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A Change in the Amount of CO_2 at the Center of the Examination Halls: Case Study of Turkey

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ABSTRACT The performances of candidates during the exam period depend on several factors, such as the temperature in exam halls. The indoor amount of CO_2 is over 1000 ppm, which in turn, could directly affect the performances of the candidates directly via headache, dizziness, fatigue, and a loss of concentration. In this study, changes in the indoor amount of CO_2 in some central exam were examined, and certain evaluations were made. The findings of the present study indicate that the threshold value is usually exceeded within 10 minutes, following the start of exams, and when indoor CO_2 amounts are higher than 1500 ppm, which is considered in most exams as the limit of harm to health, and circulating air in the hallways and keeping the doors of exam halls open throughout the exam period are not adequate for keeping the indoor CO_2 amounts below 1000 ppm. Air circulation is a must in exam halls to ensure healthy exam environments.

INTRODUCTION

Many central exams, which affect the lives of thousands of people, are held in certain fields and periods in Turkey. An example is that of 1,987,488 candidates who applied for the transition into Higher Education Examination [HEE in Turkish language is *YGS*] in the year 2015 (MSPC 2015a). At the end of the Undergraduate Placement Examination [UPE is *LYS* in Turkish language], 1,368,941 candidates were placed in higher education institutions (MSPC 2015b). 99,164 candidates took the Interuniversity Council Foreign Language Exam [ICFLE in Turkish is *UDS*] held in spring of the year 2012 (MSPC 2012a). A total number of 987,167 undergraduate level candidates applied for the Public Personnel Selection Examination [PPSE in Turkish is *KPSS*], which is one of the most important examinations for shaping the lives of people in Turkey, and 931,307 candidates (MSPC 2012b) were admitted. The candidates that sat for the Foreign Language Proficiency Examination [FLPE in Turkish is *YDS*] during Spring Term in the year 2015 equal 235,784, and in Fall Term in the year 2015 is 122,561 (MSPC 2015c; MSPC 2015d). The number of students attending the Open Education Programs of Anadolu University [AUOEE in Turkish is AUAOF] in 2015 was 1,470,901. These students also take central exams (AU 2015).

These exams, whose results are likely to affect the lives of thousands of candidates, are conducted within a couple of hours. The performances of the candidates within such short periods determine their positions among thousands of competitors and yield results that have direct impacts on their lives. The performances of people in such processes are influenced by many factors. The most important factor may be the indoor comfort conditions of the halls where exams are carried out. Though attempts have been made to control several factors, such as odor, noise, and temperature in exam halls, the amount of carbon dioxide present is ignored.

Environmental pollution in the city due to population growth, urbanization and industrialization becomes more severe and widespread (Ozdemir et al. 2014). Thus, the indoor air quality of CO_2 is very crucial. The composition of twenty-one percent O_2 and 0.033 percent CO_2 content in the air that is inhaled by people during respiration changes to sixteen percent to seventeen percent O_2 and four percent CO_2 content during discharge from the lungs. This change is visible in environments like schools, shopping malls, and hospitals where many people are present together. As a result, CO_2 level continuously rises in such crowded environments, and as the CO_2 level increases in an environment, fatigue, absence of perception, and sleepiness occur (Sevik and Cetin 2015). CO_2 levels also affected the bioclimatic comfort (Cetin 2015). The measurement of CO_2 concentration can be used to assess indoor air quality and ventilation (Marchetti et al. 2015).

A rise in CO_2 level leads to various complaints that result in loss of performance, though the reasons behind this are not easily identified. When the CO_2 amount in an environment is over 1000 ppm, headache, dizziness, fatigue, loss of concentration, and annoyance due to odor, sets in and when it is over 1500 ppm, throat irritation, nose irritation, nasal discharge, cough, and eye discharge take place (Ercan 2012), which manifests itself especially in the indoor spaces where the most part of daily life is spent, and decrease in indoor air quality affects people's performance and health (Sevik and Cetin 2015). According to the U.S. Environmental Protection Agency (EPA), the maximum amount of CO_2 allowed indoor is 800 ppm. It has been stated that the amount of CO_2 is maximum 1000 ppm in spaces like schools and conference halls, where there are many individuals at the same time (Sevik et al. 2015). The weak internal ventilation, indoor pollutants that may affect the health of students and teachers, can lead to a high level of CO_2 (Muscatiello et al. 2015).

