micronAir®

ENSURING BEST AIR QUALITY

FREUDENBERG FILTRATION TECHNOLOGIES

FREUDENBERG
INNOVATING TOGETHER

micronAir®

Outside Vehicle Air Pollutants – Review

VIAQ 19-05

Paris, March 10th 2020

Ulrich Stahl

Particulate Matter, Gases and Microbiological Substances

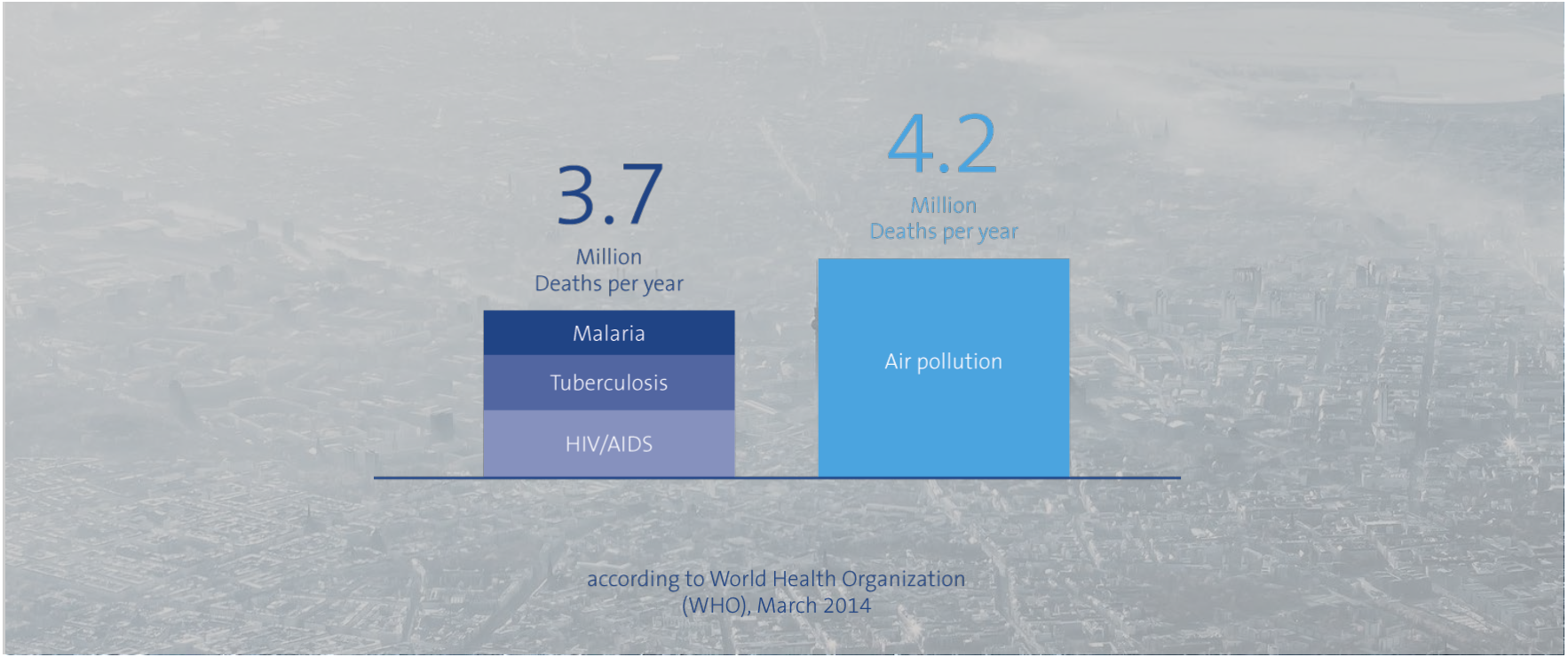
Threats to Health Worldwide

FREUDENBERG FILTRATION TECHNOLOGIES

FREUDENBERG
INNOVATING TOGETHER

Air pollution is the world's largest single environmental health risk

micronAir®



9 of 10 people worldwide breathe in unhealthy air

micronAir®

according to World Health Organization
(WHO) study, September 2016

Gaseous and particulate air pollution have IN FACT health-damaging effects

micronAir®

A broad scientific consensus supporting WHO limits and official WHO findings exists

