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Impact of CO_2 Concentration on Indoor Air Quality in Various Schools and Colleges in Baniwaleed City

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A B S T R A C T

Indoor air pollution has been known since ancient times, but the types of indoor air pollutants differ with the presence of modern buildings. Millions of people die each year as a result of the serious threat that indoor air pollution poses to human health. Numerous pollutants can cause indoor air pollution; therefore, it's crucial to identify their primary sources and concentrations and develop plans for enhancing and controlling the quality of the air indoors. Air-conditioned and tightly closed, especially since a person spends more than 80% of his day in closed environments. The current study included measuring the concentration of carbon dioxide inside some schools and colleges in Baniwaleed city to ensure air quality. Two primary schools, four secondary schools, and two colleges were selected. Measurements were taken twice, the first in November and the second in December. A HT 2000 CO_2 meter was used for measurement, located in the laboratories of the Faculty of Science, Baniwaleed University, Department of Geology and Environmental Sciences. The highest reading was recorded at 2221 ppm at Sana Muhaidli School for Secondary Education in the month of December. The second highest reading recorded in the College of Engineering was 2005 ppm, and it was in the month of December as well. There were some readings within the permissible limits (less than 1000 ppm) and some readings higher than the permissible limit.

1 Introduction

Most of the time that people are awake is spent working or studying. As a result, facility managers and building operating engineers are placing a high importance on maintaining sufficient indoor air quality (IAQ) in workplaces and educational institutions. In order to maintain adequate indoor air quality, outside air is essential for dilution of indoor air contaminants and their removal from our buildings, along with moisture and odors.

Both the combustion process and the metabolic process in living things produce carbon dioxide (CO_2). Since human metabolism produces carbon dioxide, measurements of its levels inside buildings are frequently used to determine if the area is receiving enough fresh air. Carbon dioxide is one of the pollutants of indoor air that is most frequently discussed. Despite not being considered a dangerous air pollutant, carbon dioxide replaces oxygen in enclosed spaces, lowering the quality of indoor air (Owen, 2009). According to the World Health Organization (WHO), 3.8 million people die each year as a result of indoor air pollution worldwide.

High amounts of carbon dioxide can result in nausea, dizziness, and vomiting, while moderate to high concentrations might result in headaches and exhaustion. Extreme concentrations can cause loss of consciousness.

Fresh air should be brought into the space to prevent or lower high carbon dioxide concentrations in a building or room. According to past studies, inadequate

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classroom ventilation might have a negative impact on both teachers' and students' health. In Baniwaleed, schools frequently have natural ventilation. A classroom air quality test determines the level of air pollution based on their high occupancy, allowing for the execution of corrective measures. Carbon dioxide (CO_2) is produced by both the metabolic and combustion processes in living things.

Since human metabolism produces carbon dioxide, measurements of its levels inside a structure are frequently used to determine if the area is receiving enough fresh air. High amounts of carbon dioxide can result in nausea, dizziness, and vomiting, while moderate to high concentrations might result in headaches and exhaustion. CO_2 content has frequently been employed as a gauge for ventilation system effectiveness (Coley et al, 2007). At least two factors contribute to the importance of ventilation in schools. First, there's the issue of air quality and how it affects people's health and productivity. It is also a channel for heat loss. There is conflicting information about the impact of low ventilation rates on productivity and health (Myhrvold et al, 1996).

It is quite simple to measure the amount of CO_2 gas present in a given sample of air (Mahyuddin and Awbi, 2012). Since outside CO_2 directly affects interior concentrations, it is necessary to monitor outdoor CO_2 levels when evaluating indoor concentrations. The typical range of CO_2 content in outdoor air is 350 to 450 ppm (Jones, 1999). The amount of cubic feet of air per minute (cfm) provided per person can be used to gauge how well a ventilation system is functioning. Alternately, indoor CO_2 concentrations can be used to gauge the effectiveness of ventilation. For instance, a 1000 ppm CO_2 level corresponds to 15 cubic feet of fresh air per person per minute (Ellenbecker, 1992).