Objectives

In the present study, changes in the indoor amount of CO_2 in some central exams are examined. The study attempts to determine CO_2 amounts, which influence the performances of candidates, but are ignored in practice, in the halls where exams, which students take after a long period of preparation process and that bring about change in the lives of thousands of candidates are held, to give evaluations of the factors influencing the amount of CO_2 in exam halls during exams, and to draw attention to this matter.

MATERIAL AND METHODS

The study, which was conducted in the Faculty of Forestry of Kastamonu University, is shown in Figure 1. The classroom sizes of the Faculty of Forestry, which are used in central

Fig. 1. The location of the Kastamonu University

exams, are 810 cm x 851 cm and have a ceiling height of 315 cm. The hallway on the floor where the present study was conducted has a width of 350 cm. There are four classes on both sides of the hallway (8 classes in total). While these classrooms contain an average of 50 undergraduate students in normal teaching time, in addition, 30 students take open education and public personnel selection examinations (*KPSS*), and 20 candidates take the transition to higher education examinations (*LYS*) and the undergraduate placement exams (*YGS*) there. Each exam hall has one hall head and one supervisor during exams.

In this study, examination was carried out in the exam room at a center. This hall is occupied by candidates for 30 minutes to the start of the examination before being taken to the exam room, and exam candidates who arrive after the first 15 minutes of commencement of the exam are taken into the examination hall. Therefore, there must be a certain number of candidates in the exam room for a certain period. In the study, measurements were taken at the commencement of the exam by a measuring device placed in the hall 30 minutes before the amount of CO_2 and the number of people as well as the living environment were noted at every 10-minute intervals. The same measurements were repeated several times after the data has been evaluated.

In the present study, CO_2 measurements were conducted at least five times in each one of the different classrooms at different times via the portative indoor air quality meter. During the exams, CO_2 amounts (in ppm) in the classrooms, as well as the numbers of students present were noted at every 10-minute interval. Measurements were also carried out in the hallway and at certain intervals.

The doors of examination halls are kept open throughout the central exams. Thus, the first measurements were taken when all windows of the classrooms as well as their windows and doors opening into the hallway were closed. Thereafter, measurements were carried out when the windows and the doors opening into the hallway were opened. After that, measurements were taken by making sure that two of the windows of the exam halls were half-open besides the windows and the doors opening into the hallway, which were open. The study was carried out during open education, transition to higher education (*LYS*), Academic Personnel and Postgraduate Education Entrance Exam [APPEE in Turkish is *ALES*], and public personnel selection and placement (*KPSYS*) examinations held in the year 2010, 2011, and 2012, respectively.

RESULTS

The results have emerged from the evaluation of several measurements. In this study, the possibility of erroneous results obtained from the data has not been taken into consideration, and thereby, suspected measurements were repeated. However, the work was done in the natural environment, the number of candidates in the hall, the starting amount of CO_2 in the hall, the candidates' hall downtimes and so on, has never been stable. Therefore, the standard deviation or standard error calculation facilities have not been coming up.

Based on some factors, such as the number of students in the classroom, exam time, freedom of leaving the exam hall prior to the end of the exam, outdoor air condition, and CO_2 concentration, the research results can be summarized as follows.

Candidates are mostly allowed to enter exam buildings half an hour before the start of the exam. Candidates go into their halls early and get prepared for their exams especially in very important ones, such as *LYS*, *YGS*, and *KPSS*, that causes a rise in indoor CO_2 amount in the exam building. The results of the measurement show that when the windows of the exam halls were closed, CO_2 amounts in the halls were over 1000 ppm, even at the beginning of the exams. Even values exceeding 1400 ppm were detected at the beginning of some exams.

