

TO WHOM IT MAY CONCERN

Date
18 oktober 2020

Our reference
-

Your reference
-

Department Built Environment
Building Physics

T +31 (0)40 247 2138
b.j.e.blocken@tue.nl

www.urbanphysics.net

CADR tests of PlasmaMade Air Cleaner AAC37170

1. General information

The company PlasmaMade B.V. with headquarters in Staphorst, the Netherlands, has requested the research team of Building & Urban Physics at the Department of the Built Environment at Eindhoven University of Technology to perform CADR tests of its Air Cleaner with the name AAC37170. The specifications as provided by the company are listed in Table 1 below.

The tests were performed according to the CADR standards in an airtight test room of length x width x height = 3900 x 2700 x 2300 mm³. The air cleaner with dimensions as indicated in the product sheet of Table 1 was positioned in the center of the test room (Figure 1). Aerosol generation occurred at a location in the right-half of the test room volume. Aerosol concentration measurement was always conducted at the single measurement position located in the left half of the volume, at a lateral distance of 1 m from the air cleaner and at a height of 1 m. Two different types of the AAC37170 air cleaner were assessed, type A without HEPA 7 filter unit and type 7 with HEPA 7 filter unit.



Figure 1: Left: Air cleaner in the test room. Right: Grimm 11-R particle sizer on a table in the test room.

Measurements were conducted with three types of aerosols: (1) a mixture of water and glycol representing aerosols with longer survival time than saliva with density 974 kg/m³; (2) cigarette smoke with density 1180 kg/m³; and (3) a mixture of 97% water and 3% of liquid (1), representing saliva, with density 998 kg/m³.

The following measurements were conducted:

SERIES A: WITHOUT HEPA 7 FILTER:

- Set 1: Type A air cleaner and mixture of water and glycol:
 - o A1a: Short **puff** and air cleaner off
 - o A1b: Short **puff** and air cleaner on (the 5 s puff is generated while the air cleaner is already on).
 - o A1c: Short **puff** and air cleaner on (the 5 s puff is generated before turning the air cleaner on).
- Set 2: Type A air cleaner and cigarette smoke
 - o A2a: Short **puff** and air cleaner off
 - o A2b: Short **puff** and air cleaner on (the 5 s puff is generated while the air cleaner is already on).
 - o A2c: Short **puff** and air cleaner on (the 5 s puff is generated before turning the air cleaner on).
- Set 3: Type A air cleaner and saliva mixture:
 - o A3a: **Continuous release** and air cleaner off
 - o A3b: **Continuous release** and air cleaner on

SERIES B: WITH HEPA 7 FILTER:

- Set 1: Type A air cleaner and mixture of water and glycol:
 - o B1b: Short **puff** and air cleaner on (the 5 s puff is generated while the air cleaner is already on).
 - o B1c: Short **puff** and air cleaner on (the 5 s puff is generated before turning the air cleaner on).
- Set 2: Type A air cleaner and cigarette smoke
 - o B2b: Short **puff** and air cleaner on (the 5 s puff is generated while the air cleaner is already on).
- Set 3: Type A air cleaner and saliva mixture:
 - o B3b: **Continuous** release and air cleaner on

For all measurements with air cleaner “off”, room internal air mixing was achieved by placing a fan inside the room next to the air cleaner that created an upward airflow, similar to that created by the air cleaner. This way, a similar airflow pattern was generated for both the tests with air cleaner “off” and air cleaner “on”. Additionally, this room internal air mixing was performed to obtain a more homogeneous distribution of the aerosols inside the test room. This was important because aerosol concentration measurements were only performed at one point.

The aerosol concentration measurements were performed with a Grimm 11-R particle sizer that measures aerosol numbers in 31 intervals from 0.265 to 34 µm (Figure 1).

Table 1: Product sheet of PlasmaMade Air Cleaner AAC 37170:

plasmamade®



plasmamade® air purifier		product sheet
Product name	PlasmaMade Air Purifier	
Model	AAC37170	
EAN code	8719327149058	
Voltage	220-240 V 50/60 hz	
Power Consumption	125 watt	
Power setting 1:	200 m3/h	
Power setting 2:	400 m3/h	
Color	Black or White	
Dimensions Air Cleaner	340mm x 340mm x 1700mm 13.4" x 13.4" x 66.9"	
Weight Air Cleaner	40 kg 88.20lbs	
Material	Metal white or black coated	
Mounting	Does not apply for this product	
Dimensions packaging	± 500mm x 500mm x 1800mm 19.7" x 19.7" x 70.9"	
Total weight	± 40 kg 88.20lbs	
Lifespan	PlasmaMade Air Filter: 5 years PlasmaMade Pre Filter: 1 year	
Warranty	2 years	
Maximum power / decibels	400 m3/h 39 db	
Manufacturer	PlasmaMade B.V.	
Dimensions outer packaging of 1 piece	± 500 x 500 x 1800	
Dimensions outer packaging of 2 pieces	Does not apply for this product	
Dimensions outer packaging of 4 pieces	Does not apply for this product	
Dimensions of pallet shipment (4 pieces)	± 1200 x 1000 x 1900	
Approval	CE	

2. Measurement results for mixture water and glycol

Air cleaner (without HEPA) OFF, room internal mixing ventilator on.

