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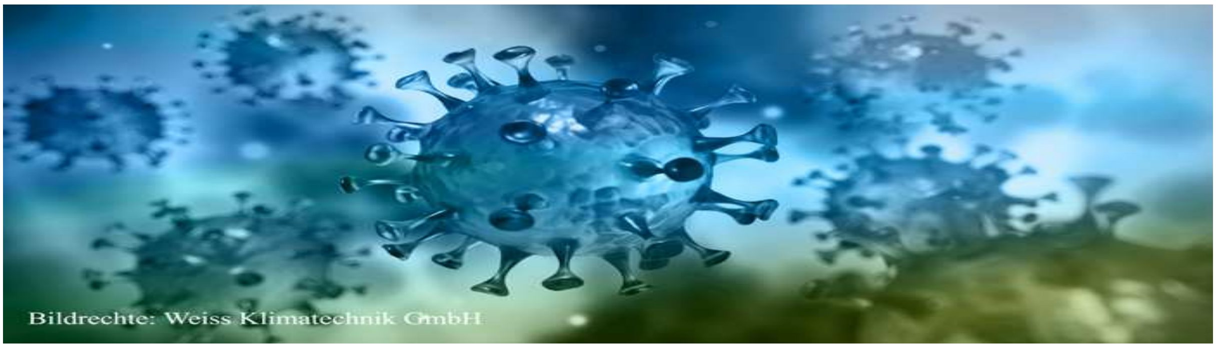
Ventilation technology to reduce the risk of infection



What potential do ventilation technologies offer for reducing the risk of infection in places of assembly, for example classrooms? Which ventilation technology can prevent the air path from infected persons to other room users as far as possible? A comparison[1] shows: Only properly operated and controlled displacement ventilation or stratified ventilation are able to eliminate almost the risk of infection. While displacement flow makes retrofitting seem unattractive due to the required technological effort and the air volume flows, retrofittable stratified ventilation systems are conceivable.

The basis of the analysis in this handout is the investigation[1] of the extent to which different room ventilation solutions are able to influence the design of the room flow, and which infection risk is shown for these by a transient calculation for the beginning and the following hours of room use.

Substance load levels for quality control of ventilation systems

A reliable and, above all, simple method of determining the risk of infection in indoor spaces is the designation of local substance load levels, see formula 1, and their linkage with the characteristic values of the infectious agents. Substance load levels, which can be easily determined for each room and each ventilation technology by measuring concentrations and balancing tracer gases or, to an acceptable degree of accuracy, by measuring and balancing carbon dioxide, can reliably show the protective effect of the ventilation measure**.**

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[1] **Potential of ventilation measures for reducing the risk of infection**

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The role of thermals

The decisive factor in assessing a ventilation technology with regard to reducing the risk of infection is the question of how to break the dominance of thermals or how to make better technical use of them to control the room flow. The higher the heat input into a room, e.g. by the room occupants or radiators, the more influence the flow-generating influence of thermals gains. The aim of ventilation technology must be to surpass this influence or to use it for its own benefit.

Room flows of different ventilation solutions to reduce the risk of infection

Mixed ventilation

The flow form of mixed ventilation is the most frequently encountered flow form in indoor spaces and one of the most unfavourable room flows from the perspective of infection risk. To reduce the risk of infection, it is necessary to prevent the flow paths from the infected person to the person in need of protection. Mixing in the room cannot fulfil this requirement. If thermals and kinetically imposed flow counteract this, it primarily leads to increased turbulence and thus to mixing. High heat loads in the room result in a mixed form of mixing and stratification ventilation. Temperature stratification close to the ceiling can also be observed here. Room air rollers, moved by thermals above warm sources, transport infectious agents from areas near the ceiling back into the occupied zone. Transverse velocities of the room air rollers increase the risk, especially for those sitting next to an emitter. As the air exchange rate increases, the risk of infection decreases along with the concentration of airborne substances. In principle, the risk of infection cannot be virtually ruled out with mixed ventilation.