The ASHRAE advises against indoor CO2 concentrations that are more than 700 ppm above outdoor ambient values. For businesses and schools, ASHRAE recommends that indoor CO2 levels be fewer than 800 ppm and 1000 ppm, respectively (ASHRAE, 1992).

CO_2 concentrations in indoor air that are greater than 1000 ppm are regarded by the National Institute for Occupational Safety and Health (NIOSH) as a sign of insufficient ventilation (Sireesha, 2017). The key measurements of occupants' thermal comfort are the indoor air temperature (T) and relative humidity (RH) (Kavgic, et al, 2012). High RH can result in condensation and the growth of mold, both of which are harmful to occupants and young children (Abuku et al, 2009).

High carbon dioxide (CO_2) levels could be dangerous for those living in houses, flats, classrooms, and workplaces, including office buildings. Many people struggle with the uncertainty surrounding what high CO_2 levels are, how to measure them, and how to mitigate them.

Organizations like the Occupational Safety and Health Administration, the Center for Disease Control, and the U.S. Green Building Council are working to provide enough information about the significance of monitoring CO_2 levels indoors and what the potential long-term effects of exposure are for people exposed to higher amounts of CO_2.

Many individuals tend to be surprised when it comes to understanding the importance of carbon dioxide monitoring and recognizing the direct impact high CO_2 concentrations can have on their overall well-being, health, and cognitive skills.

Technically, anything beyond the "safe" CO_2 levels indoors denotes a fresh air flow issue rather than excessive CO_2 levels specifically. A number of studies over the years, however, have discovered a direct link between elevated CO_2 levels indoors (caused by a lack of fresh air) and elevated levels of mold, dust, germs, and viruses in the air. Additionally, elevated CO_2 levels are linked to decreased cognitive function and an increase in sleepiness.

The aim of this study is to measure the percentage of carbon dioxide and the indoor air temperature (T) in order to ascertain the indoor air quality in a number of schools and colleges in Baniwaleed city (primary two schools, secondary four schools, and two colleges). The readings were taken over two periods, November and December of 2022, and Table 1 shows the details of the selected schools and colleges. All schools and colleges are naturally ventilated, and air can continuously enter and exit the classrooms through doors, windows, cracks, and other openings. Schools and colleges vary in age, building and size. Each designated classroom had one outer wall, one side in contact with an interior corridor, and the other two walls in contact with adjacent classrooms.

2 Methodology

2.1 Sampling Site Description and Measurement Period

The object of this paper is the analysis of CO_2 and indoor air temperature (T) and their variability in two basic education schools, four Secondary schools, and two colleges in Baniwaleed city. For all selected schools and colleges two sampling campaigns were performed during the heating season (November and December). The main parameters of the selected schools are given in Table. 1.

Table 1: shows the details of the selected schools.

no	name
1	Hafez Al-Madani School
2	Al-Barq Al-Khatif School
3	Al Quds School
4	Sanaa Muhaidly School
5	Badr Al-Kubra School
6	Almasira Alkubra School
7	College of Engineering
8	College of Medical Technology

2.2 The Device Used for Measurement

The HT 2000 CO_2 meter is located in the laboratories of the College of Science, Department of Geology and Environmental Sciences. Photo No. 1 shows the device.

Photo 1: HT 2000 CO_2 meter.

3 Results and Discussion

Indoor air quality (IAQ) in schools is an important public health concern. Especially children should be taken care of because they are more exposed to air pollution than adults. Although carbon dioxide is not considered a toxic air pollutant, its concentrations indoors can have a negative impact on users. The permissible concentration of carbon dioxide in confined spaces is 1000 ppm, these minimum health requirements are recommended by the European Office and the World Health Organization.

3.1 Al-Barq Secondary School

The average concentration of carbon dioxide in Al-Barq Al-Khatif Secondary School was 626 ppm during the month of November and 701 ppm during December, and the highest reading was recorded in November, 850 ppm, at a temperature of 21 °C and a humidity of 57%. It is within the permissible rate of carbon dioxide concentration in closed places, which indicates the presence of good ventilation in the classrooms of this school. Tables 3 and 4 and Figures 1–4 show averages of carbon dioxide concentration and temperature, as well as the highest and lowest readings recorded during November and December.

