Avoiding coronavirus infection in indoor spaces: don’t breathe other people’s air

Constant ventilation and permanent control of CO₂ levels are two of the keys to avoiding transmission in closed rooms, as fresh air dilutes the infected particles.
In closed spaces with no ventilation, such as this car, a meter shows that parts-per-million (ppm) of CO₂ accumulate to the extent that within 15 minutes we re-inhale 4% of the air we have already breathed.
If the car is shared and there is no ventilation, within the space of 10 minutes, 8% of the air we breathe in will have already been exhaled by the other passenger. That means we are sharing the air with another person and the risk of transmission is high.
If one of the two people in the car is Covid-positive, the risk of the other catching the virus is 30% in 30 minutes or 71% in an hour.
Humanitarians must open their windows to renew the air up to nine times every minute. The exhaled air disappears and the probability of transmission is low.

During this pandemic, it has been shown that poorly ventilated buildings are the most dangerous environments of all because particles containing the virus can linger in the air until someone breathes them in. And although we do not have a device that can show these particles, we can measure the air quality and CO₂ concentration using a meter. The higher the concentration of CO₂, which is exhaled when we breathe, the worse the room's ventilation. A simple measurement allows us to know if the room is loaded with air exhaled by other people or if it is well ventilated, thereby drastically reducing the risk of infection.
Because of its reduced dimensions, the interior of a car serves as a microcosm of what happens in larger rooms. When a person gets into a car where there is one other person and the windows are closed, the concentration of CO₂ soars, as a percentage of what is breathed in has already been exhaled by the other passenger. However, simply by opening the windows just a few centimeters and generating cross-ventilation, the air gets constantly refreshed. In a house, a bar or a classroom, the premise is basically the same.

**Link between CO₂ and breathed air**

The air we breathe outside contains an average of 412 parts-per-million (ppm) of CO₂. If we observe this figure on a meter, the air has not been exhaled by anyone.

<table>
<thead>
<tr>
<th>CO₂ (ppm)</th>
<th>Air already exhaled</th>
</tr>
</thead>
<tbody>
<tr>
<td>412 ppm</td>
<td>0%</td>
</tr>
<tr>
<td>600 ppm</td>
<td>0.5%</td>
</tr>
<tr>
<td>700 ppm</td>
<td>0.71%</td>
</tr>
<tr>
<td>800 ppm</td>
<td>1%</td>
</tr>
<tr>
<td>1,000 ppm</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

![Diagram of CO₂ levels and air already exhaled]

- **Acceptable risk**: 0.71%  
- **WHO limit for healthy air quality**: 1.5%

---

*Harvard and IDAEA-CSIC-LIFTEC recommended guidelines*
While the virologist Margarita del Val keeps an eye on the levels of CO₂ in cars that she uses with her own meter because “it is an indirect indication that helps us to ventilate correctly,” she is not in favor of promoting its use in the daily lives of normal people. She is, however, in favor of it being regulated and its use promoted as a tool for the authorities. “In many stable environments, such as schools, it is not necessary to have one installed; just a few measurements and you know what is required to maintain good air renewal,” notes Del Val, who is in charge of the Spanish National Research Council (CSIC) platform for Covid-19. “And that includes limiting exposure to the cold, because sometimes it is enough to open the windows just a little.”

Last week, Del Val and 100 other scientists and health professionals sent a letter to the Spanish authorities in which they demanded that urgent measures be taken to prevent transmission caused by poor ventilation. Among the measures advocated was the use of CO₂ concentration as a benchmark by which to measure air quality. Another of the letter’s signatories, Javier Ballester of the University of Zaragoza, is critical of the fact that the government is doing little to tackle existing confusion on the issue. “It’s not enough to provide information via Twitter,” he says. “It’s all very complex – biology and behavior – but there are two indisputably effective factors: ventilation and masks.” Just as the government regulates the quality of masks, it should provide information on how to properly ventilate. There have been many anecdotes describing how some individuals and educational centers ventilate prior to occupancy, leaving the room freezing cold, then close the windows as soon as people arrive, which is when the risk exists. “If they don’t know this, they won’t open the windows, or they won’t sit by the window in the bar: individual awareness is decisive,” says Ballester.

**Risks entering closed spaces and how to avoid them**

**Entering a closed space** occupied by others entails a risk if we don’t know if it contains air that has already been exhaled.

Both CO₂ and the coronavirus can linger for hours in an unventilated closed space.

If we are going to enter a closed space that does not have a CO₂ meter, it is essential to ventilate it first. Opening two windows of 10 cm per minute is essential.

