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Real-life ventilation filter performance in a city environment




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Within any building ventilation principle, the outdoor air is considered as a source of fresh, "clean" air, which is however not always the case. Air filters have the potential to improve the quality of the supplied air by mechanical ventilation systems. Nonetheless, little is known about their real-life performance within a large particulate matter size range.

Keywords: Ventilation, Particulate matter, Filter Performance, Indoor Air Quality, Outdoor Air Pollution

Within the ventilation principle of buildings, the outdoor air is considered as a source of fresh, "clean" air. Outdoor air quality monitoring by environmental agencies, academic research projects and a broad range of citizen science projects show that this is not always the case. Although the outdoor air quality in our cities already improved, the concentrations of certain pollutants, including particulate matter, remains problematic. Ventilation systems may play a role in the introduction of these outdoor air pollutants into the indoor environment, with potential adverse effects on the indoor air quality and the health of residents.

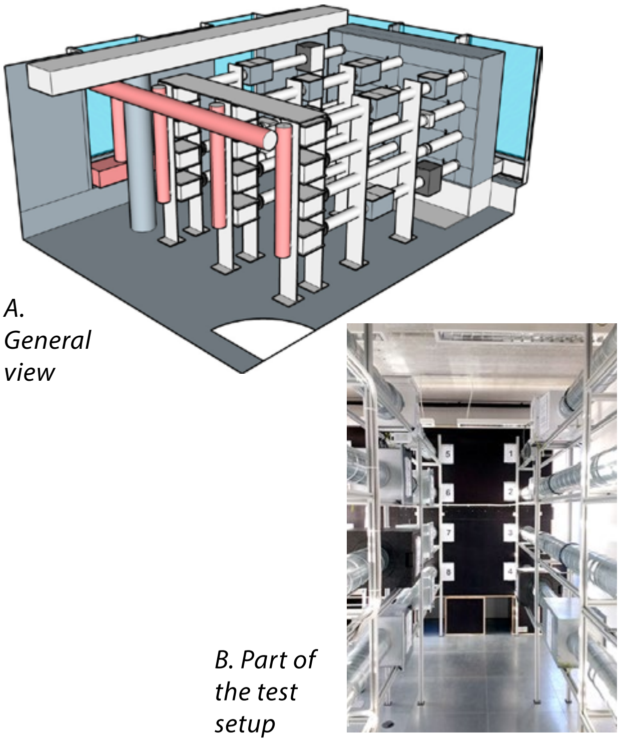
The filters that are present in certain mechanical ventilation system types are primarily present to protect the system and its components against fouling but have the potential to improve the quality of the supplied air. The efficiency of these air filters for general ventilation is nowadays measured according to the EN ISO 16890:2016 standard [1] for classification reasons and to allow mutual comparison of their performance. However, as literally stated by the standard, "the performance results obtained in accordance with ISO 16890 cannot be quantitively applied to predict performance in service with regard to efficiency and lifetime". Furthermore, the test conditions used within this standardized procedure differ from real-life conditions (e.g. in terms of air speed, filter size, the use of synthetic particles, …) and the measurement range is limited to 0.3–10 µm particles.

Therefore, within our research project (Out2In) we investigate the real-life efficiency and its evolution in function of time of air filters and precipitators compatible with domestic ventilation systems within a city environment (Brussels, Belgium) looking at particles with a size from 10 nm to 10 µm. This to get a better understanding of the (preventative) role ventilation and its filters play in the penetration of outdoor air pollutants. This paper presents some highlights of obtained results so far.

Materials and methods

Test setup

A test setup was constructed in our Brussels-based laboratory consisting of 12 parallel test lines, which are all connected to a distribution box. At his turn, the distribution box is connected to the outdoor air allowing the measurements to be conducted with the real-life pollutant load of the Brussels outdoor air (see **Figure 1 A & B**). Each test line is composed of one or two filter boxes/devices (inter)connected to the other parts by round metal ductwork (ø160 mm) (see following paragraph for the selected filters/devices) and a constant flow fan set at 150 m³/h.