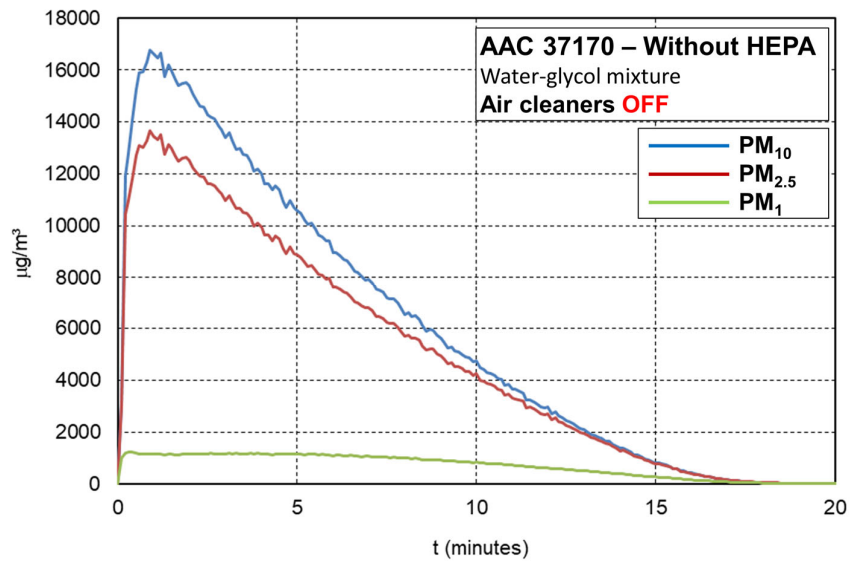


Figure 2: Concentrations for air cleaner off, room internal mixing on.

Air cleaner (without HEPA) ON (puff while AC on)

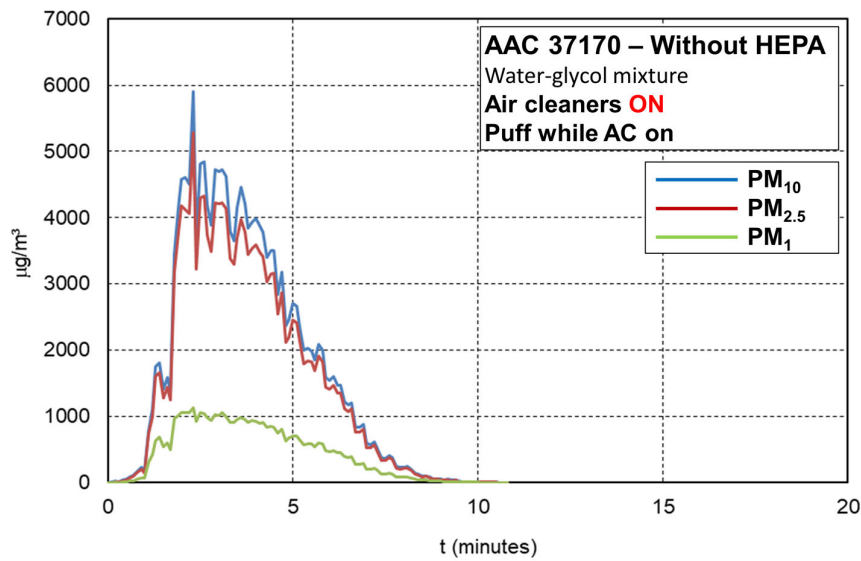


Figure 3: Concentrations for air cleaner (without HEPA) on, puff while AC already on.

Air cleaner (without HEPA) ON (puff while AC off)

