

## 5.3 Carbon Dioxide (CO<sub>2</sub>)

### Physiological Effects:

- **Normal atmospheric:** 0.04% (400 ppm)
- **1-2%:** Noticeable respiratory stimulation
- **3-5%:** Significant hyperventilation, headache, increased breathing rate (doubles at 3%)
- **>5%:** Severe physiological stress, impaired egress capability

Elevated CO<sub>2</sub> acts as a respiratory stimulant, causing occupants to breathe more deeply and rapidly, which increases the uptake of other toxic gases. The 5% threshold represents a conservative limit before significant performance degradation.

## 5.4 Carbon Monoxide (CO)

### Toxicity Mechanism:

Carbon monoxide binds to hemoglobin with 200-250 times the affinity of oxygen, forming carboxyhemoglobin (COHb) and reducing oxygen transport capacity in blood. The fractional effective dose for CO is calculated using the CO exposure dose (CED) model:

$$FED_{CO} = \sum [CO]^{1.036} \times \dot{V}_{CO_2} \times \Delta t / (3.5 \times 10^7)$$

[CO]

Carbon monoxide concentration (ppm)

$\dot{V}_{CO_2}$

CO<sub>2</sub>-induced hyperventilation factor (typically 1-7 based on CO<sub>2</sub> level)

### Exposure Effects:

- **400 ppm:** Headache after 1-2 hours
- **800 ppm:** Dizziness, nausea after 45 minutes