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Suitable Conditions in University Teaching and Learning Spaces

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Abstract. The aim of this paper is to present the results of research focused on the microclimatic situation in the lecture room, seminar classroom, laboratory and large gym in the university campus. The attention is paid mainly to the problems of dimensions of space, number of students and intensity of ventilation or air-conditioning. Air temperature, relative humidity, concentration of CO_2, total dust pollution and PM_{10} fraction were measured in the frame of this research. The recommended level of CO_2 in the interior of 1,000 ppm was exceeded very significantly in all teaching rooms, only in the gym hall was lower thanks to sufficient ventilation and large volume of this space. The ventilation or air-conditioning controlled by the people was not sufficient. The solution can be the automatic control of ventilation or air-conditioning not only according to the temperature, but also with respect to the CO_2 concentration. The total dust concentrations and PM_{10} in rooms without sufficient ventilation was over the level 50 $\mu g \cdot m^{-3}$. Intensive ventilation reduced the dust concentration significantly.

Introduction

This paper is focused on the problems of quality of teaching and learning spaces in the universities. Lectures, seminars, laboratory works and other teaching and learning processes take place in enclosed spaces. The quality of the teaching process is mainly influenced by the teacher, but the quality of teaching rooms is also very important. Good feeling of students and teacher is influenced besides the interior arrangement and equipment also by suitable microclimatic conditions [1]. These are, in particular, appropriate air temperature and humidity, air purity from the point of view of oxygen, gaseous pollutants and dust pollution, acoustics and appropriate lighting [2].

International and national regulations and standards contain prescribed and recommended values of individual requirements and parameters that should be respected. Outputs and outcomes are quite frequently and generally observed in recent years, particularly in terms of lighting and acoustics [1, 3]. These values are also included and respected in the designing principles of rooms and buildings.

The reduction of the energy consumption of buildings, the indoor environment and the ventilation of schools, including university lecture halls, are a relatively topical issue. This is due to the fact that the effort to save energy for heating often leads to insufficient ventilation [4, 5].

Some scientific and professional papers emphasize the influence of indoor climate on human health [6, 7]. In some works is shown the importance of microclimate for schools [8, 9]. Inappropriate microclimate may contribute to higher sickness rate, and thereby increase the number of days when people do not come to school.

Human senses are not able to judge the concentration of CO_2, therefore the personal assessment of air quality is very unreliable. The human organism ceases to perceive the concentration of odour after a certain moment, and olfactory organs adapt to the environment in which people find ourselves. Certainly everybody knows the situation when a person enters to a small room where already several people are there. When one enters of the environment, he feels heavy breathing, but after a while he stops to perceive it as an inconvenience. His olfactory organs adapt, he stops to perceive the concentration of odours. However, at a certain concentration, the effect of carbon dioxide is reflected by human non-concentricity, faintness, etc. At higher concentrations, human fatigue is already increasing and headaches, etc. can occur. Table 1 summarizes the approximate effects of CO_2 on the human organism [10].

Table 1. Effects of CO_2 on the human organism.

Concentration CO_2 [ppm]	Effect on the human organism
about 350	Outdoor environment
up to 1,000	Recommended indoor conditions
1,200 – 1,500	Recommended maximum level in indoor areas
1,000 – 2,000	Beginning of fatigue and decreased concentration
2,000 – 5,000	Beginning of possible headaches
5,000	Maximum safe concentration without health risks
> 5,000	Nausea and increased heart rate
> 15,000	Breathing problems
> 40,000	Possible loss of consciousness

The attention to the CO_2 concentration in classrooms is paid in some scientific articles, e.g. [11]. According to this research the levels of CO_2 were very high in all studied schools and could be diminished by intensified ventilation (from 1,459 to 1,051 ppm). In article [4] authors compared concentration of CO_2 in classrooms with different systems of ventilation and recognized problems with very high concentration CO_2 (maximum 3,964 ppm). Main most difficult situation was in winter. Installation of automatic control system with CO_2 sensor improved the situation.

Measured dust is not aggressive, therefore, as a criterion for comparative evaluation of the measured values can be also used the limit level of outdoor dust. According to [12] limit value of dust fraction PM_{10} in 24 hours is 50 $\mu g \cdot m^{-3}$.

