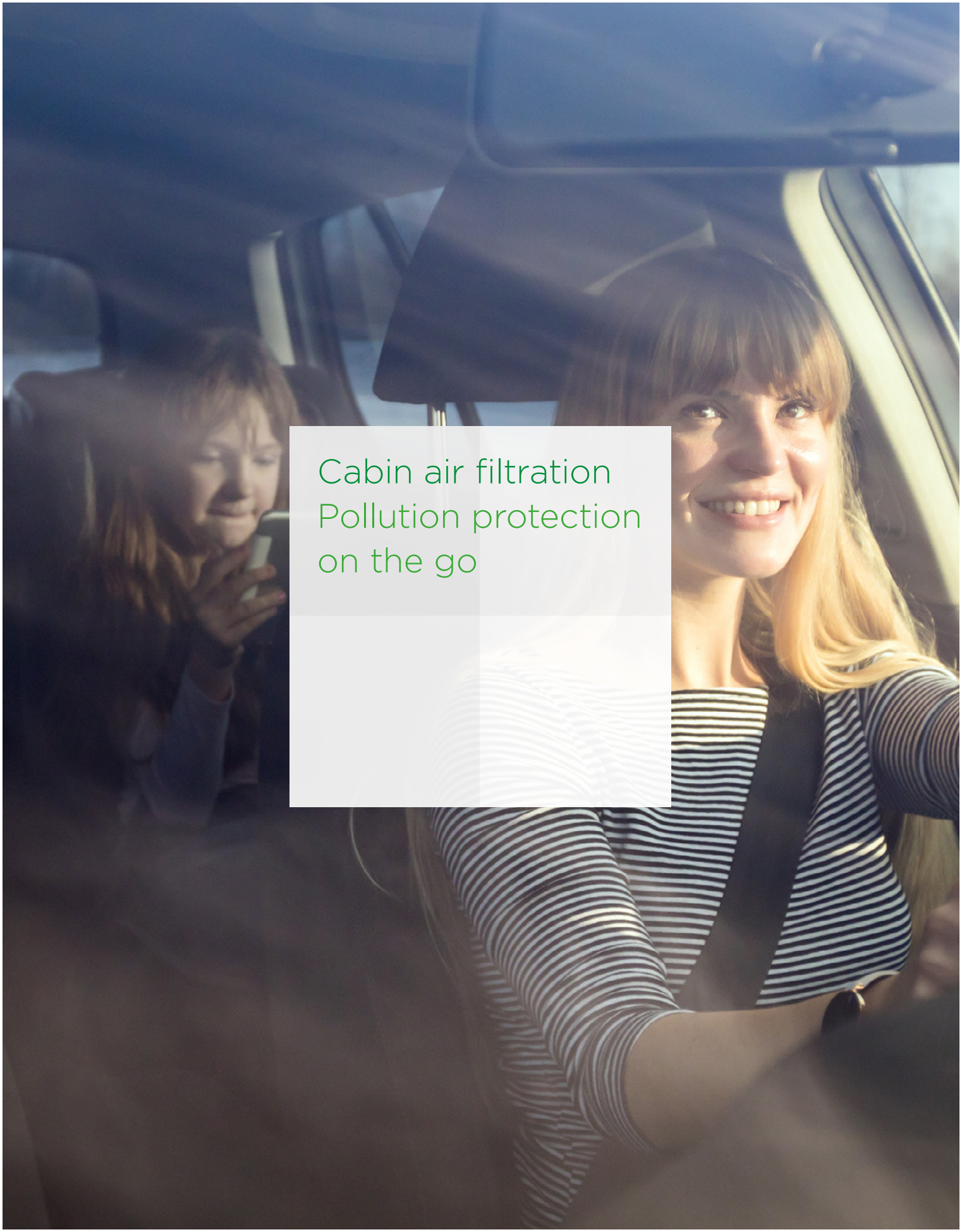


Cabin air filtration
Pollution protection on the go

Leadership in Filtration

MANN+HUMMEL

Cabin air filtration
Protection on the go

ABOUT THIS DOCUMENT

This document looks at the impact of air pollution and its context within vehicle cabin filtration. It examines what air pollution is, where it comes from and its impact on human health. The document introduces cabin air filtration and looks at how new technologies are protecting vehicle occupants from the challenge of air pollution.

CONTENTS

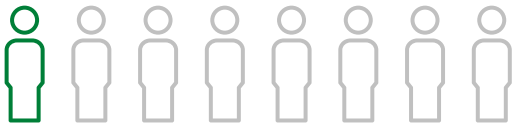
Air pollution
Taking a heavy toll on human health

THE #1 ENVIRONMENTAL THREAT TO OUR HEALTH

We take around 20,000 breaths a day. But whether we are at home, on the street or at work, each of those breaths will be contaminated with air pollution of some kind. For the 99% of us that live in areas where the air is deemed unsafe by the World Health Organization (WHO)[1], that pollution will be damaging our health with every lungful.

Experts believe that air pollution may be damaging every organ in the human body[2] – with health complaints as diverse as heart and lung disease to diabetes and dementia linked to breathing toxic air. That's why the WHO classify air pollution as the number one environmental risk to human health.

AIR POLLUTION IN NUMBERS

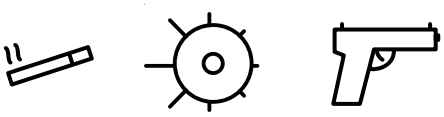


1 in 8 deaths are linked to air pollution[1]

7,000,000

People die each year from breathing polluted air[1]

3 years are taken off the average lifespan by outdoor air pollution[3]



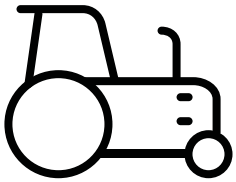
Air pollution claims more lives than smoking, HIV and war[1]

1 www.who.int/health-topics/air-pollution
2 The Guardian, Revealed: air pollution may be damaging 'every organ in the body', 17 May 2019
3 Guardian, Outdoor air pollution cuts three years from human lifespan – study, 3 March 2020

Air pollution
What is it and where does it come from?

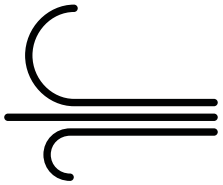
Air pollution is a cocktail of liquid and solid particles, and gases suspended in the air. These pollutants come mainly from transport, industrial and agricultural emissions – but natural sources can emit particles and gases too.

COMMON POLLUTANTS AND THEIR SOURCES[1]

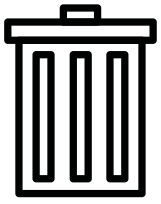


Agriculture accounts for around 90% of ammonia and 80% of methane emissions.

