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Strategies for Research and Policies to Reduce Health Effects from Fine Particles in Ambient Air

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Working Group `Fine Particles`

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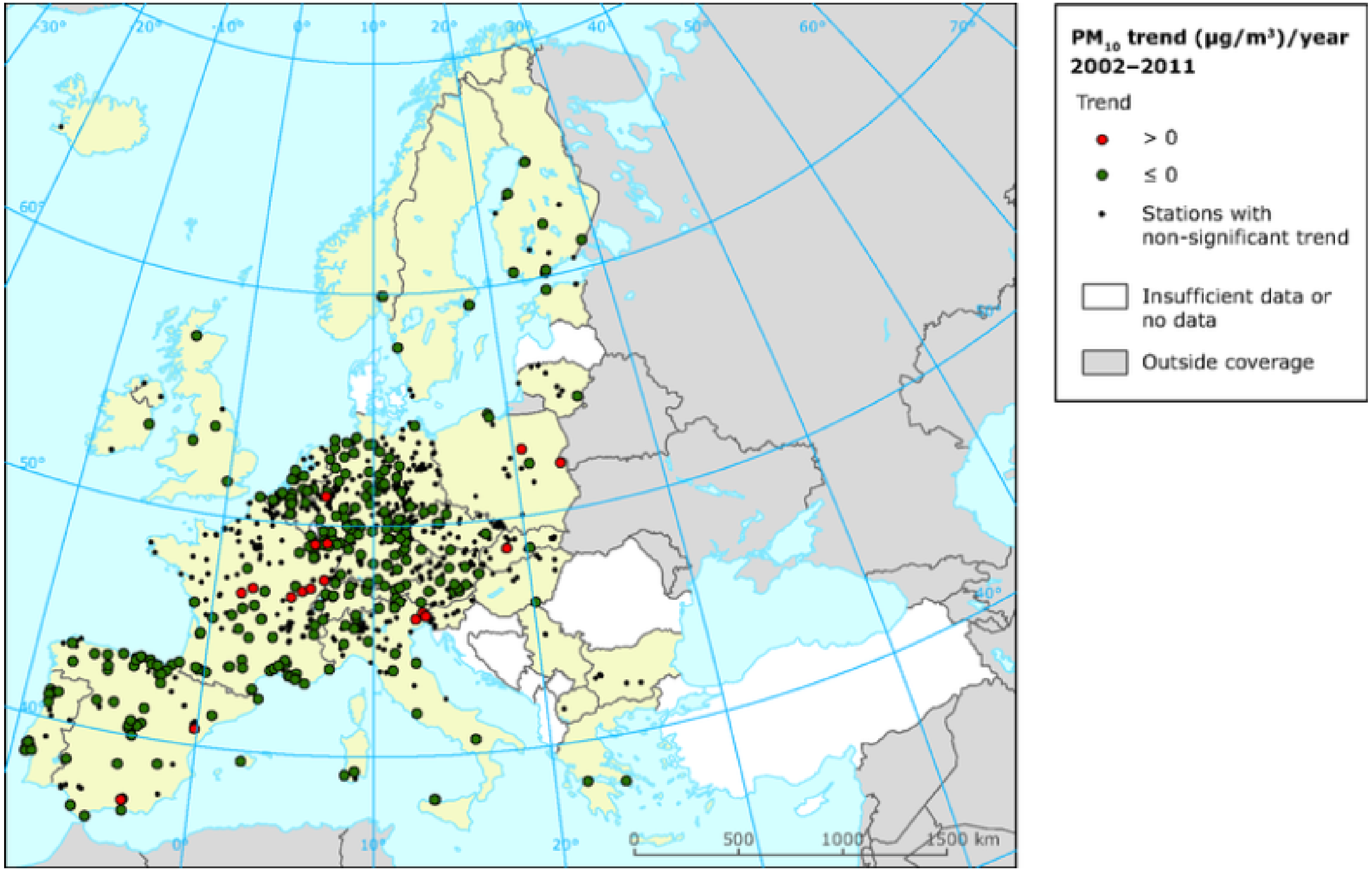
- Discussion and evaluation of the state of R+D of selected subjects
- Identification of knowledge gaps and – as the circumstances require – demands for action.
- Initiation of R+D project in order to reduce shortcomings
- Release of statements on scientific results and regulatory actions on the topics of the committee
- Holistic evaluation of fine particles including cost effectiveness considerations