The results of the measurements taken in the halls, where 30 candidates took the open education examination indicates that the amount of CO_2 was over 1000 ppm at the beginning of the examination, but rose to a minimum of 1400 ppm, 30 minutes after the start of the examination and to minimum 1800 ppm, 60 minutes after the start of the examination. Exam time is not the same in all open education examinations, and candidates are not allowed to leave the exam halls within 30 minutes after the start of an examination. In these examinations, there are usually candidates who leave exam halls at the end of this period (30 minutes following the start of the examination), and thus, the number of students in the relevant exam hall decreases.

In *KPSS*, *LYS*, and *ALES* exams, the candidates are not allowed to leave exam halls until at least half of the exam time passes. Hence, a large majority of candidates do not leave exam halls until the exam time elapses. The CO_2 amount is much more higher in exam halls in such cases. The measurements demonstrated that CO_2 amounts in the exam halls exceeded 2000 ppm, 60 minutes after the start of the exam, and exceeded 2400 ppm 90 minutes after the start of the exam as shown in Figure 2. The amount of CO_2 measurement consists of 50 people nominated in the exam room. The amount of CO_2 in the interior environment to be taken to the exam room even during the start of the examination and the placement of students in this hall was measured as 1271 ppm. After testing begins, a regulation of the amount of CO_2 has increased to 1744 ppm within 10 minutes. For examination of 20 minutes CO_2 is regulated to 2410 ppm, while for an exam of 30 minutes it is regulated to 3002 ppm. This rapid growth was measured while continuing an examination for 40 minutes, of which CO_2 increased to 3455 ppm. At the end of the exam, and 50 minutes to reach 3,742 ppm, both quantitative and qualitative data representations of the measurement are shown in Figure 2 and Table 1.

Table 1: The amount of CO_2 of KPSS exam

Time	*CO_2 (ppm)*	*Temperature (°C)*	*Humidity (%)*	*Number of people*
15:28	1236	22.3	64.6	50
15:30	1271	22.4	65	50
15:35	1606	23.1	66.9	50
15:40	1744	23.3	67.9	50
15:45	2163	23.6	69.7	50
15:50	2410	23.8	71.1	50
15:55	2753	24	72.4	50
16:00	3002	24.1	73.8	50
16:05	3228	24.1	74.7	50
16:10	3455	24.2	75.5	50
16:15	3620	24.2	76.4	50
16:20	3742	24.3	76.5	50

An attempt was made to determine the effect of ventilation of the hallway, which the doors of the exam halls opened into on CO_2 amounts in the exam halls. It was seen that CO_2 amount in the hallway affected CO_2 amounts in the exam halls, but such effect did not come as expected. It was discovered that even when the CO_2 amount in the hallway was 740 ppm, CO_2 amounts in the exam halls were not lower than 1500 ppm. Some measurements were carried out in windy weather. The measurements under such windy conditions showed that while the CO_2