Displacement flow

The safe removal of infectious agents without endangering the neighbour is only possible through vertical displacement. For the stability of the displacement flow, the orientation against or with the thermal is of decisive importance for the stability of the displacement flow. Both horizontal flow and flow directed against the thermal can be ruled out as impracticable. In the first case, neighbours of an infected person are at risk; in the second case, the required airflow is disproportionately high. The displacement flow in superposition with the thermal requires significantly lower air changes than the oppositely directed flow. Nevertheless, the comparatively high air change rates and the most uniform possible air input into the room make it difficult to retrofit displacement flow.

Recirculating air purifier

A frequently advertised practice to reduce the risk of infection is the use of recirculating air cleaners. These draw in room air, remove or at best kill almost all infectious agents depending on the process used, and then blow the contamination-free air back into the room. Since recirculating air cleaners are based on the principle of mixed ventilation, they offer increasingly less protection against infections the more influential the thermals become due to increasing heat input in the room. Under real mixed-air room flows, they cannot produce virus-free air, but at best reduce virus concentrations and thus the risk of infection. The smaller the volume flow of recirculation air cleaners, the more important it is to choose their appropriate position in the room. In rooms with high heat loads, such as classrooms, they must be installed close to the ceiling in the area of the highest virus concentrations in order to ensure effective operation. Due to the mass conservation at the base of the buoyancy plume, which acts close to the floor, room air rolls are created with or without the intervention of the recirculation air cleaners, which transport air back into the occupied zone.

Air recirculation systems

Ventilation systems with a non-decontaminated recirculated air component are not considered further here, as these systems have been shown to contribute to the incidence of infection due to the recirculation and mixing of viruses in the room.

Layer ventilation

A special form of room air flow is stratified ventilation. By tracking uncontaminated air close to the floor, stratified ventilation supports the thermal system and, if properly controlled, prevents the formation of room air rolls and thus the recirculation of polluted air from the upper temperature layers. The required air change does not serve to displace but to compensate for the buoyancy volume flows. In contrast to displacement ventilation, air tracking in stratified ventilation can be carried out selectively at one or two points in the room. The flow guidance of the layered ventilation is much more flexible than that of the displacement flow and thus much more accessible for retrofitting.
In contrast to the displacement flow, the control for the exact provision of the necessary thermal volume flow is of greater importance.

If the control is successful, significantly lower contamination levels and thus infection risks in the occupied zone can be achieved compared to mixed ventilation. Compared to displacement flow, stratified ventilation usually requires lower volume flows. Lower volume flows and the more flexible flow routing certify that layered ventilation is easier to retrofit compared to displacement flow.

Risk of infection

In the following explanations, the risk of infection and the substance contamination level are related. The use of the substance contamination level is well known from the extraction of pollutants of health concern at the workplace to ensure workplace safety. The substance load factor φ for assessing the indirect risk of infection and for assessing the effectiveness of a ventilation system is advantageously defined as the number concentration of substances foreign to the air that follow the air without inertia in the case of investigation $\Psi_{\text{measurement}}$ in relation to the concentration that would result in the ideal mixed ventilation $\Psi_{\text{mixing ventilation}}$ with otherwise identical air exchange.

$$\varphi = \frac{\Psi_{measurement}}{\Psi_{\text{mixing ventilation}}}$$

Figure 1 below shows examples of the loading levels of mixed ventilation and stratified ventilation measured in the mockup room during operation with the identical air change rate.

