Carbon Dioxide Measures up as a Real Hazard

GAS DETECTION

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Carbon dioxide is one of the most frequently overlooked of all toxic gases. Even to refer to CO_2 as a toxic gas is a surprise to many safety professionals.

Carbon dioxide is the fourth most common gas present in the earth's atmosphere, with an average ambient concentration (in fresh air) of about 350 ppm. Carbon dioxide is one of the most common byproducts of living organisms. With every exhaled breath we produce and release CO_2 into the atmosphere (with an average concentration in exhaled breath of about 3.8%). According to one USDA study, an average person produces about 450 litres (900 grams) of CO_2 per day.

Liquid and solid carbon dioxide (dry ice) are widely used as refrigerants, especially in the food industry. Carbon dioxide is also used in many industrial and chemical industry processes. Carbon dioxide is particularly associated with the beer and wine making industries, where it is produced by yeast during the fermentation process that converts sugar into alcohol. Carbon dioxide in the headspace of fermentation vessels can easily reach 50% by volume or even higher concentrations. Carbon dioxide is also widely used in the oil industry, where it is commonly injected into oil wells to decrease the viscosity and aid in the extraction of oil from mature fields. It is also one of the most common atmospheric hazards encountered in confined spaces.

Carbon dioxide is a primary byproduct of bacterial decomposition. As with people, "aerobic" or oxygen using bacteria produce carbon dioxide as a primary metabolic byproduct. In many confined spaces there is a direct relationship between low concentrations of oxygen and elevated concentrations of CO_2. In the case of a confined space where CO_2 is generated as a byproduct of aerobic bacterial action, a concentration of 19.5% O_2 (the hazardous condition threshold for oxygen deficiency in most jurisdictions) would be associated with an equivalent concentration of at least 1.4% (= 14,000 ppm) CO_2. This is substantially higher than the generally accepted workplace exposure limit for CO_2 (5,000 ppm calculated as an 8-hour TWA).

The true concentration of CO_2 could be substantially higher if the oxygen deficiency is due to displacement rather than consumption of the oxygen in the confined space. Fresh air contains only 20.9% oxygen by volume. The balance consists mostly of nitrogen, with minor or trace concentrations of a wide variety of other gases including argon, water vapour and carbon dioxide. Because oxygen represents only about one-fifth of the total volume of fresh air, every 5% of a displacing gas that is introduced into a confined space reduces the oxygen concentration by only 1%. As an example, consider an oxygen deficiency due to the introduction of dry ice into an enclosed space. In this case a reading of 19.5% O_2 would not be indicative of 1.4% CO_2, it would be indicative of 5 X 1.4% = 7.0% (= 70,000 ppm) CO_2.

The bottom line is that if you wait until the oxygen deficiency alarm is activated, and the deficiency is due to the presence of CO_2, you will have substantially exceeded the toxic exposure limit long before leaving the affected area.

In spite of these considerations, in the past the majority of atmospheric monitoring programs have treated CO_2 as only a "simple asphyxiant". An asphyxiant is a substance that can cause unconsciousness or death by suffocation (asphyxiation). Asphyxiants which have no other health effects are referred to as "simple" asphyxiants. Because CO_2 was not considered to be a toxic hazard, rather than directly measuring the CO_2 in the confined space or workplace environment, it was seen as adequate to simply measure the oxygen concentration. This attitude is changing as it becomes more feasible (and affordable) to directly measure CO_2 by means of compact, portable multi-sensor gas detectors equipped with miniaturised infrared sensors for the direct measurement of this gas.