A. General view

B. Part of the test setup

Figure 1. Computer-based design model and picture of the test setup as built.

Selected filters/devices

Classic filters – six test lines are equipped with filters or combinations of them which are nowadays already used in ventilation systems. This includes coarse filters (G3 and G4 class filters according to EN779 [2], see remark in the further research paragraph) and a fine filter (F7 class). From the same classes also different types of filters are included like duct type, wireframe, folded panel and bag type filters.

Intensive filtration – four test lines are equipped with filters which are nowadays rather exceptionally used in domestic ventilation systems including an F9 and H10 filter (= E10, Efficiency Particulate Air filter, EN 1822:2009 [2]). These filters are all of the folded panel type.

Innovative devices – two test lines are equipped with electrostatic precipitators (ESPs). Although, the principle of electrostatic precipitation is known for decades and already used in industrial applications, only recently devices connectable to domestic ventilation systems became available on the market. An electrostatic precipitator in general consists of two parts: the ioniser and the collector. Within the ioniser, the air and its particulate load will get charged (in this case positively) due to the corona discharge principle (high voltage on a small electrode). Within the second part, the ionised particles are then collected on collector plates with an opposite or neutral charge. Both tested systems differ especially in their collector part, one makes us of disposable plastic collector plates (DC), while the other makes use a collector with horizontal cleanable plates (CC).

Measurements

Differential pressure over each filter box or device is measured on a monthly basis using a TSI PVM-620 manometer. Ozone production is verified using a Teledyne T204 gas analyser.

Particulate matter load of air samples is measured in number-based concentrations within the range of 10 nm up to 10 µm using two different devices. Particles within the size range of 10–420 nm are quantified using a Scanning Mobility Particle Sizer (TSI, Nanoscan 3910 SMPS), while those between 0.3–10 µm using an Optical Particle Sizer (TSI, OPS 3330). The measurements are conducted according to a procedure based on the Eurovent 4.10 guideline [4]. This guideline describes a method for in situ determination of fractional efficiency of general ventilation filters.

Results, discussion and conclusions

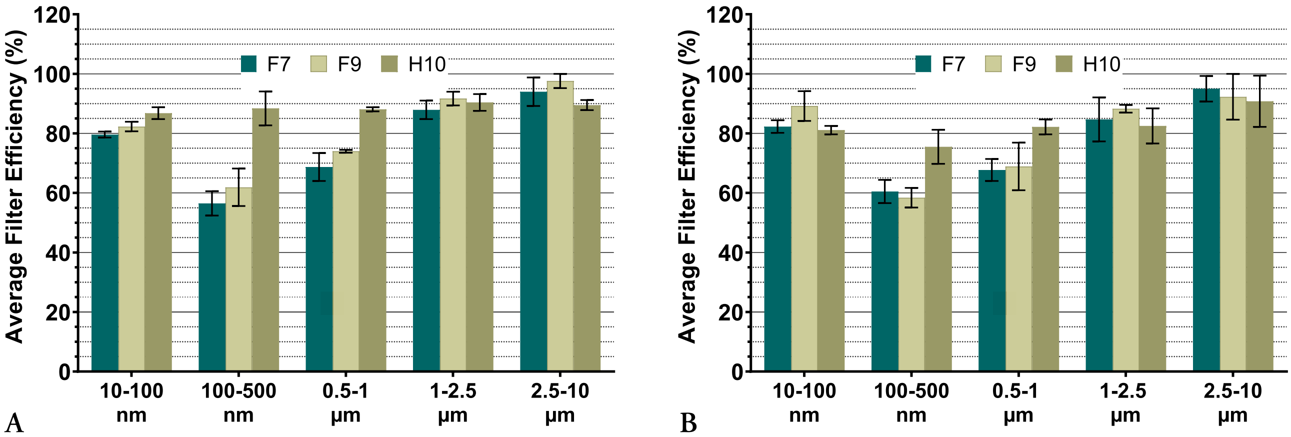
Coarse filters (G3 and G4)

Generally, the efficiency of coarse filters, especially for particles smaller than 1µm, was found to be rather limited (data not shown). Moreover, a large variability in efficiency was observed for different filter types within a same coarse filter class (G3 or G4). Therefore, coarse filters cannot be considered as contributing to an improved air quality in terms of particulate load. The use of coarse filters with a small filter surface should be avoided because of their typical very high initial and sharply increasing pressure drop (see duct type and wireframe in **Table 1**).

