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SELECTION OF MOLECULAR FILTERS FOR SUPPLY AIR FOR GENERAL VENTILATION RATED ACCORDING TO ISO 10121-3

FIRST EDITION

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Eurovent, 80 Bd A. Reyers Ln, 1030 Brussels, Belgium
secretariat@eurovent.eu

Document history

This Eurovent Industry Recommendation / Code of Good Practice supersedes all of its previous editions, which automatically become obsolete with the publication of this document.

MODIFICATIONS

This Eurovent publication was modified as against previous editions in the following manner:

Modifications as against	Key changes
1st edition	Present document

Preface

IN A NUTSHELL

This document provides comprehensive and practical guidance on the selection of ISO 10121-3 rated molecular filters for outdoor air in general ventilation systems for typical applications. It discusses issues such as the importance of molecular filtration, the most significant gaseous pollutants and their impact on health, sources of information on local concentration of gaseous pollutants in ambient air, the principle of operation and types of molecular filters, practical aspects of molecular filter exploitation and much more. The Recommendation is addressed to all HVAC professionals dealing with ventilation systems, particularly designers, facility managers and manufacturers of equipment, including air filters.

AUTHORS

This document was published by Eurovent and was prepared in a joint effort by participants of the Product Group 'Air Filters' (PG-FIL), which represents a vast majority of all manufacturers of these products active on the EMEA market. A particularly important contribution has been provided by Romano Basso, Thomas Caesar, Nils Juttner, Andrew Price, Frank Spehl and Tobias Zimmer.

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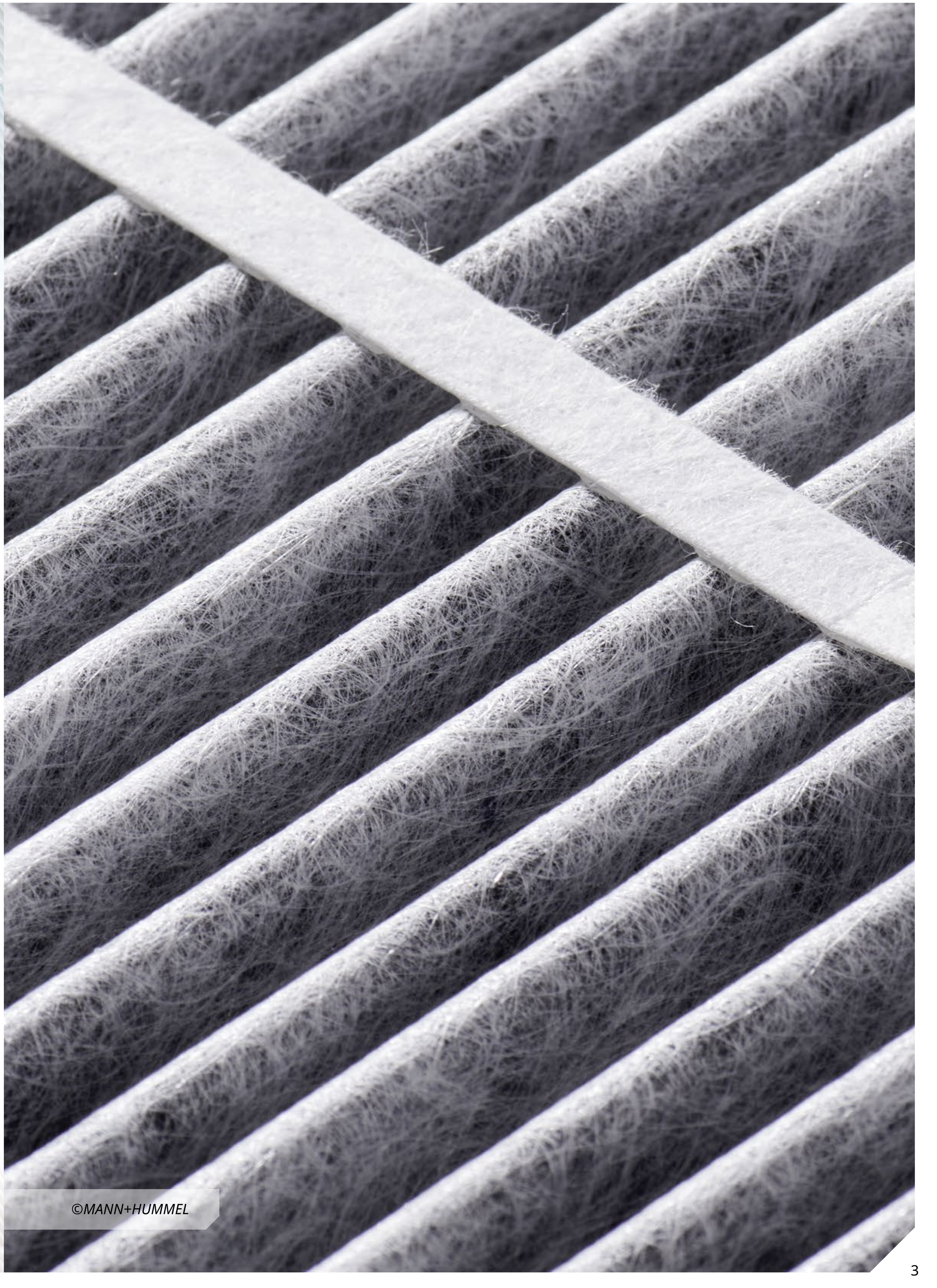

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Contents

List of abbreviations and symbols

BoD	Burden of Disease
C_7H_8	Toluene
CO	Carbon monoxide
EEA	European Environment Agency
Eionet	European Environment Information and Network
EU	European Union
GPACD	Gas-phase air cleaning devices
HD	Heavy Duty filter capacity/lifetime
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
LD	Light Duty filter capacity/lifetime
MD	Medium Duty filter capacity/lifetime
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
O_3	Ozone
ODA	Outdoor air
P1D	Daily mean
PG-FIL	Eurovent Product Group 'Air Filters'
PM	Particulate matter
SO2	Sulphur dioxide
SUP	Supply air
vLD	Very Light Duty filter capacity/lifetime
VOC	Volatile Organic Compounds
WHO	World Health Organization
WHO AQC	WHO air quality guidelines

1. Introduction

The ISO 10121-3 standard published in 2022 made it possible to evaluate gas-phase filters for Heating, Ventilation, and Air Conditioning (HVAC) applications. This fills a long-standing gap with EN ISO 16890 and its predecessors, which only addressed particle filtration. The new standard provides a tool that paves the way for improving Indoor Air Quality (IAQ) since the World Health Organization (WHO) already stated that gases can be as toxic and harmful as fine dust.