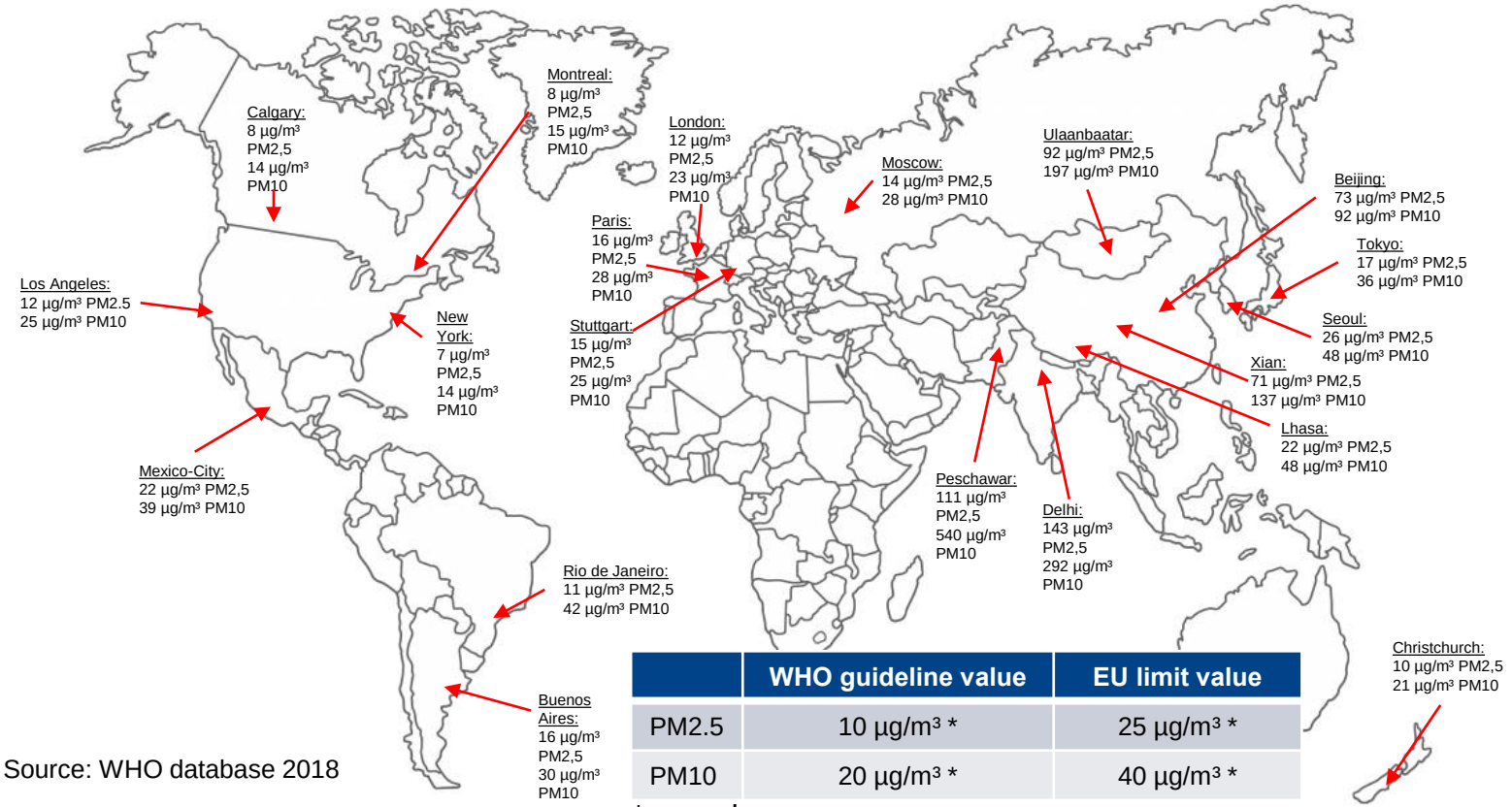
Particulate Matter air pollution

FREUDENBERG FILTRATION TECHNOLOGIES

FREUDENBERG
INNOVATING TOGETHER

PM2.5 and PM10 concentrations

micronAir®



	WHO guideline value	EU limit value
PM2.5	10 µg/m³ *	25 µg/m³ *
PM10	20 µg/m³ *	40 µg/m³ *