3.2 Hafez Al-Madani School

The average concentration of carbon dioxide in Hafez Al-Madani School for Secondary Education was 1179 ppm during the month of November and 1053 ppm during December, and the highest reading recorded in November was 1372 ppm at a temperature of 22 °C, which is higher than the permissible rate of carbon dioxide concentration in closed places, which indicates the absence of good ventilation in the classrooms. This school and classrooms need to be ventilated. Tables 2 and 3 and Figures 1–4 show averages of carbon dioxide concentration and temperature, as well as the highest and lowest readings recorded during November and December.

3.3 Al Quds School

The average concentration of carbon dioxide in Al Quds School for Secondary Education for Girls was 921 ppm during the month of November and 728 ppm during December, and the highest reading recorded in December was 1457 ppm at a temperature of 23 °C. It is higher than the allowed rate of carbon dioxide concentration in enclosed spaces, and it was recorded in one classroom while the other classrooms had less than 1000 ppm, meaning that care must be taken to ensure good ventilation in all classrooms inside the school. Tables 2 and 3 and Figures 1–4 show averages of carbon dioxide concentration and temperature, as well as the highest and lowest readings recorded during November and December.

3.4 Sanaa Muhaidly School

The average concentration of carbon dioxide in Sanaa Muhaidly Secondary School was 755 ppm during the month of November and 1477 ppm during December, and the highest reading was recorded in December at 2221 ppm, at a temperature of 19 °C. It is higher than the allowed rate of carbon dioxide concentration in enclosed spaces, meaning that care must be taken to ensure good ventilation in all classrooms inside the school. Tables 2 and 3 and Figures 1–4 show averages of carbon dioxide concentration and temperature, as well as the highest and lowest readings recorded during November and December.

3.5 Badr Al-Kubra School

The average concentration of carbon dioxide in Badr Al-Kubra School for Basic Education was 728 ppm during the month of November and 1068 ppm during December, and the highest reading was recorded in December, 1418 ppm, at a temperature of 17 °C, which is higher than the allowed rate of carbon dioxide concentration in closed places. Most of the readings for the month of December were high, exceeding the permissible limits, while the readings in November had readings within the permissible limits (less than 1000 ppm). Therefore, all classrooms must be ventilated inside the school. Tables 2 and 3 and Figures 1–4 show averages of carbon dioxide concentrations and temperatures, classroom size, the highest reading recorded, and the lowest reading recorded during November and December.

3.6 Almasira Alkubra School

The average concentration of carbon dioxide recorded in Al-Masirah Al-Kubra School for Basic Education was 724 ppm during the month of November and 970 ppm during December, and the highest reading was recorded in December, 1329 ppm, at a temperature of 17 °C, which is higher than the allowed rate of carbon dioxide concentration in closed places. There were only a few readings during the month of December that exceeded the permissible limits, while those during the month of November were mostly within the permissible limits (less than 1000 ppm). It is recommended that all classrooms be ventilated inside the school. Tables 2 and 3 and Figures 1–4 show averages of carbon dioxide concentrations and temperatures, classroom size, the highest reading recorded, and the lowest reading recorded during November and December.

3.7 College of Engineering

The average concentration of carbon dioxide in the College of Engineering at Baniwaleed University was 1405 ppm during the month of November and 1980 ppm during December, and the highest reading was recorded in December, 2005 ppm, at a temperature of 18 °C, which is higher than the allowed rate of carbon dioxide concentration in closed places, and most of the readings for the month of December were higher than the allowed rate, which indicates a problem with ventilation. Therefore, we recommend ventilating the halls between lectures for 10 minutes and taking new measurements of carbon dioxide concentration. If the concentration remains high, mechanical ventilation must be used, and suction fans should be used to exchange the air. Tables 2 and 3 and Figures 1–4 show averages of carbon dioxide concentrations and temperatures, classroom size, the highest reading recorded, and the lowest reading recorded during November and December.