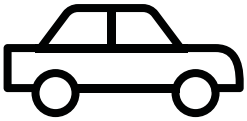
Power generation and distribution produces an estimated 60% of sulphur oxides pollution.



Natural events such as sandstorms and volcanic activity release large quantities of particles and gases into the atmosphere.



Landfill, coal mining and long-distance gas transmission are key producers of methane.



Transportation creates more than 40% of nitrogen oxides and almost 40% of PM2.5 pollution.

Households, public buildings and businesses account for around half of PM2.5 and carbon monoxide emissions.

1 European Environment Agency

KEY CONTAMINANTS

Particulate matter (PM)

A primary component of air pollution is particulate matter (PM). The particles present in the ambient air cover a size range from a few nanometers to several hundred micrometers. You may already be familiar with terms like PM2.5 or PM10. They describe a concentration in µg/m³, which can be calculated as a mass fraction from the ambient air particle size distribution via size-dependent weighting, or measured by weighing filters which sampled ambient air over 24 hours. As an example, PM2.5 comprises the mass of nearly all particles with an aerodynamic diameter of less than 2.5 µm.

In urban areas, one of the main sources of PM is road traffic – either in the form of exhaust emissions, or emissions related to other components, such as brake, tire and road wear. While legislation has reduced particle concentrations from exhaust emissions, the proportion of non-exhaust emissions has increased.

A pressing concern of recent years is ultra-fine particles (UFP) that are smaller than 0.1 microns. Many studies from all over the world have shown a direct correlation between the size of particles and the impact on human health – smaller particles cause more harm than larger contaminant. This led the WHO to recommend monitoring of UFP in its "good practice statements" in 2021.

Gaseous pollutants

Gaseous pollutants like carbon monoxide and dioxide (CO and CO_2), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone and ammonia gas are commonly found in polluted air. Excess exposure to these contaminants can lead to a number of health complaints – from irritation to the eyes, nose and throat, to heart and lung disease.

In enclosed spaces, volatile organic compounds (VOCs) are another threat to our health. VOCs are emitted by many materials used in vehicle interiors – including the dashboard covering, seat textiles, floor carpets and the adhesives that secure everything in place. Some VOCs, such as formaldehyde and benzene, are classified as carcinogens by the International Agency for Research on Cancer (IARC).

Biological contaminants

Bacteria, fungi, allergens, mold and viruses are biological contaminants which can cause a range of health complaints. In buildings or vehicle cabins, they can often spread by the heating, ventilation and air conditioning system (HVAC).

Particulate matter
The health impact

HOW FAR DOES PM PENETRATE THE BODY?

Differentiating between the various sizes of PM is important to understand the threat to human health. That's because the damage that PM can cause us increases as the size of particulate decreases – smaller particles penetrate further into our body and do more harm.

Inhalable particles (> 10 µm)

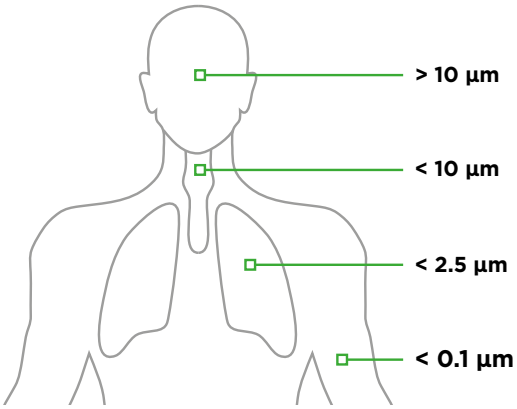
Larger particles – with a diameter of more than 10 µm – are caught by the body's natural defenses in the nose and throat.

Respirable particles (< PM10)

PM10 particles become trapped in the upper airways – nose, throat, larynx and trachea – before being coughed up or swallowed. If PM10 particles manage to bypass the transition of the trachea into the main bronchi, they are removed by the ciliated epithelium – a layer of tissue covered with cilia that move back and forth to remove the foreign particle.

Alveolar particles (< PM2.5)

PM2.5 particles bypass the ciliated epithelium and travel further into the lungs – reaching the secondary and tertiary bronchi. Here, the particulate can trigger inflammatory reactions such as acute bronchitis and asthma.



Ultra-fine particles (< PM0.1)

Particles smaller than 0.1 µm represent the greatest health risk by penetrating the air sacs where oxygen exchange takes place. Since there is no cilia to help move particles out of our body in this area, immune cells are responsible for purification. But if the level of contaminant is too high, the immune cells can trigger an inflammatory reaction in the alveoli.

Even more damaging, PM0.1 particles can penetrate through the walls of the alveoli into the blood vessels. Once in the bloodstream, the PM0.1 particles can then be distributed via the heart and circulatory system. The most immediate effect is inflammation, but as PM0.1 travels throughout the body, it has been linked with conditions as diverse as heart disease and arrhythmia, brain disorders, and various types of cancer. PM0.1 particulate has even been detected in the spleen and liver.

Humans have about 480 million alveoli with a surface area of 120 to 140 m^2, making the lungs the largest organ of our body in direct contact with the environment.

