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EFFECTS OF CO_2 ON THE ORGANISM DEPENDING ON ITS CONCENTRATION

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Abstract

Carbon dioxide (CO_2) may have toxic effects at concentrations much lower than the concentration at which its stifling effect of asphyxiant is reflected. In the workplace, the maximum permissible exposure limit of 5000 ppm is permitted on the average. However, there are certain places where the concentration of CO_2 in an enclosed room or area may potentially reach extreme and life-threatening levels. Extreme levels of CO_2 may lead to death, especially in enclosed spaces, such as in fermentation rooms or in the process of wine production or in breweries. CO_2 may have negative effects on health and safety at the workplace. Monitoring and control of CO_2 in the working environment is important for the safety and health of employees and is one of the approaches to a healthier environment in the workplace. The use of CO_2 sensors to control the ventilation can be an effective measure.

Keywords: *carbon dioxide, environment, monitoring the concentration of CO_2*

Introduction

Despite its known harmful to even deadly effect, carbon dioxide in the work working environment is still not paid enough attention. Carbon dioxide is dangerous for business and the environment. Of greenhouse gases, carbon dioxide is the most striking factor in global warming. Its quantities in the atmosphere are changing every year. For the past 30 years, however, scientists have observed a rising trend of its value to reach the level of about 3 ppm per year.[1] Intoxication by carbon dioxide in the working environment is generated by its uncontrolled build-up in the atmosphere, when a glut of CO_2 creates an unbreathable environment, for example. in fermentation rooms, silos, yeast factories, or wine cellars, where increased the concentrations of CO_2 are to be found, which is generated as a product of alcoholic fermentation by converting simple sugars to ethanol and CO_2. It is necessary to pay close attention to such operation sites. Implementation of the CO_2 control system by appropriate monitoring of the working environment is important for the safety and health of employees and is one of the approaches to a healthier environment in the workplace.

Carbon dioxide

Carbon dioxide is a colourless, not explosive, odourless gas heavier than air which is a normal constituent of the atmosphere (0.03-0.04%, or 300-400 ppm – parts per million of air particles). [2] Carbon dioxide itself is not toxic. Unlike carbon monoxide, it is heavier than air, so it accumulates in the ground, especially in poorly vented areas.

Carbon dioxide in the human body

Carbon dioxide belongs among the breathing gases. The main function of the respiratory system is to ensure an adequate exchange of respiratory gases (CO_2 and O_2) for metabolism between the surroundings and organisms (cells). This is a vital function, whose absence leads to irreversible changes and death within minutes. For resting metabolism, for example, that of 300 kJ/h, it is necessary to deliver about 240 ml of O_2 and 200 ml of CO_2 to the tissues every minute.

Breathing is controlled in an autonomous way and takes place at many levels. The most delicate mechanism governing the breathing is not the oxygen partial pressure, but the partial pressure of CO_2 in the arterial blood (p_aCO_2). Respiratory gases must be constantly transported, otherwise an important metabolic breakdown of tissues in the body, such as death, or respiratory arrest are threatening. The source of O_2 for the body is in the atmosphere. The source of CO_2 is only metabolism. The amount of CO_2 in the atmosphere is in terms of respiratory physiology is negligible. [3]

In spite of the absolute need for oxygen for metabolism, the respiratory activity is maintained by the concentration of CO_2 in body fluids. Carbon dioxide is transported by blood in two forms – as physically soluble and chemically bound in the plasma and in the red cells. Approximately 80-90% of CO_2 in the blood is in the form of bicarbonate, and 5-10% is dissolved in the plasma and bound to Hb (shares fluctuate in the venous blood and the arterial blood). CO_2 dissolved in the plasma is responsible for maintaining the activity of the respiratory centre. [2]

Effects of CO_2 on the organism depending on its concentration

In the exhaled air, there is about 4.5% of CO_2; concentrations above 5% are life-threatening. A person may be exposed to a maximum of 8 hours of inhaling the air of the concentration of CO_2 above 0.5%, for the elderly and for children the exposure time is shorter. CO_2 up to 3% in the inhaled air does not show toxic effects in the event that the air contains enough oxygen. At higher concentration of CO_2 in the inhaled air, the signs of hypoxia to anoxia arise. Dry ice from CO_2 can cause frostbite, its temperature is -42° C as opposed to ice from the water of the temperature of 0° C. CO_2 intoxication may arise when using fire extinguishers in a confined space and an extended stay in rooms with dry ice in the ventilation not working. [2]

