Could carbon dioxide monitoring allow more indoor activity during the pandemic?

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There's a useful truth in the welter of confusing information about COVID-19 and SARS-CoV-2, the coronavirus that causes it: relatively little infection occurs outdoors. Almost all transmission occurs indoors. There, insufficient ventilation can allow airborne coronavirus exhaled by infected persons to linger, so that other occupants of the building inhale enough to become infected. Outdoors, dilution by uncontaminated air can reduce exposure to the virus to below doses that cause infection.[1]

As winter approaches without a strong promise of a widely available vaccine, there's an urgent need to find ways to reduce the possibility of coronavirus infection in workplaces and publicly accessible spaces. Otherwise we may be stuck with bans on the use of these indoor spaces, which harm social and economic well-being.[2] The low rate of transmission outdoors shows a way to make indoor spaces safer: by ventilating them so that their air contains as little of the virus as outdoor air.[3]

Continuous monitoring of the carbon dioxide (CO_2) concentration of indoor air could be helpful in ensuring that the air in a building remains ventilated enough to maintain a low rate of transmission of coronavirus breathed into it. CO_2 is best known as a greenhouse gas. It's also an important constituent of human breath, which has a CO_2 concentration about one hundred times higher than the 400-500 parts per million (ppm) found in outdoor air and ten to a hundred times higher than the 500-5000 ppm in indoor air.[4]

Building engineers have long used CO_2 concentrations to indicate how well indoor spaces need to be ventilated. In some buildings, the air-handling system automatically adds outdoor air if the CO_2 level rises above 1000 ppm – an engineers' standard for adequate ventilation.[5] Human exhalation is normally the main reason why a room's CO_2 level rises above 1000 ppm.

The breathing of four moderately active adults in an enclosed, unventilated room, 6 x 6 x 3 metres (20 x 20 x 10 feet), can raise the room's CO_2 level to above 2000 ppm in an hour.[6] Continuous ventilation could keep the room's CO_2 level below 1000 ppm. Often, ventilation can be adjusted to maintain the room's CO_2 level near the 400-500 ppm in outdoor air.

Recent research suggests not only that indoor airborne transmission is a prominent source of infection by the coronavirus, but also that CO_2 levels indicate the risk of such infection.[7] Maintaining a room or a building's CO_2 level near that of outdoor air would, where possible, substantially reduce this risk. Doing this in winter would incur costs of heating added outdoor air. Typically, about 80 per cent of the air in a building is recirculated to retain heat.[8] The costs of heating added outdoor air would usually be low in relation to the costs of closing buildings.[9]

Increasing ventilation to prevent virus transmission has a long history. In North America and Europe, many schools moved outdoors during the influenza pandemic that ended 100 years ago.[10] Today, improved technology and CO_2 monitoring can help ensure that the virus-dispersing advantages found outdoors can be provided indoors.

Guidelines issued by the Federation of European Heating, Ventilation, and Air Conditioning Associations (REHVA), reflecting recent research, recommend the installation of CO_2 monitors to help prevent transmission of the coronavirus.[11] Such a monitor, often the size of a room thermostat, can display the current CO_2 level where it is mounted – preferably at breathing height and not close to other sources of CO_2 such as the beer dispensers used in bars.[12] The monitor can also provide "traffic signal" indication: a green light shows that the room is relatively safe to occupy during the pandemic; an orange light shows that early action, such as opening a window or reducing occupancy, should be taken to lower the CO_2 level; a red light indicates that the room should be evacuated.

REVHA recommends that the transition levels be set low to promote as much virus dispersion as possible but does not yet suggest specific levels, which require further investigation. Meanwhile, the green to orange transition could be 550 ppm and the orange to red transition 700 ppm. These low limits could make indoor air almost as virus-dispersing as outdoor air. In dense urban areas where outdoor CO_2 levels are raised by the proximity of traffic, industry and building operation – and thus raise indoor CO_2 levels – the indoor limits could be 50-100 ppm higher.[13]

CO_2 monitors that meet appropriate standards cost a few hundred dollars each – which could be much reduced with mass production. Authorized use of them in the above manner could open up stores, restaurants, and other workplaces and publicly accessible spaces – including public transit – with relative safety during the current pandemic, which could continue into 2022 in some countries.[14]

Achieving more healthful indoor air would not obviate other precautionary measures, including wearing masks indoors and social distancing. As well, activities involving much heavy breathing – including exercising and singing[15] – could be confined to outdoor locations or private indoor spaces. At first, for economic reasons, the proposed use of CO_2 monitors could be focused on small businesses, notably those engaged in hospitality. CO_2 monitors could also be of use in many other situations, including homes and educational institutions.

