How useful are plasma-based air cleaners in Christelijke Nationale School Staphorst?

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During the COVID-19 pandemic, surprisingly few pupils from the Christelijke Nationale School (CNS) in Staphorst, Netherlands, contracted the virus. In particular, more pupils from the Openbare basisschool (OBS) De Berkenhorst contracted the virus while studying in a different part of the same building. The purpose of this study is to test whether this can be explained by the use of a mobile air-cleaning unit from PlasmaMade® (Air Cleaner AAC37170) in each CNS classroom. Such air cleaners aim at removing aerosol particles from the air using plasma technology. Such aerosols are generated by humans when coughing, sneezing, singing, speaking or breathing and can remain in suspension in the air for several minutes/hours after being produced, leading to possible long-range airborne disease transmission from a sick individual, generating virus-laden aerosols, to a healthy one breathing them.

Since the probability of disease transmission is correlated with the concentration of aerosol in the air, a first idea was to compare aerosol levels in CNS and OBS classrooms using air quality (SDS011) sensors. In both schools, concentrations rise and fall in sync with working hours. However, significantly higher concentrations were measured in the CNS while less pupils were present in CNS classrooms compared to OBS ones. This was attributed to the presence of sand in the CNS, with which pupils can play and which could be found everywhere on the floor even after vacuum cleaning, potentially leading to the formation of solid aerosol particles. It was therefore impossible to test the efficiency of air cleaners by this method.

We therefore used a more straightforward method which consists in filling one CNS classroom with artificially generated aerosols and measuring their concentration decay over time, with the air cleaner either turned off or turned on, and checking if concentration drops faster with the air cleaner turned on. This was done on the afternoon of Wednesday, July 19th 2023 after pupils had left the school, see picture of the room in figure 1. Aerosols were generated by spraying a solution of 80%-isopropanol and 20%-glycerin by a common spray nozzle generating droplets which, after evaporation

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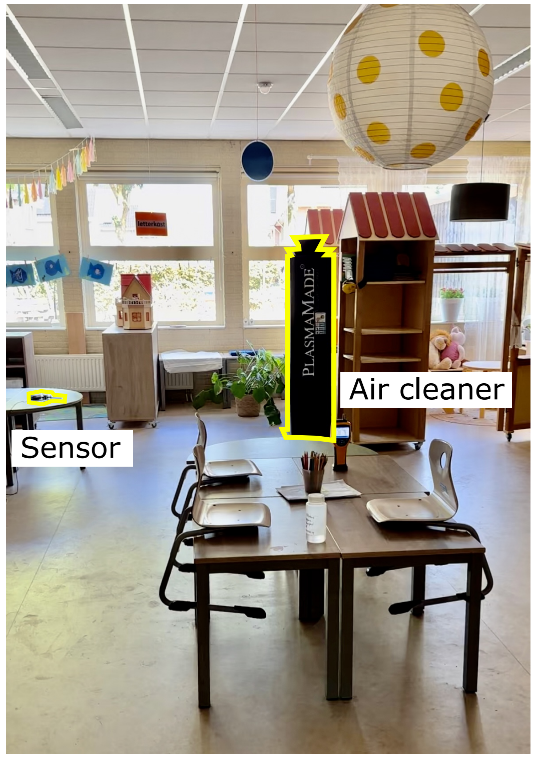

Figure 1: Image of the room where experiments were carried out.

of isopropanol, leaves a glycerin aerosol particle. One person sprays for 10 minutes while the air cleaner is off and then leaves the room, leaving the air cleaner off in one case and turning it on before just before leaving the room in the other case. Aerosol concentrations were measured by two air quality (SDS011) sensors placed on two different desks on different sides of the room. No one is present in the room during the measurement and windows are closed. Hence, the air flow in the room is set by (i) the normal ventilation system of the room (same in each CNS and OBS classrooms) which consists of supply and exhaust vents placed near the ceiling on the entrance wall, the supply vent delivering fresh (aerosol-free) air, and (ii) by the air cleaner when it is turned on.

The results are presented in figure 2 showing the time evolution of the concentration C of aerosols of size less than 2.5 μm (PM2.5) and less than 10 μm (PM10) with normal ventilation and the additional air cleaner either tuned off (a) or turned on (b). We find that, consistent with the model presented in our previous study (published soon in the journal "Intoor Air") [1], the concentration decreases exponentially as

$$C(t) = C_\infty + (C_0 - C_\infty)e^{-t/\tau} \tag{1}$$

where $C_0 = C(t = 0)$ is the initial concentration after spraying, $C_\infty \approx 0$ is the concentration at long times and τ is the characteristic time scale of the decay, more pre-