In the past, molecular filtration has been neglected in practice. The recommendation for the application of gas phase filters in the revised standard EN 16798-3 improves things, but guidance for the market on the correct selection of gas phase filtration is still lacking.

The main objective of this Eurovent Recommendation is to bridge the gap and present principles for selecting molecular filters. The current document discusses molecular filtration of outdoor (fresh) air in ventilation systems, while a future update is planned to also address the filtration of recirculated air.

The publication is addressed to all HVAC professionals dealing with ventilation systems and air filters, particularly designers, facility managers and manufacturers of equipment.

2. Why use gas-phase filtration?

2.1 IMPORTANCE OF FILTRATION

People spend, on average, up to 90% of their lives indoors, not only at home but in various places such as offices, schools, restaurants, shopping malls or cinemas. Having clean air indoors is crucial for the health of the population as a whole and, in particular, vulnerable groups such as babies, children or elderly people.

2.2 A HOLISTIC APPROACH TO CLEAN INDOOR AIR

The air we breathe contains several pollutants, having different origins, states and concentrations. According to their origin, they can be inert, viable or chemical, and they can be divided into two main groups: aerosol, either solid or liquid particles, or molecular as gas or vapour. Gas pollutants are, in many cases, overlooked while they can cause damage comparable to and closely related to toxic particles. Once inhaled, their properties allow them to reach any part of the lungs and even enter the bloodstream.

The next necessary step to improve IAQ is to address gaseous pollutants. In combination with measures against particles, every possible harmful substance in the air can be addressed.

Outdoor gaseous pollution originates mostly from combustion sources, local and distant, in particular where the levels exceed rural background. What is often not acknowledged is that in strongly polluted areas (e.g. heavy industry zones, city centres with heavy traffic) without air filtration, most ambient air pollution monitored outdoors occurs indoors. This does not apply to every gas molecule since some of them are short-lived and can react with other molecules or the surface of particles. For instance, ozone is known to be highly reactive and may, therefore, show lower concentrations indoors than outdoors, as it may quickly react with surfaces and organisms in the indoor environment.

In many cases, fine particles carry adsorbed gaseous pollutants through our lungs into our bloodstream. The results can be twofold: either more dangerous to human health or less dangerous.

Applying a correctly selected combination of efficient gas-phase filters and particle filters in ventilation systems can significantly reduce the impact of air pollution exposure on the Burden of Disease (BoD).

Despite significant reductions in emissions of harmful air pollutants over the past three decades in the European Union (EU), the number of premature deaths and non-communicable diseases attributed to air pollution, especially related to particulate matter (PM), nitrogen dioxide and ozone, is very considerable.

At the same time, the already well-established scientific evidence of the harmful effects of air pollution on human health has further developed over the past decade. This is well documented in the regularly updated WHO global air quality guidelines (AQG), which provide recommendations based on a systematic review of the relevant scientific evidence. The 2021 edition of these guidelines confirms that, for several air pollutants, adverse health effects occur at concentration levels lower than those specified in previous editions.

2.2.1 THE MOST SIGNIFICANT GASEOUS CONTAMINANTS

Common pollutants that are considered dangerous to health are ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and Volatile Organic Compounds (VOC), including toluene (C_7H_8).

- Ground-level ozone is not directly emitted by primary sources but is a secondary pollutant produced in the atmosphere in the presence of sunlight and chemical precursors. The main precursors of O_3 are nitrogen oxides (NO_x) and VOC, which originate primarily from transportation and industrial activities that are largely associated with urban areas.
- NO_2 is formed as a direct result of combustion processes (exhaust gases from means of transport, industry).
- SO_2 is mostly released from the burning of fossil fuels in power plants and industrial processes (industry).
- C_7H_8 is an organic molecule used by the standard to represent a very large group of VOC. The number of sources of VOC is endless and can be found both indoors and outdoors. These include solvents, paints, building materials, combustion processes, oil and gas, etc.

Based on the number of associated significant health effects, the WHO decided to include NO_2, O_3, SO_2 and CO as priority pollutants in the latest guidelines.

In this context, it must be emphasised how large a share of the EU's urban population is exposed to concentrations of air pollutants that exceed WHO AQG.

2.2.2 HEALTH EFFECTS OF GASEOUS POLLUTANTS

The effects of gaseous pollutants on human health have been extensively studied in the past. The results revealed that both short- and long-term exposure to the exceeded level of gaseous pollutant can pose serious health hazards, particularly in terms of respiratory and cardiovascular diseases that lead to more hospital admissions, school and work absences, medication use and even premature mortality. Concerning the pollutants identified by WHO as priority ones, their health impacts, particularly in the case of prolonged exposure to high levels, include respiratory problems, decreased lung function, aggravation of cardiovascular conditions, increased mortality and exacerbation of allergies and respiratory infections.

