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DEPARTMENT OF CIVIL ENGINEERING
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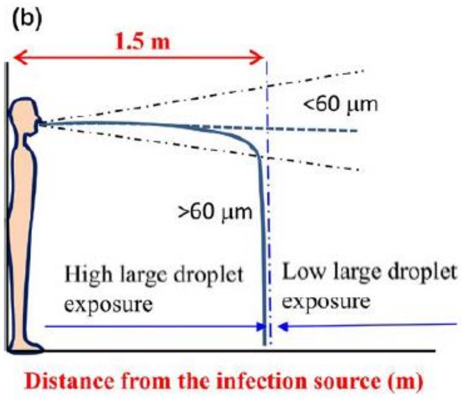
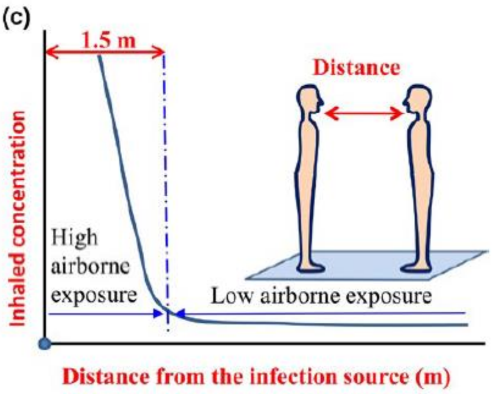
We would like to express some thoughts about the influence of the air distribution on droplet infection and airborne cross infection. The text is based on full-scale experiments with tracer gas and numerical simulation. First: what is the difference between droplet infection and airborne infection?

In droplet infection we talk about exhaled droplets (>100 μm) containing water and bacteria or virus. The droplets are heavy, and they **will fall to, especially, horizontal surfaces** at some distance shorter than 1.5 m. Airborne cross infection involves droplet nuclei (< 5-10μm). The droplet nuclei (aerosols) are so small that they **will follow the airflow** and thus they can travel long distances. It is particularly interesting that the **concentration of droplet nuclei will decrease within the first meter from a person's exhalation** see Figure 1 (c). This effect is due to the aerodynamics of the exhalation flow and the flow in the microenvironment around persons.



Exposure from droplets



Exposure from droplet nuclei (aerosols) in rooms with sufficient ventilation

Figure 1.

Field measurements (in the air) in real situations, as in a COVID-19 hospital room, will not show any difference in the two situations if the room is sufficient ventilated. The cross infection will be viewed as 'high risk' close to an infected person and 'low risk' at some distance from an infected person. It is thus difficult to distinguish between droplet infection and airborne cross infection, and the remedy to keep distance will work in well-ventilated rooms.

The concentration of virus in a room depends on the air change rate and the ventilation effectiveness of the air distribution system. Figure 2 (d) shows how a room with a low air change rate has a high concentration level everywhere, especially close to the person exhaling. This is different from droplet transmission. Pure droplet infection does not depend on air change rate, and it is controlled by cleaning of surfaces.

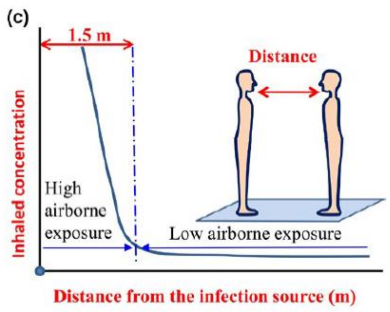
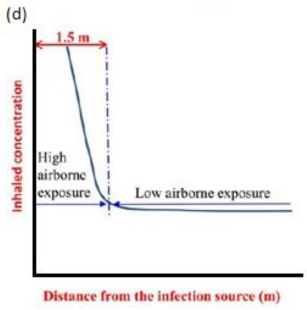
High air change rate in the room	Low air change rate in the room
	

Figure 2. Airborne concentration in a room with high and low air change rate

Figure 3 shows the concentration of droplet nuclei (aerosols) in the exhalation and how this will decrease with distance from an infected person in case of displacement ventilation, Liu et al. (2016)