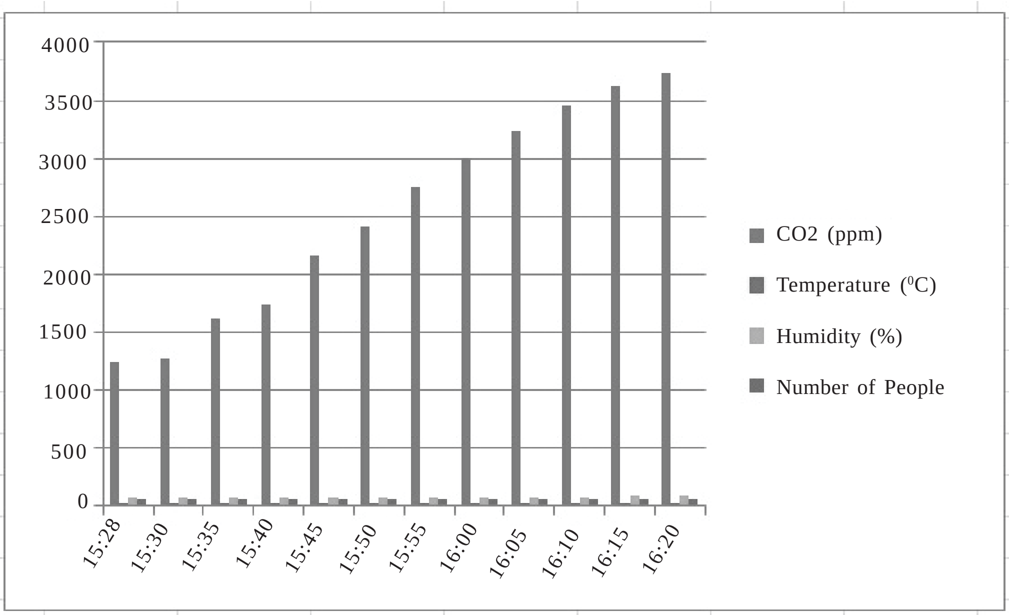

Fig. 2. The amount of CO_2 of KPSS exam

Table 2: The amount of CO_2 of LYS exam

Time	*CO_2 (ppm)*	*Temperature (ºC)*	*Humidity (%)*	*Number of people*
109:00	490	24.2	61.4	10
09:30	1181	24.4	63.4	32
09:40	1341	24.5	63.4	32
09:50	1378	24.9	63.8	32
10:00	1399	24.7	63.8	32
10:10	1670	24.8	65.3	32
10:20	1870	24.9	66.4	32
10:30	2023	25	67	32
10:40	2262	25	67.5	32
10:50	2379	25.1	67.5	32
11:00	2480	25.6	68	32
11:10	2536	25.6	68	32
11:20	1986	25.4	65.9	32
11:30	1819	25.4	66.3	32

amount in the hallway was 480 ppm (annoying airflow occurred in the hallway), the CO_2 amounts in the exam halls were found to be over 1200 ppm throughout the exams.

Different results were obtained when the windows of the exam halls were kept open. Quite a limited fall occurred in the CO_2 amounts in the halls when the windows were open, but there was no airflow recorded. However, even a light airflow in the halls in windy weather led to a sudden and high fall in the CO_2 amounts in the halls. On the other hand, even a light airflow in the exam halls disturbs the candidates. As a result, they prefer the windows closed. Candidates sometimes concentrate themselves at one point of the exam halls, and thus, they do not have a homogenous distribution in the halls. The measurements taken at different points in the exam halls under such conditions indicated that there was an almost completely homogenous CO_2 distribution in the classrooms, and the differences between the measurements taken at different points were about one percent to two percent.

The measurements taken in the hallway before and during the exams showed that CO_2 amount in the hallway rose rapidly and exceeded 1500 ppm within the first 10 to 15 minutes, and while candidates were being accepted into the exam building and placed in the halls, the CO_2 amount remained stable or fell a little at the start of the exam, and continued to be over 1400 ppm during the exam when it was not ventilated.

The amount of CO_2 in the exam halls was found to be dependent on the weather and the season under/in, which the exams were conducted. This is because when the temperature is low, exam halls are not ventilated so as not to cause any loss of heat. The second reason is the effect

