"Air conditioning" – Virus spreaders or infection prevention?

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The COVID-19 superspreading events affecting the meat industry across most parts of the western world dominated the newspapers and unsettled many people. Concerns grew that room ventilation systems aid the spread of the Corona virus, or its reproduction inside the ventilation system. Overall, these worries are unjustified in most cases.

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By means of dilution and separation of air pollutants, room ventilation systems can lower the infection risk indoors substantially. Proper planning and operation as intended, including maintenance, are important prerequisites. However, it is necessary that operators of certain room ventilation systems reassess the operation of their systems.

What is "air condition"?

In the everyday lingo, the term "air condition" is being used for all kinds of ventilation devices and systems. That is to no surprise: For non-specialists the split air conditioner available in DIY-stores is just as much an air condition as the ventilation system with an equipment room the size of a football field, supplying ventilation to e.g. 500 hotel rooms, its swimming pool, its kitchen and conferencing areas (**Figure 1**). It is this undifferentiated use of the term "air condition" which leaves users of air conditions currently in great concern.

In the meat processing industry, which was regarded as Corona "hot spot" during the summer, only a small amount of fresh air is being supplied to the processing

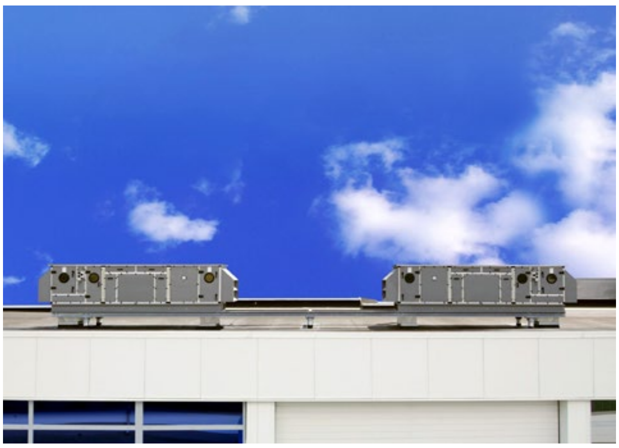

Figure 1. Room ventilation systems can help to lower infection risk. [Photo courtesy of Howatherm]

rooms. For cooling these rooms only recirculating coolers are being used. Such devices draw in the available indoor air, cool it down and blow it back into the room. A dilution of air pollutants is feasible only via the minimal required (i.e. legally specified) air change. Although the standard VDI 6022 Part 1 also requires filters for secondary air units and said recirculating air coolers, those measures are not being implemented here. Airborne pathogens and pollutants are not being separated from the indoor air in these cases. In contrast, modern ventilation systems in offices have multiple filtration stages and are being operated with a supply of 100% outdoor air. This allows for the separation of air pollutants as well as droplets carrying viruses. The overall concentration of contaminants is lowered by diluting the room air with fresh outdoor air. In fact, in order to afford the separation of viruses from indoor air HEPA filters are not always necessary. Airborne viruses are seldom "naked" but are usually attached to other, larger particles and droplets. This is in line with findings of higher infection rates in dust-carrying indoor air.

Some viruses can survive on surfaces for extended periods. However, neither will they reproduce on these surfaces nor inside room ventilation systems. Unlike bacteria, viruses themselves need a host organism in order to reproduce.

Is retrofitting filters feasible?

Retrofitting filters in existing devices is not impossible, but it also is not an all-round solution. And whether it is a practical approach is another question. Especially when using HEPA filters, the pressure loss is quite considerable. The ventilation concept therefore needs reassessment. The used air in meat-processing rooms brings a considerable humidity and particle load to the ventilation system. Thus, HEPA filters can be expected to clog quite quickly, and due to capillary action, the filter mesh will become soaked too. This increases the risk of microbial contamination and its growth on the filter. Certainly, this means increased filter inspections at the very least.

What is the role of air temperature and humidity when it comes to the spread of the corona virus?

Leclerc et al. (2020) compiled a database listing a variety of superspreading events worldwide, and many of these events started in the food processing industry. What are the driving forces behind these events?

In the food processing industry in general, but particularly in the meat processing industry low indoor air temperatures are necessary (5 – 10°C) since meat spoils rapidly at higher temperatures. Additionally, the air inside the slaughter room is being dehumidified. Even air with a relative humidity of 100% at 5°C only has 20% of humidity left when it is being warmed up to 25°C. This is what happens when the cooled air is being inhaled by the workers. The air takes humidity from the mucous membranes of the respiratory system which weakens the protective effect of these membranes (Lauc et al., 2020). The airways become more prone to infection; fewer germs (in this case viruses) suffice to trigger an infection.

