Ventilación en Aulas para prevención de COVID-19:

English Translation:
Classroom ventilation for COVID-19 prevention

Límites de CO_2 recomendados en periodo de emergencia.

English Translation:
Recommended c02 limits in emergency period

V3, 28 Enero 21, SDA

V1 English Translation 01Dec21 by Stefan Stojanovic

aireamos.org

University of Colorado Boulder

LIFTEC

MESURA
WEBMESURA.ORG

Universidad Zaragoza

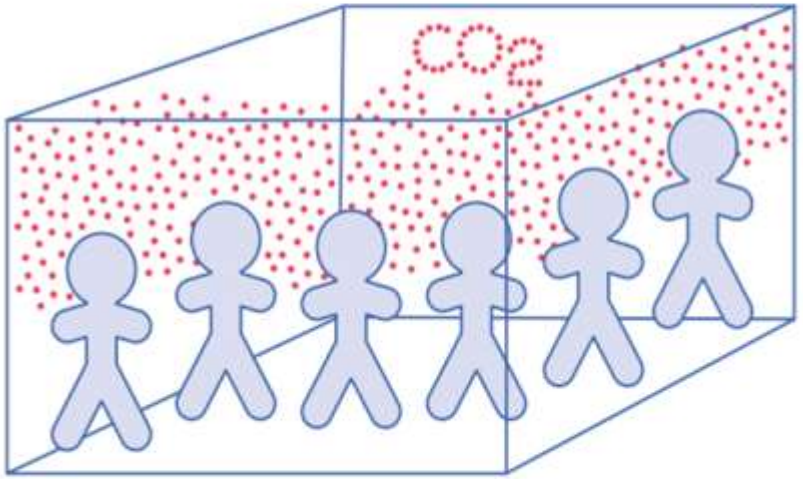
Index

01 CO_2 as an indicator of indoor air quality

The concentration of CO_2 (carbon dioxide) inside occupied premises is commonly used as an indicator of indoor air quality because of its relationship with the accumulation of air exhaled by the occupants. In this way, it is possible to relate this concentration with the accumulation of various contaminants in enclosed indoor spaces, as well as with the ability of ventilation to dilute the air, especially for premises with high occupancy densities - such as classrooms.

Because of this relationship, the measurement of the level of CO_2 in indoor spaces is a useful indicator to assess the risk of transmission of COVID-19, given that the occupants emit CO_2 along with the exhalation of aerosols that can transmit this disease.

As stated below, the recommended CO_2 concentration limits may show the level of risk to which occupants will be exposed, as well as the dwell time. This document proposes limits for reducing the risk of exposure to COVID-19 in shared indoor spaces.



02 Recommended C02 limits for classrooms

As a general preventive measure of COVID-19 transmission in classrooms, it is recommended to maintain a CO_2 concentration below **700 ppm**.

Below this value, a sufficient dilution of the aerosols exhaled by the people present in the classroom is achieved. Thus, it is possible to maintain a low risk of airborne transmission during the activities that involve occupancy for long periods in an indoor environment1, especially if combined with other layers of protection such as masks, etc.

The risk of transmission increases in direct relation to the increase in the level of CO_2 (see below) – higher levels of occupancy in an indoor environment leads to higher rates of expelled air. If the levels of CO_2 frequently remains above a value of **700 ppm** during the development of the activity, corrective measures must be adopted to minimise the risk of transmission.

In general, it has been found that, in most classrooms, it is feasible to maintain a level of **700 ppm** or below, potentially exceeding **800 ppm for brief periods**, through the use of natural and / or mechanical ventilation (if available). In most cases, a controlled opening of the gaps – in a distributed cross ventilation configuration[2] – is sufficient if they are kept open constantly during the use of the classroom. Where the configuration of the space does not allow these levels to be maintained, other measures should be applied to improve ventilation or use means complementary to the renewal of air (e.g. filtering, reduction of ratio or use of other spaces of greater volume), so that it is possible to reduce the risk of transmission.

In corridors and common areas that communicate with the classrooms, it is recommended to adopt a limit of **550 ppm**. This facilitates the correct ventilation of some classrooms, as air enters through the door and reduces the exchange of air between them. Small or very small openings of cross ventilation allow not to exceed these limits because the presence of students – therefore, contribution of breathed air – is not maintained for a long time in the common areas.