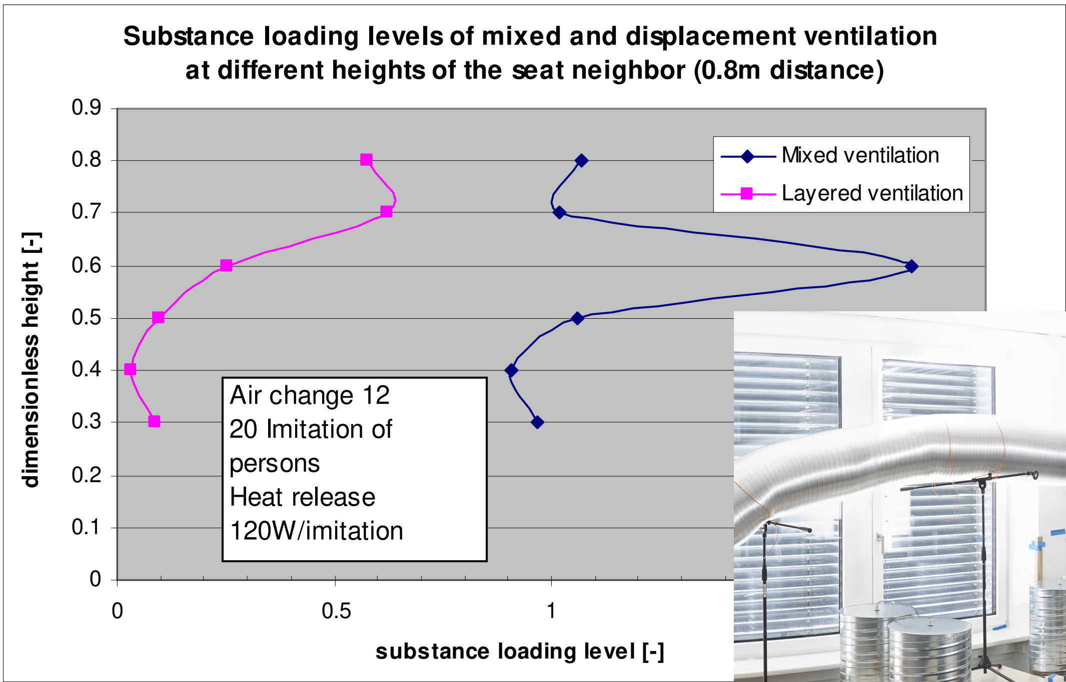
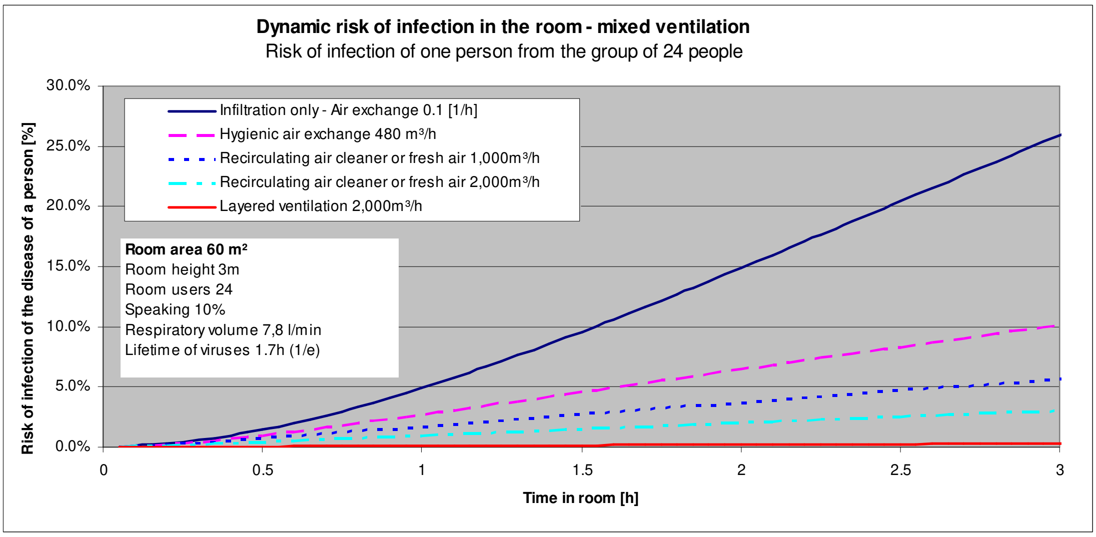