Material and Methods

For this research teaching and learning spaces were selected, which are typical for university studies. The basic parameters of these rooms are shown in Tab. 2. Room A is a tiered lecture hall used for lectures, equipped with air conditioning (AC) with air filtration, heating, cooling, air-humidification and regenerative heat exchanger. Second room B is flat classroom, used as a seminar room, ventilation is only through opened windows. Room C is a laboratory used for technical measurements and experiments. Ventilation is forced, with balanced pressure and heat recovery. The last room D is a large gym used by a students for sports games (volleyball, basketball, tennis, floorball, etc.). Ventilation is forced, with balanced pressure.

Table 2. Rooms used for the research and number of students during the measurement.

Room	Purpose	Volume [m^3]	Number of Students		Ventilation or Air-conditioning
			Seats	Present	
A	Lecture hall	374	127	40	Air-conditioning
B	Seminar room	176	30	10	Natural ventilation, windows
C	Laboratory	179	30	18	Forced ventilation, recuperation
D	Gymnastic hall	4,320	---	20	Forced ventilation

The thermal comfort in the space was continuously measured during the experiments by sensor FHA 646–21 including temperature sensor NTC type N with operative range from –30 to +100°C with accuracy ± 0.1°C, and air humidity by capacitive sensor with operative range from 5 to 98% with accuracy ± 2%. Furthermore the concentration of CO_2 was measured by the sensor FY A600 with operative range 0 – 0.5% and accuracy ± 0.01%. All these data were measured continuously and stored at intervals of one minute to measuring instrument ALMEMO 2690–8.

The total concentration of air dust was measured by special exact instrument Dust-Track aerosol monitor. After the installation of impactor the PM_{10} size fractions of dust was also measured.

Results and Discussion

Principal results of microclimatic conditions (mean values and standard deviation SD) inside the auditorium during the winter measurements in rooms A, B, C and D are summarized and presented in the Table 3 and 4 and on the Figure 1. Tables 3 and 4 show the results in teaching spaces during different level of ventilation or air-conditioning of the rooms.

Table 3. External temperature t_e, internal temperature t_i, relative humidity RH_i in the rooms during the measured periods.

Room	Measurement conditions	Measured Values		
-	-	$t_e \pm SD$ [°C]	$t_i \pm SD$ [°C]	$RH_i \pm SD$ [%]
A	AC off	1.6 ± 0.6	22.7 ± 0.1	38.9 ± 0.4
A	AC on	3.4 ± 0.3	22.7 ± 0.1	30.2 ± 2.3
B	Windows closed	9.4 ± 0.2	21.4 ± 0.5	39.8 ± 3.9
B	Windows opened	8.9 ± 0.1	20.7 ± 1.0	36.2 ± 7.3
C	Fans and ventilation of	0.3 ± 0.1	23.6 ± 0.2	30.2 ± 1.3
C	Fans and ventilation on	0.6 ± 0.1	23.8 ± 0.1	27.9 ± 1.6
D	Fans and ventilation on	7.2 ± 1.0	22.7 ± 0.1	41.3 ± 3.0

The air temperature corresponded approximately to the suitable temperature approximately from 22 to 24°C. Variations in temperature of air for the whole period were relatively small (see SD value). From the point of view of the thermal comfort of the indoor environment, neither the students nor the professor in the lecture room felt uncomfortably. Therefore, under normal conditions, the AC is usually remains switched off or ventilation is reduced. Relative humidity of air was also in suitable level approximately from 28 to 45% in all spaces throughout the whole measurement period.

Table 4. Concentration of carbon dioxide CO_2 and total dust concentration and fraction PM_{10} in the rooms during the measured periods.

Room	Measurement conditions	Measured Values		
-	-	$CO_2 \pm SD$ [ppm]	Total Dust ± SD [$\mu g \cdot m^{-3}$]	$PM_{10} \pm SD$ [$\mu g \cdot m^{-3}$]
A	AC off	2,075 ± 98	65.8 ± 15.1	57.6 ± 10.7
A	AC on	862 ± 427	15.6 ± 4.8	12.9 ± 2.9
B	Windows closed	1,463 ± 541	38.0 ± 5.0	32.7 ± 3.0
B	Windows opened	1,503 ± 744	16.9 ± 5.0	11.3 ± 2.0
C	Fans and ventilation of	1,367 ± 391	61.6 ± 10.0	53.8 ± 4.0
C	Fans and ventilation on	1,402 ± 242	60.0 ± 5.0	59.3 ± 3.0
D	Fans and ventilation on	740 ± 11	33.0 ± 7.0	29.0 ± 4.0

It is obvious from the Table 4 that the recommended level of CO_2 in the interior of 1,000 ppm was exceeded very significantly in all teaching rooms, only in the gym C was lower thanks to the sufficient ventilation and large volume of this space. Big values of SD are caused by the large increase or decrease of CO_2 concentration during the measured period.

