**COVID-19: Study on particle distribution in classrooms**

**Open windows not guaranteed to prevent high aerosol concentration levels in classrooms**

High levels of potentially infectious aerosol particles can accumulate in a classroom over the course of a lesson, even with the windows open. That is the conclusion of a study from indoor air experts Wolf GmbH, performed with the support of TU Berlin. “Airborne particles spread through a room quickly and if relying on window ventilation alone, these can only be effectively reduced by opening the windows fully at regular intervals,” according to Prof. Dr.-Ing. Martin Kriegel, Head of the Hermann Rietschel Institute. “Doing this properly would disrupt the lesson in a number of different ways.” A ventilation unit is much more effective at reducing particle concentration levels than the typical window ventilation examined in the study and also does not disrupt the lesson.

**Study demonstrates the advantages of using mechanical ventilation over window ventilation**

The study looked at how aerosols would spread in a typical classroom (approx. 60 m²) on a summer morning with an outside temperature of around 20 °C. The simulated room was occupied by one teacher and 24 pupils, one of whom was infected with coronavirus. The windows in the room were left slightly open at all times, and then opened fully for five minutes after 20 minutes, in line with scientific advice. Based on an emission rate of 50 particles per second, it took just five minutes for aerosol particles from the infected person to travel throughout the entire room. This emission rate is for nasal respiration on its own and would be much higher if the infected individual were to speak, sneeze or cough. The study mapped the spread of airborne particles using a simulated gas which closely tracked the movement of the air in the classroom. The volume of contaminated air increased the further the source of the particles was from an open window and reached more than 900 infected particles per m³ in some areas. Opening all of the windows for five minutes provided a sufficient air change rate (15 ACPH) to reduce concentration levels to less than 100 particles per m³, minimising the risk of infection. However, particle concentration levels went back up following the same pattern when the windows were closed. “The simulation showed that having windows slightly open gives you quite a low air change rate. Having the windows completely open is more effective,” explained Prof. Dr. Ing. Kriegel.

Even relatively small changes to certain parameters like wind speed, the time of year or the difference between the outside temperature and the temperature inside the room can increase particle concentration levels well beyond those observed in the simulation. It may also be impossible to fully open the windows safely in certain classrooms without supervision, particularly on upper floors.

Scientists are currently uncertain how many contagious particles are needed for somebody to become infected with coronavirus. However, it is generally accepted that the risk of infection goes up in proportion with the particle concentration level.

The study also looked at what the aerosol distribution levels would be for a classroom with permanently closed windows under the same conditions if it were fitted with a WOLF air handling unit. In this scenario, the ventilation unit fed fresh air into the room at a rate of 800 m³ per hour through ceiling vents and continuously extracted stale air at the base of the unit. Under these conditions, the air in the classroom was completely exchanged 4.44 times per hour. The unit in question is relatively simple to install. WOLF can also provide air handling units capable of delivering air at rates well in excess of ten thousand cubic metres per hour. These air handling units make sure that indoor air is replaced evenly and significantly reduce the number of areas with high concentrations of infectious particles. They also eliminate the need to fully open the windows of the classroom at regular intervals, which can cause a large amount of disruption and significant temperature fluctuations.

**Window ventilation leads to unsafe CO2 levels and expensive electricity bills**

The study also looked at changes in the temperature and CO**2** levels within the classroom over the course of a lesson. The level of carbon dioxide in the atmosphere is around 400 ppm. Indoors, levels up to 1000 ppm are considered safe. Above that level, people start feeling drowsy and unwell, and may have difficulty concentrating. According to the Federal Environment Ministry, anything above 2000 ppm is unacceptable. For the purposes of the simulation, each person was assumed to exhale CO2 at a rate of 0.016 m³/h. The continuous supply of fresh air from the ventilation unitkept the CO2 levelto a maximum of 950 ppm over a 45 minute period. When window ventilation was used exclusively, the simulation calculated CO2 level*s* of up to 1300 ppm.

A permanent heat load of 2500 W was calculated for the people and objects in the classroom. This caused the simulated temperature to increase to 24 °C within a short time frame, despite the windows being partially open. Opening the windows fully for five minutes decreases the comfort level for individuals in the vicinity of the areas due to the cold draught, while also impeding sight lines and having a negative impact on the acoustics in the room.

Increased levels of activity within the classroom or a higher outside temperature could lead to dramatic spikes in indoor temperature. For the purposes of the simulation, the ventilation unit fed air in at the same temperature as the air outside (20 °C) to keep the temperature consistent and pleasant. Air handing units can also be fitted with heating or cooling coils to change the temperature of the air.