Source: WHO database 2018

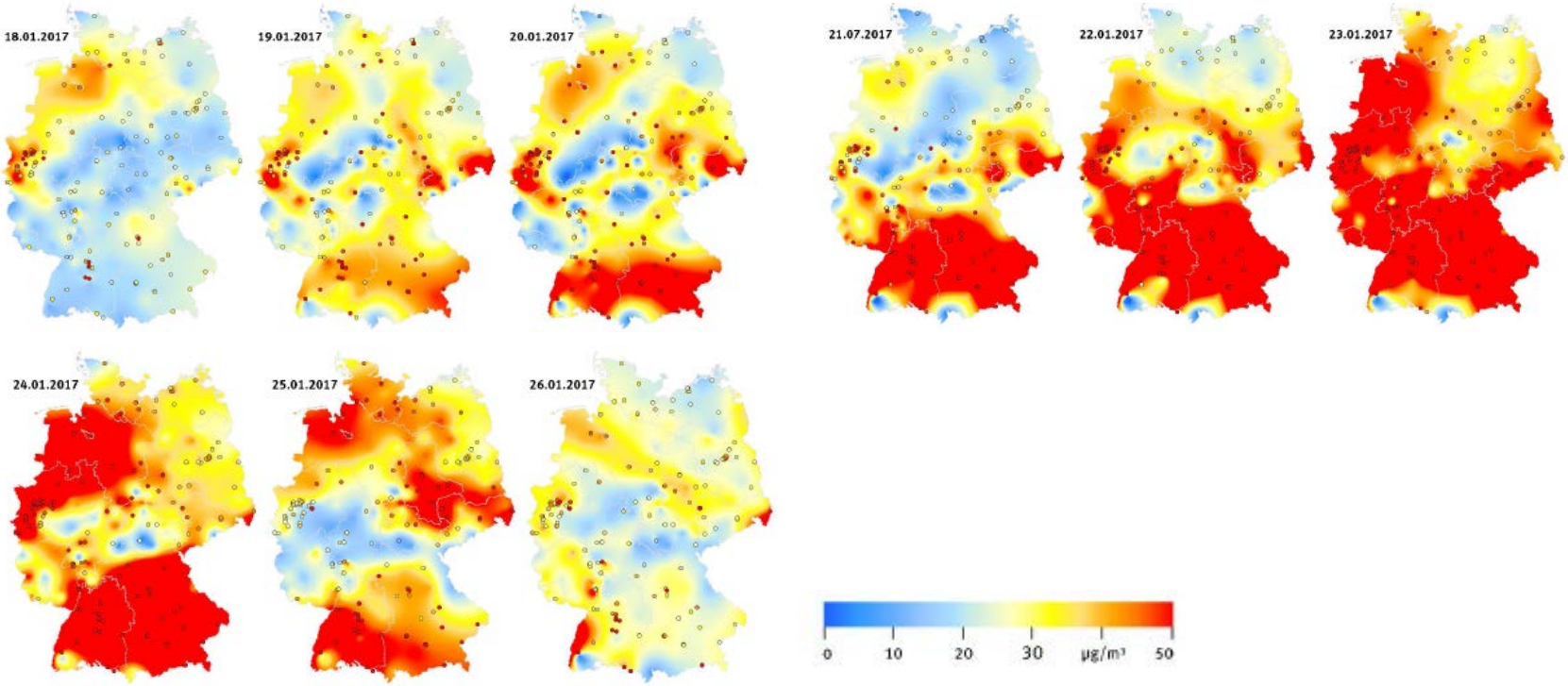
*annual mean

FREUDENBERG FILTRATION TECHNOLOGIES

FREUDENBERG
INNOVATING TOGETHER

Daily average for PM10 concentration in Germany

micronAir®



Source: Umweltbundesamt 2017 data

PM10 concentration in Germany

micronAir®

Weather dependence of PM 10 concentrations:

- in dry winters and sometimes in hot summers

➔ **Concentrations rise above 50 µg/m³**

e.g.: Germany on 23.01.2017:

➔ 56% of the PM10 measuring points exceeded the daily mean values of 50 µg / m³

➔ the peak value on this measurement day was 176 µg / m³ !

Regulation VDI 6032-1 (May 2015): Hygienic requirements for vehicle interior air quality

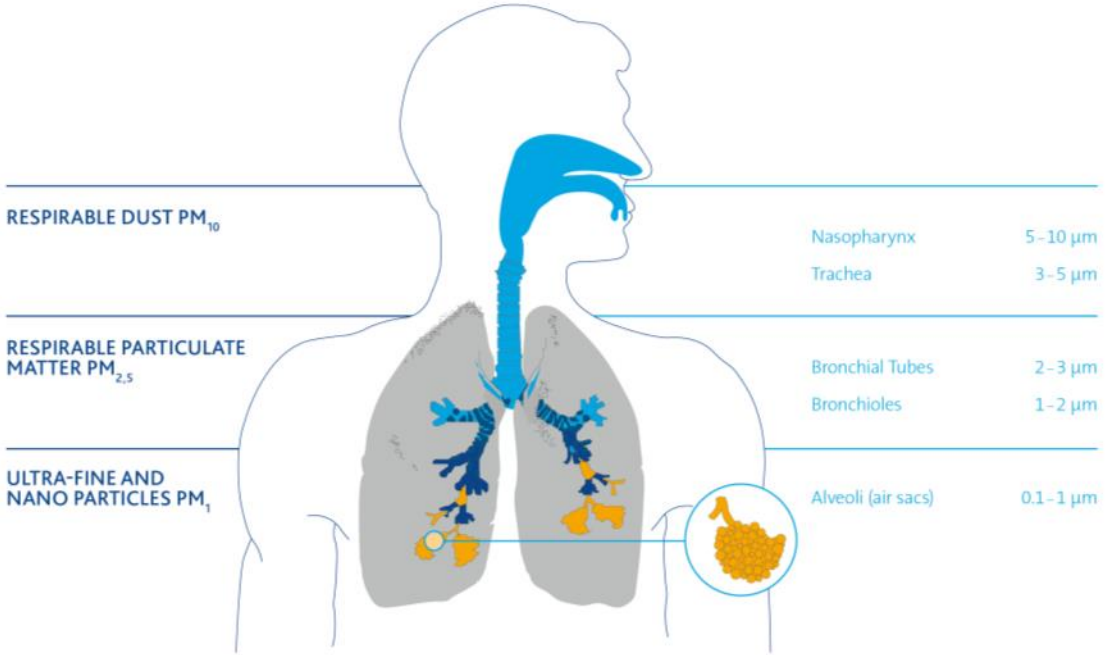
micronAir®

picture: Viktor Mildenberger/pixelo.de

Minimal requirements for vehicle cabin air filters.
Air volume flow rate 300m³/h and ISO A2 test dust.

