M.Sc. Peter Kapalo[1], Ph.D, Assoc. prof. M.Sc. Alena Pauliková[2], Ph.D
Technical University of Košice,
[1]Faculty of Civil Engineering,
Department of Technical Building Equipment
[2]Faculty of Mechanical Engineering,
Department of Environmental Studies

CONCENTRATION OF CARBON DIOXIDE IN VENTILATED ROOMS

Сьогодні існує глобальна тенденція до будівництва будівель, які класифіковані як низькоенергетичні будинки з теплотехнічного боку. Відповідно до природної вентиляції вони називаються жорсткі будинки. Обмін повітря за допомогою природної вентиляції в такому вигляді будівель знижується нижче необхідних значень згідно з гігієнічними нормами. З метою забезпечення необхідного повітрообміну потрібно встановити в цих будівлях примусову чи гібридну вентиляції.

Ключові слова: двоокис вуглецю, температура повітря, природна вентиляція.

On the present there is a global trend to construct buildings which are categorized like low-energy houses with regard to the thermal-technical viewpoint. According to the natural ventilation they are called tight buildings. An exchange of the air by means of natural ventilation in such kind of buildings is reduced below the hygienically required limit. In order to ensure the required air exchange it is necessary to install into these buildings the forced or hybrid ventilation.

Key words: carbon dioxide, air temperature, natural ventilation.

Carbon dioxide as a product of respiration. Human body of adult contains approx. 12.6 kg of carbon. Carbon is an element with the content of about 18 % in the human organisms. Redundancy of carbon atoms is removed from organism by means of respiration in the form of carbon dioxide. Energy released in such way is spent to vital processes. The carbon dioxide is transferred into the atmosphere also from the soil, water, due to decomposition of organisms and during combustion of organic matters. Energy, which is necessary for working processes, is obtained from oxidation of organic materials. The carbon dioxide is a gas without colour and odour and it is contained in the air. The exhaled air contains approx. 3,5 % of the CO_2. Such concentration is non-toxic for human. However, in the case of higher concentrations there are typical syndromes like hyperventilation, higher blood pressure and pulse, as well as reduced hearing. Even more increased concentration of the CO_2 causes serious damages to organism. At 10 % concentration occurs a blackout and comes on death due to suffocation. The 20 % concentration causes paralyse of vital centres in brain during several seconds.

During respiration the oxygen is supplied into the body and the carbon dioxide is taken away. During a restful breath and breathing out there is changed in lungs 0.5 litres of air. During a maximum breathing out after a maximum breath is changed 4 litres of air and in the case of trained sportsmen it can be more than 6 litres. The residual amount of remaining air in the lungs is 0.5 litres. The average value of respiration frequency depends on the age of person. In the case of baby it is 40 ÷ 45 breathings out per minute, for child it is 25 ÷ 30 and for adult 16 ÷ 20. The accelerated breathing means more than 20 breathings out per minute for an adult person and it can be increased up to value 100-times per minute in the case of a higher demand of oxygen consumption, i.e. during physical or psychical loading and due to a heat attack. The reduced respiration is less than 12 breaths per minute.

The breathing frequency value 14 ÷ 16 breathings out per minute means exchange of 7,5 litres of air per minute.

If there are concentrated persons in rooms that are ventilated insufficiently, the concentration of the carbon dioxide is increasing rapidly in a short time and it is necessary to ventilate such rooms with a

sufficient air exchange rate. Already the concentration level of the CO_2 over 0,1 % means an improper quality of air and if the concentration is over 0,25 %, thus the result is a harmful impact to human organism. The natural or forced ventilation has to ensure keeping of the required CO_2 concentration.

Ventilation of Buildings. Quality ventilation of buildings creates pleasant and health internal conditions for persons inside. Comfort of ventilation is perceived like a quality of indoor air, including evaluation of odour, thermal conditions and speed of air streaming. The ventilation system has to feed hygienic and healthy air without dangerous chemical and microbiological contaminants. The outdoor air incoming to internal areas has to be supplied in a sufficient amount, filtrated and with suitable moisture.

One of the most important factors of the indoor air quality is the odour component. The odour component acts on a human and it is a factor of comfort. Odour matters are gaseous components in the air that are perceived pleasantly or unpleasantly. It is possible to reduce the odour component into an acceptable level by means of ventilation. Criterion for evaluation of odour component is concentration of the CO_2 in interior. This indoor concentration is measurable more simply by means of measuring instruments. In the buildings with the forced ventilation there is measured the CO_2 level in order to regulate input of the fresh air into ventilated rooms. We are able to reduce operational costs, which are invested to ventilation and to air-conditioning plant by means of regulation of fresh air input. Sufficient ventilation can reduce concentration of harmful substances in the rooms with people.