3.8 College of Medical Technology

The average concentration of carbon dioxide in the College of Technology at Baniwaleed University was 964 ppm during the month of November and 790 ppm during December, and the highest reading was recorded in November, 1080 ppm, at a temperature of 23 °C, which is higher than the allowed rate of carbon dioxide concentration in closed places, while most of the readings were within the permissible rate, except for one reading in November, which recorded 1080 ppm.

We recommend good ventilation after each lecture by opening windows and doors to allow air to circulate inside the classrooms. Tables 2 and 3 and Figures 1–4 show averages of carbon dioxide concentrations and temperatures, classroom size, the highest reading recorded, and the lowest reading recorded during November and December.

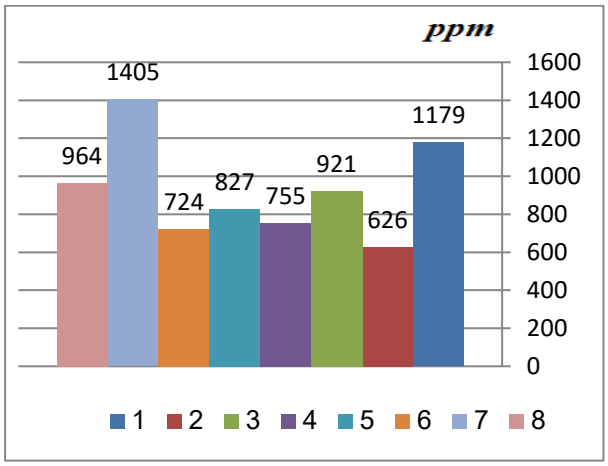

Figure 1: Average carbon dioxide concentrations (ppm) during the month of November

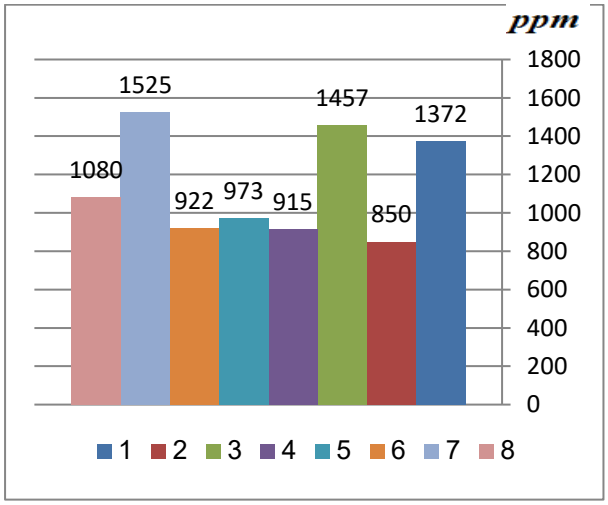

Figure 2: The highest concentrations of carbon dioxide (ppm) during the month of November

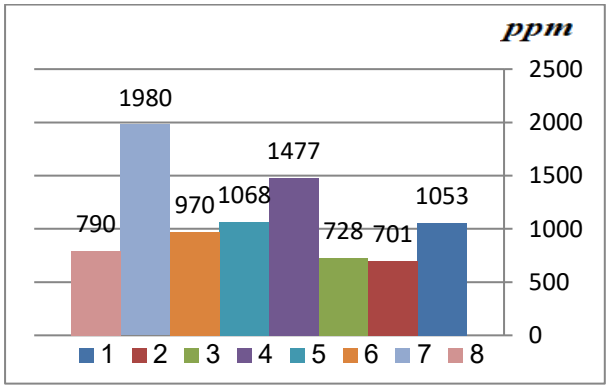

Figure 3: Average carbon dioxide concentrations (ppm) during the month of December