[1] *Z. Peng, J.L. Jiménez. Exhaled CO2 as COVID-19 infection risk proxy for different indoor environments and activities. 2020 (Preprint). DOI: 10.1101/2020.09.09.20191676*

[2] *Es recomendable que se produzca la apertura de ventanas en paredes opuestas o ventanas y puertas abiertas ("Ventilación Natural en las Aulas Guía Práctica"; LIFTEC 2020)*

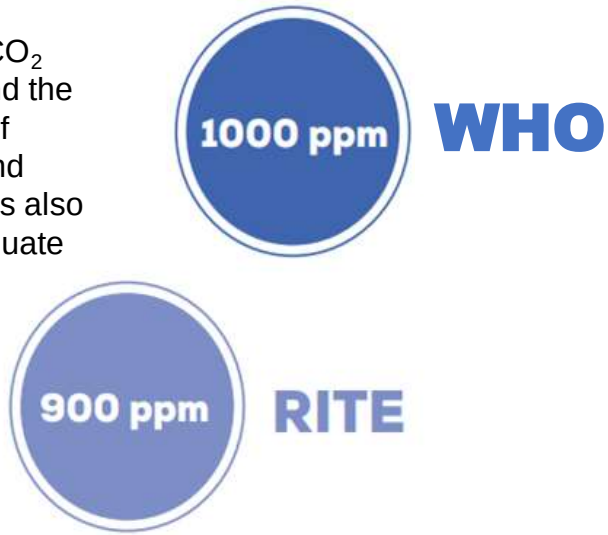
03 Difference with respect to other recommendations from others

There are other references and regulations that recommend thresholds in the concentration of CO_2 for the assessment of indoor air quality. For example:

- The WHO[3] recommends a limit of 1000 ppm to consider an environment healthy.
- The RITE[4] establishes a limit equivalent to 900 ppm (expressed as an increase of 500 ppm over the outside level) for IDA2 spaces, which include the case of classrooms.

It should be clarified that there is no contradiction in these terms. These thresholds are established against risks of a very different nature, related to the presence of different types of pollutants and toxics in the environment, as well as the effects of medium and long-term exposure to environments.

The particular case of COVID-19 requires additional effort to keep the CO_2 concentration below the indicated limits due to airborne transmission and the shorter exposure time required for contagion versus the health effects of pollutants typical of enclosed spaces – which can have a huge social and economic impact, including the collapse of the healthcare system. It has also been proven that these levels are viable in most cases through an adequate and controlled use of ventilation.



[3] D. Penney, V. Benignus, S. Kephalopoulos, D. Kotzias, M. Kleinman, and Agnes Verrier, "Guidelines for indoor air quality," 2010. doi: 10.1186/2041-1480-2-S2-I1

[4] Reglamento de Instalaciones Térmicas en los Edificios, RD 1027/2007, de 20 de julio, v. cons. septiembre 2013. (Note: HVAC regulations in Spain)

04

Relationship between CO_2 concentration and risk of transmission

The concentration of CO_2 is directly related to the amount of air that has already been breathed by the occupants of the room and, therefore, is directly related to the amount of aerosols, which could contain viruses if there is an infected person in the premises. This is an indicator of the risk of transmission, as it increases with the amount of aerosols inhaled.

With this simple reasoning, the relationship between CO_2 levels and the risk of airborne transmission of COVID-19 can be estimated.

Assuming a typical concentration of CO_2 in the outside air of 420 ppm:

- If 700 ppm is measured in the classroom, this means that 0.7% of the air we inhale has already been breathed by other people.

- If it increases to 800 ppm, the amount of air already breathed grows to 0.95%. Consequently, the risk of contagion would be of the order of 36% higher compared to an environment with 700 ppm. While it does not seem an alarming level, these numbers would already justify the adoption of corrective measures, considering the capacity of persistence in the virus in the air[5].

- And so on...[6] E.g., in case the level reaches 3000 ppm (often reached in classrooms with poor or no ventilation), 6.5% of the air has already been breathed. The risk of contagion is multiplied by 9.3 with respect to the reference case of 700 ppm. It is therefore clear that this situation should always be avoided, at all costs, during prolonged uses of space.

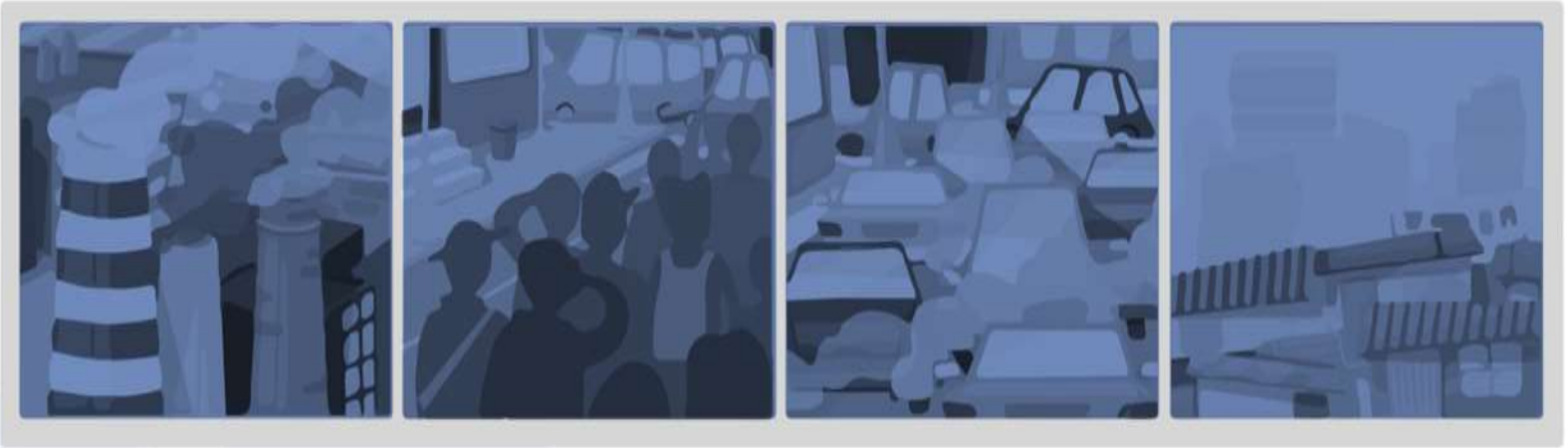
[5] *Se ha demostrado que el virus SARS-CoV-2 es estable en partículas en el aire con una vida media de más de una hora (N. van Doremalen, T. Bushmaker, D.H. Morris, M.G. Holbrook, A. Gamble, B.N. Williamson, et al.Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1N. Engl. J. Med. (2020)) y varios estudios con resultados similares.* (Note: Translation pending)
[6] *De manera aproximada, por cada incremento de 400 ppm en la concentración CO2 se estima que añade 1% de aire ya respirado.*
[5] *Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments. Allen, J.G. et al http://dx.doi.org/10.1289/ehp.1510037).*

