Onderwerp: Vraag ikv referentietaak 10 Milieu en Gezondheid – Binnenmilieu

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Vraag: **Filtering pollutions originating from residential wood burning**

Introduction

The generated smoke during the wood burning processes is known to contain many health hazardous substances, mostly resulted by incomplete combustion. Although the composition of the smoke typically is strongly dependant of the combustion process and the type of wood, the major pollutants found in the smoke from wood burning (beside the carbon dioxide and carbon monoxide) are: fine (PM2.5) and ultrafine particles (UFP((PM0.1), soot particles (organic particles consisting of elementary carbon), tar compounds (polycyclic aromatic hydrocarbons (PAHs)), dioxins and smell, caused mostly by non-combusted volatile organic substances found in the smoke (Mathijssen et al., 2018; Danish Ecological Concil, 2016a; Salthammer et al., 2014).

The residential wood burning is identified as a significant source of fine and ultra-fine PM including soot particles. Numerous studies have shown that the ambient fine and ultra-fine particle concentrations measured in areas with residential wood combustions are comparable and even higher than these measured in heavily polluted urban areas without wood combustion activities (Danish Ecological Concil, 2016a; Denier van der Gon et al., 2015; WHO Europe,2015). Furthermore, the residential wood combustion was identified as the largest organic aerosol source in Europe in the published by Denier van der Gon et al., (2015) anthropogenic carbonaceous emission inventory.

Questions concerning wood burning

1. *Is er labo-onderzoek gebeurd naar het effect van filtering op fijn stof/houtgeur, het gaat hier specifiek over filters die toepasbaar zijn in woningen met een ventilatiesysteem. Graag een overzicht van het onderzoek.*
   voor klassieke filters + koolstoffilter
   voor elektrostatische filter

PM removal by means of air filtration

A typical method to control and reduce the particles entering indoors from outdoor air is by means of mechanical ventilation with PM separation. The most commonly used method for separating PM from the air stream in the modern HVAC systems is the mechanical filtration and more specifically filtration using fibre filters (Eurovent, 2017). Currently available standards for performance requirements of ventilation systems for residential (CEN/TR 14788, 2006) and non-residential buildings (EN 16798-3, 2017) recommended using a minimum filtration efficiency to assure certain level of indoor air quality, taking into consideration the concentration of the pollutants in the outdoor air. For instance, to provide a high level of indoor air quality, the minimum combined (over single or multiple stage filtration) average filtration efficiency of the supplied air must be 96% in case of ODA 2 (typical outdoor air category in urban areas) and 99% for ODA 3 (very high polluted outdoor air). Considering the standard classification of particulate air filters for general ventilation (ISO 779:2012) such levels of combined average filtration efficiency could be reached by at least two stage filtration using filter class G5 or better as a prefilter and filter class F7 or better in the second stage (EN 16798-3, 2017). (See Annex 1 for overview of filter classification according its efficiency)

The particle collection efficiency of the individual filter of these classes have been reported to be >60% for F7 (Sadiktsis et al., 2016; Kim et al., 2016) and >80% for F9 (Sadiktsis et al., 2016; Azimi et al., 2014) tested with 0.4μm particles. However, only few in-situ studies have investigated the efficiency of these filter classes to specifically remove PM originating from wood combustion processes.

- McNamara et al. (2017) studied the influence of filter class to the concentration of air pollutants in wood stove homes. The authors reported a 66% average reduction in indoor PM2.5 concentration in houses using a single stage filtration with filter class F7 in comparison with the reference houses, where only coarse dust filter was installed (G2 filter class).

- In term of ultra-fine particles removal, a study conducted by Stephens and Siegel (2013) showed that using high class air filters (e.g. F7 – F9) could reduce the indoor ultra-fine particle concentrations with factor of 2 – 3 in a typical single-family house.

- Azimi et al. (2014) reported mean removal efficiency of ultra-fine particles above 80% for filter class F8 and higher. The authors also found nearly linear relation between the increase of the ultrafine particles removal efficiency and the increase the filter class. In addition to the particle removal efficiency, Sadiktsis et al. (2016) have also investigated the reduction of organic compounds associated with the fine and ultrafine PM. The authors reported more than 60% for F7 and more than 80% for F9 reduction efficiency of particle associated PAHs.

Although the higher-class efficiency filters class E10 – H14 (EN 1822-1, 2009) i.e. Efficiency Particulate Air (EPA) and High-Efficiency Particulate Air (HEPA) filters have minimum efficiency between 99.5% and 99.995% of removing fine and ultra-fine particles, these filters are normally not installed in residential HVAC systems. A typical residential air handling unit and the associated ductwork would not be able to accommodate such filter size and increased airflow resistance. Only specially built high performance homes may occasionally be equipped with HEPA filters installed in properly designed HVAC systems. However, those types of filters are widely used in standalone portable air purification units, where the device is designed to work with the increased air flow resistant of HEPA filters. The particle removal efficiency of such portable air purification units has been reported in the range of 40% - 90% for particle size range of 0.1 – 2 µm (Sultan et al., 2011; Wheeler et al., 2014; Barn et al., 2018; Mathijssen et al., 2018). However, the studies showed that the overall relative effectiveness of these units with respect of reducing indoor particle counts is a function of particle diameter. In a study published by Ward et al. (2005) the authors found that the overall relative efficiency of these units decreases as the diameter of particles increases above 0.25µm.

