CARBON DIOXIDE

CAS number: 124-38-9

Molecular formula: CO_2

TLV–TWA, 5000 ppm (9000 mg/m^3)

TLV–STEL, 30,000 ppm (54,000 mg/m^3)

Summary

A TLV–TWA of 5000 ppm (9000 mg/m^3) and a TLV–STEL of 30,000 ppm (54,000 mg/m^3) are recommended for occupational exposure to carbon dioxide. The recommended values are intended to minimize the potential for asphyxiation and undue metabolic stress. The TLV–STEL is based on the short-term, high carbon dioxide exposure studies that produced increased pulmonary ventilation rates. Sufficient data were not available to recommend Skin, SEN, or carcinogenicity notations.

Chemical and Physical Properties

Carbon dioxide is a colorless, odorless, noncombustible gas. Chemical and physical properties include:[1]

Molecular weight: 44.01
Density: 1.527
Melting point: sublimes at –78.33°C at 76 torr
Vapor pressure: >> 1 atm at 20°C
Solubility: soluble in water to the extent of 171 ml/100 ml at 0°C and 76 torr, 88 ml/100 ml at 20°C, and 36 ml/100 ml at 60°C. Under higher pressure carbon dioxide is more soluble.
Conversion factors at 25°C and 760 torr:
1 ppm = 1.80 mg/m^3; 1 mg/m^3 = 0.556 ppm

Major Uses

Carbon dioxide is used in carbonation of beverages, in fire extinction and prevention, as a propellant in aerosols, and as dry ice (solidified carbon dioxide) for refrigeration. It is also produced by fermentation processes such as brewing and baking.

Human Studies

Carbon dioxide, when inhaled at elevated concentrations, may act to produce mild narcotic effects, stimulation of the respiratory center, and asphyxiation, depending on the concentration present and the duration of exposure. The literature contains a variety of reports on human response at varying concentrations. Deaths have been reported from asphyxiation in workers exposed at high concentrations of carbon dioxide.[2] Stimulation of the respiratory center is produced at 50,000 ppm (5%). Submarine personnel exposed continuously at 30,000 ppm were only slightly affected, provided the oxygen content of the air was maintained at normal concentrations (minimal content 18% by volume);[3] when the oxygen content was reduced to 15%–17%, the crew complained of ill effects. The gas is weakly narcotic at 30,000 ppm, giving rise to reduced acuity of hearing and increasing blood pressure and pulse. Above this concentration, subjective symptoms occur. Signs of intoxication were produced by a 30-minute exposure at 50,000 ppm.[4] Exposure at 7%–10% produces unconsciousness within a few minutes.[5] Flury and Zernik quote Lehman–Hess[6] as stating that exposure at 5500 ppm of carbon dioxide for 6 hours caused no noticeable symptoms.

Ebersole studied the physiological effects in men and animals exposed at low concentrations of carbon dioxide for prolonged periods.[7] During one exercise, 23 men were exposed at 1.5% (15,000 ppm) for a period of 42 days. Under these conditions, certain physiological adaptions took place, and mild evidence of stress reactions was apparent. There was, however, no measurable decrement in basic physiological functions or in psychomotor performance. These data were interpreted to mean that 1.5% was the upper limit of tolerance for carbon dioxide during prolonged exposure.

Schulte reported that persons exposed at 2% carbon dioxide for several hours developed headache and dyspnea on mild exertion.[8] Borum et al.[9] showed that acidosis and adrenal cortical exhaustion occur as the result of prolonged, continuous exposure to an atmosphere containing 1 to 2% carbon dioxide. Schaefer[10] noted that 3 to 4 weeks were required after removal from this atmosphere for the complete recovery of electrolyte balance.

Kent[11] tabulated the effects of exposure to carbon dioxide in "normal" people at normal atmospheric pressure. He stated that humans could tolerate 1.5% in inhaled air for prolonged periods without adverse effect, but calcium–phosphorus metabolism may be affected. At 2%, he reported deepened respiration.

Gray et al.[12] studied 12 healthy submarine volunteers who were exposed at 1% carbon dioxide for 22 days. Serum calcium and urinary output of phosphorus fell progressively throughout the exposure period. This was interpreted as indicating a mild metabolic stress on the volunteers.

With regard to short duration exposure conditions, short-term and long-term carbon dioxide exposure studies were conducted by Sinclair and associates using healthy young men under exercise conditions.[13] At the exercise levels used, 66% of maximum oxygen consumption was reached during a 55-minute period. At this level of exercise, exposure at 27,600 ppm carbon dioxide raised the respiratory rate 15% above that produced by exercise in an atmosphere that was not enriched with carbon diox-ide. The investigators and laboratory technicians conducting this study entered the exposure cham-bers and were exposed at carbon dioxide concentra-tions of 27,600 ppm and 39,500 ppm for periods of 2 to 8 hours on a daily basis. Very little difficulty was reported by this group other than an awareness of increased ventilation noted especially at 39,500 ppm. They had no difficulty performing physiological tests and measurements during these exposures.

The question of whether negative-pressure air-purifying respirators influence ability to work in elevated carbon dioxide atmospheres has been addressed. Jones et al.[14] demonstrated that with respirator wear the increases in ventilatory and alveolar pCO_2 were dependent on the workload and the volume of added dead space. However, they showed that the magnitude of response was related to the ventilatory response of the individual to carbon dioxide measured at rest.

Craig et al.[15] noted that there was a reduction in exercise tolerance in workers exposed above 3% carbon dioxide when breathing against inspiratory and expiratory resistance.

Love et al.[16] studied British underground coal mine workers who exercised on a treadmill at 1.25 m/sec on a 9% grade while wearing a simulated respirator inspiratory resistance of 10 cm water at 100 L/min and being exposed to varying concentrations of carbon dioxide. They concluded that with increased respiratory resistance, inhaled carbon dioxide in excess of 3% is not well tolerated during exercise. Thus, short-term exposures to carbon dioxide near the TLV–STEL under conditions requiring air-purifying respirators should be considered carefully. Increased ventilatory stimulation may lead to poor respirator wear practices.

TLV Recommendation

Based on the long-term exposure studies, even though the majority of references are concerned with studies on physically fit males in confined spaces, a TLV–TWA of 5000 ppm for carbon dioxide is recommended. This value provides a good margin of safety from asphyxiation and from undue metabolic stress, provided normal amounts of oxygen are present in the inhaled air. In light of the short-term exposure, physical exercise studies by Sinclair and associates,[13] in which carbon dioxide exposure concentrations of 27,600 to 39,500 ppm produced increased pulmonary ventilation rates, a TLV–STEL of 30,000 ppm is considered appropriate.

Historical TLVs

1946–1947: MAC–TWA, 5000 ppm
1948–present: TLV–TWA, 5000 ppm
1976–1985: TLV–STEL, 15,000 ppm
1984: *Proposed:* TLV–STEL, 30,000 ppm,
1986–present: TLV–STEL, 30,000 ppm

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