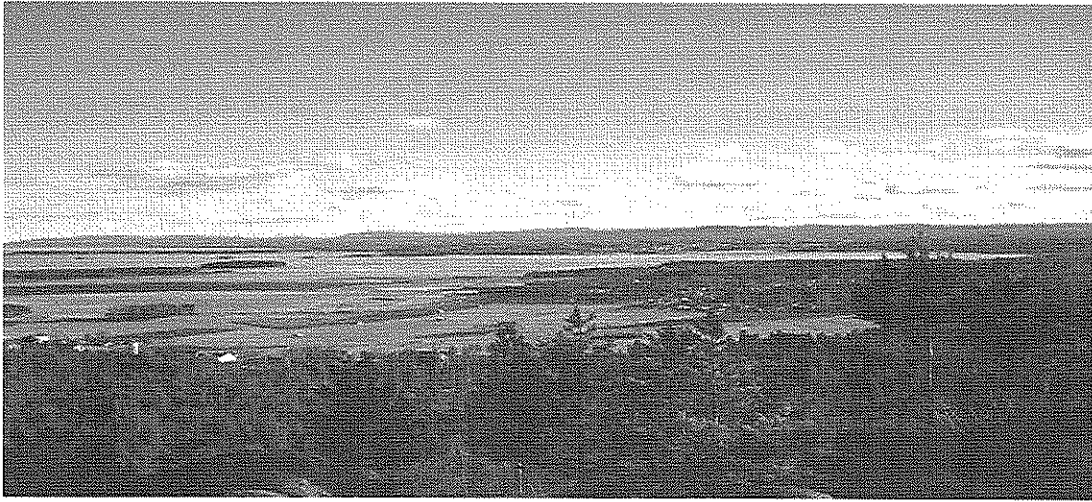


# Carbon Dioxide – Life and Death



## What is Carbon Dioxide?

Carbon dioxide is one of the more frequent found gases on the earth. It is a by-product of 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<sub>2</sub> levels usually vary between 400 and 2000 ppm (parts per million). Outdoor CO<sub>2</sub> levels are usually 350 - 450 ppm. Heavily industrialized or contaminated areas may periodically have a CO<sub>2</sub> concentration of up to 800 ppm. The levels of outdoor CO<sub>2</sub> are higher in areas where traffic is very heavy.

CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> is permitted in industrial environments, than in buildings where people-generated micro-organisms and CO<sub>2</sub> is the principal concern. In industrial environments where process generated CO<sub>2</sub> dominates (or CO<sub>2</sub> not generated by people), for example in breweries, packaging industry, freezer storages etc, the maximum permitted CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>, 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<sub>2</sub> levels in a room occupied by a lot of people indicates that the air is likely to be contaminated.

## How can CO<sub>2</sub> measuring give an indication of the ventilation efficiency in a room?

CO<sub>2</sub> measurement inside a building dynamically measures the relationship between CO<sub>2</sub> 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<sub>2</sub> 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 recommendations 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<sub>2</sub>, like all gases, will rapidly diffuse in outside air, variations in concentrations in a particular location are generally less than 50 ppm and tend to be seasonal in nature. CO<sub>2</sub> 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<sub>2</sub> levels above 500 ppm may indicate that a significant combustion source is nearby. An indoor CO<sub>2</sub> measurement provides a dynamic measure of the balance between CO<sub>2</sub> generation in the space, representing occupancy and the amount of low CO<sub>2</sub>- concentration outside air introduced for ventilation. The net effect is that it is possible to use CO<sub>2</sub> concentration to determine and control the fresh air dilution rate in a space on a per person basis.



## How does CO<sub>2</sub> affect the human body?

8,00% 80 000 ppm

Convulsions, immediate  
paralysis and death

Common main alarm  
3,00%, 30 000 ppm

Muscular pain,  
unconsciousness,  
convulsions and risk of death

Common pre-alarm  
1,50%, 15 000 ppm

Shortness of breath and  
increased heart frequency

0,50 %, 5 000 ppm

Hygienic limit value

0,10 %, 1 000 ppm

Recommended indoor limit value

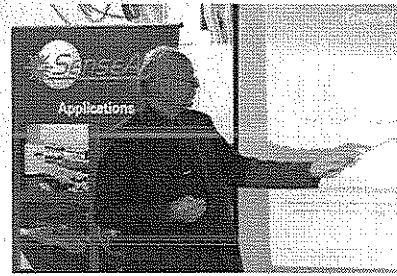
0,04 %, 400 ppm

Fresh air (normal outdoor concentration)