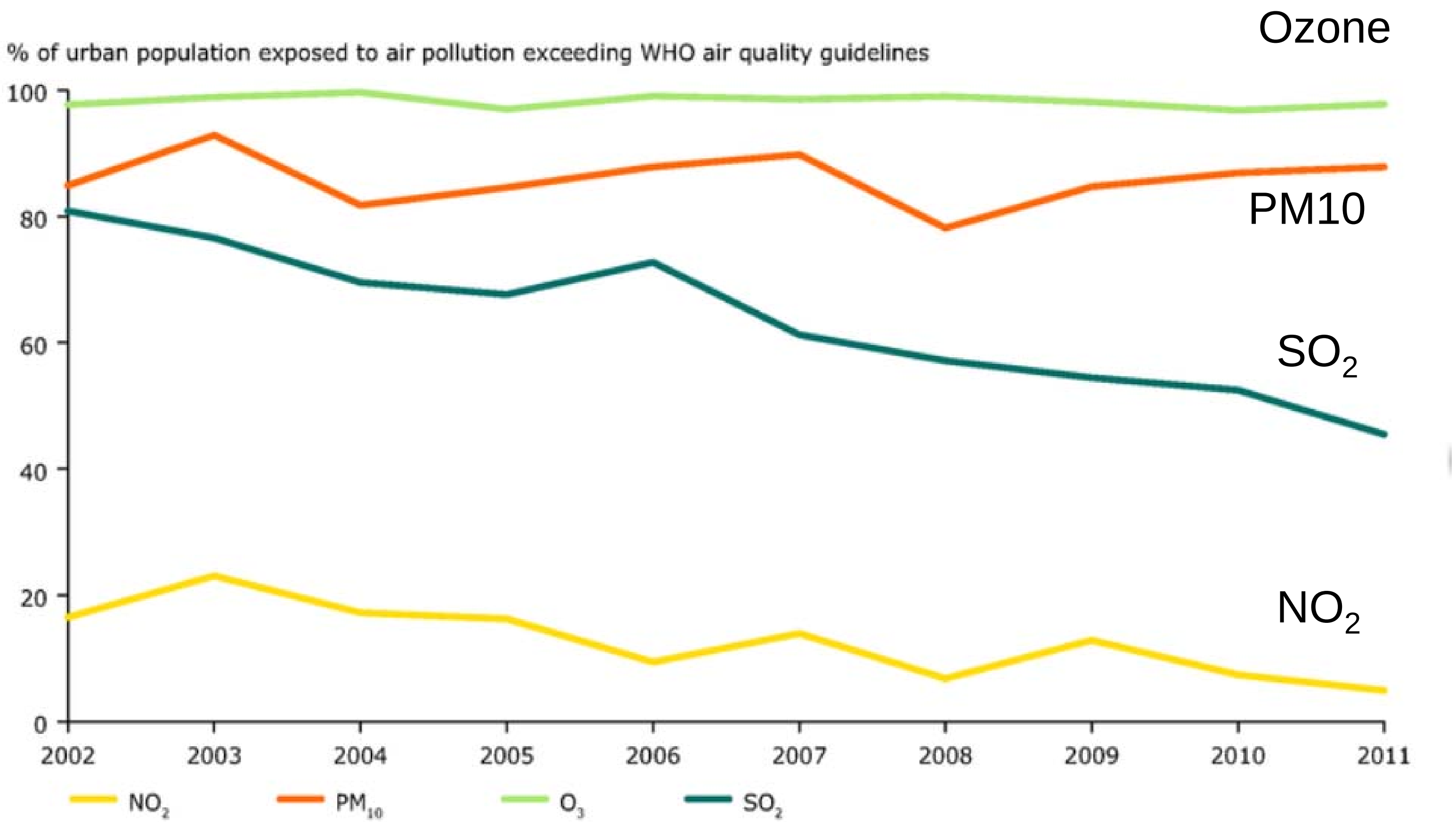
Objectives of the committee

Status paper `Fine Particles` (K.G. Schmidt, R. Zellner (Ed.), Sept. 2010)
Available for download from:
www.processnet.org/processnet_media/FG+SuPER/Statuspapier+final+klein.pdf