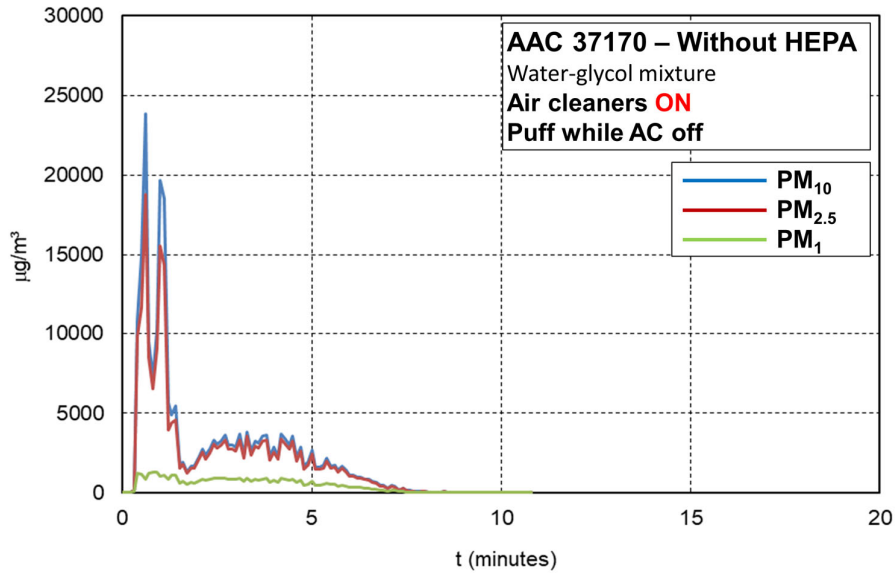


Figure 4: Concentrations for air cleaner (without HEPA) on, puff while AC still off.

Air cleaner (with HEPA) ON (puff while AC on)

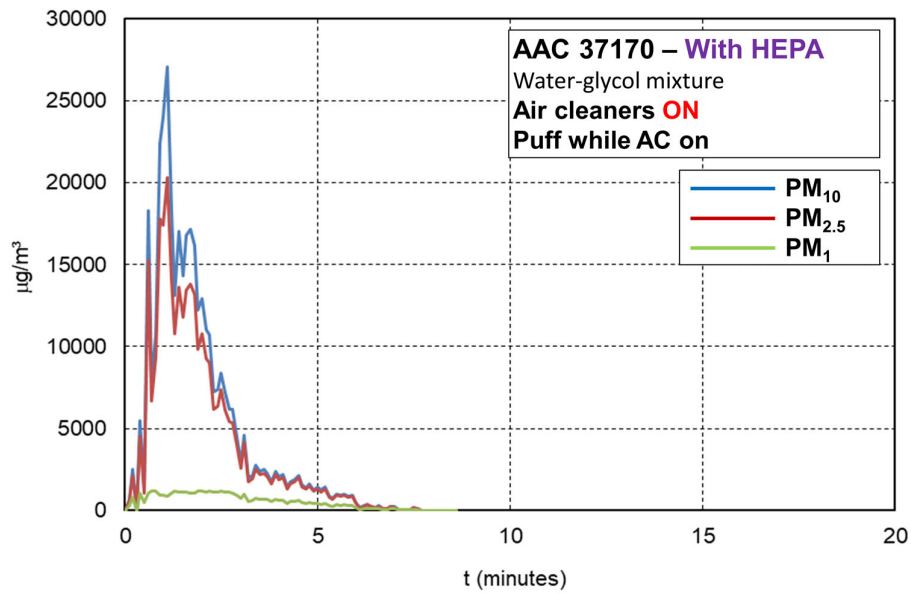


Figure 5: Concentrations for air cleaner (with HEPA) on, puff while AC still on.

Air cleaner (with HEPA) ON (puff while AC off)

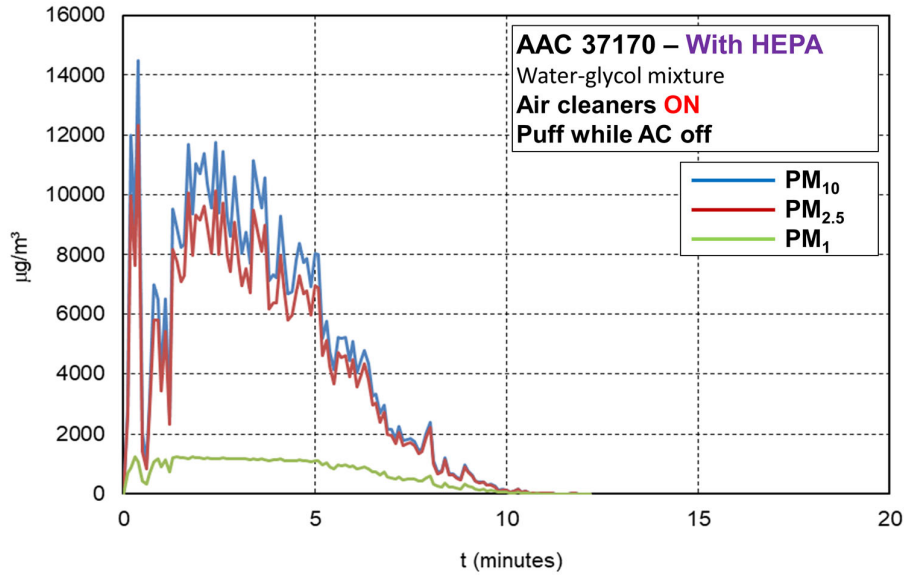


Figure 6: Concentrations for air cleaner (with HEPA) on, puff while AC still off.

3. Measurement results for cigarette smoke

Air cleaner OFF, room internal mixing ventilator on.