Optical / aerodynamic equivalent in µm	Fractional collection efficiency A2 test dust in %
> 0,3 / 0,49	> 75%
> 0,5 / 0,81	> 80%
> 1 / 1,62	> 85%
> 3 / 4,86	> 90%
> 10 / 16,2	> 95%

Particulate Matter: Absorption into lungs



Particles smaller 2.5 µm can reach central lung region and accumulate there.

Hazardous substances such as heavy metals or carcinogenic polycyclic aromatic hydrocarbons can adhere to surface of these particles.

Ultrafine particles (UFP)

micronAir®

Description: **Ultrafine particles** (UFP) may contribute to the health effects of ambient **particle** exposure because of their high number concentration and surface area, a high deposition efficiency in the pulmonary region, and a high propensity to penetrate the epithelium.

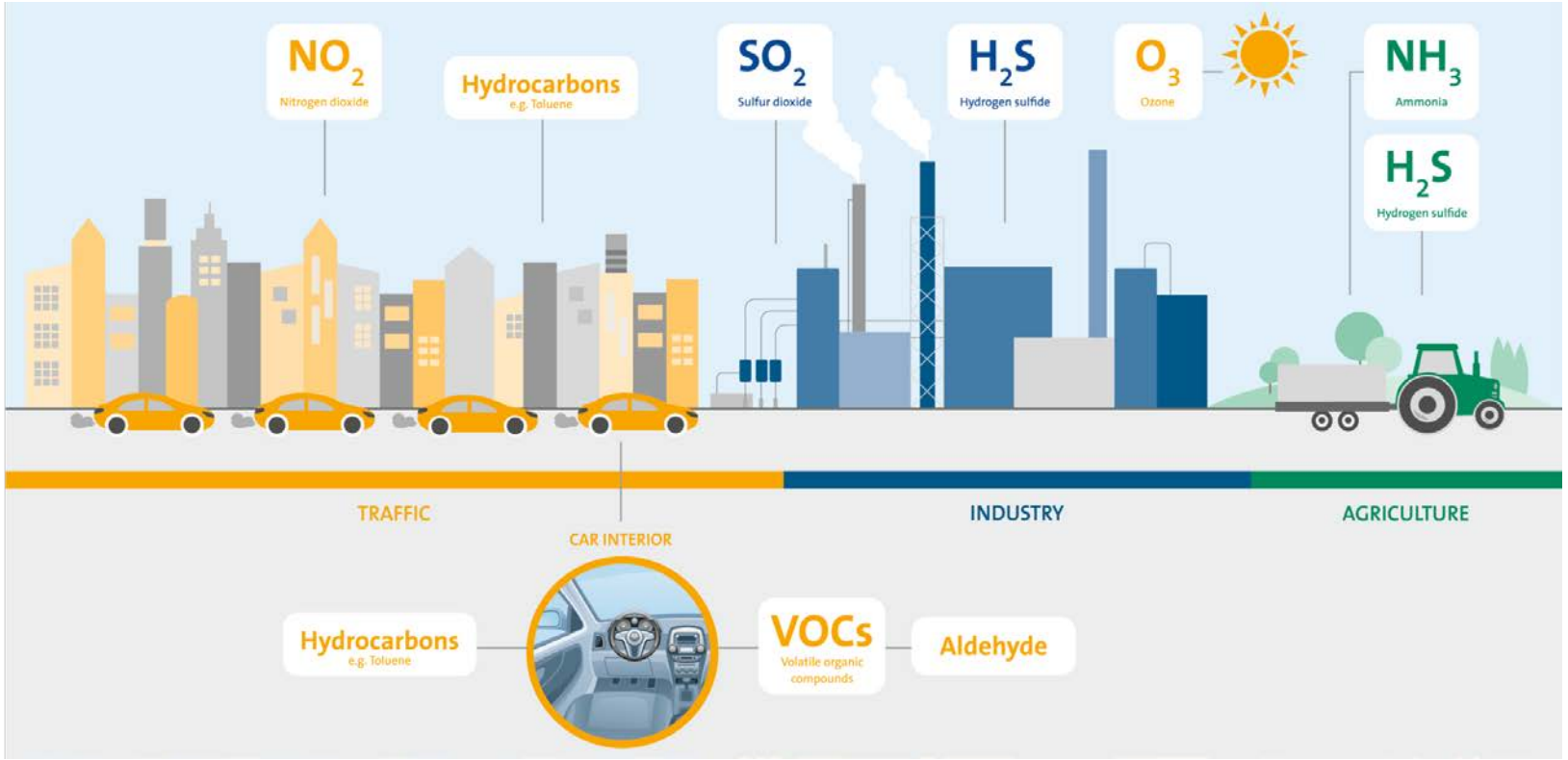
Size range : < 100 nm => e.g. virus size is 100 nm to 200 nm