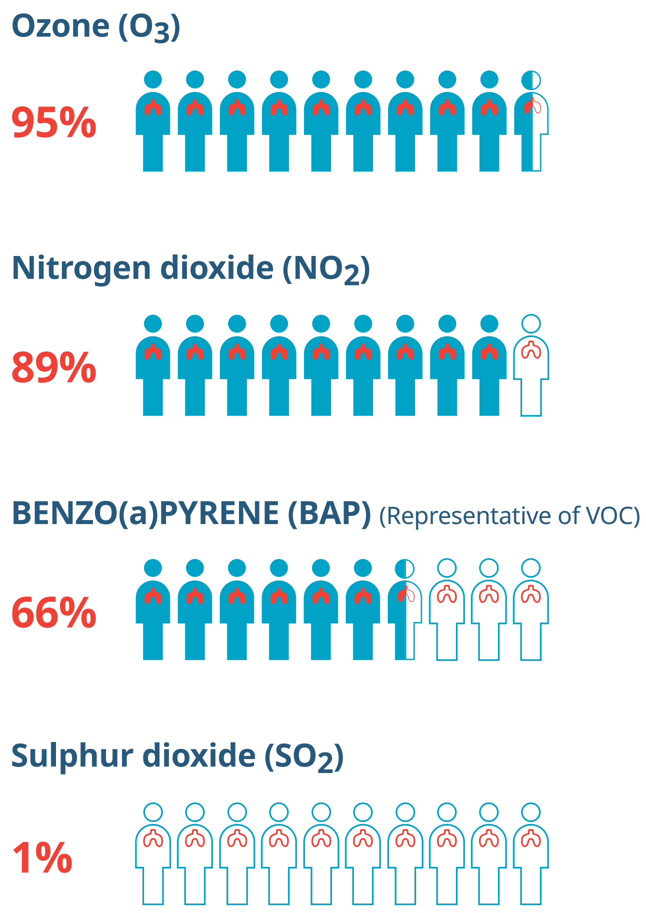


Figure 1. *Share of the EU urban population exposed to air pollutant concentrations above WHO AQG in 2020 (Source: AAQ Directive proposal - Impact Assessment report - Part 4, p. 335) @EUROPEAN UNION*

KEY LEARNING POINTS

- IAQ must be assessed in a holistic way, considering both the particulate and gaseous pollutants.
- Both the short- and long-term exposure to the exceeded level of gaseous pollutant, which are considered dangerous to health can pose serious health hazards.
- WHO has recognised NO_2, O_3, SO_2 and CO as the most harmful gaseous pollutants to health and has included their limit levels in the latest guidelines.
- Due to ventilation providing continuous air exchange in buildings, high concentrations of gaseous pollutants indoor mainly originate from outdoor air, therefore effective molecular filtration of outdoor air is crucial.
- The percentage of the EU urban population exposed to gaseous air pollutant concentrations exceeding WHO AQG, in particular for O_3 and NO_2 is very high.

3. Particle filters versus molecular filters

To understand the operating principles of air filters for HVAC applications, it is first necessary to divide them into two main groups, depending on the contaminants to be treated, which may be present in the form of aerosols or the gas phase.

Aerosol is a mixture of solid and liquid particles suspended in air, having a wide dimensional range from nanoparticles smaller than 0,1 µm up to coarse particles larger than 10 µm. Molecular contaminants are normally in the gas phase.

For air quality, different filtration systems must be used for aerosols and gaseous contamination.

Figure 2. *Particle filtration vs. molecular filtration ©MANN+HUMMEL*

3.1 PARTICLE FILTRATION (AEROSOLS)

The most common method of separating particles from air streams in ventilation and air conditioning systems is fibre filters. The pressure drop of the particle filter increases over time due to dust accumulation, which, contrary to the molecular filter, enables it to determine its end of life once the final pressure drop is reached. Another way to determine the end of life of the particle filters is the ‘time-based’ approach, meaning that the filter is changed after a fixed period for hygienic reasons, even if the final pressure drop has not yet been reached.

Further comprehensive information on particle filtration can be found in the Eurovent Air Filter Guidebook, and the principles for selecting ISO 16890 rated filters are outlined in the Eurovent Recommendation 4/23.

3.2 GAS-PHASE FILTRATION (MOLECULAR FILTRATION)

Air filters known as gas-phase air cleaning devices (GPACD) can improve IAQ by removing molecular pollutants from the air.

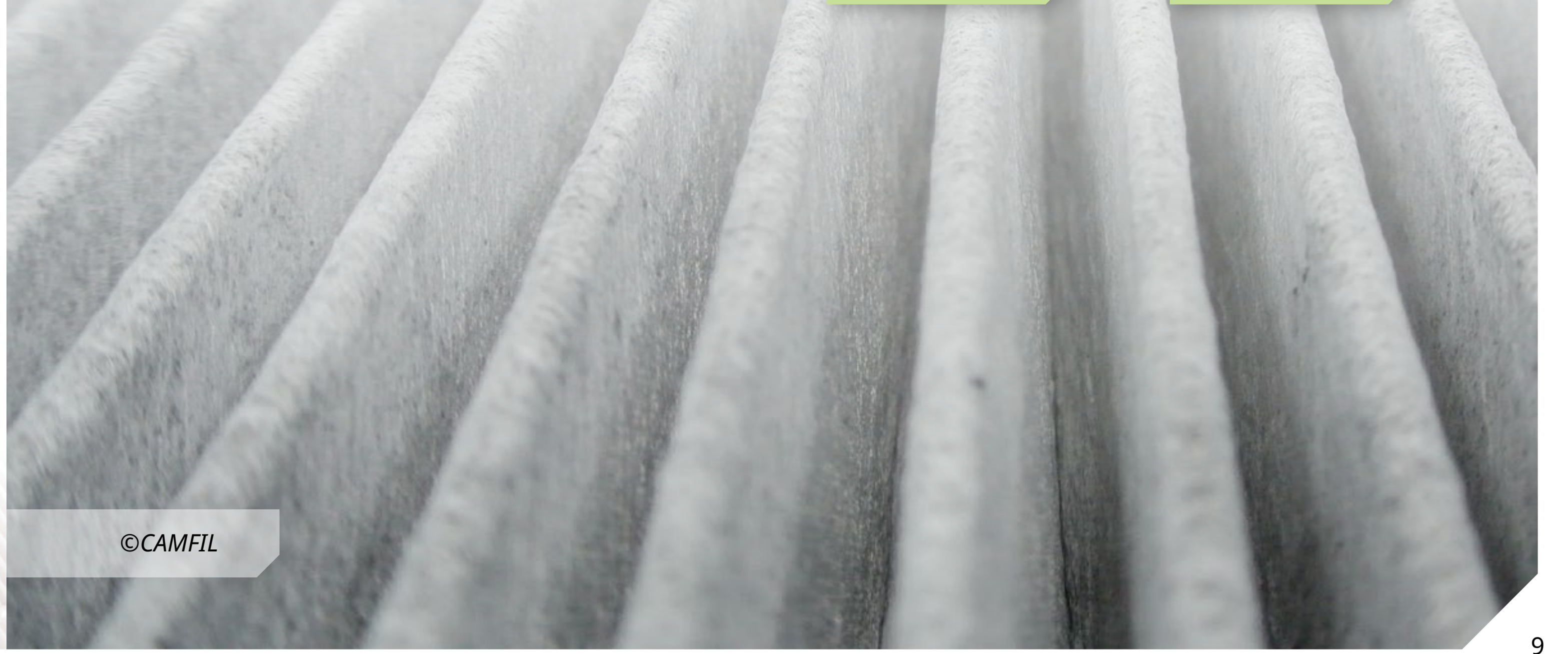
The initial efficiency of the molecular filter gradually decreases over its operating life, whereas its pressure drop remains about the same if this is sufficiently pre-filtered by a particle filter. Therefore, the pressure drop cannot be used to determine the end of the gas-phase filter’s life. Instead, the concentration of the most relevant contaminant downstream of the filter needs to be continuously or periodically monitored to determine the need for filter replacement.

