Testo Whitepaper
CO_2 monitoring and
indoor air quality

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Formation and effect on human health.

Carbon dioxide is a colourless and odourless gas. It is a natural component of ambient air, at a concentration of around 400 ppm (parts per million). CO_2 is formed during the complete combustion of carbonaceous substances with sufficient oxygen supply. In the organisms of living creatures, it is formed as a metabolite of cell respiration.[1] At higher concentrations upwards of 1000 ppm, significant negative effects on the general well-being can occur (headaches, fatigue, lack of concentration).[2]

Carbon dioxide is produced in the body's cells (at quantities of 0.7 kg per day), and diffuses from there to the surrounding capillaries. It is transported in the blood after chemically binding onto proteins such as haemoglobin, or in dissolved form. CO_2 is largely physically dissolved, only a small part is converted by carbonic anhydrase in the red blood corpuscles into carbonic acid which disintegrates into hydrogen and hydrogen carbonate ions in the aqueous environment. The carbon dioxide is exhaled via the alveolar membrane of the lung. A crucial physiological function of the carbon dioxide in the organism consists in its regulation of breathing via the chemical receptors of the aorta and the medulla oblongata, which stimulate the respiratory centre in the brain stem. Increased CO_2 concentrations in inhaled air increase the breathing frequency and the tidal volume. During this process, CO_2 has a dilatory effect on the bronchia, which causes an increase in the dead space volume (the space in the respiratory system which is not involved in gas exchange). However, the dilatory effect of the CO_2 on peripheral and central arterioles does not lead to a decrease of blood pressure, since an increased adrenalin production causes a compensatory vasoconstriction.[3]

Effect of different CO_2 concentrations

Concentration	Effect
350 to 450 ppm	Typical atmospheric concentration
600 to 800 ppm	Reliable indoor air quality
1000 ppm	Upper range of reliable indoor air quality
5000 ppm	Maximum workplace concentration over 8 hours
6000 to 30 000 ppm	Critical, only short-term exposure
3 to 8 %	Increased breathing frequency, headaches
> 10 %	Nausea, vomiting, loss of consciousness
> 20 %	Rapid loss of consciousness, death

Fig.1: Effect of different CO_2 concentrations

CO_2 in indoor air.

CO_2 is viewed as a leading parameter for human-induced air pollution, since the increase of indoor CO_2 concentration correlates well with the increase of the intensity of odours arising from human metabolism. The CO_2 content of the indoor air is thus a direct expression of the intensity of a room's use. It is therefore also suitable as an orientation marker for other areas of regulation such as for the dimensional planning of ventilation and air conditioning systems or for ventilation instructions in naturally ventilated, densely used rooms such as schoolrooms or assembly rooms.[4]

In indoor spaces which are in use, the CO_2 concentration depends mainly on the following factors:

- **Number of persons in the indoor space, space volume**
- **Activity of the indoor space's users**
- **Duration spent by the users in the indoor space**
- **Combustion processes in the indoor space**
- **Air exchange and outer air volume flow**

A rapid increase of CO_2 concentration in the indoor air is the typical consequence of the presence of many persons in relatively small spaces (e.g. assembly, conference or schoolrooms) with a low air exchange rate. Critical CO_2 concentrations generally occur together with other air contamination factors, in particular odourous substances from sweat or cosmetics, as well as microorganisms. In airtight constructions with their very low air exchange rates, the CO_2 concentration can increase even in the presence of only a few people (e.g. in apartments or offices). In both cases, the CO_2 has a direct influence on how comfortable people in feel in a room. The European Collaborative Action (ECA) has arrived at the following levels of dissatisfaction based on model calculations. From 1000 ppm, around 20 % of room users can already be expected to be dissatisfied, rising to approximately 36 % at 2000 ppm.[5]

While assembly or conference rooms are as a rule only used occasionally and for short periods, schoolrooms, in the light of the regular presence of students and teachers over hours, must be viewed as particularly critical with regard to the CO_2 concentration in the classroom air. Current and past studies in several German states on the carbon dioxide contamination of indoor air in schoolrooms have consistently demonstrated considerable deficits in indoor air quality with regard to this parameter.[6]