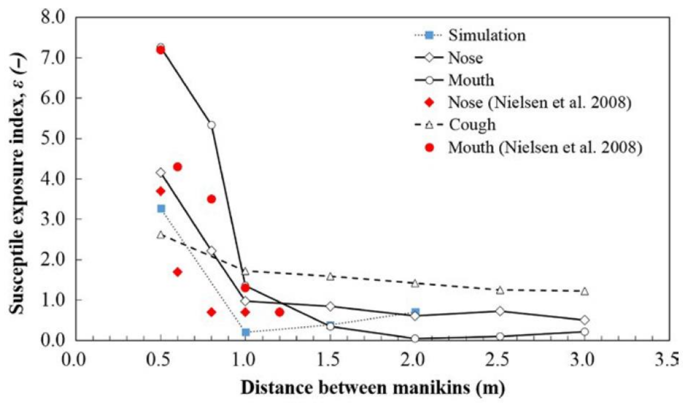


Figure 3. Exposure index versus distance ($\varepsilon = c_{max}/c_R$). c_{max} and c_R are inhaled concentration of target person and return concentration respectively.

The level and distribution of virus in a room depend on many things such **as the layout in the room, heat load distribution, positioning between persons and direction and height of their faces, the type of air distribution in the room, and location and type of air diffuser**, see for example Nielsen et al. (2008) figure 4 and Nielsen et al. (2012), figure 5:

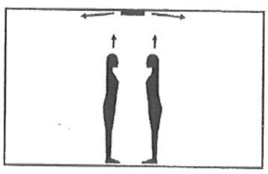
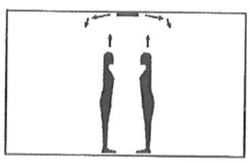
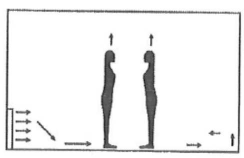
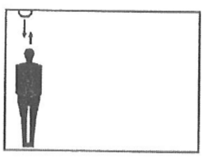
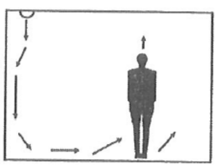
 c_{max}/c_R = 1.7	 c_{max}/c_R = 2.1	 c_{max}/c_R = 7.3
 c_{max}/c_R = 1.8	 c_{max}/c_R = 4.0	

Figure 4. Air distribution in the room, and location and type of air diffuser.

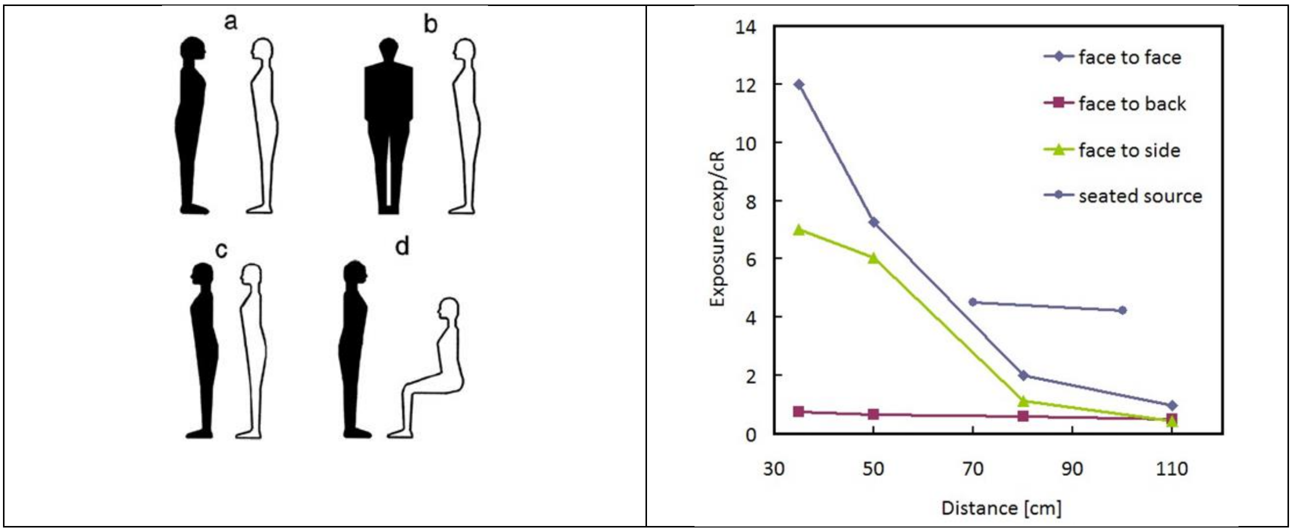


Figure 5. Different position of two people in a room with displacement ventilation