05

Places with higher level outside air CO_2

In some places, the concentration of CO_2 in the outside air is significantly higher than the average value in the atmosphere of 420 ppm. This can be the case of industrial areas or urban centres with high traffic, where it can be usual to find levels above 500 ppm.

In this case, the limits should be increased according to the difference between the ambient concentration and the value of 420 ppm. E.g. if in an area there is a concentration of 550 ppm in the outside air, the indicated limits of 700/800 ppm should be increased by 130 ppm, up to 830/930 ppm.



06 Use of Filtration Systems

In some cases, portable air filtration equipment is used, with the ability to effectively retain aerosols, which helps to control the risk of transmission. In these cases, its use does not translate into lower concentrations of CO_2 inside the premises, so if the equipment is well sized, the concentration limits indicated here could be exceeded without increasing the risk of contagion.

In any case, the CO_2 concentration should never exceed 1000 ppm on a regular basis. This is because, on the one hand, it is necessary to ensure that no excessive risk is incurred in case of improper functioning of the filtering equipment[7], and, on the other hand, it is desirable to maintain the overall indoor air quality at acceptable values for a classroom, as defined above (e.g. by the WHO) given the risk of exposure to other chemical pollutants and the impact on the performance of cognitive processes.

CO2 LIMIT AS AN INDIRECT INDICATOR OF INFECTION RISK

The risk of infection (aerosols) is proportional to the concentration of CO_2:

- It is evaluated by the CO_2 **difference** between **indoor and outdoor (ΔCO_2).**
- If ΔCO_2 **>0**, there is already a **risk**.

CO2 Levels	(Assuming an outdoor air CO_2 value of 420 ppm)
≥ 1000 ppm	WHO limit for healthy environments (1.47% air already breathed)
≥ 900 ppm	RITE limit equivalent to an IDA 2 space (classrooms)
≥ 800 ppm	0.96% of the inhaled air has already been breathed in that room
≥ 700 ppm	0.71% of the inhaled air has already been breathed in that room
< 700 ppm	"Acceptable" risk (Harvard and IDAEA-CSIC-LIFTEC recommendation guidelines)
< 550 ppm	Corridors and common areas ("spillway" spaces)

@MA_Campano

[7] *La eficiencia y correcto funcionamiento de un equipo de filtrado, especialmente los portátiles, es de compleja verificación con los medios normalmente disponibles (medir de forma fiable la cantidad de aerosoles requiere equipos especializados y, en cualquier caso, interpretar el resultado no resulta en absoluto trivial).* (Note: Translation pending)

06 Use of Filtration Systems

CO_2 LIMIT AS AN INDIRECT INDICATOR OF THE RISK OF INFECTION

The risk of infection (aerosols) is proportional to the CO_2 concentration:

- It is calculated as the **difference** between the CO_2 found **indoors** and **outdoors** (ΔCO_2).
- If ΔCO_2 **>0**, **risk** already exists.

CO_2 LEVEL ($CO_{2,ext}$ ≈ 420 ppm)	ΔCO_2 indoors-outdoors	% rebreathed air	If a HEPA filter is operating	
≥ 1000 ppm	600 ppm	1,47%	limit	**WHO** limit
≥ 900 ppm	500 ppm	1,21%	warning	**RITE** limit (IDA 2)
≥ 800 ppm	400 ppm	0,96%	acceptable	-
≥ 700 ppm	300 ppm	0,71%	suitable	-
< 700 ppm	300 ppm	0,71%	suitable	*Harvard/IDAEA-CSIC-LIFTEC* Guides
< 550 ppm	150 ppm	0,33%	suitable	Corridors and common areas

@MA_Campano

aireamos.org

aireamos.org

University of Colorado Boulder

LIFTEC

MESURA
WEBMESURA.ORG

Universidad Zaragoza