In many production areas, where the processes require lower temperatures and a low relative humidity strict rules on breaks for the workers are in place: The workers are allowed to work under these conditions only for a limited interval. They must recover from these conditions in a room with comfortable temperature and humidity before they go back to work the next interval in this stressing environment.

A noisy work environment and physical labour also play an important role. Loud talking or even shouting as well as taxing levels of manual labour not only increase the amount of aerosols emitted but also the emission speed. In addition, the size spectrum of droplets is altered.

Keep 2 m of distance, and everything is fine?

Recent footage from inside some meat processing plants show distance between the individual workers is not kept. However, 2 m is not the gold standard when it comes to a safe distance. Qureshi et al. (2020) discussed this number in a meta study and concluded that 2 m indeed is recommendable since the larger droplets sink to the floor quickly, mostly within this radius. However, using high-speed cameras Bourouiba et al. (2014) showed that aerosols produced by coughing and sneezing emits aerosols of a large range: some droplets are visible to the naked eye and sink fast, but the finer fraction can cover distances of up to 8 m.

Dry air increases the evaporation of aerosols. The individual droplets shrink in size and therefore are suspended in the air for longer periods and can cover larger distances. Studies regarding the spread of droplets only consider gravity but ignore tail- and head wind as well as thermal factors. Currents and thermal updraught distort the spreading pattern significantly. A laminar flow from the ceiling towards the floor for example is being used in operation theatres for a long time now, in order to keep the operating table protected from airborne particles. In contrast a reverse flow, from the floor to the ceiling will keep airborne particles suspended for a longer time. Thus, a ventilation concept for rooms is important when taking measures for infection prophylaxis.

UV-Radiation as silver bullet?

UV-C radiation in room ventilation systems has been used successfully for many years where disinfection and prevention of biofilm formation is required, i.e. in heat exchangers. The efficacy of UV-C radiation and its killing-effect on viruses is well proven (**Figure 2**). Researchers at the University of Boston report a very high killing rate for the Corona virus on surfaces. That is not very surprising: For many viruses the required doses for a killing-effect are known and are achievable for a range within the UV-spectrum. The reduction of various airborne viruses in room ventilation systems was proven, for example, in a research project of the German "*Stiftung Industrieforschung*".

When using radiation to kill bacteria and viruses suspended in an airflow, the dwell time of the viruses within the effective range of the radiation source is critical. Additionally, the radiation intensity needs to be sufficiently high. Currently, room ventilation systems can be fitted with low-pressure or high-pressure lamps.

The wavelength of the radiation used is important. UV-C lamps emit radiation with wavelengths far below the 254 nm emission sufficient to kill viruses. The emission at 185 nm produces ozone. This gas kills viruses, but it must not seep into the room itself due to its irritating and harmful effect on humans. Ozone-free lamps filter out this wavelength and only use the emission at 254 nm for disinfection. Ozone can also be eliminated by using filters coated with activated charcoal.

A spin-off of UV-technology is a current hype where residential lighting is equipped with UV-C lamps, which are usually labelled as "sterilization lamps". In one case these lamps are advertised with a picture of a young family and their toddler relaxing under such lamps. But: UV-C radiation is cell toxic. Not only viruses are killed by what can be considered a sun burn, but the DNA of human cells is damaged as well. UV-C cannot kill viruses and be harmless at the same time. A disinfection of a room by means of "sterilization lamps" is not realistic, especially not in occupied rooms.

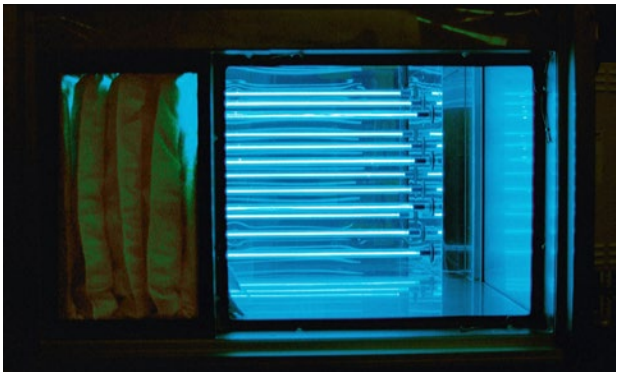

Figure 2. For many viruses the required doses for a killing-effect are known and are achievable for a range within the UV-spectrum. [Photo courtesy of Howatherm]

Masks, Shields and the like…

First and foremost, (textile) face masks hamper the spread of aerosols that are emitted during breathing, speaking and physical activity. They catch the larger droplets in particular. Since a lot of the respirated air moves through the gaps between mask and face instead of moving through the tissue, face masks are no replacement for the required distancing but are a supplementary measure. While they offer a small amount of protection for the wearer, the main purpose of textile face masks is the protection of others. Good protection for the wearer can be achieved by wearing professional personal protective equipment, certified masks, at least level FFP2. However, increased tightness comes with increased discomfort, especially when wearing masks for several hours. Ask the paramedics transporting Corona-infected persons at the height of the first wave, what wearing a tight-fitting rubber mask for hours on end does to your face!

