Carbon Dioxide – Life and Death

What is Carbon Dioxide?

Carbon dioxide is one of the more frequent found gases on the earth. It is a main product in combustion processes and the natural metabolism of living organisms.

We inhale oxygen and exhale carbon dioxide. The carbon dioxide level in exhaled air is rather constant about 3,8 % (38.000 ppm). When carbon dioxide is exhaled it will quickly be mixed with the surrounding air and, if the ventilation is good, the concentration will be reduced to harmless levels.

Indoor CO_2 levels usually vary between 400 and 2000 ppm (parts per million). Outdoor CO_2 levels are usually 350 - 450 ppm. Heavily industrialized or contaminated areas may periodically have a CO_2 concentration of up to 800 ppm. The levels of outdoor CO_2 are higher in areas where traffic is very heavy.

CO_2 must not be confused with carbon monoxide (CO), a very toxic gas that is a by-product from poor combustion in i.e. cars and fireplaces. Carbon monoxide is dangerous at very low concentrations (25 to 50 ppm).

Is CO_2 an indoor air pollution?

Carbon dioxide is not seen as an indoor air pollution but it is a suitable tracer gas for indicating possible micro-organisms generated by people that contributes to deteriorated comfort. This is why a higher level of pure CO_2 is permitted in industrial environments, than in buildings where people- generated micro-organisms and CO_2 is the principal concern. In industrial environments where process generated CO_2 dominates (or CO_2 not generated by people), for example in breweries, packaging industry, freezer storages etc, the maximum permitted CO_2 concentration according to most standards is as high as 5.000 ppm during an 8-hour working period. You will not find such high levels in a home or in an office environment where people are the main source of carbon dioxide.
Even if CO_2 itself is not dangerous in normal concentrations it is frequently used as a reference and an indicator of indoor air quality and therefore ventilation performance. That is due to the fact that people, when they exhale CO_2, even exhale and emit many other

micro-organisms. These micro-organisms may be gases, odours, particles and germs. When the concentration of these micro-organisms, as a result of bad ventilation, is permitted to increase in a room, occupants complain of tiredness, headache, and even worse; feeling of sickness. Carbon dioxide itself does not give these problems until high levels are developed. High CO_2 levels in a room occupied by a lot of people indicates that the air is likely to be contaminated.

How can CO_2 measuring give an indication of the ventilation efficiency in a room?

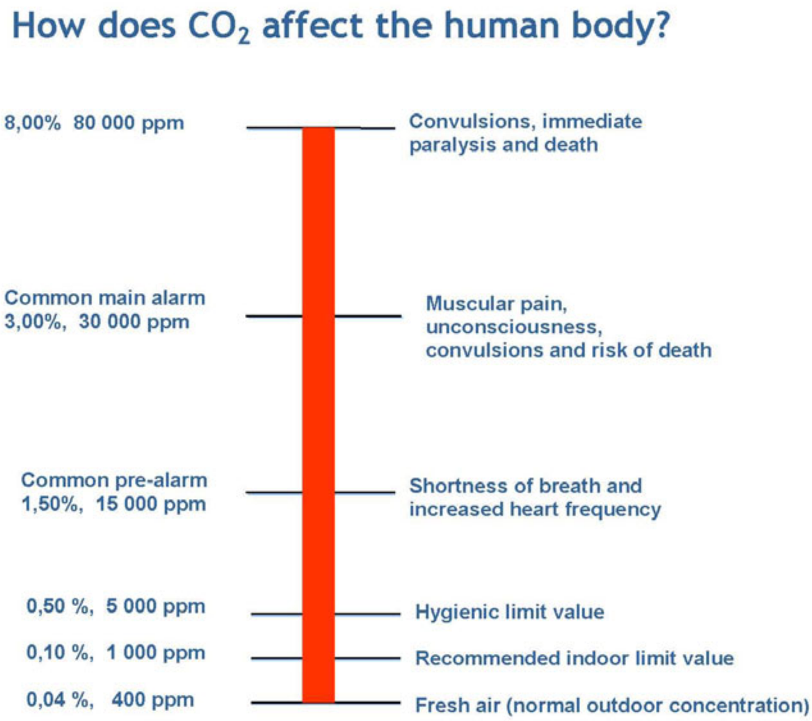
CO_2 measurement inside a building dynamically measures the relationship between CO_2 generated by people, and the "dilution effect" given by the mechanical ventilation or draught. If the difference between indoor and outdoor concentration is known and the indoor concentration is stable, it is possible to relate this CO_2 concentration to the ventilation system performance.