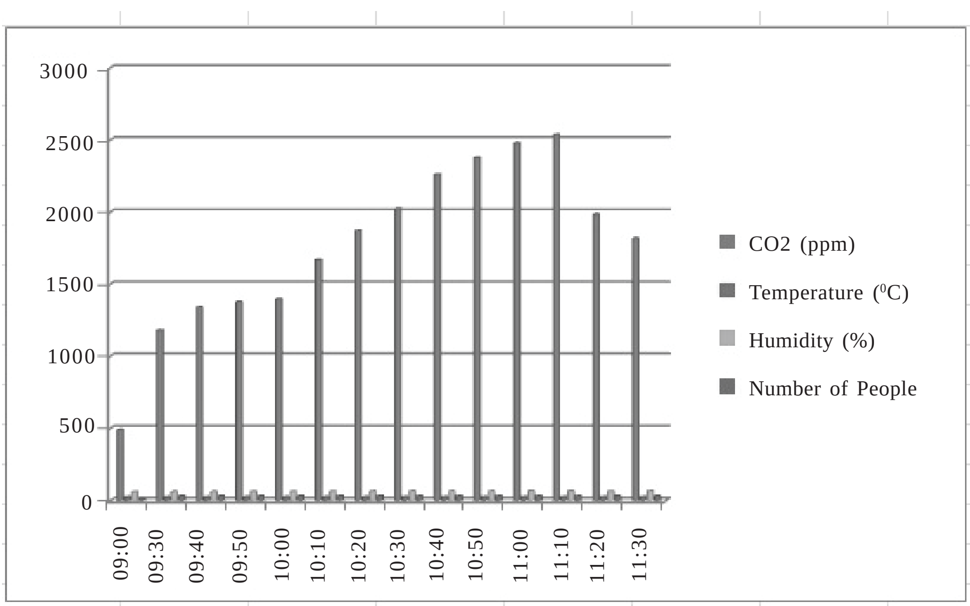

Fig. 3. The amount of CO2 of Lyscnam

of the outdoor CO_2 amount on the indoor space. The outdoor CO_2 amount is higher in winter than in summer. As a result, even when ventilation is provided, the indoor CO_2 amount does not fall to the values experienced in the summer months.

One of the factors likely to influence indoor CO_2 amount is the location of the exam building. Previous studies reported that CO_2 amount varies in city centers (Idso et al. 1998; Idso et al. 2001; Clark-Thorne and Yapp 2003), and such variation depends on factors such as the building's location, traffic density, and air circulation (Fischer et al. 2000; Clark-Thorne and Yapp 2003; Sevik et al. 2015). However, the present study came up with no data regarding the relationship between the CO_2 amounts in the exam halls and the CO_2 amount in the area where the exam building is located.

The halls used in the study do not have air conditioning or a ventilation system in place. The presence of a constant airflow that can be felt in the exam room is yet to be detected in cases where the windows are open. Prior to the presence of such airflow, candidates have already demanded the closure of the window, which disturbed the presence of airflow. However, the airflow measurement was not taken at ambient airflow.

The amount of CO_2 increased at every ten minutes interval after the start of the exam and exceeded 2400 ppm, 90 minutes after the start of the exam as shown in Figure 3. As a result, the examiners are negatively affected by the performances of the candidates. They suffered from headache, dizziness, fatigue and loss of concentration. Students in the hall began their exams at 09:00 hours, and the amount of CO_2 was measured at 490 ppm. The students in the exam room were to settle at 09:30 hours and 30 people completed the exam. The amount of CO_2 measured at the commencement of the exam at 09:00 hours, after 10 minutes and at the end of 20 minutes is 1181 ppm, 1341 ppm and 1378 ppm, respectively. Students started the exam at 09:30 hours and the amount of CO_2 measured was 1399 ppm. 10 minutes after the commencement of the exam, the amount of CO_2 is 1670 ppm and at the end of 20 minutes, it rose to 1870 ppm, and 2023 ppm is reached after 30 minutes. The amount of CO_2 continued to increase and it reached 2536 ppm at 100 minutes, and the windows were opened to avoid students from facing severe consequences. The amount of CO_2 with the opening of the window, if dropped, decline rapidly to 1866 ppm within 10 minutes and to 1819 ppm within 20 minutes. The quantitative and qualitative representation of the measured data is shown in Figure 3 and Table 2.

In the exam room, the exam start time is 14:20 hours at 725 ppm, which together with the settlement of the amount of CO_2 at 14:30, was measured as 1049 ppm. The amount of CO_2 emissions measured after 10 minutes is 1325 ppm and 1503 ppm is reached in 20 minutes. The rising amount of CO_2 content measured after 40 minutes was 1597 ppm, and the amount was 1644 ppm after 30 minutes. The amount of CO_2 measured at 50 minutes was 1760 ppm. The exam rooms on the same floor with the others became largely depleted 30 minutes after the commencement of the exam while 22 students remained in the examination room at the end of 50 minutes. The amount of CO_2 and the number of students has declined sharply after some hours. Both the quantitative and qualitative data representations of the measurement are shown in Figure 4 and Table 3.