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END NOTES

[1] Zeynep Tufekci, We need to talk about ventilation, *The Atlantic*, July 30, 2020, at https://www.theatlantic.com/health/archive/2020/07/why-arent-we-talking-more-about-airborne-transmission/614737.
Rajesh Bhagat et al, Effects of ventilation on the indoor spread of COVID-19, *Journal of Fluid Mechanics*, 903 (2020 in press).
Hua Qian et al, Indoor transmission of SARS-Cov-2, *Indoor Air*, (2020 in press). (1d) Quentin Leclerc et al, What settings have been linked to SARS-CoV-2 transmission clusters? *Welcome Open Research* (2020 in press).
Hiroshi Nishiura et al, Closed environments facilitate secondary transmission of coronavirus disease 2019 (COVID-19), (preprint posted April 16, 2020 at https://www.medrxiv.org/content/10.1101/2020.02.28.20029272v2).
Renyi Zhang et al, Identifying airborne transmission as the dominant route for the spread of COVID-19. *Proceedings of the National Academy of Sciences* (2020 in press).
Sedighe Karimzadeh et al, Review of infective dose, routes of transmission, and outcome of COVID-19 caused by the SARS-COV2 virus: comparison with other respiratory viruses, (preprint posted October 22, 2020 at https://www.preprints.org/manuscript/202007.0613/v2).

[2] Giovanni Bonaccorsi et al, Economic and social consequences of human mobility restrictions under COVID-19, *Proceedings of the National Academy of Sciences*, 117 (2020 in press).
David Miles et al, Living with COVID-19: Balancing costs against benefits in the face of the virus, *National Institute Economic Review*, 253, R60-R76 (2020), at https://www.authorea.com/doi/pdf/10.22541/au.159231548.88787102.

[3] Jensen Zhang, Integrating IAQ control strategies to reduce the risk of asymptomatic SARS CoV-2 infections in classrooms and open plan offices, *Science and Technology for the Built Environment*, 26, 1013-1018 (2020).
Position document on infectious aerosols. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), Atlanta, GA (April 4, 2020).

[4] W. Michael Alberts, Indoor air pollution: NO, NO_2, CO and CO_2. *Journal of Allergy and Clinical Immunology*, 94, 189-295 (1994).
O.A. Seppänen et al, Association of ventilation rates and CO_2-concentrations with health and other responses in commercial and institutional buildings. *Indoor Air*, 9, 226-252 (1999).
Rajesh Bhagat et al, Effects of ventilation on the indoor spread of COVID-19, *Journal of Fluid Mechanics*, 903 (2020 in press).

[5] Carbon Dioxide Concentration – Comfort Levels, at https://www.engineeringtoolbox.com/co2-comfort-level-d_1024.html.

[6] This estimate assumes CO_2 exhalation of 0.75L/min (see the source in this endnote), thus 4 x 60 x 0.75L/hr = 180L/h, thus 180L in 6 x6 x 3 x 1000L of room air, which is 180 x 100000/108000 or 1667 ppm (+410 for outside air = 2077 ppm).
Alexandro Franco and Eva Schito, Definition of Optimal Ventilation Rates for balancing comfort and energy use in indoor spaces using CO_2 concentration data. *Buildings*, 10(8), 1-19 (2020).

[7] Lidia Morawska et al, How can airborne transmission of COVID-19 indoors be minimised? *Environment International*, 142, 105832 (2020).
Renyi Zhang et al, Identifying airborne transmission as the dominant route for the spread of COVID-19. *Proceedings of the National Academy of Sciences* (2020 in press).

S.N. Rudnick and D.K. Milton, Risk of indoor airborne infection transmission estimated from carbon dioxide concentration, *Indoor Air*, 13, 237-245 (2003).
Z. Peng and J.L Jimenez, Exhaled CO_2 as COVID-19 infection risk proxy for different indoor environments and activities (preprint posted on September 10, 2020, at https://doi.org/10.1101/2020.09.09.20191676).

[8] Jensen Zhang, Integrating IAQ control strategies to reduce the risk of asymptomatic SARS-CoV-2 infections in classrooms and open plan offices, *Science and Technology for the Built Environment*, 26, 1013-1018 (2020).

[9] M.J. Mendell et al, Association of classroom ventilation with reduced illness absence: a prospective study in California elementary schools. *Indoor Air*, 23< 515-528 (2013).
Energy cost and IAQ performance of ventilation systems and controls. US EPA, January 2000, at https://www.epa.gov/sites/production/files/2015-01/documents/energy_executive_summary.pdf.

[10] Ginia Bellafante, Schools beat earlier plagues with outdoor classes. We should too. *New York Times*, July 20, 2020, at https://www.nytimes.com/2020/07/17/nyregion/coronavirus-nyc-schools-reopening-outdoors.html.

[11] REHVA Guidance for schools (2020) at https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_Guidance_School_Buildings.pdf.

[12] Why a CO_2 safety monitor will soon be required in your bar or restaurant (2020) at https://glacier-design.com/.

[13] Lin et al, CO_2 and carbon emissions from cities. *Bulletin of the American Meteorological Society*, November 2018, 2325-2339.

[14] Sarun Charumilind et al, When will the COVID-19 pandemic end? McKinsey & Company (November 2020), at https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/when-will-the-covid-19-pandemic-end# .

[15] Z. Peng and J.L Jimenez, Exhaled CO_2 as COVID-19 infection risk proxy for different indoor environments and activities (preprint posted on September 10, 2020, at https://doi.org/10.1101/2020.09.09.20191676).