The CO_2 concentration in rooms with persons is higher in comparison to the outdoor fresh air. The average CO_2 concentration during 24 hours should be 1000 ppm. If this concentration is higher than 1000 ppm, so more than 20 % of people are feeling unpleasantly. This fact is caused due to human respiration and perspiration. In the case of concentrations above 2000 ppm most of people are feeling very unpleasantly with nausea and headache.

Level of the CO_2 concentration in the interior depends on (these figures are valid for pure carbon dioxide):

- number of persons in the roomthe number of people present;
- time of staying in the room;
- how long an area has been occupiedamount of fresh incoming air the amount of outdoor fresh air entering the are;
- the size of the room or areavolume of ventilated space;
- vonkajšej koncentrácie CO_2 outdoor CO_2 concentration.

Measuring of Temperature and CO_2 Concentration. There is analysed in this paper quality of air in two ventilated rooms: in a session room and in a desk room. The fresh air in rooms is an unavoidable assumption for a health working environment and for an optimum working performance of individual employees. In the rooms with people various harmful substances pollute the air. The most relevant harmful substance caused by people is the carbon dioxide.

In the framework of this research was investigated a time behaviour of the temperature and CO_2 concentration during current operations at the given workplace. In this case the workplace was a school surrounding.

The first measuring was realized in the session room during a staff meeting with 14 persons. The volume of the room is 98 m^3. The initial indoor temperature was 25.6 °C and the CO_2 concentration was 500 ppm. During the staff meeting was opened a window partially in order to ensure a natural ventilation of the room. The time behaviour of the temperature and CO_2 concentration is recorded in the Fig.1,2. In the 4th minute from beginning of the measuring individual employees started entering the room. This process lasted to the 11th minute; the door and window were opened simultaneously. Due to an intermittent occurrence of a draught the CO_2 concentration was changing. After the 11th minute the door was closed and started a lecture up to the 30th minute. During the lecture was the CO_2 concentration stable and lower in comparison to entering process of persons. After the 30th minute started a discussion and the CO_2 concentration increased. The meeting finished after the 45th minute. During the whole time the temperature was growing due to the presence of persons. The CO_2 concentration did not reach the limit value 1000 ppm. So, in this case it was not necessary to apply a mechanical ventilation of this room.

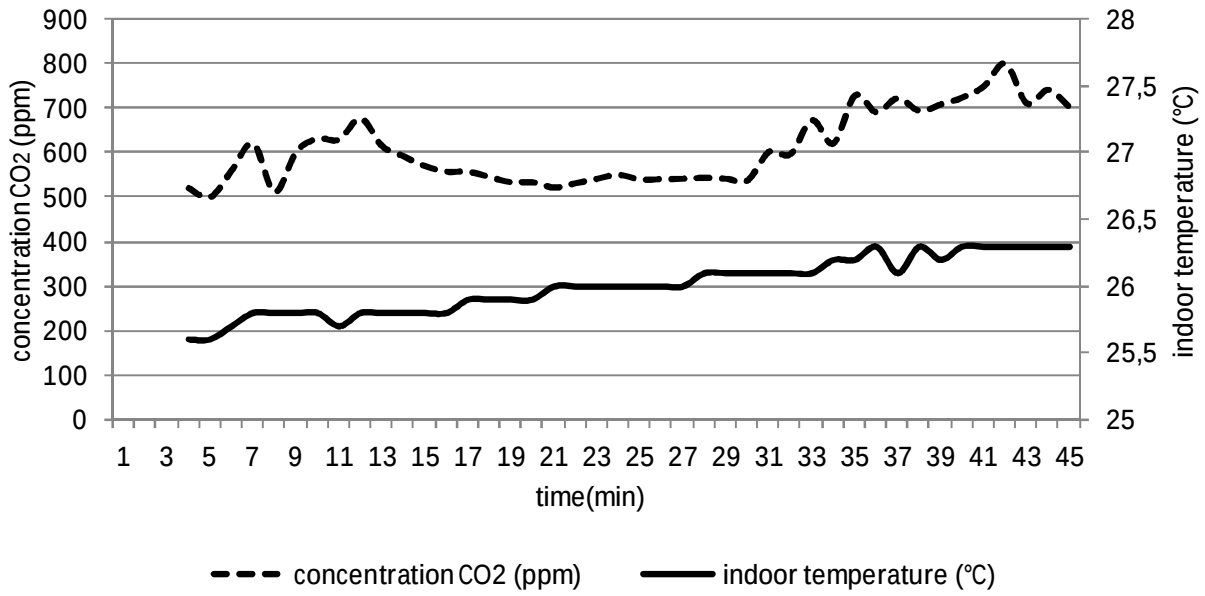

Fig. 1. Time behaviour of the temperature and CO_2 concentration in a session room

Fig. 2. Ventilation of session room

The second measurement was performed in a desk room with only one person. The volume of this room is 37 m^3. There was analysed a fact, which time is necessary for increasing of the CO_2 concentration over the limit 1000 ppm and how long time interval is necessary for reduction of concentration to the level of an outdoor air, if the window is closed. Window in the room has a damaged sealing and this fact causes a certain level of natural ventilation. The results of this measuring are presented in the Fig. 3. On the x-axis is the time course oriented from the right side to the left side, i.e. opposite in comparison to other graphs. The window was closed after the 4 p.m. In this time the indoor temperature was 25.1 °C and the CO_2 concentration was 492 ppm. From the 4 p.m. to 6 p.m. stayed one person in the room. The indoor temperature increased to the 25.8 °C and the CO_2 concentration reached 1050 ppm.