PM removal by means of particle separation

The other processes for particle separation such as cyclones, scrubbers or electrostatic precipitators (ESP) are generally more complex and are therefore only used in specific industrial areas. Nevertheless, several manufactures of HVAC systems, offers air cleaning solutions based on the electrostatic precipitators for residential uses, but still the use of these systems in residential areas is very limited (Eurovent, 2017). Although, their removal efficiency for fine and ultrafine particles is high (i.e. 55% - 85% for particles between 0.3µm and 10µm (Howard-Reed et al., 2003) and more than 50% efficiency for particles greater than 0.02µm (Wallace et al., 2004)), those type of devices are generally not recommended to be used in residences because of potential produce of ozone due to corona discharge (Boelter et al., 1997; Poppendieck et al., 2014)). However, recently published studies showed that the combination of ESP and active carbon filters could reduce the ozone concentrations generated by the corona discharge with about 40% (Poshin Leeat al., 1999; Poppendieck et al., 2014; Kim et al., 2018).

Gas phase removal by means of gas filters

In addition to the emissions of PM, significant part of the pollutants originated from wood combustion occurred in the gas phase (e.g. PAHs, VOCs, NOx). Although the contribution of the gaseous emissions from wood burning to the overall human exposure is found to be lower than PM fraction, the gaseous pollutants in the smoke from wood burning causes the odour nuisance where the most complains originated from (Danish Ecological Concil, 2016a; Salthammer et al., 2014).

To reduce the gaseous pollutants from the air stream and thus the wood burning odour nuisance, gas phase filters are typically used. One of the most widely used types of gas-phase filter in modern ventilation systems is based on the principle of dry-filtration through adsorptive media. Activated carbon is the preferable sorption media for gas removal used in ventilation systems because of its simplicity, efficiency and low cost. Several studies reported VOC removal efficiency greater than 60% for commercially available activated carbon gas phase filters (Sidheswaran et al., 2012; Gallego et al., 2013).

Table 1 Overview of recent scientific research on the effect of air filtration onto the indoor PM concentration and odour originated from wood burning

Authors	**Study**	**Results**	**Conclusion**
McNamara et al. (2017)	The study investigated the efficacy of air filter interventions in reducing indoor PM2.5, PMc and PMc – associated endotoxin concentrations in homes using a wood stove for primary heating. The study was conducted in 48 homes in the United States, where either a high efficiency filter or a low efficiency fiberglass filters were installed.	The obtained results from the study showed average of 66% (ranging from 42.2% to 79.7%) reduction in indoor PM2.5 concentrations in the sites with high efficiency filters relative to the sites with the lower efficiency fiberglass filters. Furthermore, both filter types showed relatively good removal efficiency for PMc (63.3% and 40.6% average reduction for high and low efficiency filters respectively). Both filters showed also a good removal efficiency in PMc-associated endotoxin concentrations (91.8% and 80.4% average reduction for high and low efficiency filters respectively).	The findings showed that high efficiency air filtration units could be used for reducing indoor PM2.5 concentrations in homes using a wood stove for primary heating. The authors also concluded that using lower efficiency, lower cost filter alternatives can be effective for reducing PMc and airborne endotoxin in homes burning biomass fuels.
Singer et al. (2016)	The study evaluated nine ventilation systems in an unoccupied house in the Unites States. The selected systems included variations of each major component: exhaust, supply and balanced ventilation; enhanced particle removal using MERV8, MERV13, MERV16 and HEPA filters or electronic precipitators; VOC removal using activated carbon, a chemisorbent, and a catalyst technology; supply and balanced ventilation provided via the FAU or separate ductwork. The effectiveness of the systems for reducing indoor concentrations of outdoor particles was measured during summer and fall/winter and of ozone during summer.	The study showed that exhaust ventilation without enhanced filtration provided 70% indoor PM2.5 concentration in comparison with outdoor. Supply ventilation equipped with MERV 16 class filter reduced the PM2.5 by 97-98%, UFP with 96-99%, and at least 84-96% black carbon relative to the outdoors. The supply ventilation with MERV13 filter provided slightly less protection of PM2.5 in comparison with the exhaust system without enhanced ventilation, while the supply MERV13 system with additional electrostatic precipitator showed similar results.	The results from this study showed that in moderate airtight houses the continuous exhaust ventilation provide substantial protection from outdoor PM2.5, UFP, BC, and ozone, even without enhanced filtration. To achieve similar protection, a supply ventilation requires MERV 13 filtration or better.
Sadiktsis et al. (2016)	This study investigates the particle bound PAHs remove capability of four different air filter materials (rates as:	The results from the study showed particle collection efficiency of 81% (F9), 66% (F7),	All of the tested filter materials showed PAHs removal

	F9, F7, F7+ctive carbon layer, and M6 filter class) used in mechanical ventilation systems. The study was performed at two highly trafficked locations in Stockholm, Sweden using parallel sampling systems allowing sampling of filtered and un-filtered air simultaneously. The capability of removing PAHs and reducing genotoxic effects of each air filter was determined by comparing the filtered and un-filtered air samples.	61% (F7+activated carbon), and 24% (M6) for 0.4µm particles. The particle collection efficiency for TSP was estimated as: 90% (F9), 87% (F7), 86% (F7+activated carbon), and 77% (M6). In term of reduction efficiency of particle bond PAHs, the filters showed 81% (F9), 66%(F7), 63% (F7+activated carbon) and 38% (M6). In addition, the study showed that there is no significant difference between the particle associated PAHs removal capability between F7 filter and F7 filter with additional activated carbon layer.	capability from urban aerosols. From the results of this study, the authors concluded that there is a possibility of reducing genotoxic effects from outdoor pollutants by using air filters. However, the class respectively the efficiency of the air filter is an important factor. The filters with lower particle removal efficiency showed lower capability of reducing certain mutagenic chemical compounds.
Poppendieck et al. (2014)	The study investigated the effectiveness of two popular brands electrostatic precipitator (ESP) filters to reduce UFP (4-15 nm) concentrations and quantify the resulting ozone generation in buildings. The ESP were installed in a central air handling unit in a test house.	The results showed that the removal efficiency of 8 to 14 nm for both tested devices was near to zero and always less than 10%. The authors explain that with possible particle generation or low charging efficiency of the tested devices. The added media filters downstream to the ESP increased the decay rate for particles in the same size range. The study also showed that continuous operation of the tested ESP increases the ozone concentration up to 77 ppb. In addition, using activated carbon filters downstream to the ESP reduces the indoor steady-state ozone concentration between 6% and 39%	Although previous research showed that ESP reliably and effectively removes wide range of particles with removal effectiveness greater than 80% for particles larger than 20 nm, this study showed that the removal effectiveness of the tested ESP on a household scale is less than 10% for particles smaller than 15nm. The study also showed, that using an activated carbon filer media downstream of the installed ESP could effectively reduce the generated ozone concentrations up to 39%.