THE CHANGING NATURE OF AIR POLLUTION

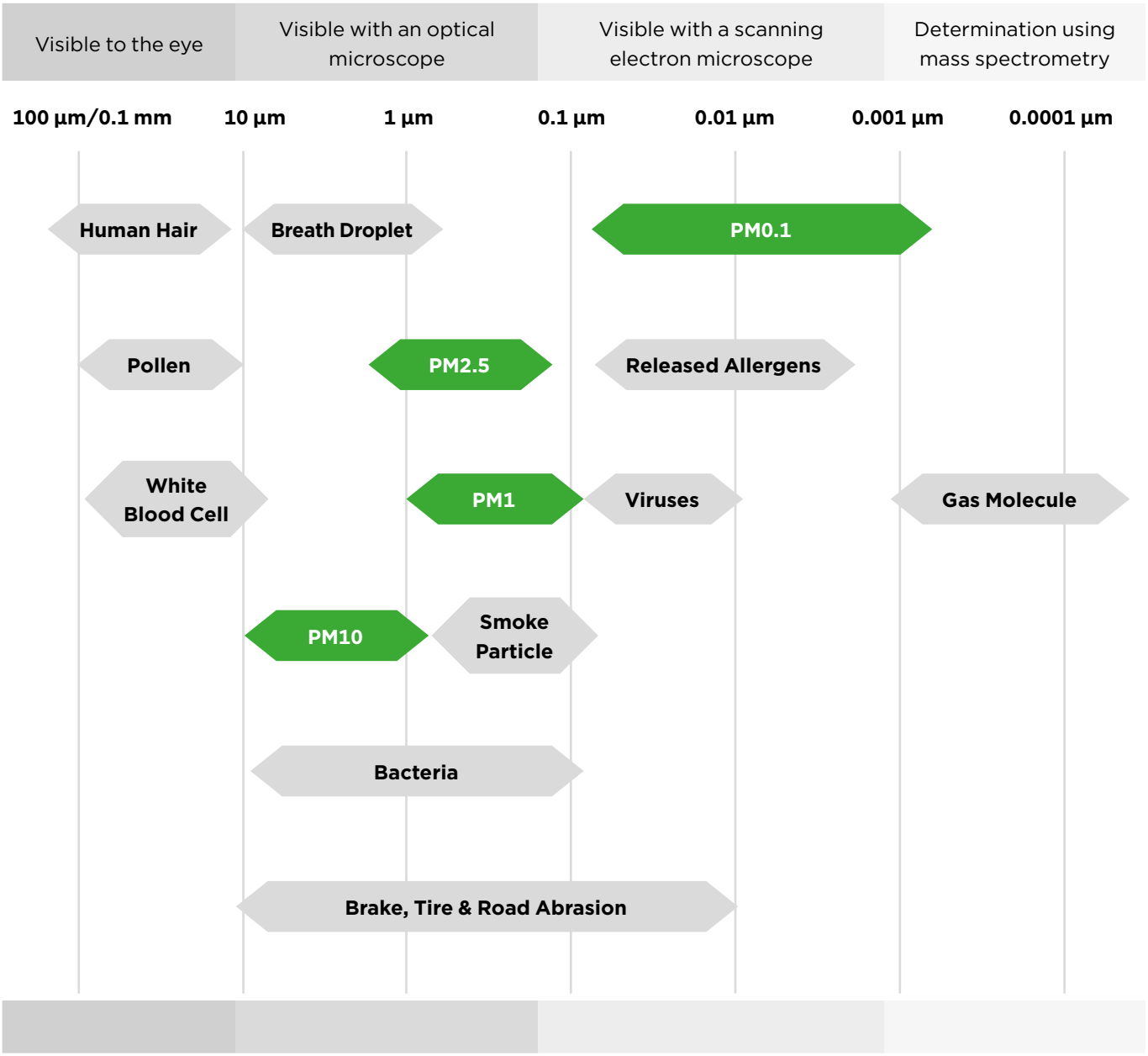
Air pollution has changed dramatically over the last 60 years. When coal was powering the industrial revolution, the smog that hung in the air was so thick and yellowy-green, it was nicknamed pea soup. But as coal power became cleaner and moved away from towns, large fly ash particles became less of a problem.

Instead, rising car ownership brought particulates that were still sooty, but much smaller in size. To combat this, advances in fuel technologies and engine filtration in the late 90's reduced the level of sooty contaminants in the air.

But these newly-filtered engines – along with modern manufacturing methods – led to even finer air pollution. And we now see a complex mix of nitrogen oxides, ozone, carbon dioxide and particulate matter (PM).

Unfortunately, these smaller particles are even more harmful to our health (see the previous page). That's why it is crucial to adapt filtration solutions to meet this new challenge.

Pollutant size in perspective



Air pollution
What are the guidelines?

WHO GUIDANCE

In September 2021, the WHO tightened its recommendations on limits for six pollutants – the first such change in 16 years. New levels were set for some of the most harmful and common components of air pollution: particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon monoxide (CO).

Pollutant	Averaging Time	WHO 2021 Air Quality Guideline	WHO 2005 Air Quality Guideline
PM2.5 (µg/m³)	Annual	5	10
	24-hour	15	25
PM10 (µg/m³)	Annual	15	20
	24-hour	45	50
O3 (µg/m³)	Peak season	60	N/A
	8-hour	100	100
NO2 (µg/m³)	Annual	10	40
	24-hour	25	N/A
SO2 (µg/m³)	24-hour	40	20
CO (mg/m³)	24-hour	4	4

WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021

IS THERE A SAFE LEVEL OF AIR POLLUTION?

In setting these tighter limits, the World Health Organization will do much to improve public health and save many lives. But scientists stress that there is no safe level of air pollution. Breathing pollutants is harmful to human health at any level of concentration. And anything we can do to limit exposure to air pollution will improve the health outcomes of millions – if not billions – of people.

WHO: ULTRA-FINE PARTICLES

For the first time, the 2021 WHO guidelines also highlight good practice for managing ultra-fine particles. Although further data is required to set formal limits for these particles, enough is known to define good practices that will help protect public health in the short term, and provide greater understanding of these particles in the long term. These good practices include quantifying particle concentrations of UFPs, utilizing new technologies, and integrating this particle size category into common air quality monitoring processes. With larger datasets, it is hoped that the WHO will be better placed to include recommended limits on UFPs in future Air Quality Guidelines.

The filtration experts MANN+HUMMEL

TWENTY SIX

With every second that ticks by, another 26 filters roll off the MANN+HUMMEL production lines. And that is part of what makes us a leading global company in filtration technology.

But it is our commitment to quality and innovation too. Of the more than 23,000 people we employ worldwide, over 1,000 work in our R&D department. That means we are at the front when it comes to finding new ways to improve air quality or deliver it more efficiently – which can be seen in the more than 3,000 patents that we have registered.

And when it comes to delivering excellent service, we are always close at hand, with more than 80 locations across the world.

MANN+HUMMEL has been a filtration specialist for more than 80 years. Leadership in Filtration is what drives us.

AUTOMOTIVE EXCELLENCE

The Original Equipment Division develops high-performance products for a wide range of applications – from passenger cars and commercial vehicles, to construction and agricultural machinery, rail vehicles, machine tools and other industrial applications. Our products meet the highest quality standards, and thus reliably protect your machines and applications.

Vehicle occupants are particularly exposed to air pollution. Most vehicles produced today are equipped with an air conditioning system and, therefore, a cabin air filter. By preventing polluted air from entering into the vehicles, MANN+HUMMEL's cabin air filters improve the air quality of every journey.

> Clean air should be a fundamental human right and a necessary condition for healthy and productive societies.
>
> Dr Hans Henri P. Kluge
> WHO Regional Director for Europe

When it comes to protecting health, you need a partner you can trust.

CABIN AIR WITH A CLEANROOM PEDIGREE

From an air filtration perspective, the most challenging contaminants to capture are those that are microscopic in size, but also present a risk to human health. That's because both the difficulty and the risk of failure are high.