KEY LEARNING POINTS

- Air contains both aerosol and gas phase contaminants.
- Particulate air filters are effective for aerosol while, for gaseous contaminants, molecular filters must be used.
- The most common gas-phase contaminants in daily life are SO_2, CO, NO_x, O_3 and VOC, as well as odours often formed in the air as secondary pollutants (such as ammonia, sulphates and organic carbon).
- The change in pressure drop of the molecular filter over time cannot be used as an indicator to determine the end of its lifetime. For this, the concentration of the gaseous contaminants downstream the filter needs to be monitored.

Eurovent Air Filter Guidebook

Eurovent Recommendation 4/23



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4. Gas-phase (molecular) filters

4.1 DESIGN AND OPERATING PRINCIPLES

For molecular filters, media such as zeolites, aluminium oxides, ion exchange resins and others can be used, but activated carbon is the most common.

Gas-phase filters are a common air purification technology that relies on GPACD to remove gas-phase impurities from the air. These filters work by adsorbing (not absorbing) pollutants onto the surface of the GPACD.

Adsorption is the process in which the molecules of a gas or vapour adhere by physical or chemical processes to the exposed surface of a solid substance, both the outer surface and inner pore surface, with which they come into contact.

The high porosity of the activated carbons ensures a wide active surface area per unit of volume, reaching well over 1.000 m^2 per gram of material and even up to and, in some cases, exceeding 2.000 m^2/g.

As polluted air passes through the filter, the pollutants penetrate inside the adsorbent material, distributing themselves inside the micropores of the activated carbon. However, the interaction between these molecules and the adsorbing material is weak (physical adsorption or physisorption), making this process reversible (desorption).

To avoid it, many adsorbent materials are impregnated with specific substances so that, in addition to physical adsorption, there is also chemical adsorption, which, thanks to reactions between the contaminant and the impregnating substance, is irreversible.

The efficiency value of a filter for these applications, as well as its operating life, depends on the total surface area of the adsorbent material, on the residence time or, inversely, on the air velocity within the filter and also on the concentration of gas contaminants.

Starting from a new gas-phase filter with a certain efficiency value for a given contaminant, efficiency will gradually decrease over its operating life, increasing the effective surface area of the coal and reaching the saturation point. As efficiency decreases, the concentration of contaminant passing through the filter, contained in the airflow downstream of the filter, increases accordingly.

This effect, although irreversible, is not infinite. The operating life of these filters is reduced as the amount of impregnating substance taking part in the chemical reaction with the contaminant in the air passing through the filter itself is reduced. Once the entire reticular structure of the filter medium has made a reaction with the substance to be adsorbed, the filter is no longer able to effectively retain the pollutants passing through it.

The total adsorbate capacity can then be defined as the maximum amount of contaminant in the gaseous or vapour phase retained by the filter system upon reaching the saturation point of the entire active pore area of the filtering medium.

4.1.1 CONTACT TIME

One of the most important parameters for the correct sizing of gas-phase filters is the contact time between the molecular contaminants and the adsorbent material. According to ISO 29464:2017, it is called residence time, and it is defined as the relative time that an increment of fluid or contaminant is within the boundaries of the medium volume. A long contact time enhances efficiency due to the molecules having more time to find empty surfaces to connect with.

The contact time is influenced by both air velocity and distance of travel through the adsorbent. In addition to these factors, the available surface area of the adsorbent, pore sizes and the addition of chemical impregnation can influence the likelihood of capture.

For this reason, it is important to select filters which are rated according to ISO 10121-3 at the required flow rate. Generally, the filter efficiency will increase at lower flow rates.

4.2 END OF SERVICE LIFE

The filter elements should be replaced when the concentration of contaminant downstream of the filter section reaches the maximum permissible design value.

The most effective way to determine the end of service life is to continuously or periodically monitor the concentration of the most relevant contaminant downstream of the filters or into the room where the air is supplied. When its concentration value is about to reach the maximum admitted threshold, it is time to replace the filter. The end of the life cannot be determined based on pressure drop.

If there is no gas concentration monitoring, a time-based approach for filter change needs to be applied.

Furthermore, the end of life can be estimated by the determination of the remaining capacity of the GPACD. This can be performed by a chemical analysis on a regular time basis.

4.3 THE MAIN TYPES OF MOLECULAR FILTERS

Filters for molecular contaminants generally consist of an adsorbent medium in granulate or powder form that can be either filled into cylindrical cartridges as well as V-shaped modules, bound to a carrier material such as a foam, metal plate or nonwoven, or mixed with other materials to allow further processing and forming via extrusion or punching operations.

4.4 COMBINED FILTERS (MOLECULAR AND PARTICULATE FILTERS)

An alternative and widely used solution in HVAC systems is combining particles and molecular filtration in a single filter element. These types are available as panel, bag or compact filter elements.

Molecular filters can be easily installed in any new or existing HVAC system.

Combined molecular and particulate filters offer a convenient opportunity to upgrade filtration in existing ventilation and air conditioning systems to improve IAQ, as they can directly replace the originally installed and designed particle filters without any structural modifications to the devices they are installed in.

An overview of molecular filter types and designs is shown in the following illustrations.

