Study - Daimler EvoBus Coaches

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Introduction

Based on current findings, aerosols are regarded as a decisive transmission path for SARS-CoV-2 viruses [RKI2020]. The Hermann Rietschel Institute (HRI) at the Technical University of Berlin has been working on the airborne spread of particles and aerosols for several years. There is no evaluation of the close range directly in front of the person.

Boundary conditions and methods

Kriegel [Kriegel2020] describes methods with which it is possible to calculate the aerosol concentration over time and the quantity of inhaled aerosols. In the following, the results of the calculations for a coach using different scenarios are presented.
The boundary conditions of the scenarios investigated are shown in Table 1.

Table 1: Boundary conditions of the investigated spaces

	Space volume in m^3	Air change rate in 1/h	Ventilation principle	Ventilation effective-ness	Maximum number of persons	Number of persons at 70% occupancy / in compliance with distancing rules
80% outside air, 20% circulating air	50	37.5	Mixing ventilation	1	55	39
30% outside air, 70% circulating air				1		
Reference office	300	1.4	Mixing ventilation	1	16	8

A filter efficiency of 99%, similar to a HEPA filter, is used for the recirculated air portion.

Three different parameters were considered for the coach:

- The duration of the trip:
  - Transfer journeys 60 minutes
  - Average journey in tourist traffic 150 minutes
  - Long distance coach ride 240 minutes
- The number of infected persons in the space
  - 1 person (based on current infection figures in Germany)
  - 10% of the maximum number of persons, as a critical case
- Activity of the persons
  - Breathing 25 particles/s [Hartmann2020]
  - Speaking 300 particle/s [Hartmann2020]

Result and discussion:

The expected course of the aerosol concentration for the scenarios in the coach and the mechanically ventilated office space is shown in Figure 1. Only the aerosols emitted by the infected person(s) are considered, as only these aerosols pose a risk of infection. For an air change rate of 37.5 1/h and an outside air rate of 80 %, there is a higher aerosol concentration than in a mechanically ventilated office room only in the case of six infected speaking persons. This number of infected persons is not likely to be expected due to the current infection situation in Germany, which is why the situation is not to be considered particularly critical with this air change rate.

If the proportion of outside air is reduced to 50%, the situation with regard to aerosols with a filter that has a separation efficiency of 99% is virtually unchanged compared to a higher proportion of outside air.

Furthermore, Figure 1 shows the course of the CO_2 concentration. With a fresh air content of 80%, the limit of 1000 ppm is maintained for 39 people. An increase in the number of persons as well as a reduction in the amount of fresh air (air change rate or proportion of fresh air) lead to a significant increase in the CO_2 concentration, the maximum of which in the case under consideration of 30% fresh air is slightly above the limit of 1500 ppm defined by Pettenkofer, but below the hygienically questionable limit of 2000 ppm.

Table 2 and Figure 2 additionally list the quantities of aerosols inhaled from the room air at different times. Due to the current lack of scientifically substantiated results regarding the number of viruses to be expected per aerosol as well as the critical dose of inhaled viruses before an infection can be expected, an interpretation of these results regarding the occurrence of infection is difficult. Again, it can be seen that there are only slight differences between the considered cases of outdoor air concentrations, if a very good separation efficiency (99 %) of aerosols in the filter is assumed. Due to the current incidence of infection, at most one infected person can be expected. Figure 3 shows a correspondingly shortened representation of the amount of virus inhaled.

Limits and restrictions

In all considerations it must be taken into account that the aerosol concentration in the direct exhalation volume flow of the person is significantly higher and the considerations for this area cannot be applied. Nor do the considerations allow any statement to be made about the survivability of the viruses in the indoor air, which depends, among other things, on the room temperature and humidity.

Table 2: Inhaled aerosol quantity in the different scenarios

	Inhaled aerosol quantity		
	after 60 minutes	after 150 minutes	after 240 minutes
37.5 1/h, 80% outside air, 20% circulating air, breathing, 1 infected person	18	45	72
37.5 1/h, 80% outside air, 20% circulating air, breathing, 6 infected persons	105	268	430
37.5% 1/h, 80% outside air, 20% circulating air, speaking, 1 infected person	211	536	860
37.5% 1/h, 80% outside air, 20% circulating air, speaking, 6 infected persons	1,265	3,213	5,161
37.5% 1/h, 30% outside air, 70% circulating air, breathing, 1 infected person	18	45	72
37.5% 1/h, 30% outside air, 70% circulating air, breathing, 6 infected persons	106	269	432
37.5 1/h, 30% outside air, 70% circulating air, speaking, 1 infected person	212	538	864
37.5 1/h, 30% outside air, 70% circulating air, speaking, 6 infected persons	1,271	3,229	5,187
Office, speaking, 1 infected person	350	1,173	2,016