Keeping schools well-ventilated will be particularly challenging in the autumn and winter months ahead. Lowering the temperature to a pleasant 20 °C is the main hurdle in warm weather. In cold weather, schools will face reduced comfort levels and a sharp increase in their energy bills as they turn to keeping their classrooms heated.

Ventilation units are one way to significantly reduce energy requirements, particularly in light of the 2030 climate targets. Heat recovery systems provide ecological and economic advantages over window ventilation by recovering up to 90 percent of the energy used for cooling or heating.

Portable air purifiers are also being discussed as another alternative. These use a variety of systems to filter viruses out of the air circulating indoors or inactivate them. However, they are no replacement for traditional window ventilation and have no impact on the quality of the air. They are unable to regulate or improve relative humidity levels, CO2 levels or temperature.

“This study clearly shows that, if you follow the window ventilation guidelines, a lot of extra work and sacrifices are required to achieve the necessary air change rates, particularly in the current situation where hygiene levels are so important.

Using a ventilation unit to provide an appropriate air change rate can reduce both CO2 and aerosols to reasonable levels. As we continue to research COVID-19, opening the windows fully in between lessons will also help,” according to Bernhard Steppe, WOLF Sales Director. The more fresh air flows into the room, the better the indoor environment, regardless of whether that air comes through a ventilation unit or an open window. WOLF GmbH has installed high-quality air handling units for around 300 educational institutions across Germany in just the last 12 months.

**Hermann Rietschel Institute at TU Berlin**

The Hermann Rietschel Institute at TU Berlin has a long history of research into the spread of airborne impurities in indoor areas. Since the outbreak of COVID-19, the institute has been researching the transmission routes and half-life of the virus under different conditions under the leadership of Prof. Dr.-Ing. Martin Kriegel. This simulation was performed in collaboration with the research team.

**WOLF company profile:**

The WOLF Group is a leading supplier of heating and air handling systems.Together with its listed parent company, CENTROTEC SE, it is also a leading supplier of comprehensive energy saving solutions to the building services sector. With around 2,100 employees working at the various company locations and 60 sales partners in more than 50 countries, WOLF has a strong international presence and generated sales of around EUR 404 million in 2019. WOLF has positioned itself as “the expert for a healthy indoor environment” and backs up this claim with a clear promise: “WOLF – Perfectly in tune with you.” More information at [www.wolf.eu](http://www.wolf.eu).

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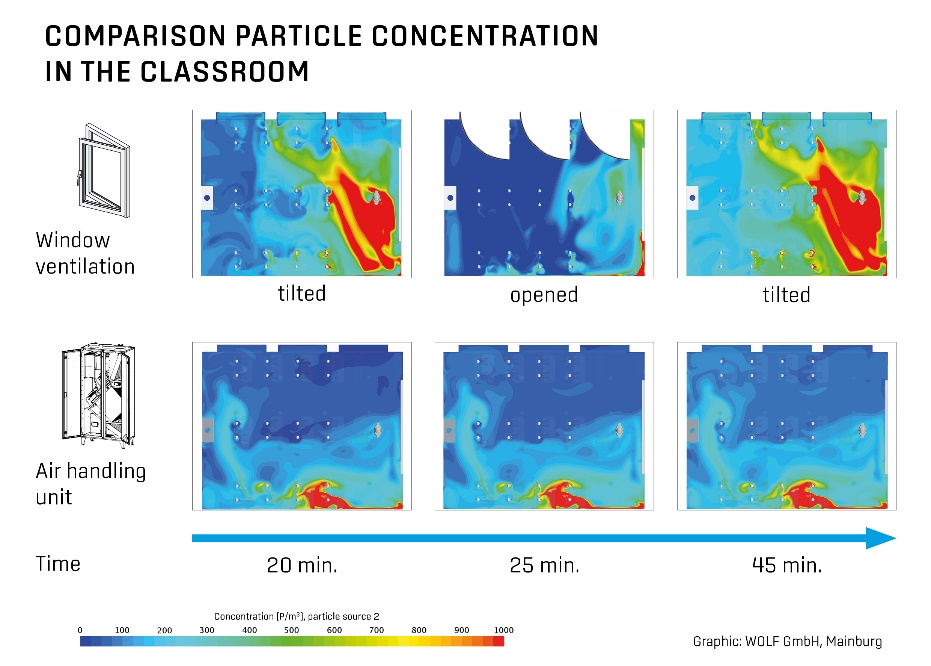
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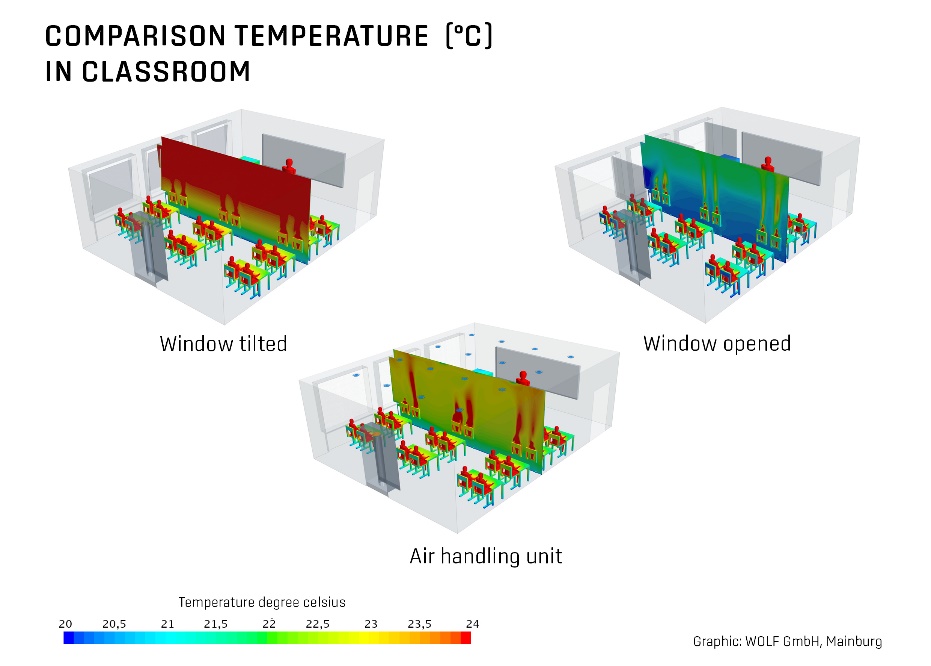
**Photos**