For more than 60 years, our filters have been in service in cleanrooms and operating rooms around the world – protecting people and the wider environment from some of the most dangerous viruses, substances and other contaminants known to man. We've used this expertise to develop a range of cabin air filters that you can count on to meet the challenges of air pollution.

Cabin air filters Protection against pollution

Air pollution is often far higher inside a vehicle than outside.

VEHICLE CABINS – POLLUTION BLACKSPOTS

It may feel that exposure to toxic air would be worse for a pedestrian or cyclist in an urban environment. But the truth is that occupants inside a vehicle often face significantly higher levels of air pollution than those outside.

One Danish study[1] found that drivers were exposed to pollutant concentrations two to four times higher than cyclists on the same streets.

The pollution outside that the cyclist encountered had dissipated into the wider environment. While pollutants circulated freely within the car, continually increasing the concentration of particles and other contaminants.

With their developing lungs, children are particularly vulnerable to this exposure, which can cause permanent damage to their respiratory system. So much so, that some experts have suggested it would be safer to walk or cycle to school than to travel by car.[2]

DIFFERENT OPTIONS FOR DIFFERENT CHALLENGES

The MANN+HUMMEL range of cabin air filters has been developed specifically to tackle the most common and harmful contaminants faced by vehicle occupants. Our filters capture particulate matter, gases, odors, allergens and virus aerosols for the safety, wellbeing, comfort and health of those travelling in a vehicle.

Due to the increased fine particulate contaminant in urban environments, our recent product development has focused on tackling the most dangerous particle contaminant: ultra-fine particles (UFP).

The four roles of a cabin air filter:

- Protection of driver and vehicle occupants against pollutants
- Comfort and wellbeing in the vehicle thanks to cleaner fresh air
- Improved safety while driving thanks to a good visibility and fewer allergy symptoms
- Protection of the air-conditioning equipment against contamination and deposits

1 www.sciencedirect.com/science/article/abs/pii/S0048969701007586
2 www.theguardian.com/environment/2017/jun/12/children-risk-air-pollution-cars-former-uk-chief-scientist-warns

Cabin air filter locations

Cabin air filter

For classic HVAC

For classic HVAC (inside or outside)

CABIN AIR FILTER TYPES

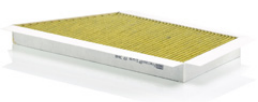
Filtration over lifetime				☑
Anti-microbial			☑	☑ Optional
Adsorption		☑	☑	☑ Optional
Filtration	☑	☑	☑	☑

Particle Filter

Synthetic filter material

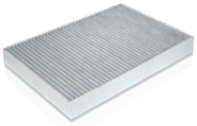
Combi Filter

Synthetic filter material with activated carbon



Bio-Functional Filter

Synthetic filter media with activated carbon and bio-functional layer



Nanofiber Filter

Nanofiber layer combined with different filter media and materials

Particle filters for basic filtration

Current cabin air filtration solutions

Particle filters | Combi filters | High efficiency filters

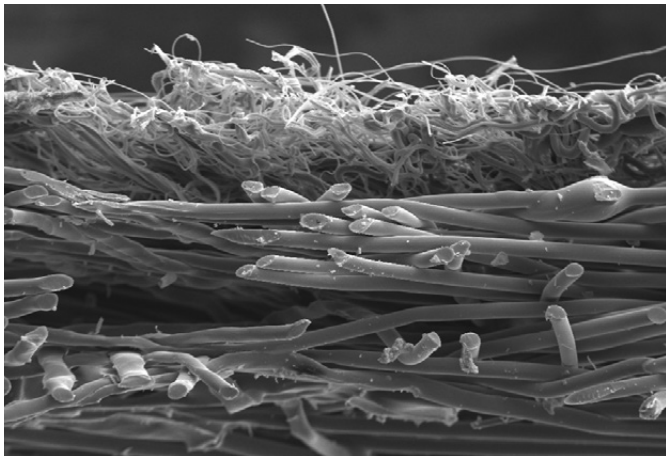
Standard particle filters – commonly known as pollen filters – protect cabin occupants from coarse particles and pollen.

KEY FACTS

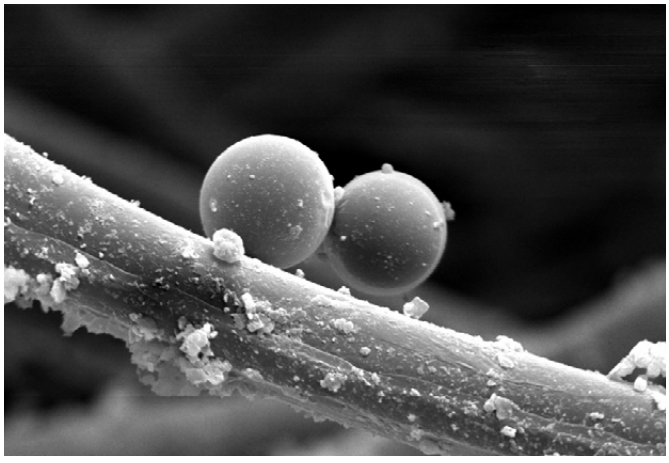
- Outstanding separation of PM10 particles – up to 95%[1]
- Available in a range of efficiency grades
- Resistance against environmental influences like humidity and temperature fluctuations

HOW DOES IT WORK?

Specially developed nonwovens capture particles in the depth of the filter medium. An additional electrostatic charge attracts oppositely-charged particles – significantly increases efficiency while maintaining air permeability.



▲ Particle filter media viewed with a scanning electron microscope (SEM)



▲ Pollen on particle filter media

1 ePM10 classification according to DIN EN ISO 16890

Combi filters for particles and gases

Current cabin air filtration solutions

Particle filters | **Combi filters** | High efficiency filters

Activated carbon filters (or combi filters) protect cabin occupants from both particles and gaseous contaminants.

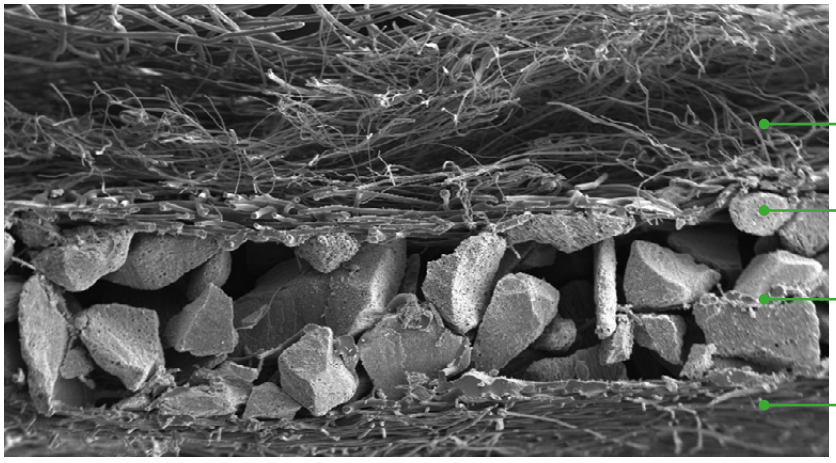
KEY FACTS

- Outstanding separation of PM10 particles – up to 95%[1]
- Available in a range of efficiency grades
- Adsorption of odors and harmful gases such as SO_2, exhaust gases like nitrogen oxides, and hydrocarbons
- Removal of ozone from the air
- Resistance against environmental influences like humidity and temperature fluctuations

HOW DOES IT WORK?