Gallego et al. (2013)	The study evaluated the performance of commercially available activated carbon filters for removing VOCs from air stream. The study assessed the filter's removing efficiency for several groups of VOCs such as: alkanes, aromatic carbons, alcohols, ketones, halocarbons, aldehydes, esters, terpenes, ethers, glycols, and nitrogenated compounds.	The obtained VOC removal efficiency of the tested filter were ranging between 51 ± 19% to 78 ± 22% for indoor air, and between 42 ±16% to 91 ± 18 % for outdoor air across tested VOC groups.	The study reported average reduction efficiency across all studied compounds of 65 ± 13 % and 62 ± 15 % for indoor and outdoor air, respectively. The obtained ozone removal efficiency of the tested filter was reported to be nearly 100% in all cases.
Stephens et al. (2013)	The study studied the UFP (7 – 100 nm) removal efficiency of six types of commercially available filters (ranged from fiberglass panel filters (MERV 4) to deep-bed electrostatically charged synthetic media filters MERV 16) installed in HVAC system in an unoccupied test house.	The resulted removal efficiency for most of the UFP sizes was 0-10%, 15-20%, 30-50%, and 60-80% for MERV4-6, MERV10-11, MERV13 and MERV16 filters, respectively.	From the obtained results, the authors concluded that installing MERV13-16 filters in a typical single-family residence, the filters could reduce the indoor proportion of outdoor UFPs (in the absence of indoor sources) by as much as a factor of 2 – 3 relative to the lowest efficiency filters.

Sidheswaran et al. (2012)	The study explores the potential environmental and energy benefits of using activated carbon fibre filters for air cleaning in HVAC systems. The authors evaluated the efficiency of the activated carbon fibre filters to adsorb VOCs at concentrations in the range of the one typically found in indoor environments. The study was performed in 19 m^3 stainless steel chamber under controlled conditions representing real indoor environments.	The results from the experiments estimated maximum adsorption capacity of 90 mg VOC per gram of activated carbon fibre. The study reported average removal efficiency of 70 – 80% for most of the VOCs and about 25 – 30 % for formaldehyde.	The model study performed by the authors showed that the combination of activated carbon fibre air cleaning and 50% reduction in ventilation will decrease indoor concentrations of VOCs by 60 – 80% and reduce formaldehyde concentrations by 12 – 40%.

2. *Is er onderzoek uitgevoerd naar plaats aanzuigopening en effect op geur in woningen, graag een overzicht van dat onderzoek.*

The performed extensive search using the most common search engines for scientific literature (e.g. www.webofknowledge.com; www.scopus.com; www.sciencedirect.com; www.ncbi.nlm.nih.gov/pubmed/) did not find any recently published studies assessing the effect of the ventilation intake position to the indoor odor nuisance related to wood burning. However, at known position of the source of wood burning nuisance, the topology of the building and the ventilation system, the effect of the position of the ventilation intake to the indoor nuisance could be calculated using appropriate computer model. Currently, we do not have appropriate computer model to perform those type of calculations.

3. *Zijn er praktijkvoorbeelden van gebruik van filters in Vlaanderen tegen fijn stof/geur in woningen die als case kunnen gebruikt worden?*

   We are not aware of any recent demonstration of such examples in residential situations. However, in case of a more specific research programme would be initiated, it could be useful step to contact suppliers of these systems (see list below) to trace suitable (ongoing or future) cases to study the system performances more in depth. In school environments, few data on air purification (target PM) are/will be soon available:

   - The Renovair study in schools (LNE, 2016): quantifying the filter efficiency to remove PMx and black carbon from the supply air in mechanically ventilated classrooms (ventilation system D, replacing filter type F7 by F9)

   - Indoor air purification in classrooms organized by the City of Antwerp by means of commercially available stand-alone air cleaning devices. A case study in two urban schools (ongoing)

4. *Kunnen de filtermogelijkheid van verschillende types ventilatiesystemen (focus op D en C) verzameld worden, gebaseerd op wat er momenteel op de markt is*

   In our knowledge, only ventilation system D allows air cleaning of the air supply stream. The system allows several air cleaning solutions, including air filtration, particle separation as well as gas filtration by means of sorption media.

   For ventilation system C, stand-alone air cleaning devices (using the same principles, thus including air filtration, particle separation as well as gas filtration by means of sorption media) offer the similar solutions; however, with less control over cleaning the incoming air supply. To our knowledge methods for supply air purification in residential ventilation system C are currently not available on the market.