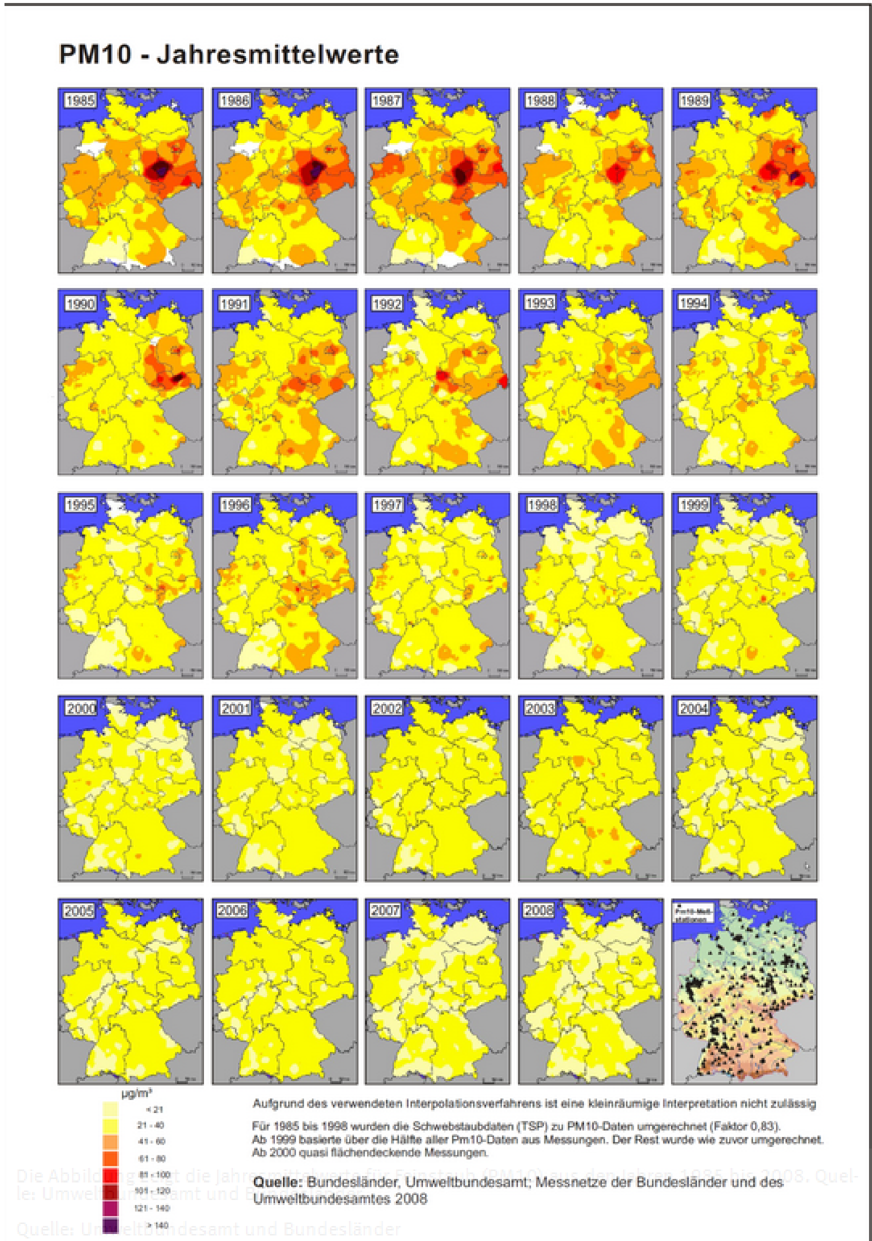
Annual changes in concentrations of PM10 in the period 2001–2010 in Europe

