Supplemental Online Material

Testing mobile air purifiers in a school classroom: Reducing the airborne transmission risk for SARS-CoV-2

J. Curtius[a], M. Granzin[a], J. Schrod[a]

[a]Institute for Atmospheric and Environmental Sciences, Goethe University Frankfurt am Main, Altenhöferallee 1, 60438 Frankfurt am Main, Germany

The Supplemental Online Material is organized in four sections:

1. Time series of the uCPC measurements
2. Use of air purifiers and window venting for reduction of virus-containing aerosols
3. Noise levels
4. Cleaning and Maintenance

1. Time series of the uCPC measurements

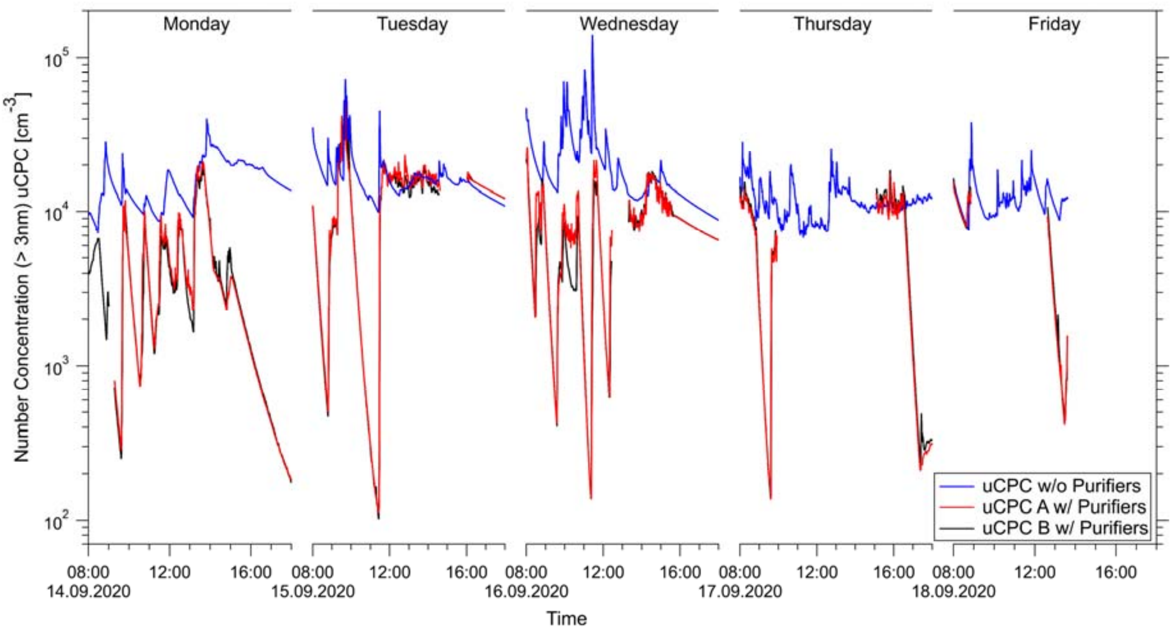


Figure S1: Complete time series of the uCPC measurements at Leibnizschule. The blue line shows the data from the measurements in class room B110 without operating any air purifiers. The red and black line show the data in class room B109, where on Monday, 14 Sept., 3 air purifiers were operated and this was increased to 4 air purifiers starting on Wednesday, 16 September.

2. Use of air purifiers and window venting for reduction of virus-containing aerosols

Here we compare different measures to reduce the concentration of potentially virus-containing aerosols in a typical class room. In addition to showing the effect of four air purifiers with HEPA filters we also show the effect of venting by opening the windows every 20 minutes for 3 minutes as it is currently recommended for schools by the German commission for indoor hygiene (IRK, 2020). While the effect of the continuous operation of the air purifiers can be specified fairly precisely if the CADR is known, the window venting depends on several parameters such as the temperature difference between outside and inside, the wind direction and wind speed, the number and size of the windows that can be opened, and the exact duration of venting. We expand the calculations shown in Figure 6 of the main text using the same general settings (class room volume 180 m^3; total CADR of air purifiers 1026 m^3; presence of one highly infective person, breathing with a rate of 10 liters per minute and exhaling 0.6 cm^{-3} aerosol particles of 5 µm wet size when speaking (50% of the time), and 0.06 cm^{-3} of 5 µm when just breathing (other 50%); the exhaled aerosol particles are assumed to contain 5 x 10^8 RNA copies of the virus per milliliter of fluid; 24 non-infected persons in the room breathe as well with a rate of 10 l per minute). For the venting we assume a broad range of efficiency, in the first case realizing a reduction of 30% of the virus-containing aerosol during 3 minutes of venting, and in the second case a 99% reduction is assumed, respectively. The first case represents a situation with just low temperature difference between outside and inside, low wind speeds, or just a few windows being opened, while the second case represents a highly efficient venting when a high temperature difference is present and many large windows are opened.