Figure 3. *Honeycomb filter ©MANN+HUMMEL*

Figure 4. *Compact filter @TROX*

Figure 5. *Pleated filter ©HENGST*

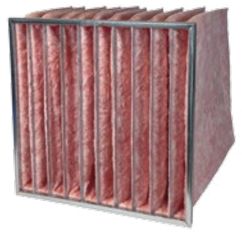


Figure 6. *Combined molecular and particle bag filter ©AAF*

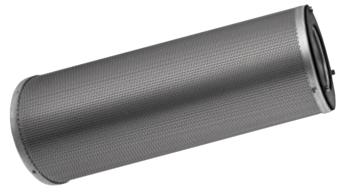


Figure 7. *Cylindrical filter ©KALTHOFF*

Figure 8. *V-shaped modules ©FREUDENBERG*

Figure 9. *MultiV carbon cell ©JASUN*

Figure 10. *Filter housing with cylindrical filters ©CAMFIL*

Figure 11. *Cassette filter ©VENFILTER*

5. Molecular air filter classifications according to ISO 10121

The ISO 10121 series of standards provides test methods to define the filtration efficiency of molecular air filters and filter media against various gases. ISO 10121-3, published in October 2022, is the first classification system for molecular air filters for general ventilation. It contains comprehensive filter classes for common air pollutants in outdoor air, namely O_3, NO_2, SO_2 and VOC (C_7H_8). This greatly facilitates the selection of the molecular filter, depending on the local outdoor air quality.

5.1 EASIER SELECTION OF MOLECULAR FILTERS

The clear and easy-to-understand filter classes of ISO 10121-3 enable a quick and easy selection of the right molecular air filter for a specific supply air application, similar to the selection of a suitable particle filter according to ISO 16890.

The ISO 10121-3 molecular filer classes consist of 3 parts:

- The capacity/lifetime of the filter
  - O_3, NO_2, SO_2 or C_7H_8
- The capacity/lifetime of the filter
  - vLD (**v**ery **L**ight **D**uty)
  - LD (**L**ight **D**uty)
  - MD (**M**edium **D**uty)
  - HD (**H**eavy **D**uty)
- The average efficiency over the filter's lifetime against the respective gas

The following example of the complete filter class:

Ozone	MD	60
reference gas	capacity / medium lifetime	average efficiency over lifetime

This means that this filter would have a medium capacity/ medium lifetime against Ozone and would remove, on average, 60% of Ozone over its lifetime.

The doses of gas corresponding to the rated capacity predict the lifetime of the filter.

- LD means low capacity and relatively short lifetime with rated average efficiency
- MD means four times higher capacity and lifetime compared to LD
- HD means 16 times higher capacity and lifetime compared to LD

An example of the relation between efficiency and lifetime for various types of molecular filters is illustrated in Figure 9.

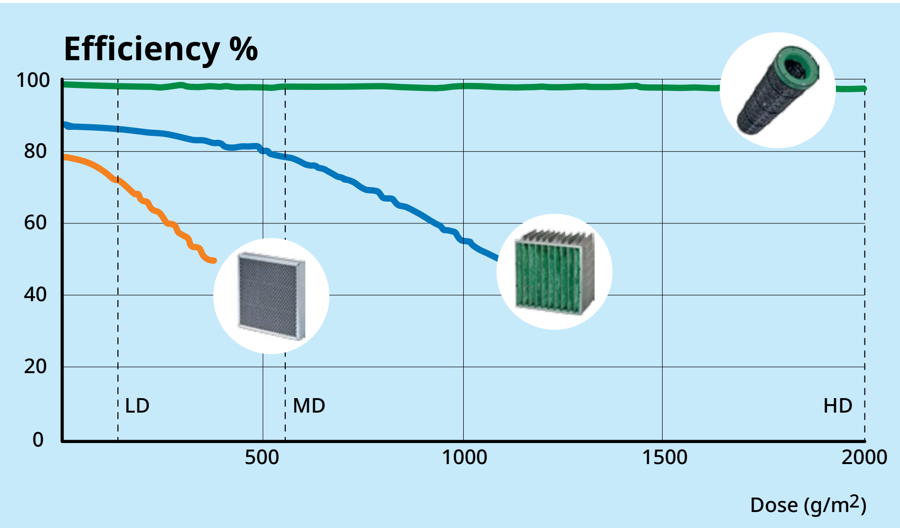


Figure 12. *Illustrative chart 'efficiency vs gas dose (lifetime)' for various filter types ©CAMFIL*

6. Recommendation on selection of ISO 10121-3 rated filter

6.1 NEW WHO GLOBAL AIR QUALITY GUIDELINES

WHO published an update to its AQG in September 2021, classifying several common gases in outdoor air as hazardous to health in addition to PM2,5 and PM10. Concentration limits for these gases have also been endorsed in the guidelines to ensure air quality is safe for human health.

The recommended annual mean limits to be observed when selecting molecular filter classes are the following:

- Annual average for NO_2 < 10 µg/m^3
- Peak season average for O_3[1] < 60 µg/m^3
- 24h average for SO_2[2] < 40 µg/m^3

At the time being, there are no recommendations for VOC concentrations (e.g. C_7H_8).

It is worth noting that, in light of new scientific evidence, WHO has considerably reduced and complemented the recommended levels in the 2021 guidelines, compared to the 2005 guidance, which is shown in Table 1.

Pollutant	UoM	Averaging time	WHO 2005 AQG level	WHO 2021 AQG level
O_3	µg/m^3	Peak season	–	60
		8-hour	100	100
NO_2	µg/m^3	Annual	40	10
		24-hour	–	25
SO_2	µg/m^3	24-hour	20	40

Table 1: *2021 and 2005 WHO recommended levels of gaseous pollutants*

[1] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration

[2] 99th percentile (i.e. 3-4 exceedance days per year)

6.2 DATA FOR MOLECULAR FILTER SELECTION - AMBIENT AIR POLLUTION DATABASE

Data on monitored levels of gaseous pollutants in the ambient air can be obtained from local authorities and monitoring stations. Alternatively, data for the selection of a molecular filter can be found in European database resources. Member States monitor ambient air quality through their network of measuring stations and, under the ambient air quality directives, share and exchange this information via the European Environment Information and Network (Eionet) within the European Environment Agency (EEA). The aggregated analyses and reports can be found on the EEA website (www.eea.europa.eu), including the annual statistics maps by pollutant and year. An example of such a map for 8-hour O_3 concentration across the EU in 2022 is presented in Figure 10.

For the selection of the molecular filter according to the recommended method described in section 6.3, the necessary input data on the concentrations in the ambient air can be found at:

https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics (access: October 2024).