5. *Welke filtersystemen zijn geschikt om uitstoot van houtverbranding tegen te gaan er op de markt zijn in Vlaanderen/Europa (ventilatiesystemen, dus niet op de schouw)?*

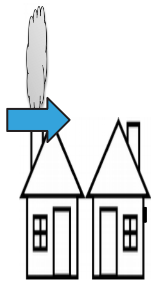
   Market available systems to reduce the emissions/exposure to wood burning can be grouped into 3 categories, depending of the person who takes the initiative:

   (a) Devices to reduce combustion components of the exhaust of wood-burning appliances (chimney), installed by the user of the wood burning appliance

   (b) Devices to reduce combustion components in the air supply of a mechanical ventilation system

   (c) Devices to reduce exposure to combustion components in indoor environments

(a) Devices to reduce combustion components of the exhaust of wood-burning appliances (chimney), installed by the user of the wood burning appliance



As mentioned above, the combustion conditions in residential wood burning appliances may not be ideal, resulting in the emission of hazardous pollutants (e.g. PM, BC, PAHs, VOCs), usually due to incomplete combustion. In addition, because of the complexity of the combustion process, the reduction of these emissions from wood burning appliances is not simple process. The measures that can be taken to reduce the emissions can be divided into four aspects: (1) improvement of the combustion techniques, (2) reduction of ash vaporization, (3) correct use of equipment and (4) cleaning of particles from flue gases. Among all aspects, the process of cleaning particles from flue gasses shows to be most suitable, regardless the type of wood burning appliances used. Currently, there are several techniques for particle removal from flue gasses, targeting the small-scale residential combustion appliances. An overview of these cleaning technique types for residential applications is shown in Table 2.

Table 2 Overview of particle cleaner types for residential applications (Hartmann et al., 2011)

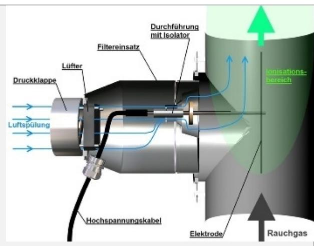
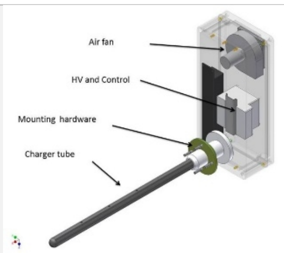
Principle	Advantage	Disadvantage
Electrostatic precipitators	Low pressure drop, low cost	Lower efficiency for organic particles
Filters (e.g. baghouse filters)	Good separation efficiency	High pressure drop, High technical efforts
Cyclone separators	Low cost	Low particles separation efficiency
Scrubbers	Flue gas condensation	High technical efforts Medium separation efficiency
Flue gas condensation	Additional heat gain	Low separation efficiency
Catalyst	Gaseous and particle phase	Low separation efficiency

efficiency

However, the most common types of particle cleaners for residential wood burning appliances on the market are based on electronic particle removal. An overview of the products currently available on the EU market is shown in Table 3

Table 3 Overview of some devices for cleaning particles from flue gasses from small scale wood burning appliances available on the market

System name/Brand	Principle		URL
TOP CLEAN PARTICLE FILTER /Poujoulat/	Electrostatic precipitation		https://fr.poujoulat.be/nos-solutions/logement-individuel/ameliorer/filtration/top-clean
Particle Separator Airjekt 1 /Kutzner + Weber/	Electrostatic precipitation		https://www.kutzner-weber.de/gb/products/particle-separator/particle-separator-airjekt-1.html
OekoTube /OekoSolve/	Electrostatic precipitation		http://oeko.be/producten.html https://www.polvo.be/oekosolve-houtrook-home-industrie/
Airbox (for fireplace inserts) /Spartherm/	Electrostatic precipitation		https://www.spartherm.com/nl/producten/accessoires/techniek-om-lucht-schoon-te-houden/

Zumikron **/ Rüegg Ecotec/**	Electrostatic precipitation		http://www.ruegg-ecotec.ch/ zumikron.htm
ABCAT houtrookfilter **/ABCAT/**	Catalyst		http://www.houtrookfilter.nl/ wat-is-een-houtrookfilter/
Tassu EDF **/Tassu ESP/**	Electrostatic precipitation	 	https://www.tassuesp.com/ #domestic

(b) Devices to reduce combustion components in the air supply of a mechanical ventilation system

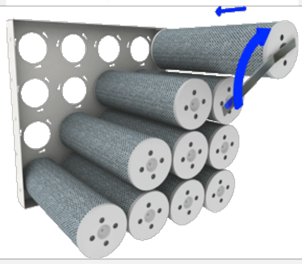
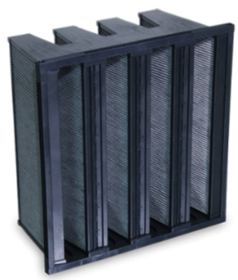
As mentioned above, the main pollutants originating from wood burning processes (beside carbon monoxide and carbon dioxide) are: particulate matter (i.e. fine (PM2.5) and ultrafine particles (UFP((PM0.1), soot particles) and the gaseous compounds (i.e. tar compounds, dioxins and non-combusted volatile organic substances (causing the typical wood burning smell) (Danish Ecological Concil, 2016a; Salthammer et al., 2014; Mathijssen et al., 2018). Therefore, to reduce the indoor exposure of the occupants to pollutants from wood burning processes originating from outdoors, the ventilation system needs to be able to efficiently reduce the amount of PM and gaseous compounds form the supply air stream to the indoor environment. The most commonly used purification technologies and their characteristics are shown in Table 4.