Droplet infection and airborne infection as discussed in the introduction are **main parameters in the medical literature**. Different diseases are expressed as **droplet infection or airborne infection**. When we look on the definition from a fluid dynamic point of view, the situation is floating. Figure 6 shows exhalation from a person in a room with two levels of humidity, Liu et al. (2016):

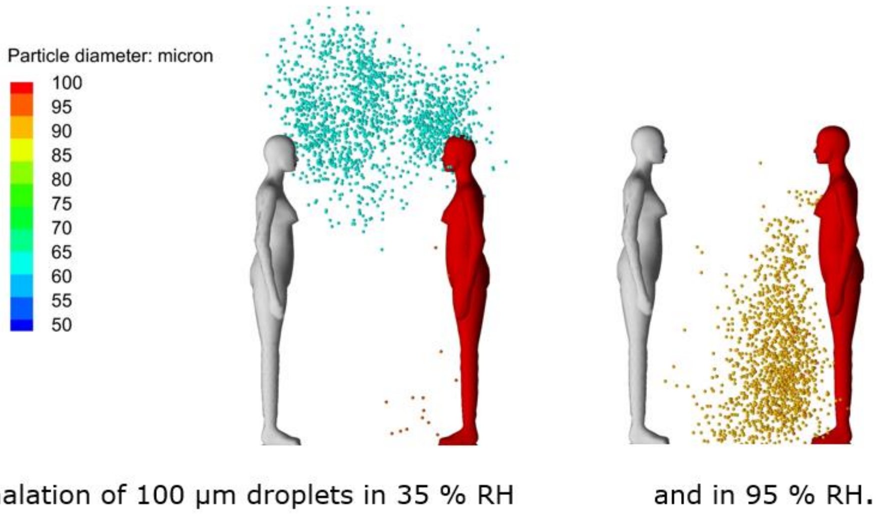


Figure 6. Computational Fluid Dynamics (CFD) simulation. RH: Relative Humidity

When the room air is dry (35% RH), the exhaled droplets will evaporate rapidly and continue as **air borne droplet nuclei (aerosols)** whereas they will fall to the ground as **droplets** if the room has a high moisture level (95% RH).

Different diseases are characterized by **different exposures to the surroundings**. Droplet nuclei are distributed through breathing and talking, while droplets and droplet nuclei are distributed through coughing; all scenarios at different levels according to the disease. The CFD model in figure 6 is only a part of the process in some situations.

In general: Personal protection equipment (PPE) and ventilation are mandatory for the public and the healthcare workers (HCWs) in particular, in order to minimize the infection risk.

Literature

Liu, L, Nielsen, PV, Xu, C, Wei, J & Li, Y 2016, Impacts of Modelling Simplifications on Predicted Dispersion of Human Expiratory Droplets. In 14th International Conference on Indoor Air Quality and Climate (INDOOR AIR 2016). bind 3, International Society of Indoor Air Quality and Climate, s. 1484-1491, Indoor Air 2016, Ghent, Belgium, 03/07/2016.

Nielsen, PV, Winther, FV, Buus, M & Thilageswaran, M 2008, 'Contaminant Flow in the Microenvironment between People under Different Ventilation Conditions', ASHRAE Transactions, no. Part 2, s. 632-640.

Nielsen, PV, Olmedo, I, Adana, MRD, Grzelecki, P & Jensen, RL 2012, 'Airborne Cross-Infection Risk Between two People Standing in surroundings with a Vertical Temperature Gradient', HVAC&R Research, 18(4):552–561, 2012. Copyright C 2012 ASHRAE. ISSN: 1078-9669 print / 1938-5587 online DOI: 10.1080/10789669.2011.59844

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