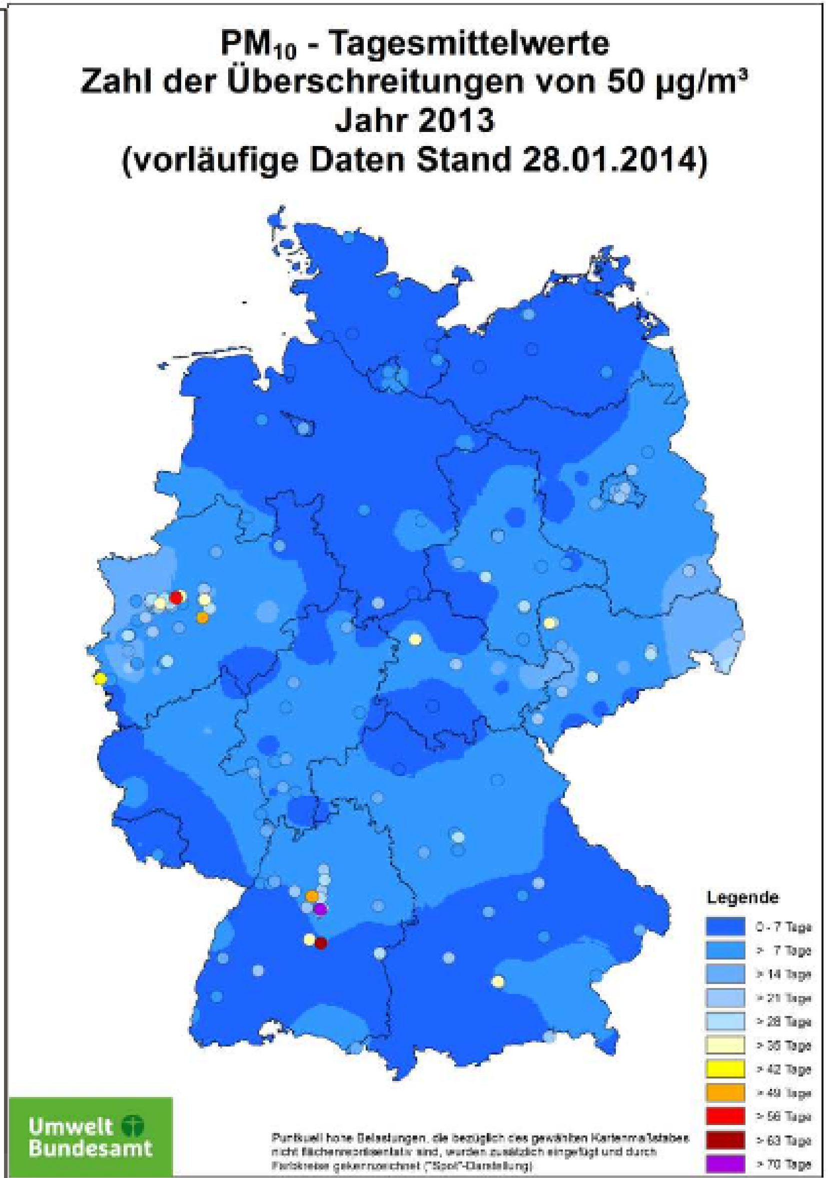
EEA (2013): „Air quality in Europe“



Percentage of the EU urban population exposed to air pollution exceeding WHO air quality guidelines

EEA (2013): „Air quality in Europe“





PM10 annual averages (left) and exceedances in 2013 (right)

The perception of a correlation between PM concentrations and their adverse effects on human health (respiratory tract and cardiovascular system) has substantially intensified

- Short and long term effects have been documented – even at concentration levels below 10 $\mu g/m^3$ (for PM2.5)

- Still an effect threshold value has not been noted

Current Assessment of Particle (PM10 and PM2.5) Health Effects by WHO (2013)

1. Re-evalution of the different sources that contribute to ambient fine particles including agriculture, domestic heating, traffic and industry.
2. Source extension to include biological particles (PBAP), semi-volatile organic compounds (SOCs) and secondary organic aerosols (SOA).
3. Consideration of weather and transport of fine particles.
4. Proposition of a

   - chemically differentiated and
   - biological effect related

   metric of fine particles.

