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#### Outline





#### ►► Outline





#### **Standard cabin air filter types**





#### Media approaches for good separation efficiency at low pressure drop

Electret media	Nanofiber media	Composite media
<ul><li>Electrostatic charge</li><li>High air permeability</li></ul>	<ul><li>Sub-micron fibers</li><li>Typically top-layer</li></ul>	<ul> <li>Gradient structure</li> <li>Usage of electrete and</li> </ul>
Sensitive to heat, humidity	application	mechanical separation

- Surface filtration effect
- effects



and fluids













#### Performance Characteristics – looking for a specific optimum





#### **b** Combi filter spec comparison for two succeeding car platforms





- Significant increase of separation efficiencies required
- Pressure drop has to remain at the same level



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Worldwide distribution of PM2.5 concentrations



2

5

10

20 50 PM<sub>2.5</sub> [μg/m<sup>3</sup>] 100

200



**Cabin air filter media to meet high PM2.5 separation efficiencies** 





Standard filter media with medium separation efficiency

Fine dust filter media for highly efficient PM2.5 retention



#### Practical setup for testing PM2.5 removal efficiency



From standardized lab tests acc. to DIN/ISO...





...to in-cabin PM concentration measurements



#### Practical test results (extremely high PM2.5 concentrations)



PM2.5 concentration [µg/m3]	PM2.5 before	PM2.5 after	PM2.5 conc. reduced by	Remaining PM2.5 percentage
PM2.5 filter element	1334.3	8.9	99.3%	0.7%
Standard filter element	570.8	44.4	92.3%	7.7%

critical PM2.5 conc. on map shown on slide 10:  $\leq$  200 µg/m<sup>3</sup>



#### Practical results – creating comparable conditions

Idea for standardizing cabin-tests using a test chamber

- Setup similar to recirculation mode in a car cabin
- Usage of a sealed test chamber with a filter and blower inside
- Start with a well-defined initial PM2.5 concentration in the chamber
- PM2.5 concentration sampling and recording the "decline curve" over the time





▶▶ PM1, PM2.5 and PM10 distributions in ambient air





	Ambient Air [µg/m³]		
Road section	<b>PM</b> <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>1</sub>
1: St2111 "Country road"	20.2	19.1	18.3
2: Dingolfing "City"	26.2	24.5	23.6
3: A92 "Highway"	18.0	16.5	15.9
Whole road section	20.5	18.9	18.2
WHO Suggestion	50	25	
(Daily average value)	50	23	-

Photo: GRIMM

 Fine particles (PM1) are strongly represented in ambient air



#### **Test of the fine particle concentrations in a truck cabin**





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#### **>>** Typical gases for cabin air filter adsorption tests

test gas	represents	test gas concentration
n-butane (	VOC (volatile organic compounds)	80 ppm <sub>v</sub>
toluene	Aromatic hydrocarbons e.g. benzene	80 ppm <sub>v</sub>
SO <sub>2</sub>	Emission from traffic & industry	30 ppm <sub>v</sub>
NO <sub>x</sub>	Emission from traffic & industry	30 ppm <sub>v</sub>
Aldehydes	Diesel exhaust, cigarette smoke	30 ppm <sub>v</sub>
NH <sub>3</sub>	Agriculture emission	30 ppm <sub>v</sub>



#### Chinese standard GB/T 27630 – VOC concentration limits



#### **Conditions:**

- Temperature: 25 ± 1 °C
- Relative humidity: 50 %
- Vehicle stopped, all vehicle doors, windows and passenger compartment vents closed, engine and air conditioning deactivated

本电子版为发布稿。请以中国环境科学出版社出版的	NO.	Name	Concentration limits, mg/m3	Odor
	1	Benzene	≤0.11	Strong aromatic odor
	2	Toluene	≤1.10	Aromatic odor
	3	Xylene	≤1.50	Aromatic odor
	4	Ethylbenzene	≤1.50	Aromatic odor
	5	Styrene	≤0.26	Sweet smell
	6	Formaldehyde	≤0.10	Pungent, irritating odor
	7	Acetaldehyde	≤0.05	Irritating odor
	8	Acrolein	≤0.05	Piercing, acrid smell.

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#### Investigations on in-car VOC concentrations in China





#### Exemplary results of a test drive in China (<u>no</u> cabin air filter in use)





#### **Exemplary comparison of VOC conc. using different cabin air filters**



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#### **TVOC and PM2.5 concentrations using advanced PM2.5 combi filter**



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#### Outline





#### Additional protection against allergens



American Academy of Allergy Asthma and Immunology (AAAAI): Allergy Statistics, 2012.

Increasing part of population suffering from allergies



#### Additional protection against allergens



Grote, M. et al.: Release of allergen-bearing cytoplasm from hydrated pollen: A mechanism common to a variety of grass (Poaceae) species revealed by electron microscopy. J. Allergy Clin. Immunol. 108,109-115, 2001.

Grote, M. et al: Expulsion of allergen-containing materials from hydrated rye grass (Lolium perenne) pollen revealed by immunogold field emission scanning and transmission electron microscopy. J Allergy Clin Immunol. 105(6), 1140-1145, 2000.

- Increasing part of population suffering from allergies
- Allergen proteins released from e.g. pollen are a cause for allergic reactions



#### Anti-allergen function of polyphenols ••





Reduction of allergen effect (e.g. grass pollen allergen): > 95% (tested by external institutes acc. to ELISA method)





- Unfavorable conditions can lead to growth of microorganisms on dirt layer
- Target: reduction of microbial growth, especially mold growth



#### Anti-microbial functionality



- Unfavorable conditions can lead to growth of microorganisms on dirt layer
- Target: reduction of microbial growth, especially mold growth
- Anti-microbial equipment reduces growth of microorganisms by > 98% (acc. to tests of external institutes)
- Significant reduction of odor issues caused by microorganisms



#### **>>** State of the art cabin air filter media featuring additional functions





#### ►► Outline



#### Summary and outlook

- Increasing demand for better cabin air filter separation and adsorption performance, especially for PM2.5 and VOC
- By using new media compositions significantly better performance can be achieved without affecting the general differential pressure and dust holding capacity levels
- With advanced adsorbent materials and additional biofunctional treatments, an extensive protection against unpleasant odors, mold growth and allergen input into the clean air can be realized
- Practical tests help to understand the impact on in-cabin concentrations and to improve filter media properties











►► Thank you for your attention!

