

**Peter KAPALO**

Faculty of Civil Engineering, Technical University of Košice, Slovakia

## ANALYSIS OF VENTILATION RATE IN THE OFFICE

The aim of the article is to establish the necessary air exchange rate in the room at the principle production carbon dioxide calculation and experiment. There was calculated CO<sub>2</sub> produced by humans in the room. Ventilation rate was calculated by several methods and compared with the measured carbon dioxide production.

**Keywords:** carbon dioxide (CO<sub>2</sub>) production, respiration, ventilation, air temperature, relative humidity

### INTRODUCTION

In recent decades, European standard of living has increased. The consequence is high energy consumption of buildings, the environmental burden on the environment. A larger number of appliances in a house increases energy consumption. The construction of buildings exerts great pressure on construction of low energy [1, 2]. By improving the thermal properties and air tightness of a building, there is a change of air quality in buildings. People living in the room can not guess the momentary air quality.

The aim of the research is to determine the necessary exchange of indoor air and eliminated pollutants on the basis of calculation and experiment.

### 1. CARBON DIOXIDE AS A PRODUCT OF RESPIRATION

Adult human body contains approximately 12.6 kg of carbon. Carbon is an element with the content of about 18% in 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 on vital processes. Carbon dioxide is a gas without colour and odour and it is contained in the air. The exhaled air contains approximately 4% of CO<sub>2</sub>. Such concentration is non-toxic for humans.

However, in the case of higher concentrations there are typical symptoms like hyperventilation, higher blood pressure and pulse. Even more increased concentration of CO<sub>2</sub> causes serious damages to organism. At 10% concentration occurs a blackout and comes death due to suffocation.

During respiration oxygen is supplied into the body and carbon dioxide is taken away. During a restful breath and breathing out there is changed in lungs 0.5 litre

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 litre. The average value of respiration frequency depends on the age of person. In the case of babies it is 40÷45 breathings out per minute, for children it is 25÷30 and for adults 16÷20.

Table 1. Composition of air inhaled and exhaled by healthy humans [1]

Breathing substance	Inhaled air [%]	Exhaled air [%]
Oxygen	20.96	15.4÷17
Carbon dioxide	0.04	4÷5.6
Nitrogen	78	78
Other gas	1	1

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.

## 2. CALCULATION OF THE VENTILATION RATE

In the course of the research there have been detected in the selected room (office for one person) environment parameters: temperature, relative humidity and carbon dioxide concentration (Fig. 1).

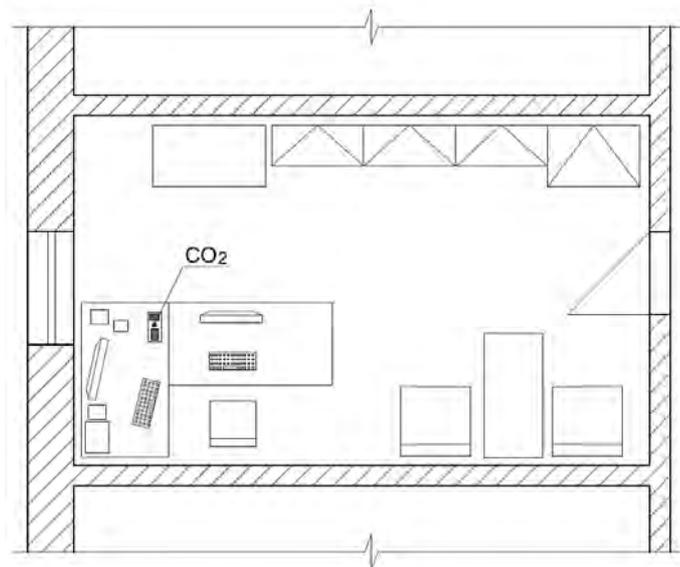


Fig. 1. Plan of the office with an indication of CO<sub>2</sub> concentration sensor

Experimental measurements were carried in the office with dimensions: length 5.63 m, width 3.4 m and height 2.72 m. The room is fitted with a window with dimensions: height 1.75 m and width 1.1 m.