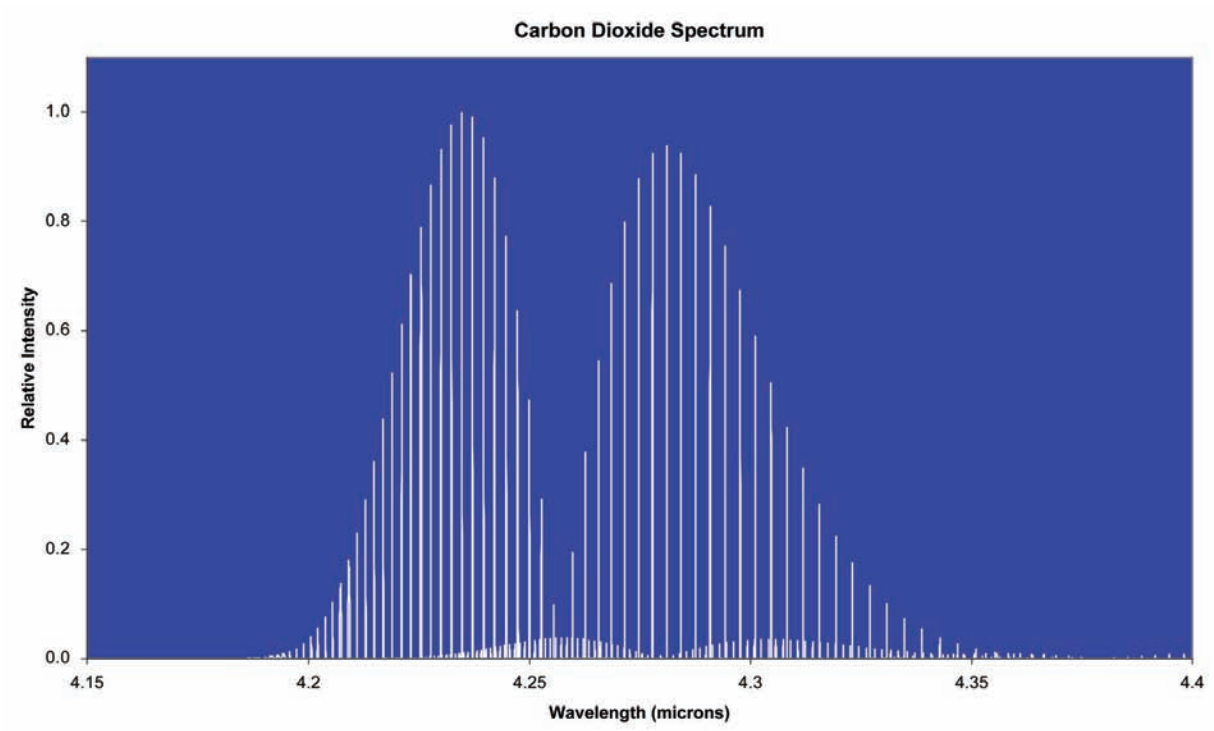

Figure 1: The infrared absorbance spectrum of carbon dioxide shows a strong peak at 4.26 µm

Figure 2: Miniaturised NDIR sensors directly measure CO_2 by means of absorbance of infrared light

Carbon dioxide is a toxic contaminant with strictly defined workplace exposure limits

Carbon dioxide is listed as a toxic contaminant with strictly defined occupational exposure limits in almost every jurisdiction. The most widely recognised exposure limits for CO_2 reference an 8-hour Time Weighted Average (TWA) of 5,000 ppm, with a 15-minute Short Term Exposure Limit (STEL) of either 15,000 ppm or 30,000 ppm. The following table lists several of the most commonly cited workplace exposure limits:

Standard / Country	8-hour Time Weighted Average	15-minute Short Term Exposure Limit
United Kingdom WEL	5,000 ppm	15,000 ppm
USA NIOSH REL	5,000 ppm	30,000 ppm
USA OSHA PEL	5,000 ppm	None Listed
ACGIH® TLV®	5,000 ppm	30,000 ppm

Carbon dioxide is heavier than air, with a density of 1.5 times that of fresh air. When carbon dioxide is released into an enclosed or confined space it tends to settle to the bottom of the space, reaching the highest concentration in the lowest parts of the space. Because of this tendency to settle, as CO_2 is produced it can reach higher and higher concentrations in localised regions of the space (such as the head space immediately above the liquid in fermentation vats).

While present as a natural component in fresh air, at higher concentrations exposure symptoms include headaches, dizziness, shortness of breath, nausea, rapid or irregular pulse and depression of the central nervous system. Besides displacing the oxygen in fresh air, high concentrations of CO_2 may exacerbate or worsen the symptoms related to oxygen deficiency, and interfere with successful resuscitation. Even moderately elevated concentrations associated with poorly ventilated indoor spaces can produce physiological symptoms. According to NIOSH, chronic exposure to elevated indoor CO_2 concentrations have been linked with the following symptoms: