The Effects of Indoor Carbon Dioxide on Human Health and Performance

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Background

Carbon dioxide (CO_2) is a naturally occurring gas produced by human respiration, combustion, and other indoor sources. While outdoor ambient CO_2 levels are approximately 420 parts per million (ppm), indoor concentrations routinely range from 400 ppm to over 3,000 ppm depending on occupancy, ventilation, and building design [1]. Research over the past decade has established that indoor CO_2, even at moderate levels, can significantly affect human cognition, sleep, health symptoms, and physiological function.

Cognitive Performance and Decision-Making

Multiple studies demonstrate that elevated CO_2 impairs cognitive function. A landmark study found that at 1,000 ppm CO_2, moderate and statistically significant decrements occurred in six of nine scales of decision-making performance compared to 600 ppm. At 2,500 ppm, large reductions occurred in seven scales including strategy, initiative, and information utilization. These effects were observed even when pure CO_2 was added while keeping ventilation constant, indicating CO_2 itself is a direct indoor pollutant, not merely a marker of poor ventilation [2].

These effects are often invisible until performance drops. Continuous personal CO_2 monitoring lets individuals see when levels are rising in meeting rooms, home offices, or study spaces and act before cognitive function is noticeably impaired.

Work and Office Environments

In office settings, CO_2 levels frequently exceed 1,000 ppm, especially in open-plan layouts with inadequate ventilation. A review of low-level CO_2 exposure found linear physiological changes in circulatory, cardiovascular, and autonomic systems beginning at concentrations of 500 - 5,000 ppm, and cognitive effects starting at approximately 1,000 ppm [1]. Office workers exposed to indoor CO_2 levels above 800 ppm were more likely to report eye irritation and upper respiratory symptoms [4]. The rising atmospheric CO_2 concentration - projected to reach ~950 ppm by 2100 under "business as usual" scenarios - will drive indoor CO_2 to levels that may substantially impair cognition, even if buildings follow current ventilation standards [3].

Schools and Classrooms

Children spend 6 to 7 hours daily in classrooms, where CO_2 can accumulate rapidly due to high occupant density. A study of UK schools found CO_2 exceeded 1,500 ppm for 31% of the school week on average, with one classroom exceeding this threshold 72% of the time [5]. Elevated classroom CO_2 has been associated with poorer academic attainment, reduced attendance, and increased respiratory symptoms in children [5]. Teachers are also affected: for every 100-ppm increase in maximum classroom CO_2, the odds of reporting neuro-physiologic symptoms (headache, fatigue, difficulty concentrating) increased by 30% [6].

Sleep Quality and Bedrooms

Bedrooms with closed doors and windows often have very poor ventilation. A controlled chamber study demonstrated that at 3,000 ppm CO_2, subjective sleep quality was only 80.8% of that at 800 ppm, and slow-wave (deep) sleep decreased linearly with rising CO_2, while sleep onset latency increased [7]. A field intervention study found that objectively measured sleep quality, perceived freshness of bedroom air, next-day sleepiness, ability to concentrate, and performance on a logical thinking test all improved significantly when nighttime CO_2 was lower (~660 - 835 ppm compared to ~2,400 - 2,600 ppm) [8]. A review of bedroom ventilation standards noted that inadequate ventilation is a widespread problem with direct consequences for sleep and daytime function [9].

This is why many people are now using personal environmental monitors in their bedrooms. By tracking nighttime CO_2 trends alongside temperature and humidity, users can identify ventilation issues that fragment sleep and test simple changes to improve next-day energy and focus.

Physical Exercise

During physical activity, CO_2 production increases substantially, and indoor exercise environments such as gyms, fitness studios, and home workout spaces can accumulate CO_2 rapidly. Studies examining CO_2 inhalation during exercise and recovery have shown that elevated CO_2 can impair psychomotor and mental performance. Higher inspired CO_2 levels during exercise increase the work of breathing and can alter acid-base balance, affecting endurance and perceived exertion [11].

Health Symptoms and Sick Building Syndrome

Epidemiological studies consistently link indoor CO_2 levels beginning at approximately 700 ppm with building-related symptoms (Sick Building Syndrome), including headache, fatigue, eye irritation, and upper respiratory symptoms. The physiological mechanisms may involve mild acidosis, autonomic nervous system changes, and compounding effects with other indoor pollutants [1]. These symptoms reduce occupant comfort, health, and productivity across all indoor settings [4].

Many of these symptoms are misattributed to stress or poor sleep. Personal monitors that log CO_2 alongside other environmental factors help users correlate how they feel with specific conditions in their home, office, or classroom and make targeted improvements.

Practical Implications

The weight of evidence suggests that maintaining indoor CO_2 below 800 to 1,000 ppm is important for protecting cognitive function, sleep quality, and health. Key strategies include increasing ventilation rates, using mechanical ventilation with CO_2-based demand control, opening windows where possible, and limiting occupancy density. As atmospheric CO_2 continues to rise globally, the challenge of maintaining healthy indoor CO_2 levels will intensify, making energy-efficient ventilation design increasingly critical [3].

Continuous, personal monitoring makes these guidelines actionable in daily life. Portable sensors that track CO_2 in real time, along with related factors like particulates and pressure, allow individuals to identify problematic spaces, adjust behavior, and see the immediate effect on their environment and well-being.

References

[1] K. Azuma, N. Kagi, U. Yanagi, and H. Osawa, *"Effects of low-level inhalation exposure to carbon dioxide in indoor environments: A short review on human health and psychomotor performance"*, Environment International, vol. 121, pp. 51–56, Dec. 2018. DOI: 10.1016/j.envint.2018.08.059

[2] U. Satish et al., *"Is CO_2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO_2 Concentrations on Human Decision-Making Performance"*, Environmental Health Perspectives, vol. 120, no. 12, pp. 1671–1677, Dec. 2012. DOI: 10.1289/ehp.1104789

[3] K. B. Karnauskas, S. L. Miller, and A. C. Schapiro, *"Fossil Fuel Combustion Is Driving Indoor CO_2 Toward Levels Harmful to Human Cognition"*, GeoHealth, vol. 4, no. 5, May 2020. DOI: 10.1029/2019gh000237

[4] D.-H. Tsai, J.-S. Lin, and C.-C. Chan, *"Office Workers' Sick Building Syndrome and Indoor Carbon Dioxide Concentrations"*, Journal of Occupational and Environmental Hygiene, vol. 9, no. 5, pp. 345–351, May 2012. DOI: 10.1080/15459624.2012.675291

[5] J. Miller, S. Semple, and S. Turner, *"High carbon dioxide concentrations in the classroom: the need for research on the effects of children's exposure to poor indoor air quality at school"*, Occupational and Environmental Medicine, vol. 67, no. 11, pp. 799.1-799, Oct. 2010. DOI: 10.1136/oem.2010.057471

[6] N. Muscatiello, A. McCarthy, C. Kielb, W.-H. Hsu, S.-A. Hwang, and S. Lin, *"Classroom conditions and CO_2 concentrations and teacher health symptom reporting in 10 New York State Schools"*, Indoor Air, vol. 25, no. 2, pp. 157–167, Jul. 2014. DOI: 10.1111/ina.12136

[7] X. Xu et al., *"Experimental study on sleep quality affected by carbon dioxide concentration"*, Indoor Air, vol. 31, no. 2, pp. 440–453, Oct. 2020. DOI: 10.1111/ina.12748

[8] P. Strøm-Tejsen, D. Zukowska, P. Wargocki, and D. P. Wyon, *"The effects of bedroom air quality on sleep and next-day performance"*, Indoor Air, vol. 26, no. 5, pp. 679–686, Nov. 2015. DOI: 10.1111/ina.12254

[9] C. Sekhar et al., *"Bedroom ventilation: Review of existing evidence and current standards"*, Building and Environment, vol. 184, pp. 107229, Oct. 2020. DOI: 10.1016/j.buildenv.2020.107229

[10] A. K. Mishra, S. Schiavon, P. Wargocki, and K. W. Tham, *"Respiratory performance of humans exposed to moderate levels of carbon dioxide"*, Indoor Air, vol. 31, no. 5, pp. 1540–1552, May 2021. DOI: 10.1111/ina.12823

[11] Y. Xia, S. Shikii, and Y. Shimomura, *"Determining how different levels of indoor carbon dioxide affect human monotonous task performance and their effects on human activation states using a lab experiment: a tracking task"*, Ergonomics, vol. 63, no. 11, pp. 1350–1358, Jun. 2020. DOI: 10.1080/00140139.2020.1784466