Process carbon dioxide concentration in the air in the room is calculated [4]:

$$C_{IDA} = C_{SUP} + \frac{q_{m\dot{s}}}{q_V} \cdot \left\{ 1 - \exp \left[ \left( \frac{-q_V}{V_M} \right) \cdot t \right] \right\} \quad (1)$$

where:

$C_{IDA}$  - concentration of pollutants in the air in the room at the time  $t$  [ $\text{mg}/\text{m}^3$ ];

$C_{SUP}$  - concentration of pollutants in the air supply at a time  $t$  [ $\text{mg}/\text{m}^3$ ];

$q_{m\dot{s}}$  - mass flow of pollutants into the room from the source of pollutants [ $\text{mg}/\text{s}$ ];

$q_V$  - air flow required for room ventilation [ $\text{m}^3/\text{s}$ ];

$V_M$  - room volume [ $\text{m}^3$ ];

$t$  - time [s].

The formula (1) has been given values in Table 2 and  $C_{SUP} = 420$  ppm was measured in outdoor. For different values respiration intensity of results of the calculations are shown in Figure 2. The figure shows the measured value of  $\text{CO}_2$  production.

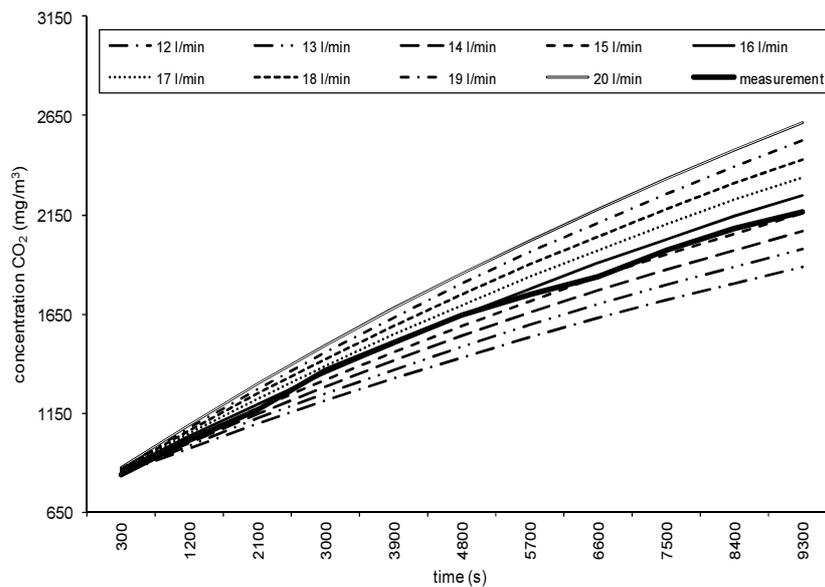


Fig. 2. Production of  $\text{CO}_2$  calculated for different respiration intensity

According to the measured and calculated values, it can be concluded that the production of  $\text{CO}_2$  created people with the intensity of breathing 15 l/min. This value is corresponding to the production of  $\text{CO}_2$   $q_{m\dot{s}} = 9.82$  mg/s.

Table 2. **Calculated production of CO<sub>2</sub> in varying degrees of breathing (0.5 litre for one inhalation/exhalation)**

Respiration intensity [l/min]	Volume inhale/exhale [l/s]	CO <sub>2</sub> production [mg/s]
13	0.11	8.51
14	0.12	9.17
15	0.13	9.82
16	0.13	10.47
17	0.14	11.13

### 3. DETERMINATION OF VOLUME FLOW OF FRESH AIR

Volume flow of fresh air we determine by graphically similar method such as concentration CO<sub>2</sub> [5, 6]. By making process concentration CO<sub>2</sub> we use Formula (1), to which we substitute mass flow CO<sub>2</sub>, volume of the room and calculated started concentration CO<sub>2</sub>. The calculation we perform for all hours and for different intensity of ventilation. The result is necessary adjusted so that the resulting value of concentration CO<sub>2</sub> was determined in units' ppm [7]. For our case, all results are shown in Figure 3.

