Covid-19 and the role of aerosol particles

Statement of the working committee Feinstäube (particulate matter) (AAF) of DECHEMA/ProcessNet, GDCh und KRdL[a,b]

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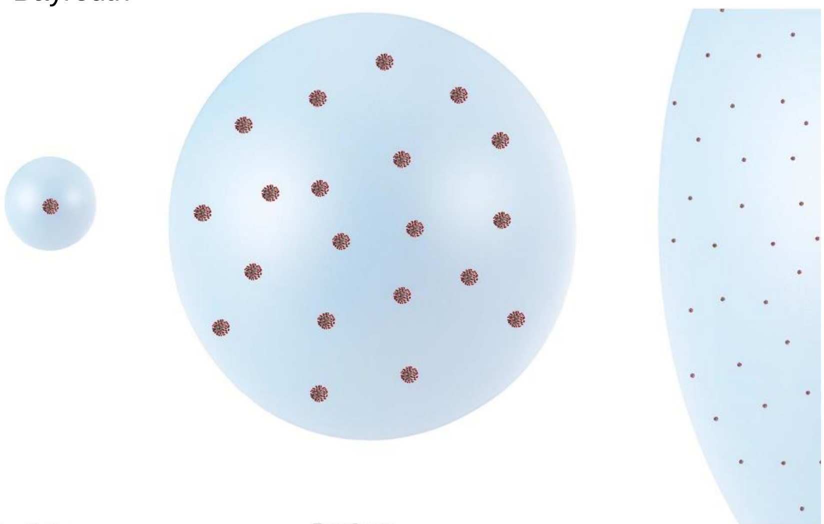

Schematic representation of the proportions of SARS-CoV-2 viruses (0,1 µm) in aerosol particle emissions of the nose and the mouth. From left to right: (A) Basal respiration, (B): Speaking, singing, and shouting (mouth), (C): Even larger droplets are emitted of the nose and the mouth when sneezing. Suspended viruses are embedded in saliva or dried up lung liquid, cold and damp climate and darkness extend their activity. The particles A can hover longer than one day in unventilated rooms, the particles B several hours. The largest particles (C and mostly bigger) of the sneezing sink to the ground within few seconds. In contrast to cloth face masks N95 and FFP2 masks protect as well against the particles A.

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[a]: Scientific Associations: DECHEMA (Society for Chemical Engineering and Biotechnology, Frankfurt; ProcessNet: Platform for Chemical Engineering of DECHEMA and VDI-GVC; VDI: Association of German Engineers, Düsseldorf; GVC (Society for Technology and Chemical Engineering in the VDI, Düsseldorf); GDCh (German Chemical Society, Frankfurt); KRdL (VDI/DIN commission Air Monitoring (KRdL) – standards committee, Düsseldorf)

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In the AAF working committee experts in the field of Chemistry, Aerosol Physics and Engineering Sciences deal with questions on the origin, the spreading, the composition, and the impact of particulate matter in the environment. Many aspects of these works do also matter in the current pandemic.

Scientic state of knowledge

The SARS-CoV-2 virus spreads in three ways [1, 2, 3]: (i) through skin-to-infected-surfaces contact, (ii) through larger droplets, which are emitted from infected persons when coughing, sneezing, singing or speaking loudly and are absorbed through the mucous membranes of the mouth, the nose and the eyes (iii) through inhaling suspended particles – the so-called aerosol particles. Unlike the medium sized and bigger droplets B and C, the aerosols A are even being exhaled while sleeping. The particles A and B penetrate the lowest areas predisposed to infections of the lung and can just be held back with N95 or FFP masks since the maximum permeability of the hygiene masks lies within this size range. When particles B penetrate the alveoli, they are preferably absorbed there and pose a particular risk of infection through their hundredfold volume.