Objectives of strategy paper

Chairmen of the committee:

Prof. Dr. Th. Eikmann, Universität Gießen
Prof. Dr. H. Herrmann, Leibniz-Institut für Troposphärenforschung, Leipzig
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Strategy paper `Fine particles` of the ProcessNet/GDCh/KRdL Committee (March 2014)


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Emissions of fine particles and precursors in Germany in 2010 in Gg/a (Source: PAREST (www.PAREST.de))

Sector	Unit[1])	PM10	PM2.5	SO_2	NOx	NH_3	NMVOC
Energy conversion	Gg/a	10	9	237	258	3	8
Other firing installations (Domestic, industry, crafts, services)	Gg/a	29	27	48	105	3	85
Industrial firing systems	Gg/a	18	8	62	69	1	4
Production processes	Gg/a	44	13	101	73	10	80
Production and distribution of fossil energy sources	Gg/a	4	1	6	-	-	17
Road transport	Gg/a	83	28	1	457	9	109
Other mobile sources	Gg/a	16	16	1	201	1	71
Agriculture	Gg/a	27	6	-	83	576	255
Other sources [2])	Gg/a	9	9	-	-	2	685
Total	**Gg/a**	**240**	**116**	**456**	**1246**	**605**	**1314**

[1]) 1 Gg = 1 kt; [2]) other sources of fine particles include cigarette smoking and fireworks; other sources of NMVOC include primarily solvents

- NH3 from animal farming is a substantial source of secondary inorganic aerosols such as NH_4NO_3 and $(NH_4)_2SO_4$ accounting for 30-50% of the urban background.
- Emission factors for primary aerosols and gaseous precursors (NH_3, VOC) are highly uncertain. No information is available at all on seasonal variability.
- Relation between NH_3 reduction and resulting aerosol is complex and non-linear
- Reduction potentials are high and their measures are cost-effective.
- However, emissions are expeced to further increase with the intended strengthening of the protection measures for farm animals in the EU.

Source considerations: Agriculture

- Small domestic heating installations are important sources of primary particles. Ca. 90% of these are due to the burning of fire wood and wood waste.
- Particle emission is due to the mineral content in biomass as well as to incomplete combustion (soot, OC). Due to the formation process of the particles (condensation, re-sublimation) the particles are of small sizes (<1 μm, max #density near 60 nm). The OC content may have significant health effects due to PCAs or nitro-aromatics or phenols, some of which are formed in subsequent atmospheric chemical reactions.
- Emissions are close to the surface and therefore effect the air quality of the breezing zone in low exchange weather conditions.
- Improvements are expected from improved combustion technology and/or other technical measures (particle filters).
- The modelling of emissions from small firing installations is currently not possible due to a complete lack of emission factors.

Source consideration: Firing systems (heat and power)

- Road transport still accounts for the largest source of primary environmental particles, both for PM10 and PM2.5.
- The highest threshold exceedances for PM10, the highest values for PM2.5 and the highest #concentrations for UFP are at traffic-related hotspots.
- The largest concern is for soot particles from Diesel engines, probably in synergistic effects with surface and gas constituents (NOx, SOCs)
- Other emissions such as NO_2 and NH_3 (catalysts), metals & metal oxides (engine wear & lubrication oils) and silicates, carbonates, Zn, Cu and Sb from re-suspension and abrasion from surfaces (brakes & tyres) are also important. In total, re-suspension may account or 20-50% of total particles.
- An evaluation of reduction measures requires a better knowledge on sources and source strengths, important chemical contents (BC, OC, organic markers (hopanes)), Diesel engine emission factors in dependence of driving dynamics and efficiency of DPF after-treatment.
- What effects will be caused by increased substitution of Diesel and gasoline by Bio-Diesel and ethanol?
- Particle reduction measures from traffic are of technological nature (after treatment, road surfaces) or they effect mobility (modal split, LEZ, speed limits)