For a particular location (the closest monitoring station), the following statistic should be taken:

O_3 - Yearly highest six-monthly average of daily maximum 8-hour mean concentration

NO_2 - Annual mean / one calendar year

SO_2 - 1 year 99 percentile of daily means (P1D)

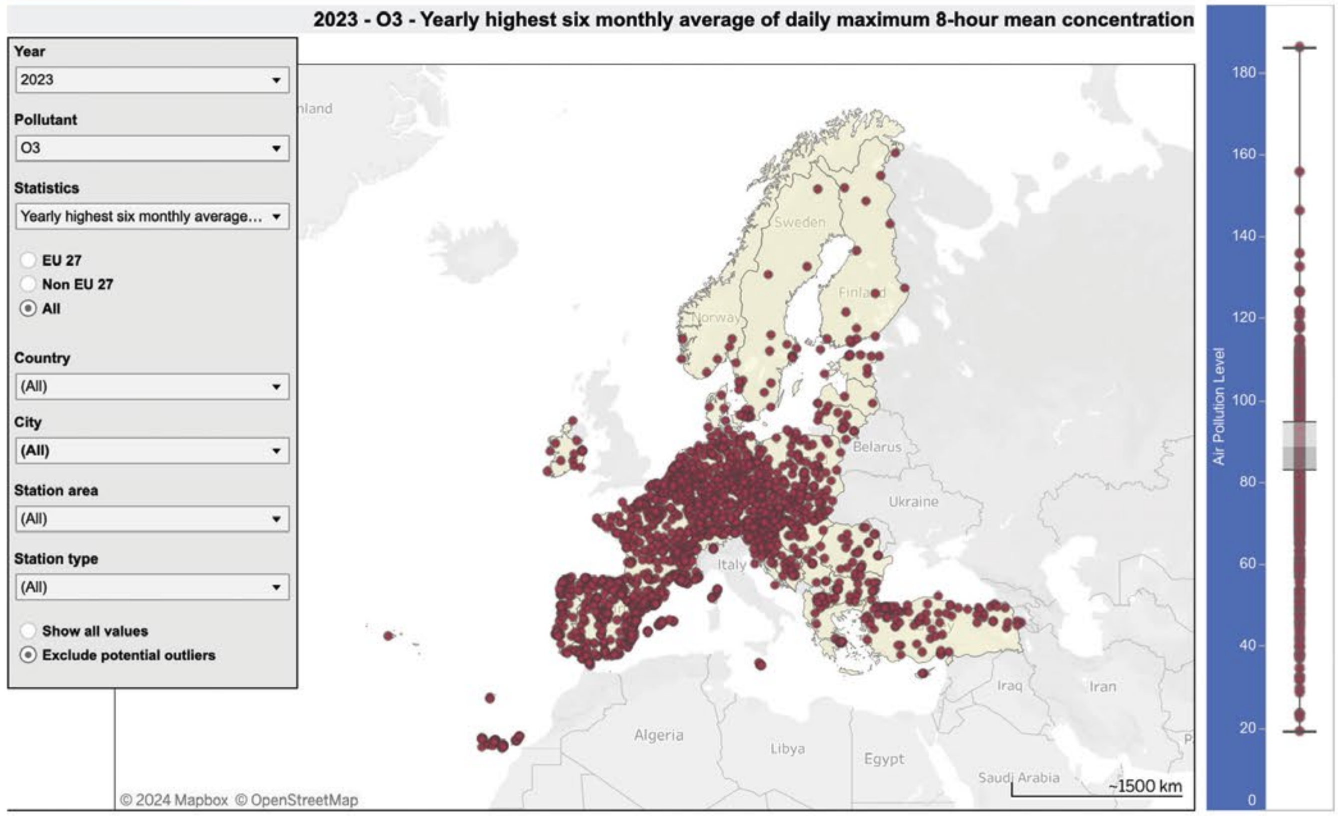


Figure 13. *Example map for annual gaseous pollutant concentration in the EU @EEA*

6.3 RECOMMENDED FILTRATION CLASS DEPENDING ON OUTDOOR AND SUPPLY AIR CATEGORY

This Recommendation provides guidance for the proper gas-phase filtration of outdoor air gaseous pollutants. Nevertheless, if the air in the building is recirculated, it may be necessary to install the molecular filters in a stage that catches the recirculated air.

To simplify the selection procedure of the molecular filter class but still consider all relevant factors, this Eurovent Recommendation introduces a method which matches the recommended minimum filtration efficiency with both the outdoor air and supply air categories. To maintain consistency on an international level, the method refers to limit values recommended by WHO.

As it is usually difficult to estimate indoor gas emissions, the Recommendation also indicates examples of typical applications assigned to the respective supply air category.

This Recommendation defines three categories of outdoor air conditions ODA (G) and five categories of supply air conditions SUP (G) related to gas concentrations. The definitions and descriptions of ODA and SUP categories are given in EN 16798-3 and Eurovent Recommendation 4/23.

The practical use of the recommended procedure is demonstrated by an example of molecular filter selection presented in Annex 2.

6.3.1 OUTDOOR AIR CATEGORIES

Category	Description	Typical environment
ODA 1 (G)	Applies where the 2021 WHO AQG are fulfilled: NO_2 mean* ≤ 10 µg/m^3 SO_2 mean* ≤ 40 µg/m^3 O_3 mean* ≤ 60 µg/m^3	
ODA 2 (G)	Applies where concentrations exceed the 2021 WHO AQG by a factor of up to 1,5: NO_2 mean* ≤ 15 µg/m^3 SO_2 mean* ≤ 60 µg/m^3 O_3 mean* ≤ 90 µg/m^3	
ODA 3 (G)	Applies where concentrations exceed the 2021 WHO AQG by a factor of greater than 1,5: NO_2 mean* > 15 µg/m^3 SO_2 mean* > 60 µg/m^3 O_3 mean* > 90 µg/m^3	

*Mean values according to the 2021 WHO AQG:

