

Study reveals how poor bedroom air quality affects sleep and next-day work performance

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A night in a well-ventilated bedroom benefits your next-day performance. This conclusion is drawn from an international DTU-based research project studying how poor air quality in the bedroom affects

your sleep.

"It has previously only been sparsely documented that [bedroom air quality](#) can affect your [sleep](#). Our study has now clearly proven that it can," says Pawel Wargocki, Associate Professor at DTU Sustain.

He has headed an international research project that has conducted a number of studies to determine if and how bedroom air quality affects sleep. One of the researchers' findings is that a night in a stuffy bedroom may contribute to poorer sleep and next-day work performance.

In the research project's studies, measurements have been made in more than 100 households, which agreed to let the researchers measure the air quality in their bedroom while they slept. In addition, their sleep was tracked and their cognitive abilities tested. The measurements were made by researchers in both Denmark and at Jiao Tong University in Shanghai, China. The study is published in the journal *Building and Environment*.

Need for twice as much ventilation as the rules prescribe

At night, both people and furnishings affect bedroom air quality. As a consequence of the body's metabolic processes, we humans affect air quality while we sleep. Computers, TV screens, furniture, and clothes also pollute air quality in the bedroom. Together, this pollution accumulates during the night if it is not diluted by, for example, ventilating.

"The air quality in the bedroom can affect your cognitive abilities, such as your ability to concentrate, to understand, and to react. Sleeping in a well-ventilated bedroom benefits your cognitive abilities," says Pawel

Wargocki.

The new studies from DTU suggest that twice as much ventilation in the bedroom as the currently recommended level in Danish building regulations is needed to support your sleep optimally.

An open window improves air quality in the bedroom

In Denmark, there is normally not high outdoor air pollution—typically from traffic and industry—and an open window may therefore be enough. But, in China, the study showed that air pollution is so high that the [indoor air quality](#) was polluted with health-hazardous particles from the outside during the night when the window was open.

"An open window is recommended when air pollution is low and if there is no ventilation system in the home. Otherwise, the best solution is mechanical ventilation," says Pawel Wargocki.

In Denmark, mechanical ventilation has been part of the building regulations' recommendations for newly built and renovated homes since 2008. But this is not yet the norm in Danish bedrooms, nor is everyone able or willing to sleep with the window open.

"We're studying whether other technologies such as air purifiers can ensure just as clean air in the bedroom as [mechanical ventilation](#) or an open window," says Pawel Wargocki.

From plexiglass box to own bed

The researchers' conclusion is based on a number of sub-studies, including having a large number of volunteers spend the night in a so-called climate chamber; a transparent plexiglass box that makes it

possible to monitor and analyze air quality minutely during the night. They have measured what type of emissions we humans produce and how they affect sleep.

Although measurements from the plexiglass box are accurate, very few people sleep unaffected in unfamiliar surroundings and with measuring equipment attached to their bodies. Therefore, the researchers have also conducted a study in people's own bedrooms. More than 100 households let the researchers study the air quality in their bedrooms while they slept with windows and doors open and closed, respectively.

"An open window improved the air quality in the participants' bedrooms so much that they slept better. The following morning, their cognitive abilities also tested better," says Xiaojun Fan, Ph.D. student at DTU and lead author of the latest sub-study under the study, published in the scientific journal *Building and Environment*.

"This suggests that bedrooms should be ventilated with clean outdoor air or supplied with air equivalent to clean outdoor air during the night," says Xiaojun Fan.

An open door is not enough

The air quality in each bedroom was measured via a box, while the participants' sleep quality was monitored through a wristwatch. The participants were also asked to update an electronic log before and after sleeping so that the researchers could take into account any activities that could affect their sleep. When they woke up, they had to record their experience of the night's sleep and undergo a three-minute test of their cognitive abilities.

The researchers have also examined whether sleeping with the windows closed, but with the door open to the rest of the home, made a

difference. However, no effect on the participants' sleep quality could be seen.

"During the night, we humans generate emissions in the bedroom, not in the rest of our home. When you sleep with the door open, air from elsewhere in the home mixes with the air in the bedroom, which dilutes air pollution in the bedroom, but it isn't necessarily clean air that comes from the other rooms in the home," explains Pawel Wargocki.

About the research project

Since 2019, an international group of researchers has been working to document the importance of ventilation and fresh air to sleep quality. The project has been conducted in collaboration with Jiao Tong University in Shanghai, China, with support from the American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE.

The latest study, which builds on knowledge from the group's previous experiments, has been published in the journal *Building and Environment*. It was conducted in Danish bedrooms in the period from September to December 2020.

Over a two-week period, researchers monitored the air quality in the bedrooms while tracking the participants' sleep quality. The participants were asked to sleep as usual for a week, with either the window or door open or closed. Some of the participants continued in the experiment for another week, where they had to do the opposite. During each night, the different parameters characterizing the air quality in the bedroom were measured, while the participants wore a wristwatch tracking how quickly they fell asleep, how often they woke up, whether sleep was light, deep, or REM sleep, etc.

Participants also kept an electronic log of the day's activities and the

night's sleep, which they updated 10 minutes before bedtime and again when they got up. Each morning, they also did a three-minute test of their cognitive abilities.

The study concluded:

- that an open window improves air quality in the participants' bedrooms.
- that the participants sleep better if the window is open and they perform better
- if they sleep with the window open.
- that an open door to the rest of the home does not have a measurable effect on sleep quality.

When does air quality affect our sleep?

If ventilation keeps CO₂ from persons sleeping in a bedroom below 750 ppm, then the air quality in the room is so good that it does not affect sleep quality. If CO₂ exceeds 2,600 ppm, the air quality is so poor that it affects sleep quality to such an extent that [cognitive abilities](#) are affected the next day; this may also be the case at lower CO₂ concentrations.

CO₂ is used as an indicator of how good the ventilation is in rooms where there are people. Indoor CO₂ is mainly released by humans due to the metabolic processes of the body. The concentration is measured in mg/m³ or in ppm (ppm, parts per million, refers to the number of carbon dioxide molecules per million molecules of dry air).

- Below 750 ppm: Adequate ventilation—no negative effect on sleep quality. This will be a typical measurement for a well-ventilated bedroom.
- Between 750 ppm and 1150 ppm: Possibly insufficient ventilation—in some cases, sleep quality may be adversely

affected.

- Above 1150 ppm: Insufficient ventilation—sleep quality will be adversely affected. CO₂ levels that are higher than 1150 ppm will typically occur in bedrooms that are not fitted with a ventilation system and where windows and doors are closed.
- Above 2600 ppm: Insufficient [ventilation](#)—both sleep quality and next-day performance are adversely affected.

More information: Xiaojun Fan et al, A field intervention study of the effects of window and door opening on bedroom IAQ, sleep quality, and next-day cognitive performance, *Building and Environment* (2022). [DOI: 10.1016/j.buildenv.2022.109630](https://doi.org/10.1016/j.buildenv.2022.109630)

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