Fine filters (F7, F9, H10)

As can be expected, fine filters are in general more efficient than coarse filters. Upon comparison of the tested F7 and F9 filter, the results indicate a slightly, but nonsignificant, higher efficiency for the F9 filter throughout the complete measurement range (see **Figure 2**). Both filters however show a dip in their efficiency for the particle range 100–500 nm and 0.5–1 µm. As shown by the fractional efficiency profile for the F7 filter (**Figure 2 C**) this dip in efficiency (< 80%) extends from particles with an aerodynamic diameter of 60 to 700 nm (See vertical lines in **Figure 2 C**). The tested H10 filter at new state on the other hand, shows a very high efficiency within the full measuring range (see **Figure 2 A & B**). After two and a half months in continuous use (see **Figure 2 B**), the F7 and F9 filters do not show an obvious difference in efficiency, while for the H10 a decrease for the particles in de size ranges from 100–500 nm and 0.5–1 µm can be observed.

At new state, the pressure drop caused by the fine filters is larger than the ones observed for most coarse filter types (except for the wireframe and duct type filter) (see **Table 1**). During the 2.5 months term, the pressure drop increased gradually and equally for the F7 and F9 filter, while for the H10 filter the increase is higher. The increase in pressure drop for all fine filters is however lower than the one for the G4 folded panel (FP) coarse filter. It must be mentioned that each of the fine filter classes is installed in a test line with the same G4 FP filter as a prefilter. Unprotected fine filters have not been tested. In conclusion, fine filters have the potential to improve the quality of the supplied air by a ventilation system in terms of particulate load with a rather limited increase in pressure drop when protected by a coarse filter.



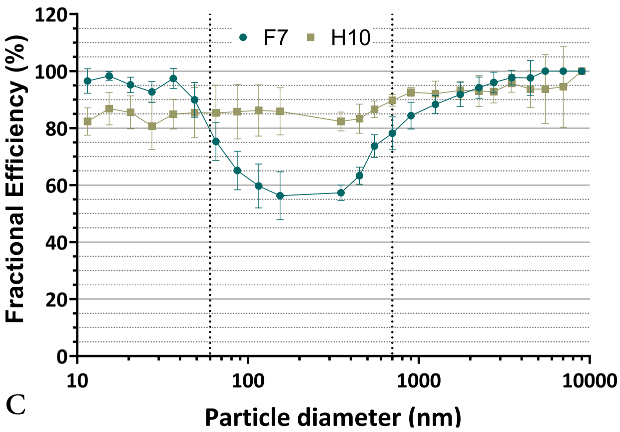


Figure 2. Average filter efficiency of fine filter types with indication of the 95% confidence interval at new state (A) and after 2.5 months of continuous use (B). Fractional efficiency profile within the complete measurement range (10 nm–10 µm) for an F7 filter and an H10 after 1 month in continuous use (C).

Table 1. *Pressure drop (Pa) as a function of time for the coarse and fine filters and the electrostatic precipitators (ESP), cc = cleanable collector, dc = disposable collector, FP= folded panel, B=bag, duct-type = round filter with the same diameter as the ductwork, wireframe = metal frame wrapped with a single layer of filter material.*

Time elapsed	Filter class and type									
	G3		G4			F7*	F9*	H10*	ESP	
	Duct type	FP	Wire-frame	FP	B	FP			cc	dc
Initial	98	9	31	11	7	23	23	27	8	16
1 month	200	12	67	18	8	24	21	28	9	16
2.5 months	285	12	125	43	16	32	36	47	10	21