Figure 1: Top: Measured loading levels 0.8 m next to the emission source for stratified and mixed ventilation.
Right: Basis of the flow experiments is the simulation of a partially or fully occupied class within a mockup room

In the area of seated persons, the degree of contamination and thus the risk of infection is lower by a factor of about 10. Particularly noticeable is the substance contamination level of the mixed ventilation at approximately head height of the person sitting next to the emitter. The resulting increased risk of infection is explained by flow streaks starting from the emitter, which occasionally pass directly through the person sitting next to him in the mixed ventilation mode.

Statements on the risk of infection require knowledge of the virus concentration at the site of assessment, in addition to the substance contamination level already introduced. Current statements on virus concentration and thus on the risk of infection in indoor spaces are mostly based on steady-state persistence, both in terms of enrichment of the room air and in terms of virus death. However, especially at the beginning of room use, the specific virus load is low and only increases with increasing room saturation in mixed ventilation. The larger the room and the lower the air exchange rate, the higher the influence of virus mortality. In the transient observation made here, the exponential approach for calculating the virus lifetime is integrated via the emission time and a time-dependent survival rate of the viruses is applied to the room concentration. This results in the infection risks in rooms with 60m² and 120m² area shown as examples in Figure 2. The strong increase in the risks of "free ventilation" is striking. Mixed or recirculating air cleaners benefit from high air volume flows. Only stratified ventilation shows an infection risk in the per mille range over a period of 3 hours.



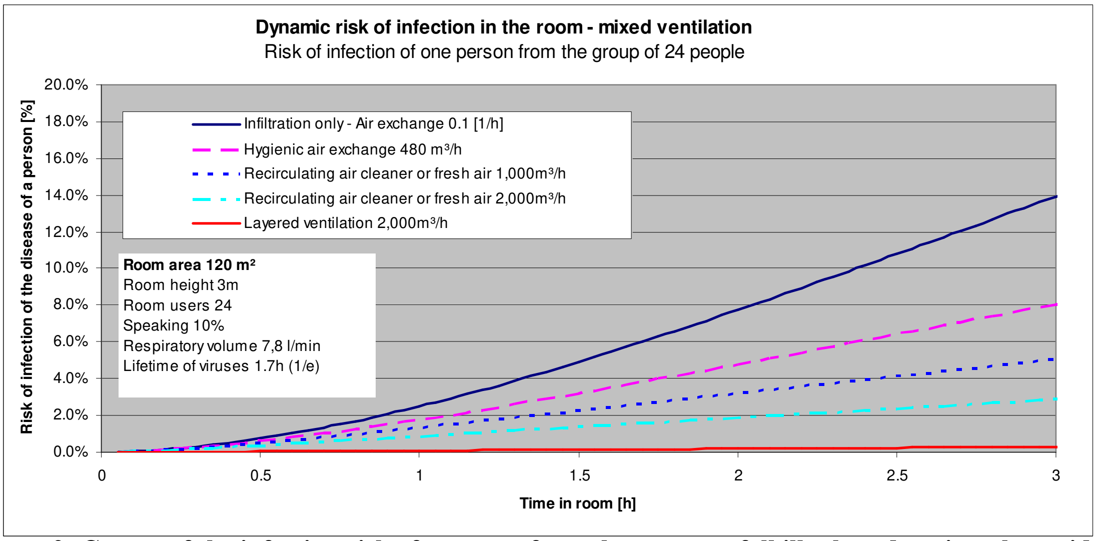


Figure 2: Course of the infection risk of a person from the group to fall ill, plotted against the residence time for different ventilation situations and rooms.