Table 3: The amount of CO_2 of AUOEE exam

Time	*CO_2 (ppm)*	*Temperature (ºC)*	*Humidity (%)*	*Number of people*
14:20	725			
14:30	1049			
14:40	1325	22.1	53.4	30
14:50	1503	22.3	54.2	31
15:00	1597	22.5	54.3	31
15:10	1644	22.6	53.9	27
15:20	1760	22.9	54.4	22
15:30	1681	23	53.9	20
15:40	1503	22.8	53.1	14
15:50	1429	23	52.7	10
16:00	1219	23	51.8	8
16:10	1070	23	50.7	5

DISCUSSION

The indoor CO_2 amount has so far been subjected to several studies. Several studies have been conducted on CO_2 amounts at schools, both in Turkey (Gul et al. 2011; Babayigit et al. 2014), and in various cities across the world (Lundin 1999; Fuji et al. 2002; Zhang et al. 2006; Godwin and Batterman 2007; Santamouris et al. 2008; Yang et al. 2009; Jones and Kirby 2012), and an attempt has been made to reveal the effects of indoor air quality on human health and performance (Mendell and Heath 2005).

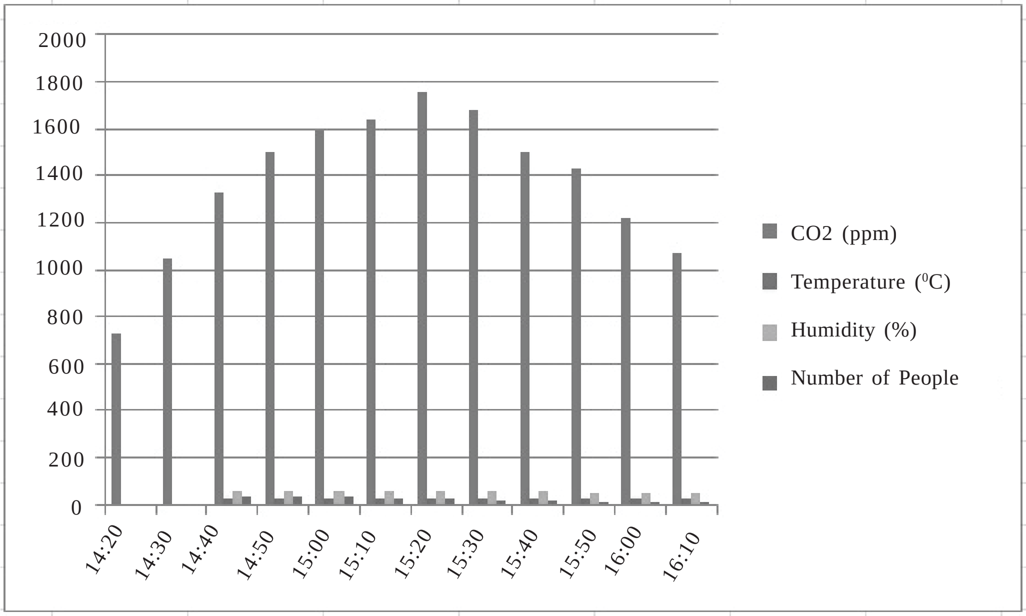

Fig. 4. The amount of CO_2 of AUOEE exam

Excellent indoor air quality in exam halls is significant because it provides a comfortable, healthy, safe and productive environment for examiners. However, according to the measurements of CO_2 the air quality is sometimes determined at elevated concentration in exam halls. Also, it has been shown from the data that poor CO_2 should affect children's health. Many classrooms in exam halls are not adequately ventilated. The available measurements of CO_2 in exam halls suggested that based on the current CO_2 standard (Azmi et al. 2012).

All research usually recommends a consistent relationship for indoor environments even though results from the few measurements in schools have been inconsistent with associating CO_2. These findings were sensitive especially relating to examiners, and it covered exams related to ventilation. Thus, the building during exam needs to be a major focus of design or of remediation efforts for ventilation. Although in most cases, health symptoms were not measured in these studies because of the duration of the exam (Daisey et al. 2003).

Majority of the CO_2 measurements, particularly CO_2 levels, were generally low. Research recommends that even low levels should tend toward CO_2 by a raised risk of sensitization. This research presents data on indoor air quality to exposure measurements in exam halls as perceived by those examiners. Data on exposure of examiners was collected in exam classrooms during the exam. In buildings without ventilation, there was less dissatisfaction with the air quality. Ventilation rates should be checked in the building of adequate levels of pollutants (Maddalena et al. 2015). There were no significant relationship between air exchange rate and the concentration of carbon dioxide (Nabinger et al. 1994). Air concentrations of carbon dioxide and air temperature increases poor ventilation (Chen and Hsiao 2015).