A difference of 700 ppm corresponds to an air intake of 10 litres/second and person. The maximum value of 1000 ppm recommended by, among others, the Swedish Work Environment Authority and AHR, can be directly related to the "dilution effect" that occurs when you bring outdoor air with a carbon dioxide level of 400 ppm into a room and have an air flow of 7 litres/second and person.

Organizations and authorities all over the world have established recommen-dations for the maximum permitted concentration of carbon dioxide and/or permitted minimum air flow in occupied buildings:

5.000 ppm	Maximum concentration during an 8-hour working-day according to the Swedish Work Environment Authority
2.000 ppm	According to many investigations this level produces a significant increase in drowsiness, tiredness, headache and a common discomfort
1.000 ppm	According to the American ASHRAE 62-1989 this is the recommended maximum carbon dioxide concentration in a room. It is also a recommended as the maximum comfort level in many other countries, i.e. Sweden and Japan. It corresponds to an airflow (a need of fresh air) of approx 7 litres/second and person.
800 ppm	The company Ericsson, for example, suggests this value as a maximum carbon dioxide level. It is also a maximum permitted concentration for offices in California. It corresponds to an airflow (a need of fresh air) of about 10 litres/second and person.
400-600 ppm	Risk for over - ventilation
350-450 ppm	A common outdoor concentration

Because CO_2, like all gases, will rapidly diffuse in outside air, variations in concentrations in a parti-cular location are generally less than 50 ppm and tend to be seasonal in nature. CO_2 is also one of the most plentiful by-products of combustion (9% to 13% by volume) and as a result, outside air measurements can be affected by extremely localized sources of combustion such as exhaust flues or running vehicles. Measurement of outdoor CO_2 levels above 500 ppm may indicate that a significant combustion source is nearby. An indoor CO_2 measurement provides a dynamic measure of the balance between CO_2 generation in the space, representing occupancy and the amount of low CO_2- concentration outside air introduced for ventilation. The net effect is that it is possible to use CO_{2}- concentration to determine and control the fresh air dilution rate in a space on a per person basis.



Advantages of measuring Carbon Dioxide

- ### Good economy and performance

There are a lot of different advantages of measuring carbon dioxide. CO_2 is the dominating gas in all kinds of open combustion. Therefore it is a good indicator of the *total emission load* of internal-combustion engines. Because CO_2 is the dominating emission gas, you can define this total emission load with high reliability at a very low cost by using IR-technology.

- ### CO_2 is a neglected health hazard

Since the share of cars with catalytic converters is increasing rapidly, it is, for reasons of health, important to measure the CO_2 concentrations. From a warm engine, when the catalytic converter is fully efficient, great concentrations of CO_2 are emitted, in comparison to the *toxic* exhaust substances. In this case the CO_2 gas could actually constitute the potential threat. It would therefore be irresponsible to disregard this risk (product *aSENSE mIII)*

- **CO_2 as an exhaust indicator correlates with all toxic emissions**

Using demand controlled ventilation where you make sure that the CO_2 concentrations are kept low, the toxic emissions will also be ventilated automatically. If you are interested in knowing the exact relations in this case, you must, for example in the return air duct, measure the air mixture regarding all relevant gases, including CO_2. The occurrence of the different gases, relative CO_2, gives you a value of the average exhaust mixture of the current vehicles at this particular time. This value can be used to make an approximate calculation of each gas concentration´s time variation along the entire system where CO_2 sensors are installed (e.g. in road tunnels or garages). The locally measured CO_2 emissions give you the exhaust quantity and, at this particular time, the centrally measured mixture gives us the local concentration of NO_2 and, if requested, also CO. This solution admits flexibility in the event of possible future changes concerning ventilation components and/or air quality regulations.