Table 4 Overview of air cleaning technologies (Liu et al., 2017)

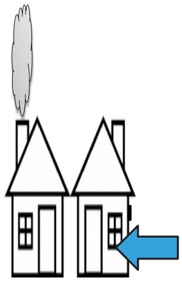
Technology	Target pollutant(s)	Advantage	Disadvantage	Efficiency
Fibrous filter media	Particles	Low cost, convenient installation	Resistant related to the purification efficiency	Can achieve 99.99999%
Electrostatic precipitation	Particles	High efficiency and wild range of particle size, Small pressure drop	High cost, efficiency decline after dust discharge, electric field easy to breakdown	50% (some only 20%)
Ionizers (i.e. ion generators)	Particles	Accelerate metabolism, strengthen cell function, effective to some disease	Produce ozone, cause second pollution, deposition of dust damage the wall	73.4%
Adsorbent media	Gases	Wild sources, bigger pollutant purifying range, not easy to cause the secondary pollution	Saturated regeneration problems, resistance is bigger, mineral processing, is not good	
Photocatalysis	Gases	Wide range of purification, mild reaction conditions, no adsorption saturation phenomenon, long service life	Compared to the activated carbon adsorption technology, slower purification process, easy to cause the secondary pollution if response is not completed	75% (some may only 30% or even negative)
Plasma	Gases	Big range of pollutants	Cannot completely degrade pollutants and	66.7%

		produce by-products	

Table 5 Overview of some devices used to reduce combustion components in the air supply of a mechanical ventilation systems, available on the market

System name/Brand	Technology		Class
Bag filters	Fibrous filter media		F7 – F9 ePM1: 55- 85%
Panel filters	Fibrous filter media		F7 – F9 ePM10: 65% ePM2.5: 55 – 90% ePM1: 50 – 70%
Compact filters	Fibrous filter media		F7 – F9 ePM10: 75% ePM2.5: 55 – 95% ePM1: 50 – 85%
Molecular filters /Cartridges/	Adsorbent media		
Molecular filters /compact filters/	Adsorbent media		
Molecular filters /combo/	Combination of Fibrous filter media and Adsorbent media		F7 ePM2.5: 85%

(c) Devices to reduce exposure to combustion components in indoor environments



As discussed above, the standalone air purification devices (typically equipped with high efficiency HEPA filters), could efficiently remove significant part of the PM originating from combustion processes. In a review study published by the National Institute for public health and the environment (RIVM) of Netherlands, the authors concluded that placing standalone air purification device in the living room or the bedroom improves the overall IAQ by reducing the PM2.5 concentrations with 37 – 85% and the concentrations of levoglucosan (typical indicator for wood smoke) with 35 – 75% (Mathijssen et al., 2018). In addition, many of the available on the market standalone air purification devices combine high efficiency HEPA filters for particle filtration with gas fitration technologies to provide combined removal of particle and gaseous pollutants from the air in indoor environments.

When selecting a standalone air purification device, there are few factors that need to be considered (based on the EPA "Guide to Air Cleaners in the Home" 2nd Edition, 2018 included in Annex 3):

1.Type of air contaminants

Although, most of the standalone air purification devices are equipped with gas and high efficiency particle filters, different models work better on different issues. For instance, one purifier might be excellent of removing viruses and bacteria but be poor at removing smoke or VOCs. Another may be very efficient in removing asthma sufferers, but poor at removing odours. Therefore, before selection of an air purification device, it is important to be decided what type of air contaminants or health issues need to be addressed. Usually the manufacturers of the devices provide sufficient information regarding the type of air contaminants that certain device is suitable for.

2. Room size

Most of the standalone air purification devices are rated according their cleaning capacity or the amount of air they can clean for defined period of time. To provide sufficient air cleaning the selected device must be able to handle the total volume of air in the indoor environment where is used. The technical information provided with most of the devices usually includes information regarding the maximal size area or room that the device should be used in.

Some of the available standalone air purification devices are rated according their Clean Air Delivery Rate (CDAR). In general, this numeric value shows how much of the specific particles to be removed from the air. In other words, CADR rating indicates how fast the air purifier can clean the air within a particular size room. The higher the CADR, the more particles the air purifier can filter and the larger the area it can serve. Typically, the CADR raring focuses to three particle size groups: tobacco smoke (particles with sizes between 0.09 µm and 1 µm), dust (particles with sizes between 0.5 µm and 3 µm), and pollen (particles with sizes between 5 µm and 11 µm). The provided by the manufacturer of the purifier CADR value for each group indicates its particle removal performance for each particle size group. It is important to be noted here that the CADR rating system is for particles only.

3. Noise level

Although most of the modern air purification devices are designed to be extremely quiet they do contribute to the noise background levels indoors. Noise levels generated from the devices pretty much depend on the speed setting of the fan. If the device needs to be used in noise sensitive environments (e.g. bedrooms) then an air purification device that has a low published noise rating must be considered. For reference, a noise rating around 50 dB is roughly the operating noise of a modern refrigerator.

Examples of commonly used standalone air purification systems are shown in Table 6.

Table 6 Overview of some standalone air purification systems available on the market

System name/Brand	**Filter type**		**URL**
Novaerus /Polovo/	M5/H13/ Molecular filter (carbon)		https://www.polvo.be/ luchtzuivering-home/
Genano /Genano/	Electrostatic precipitation / Molecular filter (carbon)		https://www.genano.com/ genano-products

City Air Purifier /Camfil/	H13/Molecular filter (carbon)		https://www.camfil.com/en/products/air-cleaners-,-a-,-air-purifiers/city-air-purifiers