NO_2 – Annual average
SO_2 – 24h Average
O_3 – Peak season average

Table 2: *Outdoor air categories in terms of gas concentrations*

6.3.2 SUPPLY AIR CATEGORIES

Category	Description	Values
SUP 1 (G)	Refers to supply air with concentration which fulfil the 2021 WHO AQG limit values multiplied by a factor x 0,25	NO_2 mean* ≤ 2,5 µg/m^3 SO_2 mean* ≤ 10 µg/m^3 O_3 mean* ≤ 15 µg/m^3
SUP 2 (G)	Refers to supply air with concentration which fulfil the 2021 WHO AQG limit values multiplied by a factor x 0,50	NO_2 mean* ≤ 5 µg/m^3 SO_2 mean* ≤ 20 µg/m^3 O_3 mean* ≤ 30 µg/m^3
SUP 3 (G)	Refers to supply air with concentration which fulfil the 2021 WHO AQG limit values multiplied by a factor x 0,75	NO_2 mean* ≤ 7,5 µg/m^3 SO_2 mean* ≤ 30 µg/m^3 O_3 mean* ≤ 45 µg/m^3
SUP 4 (G)	Refers to supply air with concentration which fulfil the 2021 WHO AQG limit values	NO_2 mean* ≤ 10 µg/m^3 SO_2 mean* ≤ 40 µg/m^3 O_3 mean* ≤ 60 µg/m^3
SUP 5 (G)	Refers to supply air with concentration which fulfil the 2021 WHO AQG limit values multiplied by a factor x 1,50	NO_2 mean* ≤ 15 µg/m^3 SO_2 mean* ≤ 60 µg/m^3 O_3 mean* ≤ 90 µg/m^3

*Mean values according to 2021 WHO AQG:

NO_2 – annual average
SO_2 – 24h average
O_3 – peak season average

Table 3: *Supply air categories in terms of gas concentrations*

6.3.3 EXAMPLES OF TYPICAL APPLICATIONS CORRESPONDING TO SUP CATEGORIES

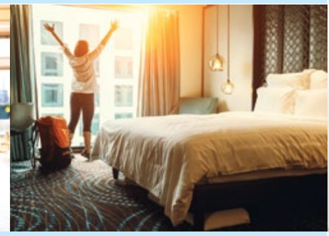
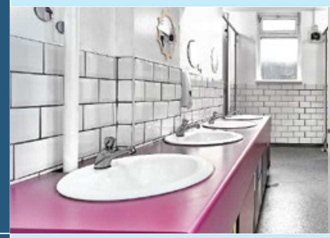
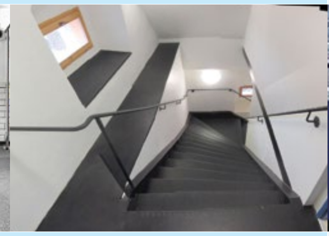
Category	General ventilation	Industrial ventilation
SUP 1 (G)		**Applications with high hygienic demands** Examples: Hospitals, pharmaceutics, electronic and optical industry, supply air to clean rooms 
SUP 2 (G)	**Rooms for permanent occupation** Examples: Kindergartens, offices, hotels, residential buildings, meeting rooms, exhibition halls, conference halls, theatres, cinemas, concert halls  	**Applications with medium hygienic demands** Examples: Food and beverages production 
SUP 3 (G)	**Rooms with temporary occupation** Examples: Storage, shopping centres, washing rooms, server rooms, copier rooms  	**Applications with basic hygienic demands** Examples: Food and beverages production with a basic hygienic demand 
SUP 4 (G)	**Rooms with short-term occupation** Examples: Restrooms, storage rooms stairways  	**Applications without hygienic demands** Examples: General production areas in the automotive industry 
SUP 5 (G)	**Rooms without occupation** Examples: Garbage rooms, data centres, underground car parks  	**Production areas of the heavy industry** Examples: Steel mills, smelters, welding plants 

Table 4: *Examples of typical applications corresponding to SUP categories*

6.3.4 RECOMMENDED MINIMUM EFFICIENCIES

Table 5 shows the required/recommended filtration efficiency (ISO 10121-3) needed to go from an ODA (G) level to a desired SUP (G) level for NO_2, SO_2 or O_3. In case more than one of those gases exceeds the limits, at least the gas with the highest exceedance of the limits (in per cent of the limits) should be considered.

6.3.5 FILTER LIFETIME

The lifetime of the gas filters, according to EN ISO 10121-3, goes from short to long, from vLD over LD and MD to HD. The selection of gas filters shall consider a reasonable lifetime for the specific application.

Category	SUP 1 (G)	SUP 2 (G)	SUP 3 (G)	SUP 4 (G)	SUP 5 (G)
ODA 1 (G)	70%*	–	–	–	–
ODA 2 (G)	80%**	70%**	50%*	–	–
ODA 3 (G)	90%**	80%**	70%*	–	–

*Recommended
**Required

Table 5: *Recommended and required integrated gas filtration efficiencies for the respective gas*

7. Annex 1: Practical considerations for molecular filters

7.1 SPECIFIC ISSUES

7.1.1 LIFETIME AND EFFICIENCY OF MOLECULAR FILTERS

The lifetime and efficiency of molecular filters can vary largely, depending on the application and operating and environmental conditions. Consequently, a deep knowledge of all product and operational parameters is required to do a proper lifetime estimation. If installing molecular filters for the first time in a given environment, the support of an experienced filtration expert is advisable regarding filter selection and lifetime prediction. With increasing practical experience, the exchange intervals can be defined more precisely.

A first indication of the expected lifetime for a molecular filter is already given in the filter classes according to EN ISO 10121-3. While in a specific application, an LD filter may last only three weeks, an MD filter could last about three months, and an HD filter is expected to last about a year. It must, however, be stressed that in real applications, the lifetime may considerably differ.

As different gases can show fundamentally different reactivity, the efficiency and lifetime of a specific molecular filter can be very different for those different gases. The same molecular filter may have an HD of 85% against O_3 and only an LD of 85% against SO_2.
The lifetime of this filter against O_3 would be roughly 16 times longer than against SO_2, assuming the same gas concentration.

7.1.2 CHEMICAL COMPOSITION OF THE FILTER AND THE POLLUTANT(S)

Each filter material reacts differently to different pollutants. Typically, activated carbon adsorbs a wide range of different gases, while other adsorbents might be very specific to a certain gas or a certain range of pollutants. Besides the classical physical adsorption (also called physisorption), where molecules are physically attached to the inner surface of the adsorbent, the efficiency of certain gases can be increased by adding chemical treatments to the adsorbent, adding the process of chemisorption. Depending on the material combination of adsorbent (the filtering material) and adsorbate (the gas being filtered), the filtering efficiency and the filter lifetime can differ very largely.