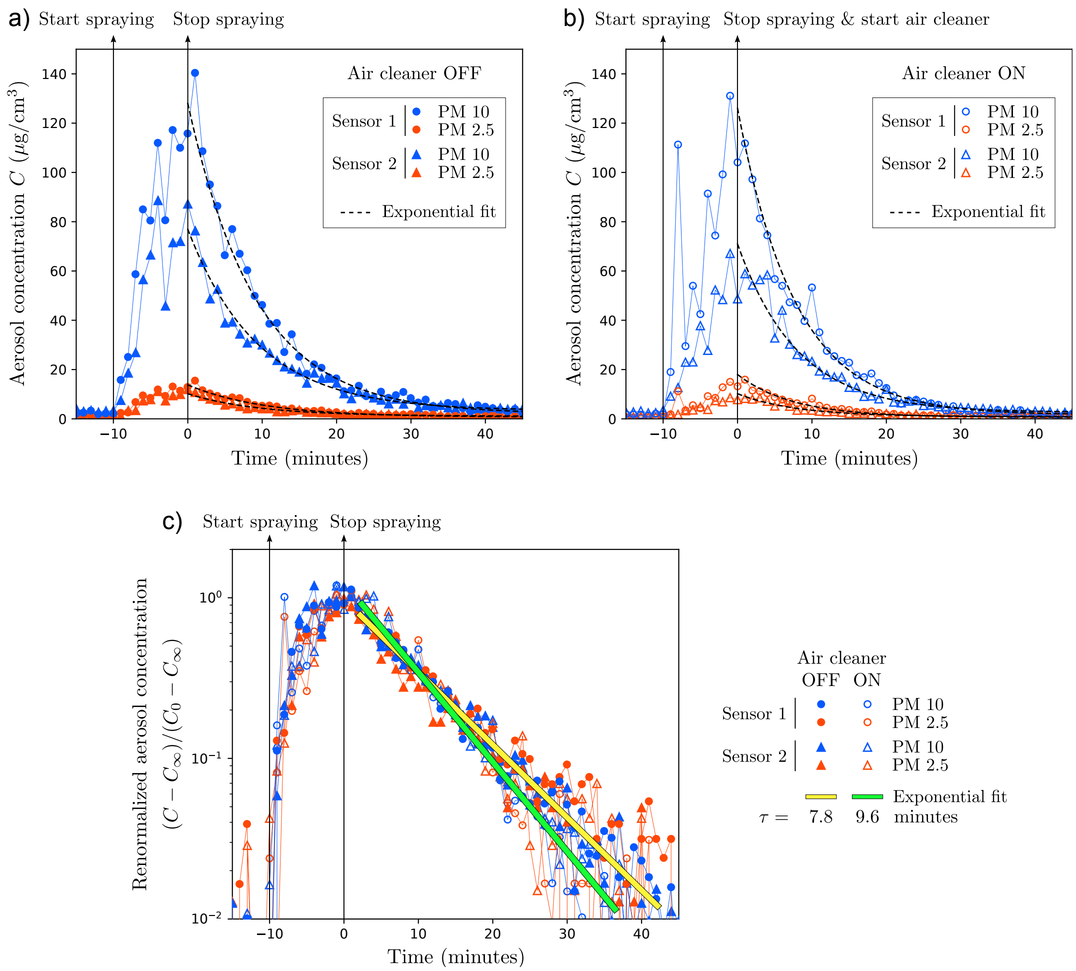

Figure 2: (a,b) Time evolution of the concentration C of aerosols of size less than 2.5 μm (PM2.5) and less than 10 μm (PM10) measured by two sensors in the room with normal ventilation and the additional air cleaner either tuned off (a) or turned on (b). (c) Re-normalized concentration $(C - C_\infty)/(C_0 - C_\infty)$ for the same data as in panels (a) and (b). Aerosols were generated during 10 minutes until the reference time $t = 0$, at which point aerosol generation was stopped and, in (b), the air cleaner was turned on.

cisely, the time it takes to reduce the concentration by a factor $\approx$ 2.72 compared to C_0. In figure 2(c), the time evolution of the re-normalized aerosol concentration $(C(t) - C_\infty)/(C_0 - C_\infty)$ is plotted for all curves in panels (a) and (b), in logarithmic scale to show that the decay is indeed exponential.

The time scale τ is the key parameter to quantify the effectiveness of the ventilation system or, equivalently, the elimination rate of aerosols. According to the model in [1], the total ventilation flow rate Q in m^3/h (cubic meter of fresh air delivered in the room per hour) is

$$Q = V/\tau \tag{2}$$

where $V = 9.65$ m (lenght) $\times 7.03$ m (width) $\times 2.76$ m (height) $= 187$ m^3 is the volume of the classroom. We find $Q = 1170 \pm 40$ m^3/h with air cleaner turned off and $Q = 1440 \pm 40$ m^3/h with air cleaner turned on, hence an improvement of about 270 m^3/h with air cleaner on, which is close to the value 200 m^3/h (power setting 1) claimed to be achieved by PlasmaMade according to the user manual. Therefore, nothing surprising.

We conclude that the use of air-cleaners in CNS classrooms only improves the ventilation efficiency (or elimination rate of aerosols) by 23% compared to when not using them, i.e., when aerosols are only removed by the normal ventilation system of the school. According to the model in [1], the typical aerosol concentration in the air when pupils are in the classroom should hence only decrease by 23% when turning air cleaner on. This is a relatively small reduction compared to, e.g., having pupils and teachers wear face masks, which can reduce the aerosol concentration by a much larger factor.

References

[1] A. Gaillard, D. Lohse, D. Bonn, F. Yigit, Reconciling airborne disease transmission concerns with energy saving requirements: the potential of uv-c pathogen deactivation and air distribution optimization (2023).
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