* protected by a G4 FP coarse filter

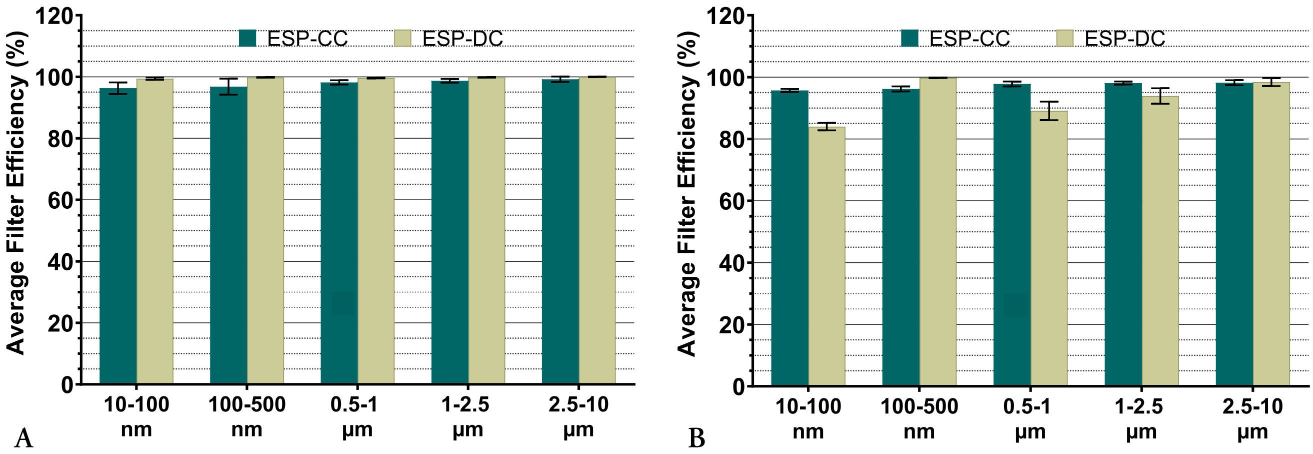


Figure 3. Average filter efficiency of the electrostatic precipitators with indication of the 95% confidence interval at new state (A) and after 2.5 months of continuous use (B). cc = cleanable collector, dc = disposable collector.

Electrostatic precipitators

Both precipitators exhibit a very high efficiency (>96%) within the full measuring range at new state. After 2.5 months in use, the version with the cleanable collector still shows a high efficiency throughout the measuring range, while for the version with the disposable collector the efficiency for some particle ranges, more precisely 10–100 nm and 0.5–1 µm dropped. Visual inspection of the collector plates indicates that a black coloration can be observed at the back of the collector plates, indication that the collector gradually becomes saturated.

The pressure drop over the system with the cleanable collector is lower than that of the version with the disposable collector (see **Table 1**). This is a result of the more open inner structure of the cleanable system. However, for both systems their pressure drop is rather small in comparison to the pressure drop over the tested fine filters and only has a small tendency to increase in function of time. Moreover, the ESPs are not protected by a prefilter as is the case for the fine filters. The ozone production was found to be limited for both systems (cleanable: 9.1±1.5 and disposable:5.9±1.8 ppb). In conclusion, electrostatic precipitation seems a promising technique due to the high efficiency of particle capture within the full range (10 nm–10 µm) and the associated low pressure drop in comparison to fine filters.

Further research

Further follow-up is necessary to get a more complete picture of the evolution of the efficiency of these filters and their pressure drop. For the electrostatic precipitators also the potential effect that ionized air might have on human health should be looked at. Remark: By the time the filters were purchased, the EN 779:2012 standard was still in use. In the meanwhile, is has been replaced by the EN ISO-16890:2016 standard [1] which makes use of a different method and classification of filters. Therefore, there is no one on one relation between the old and new classification. As an indication, the G3 and G4 classes would now correspond to ISO-coarse >80% and >90% (dust arrestance), F7 to ePM_1 50–65% (efficiency) or $ePM_{2.5}$ 65–95% and F9 to ePM_1> 80% or $ePM_{2.5}$>95%. In further research the test setup will be relaunched with a new composition guided by the results of initial one and making use of filters classified according to ISO-16890 standard. ■

Acknowledgments

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