⇒ Test equipment used, should be able to detect particles below 100 nm

Gaseous air pollution

Types and sources of gaseous air pollution

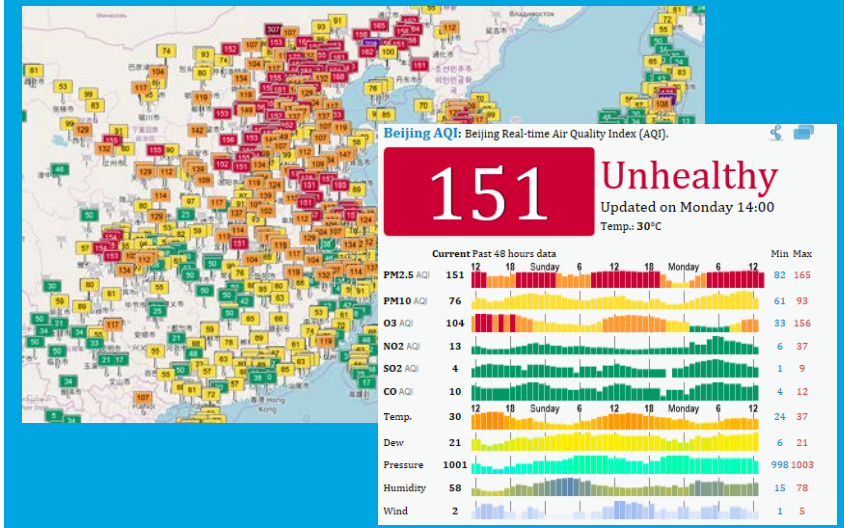
micronAir®



Different regions, different patterns of pollution
Air quality data: China vs. Europe

micronAir®

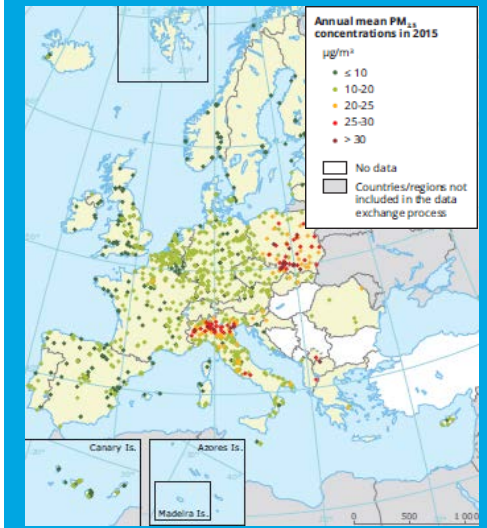
China

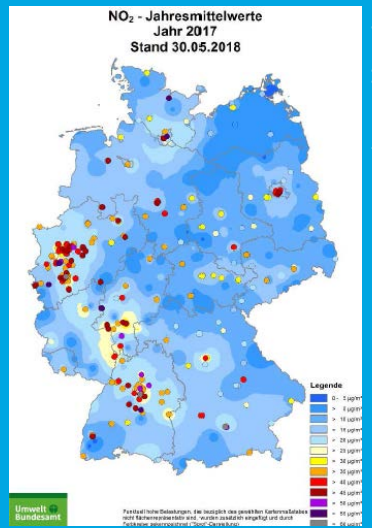


aqicn.org/city/beijing

China AQI:
PM2.5, PM10, O_3, NO_2, SO_2, CO

Europe / Germany





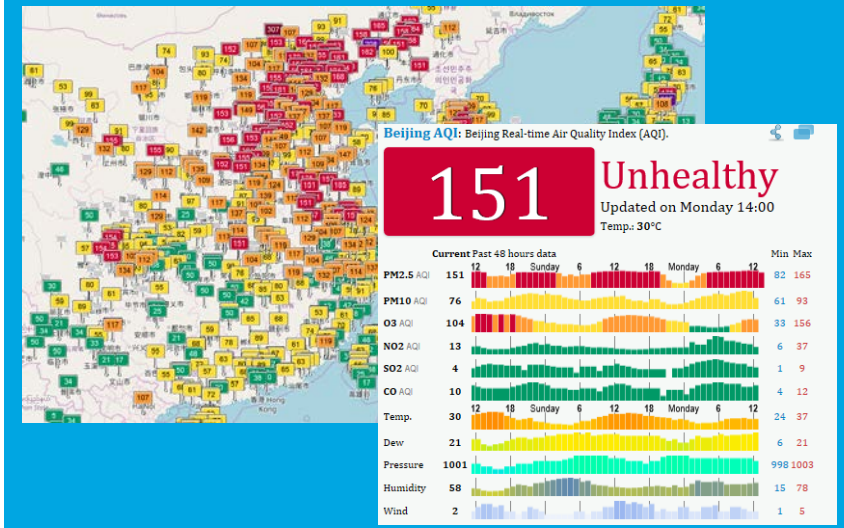
eea.europa.eu / umweltbundesamt.de

Different regions, different patterns of pollution
Air quality data: China vs. USA