Figure S2 shows the resulting time series for the concentration of virus-containing aerosols in the room, while Figure S3 shows the resulting dose that is taken up by the recipients over the time of 1 hour in the room. After 1 hour the dose of virus-RNA copies that are taken up amounts to 5.2 (closed room), 3.2 (-30% venting), 1.5 (-99% venting), 1.5 (air purifiers), 1.3 (air purifiers and -30% venting) and 0.9 (air purifiers and -99% venting). The 30%-efficient venting reduces the inhaled dose by about 33%, while the 99% venting and the purifiers alone reduce it by 71%. The best reduction is achieved by the combined measures, totaling a reduction of the dose of 83%. Of course, it has to be considered that exchanging the room air almost completely by venting also means that the 180 m^3 (corresponding to 229 kg) of air entering in winter time at temperatures typically below 5°C have to be warmed to 20°C which yields an energy need of more than 3.5 MJ for each venting that has to be supplied by the heating system.

In summary it can be stated that the highly efficient venting every 20 minutes alone produces about the same overall dose in one hour as the air purifiers with a CADR of 1026 m^3/h alone. The best reduction is achieved by a combination of the measures. In this way the advantages of both safety measures are combined, yielding a continuous and constant reduction that is independent of the outside conditions from the air purifiers, as well as the reduction from the venting, which is also reducing the CO_2 levels in the room. Additional measures, such as the highly recommended use of face masks, will reduce the risks further but are not considered here.