CONCLUSION

This study determines how the indoor CO_2 parameters influence the students' performance of activity in the exam halls. The study was conducted in exam rooms during exams at the Faculty of Forest Engineering from the Kastamonu University. To determine the efficiency of students during each exam, students were tested.

The study shows a variation in indoor parameters. For each exam hall, the following parameters were used to measure the indoor CO_2 concentration that is, relative humidity, and temperature. The efficiency of the students was based on the outcome of this. The number of examiners, exam rooms, structure of rooms has been found to be effective in influencing the indoor air quality. According to measurements made of the factors distorting the internal air quality in a human density environment, the distorting factors has been found to be more of internal pollutants.

Measurements relating to the amount of particulate matter were reported to be above the values specified in international standards. 1000 ppm exceeds the recommended value for acceptable indoor air quality and the measured amount of CO_2 was found to be dependent on the number of examiners and exam rooms. The set value of the internal air temperature and relative humidity comfort conditions was generally observed to be lower.

To provide a good indoor air quality on examiners density controlled ventilation and air conditioning of exam halls must be done. At least the expenditure of energy and indoor air quality, as well as thermal comfort can be achieved using ventilation systems based on the needs of employees, according to the CO_2 measurement. Internal pollutant concentration levels can be reduced through the exhaust, given the outside fresh air and the polluted indoor air. The density of examiners in exam halls should be minimized, and also furniture that could be sources of pollution.

As a result, the air one breathes should be clean to ensure a healthy and productive life in order to provide an acceptable indoor air quality. An adequate amount of fresh air is required to provide thermal comfort and to control pollutants. Based on this, the indoor air quality monitoring needs to be controlled. In addition, the monitoring of indoor air quality standards with regard to the indoor environment are used for different purposes and should be applied in Turkey.

It was seen in the present study that CO_2 amounts in the examined exam halls were over 1000 ppm, which is, according to EPA, the allowed amount of indoor carbon dioxide in common areas, such as schools and conference halls, almost throughout the exams. It is clear that the performances of the candidates are negatively affected by this. From previous studies, it was reported that when the indoor CO_2 amount is over 1000 ppm, headache, dizziness, fatigue, loss of concentration, and getting annoyed of odor occurs, and when it is over 1500 ppm, throat irritation, nose irritation, nasal discharge, cough, and eye discharge take place. However, the findings of the present study show that the CO_2 amounts in exam halls may become much higher than 1500 ppm in most exams, with longer duration *KPSS*, *LYS*, and *ALES* being in the first place.

It was reported that as the number of candidates in an exam hall increases, the amount of CO_2 as well as the maximum CO_2 level also increased. In this regard, decreasing the number of students per exam hall may have a positive effect on CO_2 level, although, it may not bring it to a satisfactory level.

The studies conducted to improve the indoor air quality at schools reported that the most effective way is the ventilation of classrooms. The studies of the United States Environmental Protection Agency (EPA) indicate that the indoor pollutants may be almost 5 to 100 times as much as those of the outdoor air. However, the present study shows that ventilating exam halls and the hallways in which their doors open into, decreases CO_2 amounts in the exam halls, but does not reduce them to satisfactory levels. Air circulation is a must in exam halls in order to keep the CO_2 levels below 1000 ppm, which is the accepted value by the EPA, possible through the use of appropriate air conditioning systems. However, these systems should be capable of working silently, and circulating air without disturbing candidates.

RECOMMENDATIONS

Studies on the CO_2 content in the examination room, it was observed that the students' concentration and performance, affects their health. However, the increase in the amount of CO_2 in the exam room, living room size, ventilation conditions, the number of candidates, the position of the hall and so on, is influenced by several factors. Therefore, in the subsequent work, in establishing a multifactorial experiment, the examination halls must be kept under conditions that will not affect the performance and health of the candidates as well as the amount of CO_2, and the examination rooms should be designed according to these conditions provided.

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