Some international studies focus on the effects of carbon dioxide on human beings. Some studies explore the link between the increased concentration of CO_2 in the air and a decrease in productivity, decision making skills, and human performance. According to the Lawrence Berkeley National Laboratory in California, undesirable effects of the exposure to carbon dioxide occur at much lower concentrations than is the maximum NPEL permissible exposure limit. According to the study carried out, in which the decision-making performances have been rated, the test participants showed significant reductions in the six grades at levels of

CO_2 of 1000 ppm and at the levels of 2500 ppm, the performance was significantly reduced in in seven out of nine performance indicators, and the percentile order of some of the performance indicators dropped at the levels associated with marginal or dysfunctional performance. The most dramatic decrease in performance, in which the entities were rated as "dysfunctional", included the effort to be pro-active and to think strategically."[4]

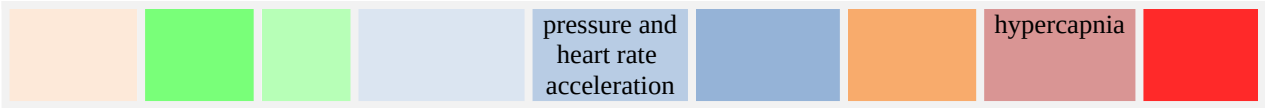
In the surveys of ambient concentrations of CO_2 in school classrooms in California and Texas, the average concentrations of CO_2 of over 1000 ppm have been measured, many have crossed 2000 ppm and in 21% of Texan classrooms the maximum concentration of CO_2 was higher than 3000 ppm [4]. Such high levels of CO_2 could have a particularly detrimental effect on the concentration. In general, if a large number of people gather in a room, CO_2 rapidly increases and contributes to poor air quality and its pollution, for example, in the boardrooms, where more staff members convene for an extended time in confined premises. Other places, such as gyms, shopping centres, cafés, bars, and libraries, are increasingly recognised as internal environment with higher CO_2that would be appropriate to monitor by detectors. For example, a newly built state of the art library in Geelong, Victoria, Australia, has installed CO_2 detectors.

The concentration of CO_2 of about 5% causes hypercapnia in 30 minutes, concentrations between 6 and 10% are fatal within a few minutes. CO_2 causes hypoxemia by removing oxygen from the atmosphere, in itself it is not toxic, but it has been shown experimentally that even without a decrease in oxygen concentration, CO_2 has a system toxic effect. Haemoglobin carries oxygen and CO_2 at the same time, but by different mechanisms. CO_2 is a mediator of self-regulation of the blood supply in the tissues, its increase causes vasodilation, improves perfusion in the tissues. Concentration of around 0.1% of the CO_2 in the air is to be found e.g. in crowded lecturing rooms with poor ventilation and causes drowsiness. At a concentration of more than 2%, symptoms may already occur, such as feeling of heaviness in the chest and breathing begins to deepen. Respiratory rate is doubled at a concentration of 3% and four times higher at the CO_2 concentration of 5%. At a concentration of more than 5% the CO_2 is directly toxic, up to that concentration it is only indirectly toxic by reducing the concentration of oxygen .[2]

Carbon dioxide poisoning is not related to the effects that occur in insufficient supply of oxygen, therefore the oxygen content in the air is not an effective indicator of intoxication. Individual tolerance limits may vary greatly depending on the physical condition of the person and the temperature and humidity of the air.

Table 1. Effects of the CO_2 depending on its concentration in the atmosphere

CO_2 in the air [ppm]	**350-450 -0.045 0.035%**	**600-1200 0.06-1.2%**	**> 1000 > 0.1%**	**3000 0.3%**	**5000 0.5%**	**10 000 1%**	**4-5%**	**6-10%**
Effects on organism	fresh air	room air	fatigue and difficulty concentrating	fatigue, drowsiness, deep breathing, decreased hearing and headache, increased blood	top permissible exposure limit, the average in the working air	rapid breathing, hypoxia,	respiratory rate is about four times faster, feeling of choking, poisoning symptoms and acute	nausea, coma, death within a few minutes



Monitoring the concentration of carbon dioxide in the atmosphere

Because we are able to assess the concentration of CO_2 by our senses, the subjective assessment of indoor air quality is very unreliable. The proof is in the number of fatal cases of intoxication of carbon dioxide in the atmosphere without monitoring the concentration of CO_2. [7]

The solution to this problem is the introduction of a system in the control of the CO_2 concentration in the working environment. For measuring the concentration of CO_2 in the air, a number of principles are employed. The most widespread are sensors, which operate on the basis of absorption of infrared radiation (non-dispersive infrared NDIR method), sensors, which operate on the electroacoustic principle, and sensors operating on the electrochemical principle. Each has its advantages and disadvantages.