When staff are required to wear masks in their work environment, a proper introduction to mask hygiene is highly recommended.

Plexiglass-shields are also useful physical barriers for the larger droplets and are helpful when two people are standing face-to-face at a small distance, such as reception areas and check-outs. Regular disinfection is vital, i.e. a wipe down of said shields with a disinfectant. Shields are not a solution when it comes to increase occupancy rates for rooms since they do not decrease the spread of fine aerosols. Those must be removed or reduced by ventilation.

How should owner-operators react to new findings?

Technical solutions

Ventilation: Currently, the focus lies on increasing the rate of fresh air. Fresh air dilutes the concentration of airborne viruses inside a room. Wherever feasible, room ventilation systems should be operated with a supply of 100% outdoor air. Depending on the outdoor conditions, air must be humidified to comfortable levels, i.e. 40% to 60% r. h..

In rooms without mechanical ventilation effective window ventilation is of high importance.

Filtration: When technical reasons only allow recirculation of air, indoor air should be decontaminated by air purifiers. Fine aerosols can be separated by fine filters. However, those filters tend to clog quickly and under conditions of high relative humidity they carry the risk of mould growth and growing through of microorganisms. Frequent inspections and, possibly, replacement of filters is required.

UV-Radiation: Ozone free UV-C radiation devices suitable for installation in room ventilation systems are available and promise a high killing-effect.

Curtailing maintenance intervals: room ventilation systems and all their components are to be maintained as per manufacturers specifications as well as according to the current acknowledged rules of technology, especially VDI 6022 and VDI 3810 Part 4. With respect to the currently increased infection risk, shortening maintenance intervals can be required.

Organizational measures, such as reducing the occupancy rate of rooms and social distancing, cohort rules or the introduction of regeneration breaks during work carried out in dry, cold air and personal protective equipment such as face masks also offer a potential for risk reduction.

Do not underestimate the effect of instruction

All measures that require cooperation of the person to be protected work the better, the more the person understands the mechanism. These mechanisms need to be understood and accepted as well as supported by stringent personal hygiene.

What must the owner-operator do?

The infection risks described in this article do not only occur in the meat processing industry but also in other branches. Whenever special and hitherto unknown risks occur, in this case the Corona pandemic, operators must make use of advanced technology and recent scientific findings in order to avoid an increased infection risk. When encountering new findings regarding risk potentials they must take anticipatory action. A currently valid risk assessment of each room ventilation system must be checked and updated accordingly when new findings arise. The operator cannot entirely delegate this responsibility to a third party or by means of a service contract. Operators are always obliged to at least perform suitable checks to make sure tasks delegated are indeed carried out effectively.

Conducting a risk assessment of room ventilation systems requires skilled knowledge, such as provided by VDI certified experts for indoor air quality. Even the selection of the personnel and experts carrying out risk assessment is the operator's responsibility. ■

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Literature

Leclerc QJ, Fuller NM, Knight LE et al. What settings have been linked to SARS-CoV-2 transmission clusters? [version 2; peer review: 2 approved]. *Wellcome Open Res* 2020, **5**:83

Lauc G, Markotić A, Gornik I, Primorac D. Fighting COVID-19 with water. *J Glob Health*. 2020;10(1):010344. doi:10.7189/jogh.10.010344

Qureshi, Z., Jones, N., Temple, R., Larwood, J. P., Greenhalgh, T., & Bourouiba, L. What is the evidence to support the 2-metre social distancing rule to reduce COVID-19 transmission? https://www.cebm.net/covid-19/what-is-the-evidence-to-support-the-2-metre-social-distancing-rule-to-reduce-covid-19-transmission/ (Geprüft am 21.07.2020)

Bourouiba, Lydia, Eline Dehandschoewercker, and John WM Bush. "Violent expiratory events: on coughing and sneezing." *Journal of Fluid Mechanics* 745 (2014): 537-563.