautions accordingly and to raise awareness. Therefore, it was aimed in this cross-sectional study to determine the incidence of the "Sick Building Syndrome" in employees working in a public building and some factors affecting it [8]. In this study, it was also found out that when the human density increases even in different places when windows are not opened and air conditioners do not work, the amount of CO_2 increases and people have to work all day in this environment.

There are also studies in the literature indicating that it will be very useful to create a personalized environment (a zone or area in which people are found) considering a number of criteria such as the thermal comfort, air quality, lighting, noise, and energy efficiency. In this context, it is necessary to perform temperature control and indoor air quality control in neighbourhoods. The increased efficiency of air cleaning systems in ventilation will help reduce the external air flows [3]. In the second measurement performed in the bank within the scope of the study, the effect of the working air conditioners was clearly observed at the most in noon hours. When the averages of the values obtained throughout the day were examined, the average of the 1st measurement day was 1145 ppm and the average of the 2nd measurement day was 1009 ppm. The use of effective ventilation systems significantly reduces the CO_2 concentration. However, it is important that the maintenance of air conditioners, which are the main source of Legionnaires' disease, is performed regularly, the ambient temperature and humidity balances are considered, and that air conditioners are placed in a way not to disturb employees. Direct ventilation from the outside is not possible in the bank since the windows are not opened. When the initial CO_2 rates on both days are examined, the shift is started with a high CO_2 concentration because sufficient ventilation from the previous day cannot be ensured. With the increased human density and insufficient ventilation during the day, CO_2 can exceed the limit value.

In general, in the measurements performed in the FHC during the study, the limit value of 1000 ppm was not exceeded in two different types of rooms. However, if there is no CO_2 measuring device and windows are not opened by checking this device, it is very likely that it will exceed 1000 ppm on busy days or in winter months (Table 4). The oscillations in the measurements of the less busy day are less than those of the busier day. The effect of opening the windows on the sudden decrease in the CO_2 concentration on a busy day is great (Figure 2). Moreover, due to a misaligned ventilation grill, the desired effect cannot be achieved in the rooms without windows, in which providing fresh air is tried to be achieved through the central ventilation system.

When the CO_2 concentration reached 800 ppm in different studies, it was emphasized that the complaints of the sick building syndrome emerged and the highest level that could affect the health was 5000 ppm; the heart rate increased and respiratory distress was observed at 15000 ppm; muscle pain, convulsions, poor concentration and risk of death occurred at 30000 ppm [17-20]. In this study, it was determined that the CO_2 concentration in the three places where measurements were performed exceeded 800 ppm, and it exceeded 1000 ppm especially in the bank.

5. Conclusion and Recommendations

According to the results of the study, it was concluded that the CO_2 concentration increased and was over 1000 ppm during the day in the working areas where the air conditioner was off and windows were closed and the density of work increased the human density, which resulted in the increased CO_2 concentration, opening the ventilation systems such as air conditioner or opening the windows, i.e. the human intervention in the environment, had a positive effect on reducing the CO_2 concentration, the indoor air quality was important for the employee health, and that employees working in the places where the study was conducted faced the Sick Building Syndrome. Furthermore, certain recommendations have been made to the responsible people and employees of the places where measurements were made. The primary ones of these are as follows: it is necessary to carry out more detailed studies in places, especially in the winter months; cleaning and maintenance of the mechanical ventilation systems such as air conditioning and central ventilation should be performed periodically; the working environment should be ventilated during the lunch break or at not busy times; managers and employees should be trained on subjects such as the importance of indoor air quality, the Sick Building Syndrome, etc.

Despite the natural ventilation in some places, sufficient ventilation may not be achieved. Furthermore, the ventilation systems or noises coming from the outside can disturb employees. It would be appropriate to design the ventilation systems according to the place to prevent such inconveniences.

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