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AIR QUALITY MONITORING IN A SELECTED CLASSROOM

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As part of the research entitled "Experimental determination of the optimal amount of air in a selected room in Ukraine based on measurements of carbon dioxide concentration", an experimental measurement was performed in a selected school room in Ukraine. The aim of the experimental measurement was to determine the course of air temperature, relative humidity and carbon dioxide concentration during the teaching process. From the carbon dioxide concentration curves, it is possible to calculate the required ventilation intensity in the room. This article documents the results of measuring the air temperature and the carbon dioxide concentration in the room, as well as the reactions of people in the room to the air quality.

Key words: carbon dioxide concentration; relative humidity; air temperature; air velocity; air quality; monitoring.

Introduction

Due to the use of plastic windows in modern buildings, it is possible to avoid heat loss, especially to increase the energy performance of modern buildings. The air that a person exhales contains a large amount of CO_2 gas. Due to the accumulation of this gas in the indoor air, air quality deteriorates. In rooms where a large number of people are, this gas has become a marker of indoor air quality (Batterman, 2017). This issue became especially relevant during the COVID-19 pandemic. In places where are many people, the concentration of respiratory pathogens is increasing, including coronavirus infection (Zemouri et al., 2020) (Richardson et al., 2014; Wood et al., 2014; Huang, 2021).

Air quality in offices and classrooms changes significantly after opening windows or using air conditioners. Changes in indoor air quality also depend on factors such as air temperature and relative humidity. However, it is not always possible to establish a reliable statistical relationship due to the simultaneous action of these factors (Batterman, 2017; Huang, 2021).

Air quality requirements vary from country to country. For example, in Slovakia, Order 527/2007 states that air exchange should be 20–30 m^3/h per person, and in Poland, document PN-83/B-03430/Az3: 2000 confirms that this norm is at least 20 m^3/year per person. In Ukraine, the document DBN B.2.2-3-97 sets the requirements of 16–20 m^3/h per 1 person depending on the type of educational institution. The most obvious of such studies is the use of mathematical modeling methods (Adamski, 2015). As there are no uniform standards, this topic needs further careful study.

This issue is very relevant in modern urban planning. The study of this decision, approved by the international project VEGA 1/0697/17, was conducted by us together with colleagues from the Technical University of Košice, Slovakia, and the Technical University of Białystok, Poland (Kapalo, 2020).

The aim of this work is to study the parameters of the air environment of the classroom, during training sessions, to determine their impact on the well-being of students.

Materials and Methods

Experimental measurements took place in a selected room in Lviv polytechnic National University. During the measurement following parameters were recorded: air temperature, relative humidity and carbon dioxide concentration. A subjective evaluation was also carried out in the form of questionnaires, in which the individual people in the room commented on the indoor air quality.

Room characteristics. The room in which the experimental measurement took place is located in a seven-storey building on the fourth floor. The dimensions of the classroom are: length: 5.90 m, width: 6.30 m and height: 3.30 m. The volume of the room is 123 m^3. The windows of the room are oriented to the northwest. During the people's stay, the room was not exposed to direct sunlight (Fig. 1).

Fig. 1. Interior of the room in which the experimental measurement took place

Fig. 2. Carbon dioxide concentration sensor C-AQ-0001R

The doors and windows were closed during the teaching process. Ventilation was provided by leaks in the building structure and a ventilation opening located above the door in the corner under the ceiling of the room.

Used measuring instruments. A temperature and humidity sensor S3541, a carbon dioxide concentration sensor C-AQ-0001R and an atmospheric pressure gauge were used to measure the indoor air parameters (Fig. 2–4).

The C-AQ-0001R (Fig. 2) sensor contains a room sensor for the concentration of carbon dioxide in the air.

Technical parameters of the device C-AQ-0001R:

CO_2 concentration measuring range	0–5 000 ppm
Accuracy of CO_2 concentration measurement	± 75 ppm
Influence of temperature on measurement	± 0.5 % ppm na 1 °C

Thermo-hygrometer S3541 (Fig. 3) Aneroid device is designed for recording temperature and humidity.