## Advantages of measuring Carbon Dioxide

- **Good economy and performance**

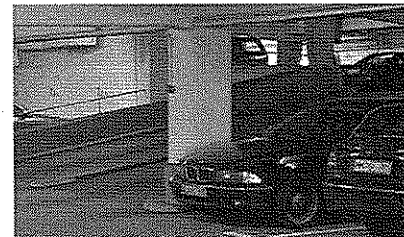
There are a lot of different advantages of measuring carbon dioxide. CO<sub>2</sub> is the dominating gas in all kinds of open combustion. Therefore it is a good indicator of the *total emission load* of internal-combustion engines. Because CO<sub>2</sub> is the dominating emission gas, you can define this total emission load with high reliability at a very low cost by using IR-technology.



- **CO<sub>2</sub> 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<sub>2</sub> concentrations. From a warm engine, when the catalytic converter is fully efficient, great concentrations of CO<sub>2</sub> are emitted, in comparison to the *toxic* exhaust substances. In this case the CO<sub>2</sub> gas could actually constitute the potential threat. It would therefore be irresponsible to disregard this risk.

(SenseAir's aSENSE mIII)



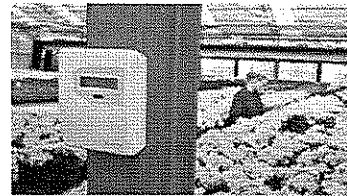
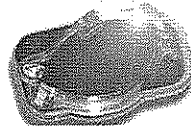
- **CO<sub>2</sub> as an exhaust indicator correlates with all toxic emissions**

Using demand controlled ventilation where you make sure that the CO<sub>2</sub> 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<sub>2</sub>. The occurrence of the different gases, relative CO<sub>2</sub>, 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<sub>2</sub> sensors are installed (e.g. in road tunnels or garages). The locally measured CO<sub>2</sub> emissions give you the exhaust quantity and the, at this particular time, centrally measured mixture gives us the local concentration of NO<sub>2</sub> 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<sub>2</sub> is an excellent fire indicator**

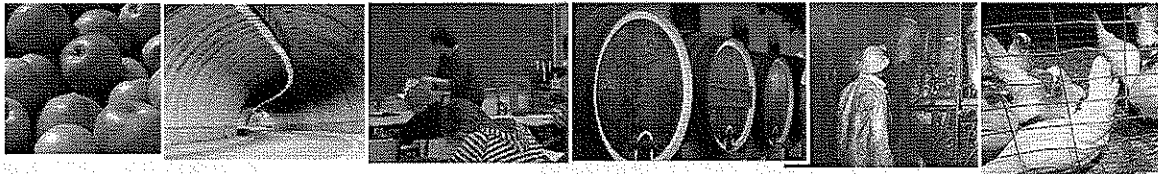
A CO<sub>2</sub> sensor can also function as a fire detector. In case of an open fire, very high concentrations of CO<sub>2</sub> are emitted within a short time interval. Much higher concentrations than what could ever be generated from internal-combustion engines. Hot high concentration CO<sub>2</sub> gas is developed and quickly spread together with the fire smoke. Fire tests show that the CO<sub>2</sub> "cloud" actually spreads faster than the possible smoke. In all cases of open test fires, according to the EN54 norm, *CO<sub>2</sub> 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<sub>2</sub> emission is very high. Unlike optical or ionizing smoke detectors, the CO<sub>2</sub> fire detection technology is secure to false alarms, which is most obvious in dirty and dusty environments where smoke can occur out of other reasons than fire.

## Areas of application



Few gases have so varied and unexpected areas of application as Carbon dioxide (CO<sub>2</sub>).

Interest and demand for the gas is on the increase. This is mainly a result of its proving to be the most environmentally friendly alternative to many different hazardous species used in our society. Carbon dioxide, in spite of not being toxic itself, is an insidious gas. It is harmless in small quantities (we exhale CO<sub>2</sub>) but in high concentrations it is fatal. Because the gas is odourless it cannot be detected without measuring instruments and many fatal accidents have occurred in e.g. beer cellars where beer or carbonated drinks are stored in barrels. New legislation on serving and storing beer and soft drinks are opening big new markets for CO<sub>2</sub> - alarms. One big end user of these CO<sub>2</sub> alarms, (delivered by a *SenseAir*<sup>™</sup> OEM customer) is MacDonald's.