micronAir®

China

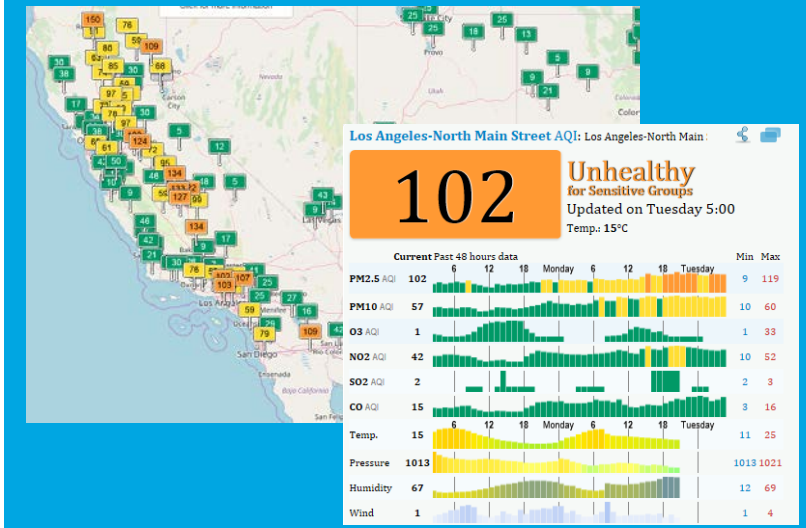
aqicn.org/city/beijing



China AQI:
PM2.5, PM10, O_3, NO_2, SO_2, CO

USA

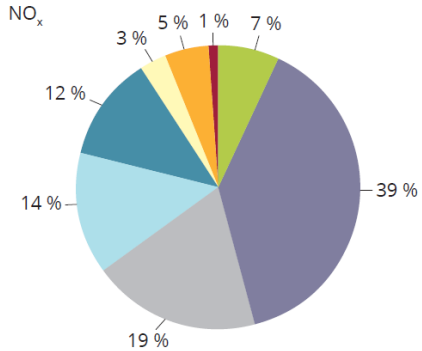
https://aqicn.org/city/usa/losangeles



USA AQI:
PM2.5, PM10, O_3, NO_2, SO_2, CO

Relevant gases
Air quality in Europe - NOx

- Road transport is the largest contributor to total NOx emissions (39%)

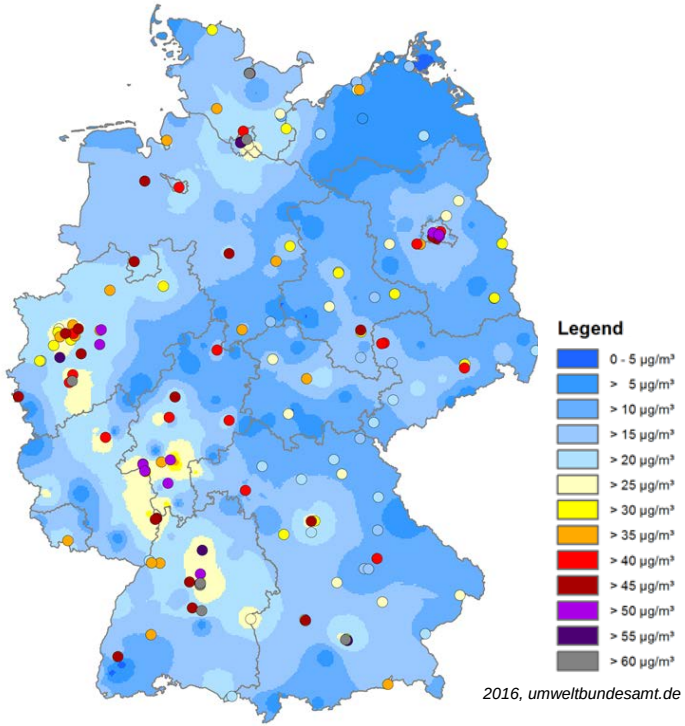


Sources: EEA, 2017c, 2017e.