Precautionary measures for these three paths of infection are careful hand washing, wearing breathing masks as mouth-and-nose masks and keeping sufficient distance from others (AHA measures). Furthermore, visors or goggles as eye protection are necessary when working with infected persons in hospitals. While hand washing and social distance keeping are simple and understanding preventive measures, there is a good deal of missing knowledge when it comes to the effect of masks and how to correctly wear them. The positive thing about masks is in general that they reduce the loss of breathing moisture in dry air – as well as in overheated rooms – and hence, keep the mucous membranes moist and lower the penetration depth of the aerosols into the airways. The so-called cloth face or community masks protect from the larger aerosols C. However, these masks do protect less against the suspended particles A and B what also applies for cutting discs or face visors which just serve as splash guards for droplets. As regards the inhalation of aerosol particles N95 and FFP2 masks guarantee a better protection, but only when the mask is in the optimal position and the metal reinforced sealing perfectly sits at the nasal bridge. Many useful and current information on masks and their properties can be found under [4].

The spread of SARS-CoV-2 viruses via the aerosol particles A and B explain multiple infections in largely occupied interiors as in schools, restaurants, busses, local trains or planes as well as in cruise liners and ferries, during church services [1] and choir rehearsals [5].

The infection through skin contact (i) is presently regarded to not contribute much anymore to the occurrence of infection, what was differently assessed earlier in the pandemic. Since larger droplets (ii) behave ballistic their duration of stay in the air is short and their spatial range very limited. The drag and gravity ensure that emitted droplets with a 0,1 mm = 100 µm radius for instance (C in the Figure) sink to the ground within 10 secs in stationary air through sedimentation. Such droplets are formed when shouting, singing, or speaking loudly and especially when coughing or sneezing forming the basis for the social distancing rule of 1,5 – 2 m. Indoors, the downwelling of the larger particles is somewhat delayed through the buoyancy of the warm breathing air. However, the lift of the small aerosol particles (A and B) is so strong that they first rise towards the ceiling and will then spread from there.

The aerosol particles A and B have a much different propagation behaviour as the bigger droplets C. Aerosol particles (= suspended particles) do not immediately descend but hover in the air for a longer period [4] and are widespread and mixed up through flow and turbulence. In contrast to the droplets, finest particles (A in the Fgure) already arise when breathing normally since they are formed in the lower airways in the region of the alveoli. But not only breathing in a forced way while doing sports or singing extremely increases the emission, also the individual fluctuation margin of this aerosol emission is high. Differences from person to person with a factor of 100 when basally respiring or speaking are observed, regardless of the lung volume, the breath deep, and the age and medical history. Therefore, some of us are ‘super emitters’ [6], without being aware of that. Emission concentrations of these aerosol particles A of the mouth linearly increase with the volume when singing and speaking. They also individually vary up to a factor of 10 – there are also super emitters for this size category [7]. Hence, infected super emitters can as well be ‘super spreaders’, and might thereby considerably contribute to infections and possibly infect many persons at the same time. In addition, larger particles are emitted when speaking, sneezing, and coughing [8]. The biggest particles at all are emitted when sneezing [9]. A smaller part of infected persons causes the larger part of the infections.

Exhaled droplets which consist of aqueous and/or mucus-loaden solutions have a very dynamic behaviour – depending on the temperature and the humidity of the air. The water-based fraction evaporates in dry and warm air, the droplets shrink and so increase the retention time in the air. It is thus advantageous to let the relative humidity in the indoor air not decrease too much to not increase the aerosol particle life spans through drying [10]. Moreover, an indoor air humidity which is not too low is of advantage for the physiological function of the human mucous membranes.

The risk of a virus infection outdoors is low in most cases due to the relatively quick dilution and the limited lifetime. However, when mouth-and-nose masks and the obeyance of social distancing rules are disregarded at big family gatherings or mass events such as ‘anti-corona-demonstrations’ all the infection routes come together at the same time.

The risk of a Covid-19 infection will be unexceptionally the greatest indoors without mechanical ventilation and with a high fraction of circulated air, if more or many people stay indoors for a long period of time and it is window-ventilated too little. Here, virus-infected aerosols concentrate and increase the risk of an infection, even when mouth-and-nose masks are worn. An intensive and effective ventilation can be achieve by window opening as a simple and cost-effective measure. Mechanical ventilation is also a good method but then a high possible fraction of outdoor air and an effective filtering of the unavoidable amount of circulating air are important. The infection protection against virus- infected aerosol particles is thus important for the current situation and for the coming cold and damp winter months, but at the same time probably the most challenging to technically realise. The situation here is technically different from the US to Europe.