**Open windows do not prevent high aerosol concentration levels in classrooms**

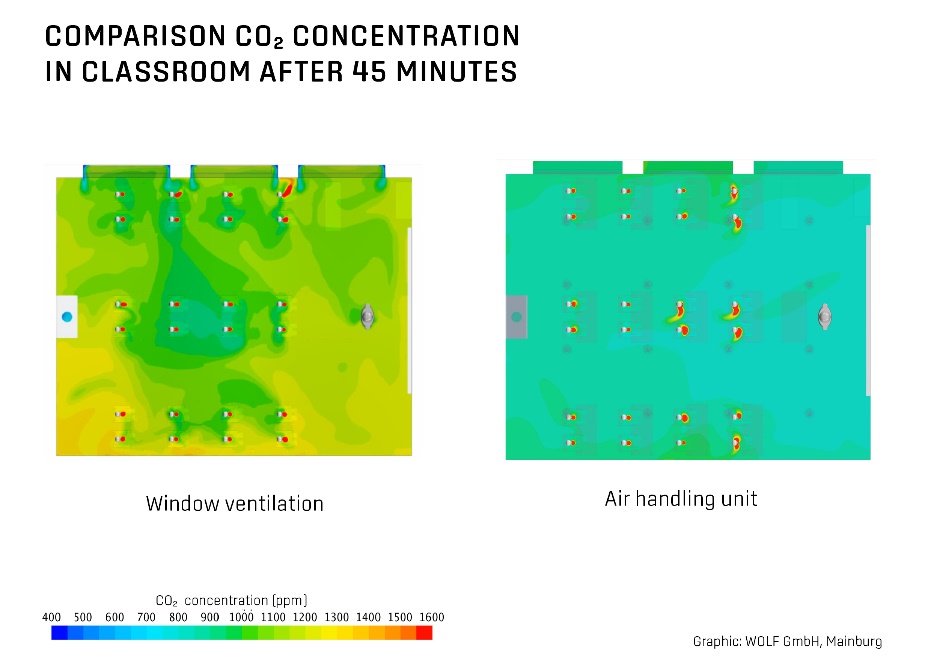
Source: WOLF GmbH



**Caption:** Concentration of particles from an infected person (sitting in the first row, next to the wall) over the course of a lesson. Impact of ventilation unit compared to window ventilation.



**Caption:** Stationary temperature profile established in the classroom after a brief period in the analysed ventilation scenarios.



**Caption:** CO2 concentration distribution at a height of 1.0 m after a lesson - comparison between window ventilation and ventilation unit.