### *SenseAir*<sup>™</sup> products can add:

- *energy saving intelligence and comfort* added features, to traditional ventilation components like *stand-alone fans, exhaust valves, window openers, fresh air supply actuators, etcetera.*
- *process yield and economic outcome* in many bio-related processes, such as in *greenhouses, mushroom farming, food transportation /storage, chicken hatcheries, incubators, dairying....*
- *personal safety* - in confined spaces where combustion may be present, or gas leakage is possible, such as *garages, tunnels, loading docks, public bars and restaurants, burners and Kerosene heaters*

### New applications for *SenseAir*<sup>™</sup> gas sensors:

- *automotives - refrigerant leakage control, plus HVAC fresh air supply demand sensing*
- *global environmental surveillance - ground and atmospheric CO<sub>2</sub> sensing*
- *homeland security*
- *household appliances (Kitchen Fans, Kitchen Ranges)*
- *healthcare, sports & leisure*

*SenseAir*<sup>™</sup> sensors can easily be included as partial systems in larger system solutions. The products can easily be adjusted to comply with differing customer requirements.



## 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 to 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<sub>2</sub>). The heating, ventilation and air-conditioning (HVAC) system can use DCV to tailor the amount of ventilation air to the occupancy level.



### Advantages of CO<sub>2</sub> – based DCV:

- **Improved IAQ**  
By increasing the supply of fresh air to the building, if CO<sub>2</sub> 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 ventilation-related illness or damage claims.
- **Estimated savings**  
The potential of CO<sub>2</sub>-based DCV for operational energy savings has been estimated in the literature at from \$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.

## Energy –saving Mechanism

To ensure adequate air quality in buildings, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommended a ventilation rate of 15-20 cfm per person in ASHRAE Standard 62-1999.

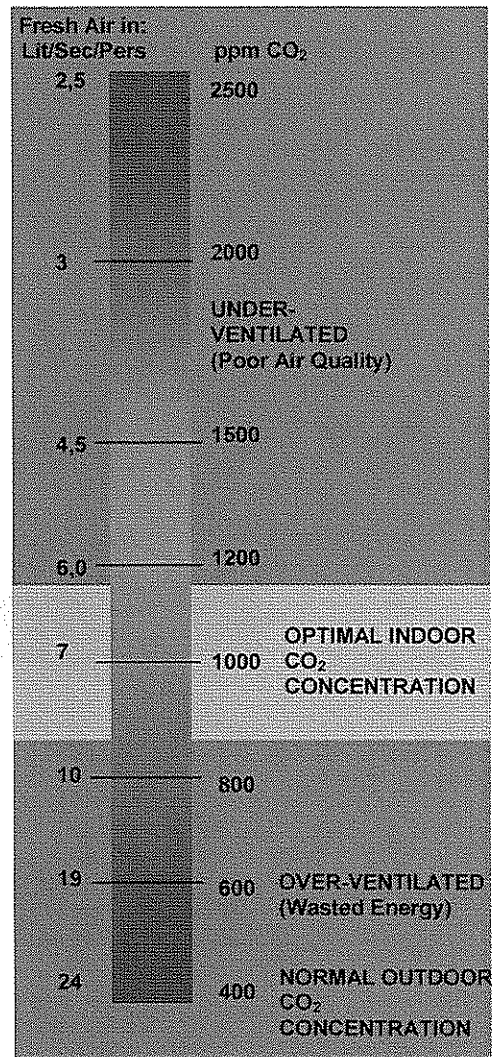
To meet the standard, many ventilation systems are designed to admit air at the maximum level whenever

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<sub>2</sub> 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.

## About the Technology

Demand-controlled ventilation(DCV) using carbon dioxide (CO<sub>2</sub>) sensing is a combination of two technologies: CO<sub>2</sub> sensors that monitor CO<sub>2</sub> levels in the air inside a building, and air-handling systems that uses data from the sensors to regulate ventilation. CO<sub>2</sub> sensors continually monitor the air in a conditioned space. Since people exhale CO<sub>2</sub> the difference between the indoor CO<sub>2</sub> concentration and the level outside the building indicates the occupancy and/or activity level in a space and thus its ventilation requirements. The sensors send CO<sub>2</sub> readings to the ventilation controls, which automatically increase ventilation when CO<sub>2</sub> concentrations in a zone rise above a specific level.



## Facts about SenseAir

**SenseAir**® is an expert company in the field of *infrared technology for gas sensing* and is one of the largest producers in the world on CO<sub>2</sub> sensors. SenseAir engineers have pioneered low cost infrared gas sensor technology since 1989 and paved the way for today's state-of-the-art technology by unique technical achievements.

**Name:** SenseAir AB  
**Work:** Research & development, production of gas sensors with IR- technique  
**Founded:** 1993 (R&D since 1987)  
**Management:** Arvid Egeland MD, Hans Martin, R&D manager



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