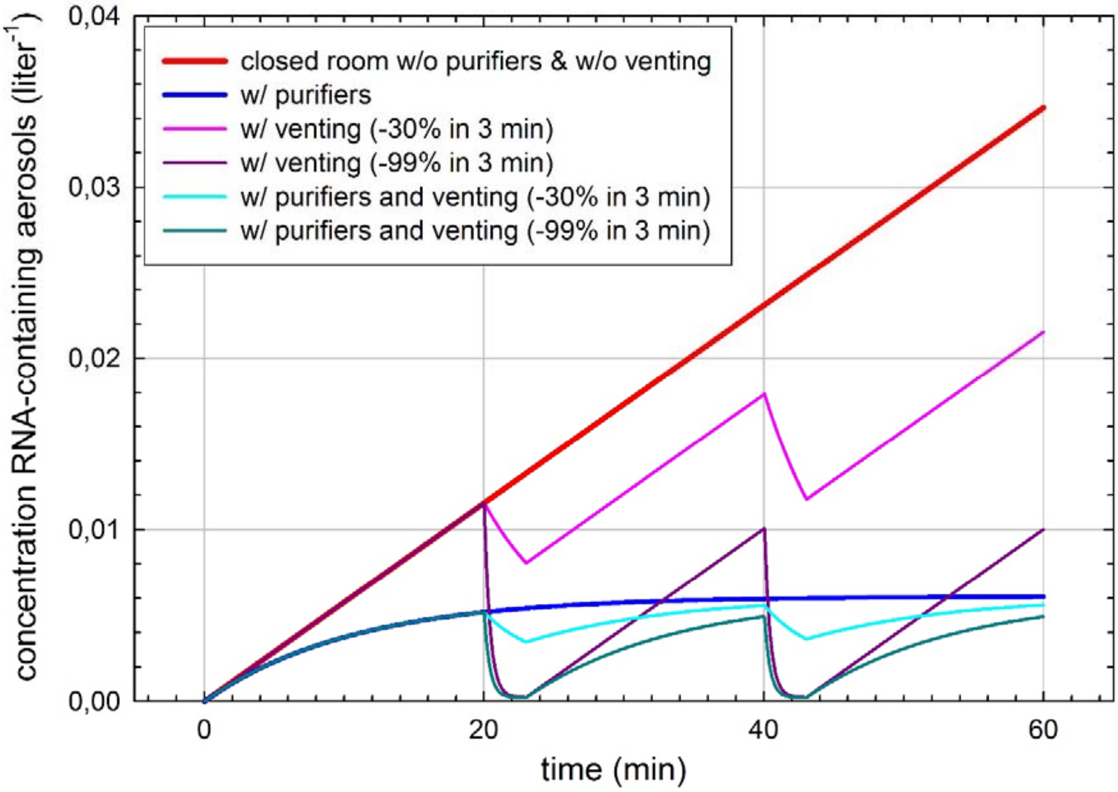


Figure S2: Time series of the concentration of virus-containing aerosol particles in a class room with a highly-infective person present, speaking 50% of the time. Closed room without venting or air filtration (red); closed room with continuous use of air filters with CADR of 1026 m^3/h (blue); venting every 20 minutes for 3 minutes with low (-30%, pink) and high (-99%, purple) efficiency, and combined filtering and venting (cyan and green).

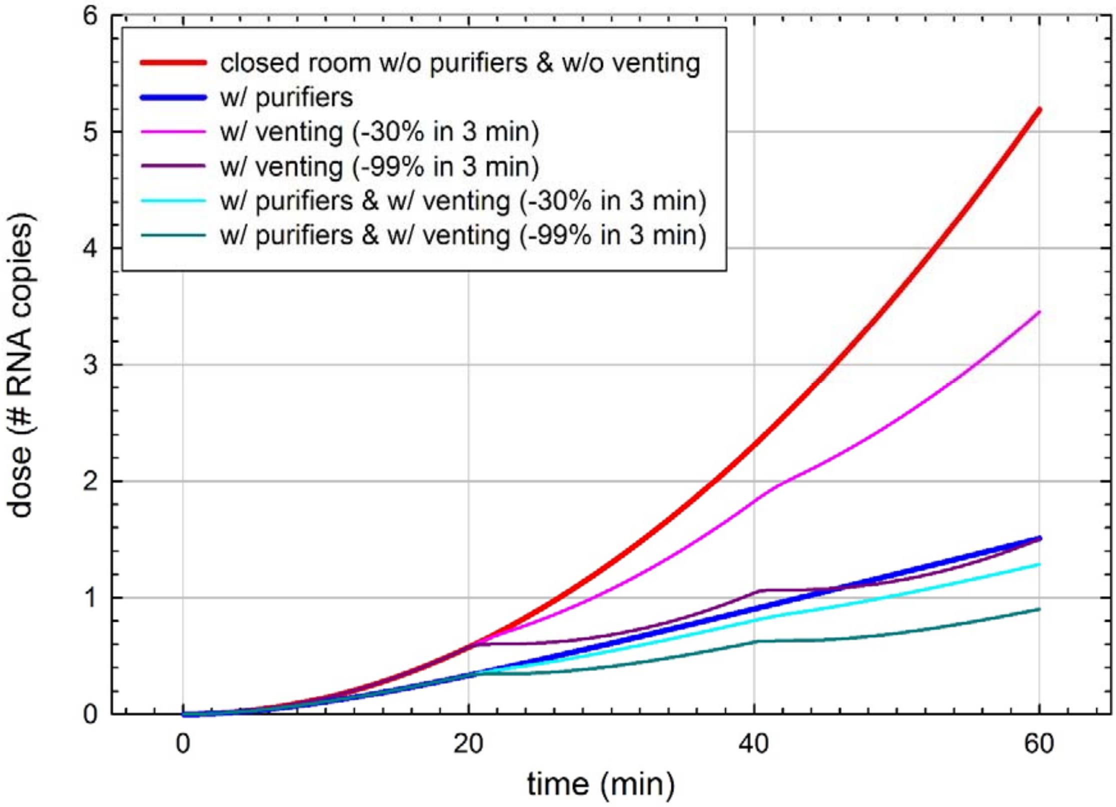
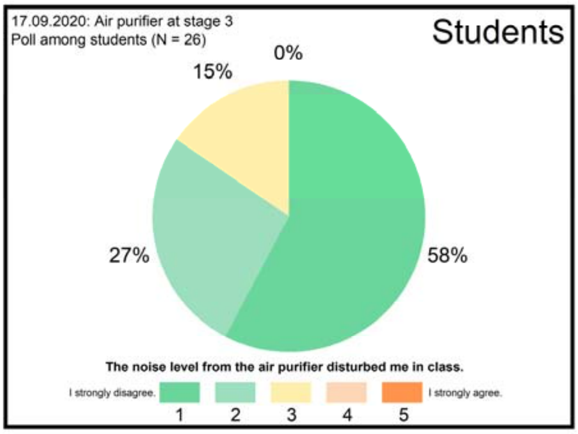


Figure S3: Dose of RNA copies taken up by a susceptible person in the room over 1 hour for the same conditions as in Figure S2.