Typically, there is not only one gas in the air but a mixture of various gases. Therefore, the collection efficiency of one gas can influence the collection efficiency of another gas and vice versa. Therefore, the whole regime of gas pollutants must be known. A very common example is water vapour in the air, which is very well adsorbed by activated carbon and will reduce the capacity of the molecular filter for other gases. On the other hand, in the case of chemisorption, if water is part of the chemical reaction involved in collecting a certain pollutant, a certain humidity of the air is required.

7.1.3 PARTICULATE CONTAMINANTS

Even though a molecular filter is not designed to filter particles, it may also collect by its nature at least coarser particles, which may lead to an increase in the filter's flow resistance and may also have a negative influence on the molecular filtration performance. Therefore, a sufficient pre-filtration of particles is recommended.

7.1.4 MEDIA VELOCITY

As adsorption is a chemical or physical mechanism that requires some time to take place, the residence time of the air in the filter is an important parameter. It is proportional to the airflow. Low airflow typically results in a higher collection efficiency compared to high airflow. Additionally, a high airflow will transport significantly more pollutants to the filters, which in turn will shorten the lifetime.

7.1.5 TEMPERATURE

With rising temperature, molecules collected on the filter can be more easily removed (desorbed). Therefore, high temperatures can lower the efficiency of molecular filters. Desorption at high temperatures is even a process that is used in industrial applications to clean and reuse filters.

7.1.6 HUMIDITY

The influence of water vapour in the air on molecular filters was already described above. Relative humidity of the air is an important parameter that determines the efficiency and lifetime of molecular filters. Therefore, it must be known and controlled very carefully.

7.1.7 EXCHANGE, DISPOSAL AND PERSONAL PROTECTION EQUIPMENT

In general, depending on the nature of pollutants being collected, it is advisable to use appropriate personal protection equipment when changing air filters.

Molecular filters, in particular, may contain hazardous materials. Depending on the type of adsorbent, its chemical composition (e.g. potassium permanganate, phosphoric acid, etc.) and the gases adsorbed during operation, appropriate personal protection equipment shall be used during installation and removal of the filters. Molecular filters also may require special disposal routes. The appropriate measures during installation, removal and disposal of air filters shall be based on a risk assessment. Local legal requirements for handling hazardous goods also need to be considered.

7.2 APPLICATIONS EXAMPLES FOR MOLECULAR FILTRATION OF OUTDOOR AIR

The decision on the use and appropriate choice of molecular filter depends on individual conditions such as location and ambient air quality, as well as the type of building and its occupants.

The application of molecular filtration is particularly worth considering in facilities such as:

- Hospitals
- Schools and kindergartens
- Public buildings
- Office buildings
- Multifamily residential buildings

which are situated in areas exposed to high levels of concentrations of gaseous pollutants identified by WHO as particularly harmful (O_3, NO_2, SO_2), namely:

- City centres with heavy traffic
- Industrial areas
- Vicinity of rivers and seaports (ship engines fumes)
- Vicinity of airports (aircraft engine exhaust)

8. Annex 2: Example of a molecular filter selection

ASSUMPTIONS AND INPUT DATA

Filter to be installed in a ventilation system supplying outdoor air (without recirculation) to an office.

Location:	Milan, Italy
Airflow rate:	3.400 m^3/h
Time of operation:	6.000 h/a
SUP category[3]:	SUP 2 (G)

Outdoor air quality:

Pollutant	Mean value[4] µg/m^3	Corresponding ODA class[5]	SUP 2 (G) limit value (µg/m^3)	Exceeding SUP 2 (G) limit
O_3	115	ODA 3 (G)	≤ 30	383%
NO_2	40	ODA 3 (G)	≤ 5	800%
SO_2	5	ODA 1 (G)	≤ 20	–

Table 6: *Outdoor air quality parameters in Milan based on EEA monitoring data[6] and the corresponding percentage exceedances of SUP 2 (G) limit values*

FIRST SELECTION STEP - REQUIRED FILTER EFFICIENCY

Based on Table 5, the required average efficiency of a selected filter over its lifetime, depending on the pollutant, should be as follows:

O_3 – 80%
NO_2 – 80%
SO_2 – no requirements

As both NO_2 and O_3 exceed the SUP 2 (G) limits, the selected filter must meet the required efficiency, at least for NO_2, which has the highest limit exceedance.

For the considered case, the following example filters 1 and 2 are suitable to be applied. Filter 1 because its efficiency is higher for both NO_2 and O_3 than the required 80%, and filter 2 because its efficiency for NO_2 is equal to 80%.

Filter 1 - ISO 10121-3 classification:

O_3 HD **85**
NO_2 LD **85**
SO_2 MD 55

Filter 2 - ISO 10121-3 classification:

O_3 HD 75
NO_2 MD **80**
SO_2 MD 55

However, an example filter 3, which meets the required efficiency for O_3 but not for NO_2, cannot be used for this application.

Filter 3 - ISO 10121-3 classification:

O_3 HD 85
NO_2 MD **70**
SO_2 LD 65

SECOND SELECTION STEP – CHOICE OF THE FILTER LIFETIME

For the conditions assumed in the example, the estimated lifetime, depending on the filter capacity, would be as follows:

LD - around two weeks
MD - around eight weeks
HD - around eight months

In other words, the example filter 1 would maintain its rated efficiency for O_3 for around eight months and NO_2 for around two weeks. While the example filter 2 would maintain its rated efficiency for NO_2 for around eight weeks.

It must be emphasised that the lifetimes presented are only indicative. More precise values can only be estimated by the filter supplier based on complete information on the operating conditions.

[3] Based on Table 3
[4] Average of values monitored by different stations in Milan
[5] As defined in Table 2
[6] See section 6.2

Literature

[1] WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide. World Health Organization 2021.

[2] Impact assessment Report. Proposal for a Directive of the European Parliament and of the Council on ambient air quality and cleaner air for Europe. Brussels 2022.

[3] EEA (2021) Air Quality in Europe 2021 Web Report (accessed: October 2023).

[4] EN ISO 10121-3:2022 - Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation - Part 3: Classification system for GPACDs applied to treatment of outdoor air.

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ADDRESS
80 Bd. A. Reyers Ln
1030 Brussels, Belgium

PHONE
+32 466 90 04 01

EMAIL
secretariat@eurovent.eu

www.eurovent.eu

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