The basis of any filter technology of virus-infected particles is the deeper knowledge of the physico-chemical and biological properties of those particles. A comprehensive collection of material on the issue ‘FAQs on the protection against Covid-19 aerosol transmission’ where the chairman of the AAF is a co-author is available in the internet under https://t.co/YhMaeLnEN3?amp=1 [1]. In the meantime, mathematical models have also been developed simulating the behaviour of certain droplets and aerosol particles indoors in the presence of a variable number of persons in several situations which clearly show the risk of an infection [11].

What to do - which measures are necessary?

The members of the AAF working committee of DECHEMA/ Processnet, GdCh and KRdL support all reasonable measures for the containment of the spread of the virus. These measures primarily and in the short-term should deal with the interruption of the infection chains to restore the tracking of the spreading as well as to avoid an collapse of the medical care and especially ICUs. We also support the warning call of the presidents of the leading German Research Associations and of the National Academy of Sciences Leopoldina who call for the urgent need for protective action [12], which is required again due to the high number of infections – this currently hold for many regions of the world, unfortunately. We see very clearly the short- and medium- term related technical and staffing effort but are convinced that the appropriate consideration of the spreading of the virus via the aerosol path can lead to a short-term and also substantial containment of the present occurrence of infection and might in addition be advantageous for the future. Accodingly, we also share the current recommendations of the Robert Koch Institute.

Besides the already discussed precautionary measures such as the wearing of mouth-and-nose masks and the compliance with the social distancing rule in general as well as the setting up of plexiglas at highly frequented places (cash registers, information desks and bank counters) N95 and FFP2 masks should be widely used and active ventilation techniques be further developed and implemented indoors. Window ventilation is recommended as a protective measure in schools for quite some time, now and in the coming months. Better ventilation effectiveness will be achieved if a cross ventilation (e.g. opening of a door across to the windows) can be performed. A monitoring of the CO_2 concentration to control the achieved air exchange is a highly useful and necessary addition.

According to recent studies there improvement in active ventilation measures is possible and should be aimed at. So far, conventional ventilation systems run with a fresh air supply from above in busses, trains, and planes. Those procedures are also used in churches, office buildings, stores etc. mostly in combination with air conditioning and heating systems. Regarding a cold regulation such a set-up just makes sense as the colder air automatically sinks down. However, when it comes to the protection against infectious particles the ventilation from above could be counterproductive as it flows against the emitted particles and fosters their spreading through the turbulence thus created. The same applies for ceiling fans which are used in warmer world regions and just mix the air and spread potential contaminants. Accordingly, an air suction upwards would be more advisable. This supports the natural motion of the exhaled warm air with the particles and could deliver the virus-loaden particles to outbound so that the particles do not further spread indoors. Again, air quality can be further controlled with a continuous monitoring of the CO_2 content with simple measuring devices while higher CO_2 is as well removed at the same time. Questions on air purification indoors related to health issues are a subject for engineering research for a long time [13, 14]. Regarding ventilation and air purification as well as sources, characteristics, and the behaviour of aerosols there are clear progresses and new findings of research and industrial laboratories such as the Max Planck Institute for Chemistry in Mainz [15], the German Aerospace Center (DLR) [16], the Fraunhofer Institute for Toxicology and Experimental Medicine in Hannover [17] as well as of Mr. A. Mayer (NanoClearAir, Switzerland) [18]. According to the mentioned researchers and developers approx. 90% of all aerosols potentially containing the virus could be removed of the classrooms.

The AAF recommends in detail:

