

Air Quality System II - Extension of the Features of the Air Quality System

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Laboratory 11 Tasks

- ❑ Task 1: Sending CO₂, Humidity, and Temperature to a Remote Location.
- ❑ Task 2: Simple Display of CO₂ Level
- ❑ Task 3: Doxygen Documentation of Your Multi-Module Program.

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Safe Levels of CO₂ in Rooms

What are safe levels of CO and CO2 in rooms?

CO2

250-400ppm	Normal background concentration in outdoor ambient air
400-1,000ppm	Concentrations typical of occupied indoor spaces with good air exchange
1,000-2,000ppm	Complaints of drowsiness and poor air.
2,000-5,000 ppm	Headaches, sleepiness and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea may also be present.
5,000	Workplace exposure limit (as 8-hour TWA) in most jurisdictions.
>40,000 ppm	Exposure may lead to serious oxygen deprivation resulting in permanent brain damage, coma, even death.

Safe Levels of CO₂ in Rooms (cont. 1)

Table 2 Human studies that met our inclusion criteria										
Studies	Experimental design	CO ₂ concentrations considered (ppm)	Total exposure duration (h)	CO ₂ concentration range at which effects are observed (ppm)	Outcome variable	Effect present?	Main findings	Sample size and type	Difficulty of task	Physiological data
Katzen and Herzog (ref. 17)	A	1,500-2,500; 600-5,000	2.3	n.a.	Proofreading task	No	No significant differences in proofreading performance	10 healthy young adults	Simple	Blood pressure, heart rate, skin temperature
Katzen and Herzog (ref. 17)	A	1,500-2,500; 600-5,000	2.3-3.5	3,000-4,000	Proofreading task	Yes*	Accuracy declined at 4,000 compared to 600 ppm after 2.3 h	10 healthy young adults	Moderate	Blood pressure, heart rate, skin temperature
Saitoh et al. ¹⁸	B	600-1,000-2,500	2.5	1,000-2,500	SMS	Yes*	Significant dose-dependent declines in SMS performance	22 healthy young adults	Difficult	None
Allen et al. ¹⁹	B	550-945-1,400	~7.5	945-1,400	SMS	Yes*	SMS performance was 10% lower for 945 ppm and 50% lower for 1,400 ppm relative to 550 ppm	24 professional-grade employees	Difficult	MacNaughton et al. ¹¹
Zhang et al. ¹⁵	B	500 or 5,000	2.5	5,000	Tai-Partington test typing addition	No	No difference in cognitive performance; ETCO ₂ and salivary amylase increased at 5,000 ppm	10 healthy young adults	Simple and moderate	Heart rate, ETCO ₂ , pulse oximetry, salivary stress biomarkers
Zhang et al. ¹⁵	B	500-1,000-3,000	4.25	1,000-3,000	Office work, neurobehavioural	Yes	No significant decreases in cognitive performance	25 healthy young adults	Simple and moderate	Zhang et al. ¹⁵
Allen et al. ¹⁹	B	700-1,500-2,500	3	1,500-2,500	Aeroplane flight manoeuvres	Yes*	Onset of passing flight manoeuvres declined at 1,500 and 2,500 ppm; performance decrements were more pronounced with increasing manoeuvre difficulty and exposure duration	30 commercial aeroplane pilots	Both simple and difficult manoeuvres	Cao et al. ¹⁶
Rodehorst et al. ¹⁴	C	600-2,500-15,000	21	2,500	SMS	Yes, at 2,500 ppm	No significant differences between exposure groups; however, post estimates declined from 600 to 2,500 ppm	36 submariners (12 per condition)	Difficult	None
Snow et al. ²⁰	C	800 or 2,700	0.17-0.3 (post-ventilation)	2,700	EEG indicative of drowsiness	Yes	EEG under elevated CO ₂ more indicative of drowsiness	23 experimental/13 n.a. control university students and staff	n.a.	EEG
Snow et al. ²⁰	B	800 or 2,700	0.89-14	2,700	Cognitive battery (CNS vital signs); EEG	Yes	Absence of expected learning effects; EEG more indicative of drowsiness in participants who slept less in the previous night	38 university students and staff	Simple and moderate	EEG, heart rate, skin temperature, respiratory rate

All studies measured the effects of exposure to artificially raised (pure) CO₂. *The first series of experiments of ref. 11. †The second series of experiments of ref. 11. Experimental designs: A, within-subject, series exposure; B, within-subject, counterbalanced; C, between-subject, n.a., not applicable. Total exposure duration refers to the total amount of time participants were exposed to an experimental condition. For series exposure, study participants were exposed to different experimental conditions consecutively and in the same specified order; proofreading tasks started immediately. The SMS takes 1.5 h; therefore, approximate exposure duration before testing can be determined by subtracting this amount from the total exposure duration. The concentration range at which effects are observed refers to the exposure levels where cognitive or neurophysiological changes were recorded. The level of difficulty is relative to the SMS; the SMS was considered the most difficult test of cognitive performance. *Statistically significant (P < 0.05).

Safe Levels of CO₂ in Rooms (cont. 2)

Normal CO₂ Levels

The effects of CO₂ on adults at good health can be summarized to:

- normal outdoor level: 350 - 450 ppm
- acceptable levels: < 600 ppm
- complaints of stuffiness and odors: 600 - 1000 ppm
- ASHRAE and OSHA standards: 1000 ppm
- general drowsiness: 1000 - 2500 ppm
- adverse health effects may be expected: 2500 - 5000 ppm
- maximum allowed concentration within a 8 hour working period: 5000 - 10000 ppm
- maximum allowed concentration within a 15 minute working period: 30000 ppm

The levels above are quite normal and maximum levels may occasionally happen from time to time. In general - ventilation rates should keep carbon dioxide concentrations below 1000 ppm to create indoor air quality conditions acceptable to most individuals.

Extreme and Dangerous CO₂ Levels

- slightly intoxicating, breathing and pulse rate increase, nausea: 30000 - 40000 ppm
- above plus headaches and sight impairment: 50000 ppm
- unconscious, further exposure death: 100000 ppm

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Using a Multicolor Bar Graph LED to Simply Indicate CO₂ Quality in a Room



Turn ON the bottom LED for CO₂ concentrations from 400 to 499 ppm. Then turn ON the bottom two LEDs for concentrations from 500 to 599 ppm, and so on.

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