- **CO_2 is an excellent fire indicator**

A CO_2 sensor can also function as a fire detector. In case of an open fire, very high concentrations of CO_2 are emitted within a short time interval. Much higher concentrations than what could ever be generated from internal-combustion engines. Hot high concentration CO_2 gas is developed and quickly spread together with the fire smoke. Fire tests show that the CO_2 ”cloud” actually spreads faster than the possible smoke. In all cases of open test fires, according to the EN54 norm, *CO_2 was found to be the absolute best (=fastest) fire indicator (ref.3)*. Also, at some alcohol- and gasolin fires, no smoke is developed but still the CO_2 emission is very high. Unlike optical or ionizing smoke detectors, the CO_2 fire detection technology is secure to false alarms, which is most obvious in dirty and dusty environments where smoke can occur out of reasons other than fire.

Demand-controlled ventilation (DCV)

Either too little or too much fresh air in a building can be a problem. Over-ventilation results in higher energy usage and costs than are necessary with appropriate ventilation while potentially increasing IAQ problems in warm, humid climates. Inadequate ventilation leads too poor air quality that can cause occupant discomfort and health problems. The solution of the problem is Demand-controlled ventilation (DCV) using carbon dioxide (CO_2) . The heating, ventilation and air-conditioning (HVAC) sytem can use DCV to tailor the amount of ventilation air to the occupancy level.

Energy - saving mechanism

To ensure adequate air quality in buildings, the American Soceiety of Heating, Refrigerating and Air -Conditioning Engineers (ASHRAE) recommends a ventilation rate of 15–20 cfm per person. To meet this standard, many ventilation systems are designed to admit air at the maximum level whenever a building is occupied, as if every area were always at full occupancy. The result, in many cases, has been buildings that are highly overventilated.

The energy savings from CO_2 sensors for DCV result from the avoidance of heating, cooling and dehumidifying fresh air in excess of what is needed to provide recommended ventilation rates.

Advantages of CO_2 - based DCV:

- **Improved IAQ**

By increasing the supply of fresh air to the building, if CO_2 levels rise to an unacceptable level, the technology could prevent under-ventilation that results in poor air quality and stuffy rooms.

- **Improved humidity control**

In humid climates, DCV can prevent unnecessary influxes of humid outdoor air that causes occupants to be uncomfortable and encourages the growth of mold and mildew.

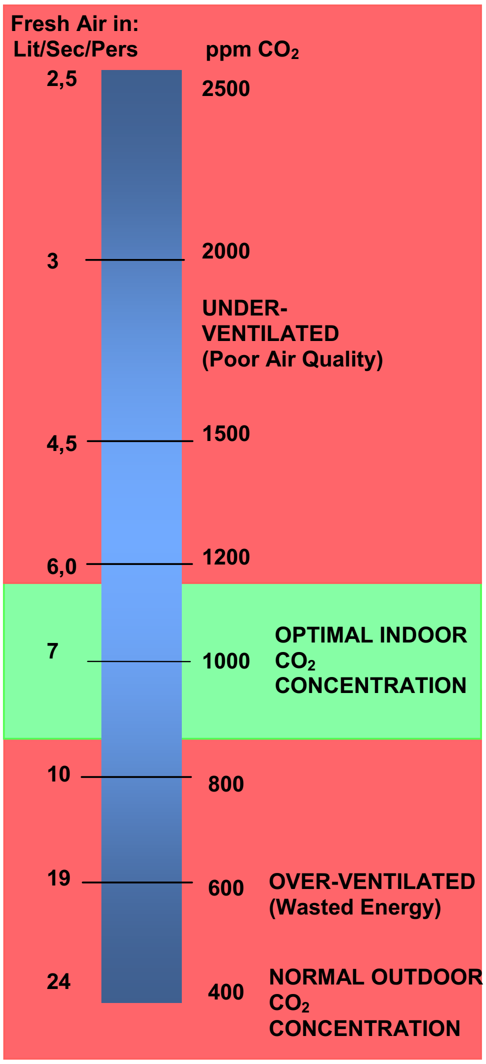
- **Records of air quality data**

Sensor readings can be logged to provide a reliable record of proper ventilation in a building. Such records can be useful in protecting building owners against ventialtion-related illness or damage claims.

- **Estimated savings**

The potential of CO_2-based DCV for operational energy savings has been estimated in the literature between $0.05 to more than $1 per square foot annually. The highest payback can be expected in high-density spaces in which occupancy is variable and unpredictable (e.g., auditoriums, some school buildings, meeting areas and retail establishments), in locations with high heating and/or cooling demand and in areas with high utility rates.