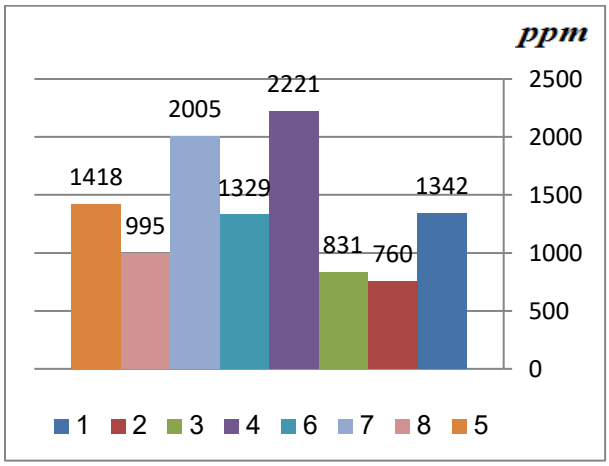

Figure 4: the highest concentrations of carbon dioxide (ppm) during the month of December

Table 2: show averages of carbon dioxide concentrations, temperatures, classroom size, the highest reading recorded and the lowest reading recorded during November

no	max ppm	min ppm	temperature ° C	size m^2	CO_2 ppm	Student
1	1372	820	22	35	1179	27
2	850	512	21	35	626	28
3	1457	643	23	30	921	33
4	915	532	25	35	755	36
5	973	594	19	30	827	21
6	922	516	19	30	724	27
7	1525	1289	27	120	1405	33
8	1080	574	23	80	964	35

Table 3: show averages of carbon dioxide concentrations, temperatures, classroom size, the highest reading recorded and the lowest reading recorded during December.

no	max ppm	min ppm	temperature ° C	size m^2	CO_2 ppm	Student
1	1342	763	18	35	1053	27
2	760	582	19	35	701	28
3	831	647	23	30	728	33
4	2221	1153	19	35	1477	36
5	1418	785	17	30	1068	23
6	1329	684	17	30	970	27
7	2005	1290	18	120	1980	74
8	995	586	18	80	790	35

4 Conclusion

As a result of regular metabolic processes, people create and exhale carbon dioxide (CO_2), which is why indoor CO_2 concentrations are higher than outdoor CO_2 concentrations in occupied buildings. Higher CO_2 levels when our bodies go through their natural cycles might be blamed for unpleasant sensations, fatigue, lack of concentration, and even nausea. This may result in sick building syndrome indoors. In fact, elevated CO_2 levels indoors may potentially exacerbate a number of the sick building syndrome symptoms.

The amount of CO_2 in school classrooms has a significant impact on indoor air quality. Low indoor air quality appears to be an issue in both newly constructed buildings and older structures in naturally ventilated schools. The aim of this study is to measure the percentage of carbon dioxide and the indoor air temperature (T) in order to ascertain the indoor air quality in a number of schools and colleges in Baniwaleed city (primary two schools, secondary four schools and two colleges). The readings were taken over two periods during the heating season: November and December of 2022. All schools and colleges are naturally ventilated, and air can continuously enter and exit the classrooms through doors, windows, cracks, and other openings. Schools and colleges vary in age, building, and size. Each designated classroom had one outer wall, one side in contact with an interior corridor and the other two walls in contact with adjacent classrooms. Results obtained in this study confirm that the levels of carbon dioxide concentrations in some schools and colleges in Baniwaleed city are higher than the permissible limits, which will affect the health of students and thus their academic achievement. The highest reading was recorded at 2221 ppm at Sana Muhaidli School for Secondary Education in the month of December. The second highest reading recorded in the College of Engineering was 2005 ppm, and it was in the month of December as well. There were some readings within the permissible limits (less than 1000 ppm) and some readings higher than the permissible limit. The study also made the following observations:

- The amount of time between classes is insufficient to allow the CO_2 concentration to decrease sufficiently to reach the outside level.
- High CO_2 concentration levels in the classrooms and poor air exchange rates in naturally ventilated schools are mostly caused by insufficient ventilation and the frequency and length of window openings.
- The findings of this study further highlights the requirement for a management approach for monitoring CO_2 concentration levels and air exchange rates in educational facilities.

Overall, by keeping an eye on CO_2 levels, one can safeguard tenant health, boost productivity, control costs, adhere to rules, and uphold a good reputation. The prevalence and effects of sick building syndrome can be reduced by establishing healthier and cozier indoor settings, which will help both people and businesses.

Conflict of Interest: The authors declare that there are no conflicts of interest.

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