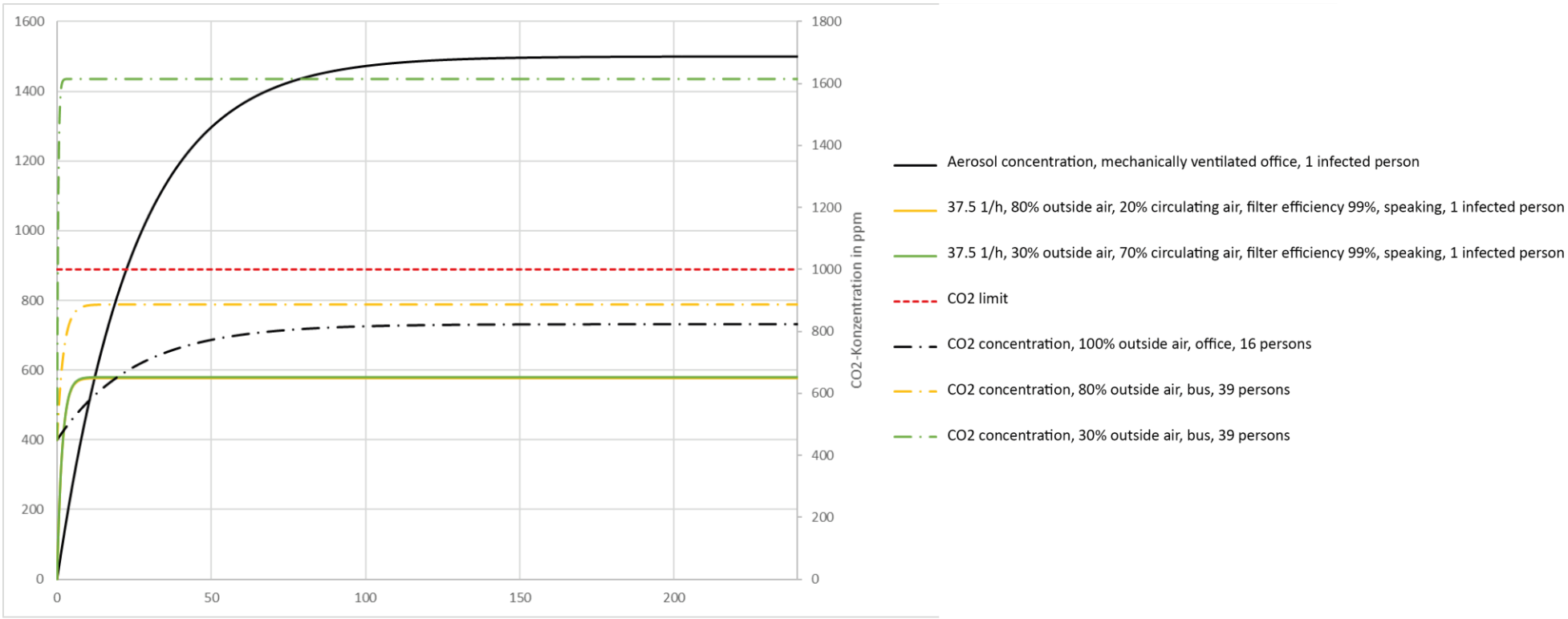

Figure 2: Exemplary course of aerosol concentration (left axis) and CO_2 concentration (right axis) during a coach journey without a break of up to 240 min with an infected, speaking person

Figure 1: Exemplary course of aerosol concentration (left axis) and CO_2 concentration (right axis) during a coach journey without a break of up to 240 min with an infected, speaking person