Fig. 3. Thermo-hygrometer S3541

The sensor was used simultaneously with the carbon dioxide concentration sensor C-AQ-0001R.
Technical parameters of Thermo-hygrometer S3541:

Temperature measuring range	–30–70 °C
Temperature measurement accuracy	± 0.4 °C
Operating temperature range	–30÷(+70) °C
Humidity measuring range	from 5 % to 95 %
Humidity measurement accuracy	± 2.5 % RV at the temperature 25 °C

Atmospheric pressure (Fig. 4) gauge with a measuring range from 80 kPa to 160 kPa.

The course of measurement. Indoor air gauges were in the room approximately 90 minutes before class in the ventilated room. Until the beginning of the class, the room was closed without people. The first class was taking from 8:30 to 10:05 (hour: minute) – marked with the letter A. This was followed by a 15-minute break. The second lesson was taking from 10:20 to 11:55 – marked with the letter B. The third lesson was taking from 12:10 to 13:40 – marked with the letter C. During the breaks between the lessons, windows and doors were opened to make the room ventilated.

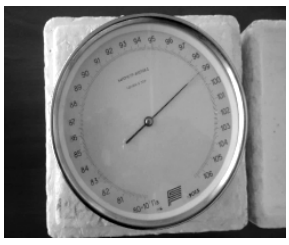

Fig. 4. Aneroid device

Table 1

Time of stay of persons in the room

Measurement designation	Time of stay of persons in the room (h:min)
A	08:30 – 10:05
B	10:20 – 11:55
C	12:10 – 13:40

During classes A, B, C, there were always other groups of people in the room. All persons who participated in the experimental measurement gave their consent to the processing of their data before the actual measurement. The questionnaires were anonymous. The experimental measurements involved persons whose basic average values of physical characteristics are documented in Table 2.

Table 2

Characteristics of persons

Measure-ment designation	Num-ber of men	Num-ber of women	The average age of a person,	Average weight of a person,	The average height of a person,	Average body area	Mean basal metabolism,
	(–)	(–)	years	kg	mm	m^2	MJ
A	6	1	21.00	75.60	1799	1.94	7.66
B	13	3	19.27	70.69	1781	1.88	7.35
C	3	7	19.78	64.30	1666	1.72	6.95

At the beginning of each lesson, students were given a brief instruction on how to complete an anonymous questionnaire of subjective assessment of the quality of the indoor environment. People completed the questionnaire at the beginning of the class and at the end of the class. In the questionnaire, all those present evaluated the thermal comfort in the room, the smell of the air in the room and the overall air quality in the room.

Table 3

Subjective evaluation of room air parameters

Evaluation of thermal comfort in the room	Evaluation of the smell of air in the room	Evaluation of the overall air quality in the room
It's cold	Clean	Suitable
Slightly cold	Neutral	
Neutral	Slight odor	Not suitable
Mild heat	Very smelly	
Heat		

Results and Discussion

Outdoor air and indoor air parameters were recorded during the measurement. Outdoor air parameters are documented in Table 4.

Table 4

Outdoor air parameters

Measure ment designation	Average air temperature,	Average relative humidity,	Wind direction,	Average wind speed,	Air pressure,	Clouds,
	°C	%	–	km/h	hPa	–
A	4.25	91.50	South	8.75	972.63	Cloudy
B	6.50	78.75	Southwest	9.00	972.39	Partly cloudy skies
C	7.75	66.25	West	10.00	971.42	Mostly cloudy

The measured indoor air parameters are documented in Fig. 5. The increase in carbon dioxide concentration is short-lived, so it was not dangerous for people in the room.

