Outlook

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1. General

Atmospheric aerosols are important for many atmospheric processes. The liquid or solid particles provide surfaces for condensation as well as for chemical reactions of gaseous and non-gaseous atmospheric constituents. Inside a bulk particle the considerably higher density enables conversion processes at much higher concentration (and conversion rates) than in the gas phase, and moreover facilitates the transport of trace material over large distances. Particles affect the optical properties of the atmosphere. They form nuclei for particle growth and cloud droplet or ice particle formation and contribute to the self-cleansing mechanisms of the atmosphere through wet and dry deposition. While being present as trace constituents only, the high surface-to-volume ratio of airborne particles enhances the effects particles may have on substrates, specifically on human body tissues and impacting human health.

The contributions collected in this compendium demonstrate the wide variety of topics that need to be covered in order to respond to the challenges posed by the presence of fine particles in the atmosphere. While focusing on research performed in Austria, the issues of the current state of scientific discussions are reflected in general.

2. New directions

Challenges for research typically arise from societal needs as much as from the scientific progress itself. Some of the open questions in aerosol research have been addressed in the previous sections of this report.

European legislation requires member countries to comply with PM10 air quality standards (max. 35 exceedances – 25 according to the somewhat stricter legislation in Austria – of 50 $\mu g/m^3$ as a daily mean value, and an annual mean of 40 $\mu g/m^3$) in order to safeguard the health of the European population. Ambient monitoring needs to be provided by administrative bodies, and in the case of exceedance action plans need to be established. This routine exercise would not require scientific support. Scientific questions to be addressed, however, are rather posed by the allowed exemptions, i.e. quantifying the contributions of natural sources. Exceedances due to contributions from such sources, according to EU legislation[1], may be subtracted when assessing compliance if they can be determined with sufficient certainty.

1 Directive 2008/50/EC of the European Parliament and of the Council.

This requires, on the one hand, consistent and precise methods to determine the contribution of natural aerosols (e.g. Saharan dust, sea salt), which cannot be controlled in principle. On the other hand, the protection of citizens requires to study in more detail to which extent such aerosols remain health relevant, as health effects may warrant additional efforts in reducing anthropogenic pollution. Soluble particles potentially may carry less risk, as they are immediately being resorbed in the human body unless they contain an insoluble core.

Improvements of metrics with regard to health relevant parameters will constitute a future challenge in general. PM2.5 has been recognized already as being more relevant to health than PM10, and thus is also subject to limits. The EU set a standard of 25 µg/m³ as an annual mean (valid from 2015), which does not fully address proven health risks (Ballester et al. 2008) and is lacking a short term limit (Neuberger et al. 2007). Possible other metrics, which have not seen sufficient scientific confirmation yet, are the particle number and surface, the insoluble fraction of aerosols, (certain) organic compounds, aerosol acidity, and heavy metals.

The development of nanotechnology and the engineering of nanoparticles have been discussed as a potential future threat. Long multiwalled carbon nanotubes showed similar changes in animal experiments as naturally occurring asbestos fibers (Poland et al. 2008, Takagi et al. 2008), indicating additional risk due to uptake of engineered nanoparticles. While being of considerable concern for indoor environments and an issue of workplace safety, an extrapolation to all nanomaterials and the environment in general does not seem to be justified. In ambient conditions, considerable dilution of such new engineered nanoaerosols will occur and thus concentrations likely far too small to become relevant compared to existing ultrafine particles, such as fresh combustion aerosol.

Future attempts to understand the effects of PM pollution on human health will need to, more strongly, consider individual exposure. It will be of interest to understand why, under the conditions of often strikingly different concentrations indoors compared to outdoors, outdoor air influence still is discernable even if people spend only a fraction of their time outdoors.

Another scientific challenge will derive from changing exposure patterns over time, e.g. regarding cigarette smoke. While reducing exposure to passive smoke in offices, public buildings and restaurants improves health conditions, it will become more difficult to assess the influence of effects related to outdoor air, combined effects of pollutants from outdoor and indoor sources and compare studies performed at different times. Positive developments in the indoor environment may thus add to the number of confounders to be separated in epidemiological studies, adding to the need for more detailed exposure assessment.

The ever-increasing anthropogenic impact on natural cycles (Haberl et al. 2007) also poses challenges in terms of aerosols. Aerosols may be carriers of toxic substances, pathogens, or of radioactive material. With the appropriation of natural processes by humans in the era of the anthropocene (Steffen et al. 2007), not only the scientific interest of understanding natural processes needs to be satisfied, but also the cause-effect relationships of certain human activities require clarification. Furthermore geo-engineering impacts as well as side-effects need to be isolated at a level of sufficient confidence.

The importance of aerosols on the global radiation budget has been recognized already in the previous IPCC assessment reports. A major drawback in properly assessing the topic also with regard to international agreements, in order to reconcile short-term and long-term climate targets, consists of the limited scientific knowledge to translate emission abatement into measures of climate protection. Quantifying the aerosol effects and reducing the huge uncertainties associated will be urgently needed.

3. The role of science in Austria

Society's challenges as outlined above can and will be the subject of future scientific efforts. With the demand directed to human health on the one hand, and climate related studies on the other hand, the need for monitoring sites also extends towards urban as well as background stations (the latter also covering situations of health relevant background aerosol). While routine monitoring is not a task of science, KRL in a vision paper focuses on measuring sites in the city of Vienna itself, and on the Sonnblick observatory at an elevation of 3105 m a.s.l – the former predominantly with respect to human health impacts, the latter to assess background conditions including the global background considered relevant for climate related questions. Both sites are well established to also support instrumental development.

Further functions, effects and uses of aerosol may come up in the future. Tasks can hardly be predicted in detail but may be derived from events in the past. Examples include high altitude aerosol from a volcanic eruption with possible effects on air traffic safety, as measured on Sonnblick observatory during the Eyjafjallajökull eruption in 2010, or even questions about extraterrestrial prebiotic or life signs, with aerosols as carriers and particles being transported across extremely life-adverse environments. Based on the successful previous collaboration of the respective institutions and researchers, Austrian science will be able to participate in as well as lead international atmospheric aerosol research.

4. References

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