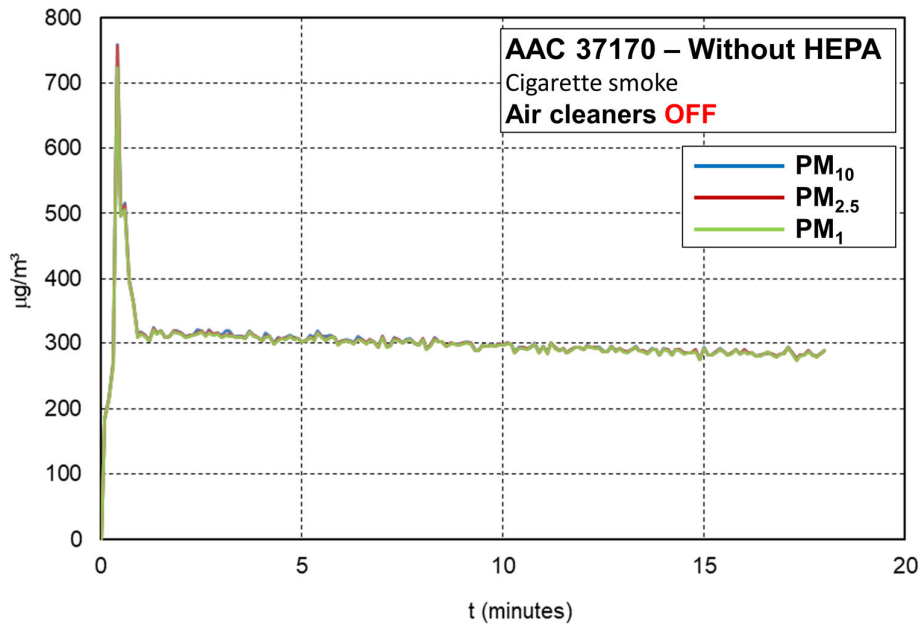


Figure 7: Concentrations for air cleaner off, room internal mixing on.

Air cleaner without HEPA ON.

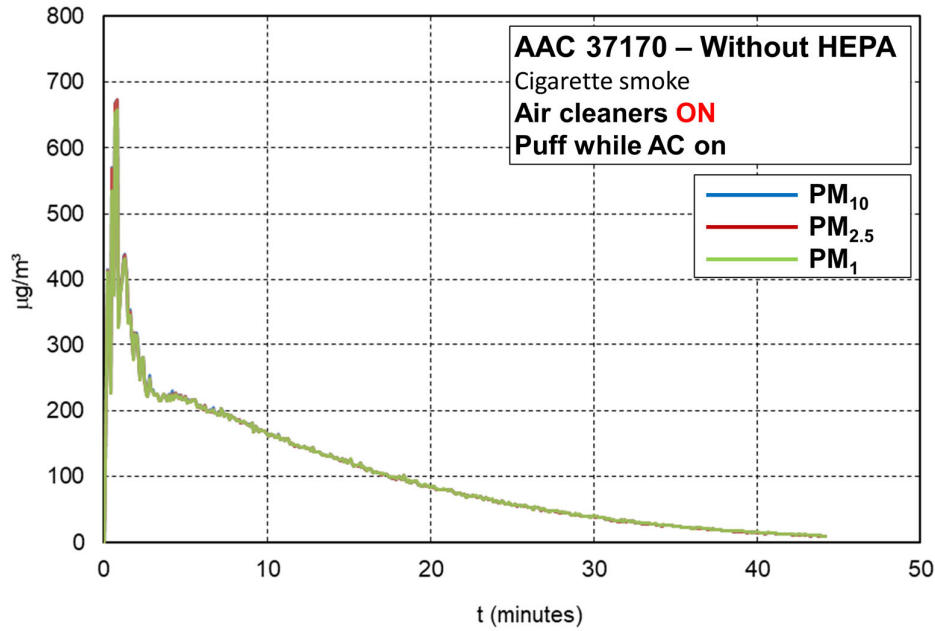


Figure 8: Concentrations for air cleaner (without HEPA) on, puff while air cleaner already on.

Air cleaner with HEPA ON.