The filter media features three layers to capture different airborne contaminants. Most special is an activated carbon layer, which is made from coconut shells for the best adsorption capacity and eco-friendly performance. This carbon media binds harmful gases to pores which are 10.000 times smaller than a human hair.

The adsorption performance can be targeted to certain gases or to meet vehicle manufacturers' specifications by tailoring the activated carbon to different applications.



COMBI FILTER MEDIA

Prefilter layer: captures coarse particles

Primary filter layer: removes fine particles

Activated carbon layer: adsorbs odors and harmful gases

Support layer: provides mechanical stability

1 ePM10 classification according to DIN EN ISO 16890

High efficiency filters with a bio-functional layer

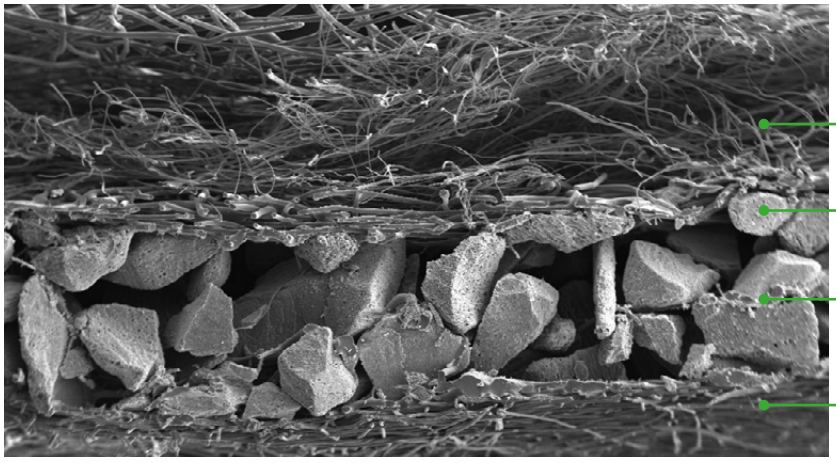
High efficiency filters with anti-allergen and anti-microbial properties.

KEY FACTS

- Outstanding separation of PM10 particles – up to 95%[1]
- Available in a range of efficiency grades
- Capture of allergens – up to 99%[2]
- Protection of the filter through active inhibition of bacteria and mold growth – tested according to DIN EN ISO 846
- Adsorption of odors and harmful gases such as SO_2, exhaust gases like nitrogen oxides, and hydrocarbons
- Removal of ozone from the air
- Filtration of virus aerosols
- Resistance against environmental influences like humidity and temperature fluctuations

HOW DOES IT WORK?

An additional anti-microbial coating prevents bacteria and fungi (especially molds) from growing on the filter media.



LAMINATED COMBI FILTER MEDIA

Prefilter layer: captures coarse particles

Primary filter layer: removes fine particles

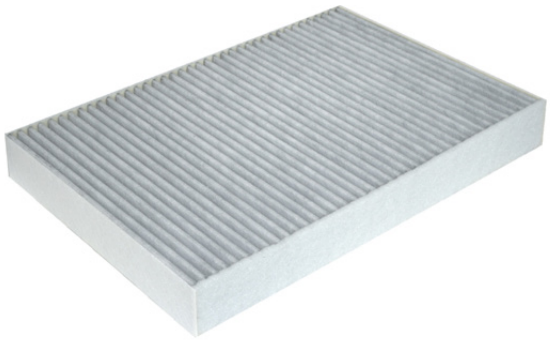
Activated carbon layer: adsorbs odors and harmful gases

Bio-functional layer: provides anti-microbial protection

1 ePM10 classification according to DIN EN ISO 16890
2 According to tests performed at external institutes

High efficiency filters with a nanofiber layer

High efficiency filters with a special nanofiber layer to more efficiently capture finer contaminant.

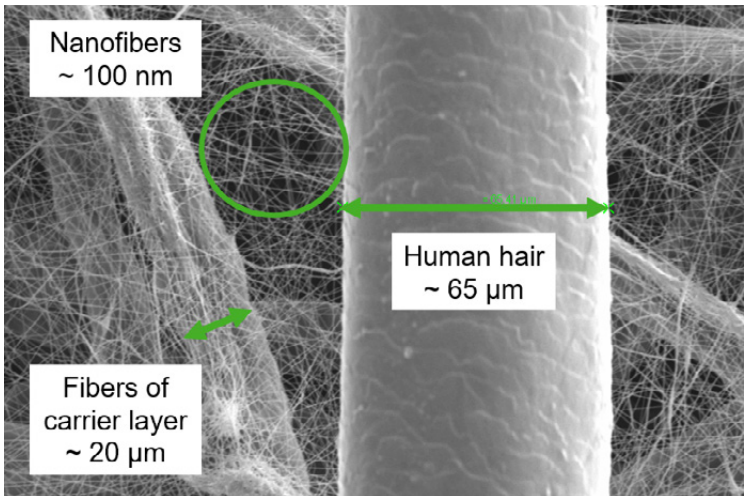


KEY FACTS

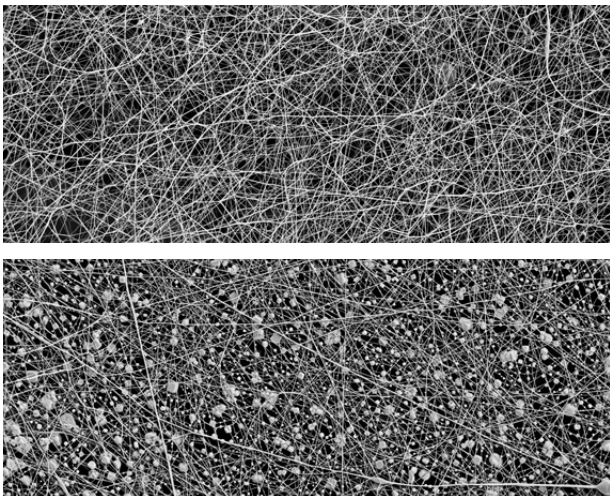
- Outstanding separation of PM1 particles – up to 95%[1]
- Available in a range of efficiency grades
- Filter media refined with nanofibers
- Hybrid non-woven media, combining an electret-based spunbond for pre-separation and a pure mechanical fine filtration layer
- Stable filtration performance over lifetime
- Flexible combination of different filter media types possible
- Low air flow resistance due to low grammage of fiber layer and very fine fiber diameter
- Increased resistance against environmental influences like humidity and temperature fluctuations
- Granted patent in Germany protecting specific aspects of the filter media and the underlying production process

HOW DOES IT WORK?