Non-road transport | Road transport | Energy production and distribution | Commercial, institutional and households
Energy use in industry | Industrial processes and product use | Agriculture | Waste | Other

→ NO_2 causes significant health burden

Relevant gases
Annual NO_2 mean value in Germany



2016, umweltbundesamt.de

NO_2 limit values in Germany:

- **1 hour limit value**

  200 µg/m³ (exceeding allowed 18 times a year)

- **Annual limit value**

  40 µg/m³

Globally relevant target gases (1)

micronAir®

	Target Gas	Region	Properties	Cabin air use	Adsorbent	Relevance
HYDROCARBONS	**HC short-chain** e.g. n-Butane	Global	Test procedure target gas for quick testing	No relevance in use	Physisorption on activated carbons	**No relevance in use**
HYDROCARBONS	**HC long-chain (aromatic)** e.g. Toluene	Global	Target gas for physisorptive tests	Fast adsorption kinetic important widespread hydrocarbon	Physisorption on activated carbons	**Typical VOC representative (car interior) with strong smell**
HYDROCARBONS	**HC cyclic** e.g. Cyclohexane	Global	Agriculture vehicles test procedure target gas	Only for agriculture cabins and fast adsorption kinetic important	Physisorption on activated carbons	**Could be target gas for VOCs**
ACIDS	**SO_2**	Asia	SO_2 well established with long historical database	Fast adsorption kinetic important, widespread acid gas	Chemisorption on impregnated activated carbons	**Representative gas for acid gases**
ACIDS	**H_2S**	Asia	Highly toxic, extremely low threshold limit, difficult to measure (HSE)	Representative for sulfur containing gases	Chemisorption on impregnated activated carbons	**No relevance → SO_2 preferred**
ACIDS	**NO_2**	Global	Target gas for EU and Diesel emission regions	Fast adsorption kinetic important	Chemisorption on impregnated activated carbons	**High, Complex chemical equilibrium NO_x → NO + NO_2 incl. side reactions**

Globally relevant target gases (2)

micronAir®

	Target Gas	Region	Properties	Cabin air use	Adsorbent	Relevance
ALKALINES	**NH_3**	Rural areas	Strong smell from organic processes, SCR Cat for NOx reduction	Not an issue in automotive	Impregnated activated carbons or Ion exchange resins	**No subjective relevance**
	Methyl-amine/ Trimethyl-amine	Coastal areas	Strong smell	Not an issue in automotive	Comparable with Ammonia	**Low – only for specific regions (coastal area)**
ALDEHYDES	**Formaldehyde**	China	Target gas for interior air quality in buildings	Recirculation air more important then fresh air	Chemisorption on various Amine impregnations on activated carbons	**Relevant for special decorative wooden interior applications**
	Acetaldehyde	Asia	Target gas for interior air quality, typical VOC representative	Recirculation air more important then fresh air	Chemisorptive on various Amine impregnations on activated carbons	**High, due to interior emissions, possible oxidation into acetic acid during process**
OTHERS	**Ozone**	Global	Low threshold limits in cabin, strong smell	Fast reaction important (reduction) → AC preferred	De-composition on activated carbons	**In case of pro-active ozone generation (oxidation processes)**

Microbiological air pollution

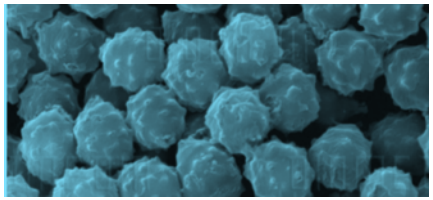
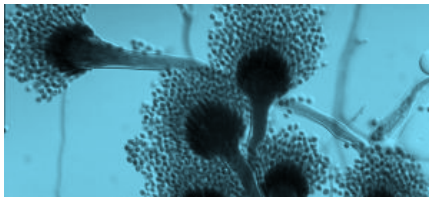
FREUDENBERG FILTRATION TECHNOLOGIES

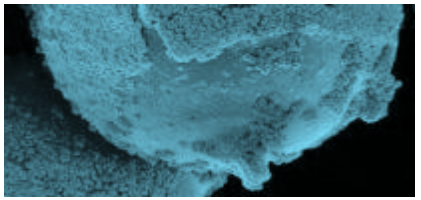
FREUDENBERG
INNOVATING TOGETHER

Inhalation Allergens: Carried over ambient air

micronAir®

Plant pollen Fragments	**Molds** Spores	**Dust mites** Excrements	**Animal hair** Ultra fine particles
• Trees • Weeds • Herbs	• Alternaria • Aspergillus • Chladosporium	• Dermatophagoide *human skin scales as mite's nutrition*	• "Cat" and "dog" proteins *emitted by glands; transferred via saliva through coat care*

Around **20,000 allergens** are currently known to science.