Leaving two car windows open several centimeters while we drive allows cross-ventilation that constantly renews the air.

Stationary vehicle

- 50 km/h 10 cm
- 100 km/h 2 cm

Source: Calculations of air renewal obtained by David Higuera, an industrial engineer and expert in
Scientist Pedro Magalhães de Oliveira, from Cambridge University, has studied how infected aerosols – the suspended viral particles exhaled when talking, singing or breathing – work. To calculate optimum conditions for daily scenarios, Oliveira has developed an online tool called **airborne.cam**. “The potential for measuring indoor CO₂ levels has been largely overlooked,” he says. “Health authorities could do this to identify high-risk locations and better inform the people who manage them.” He does point out, however, that even in a well-ventilated space, there could be short-range transmission when viral particles are breathed in soon after a positive Covid case exhales if there is not enough time for the aerosols to be diluted. “That’s why it’s so important to wear a mask and keep a safe distance, even outdoors,” he says.

Some authorities have taken note. For example, the regional government of Navarre in northern Spain includes the measurement of CO₂ as a important tool for the hospitality sector. A document advising on measures to be taken during the Easter holidays states: “Ventilate as much as possible and measure air quality, using CO₂ meters... If the concentration of CO₂ exceeds 800 parts per million, increased ventilation is recommended or decreased attendance until it [CO₂] falls below that indicator.” In the event, the region has
opted to ban indoor drinking and dining altogether over the Easter period.

Effectiveness of constant ventilation

Measurements of air quality in more than 20 educational centers show that only constant ventilation in closed spaces, whether natural or mechanical, keeps the risk of transmission low.

Constant ventilation maintains the concentration of exhaled air outside the risk zone.

CO2 (ppm)
1,500
1,000
500
0

High risk

Sporadic ventilation

Every time the windows are closed, the levels of CO2 shoot up.

CO2 (ppm)
1,500
1,000
500
0

3 hours

Source: Measurements of CO2 coordinated by Francisco Javier Moya López, director of Indoor Air Quality at Auding Control.
Meanwhile, countries such as Germany, Canada and the UK include CO₂ monitoring in their pandemic guidelines. Last summer, the Harvard School of Public Health published a guide for reopening schools that became a reference. The guide points to these monitors as a key tool for calculating the air quality of classrooms. The CSIC also included them in its recommendations. And the World Health Organization has just released its own detailed manual for adequate ventilation against Covid.

**Mechanical Air Extraction and Natural Ventilation**

Measurements of CO₂ carried out in a bar occupied by almost 100 people on January 21 showed the effectiveness of mechanical air extraction and natural ventilation in reducing the risks of breathing shared air.

Despite the mechanical air extraction and ventilation, the high number of customers maintained the concentration of CO₂ at high-risk levels.

Source: Measurements of CO₂ coordinated by [Javier Ballester](https://elpais.com/especiales/coronavirus-covid-19/how-to-avoid-the-infection/), professor of Fluid Mechanics at the...
But Del Val highlights a major drawback in CO₂ measurement, namely that it does not distinguish between scenarios in which masks are worn or taken off. “Measuring CO₂ in a bar where you can uncover your mouth and talk and shout should not be the same as in a theater or a museum, where you are quiet all the time and wearing a mask,” she says. Del Val believes that the benchmark CO₂ levels for premises where the mask can be removed should be stricter. “It would be a perfect tool for the hospitality industry, to get them on our side,” she says. “You have to support the bars, but first there needs to be a good understanding of what a lower-risk environment consists of, if using these tools.”

Methodology: The infrared camera images were recorded by the Leeds Environmental Fluid Dynamics Laboratory. In-car measurements were taken with an air quality monitor (Aranet Pro Home) in a vehicle with the windows closed and no ventilation last February 25. The risk
of transmission was obtained using the airborne.cam simulator developed by the University of Cambridge and the calculations of air renewal inside the vehicle were obtained with an anemometer (David Higuera, industrial engineer and expert in installations.)

**Development:** Jacob Vicente López.

---

**MORE INFORMATION**

**CORONAVIRUS CRISIS** Spanish scientists demand ‘urgent’ action to curb airborne transmission of coronavirus

**CORONAVIRUS** MIS-C: The strange syndrome that is attacking some children one month after they are infected with the coronavirus

**COVID-19** Coronavirus: How infected air can flow from one apartment to another
CORONAVIRUS A room, a bar and a classroom: how the coronavirus is spread through the air