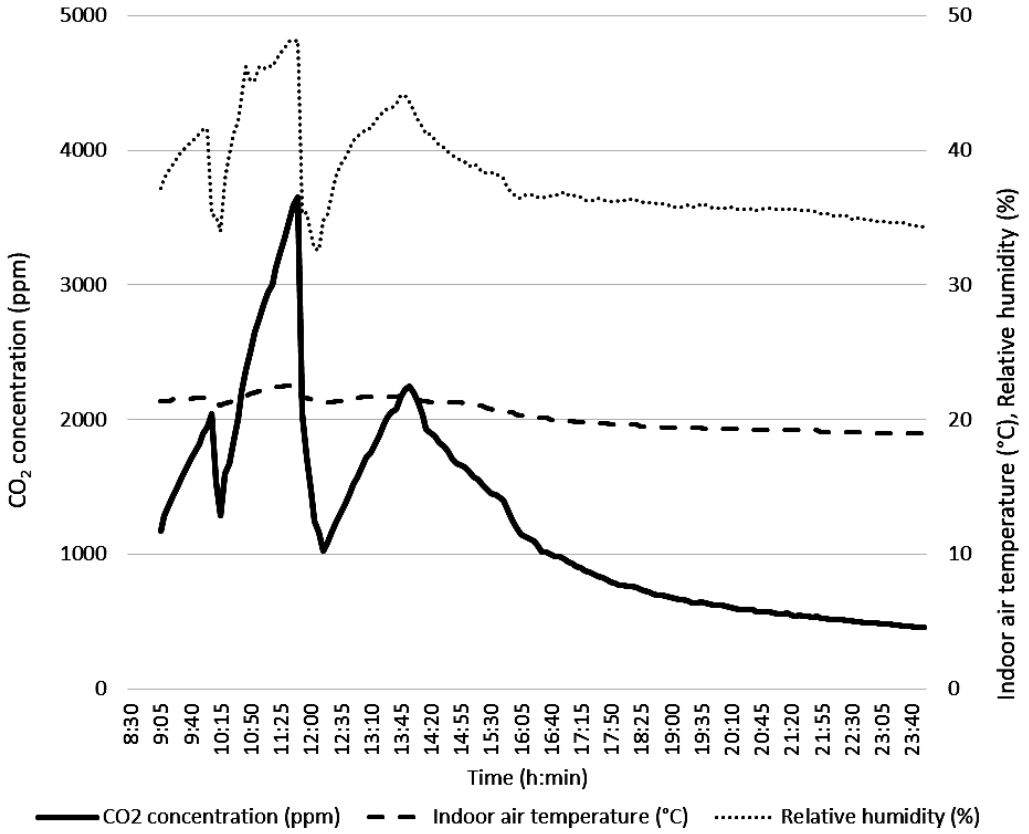

Fig. 5. Measured room air parameters

Evaluation of thermal comfort in the room. According to the data shown in Fig. 6, the measured room temperature complied with Slovak and Ukrainian legislative requirements. The temperature rise during lesson A was 0.1 °C, lesson B was 1.6 °C and lesson C was 0.4 °C.