A carrier media and an extremely thin layer of ultra-fine polymer fibers is added to the filter media leading to the removal of very fine particles.



▲ The fibers with a diameter of less than one micrometer are approximately 200 times smaller than the fibers of the carrier material or 650 times smaller than a human hair.



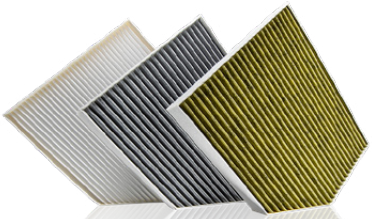
▲ MANN+HUMMEL nanofiber media before and after loading with sodium chloride

1 ePM1 classification according to DIN EN ISO 16890

The future of cabin air is already underway

As fuels and exhaust filtration have advanced, the make up of air pollution has become finer. HEPA filtration is the only viable solution for protecting vehicle occupants from this ultra-fine particulate.

THE EVOLUTION OF CABIN AIR FILTRATION



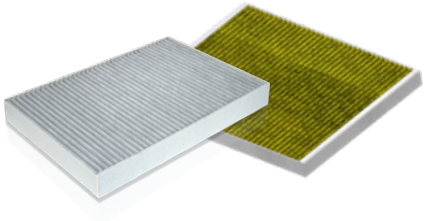
Particle, activated carbon and bio-functional filters

Prefilter and system concepts for improved HVAC filters

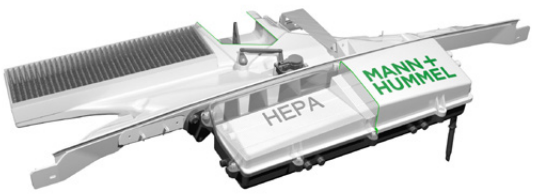
TODAY

TOMORROW

Nanofiber and bio-functional filters



Smart HEPA cabin air filter system



HEPA filters
For ultimate protection

HEPA is a commonly-used filtration technology in industries such as the pharmaceutical and healthcare sectors, where MANN+HUMMEL has been active for over four decades. “HEPA” stands for High Efficiency Particulate Air, and these products capture the tiniest of contaminants, providing safety to people, animals, processes and the wider environment in a number of applications.


Pharmaceuticals


Operating theaters


Laboratory


Food and beverage


Microelectronics


Gas masks


Nuclear power plants


Hospitals

EPA, HEPA AND ULPA CLASSIFICATION

High efficiency filters are tested and rated according to the DIN EN 1822 standard. This covers three filter groups: EPA (Efficient Particulate Air), HEPA and ULPA (Ultra Low Penetrating Air).

Filter group	Filter Class	Efficiency [%]	Penetration [%]
EPA	E10	≥ 85	≤ 15
	E11	≥ 95	≤ 5
	E12	≥ 99.5	≤ 0.5
HEPA	H13	≥ 99.95	≤ 0.05
	H14	≥ 99.995	≤ 0.005
ULPA	U15	≥ 99.9995	≤ 0.0005
	U16	≥ 99.99995	≤ 0.00005
	U17	≥ 99.999995	≤ 0.000005

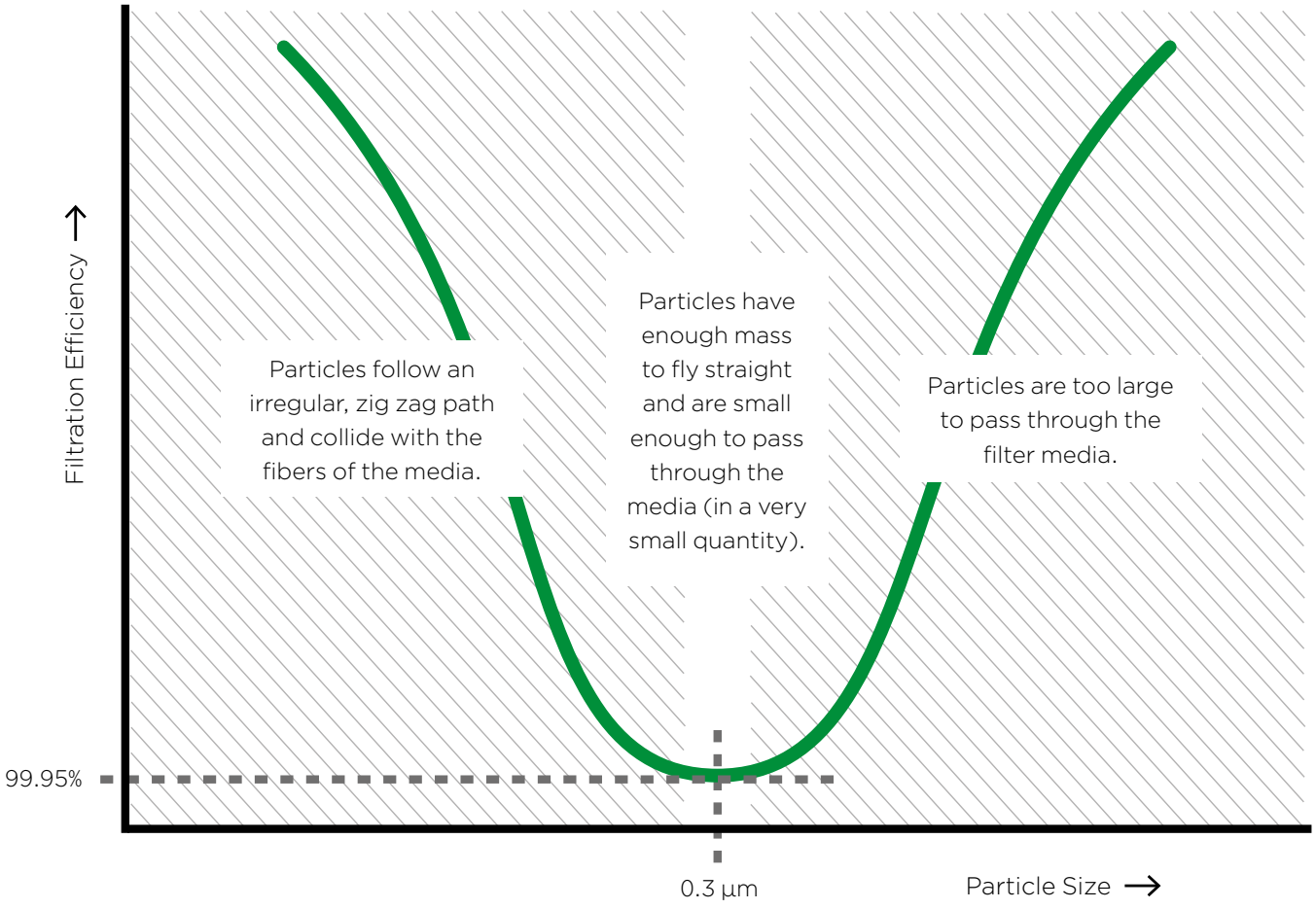
Understanding HEPA filtration efficiency