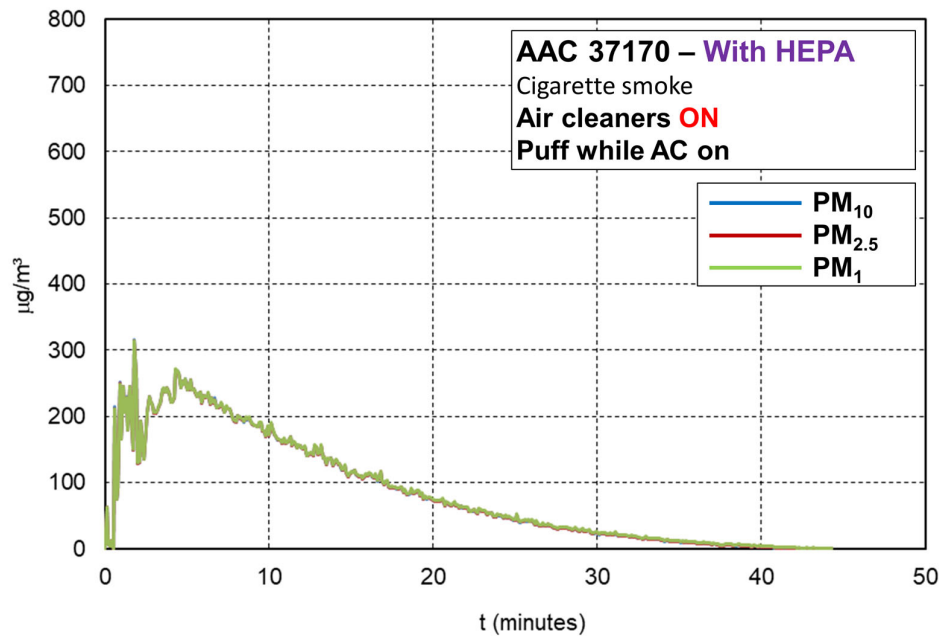


Figure 9: Concentrations for air cleaner (with HEPA) on, puff while air cleaner already on.

4. Measurement results for saliva

Air cleaner OFF, room internal mixing ventilator on.

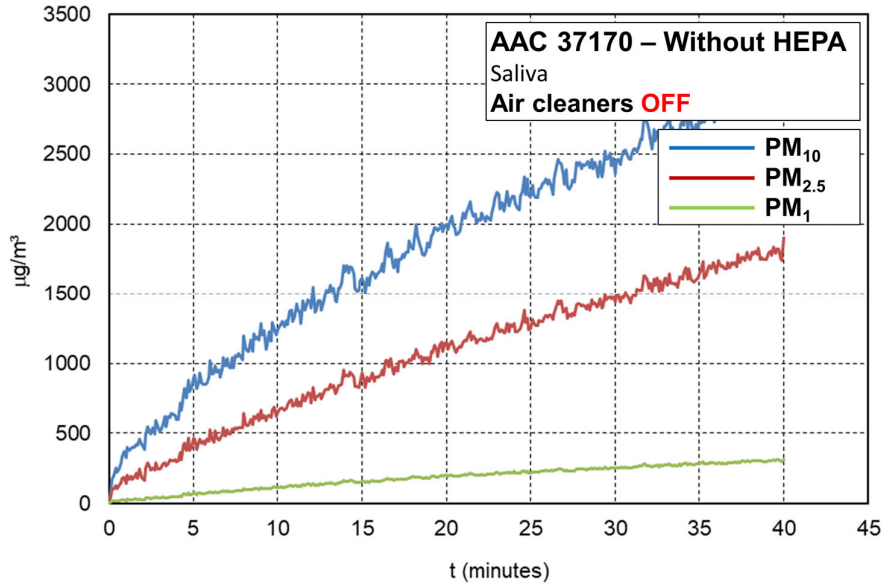


Figure 10: Concentrations for air cleaner off, room internal mixing on.

Air cleaner with HEPA OFF.

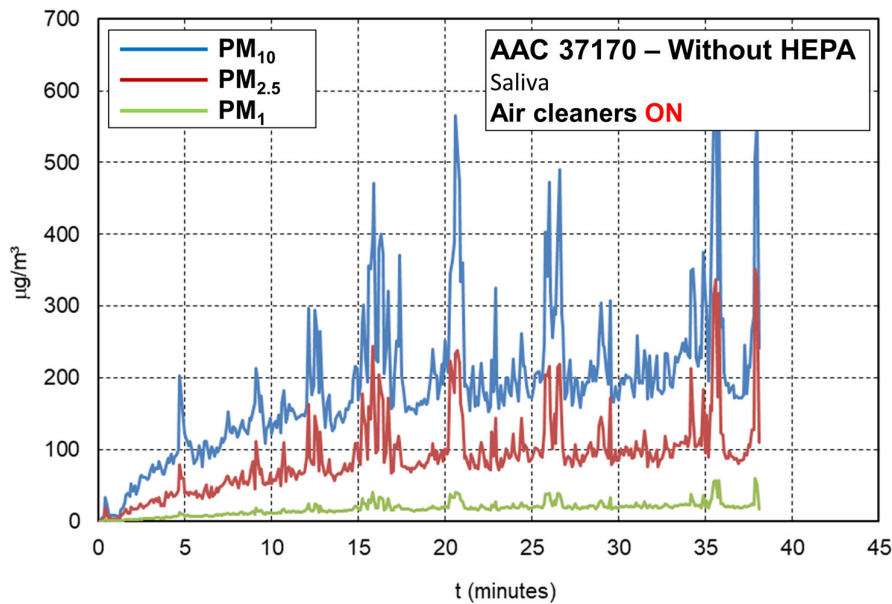


Figure 11: Concentrations for air cleaner (without HEPA) on.