3. Noise levels



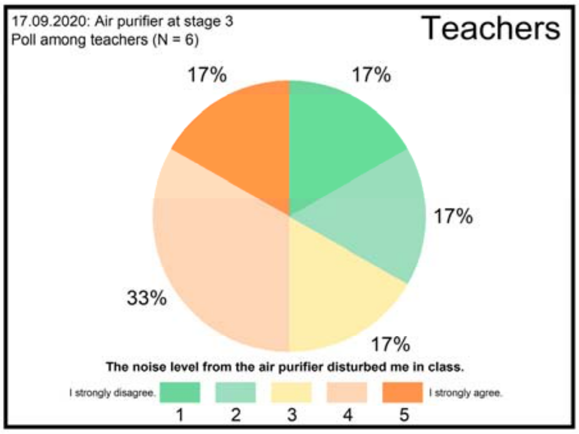


Figure S4: Results of the survey among students (left, n=26) and teachers (right, n=6) on disturbances by the noise levels produced by the purifiers when running four purifiers at stage 3 (total volume flow 1026 m^3/h, air exchange rate 5.5 h^{-1}).

4. Cleaning and Maintenance

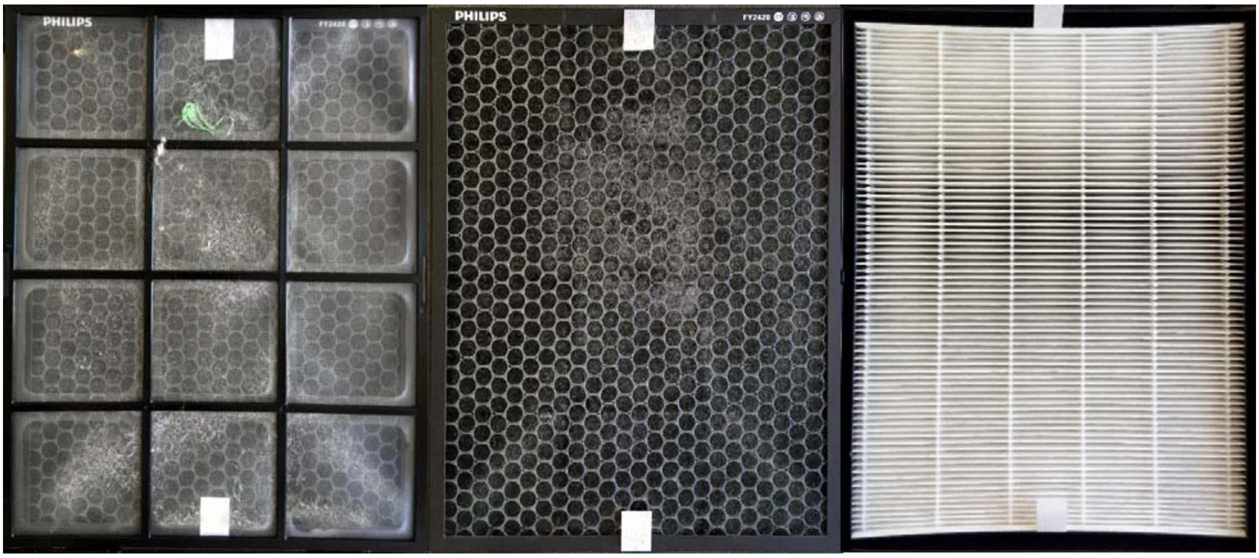


Figure S5: Pre-filter (left), active charcoal filter (middle) after one week of operation in the classroom. Coarse dust, hairs and fluff can be discerned. No deposits of particles could be discerned by eye on the HEPA filter (right). Sections that appear darker are due to the illumination.

References:

IRK (Kommission Innenraumlufthygiene). 2020. Einsatz mobiler Luftreiniger als lüftungsunterstützende Maßnahme in Schulen während der SARS-CoV-2 Pandemie, Stellungnahme der Kommission Innenraumlufthygiene am Umweltbundesamt, 16 Nov. 2020, https://www.umweltbundesamt.de/dokument/stellungnahme-IRK-luftreiniger.