Annex 1: Classes for air filter efficiency

CLASSIFICATION	Arrestance or Dust Spot Efficiency	US ASHRAE 52.2	European Union EN779 Class		Typical Controlled Contaminant	Application
PRE Filter (G Class)	AFI <65 %	MERV 1	G1	Am< 65%	Particle bigger than 10.0μm (Pollen) (Spanish moss) (Dust mites) (Sanding dust) (Spray paint dust) (Textile fibers)	Gross filter, domestic and commercial
	AFI 65%-70%	MERV 2	G2	65% ≦Am< 80%		
	AFI 70%-75%	MERV 3				
	AFI 75%-80%	MERV 4				
	AFI 80%-85%	MERV 5	G3	80% ≦Am<90%	Particle size within 3.0μm-10.0μm (Mold) (Spores) (Hair spray) (Cement dust) (Snuff) (Powdered milk)	Commercial, industrial, paint shop
	AFI 85%-90%	MERV 6				
	NBS 25%-30%	MERV 7	G4	90% ≦Am		
	NBS 30%-35%	MERV 8				
MEDIUM Filter (F Class)	NBS 40%-45%	MERV 9	F5	40% ≦Em< 60%	Particle Size within 1.0μm-3.0μm (Lead dust) (Milled flour) (Coal dust) (Auto emissions) (Nebulizer drop) (Welding fumes)	IAQ concerned commercial & industrial, medical
	NBS 50%-55%	MERV 10				
	NBS 60%-65%	MERV 11	F6	60% ≦Em< 80%		
	NBS 70%-75%	MERV 12				
	NBS 80%-85%	MERV 13	F7	80% ≦Em< 90%	Particle size within 0.3μm-1.0μm (All bacteria) (cooking oil) (Most smoke) (Copier toner) (Most face powder) (Most paint pigments)	IAQ concerned commercial, industrial, medical, food etc
	NBS 90%-95%	MERV 14	F8	90% ≦Em< 95%		
	NBS>95%	MERV 15	F9	95% ≦Em		
		MERV 16				

From January 2017 a new standard EN ISO 16890 (1-4) for air filters for general ventilation became active. The new EN ISO 16890 will suppress the currently used EN779:2012. The new EN Iso 16890-1 determines an air filter's efficiency class by using its efficiency factor for the environmental measuring of the relevant PM10, PM2.5 and PM1. Because the EN 779 and EN ISO 16798-1 uses different methods for assessment and classification of the filters, at the time of this report there is no a direct methodology for conversion between the two classification schemas. However, some indicative conversion can be defined based on existing experimental data. An example of such indicative comparison is shown in Table 7.

Table 7 Filter class conversion between EN 779 and EN ISO 16890-1 (VDI 3803-4, 2012; Eurovent, 2017)

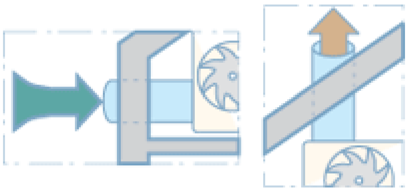
EN 779:2012	EN ISO 16890-1:2016		
Filter class	**ePM1**	**ePM2.5**	**ePM10**
M5	5% - 35%	10% - 45%	40% - 70%
M6	10% - 40%	20% - 50%	60% - 80%
F7	40% - 65%	65% - 75%	80% - 90%
F8	65% - 90%	75% - 95%	90% - 100%
F9	80% - 90%	85% - 95%	90% - 100%

Annex 2: Guidelines for the position of the ventilation air intake

https://www.wtcb.be/homepage/index.cfm?cat=publications&sub=infofiches&pag=42&art=6&lang=nl

Ventilatie van gebouwen – Luchttoevoeropeningen en luchtafvoeropeningen (mechanische ventilatie)

Verschenen : februari 2010



De gewestelijke EPB-regelgevingen specificeren de eisen voor zowel de ventilatie van gebouwen als de componenten van het systeem (zie Infofiche 42.1). Deze Infofiche behandelt de problematiek van de luchttoevoer- en luchtafvoeropeningen voor mechanische ventilatie. Ze is hoofdzakelijk bestemd voor bouwprofessionelen die instaan voor de dimensionering en de installatie van mechanische ventilatiesystemen, alsook voor de ontwerper van het project. Luchttoevoer- en luchtafvoeropeningen kunnen soms ook door de aannemer van de ruwbouwwerken of de dakwerken geïnstalleerd worden.

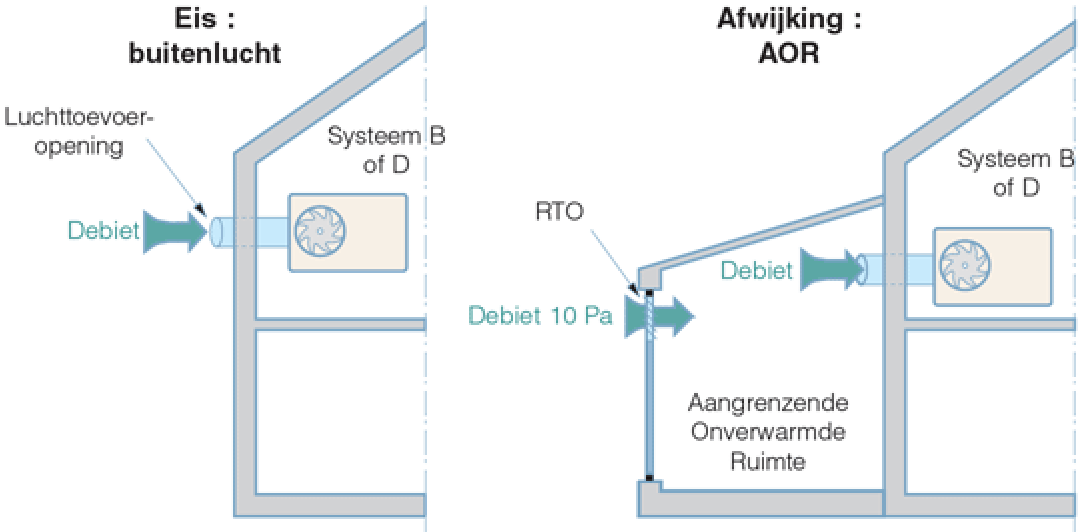
1. Inleiding

In mechanische ventilatiesystemen zorgen de luchttoevoeropeningen voor de aanvoer van verse buitenlucht terwijl de luchtafvoeropeningen de vervuilde lucht naar buiten afvoeren.
Over het algemeen worden de luchttoevoer- en de luchtafvoeropeningen in een buitenmuur of in het dak aangebracht.