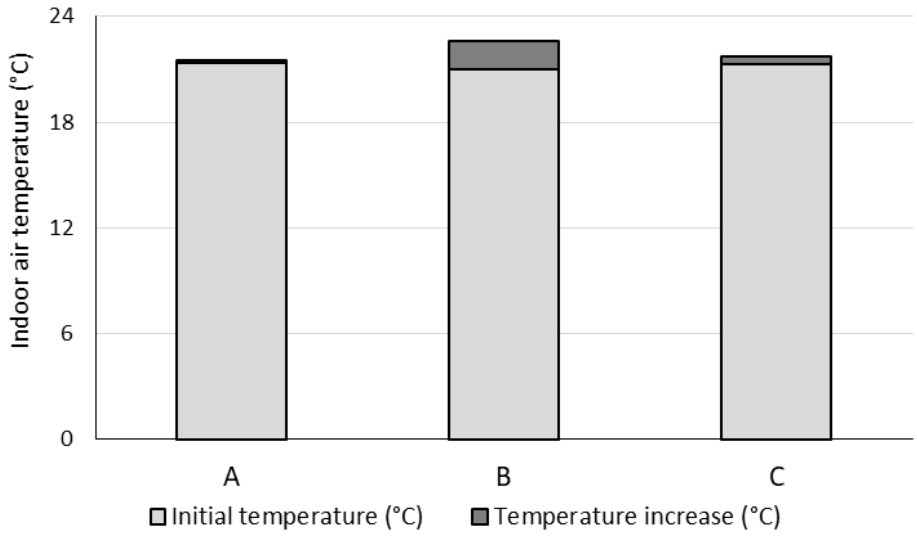

Fig. 6. Measured room air temperature

From Fig. 7, where the perception of temperature change during the lesson was documented and it can be stated that during the first lesson, most people provided the correct assessment. During the second and third lessons, the evaluation of most people no longer corresponds to the measured values.

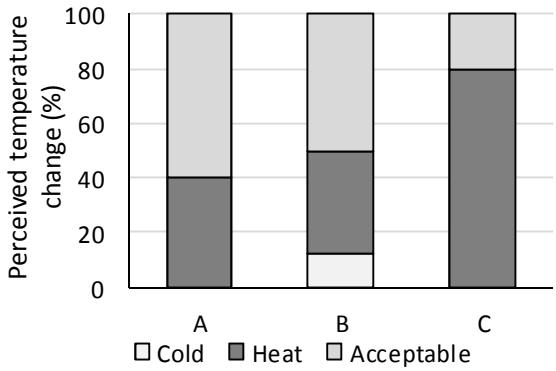

Fig. 7. Perceived room air temperature

Odor evaluation in the room. Carbon dioxide (CO_2) is an odorless, colorless gas. In our case, it is a product of the breathing of people in the room. Since the product of people's stay in the room is also odor, a questionnaire was chosen for the perception of the smell of air in the room, which was compared with the measured concentration of carbon dioxide. Fig. 8 documents the measured level of carbon dioxide concentration during the stay of persons in the room.

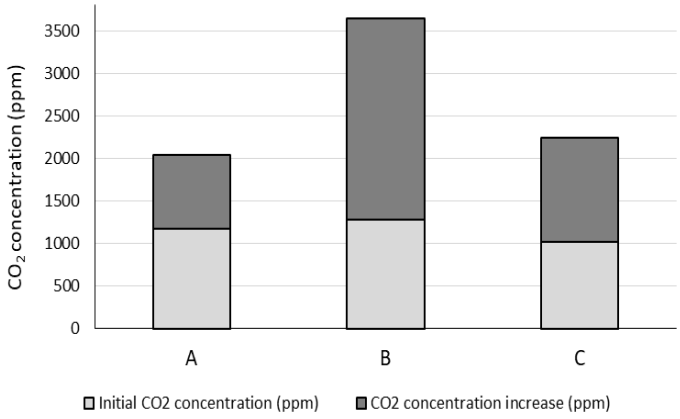

Fig. 8. Measured carbon dioxide concentration in the room

The measured increase in carbon dioxide concentration corresponds to the number of people present in the room.

Fig. 9 documents the perception of odor change during lessons. From Fig. 9 it can be stated that during the first lesson A, when there was the smallest increase in the level of carbon dioxide concentration, the fewest persons experienced an increased odor in the room.

The percentage of people experienced an increased odor in the room, when the highest concentration of carbon dioxide had not yet been measured during the third lesson B. However, the number of people who recorded the largest increase in the odor in the room was during the second lesson B, which corresponds to the measured increased concentration. carbon dioxide.

From the measured values of carbon dioxide concentration, the production of carbon dioxide was determined according to the methodology described in publications (Kapalo, 2018) and then the required ventilation intensity in the selected classroom was calculated. From the decrease of the carbon dioxide

concentration in the room, when there was no source of carbon dioxide production in the room, the ventilation intensity was calculated to be 0.31 1/h. The calculated required ventilation intensity of the room during the first lesson is 1.8 1/h, during the second lesson it is 4.2 1/h and the third lesson is 1.9 1/h.