MOST PENETRATING PARTICLE SIZE

HEPA filters are tested and rated by their performance at retaining particles at the most penetrating particle size (MPPS). This is the particle size that is most able to pass through the filter, typically 0.3 microns (µm). Particles that are smaller or bigger than the MPPS are more likely to be captured by the filter.

The rated efficiency of a HEPA filter is therefore the worst case scenario. This means an H13 filter will capture 99.95% of MPPS particles, but offer higher filtration efficiency for smaller or larger particulate.

TYPICAL FILTRATION EFFICIENCY FOR AN H13 HEPA FILTER



HEPA filters
For ultimate protection

HEPA filters protect vehicle occupants from the smallest of particles that can evade traditional cabin air filters.

KEY FACTS

- Removal of any solid or liquid particle from the air with an efficiency of at least 99.95%
- Several HEPA media classes available
- Effective defense against viruses
- Fully synthetic media which consists of several layers of fine fibers
- Fulfillment of the requirements of the DIN EN 1822 standard

HOW DOES IT WORK?

As a HEPA filter captures much smaller particulate than a conventional cabin air filter, its fiber structure is much more densely packed with a significantly lower air permeability. To combat this, HEPAs feature an increased filter media surface compared to standard cabin air filters to achieve the lowest possible pressure drop. In fact, the surface of our HEPA cabin air filter is approximately five times larger than a regular element thanks to a smaller pleat distance.

It is not currently possible to retrofit or replace a standard cabin air filter with a HEPA element - due to the larger size of the replacement filter and the limitations of an air handling unit that has not been designed to hold a high efficiency filter.

Instead, a HEPA filter is part of a dedicated system that incorporates a prefilter to capture the larger dust and pollen particles. This prefilter protects the HEPA element from damage and prevents it from becoming clogged – extending the service life of high efficiency filter.

FULLY TESTED. FULLY COMPLIANT

Unfortunately HEPA is not a protected designation, so anybody can call their product a HEPA filter.

To guarantee the safety and quality of the HEPA product you are buying, check that it has been manufactured and tested according to the DIN EN 1822 and ISO 29463 standards.

Cabin air filter system locations

Cabin air filtration system

For classic HVAC

For classic HVAC

Cabin air filter systems
Multi-stage solutions

Cabin air filter systems incorporate a number of filter stages – each designed to target certain pollutants – to protect vehicle occupants while ensuring high performance over the filter lifetime.

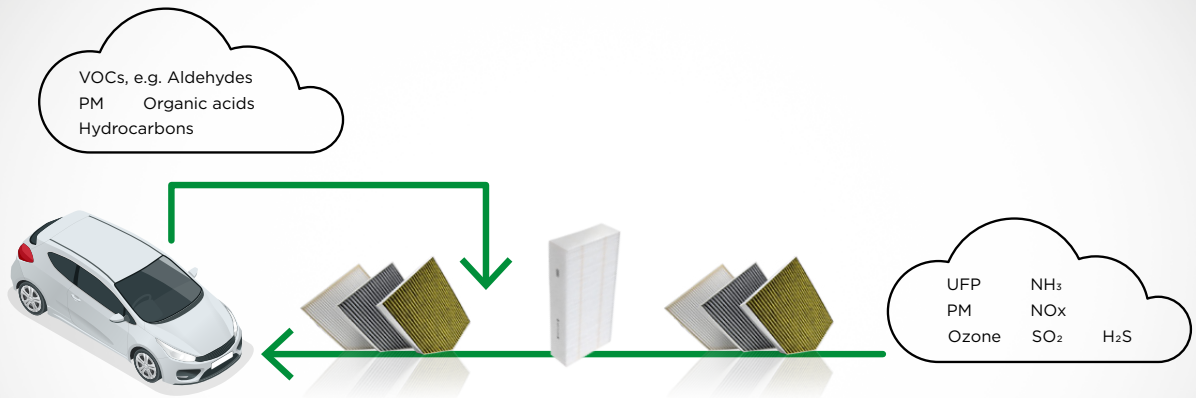
KEY FACTS

- Multi-stage filtration concept for maximum protection of vehicle occupants
- Flexible media combinations to suit different environments
- Removal of any solid or liquid particles from the air with an efficiency of at least 99.95%
- Variable sealing technology

HOW DOES IT WORK?

A three-stage filter solution – comprising a prefilter, HEPA filter and cabin air filter – provides a balanced, effective defense against air pollution. This approach also makes it possible to tackle a range of contaminants with different combinations of filter media – such as activated carbon media for the adsorption of harmful gases and odors, or a bio-functional layer with anti-allergen and anti-microbial properties. The cabin air filter system is usually placed in a filter housing with a secure sealing concept in front of the air conditioning system.

THE CABIN AIR FILTRATION SYSTEM CONCEPT



Interior filter or cabin/HVAC filter
Particle filter optionally with activated carbon, nanofibers or bio functional layer.

HEPA filter
Medium class (according to DIN EN 1822)

Ambient filter or prefilter
Particle filter optionally with activated carbon, nanofibers or bio-functional layer.

Smart cabin air filter systems
Adaptable and intelligent

A smart cabin air filter system uses sensors to determine when to activate its various stages – lengthening service life and reducing cost of ownership.