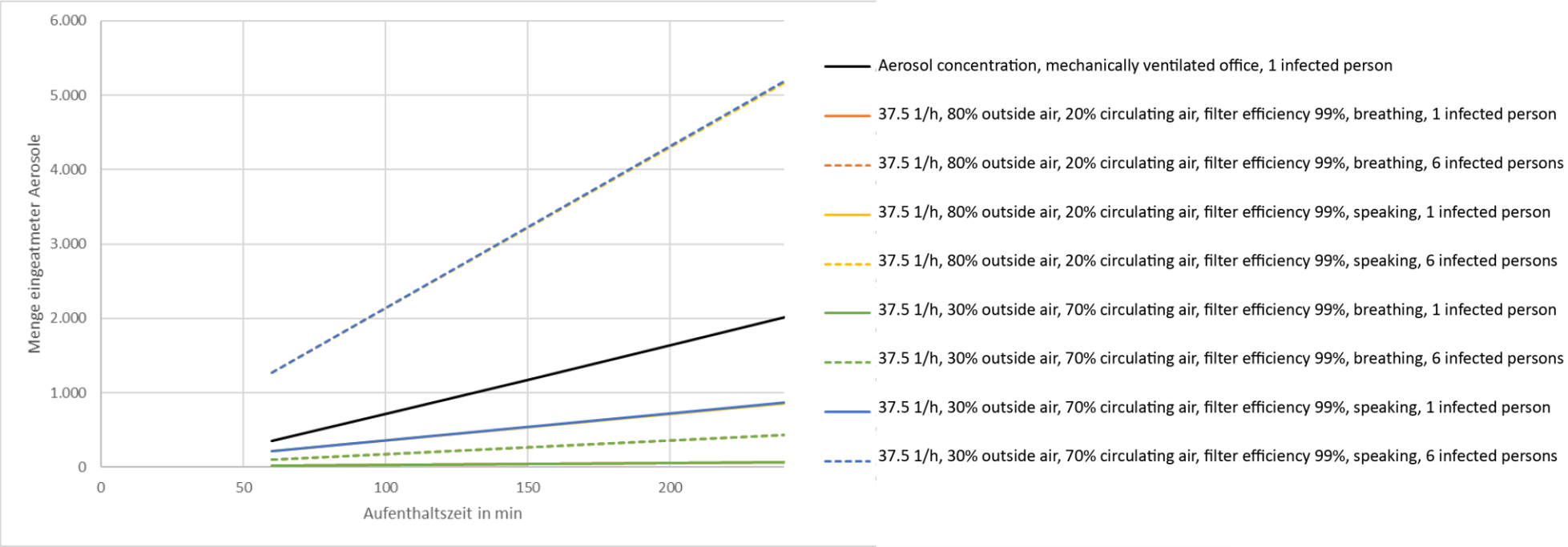

Figure 3: Quantity of inhaled aerosols as a function of exposure time for different scenarios

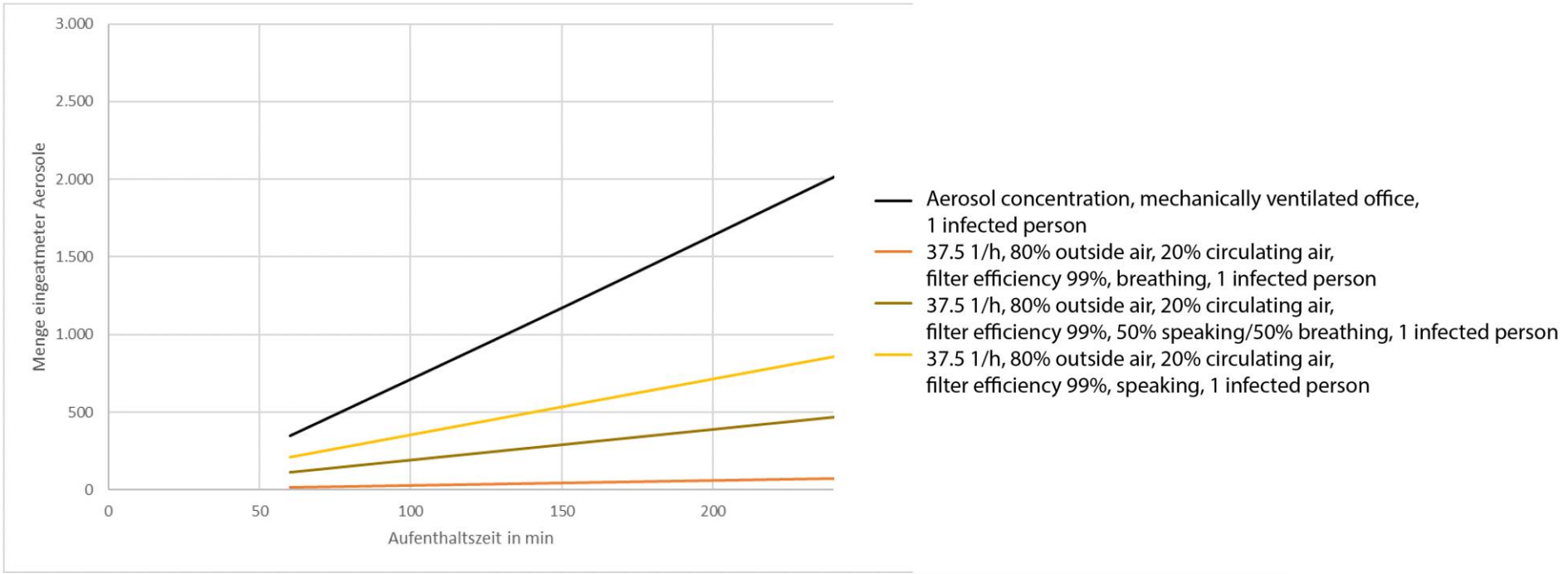

Figure 4: Quantity of inhaled aerosols as a function of exposure time for different scenarios

Sources:

[Hartmann2020] Hartmann, A. , Lange, J. , Rotheudt, H. , Kriegel, M. (2020): Emissionsrate und Partikelgröße von Bioaerosolen beim Atmen, Sprechen und Husten (Emission rate and particle size of bioaerosols when breathing, speaking and coughing), in: Preprint, http://dx.doi.org/10.14279/depositonce-10332

[Kriegel2020] Kriegel, M., Hartmann, A. (2020): Risikobewertung von Innenräumen zu virenbeladenen Aerosolen (Risk assessment for internal spaces regarding aerosols loaded with virus), Preprint, http://dx.doi.org/10.14279/depositonce-10343.2

[RKI2020] Robert-Koch-Institut (2020): SARS-CoV-2 Steckbrief zur Coronavirus-Krankheit-2019 (COVID-19) (SARS-CoV-2 Coronavirus disease profile 2019 (COVID-19)), https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Steckbrief.html#doc13776792bodyText1, last accessed: 16.09.2020, 08:30 a.m.