Air cleaner with HEPA ON.

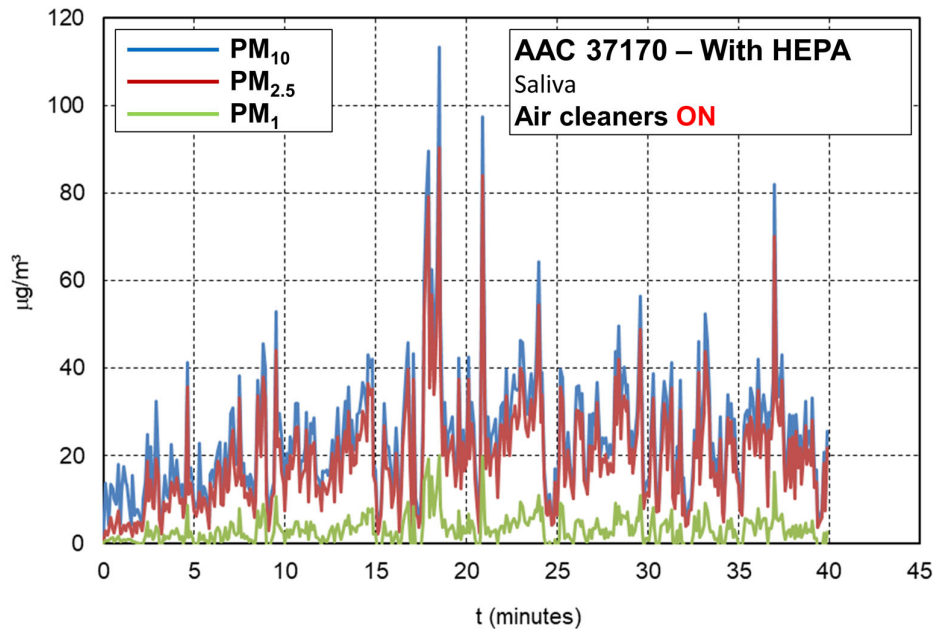


Figure 12: Concentrations for air cleaner (with HEPA) on.

5. Discussion

Figure 2 indicates the decrease of PM₁₀, PM_{2.5} and PM₁ over time when the air cleaner is switched off. The concentration decay takes about 18 minutes.

Figure 3 shows the concentrations when the air cleaner is switched on. While the air cleaner is on and the airflow pattern in the room is determined by the air cleaner, a 5 s puff of aerosols is injected in the room. It is clear that the peak concentrations are lower than in Figure 2, and that the concentrations decrease much faster due to the action of the air cleaner.

Figure 4 shows the concentrations for the situation where the air cleaner is turned on only after the puff has been released. In this situation, the air cleaner needs some time to establish the airflow pattern in the room, which results in a highly irregular pattern of concentrations.

Figure 5 displays the concentrations for the air cleaner with HEPA filter included when the puff is released while the air cleaner is already on. The peak is higher than in Figure 3 but this is attributed due to the irregular local turbulent airflow pattern in the room. But the concentration decay is much faster than in Figure 3, which is expected due to the addition of the HEPA filter.

Figure 6 shows the concentrations for the air cleaner with HEPA filter included when first the puff is released and only directly afterwards the air cleaner is already on. In this case the concentration decay takes longer than in Figure 5.

Figure 7 depicts the concentrations of PM₁₀, PM_{2.5} and PM₁ over time when the air cleaner is switched off. Two main observations are: (1) The cigarette smoke mainly produces PM₁. The fractions of aerosols with diameter higher than 1 µm is almost zero. (2) The concentration decay is very slow.

Figure 8 shows the concentration decays when the air cleaner is switched on. The puff is generated while the air cleaner is already on. The decay still goes rather slow but evidently much faster than in Figure 7 due to the action of the air cleaner.

Figure 9 shows that adding the HEPA filter has a small additional beneficial effect: it reduces the peak at the beginning and speeds up the decay a bit.

Figures 10-12 show results for the saliva mixture. A continuous release was used because these aerosols evaporate quickly and working with a puff was not possible because the concentrations could not be detected.

Figure 10 shows the continuous increase of concentrations when the air cleaner is off but the room internal mixing is on. Figure 11 shows that the increase of concentrations is much less pronounced when the air cleaner is switched on. When the HEPA filter is also present, this additionally decreases the concentrations further.