KEY FACTS

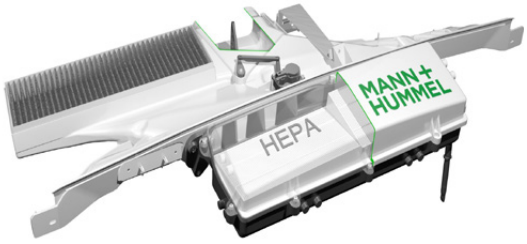
- Intelligent best air quality management for an optimized energy consumption and extending the driving range
- Continuous system control and air quality monitoring by sensors
- Increased filter lifetime as filters are only activated as required
- Less installation space needed due to an optimized HEPA filter size
- Lower costs and use of natural resources from reduced charging cycles, fuel consumption and filter replacements

HOW DOES IT WORK?

An important part of the system is an intelligent algorithm which ensures the most efficient use of the re-circulated air inside the vehicle. As a result, the system fresh-air intake adds only the lowest required amount of fresh air into the vehicle and adjusts the temperature to match that of the current cabin condition – saving energy or fuel, and extending the driving range.

In addition, sensors continually monitor the air quality inside the vehicle cabin in order to ensure the ideal air quality in all environmental situations. These sensors monitor the levels of CO_2, particle concentrations and relative air humidity in the vehicle cabin. If the prescribed limit values are reached, the intelligent cabin air filter system increases the intake of fresh air. Sensors detect the quality of the added air and provide data which the system analyzes and then decides which of the three filters the air will flow through.

Extensive simulations were carried out to confirm the feasibility of this smart cabin air filter concept. Various tests and field trials showed that the system is able to filter up to 98% of all particles smaller than one micrometer (PM1) from the ambient air. The driver can view the air quality inside the vehicle on the display at any time.



NEXT GENERATION FILTRATION FOR THE NEXT GENERATION OF VEHICLES

When the cabin air filtration system can impact the distance you can travel, it becomes a lot more interesting to the average driver. That's why MANN+HUMMEL is working intensively on developing cabin air filter systems that maximize the efficiency of electric vehicles. Our smart technology cuts the overall resistance of the air delivery system and provides more kilometers to the end user.

Smart cabin air filter systems
Adaptable and intelligent

PROTECTION (ONLY) WHEN IT'S NEEDED

To minimize the size of the system and extend the life of the HEPA filter, it makes sense to use the HEPA stage only when the level of ambient air pollution requires it. That's the concept of a smart cabin air filter system.

Our smart cabin air filter systems utilize sensors to monitor the air quality inside and outside the vehicle, and also the performance of the individual filters.

The smart system activates the HEPA filter stage when the level of air pollution requires it – such as in a tunnel or traffic jam. This reduces the level of contaminant loaded on the HEPA unnecessarily – prolonging its service life.

THE PERFECT BALANCE IN ANY CONDITION

	100% recirculation	Opti-mode	100% fresh air
CO_2 concentration level	X	Smart controlled recirculation ratio to find best trade-off depending on driving condition	✓
Pollutant and Particle level	✓		X
Infiltration flow rate	X		✓
Energy savings	✓		X
Filter lifetime savings	✓		X
Humidity management	Dependent on ambient conditions		

Validation and test methods for the best results

PERFORMANCE YOU CAN DEPEND ON

The filtration and adsorption performance of cabin air filter elements are tested in accordance with DIN 71460-1 and ISO 11155-2.

Since cabin air filter elements tests are very sensitive to fluctuations in ambient conditions, the DIN standard requires very tight controls of climate conditions. To determine the filtration efficiency, coarse (A4) or fine (A2) standard dust aerosols according to ISO 12103-1 or NaCl/KCl aerosols are used.

In order to determine the performance classes of the filter elements and ensure comparability, laboratory testing is performed under reproducible conditions. This includes constant particle and gas concentrations, standardized test particles and gases as well as the ideal inflow of the test filters.

A considerable proportion of those test dust particles are above 1 µm particle size. But the majority of particles in the atmosphere are below 1 µm in size, so that the results from the laboratory tests cannot be transferred to the real contamination in road traffic.

In contrast to the test benches, the filter elements are exposed during their use in the air-conditioning system to varying climatic conditions under real driving situations (e.g. temperature fluctuations, changing relative humidity) as well as fluctuating particle concentrations.

The type of particles in the air is also strongly dependent on the environment and the conditions prevailing there. For example, salt particles can occur more frequently near the coast, and soot particles can be emitted in cities, in traffic jams or on motorways. To be able to make statements about the efficiency of cabin air filters under real conditions, field investigations are inevitable.

To assess the efficiency of a cabin air filter in real operation, stationary measurements are carried out at polluted sites in addition to long-term studies. However, they can only simulate the real conditions in the vehicle interior to a limited extent, since the aging of filter elements depends on environmental conditions. In order to be able to make statements about the air quality in different driving situations, measurements are carried out on a defined route during driving.

Such field studies represent an important supplement to laboratory tests in order to be able to classify the performance of cabin air filters measured in test benches and to spur on the targeted development of filter media accordingly.

Filter media must also fullfil the automotive interior standards for odor (VDA 270), fogging (DIN 75201) and burning behavior (DIN 75 200 / FMVSS 302). Both burning norms refer to the horizontal testing of vehicle interior materials and are only applicable for the testing of flat materials.

Since awareness of mechanical filtration has grown, manufacturers are validating more and more of their cabin air filters in accordance with the DIN EN ISO 16890 standard for “air filters for general ventilation”. As the electrostatic separation mechanism is minimized through targeted discharge (by dipping in isopropanl) under part 4 of this standard, the filter medium must demonstrate excellent mechanical separation efficiency – > 50% to reach ePM1 or ePM2.5 classification.

The performance of a filter is evaluated according to its collection efficiency against particle sizes 0.3 – 10 µm and categorized into one of four different filter groups – ISO ePM1, ePM2.5, ePM10, and Coarse.

MAXIMUM PRODUCT SAFETY THROUGH COMPLIANCE

Cabin air filters must comply with numerous standards that cover various aspects of health and safety. MANN+HUMMEL tests its products in accordance with the relevant standards.

FOCUS	STANDARDS
Quality, efficiency, technology	DIN 71460-1, ISO 11155-2, DIN EN 1822, ISO 29463, DIN EN ISO 16890, ISO 12103-1
Hygiene/vehicle cabin specific	DIN EN ISO 846, VDA 270, DIN 75201, VDI 6032, DIN EN ISO 20743, VDA278, ISO 18184
Fire protection	DIN 75200, FMVSS 302

A call to action for OEMs

DEAR VEHICLE MANUFACTURERS

The air pollution that we face today is very different to that which we have seen before. The finer nature of pollutants means that we must adapt and develop new technologies to protect people from toxic air.

As a vehicle manufacturer, you have an opportunity to protect the drivers and passengers of your vehicles, while also lowering costs of ownership and increasing efficiency.

We help you protect your customers and deliver greater value.

Please contact us for more information.

MANN+HUMMEL

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