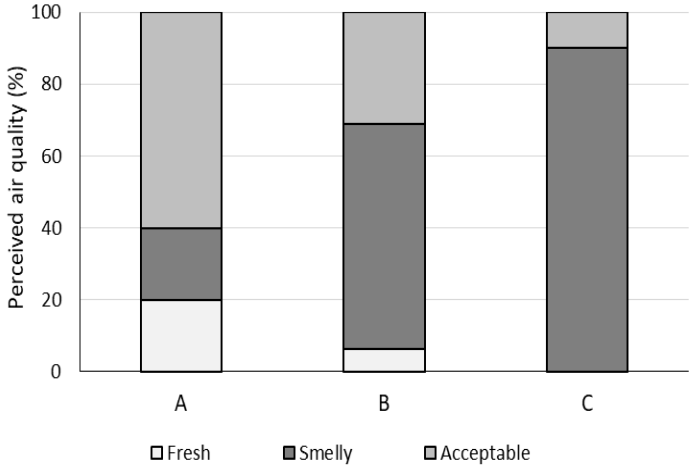

Fig. 9. Perceived odor in the room

Conclusions

During the experimental measurement, the measured values of carbon dioxide concentration were not known to the persons in the room. The values were found only after the completion of all experimental measurements. It is possible to assume that if there was a device for measuring the concentration of carbon dioxide in the classroom, which would give an acoustic signal after reaching the value of 1.000 ppm, the room present would start to ventilate the room. Often, however, people in the classroom are so preoccupied with the teaching process that they only notice a deterioration in air quality after they have left the room, when they leave the room and down the hall.

From the calculated room ventilation intensities, it is clear that during the stay of the persons in the classroom, 5.8 to 13.5 times higher ventilation intensity was needed than was actually provided.

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МОНІТОРИНГ ЯКОСТІ ПОВІТРЯ У ВИБРАНОМУ КЛАСІ

Під час дослідження "Експериментальне визначення оптимальної кількості повітря у вибраному приміщенні в Україні на основі вимірювань концентрації вуглекислого газу" було проведено експериментальне вимірювання у вибраній навчальній аудиторії України. Мета експериментального вимірювання – визначити зміну температури повітря, відносної вологості та концентрації вуглекислого газу під час навчального процесу. Потім за кривими концентрації вуглекислого газу можна розрахувати необхідну інтенсивність вентиляції у приміщенні. У статті викладено результати вимірювання температури повітря та концентрації вуглекислого газу в приміщенні, а також визначення реакції людей у приміщенні на якість повітря.

Низка досліджень підтверджують, що якість повітря у навчальних аудиторіях істотно впливає на здоров'я та успішність учнів і вчителів. Відповідно до Указу 527/2007 [1], приміщення, які використовують для навчання дітей та молоді, повинні опалюватися так, щоб забезпечити температуру не менше ніж 20 °C у приміщеннях, де учні працюють чотири години і більше. Для забезпечення повітрообміну від 20 до 30 м^3/год на учня необхідна вентиляція. Згідно з українським стандартом ДБН V.2.2-3: 2018, мінімальна температура повітря – 18 °C і повітрообмін 20 м^3/год на одну людину.

Можна припустити, що якби в класі був прилад для вимірювання концентрації вуглекислого газу, який би подавав акустичний сигнал після досягнення значення 1000 ppm, то приміщення почали би провітрювати. Однак часто люди в класі настільки зайняті навчальним процесом, що помічають погіршення якості повітря лише після того, як покинуть кімнату, вийдуть у коридор.

Ключові слова: концентрація вуглекислого газу; відносна вологість повітря; температура повітря; швидкість повітря; якість повітря; моніторинг.