Afb. 1 Voorbeelden van een luchttoevoeropening in een buitenmuur en een luchtafvoeropening in het dak

2. EPB-regelgeving

De enige eis die de EPB stelt, is dat de luchttoevoeropeningen zodanig aangebracht dienen te worden dat ze buitenlucht kunnen aanvoeren. Op deze regel bestaat echter een afwijking voor woongebouwen, waardoor het toegelaten is dat de luchttoevoeropeningen voor de systemen B en D lucht aanzuigen uit een aangrenzende onverwarmde ruimte (AOR). In dat geval moeten tussen deze aangrenzende ruimte en de buitenomgeving één of meerdere natuurlijke toevoeropeningen voorzien worden voor de realisatie van het totale minimumontwerpdebiet voor een drukverschil van 10Pa.



Afb 2 Luchttoevoer van de systemen B en D : ofwel rechtstreeks van buiten ofwel via een aangrenzende onverwarmde ruimte (AOR) en de vereiste natuurlijke toevoeropening naar buiten, met de gepaste afmetingen voor een maximum drukverschil van 10 Pa.

Naast de EPB-regelgeving kunnen ook andere aanbevelingen, vooral met betrekking tot de plaats van de luchttoevoer- en luchtafvoeropeningen, een grote invloed uitoefenen op de luchtkwaliteit. Verder in deze Infofiche worden deze aanbevelingen kort aangehaald omdat zoveel verschillende aannemers betrokken kunnen zijn bij de installatie.

3. Rol van de aannemer en de ontwerper

In Infofiche 42.1 vindt u een overzicht van de taken van elke aannemer.

De ontwerper moet normaal gezien:

- een ventilatiesysteem kiezen naargelang de omstandigheden en het correct ontwerpen en dimensioneren volgens de EPB-regelgeving wat in het bijzonder de bepaling van het ontwerpdebiet per ruimte inhoudt (zie Infofiche 42.2) en dus ook het totale debiet dat door de luchttoevoer- of luchtafvoeropeningen stroomt;
- de plaats van de luchttoevoer- en de luchtafvoeropeningen bepalen en de bij de installatie betrokken aannemers informeren: de dakdekker en/of de aannemer belast met de dakafdichting, de aannemer van de ruwbouwwerken en de installateur van het ventilatiesysteem;
- bijzondere aandacht besteden aan de coördinatie van de installatie wanneer de luchttoevoer- en luchtafvoeropeningen door één aannemer geleverd, maar door een andere geïnstalleerd worden.

De aannemer belast met de werken moet zich er bovendien toe verbinden te voldoen aan de eisen van het bijzondere bestek en de plannen, voornamelijk in verband met de plaats van de luchttoevoer- en/of luchtafvoeropeningen.

4. Aanbevelingen

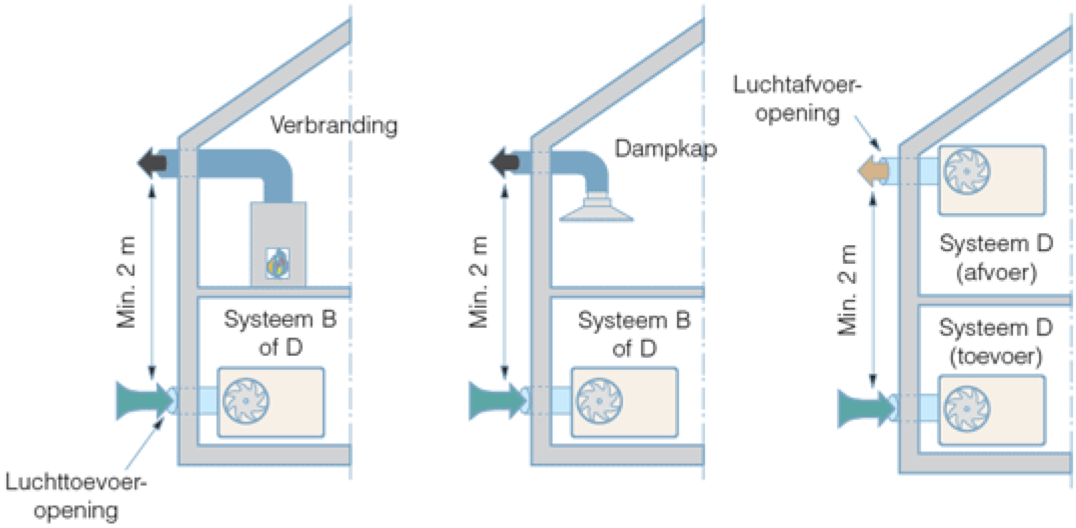
4.1. Plaats van de luchttoevoeropeningen

Afb 3 Te dicht bij elkaar geplaatste luchttoevoer- en luchtafvoeropening, waardoor er gevaar voor hercirculatie van de lucht ontstaat.

Bij de plaatsing van de luchttoevoeropeningen voor mechanische ventilatie moet absoluut vermeden worden dat lucht van slechte kwaliteit, bijvoorbeeld afkomstig van een luchtafvoeropening of een schouw, rechtstreeks in het ventilatiesysteem wordt gezogen, waardoor de binnenluchtkwaliteit aangetast wordt.