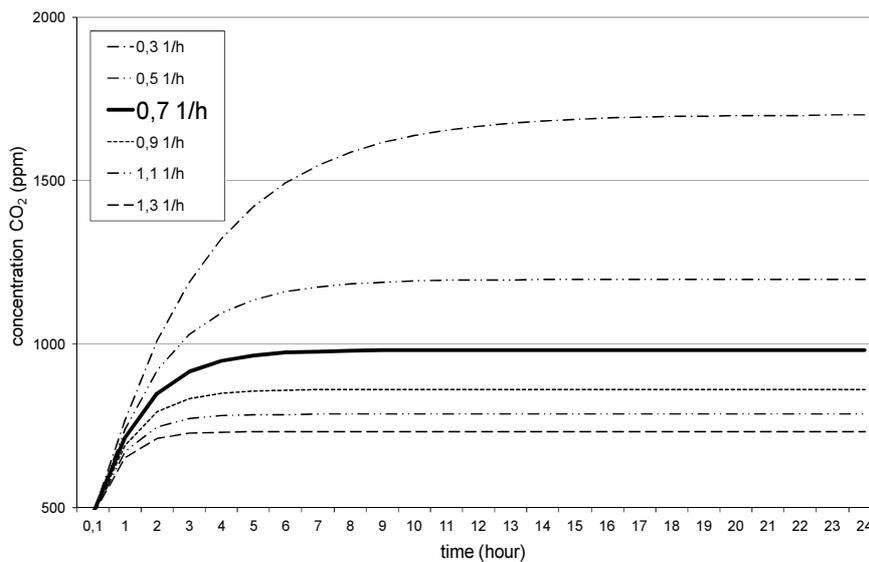


Fig. 3. The course of CO<sub>2</sub> concentration for different ventilation rates

If we have required level of CO<sub>2</sub> together 1000 ppm, in the picture we are looking for course of CO<sub>2</sub> concentration, which does not exceed the limit of the 1000 ppm. In our case is it course of concentration with an indication of intensity ventilation 0.7 1/h.

This method is exact enough but on finding necessary intensity ventilation is very hard and long. The resulting value of intensity ventilation we compare with values intensity ventilation obtained from other sources: legislation and standards applicable in Slovakia [8, 9].

## CONCLUSIONS

Needed value ventilation rate detected by measurement is 0.7 - multiple air exchange per hour in room. The resulting value of ventilation intensity we compared with values intensity ventilation obtained from other sources: legislation and standards applicable in Slovakia (Fig. 4).

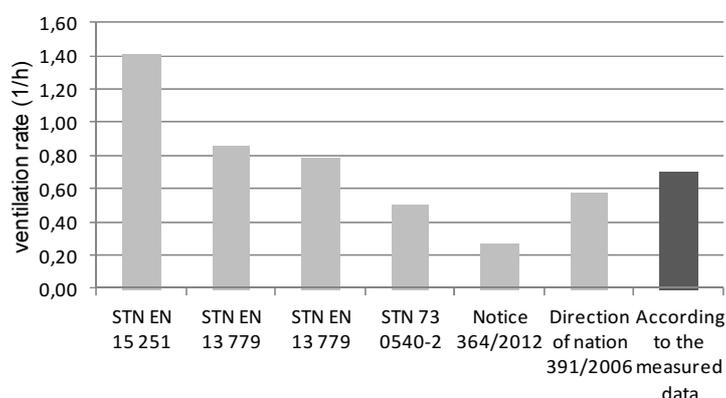


Fig. 4. Comparison of ventilation rates

According to the measured data of concentration of CO<sub>2</sub> and calculated value of ventilation intensity in the considered room it is possible to allege, that the result is the closest to actually necessary intensity of ventilation according to STN EN 13 779 [2].

## Acknowledgements

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### ANALIZA INTENSYWNOŚCI WENTYLACJI W BIURACH

**Przedmiotem artykułu jest określenie niezbędnej ilości wymian powietrza w pomieszczeniu biurowym w odniesieniu do produkcji dwutlenku węgla na podstawie kalkulacji i badań w warunkach rzeczywistych. Dokonano pomiarów ilości CO<sub>2</sub> wyprodukowanej przez ludzi w pomieszczeniu. Intensywność wentylacji oszacowano, porównując się kilkoma metodami i zestawiono ze zmierzoną ilością CO<sub>2</sub>.**

**Słowa kluczowe: produkcja CO<sub>2</sub>, oddychanie, wentylacja, temperatura powietrza, wilgotność względna powietrza**