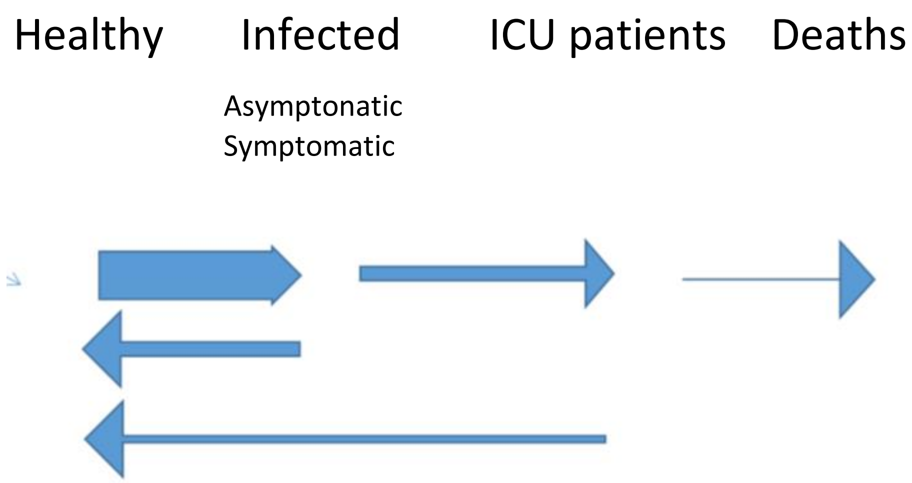
- Ventilation and suction systems with or without a recirculation of filtered air can and should be installed in sectors where many people meet in the short-term.
- Means should be provided in the Federal States to install ventilation and suction systems, adequate air purification systems and CO_2 measuring instruments in school classes. It would also be helpful to ease the administrative rules at the local level and put the personal responsibility and initiative on the school management and provide means for the climatic and air ventilation consulting.
- Proper ventilation systems, mobile air purifiers and CO_2 measuring instruments should also be implemented in other highly frequented areas as in restaurants, bars and eating places and their procurement according to air ventilation consulting should be facilitated. Also for cultural events, possibilities for a normalisation of the business could arise through monitoring the CO_2 level and thus air hygiene.
- It has consistently been reported about infections in planes [19]. The air supply from top to bottom in passenger planes contradicts the natural uplifting of warm particle loaded air and fosters its spatial expansion and increases thus the risk of infection. A reversal of the fresh air supply is technically feasible for sure and should be considered.

- The AAF also points out that the situation in busses (especially when pupils travel to and from school), local trains as well as in city trains and light rails is not satisfying. It cannot be excluded that passengers are exposed to a high risk of infection during the rush hours in these vehicles due to the high surface density even though people wear masks as prescribed. Here, an improved air supply if necessary, could generate positive effects.

- N95 and FFP2 masks are highly recommended because of their filtering efficiency for particles A. They should be mandatory in many sectors instead of the simple hygiene masks and be improved as regards the breathing resistance and the sealing.

- Recovered infected persons could be offered the option of a medical check-up of the individual particle and virus emission during basal respiration and when speaking, so that potential individual super emitters could act extra-responsibly in the future such as wearing respirator masks as much as possible.

- During the Covid-19 pandemic, healthy infected, ill and dead people follow a dynamic – as with any infection – which can be shown in a flow chart of the following way.



- The present situation with very high daily new infections indicates that the initial occurrence of infection in a “lock down light” (such as in Germany) is – despite the current measures – not under control. As a consequence of that, the number of the patients with a need for treatment gradually increases in the intensive care units and also the one of the dead persons. To prevent a collapse of healthcare the occurrence of infection has to be reduced as to restore the tracking of the health authorities. Only this will further reduce the occurrence of infection, see for instance [20].

The members of the AAF working committee of DECHEMA/ ProcessNet, GDCh and KRdL expressly endorse the consideration of the findings and recommendations for action compiled within the ‘aerosol-FAQ’ [1] and they particularly emphasise the need for a rethinking in the ventilation technology. Moreover, they call upon the responsible persons within the health care sector in Germany and Europe as well as in the relevant supranational institutions (in particular the WHO) – insofar as they have not explicitly done so – to recognise the role of aerosol particles (i.e. ‘airborne transmission’) within the spread of the SARS-CoV-2 virus and take measures fighting against it.

The AAF fully supports the political will in Germany and elsewhere to maintain the economic life and school activities in the pandemic, if possible, and provide special protection for the sensitive and/or elder population with underlying medical conditions. The society owes itself that due to economic and ethical grounds. The most important means will be the successful application of vaccines soon. Until then we have to trust and apply the further protective measures in the short-term, as explained in detail above. These protective measures should be applied until vaccination really reaches wide parts of the population. On the timescale beyond, the measures detailed here might prove useful for possible future pandemics, and, generally, for the reduction of infections via the air pathway in general.

Literature and internet resources

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