Improving the ability to condition the building could delay start-times of the HVAC equipment during morning pre-conditioning periods by as much as several hours on a Monday morning in humid climates, resulting in incremental energy and cost savings.



About the Technology

Demand-controlled ventilation(DCV) using carbon dioxide (CO_2) sensing is a combination of two technologies: CO_2 sensors that monitor CO_2 levels in the air inside a building, and air-handling systems that uses data from the sensors to regulate ventilation. CO_2 sensors continually monitor the air in a conditioned space. Since people exhale CO_2 the difference between the indoor CO_2 concen-tration and the level outside the building indicates the occupancy and/or activity level in a space and thus its ventilation require-ments. The sensors send CO_2 readings to the ventilation controls, which automatically increase ventilation when CO_2 concentrations in a zone rise above a specific level.

NDIR

Non-Dispersive Infrared (NDIR) technique. relies on the fact that molecules absorb light (electro-magnetic energy) at spectral regions where the radiated wavelength coincides with internal molecular energy levels. In accordance to well known quantum mechanical theory in physical chemistry such energy resonances exist in the mid-infrared spectral region due to interatomic vibrations. Since different molecules are formed by different atoms (with different masses) the vibrational resonance frequencies (and wavelengths) are different for every specie. This fact is the basis for *gas sensing through spectral analysis*. By detecting the amount of absorbing light, within just a small spectral region that coincides with the resonance wavelength of the specie selected, one gets *a measure of the number of molecules of this particular specie, free from interference of other species*.

Well known properties of *NDIR* gas detection are:

- *high selectivity - free from cross-interference*
- *sensitive & accurate*
- *environmentally resistant*
- *able to put on stock over long time periods*
- *no over exposure problems (no negative*
- *memory effects or exposure hysteresis)*
- *described by relatively simple physics (predictable)*

Differences between *CO_2 sensors* and *VOC sensors*

People (still) sometimes ask about the differences between *Air quality sensors (VOC sensors)* and *CO_2 sensors*. These sensors are not interchangeable. They measure very different things. In fact, because carbon dioxide is an inert gas, it is one of the few elements that will not cause an *air quality sensor* to react. Also, *CO_2 sensing* technology is stable and is not subject to the short-term, random drift found in *air quality sensors*.

Most *carbon dioxide sensors* only measure CO_2. People are the principal source of CO_2 in indoor air. Outside levels tend to be at a relatively low level and are fairly constant. An indoor CO_2 measurement can be compared to outside concentrations to provide an indication of the amount of outside air ventilation, on a cfm-per-person basis, that is being provided to an occupied building space.

An *air quality* sensor cannot indicate ventilation rate. It also cannot necessarily indicate whether safe or harmful concentrations of contaminants are present. It can indicate a general change in the concentration of contaminants. A CO_2 measurement cannot indicate if outside air quality is good, although a high outside CO_2 level (over 600 ppm) can indicate the outside air is quite polluted. A *CO_2 sensor* controls the ventilation rate in occupied spaces.

Air quality sensors are best used in applications where unusual, non-occupant-related sources periodically may be present. As a control, the sensor can activate an alarm or mitigation strategy (activate filters or ventilation).

Both approaches can be applied to a demand-controlled ventilation strategy, but the results may be very different. In the case of CO_2, *energy savings* can result because ventilation is based on actual occupancy of the space rather than the design occupancy of the space.

Energy is saved when pollutant loads are low and ventilation can be reduced, which may occur during or after occupied hours. Where a *CO_2 sensor* would specifically reduce ventilation during unoccupied periods, an *air quality sensor* may actually maintain ventilation rates during unoccupied periods if there is a significant pollutant level in the building.

In the case of *IAQ sensors*, ventilation is regulated based on the actual presence of some pollutants sensed by the air quality sensor. This may or may not conflict with established ventilation codes.
These sensors can also be used to sense periodic episodes of high pollution that might occur when special equipment is being used, or when potent chemicals from cleaners are released into the air.

All *air quality sensors* are basically the same. Some manufacturers of *air quality sensors* are now providing an output in " *CO_2 equivalent units*." This measure is considered misleading and may confuse many new to the indoor air quality industry.

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