After the 6 p.m. the person left the room. The window and the door remained closed. The CO_2 concentration descended during the first next hour rapidly, but after 7 p.m. was decreasing moderate. The concentration value of outdoor air 415 ppm was reached in the room with closed window after 13.5 hours, however if the window is opened, this level was achieved in a short time 0.5 hour (this measuring is not illustrated in the figure).

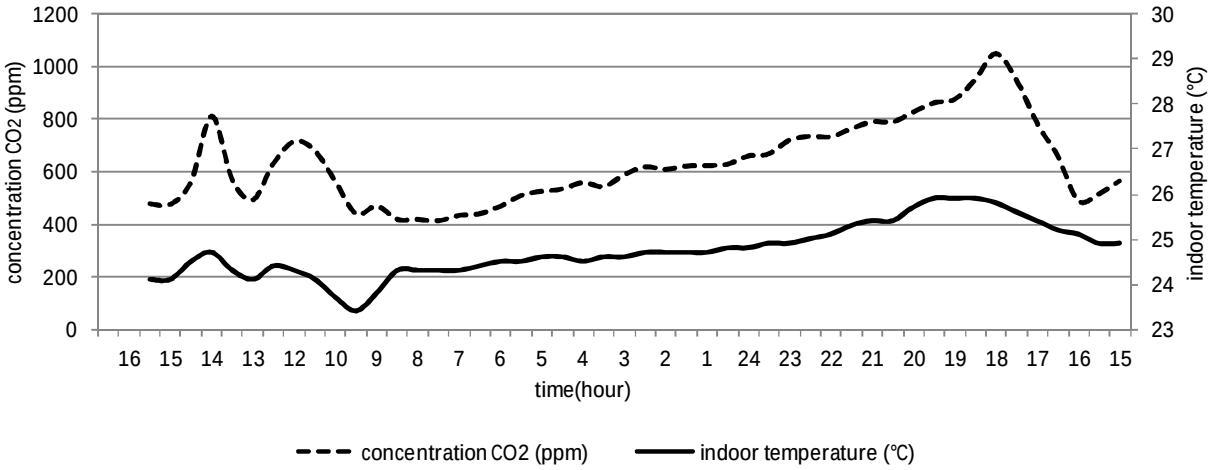

Fig. 3. Time behaviour of the temperature and CO_2 concentration in a desk room

Conclusion. According to the obtained results it is possible to state that the CO_2 concentration was not dangerous for human health. In the case of concentration above the 1000 ppm was perceivable a smelt as a result of human stay. In the next part of the research will be measured the CO_2 concentration together with the indoor air temperature and humidity. There will be investigated mutual relations among the individual measured values, as well as other collateral phenomena. The final output should be a suggestion of concrete scale of the CO_2 concentration and air humidity at various air temperatures, in order to define a necessary intensity of the room ventilation, taking into consideration also hygienic requirements concerning the given place of person stay, together with energetic requirements.

"This article was elaborated in the framework of the international scientific-technical cooperation between the Slovakia and Romania in the form of the APVV Project with the title Energetic Efficiency of Ventilation System, Identification Project No. SK-RO-0010-10".

1. Vykurovanie a vetranie nízkoenergetických domov. WITTNER HAUS spol. s r.o., wittner@wittner-haus.sk. 2. Alan Hedge: Psychologické aspekty kvality vnútorného ovzdušia. Katedra dizajnu a environmentálne analýzy. Cornell University, Ithaca, NY 14853, USA. 3. STN EN 13 779:2007 Vetranie nebytových budov. Všeobecné požiadavky na vetracie a klimatizačné zariadenia. 4. Koralová, K.: Evaluation of actual condition realisation of project "Eco-school" on all levels of schools in the term of the Slovak republic, In: International Joint Conference on Environmental and Light Industry Technologies, Budapest, Hungary. Óbuda University, 2010. – P. 35–38. 5. Kopas, M.: Plynné emisie leteckých prúdových motorov, In: Strojárstvo extra. č. 7÷8, 2011, S. 15/1. 6. Chovancová, J.: Systémy environmentálneho manažérstva, Prešovská univerzita v Prešove, I. vydanie, 96 s. Svetský, Š.: Multilingual Self-E-learning in Support of Sustainability. Online. ATVN-EU-GP-Warszav [cit.2011/02/15]. Available at http://www.atvn-eugp.pl/broker/resource/stefan svetsky.pdf