Figure 1 shows a simplified diagram of the CO_2 sensor based on the NDIR. At its one end, there is a source of infrared light emitting LED, and at the other end there is a detector with a specific light filter to only detect the CO_2. The gas defunds into the chamber between the LED source and the detector. The amount of CO_2 in the chamber is directly proportional to the quantity of absorbed light.

The measurement itself is based on a method that uses two beams with two sources. The sensors operate on the principle of measuring the absorption of infrared radiation (of specific wavelength) in the air. The signal from the IR detector is further amplified and then by the use the other electronic devices it evaluates the attenuation of radiation, and on this basis the current concentration of CO_2 in the air is calculated.

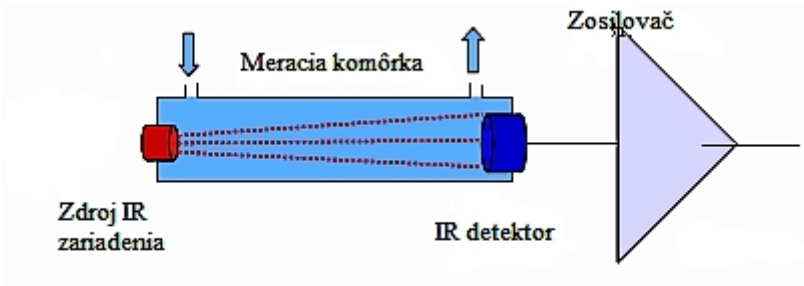


Fig. 1. A simplified diagram of the NDIR sensor (the Internet source)

Meracia komôrka = Measuring chamber
Zosilovač = Amplifier
Zdroj IR zariadenia = Source of IR device
IR detektor = IR detector

Sensors of all types of monitors usually have a continuous voltage output (0 to 10 V) or current output (0-20/4-20), which transmits the information on the concentration of CO_2 in the air to the superior ventilation system. [5]

Long-term stability of the CO_2 measurements is guaranteed thanks to the non-dispersed infrared (NDIR) CO_2 measuring sensor. The patented self-calibration process compensates for ageing of the infrared source, ensures high reliability of the measurements within the range of ± 1% a year and eliminates the need for periodic recalibration in the place of use. In addition to transferring the data to a computer and a mobile phone equipment of the operator, the T

sensor signals by colour and sound alerts the staff to the concentrations of CO_2 and the eventual abandonment of the site. The sensor also controls an external device – suction directly in the production. [6]

Conclusion

Carbon dioxide CO_2 is odourless gas. It is a normal product of metabolism. It arises when breathing, but also during different manufacturing processes, for example during fermentation. In the atmosphere, its amount is of about 0.04%, however, its amount keeps increasing and causes the greenhouse effect. Chronic intoxication in humans is unlikely to occur. However, research has shown that carbon dioxide is far more dangerous than it had been previously thought.

Despite the fact that it does not belong among toxic gases, in certain concentrations toxic effects occur and appear at a concentration of 2%, at the level of 5% of the content, the body is no longer able to vent the carbon dioxide, and its accumulation in the body starts. Carbon dioxide suppresses the central nervous system and the respiratory centre. The affected persons complain of headaches and a feeling of suffocation.

The resulting evaluation of the time-weighted average of concentration of carbon dioxide during eight hours of exposure and subsequent comparison with the highest permissible exposure limit, as is average in the workplace atmosphere, is questionable. Is it even possible to average the values of carbon dioxide?

For the chemical substances which are potentially dangerous under the level of human perception, continuous monitoring devices should be used. With the employees who are exposed to carbon dioxide health protection is paramount. Monitoring of the workplace air should be a prerequisite for greater safety in the workplace.

The monitoring device with a link directly to the exhaust, as well as providing information online, can be a convenient choice in all plants where the CO_2 release takes place, for example in the food industry.

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