6. Calculation of CADR

The Particle Removal Rate (PRR) for a given aerosol diameter d and at time t is given by:

$$\text{PRR}(d, t) = \frac{1}{t} \ln \left[\frac{C_{\text{AP}}(d, t=0)}{C_{\text{AP}}(d, t)} \right] - \frac{1}{t} \ln \left[\frac{C_{\text{natural}}(d, t=0)}{C_{\text{natural}}(d, t)} \right]$$

where C_{AP} is the concentration with the air cleaner (AC or AP = air purifier) switched on and C_{natural} is the concentration with the air cleaner switched off (i.e. representative of natural concentration decay). The Clean Air Delivery Rate (CADR) is given by:

$$\text{CADR}(d, t) = V \times \text{PRR}(d, t) \text{ [m}^3/\text{h]}$$

where V is the air volume of the room (= 24.219 m³). Based on these equations, the CADR can be calculated for every fraction (PM10, PM2.5, PM1) as a function of time, as presented in Figures 13-16.

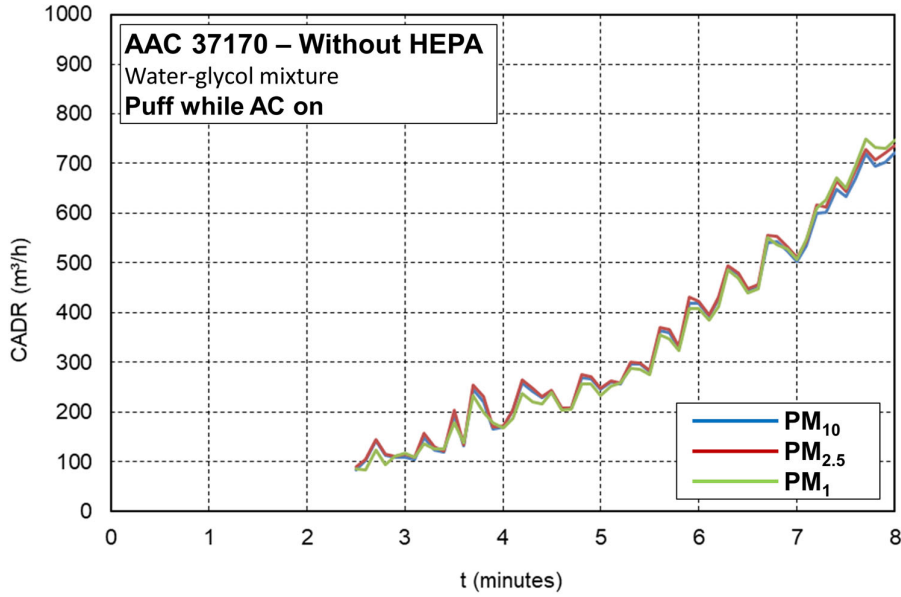


Figure 13: CADR for air cleaner (without HEPA) on.

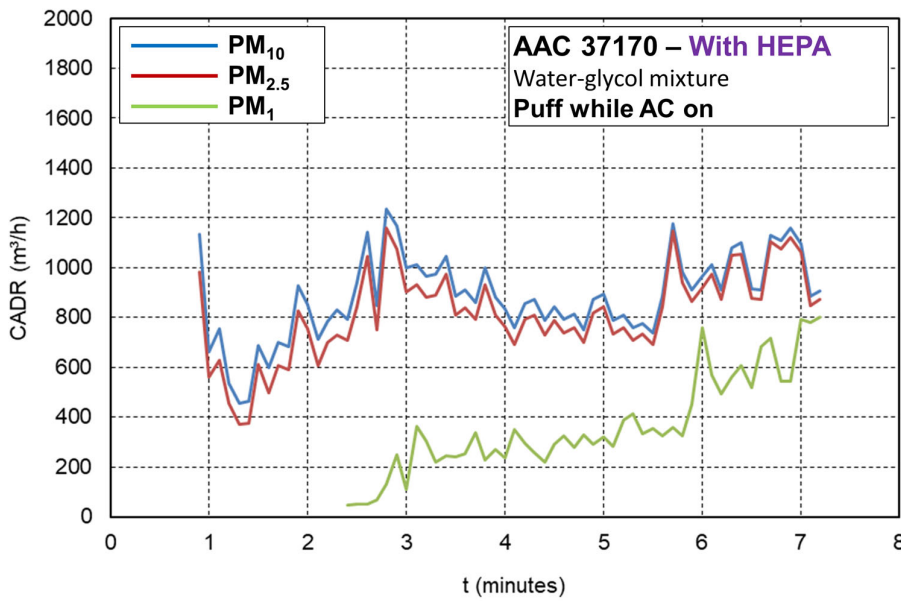


Figure 14: CADR for air cleaner (with HEPA) on.