Scientific validation of cabin air filter performance

micronAir®

- Cross- functional team of scientists, research institutes and certification authorities

FREUDENBERG FILTRATION TECHNOLOGIES

ECARF European Centre for Allergy Research Foundation

ofi FORTSCHRITT IN GUTEN HÄNDEN

DAIMLER

EUREKA Σ! innovation across borders

- Development of a valid systematic testing strategy to evaluate filters for separation efficiency of allergenic fine dust and airborne mold spores
- Study Design for allergenic fine dust and mold spores

1. Preclinical evaluation of a filter medium at laboratory scale
2. Preclinical evaluation of a filter in an air condition device
3. Clinical evaluation of a filter by exposing allergy sufferers

Validation of cabin air filters
Scientific performance validation

micronAir®

- Real-life simulation by testing of a filter in air condition device for cars
- Worst-case scenario by high concentrations of allergens:
  - Cladosporium cladosporioides: up to 750,000 spores per m^3
  - Cat epithelia: 4,350 HEP* per gram of mineral dust

* 1 HEP generates the same wheal size in prick testing of sensitized patients as 10 mg of histamine

$$\textbf{Separation rate}\ [\%] = \left(1 - \frac{allergen\ in\ breakthrough}{allergen\ on\ filter}\right) * 100$$

Validation of cabin air filters
Scientific performance validation

micronAir®

Summary of pre-clinical tests

- Separation rates for all allergens were excellent (> 97%)
- There was no significant difference between separation rates observed in laboratory media testing and filter testing within an air conditioning device

Separation rates for tested allergens [%]				
	Cladosporium	Cat	Birch[x]	Alternaria[x]
	Cladosporoides	Epithelia	Pollen	Alternata
Laboratory scale	98.3 ± 0.9	99.7*	→100	→100
HVAC system	97.4 ± 1.6	98.5 ± 1.4	–	–

* due to the specific detection limit of the ELISA Kits, only a minimum separation rate could be calculated as no allergen was detected in the filter breakthrough

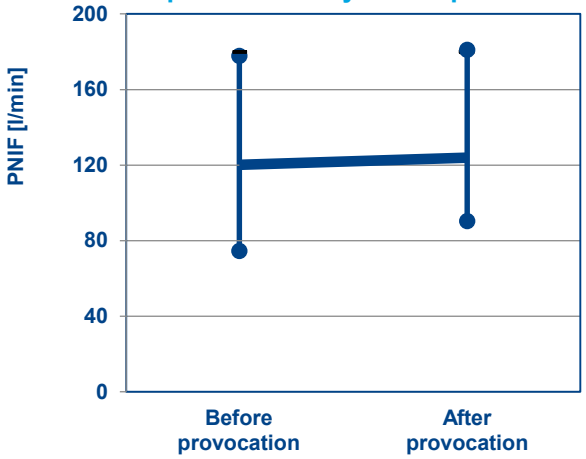
[x] as laboratory testing did not show any breakthrough, testing via air conditioning device was focused on cladosporium cladosporioides and cat epithelia only

Validation of cabin air filters
Scientific performance validation

micronAir®

Clinical evaluation by exposing allergy sufferers with installed micronAir cabin air filter

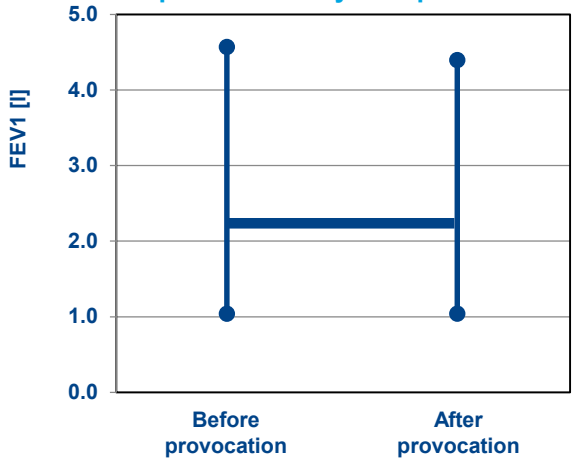
Positive nasal inspiratory flow
provocation by mold spores



Allergic rhinitis

PNIF "positive nasal inspiratory flow" is stating the amount of air that can be inhaled through both nostrils, indicating mucosal swelling as a result of the stay in the provocation chamber

Forced one-second bronchial capacity
provocation by cat epithelia



Allergic rhinitis

FEV1 "forced one-second capacity" is the amount of air that can be exhaled in the first second of increased exhalation, indicating bronchial reactions as a result of the stay in the provocation chamber

Microbiological air pollution
Denaturation technologies

micronAir®

	Effect	Toxicity	Human Compatibility
Fruit extracts	**Natural denaturation of allergens** Hindering fungal and bacteria growth	**Non-toxic** ✓	**Harmless**
Nano-silver	**Antibacterial effect**	**Possibly toxic** (depending on amount) 	• **Enter body via various paths** (skin, respiratory, gastrointestinal) • **Pass into cells quickly** • **Alarming health effects observed in animals**
Octylisothia-zolinon (OIT)	**Active against fungi and molds**	**Toxic** 	**Severe burns and eye damage in skin contact**

micronAir®

ENSURING BEST AIR QUALITY

FREUDENBERG FILTRATION TECHNOLOGIES

FREUDENBERG
INNOVATING TOGETHER

Thank you.