Source consideration: Road transport

- Total contribution is on average approx. 20%; local contributions can be as high as 50%.
- An important criterium for industrial emissions is the emission height. Emissions from high stacks contribute considerably to the large scale background.
- Diffuse emissions from metallurgy, mines, quarries, handling of bulk materials etc. are causes for local threshold exceedances of PM10.
- Important contributions are from building sites and building machineries,including off-road vehicles.
- Methods for the quantification and modelling of diffuse emissions are currently unavailable.
- Because of their chemical contents (metals, soot) some industrial sources are of substantial health relevance.
- Since particle emissions are only high in the immediate vicinity of the industrial source and since the no. of measurement stations is limited, we may assume that not all of the exceedances are known.

Source considerations: Industry

- Biological particles: PBAPs include micro-organisms (bacteria, algae), reproductive units (pollen, fungal, fern and moss spores), abrasions of plants, parts of insects and biopolymers (DNA, chitin, cellulose, polysaccharides, etc.).

- Their sizes range from a few nm to hundreds of μm.

- They are ubiqitous in the atmosphere with mass fractions up to 50% (above vegetation covered areas). Fungal spores alone account for approx. 1 $\mu g/m^{-3}$ in the continental boundary layer.

- Enhanced bioaerosol concentrations also occur near sites for biological waste and water treatment as well as near industrial farms.

- Health effects from biological particles (irritative, allergic, toxic, infectious) are highly likely. However, dose-effect relationships and thresholds are not known.

Source considerations: Primary biological particles

- SOA and SOCs: Secondary organic aerosols (SOA) are formed from VOCs and SOCs as a result of gas-particle conversion in the atmosphere.

- SOCs form in the oxidation of VOC or are directly emitted from anthropogenic (e.g. pesticides) or biogenic (e.g. paraffins) sources.

- SOA shows the most complex chemical composition of all particles; only about 20-30% are identified on a molecular level.

- Many of the substances involved (PCAs, functionalized organics) are toxic and pose health risks.

- The total SOA concentration is still difficult to quantify.

- The atmospheric behaviour of SOCs differs from that of VOCs in that they occur and are processed or transported in two phases (grasshopper-effect).

Source considerations: SOA and SOCs

- Not only mass but also chemical composition, size, shape, surface properties, #densities, morphology, reactivity in biological media and bio-persistence determine the health effects of particles.

- An important point for future research is the identification of critical components and to unravel the correlations between different properties of aerosols with the endpoints of health effects, both epidemiological and toxicological, and to develop and validate the necessary (routine) measuring technique.

- BC or soot is still in the focus. Recent evaluations by EPA and WHO conclude that it is probably not the soot kernel itself but rather the complex chemical composition of surface adsorbats with different toxicity that effect health. Synergisms with exhaust gases can also not be excluded.

Effect related metrics

Parameter	C(street canyon) / C(urban background)
PM10	1.3 : 1
BC	3 : 1
NO	5 : 1
Particle # (30 nm)	10 : 1

W. Birmili: Meteorolog. Z. 22(2) 195-211 (2013)

Indicators for dominating traffic emissions

- Already now national networks exist in which measurements of particle properties beyond the currently legal requirements are being made.

  Example:

  GUAN: German Ultrafine Aerosol Network (since 2008)

- Measurements of

  -- BC

  -- size distributions

  -- # concentrations

- Hypothesis: There are particle metrics that better correlate with health effects than PM10 or PM2.5
- Such metrics include: Soot (BC), UFPs (<100 nm), surface area, # concentrations, organic constituents (PACs, nitroaromatics), transition metals (Cu, Zn), endotoxins. They hence involve physical, chemical and biological properties (in single or combined applications).
- The techniques to establish new metrics are partly available but need further development, deployment and field tests.
- To achieve an acceptance of alternative particle metrics epidemilogical studies should be performed, in which health effects are correlated with these metrics as well as with PM10, PM2.5 etc.

Conclusions

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