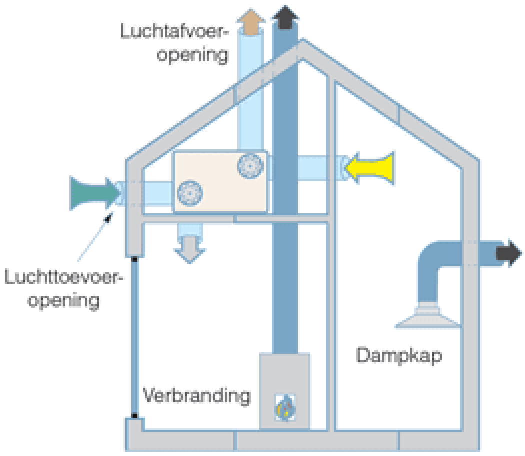
Bijlage A.2.4 van de norm NBN EN 13779 [2] bevat aanbevelingen voor de minimumafstand tussen een luchttoevoeropening enerzijds en een luchtafvoeropening (ventilatie, maar ook dampkap, ...) of een rookafvoer van een verbrandingsketel (gas of stookolie) anderzijds. Deze aanbevelingen zijn gebaseerd op het begrip 'verdunningsfactor' en zijn gericht op een aantal mogelijke plaatsingen van deze openingen (in eenzelfde gevel, in een gevel en een dak, ...).

Voor woongebouwen wordt algemeen aanbevolen een luchttoevoeropening een niveau lager te plaatsen dan nabije afvoeropeningen (ventilatie, verbranding). Volgens deze aanbeveling zou een minimumafstand van 2 m tussen de toevoer- en de afvoeropening problemen meestal voorkomen.



Afb. 4 Aanbevelingen voor de plaats van een luchttoevoeropening : een

niveau lager dan de afvoeropening en op een minimumafstand van 2 m.



Afb. 5 Voorbeeld van luchttoevoer en luchtafvoer via verschillende zijden
De plaatsing van deze openingen in verschillende muren kan nog een beter resultaat opleveren door ze bijvoorbeeld in twee gevels met verschillende oriëntatie te plaatsen of door de luchttoevoer in een gevel en de afvoer in een hoger gelegen dak te voorzien.

Er wordt eveneens aanbevolen de luchttoevoeropeningen zo ver mogelijk van drukke verkeerswegen, parkings en afvalverzamelplaatsen te voorzien en ook niet te dicht bij de grond of beplanting. Toe- of afvoeropeningen die aansluiting geven op een ingesloten ruimte, zoals een koertje, verdienen bijzondere aandacht.

4.2. Bescherming van de luchtopeningen

Het spreekt voor zicht dat luchtopeningen van een regenkap voorzien moeten zijn om directe regeninval te voorkomen. Door de toevoeropeningen groot genoeg te maken, blijft de luchtsnelheid lager dan 2 m/s en wordt het aantal regendruppels dat met de lucht mee binnenstroomt bovendien beperkt.

Om insecten tegen te houden is het aan te bevelen een rooster te installeren. Kies wel voor een luchttoevoer met beperkt drukverlies.
Tot slot moeten de luchtopeningen in het dak voldoende boven het dak uitsteken om verstopping bij sneeuwval te voorkomen.

4.3. Thermische isolatie en luchtdichtheid

Het feit dat luchttoevoer- en luchtafvoeropeningen door de gebouwschil heen steken, heeft gevolgen voor het warmteverlies van het gebouw door warmtetransmissie en luchtlekken. Het constructiedetail van de doorgang van het kanaal door de schil zou de koudebrug op die plaats moeten beperken en een perfecte luchtdichtheid van de aansluiting moeten garanderen.

Literatuurlijst

Voor meer details over de EPB kunnen de gewestelijke regelgevingen geraadpleegd worden (zie hieronder).
Meer informatie over de ventilatienormen vindt u op de website van de Normen-Antennes op www.normen.be.
Momenteel werken de drie gewesten samen aan een databank van producten

die aan de EPB-eisen voldoen (zie www.epbd.be).

Het Vlaams Gewest stelt een lijst met antwoorden op veelgestelde vragen (FAQ) en bijkomende uitleg over de interpretatie van de regelgeving voor ventilatie ter beschikking op www.energiesparen.be.

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NBN D 50-001 Ventilatievoorzieningen in woongebouwen. Brussel, NBN, 1991.

2. **Bureau voor Normalisatie**
NBN EN 13779 Ventilatie voor niet-residentiële gebouwen. Prestatie-eisen voor ventilatie- en luchtbehandelingsystemen. Brussel, NBN, 2007.

3. **Ministerie van de Vlaamse Gemeenschap**
Besluit van de Vlaamse Regering van 11 maart 2005 tot vaststelling van de eisen op het vlak van de energieprestaties en het binnenklimaat van gebouwen. Brussel, Belgisch Staatsblad van 17 juni 2005.

4. **Ministerie van het Brussels Hoofdstedelijk Gewest**
Besluit van de Brusselse Hoofdstedelijke Regering van 21 december 2007 tot vaststelling van de eisen op het vlak van de energieprestaties en het binnenklimaat van gebouwen. Brussel, Belgisch Staatsblad van 5 februari 2008.

5. **Ministerie van het Waalse Gewest**
Besluit van de Waalse Regering van 17 april 2008 tot vaststelling van de berekeningsmethode en de eisen, de goedkeuringen en de sancties op het vlak van de energieprestaties en het binnenklimaat van gebouwen. Brussel, Belgisch Staatsblad van 30 juli 2008.

6. **Vlaamse overheid**
Besluit van de Vlaamse Regering tot wijziging van het besluit van de Vlaamse Regering van 11 maart 2005 tot vaststelling van de eisen op het vlak van de energieprestaties en het binnenklimaat van gebouwen. Brussel, Belgisch Staatsblad van 6 juli 2009.

7. **Wetenschappelijk en Technisch Centrum voor het Bouwbedrijf**
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Opmerking

Departement 'Akoestiek, Energie en Klimaat', WTCB

Annex 3: Guide to Air Cleaners in the Home (EPA, 2018)

https://www.epa.gov/sites/production/files/2018-07/documents/guide_to_air_cleaners_in_the_home_2nd_edition.pdf

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