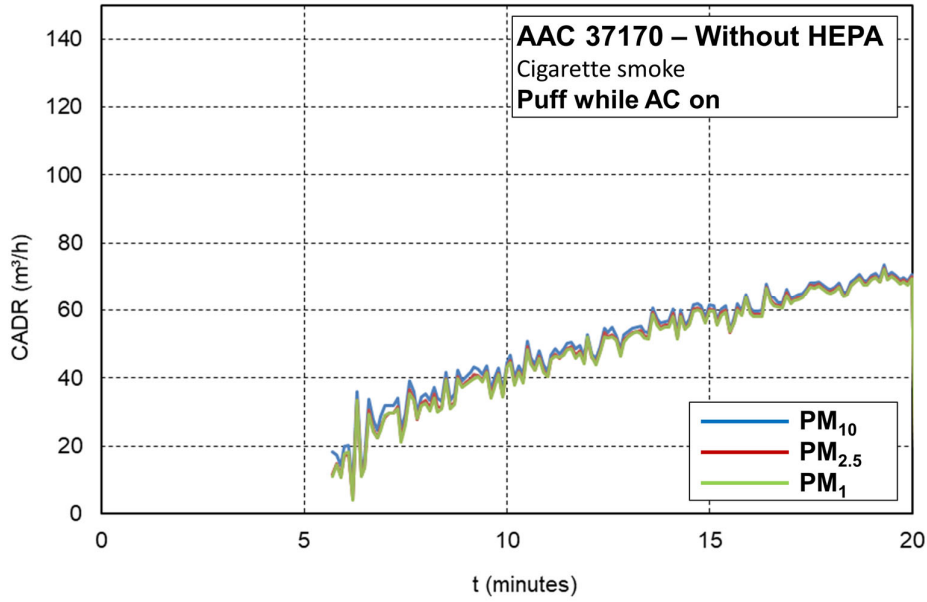


Figure 15: CADR for air cleaner (without HEPA) on.

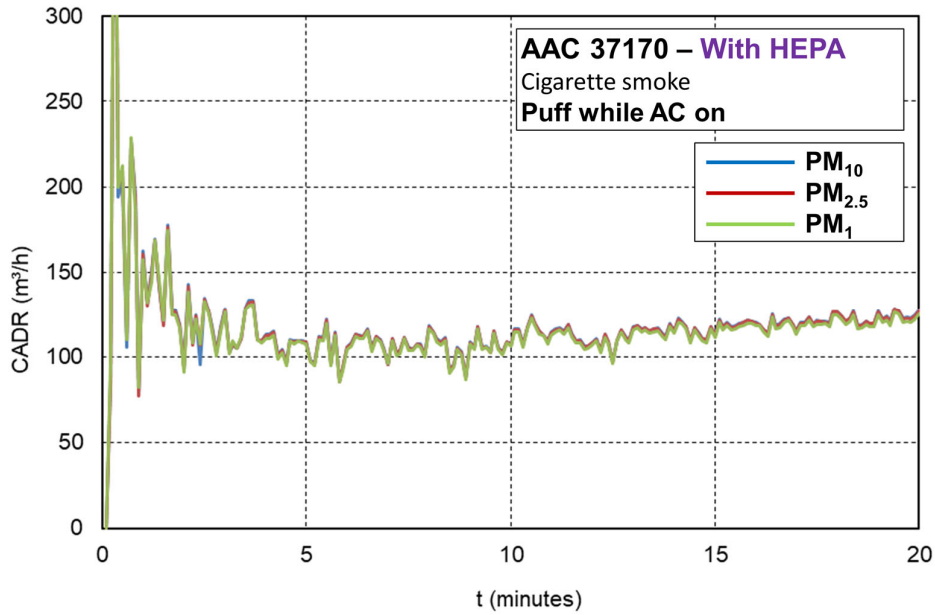


Figure 16: CADR for air cleaner (with HEPA) on.

7. Ozone, NO and NO₂

Additional important requirements for air cleaners are low generation of ozone (O₃), NO and NO₂. During the measurements reported above, the following maximum concentrations occurred: O₃: 27.4 ppb, NO: 106.9 ppb, NO₂: 53.0 ppb.



Prof. dr. ir. Bert Blocken

Prof. dr. ir. B. Blocken - Civil Engineer, PhD, MSc
Unit Building Physics & Services
Department of the Built Environment
Eindhoven University of Technology (TU/e)
P.O.Box 513, 5600 MB Eindhoven, The Netherlands
URL: <http://www.UrbanPhysics.net>

Also Part-Time Full Professor at:
Building Physics Section
Department of Civil Engineering, *KU Leuven*
Kasteelpark Arenberg 40 – bus 2447, 3001 Leuven
Belgium

Scientific Director: *Eindhoven Atmospheric Boundary Layer Wind Tunnel*

Editor: *Building & Environment*
<http://www.journals.elsevier.com/building-and-environment>
Associate Editor: *Journal of Wind Engineering & Industrial Aerodynamics*
<http://www.journals.elsevier.com/journal-of-wind-engineering-and-industrial-aerodynamics>
Assistant Editor: *Sports Engineering*
<https://link.springer.com/journal/12283>