A typical example of the CO_2 changes inside the teaching room is on the Figure 1. From the course of CO_2 concentration in seminar room B on Fig. 1 it is obvious that even if the initial CO_2 level was low (approximately 350 ppm) under influence of the metabolism by breathing in the auditorium, it increased further to 2,400 ppm. Neither students nor professor did not perceive increasing concentrations of CO_2 due to the slow gradual increase.

After 15 minutes the indoor environment was unpleasant for many people inside the room and therefore the windows were fully opened. By intensive ventilation through the opened windows the CO_2 concentration was gradually reduced from 2,380 ppm to 480 ppm.

If the teaching process lasts longer time, similar cycle of varying ventilation intensity usually changes; windows are closed again because students sitting near the windows suffer from drafts and colds. Then the CO_2 concentration rises again rapidly.

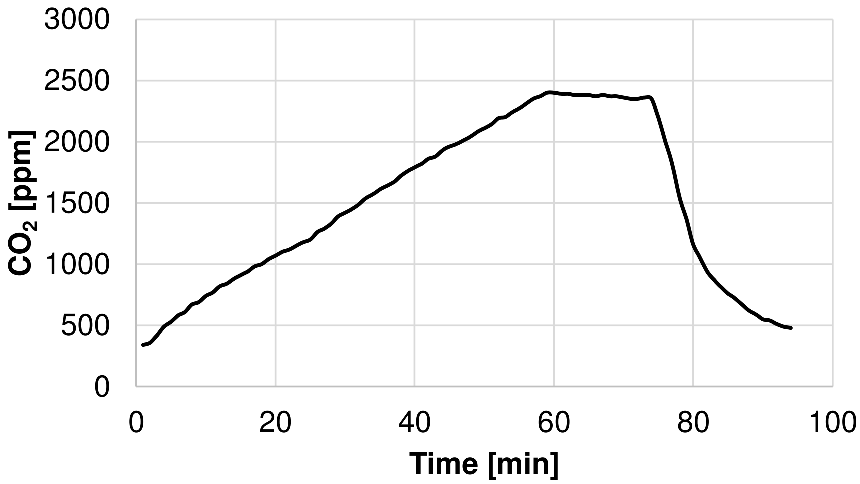

Figure 1. The course of CO_2 concentration during the measurement in the seminar room B.

The intensive ventilation in the lecture room A and seminar room B reduced the concentration of dust. The worst situation was in the laboratory C. Intensive ventilation did not reduced sufficiently the dust pollution inside. It can be explained by not good positioning of air inlets and outlets, not good quality of filters and not sufficient ventilation rate.

Conclusions

The results of main indoor parameters measurements presented in this paper show that the CO_2 concentration significantly exceeds the recommended maximum values inside the lecture rooms during the winter period. The internal temperature inside the lecture rooms and classrooms is increased only slightly (increment about 1 K), but the concentration of CO_2 grows rapidly. The reaction of people staying inside the rooms is disproportionately slow. The natural or forced ventilation controlled by the people (usually teacher) is therefore not sufficient.

The smaller the interior of the classroom and the greater the number of students is, the faster and more pronounced the indoor environment gets worse. Impaired quality of the indoor environment therefore reduces the student's attention and increases the risk of transmission of infectious diseases.

The suitable solution can be the installation of CO_2 sensors and automatic control of ventilation or air-conditioning not only according to the temperature, but also with respect to the CO_2 concentration.

The results of dust measurements showed that total dust concentrations as well as PM_{10} in rooms without sufficient ventilation was over the level 50 $\mu g \cdot m^{-3}$. Intensive ventilation can reduce the total dust concentration and therefore also the concentration of all dust particles, including fraction PM_{10}.

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