Ultrafine Particles - Sources, Effects, Risks and Mitigation Strategies

Conference report of the third EFCA-symposium, Brussels, 26-27 May 2011

What are the right metrics for Particulate Matter?

EFCA's third symposium on Ultrafine particles was conducted on 26 and 27 May 2011 in Brussels. The series, under the continuous chairmanship of GUS president and KIT Program Director Karl-Friedrich Ziegahn since 2007 now provides a very informative mix of contributions which add to the general body of knowledge as well as a number of review papers by experts who try to construct consistent pictures which explain all observations within one of the sub-themes.

At the third symposium time seemed to be ripe to reconsider the ongoing development of PM policy with its gradual development of regulating smaller size fractions and consider alternatives in a discussion on the Metrics of Particulate Matter.

Directions of investigations

From the about forty research papers presented a considerable number reflected the progress made in the collection of actual data on ambient concentrations of the smallest fractions of particulate matter, as well as their chemical composition. Apart from the conventional gravimetric approach for the various size fractions, data include particle number counts and lung deposited surface area. These presentations were complemented with reports on emissions measurements on specific sources, such as traffic and industrial sources. In addition, modelling studies which may connect both information streams were presented.

While epidemiological studies provide convincing evidence for health risks of particulate matter in relation to particle size, the mechanisms behind it are still largely unclear. Several experimental investigations, often on cell systems, contributed to our understanding of *in vivo* effects. Some specific mitigation options for different circumstances were presented and followed by a group of presentations of new insights in the present metrics approach.

Can we do without source-specific metrics for PM?

Professor *Martin Williams* (Kings College, London) as the first Keynote speaker set the tone by contrasting the increased understanding of air quality in general (and its improvement in Europe) during recent decades with the less favourable situation when PM is concerned. He pointed to the fact that in spite of existent policies on nearly all PM components we do not know which ones of these are not toxic. Therefore, these policies could, at least in part, be ineffective in improving public health. There is no full understanding of why PM levels did not continue to decrease during the last decade. There is some evidence that traffic-related primary PM is more toxic than other components; however, a corresponding legal target for ambient air has not been set (and Member States may not want another target with corresponding monitoring and reporting obligations).

The second keynote speaker, *Xavier Querol*, (IDAEA-CSIC, Barcelona) addressed the problem of what should be monitored. This was based on an in-depth analysis of correlations between the various components of air pollution and with the objective to identify a source specific component for traffic which is already monitored. The results of his team included the following conclusions:

- PM_{10} may sometimes correlate with a traffic component like black carbon (BC) but not at every time and place
- CO, NO_2 and NO sometimes correlate with BC but this is not always the case
- Particle numbers sometimes correlate with BC but this is not always the case

- The correlation between particle numbers and traffic intensity varies considerably

He concludes that PM10 (mixture of source contributions) and BC (as a source tracer for traffic and biomass burning) offer a good combination for air quality monitoring, in particular because exceedances are usually in traffic hotspots.
A second approach he described was based on quantitative receptor modelling. When applied to data sets of PM speciation the possibility arises for setting limit values for PM contributions from road traffic. However, BC measurements yield similar information, with real time data, low operational cost and an easily standardized method.
Another conclusion from his work is that current limit values for PM_{10}/$PM_{2.5}$ and NO_2 do not protect against exposure to high UFP episodes and that separate UFP measurements (<45 nm) may be necessary, in addition to BC.

Metrics of particulate matter

Both keynotes set the scene for the session addressing the Metrics of Particulate Matter. It started with a review paper by *Nicole Jansen* (RIVM, Bilthoven) in which she questioned the general mass-based regulation (PM_{10}, $PM_{2.5}$). She pointed to evidence that combustion related particles are more harmful than particles from other sources and expressed the need for an additional PM-indicator which could make the impact of traffic related measures visible; as such she proposed Black Carbon Particles (BCP).
An evaluation of BCP produced several arguments in favour:

- A set of optical measurement techniques (Black Smoke, BS; Black Carbon, BC; Absorption, Abs) is available which produce results that highly correlate. In addition, the thermal technique to measure Elemental Carbon (EC) has been used in relevant studies, though it produces more variance
- A summary of pooled acute effects from several studies showed significantly stronger effects for BCP than for PM on mortality as well as on hospital admission following cardiac complaints; for respiratory complaints the effect varied; the higher risk for BCP is more pronounced when evaluated by means of two-pollutant models for BS
- In a set of four pooled cohort studies (mortality) the Relative Risk for EC was 5 to 14 times higher when compared to $PM_{2.5}$
- Roadside increments of $PM_{2.5}$ are dominated by EC.

As an example a hypothetical traffic management plan which would reduce $PM_{2.5}$ by 1 $\mu g/m^3$ and EC by about 0.5 $\mu g/m^3$ was presented. It was estimated to result in an increased life expectancy of 21 days for the effect on $PM_{2.5}$; when considering the higher Relative Risk which was found in the cohort studies for EC the gain in life expectancy was estimated to amount at least 3 months.
Because pulmonary complaints may rather be caused by PM_{10}/$PM_{2.5}$ BCP is recommended as a valuable, additional air quality indicator in order to avoid the present serious underestimation of the benefits from traffic abatement measures.

These conclusions were supported by air quality data reported by *Sef van den Elshout* (Environmental Agency Rijnmond, Rotterdam). His measurements show that BCP has the strongest correlation with traffic density, with NO_x as second best; PM_{10}, $PM_{2.5}$ and NO_2 show different patterns. The correlation could be further improved by taking into account the atmospheric stability during the day.
A first evaluation of the effects of Rotterdam's Low Emission Zones revealed a 1% reduction in PM_{10}/$PM_{2.5}$ levels, while BCP was reduced by about 5%. His data also reveal that $PM_{2.5}$ is even inferior as an indicator of traffic when compared with PM_{10}; this might be caused by traffic-induced re-suspension of particles. NO_x has a good correlation with traffic as well; however, the correlation is less certain because other sources contribute substantially to NO_x-levels. In conclusion, BCP is the preferred metric for evaluating traffic measures.

In a presentation by *Gaëlle Guillossou* (EDF DRH Group, Etudes Médicales, Paris) it was also argued that progressive increases in knowledge have now made the representation of particulate matter in present legislation inadequate. A consequence of this misrepresentation becomes apparent when considering the details of the integrated assessment model RAINS/GAINS, developed and implemented by IIASA, which is the politically agreed tool for estimating benefits of clean air policies in the EU and in wider Europe. Present estimates by GAINS (and EMEP) are made for the mass-based parameters PM_{10}/$PM_{2.5}$. It means that in new policy development the projected benefits of policies are being realised by selecting measures for all sources which contribute to the mass of PM in the atmosphere. She then explained why such policies are not likely to deliver the reductions in health risk which are calculated.

PM is primarily composed of three classes of components:

- Secondary inorganic aerosols (SIA; sulphates, nitrates) which result from atmospheric oxidation of their precursors SO_2 and NO_x; SIA toxicity, however, is low at ambient levels; reported Relative Risks of sulphate may result from studies with less well defined particles and are generally lower than that of $PM_{2.5}$;
- Secondary organic aerosols (SOA); their precursors (NO_x, VOC) are not taken into account as a source term for PM within GAINS;
- Carbonaceous compounds (BCP, organics) which are predominantly emitted in the ultrafine size range and constitute a small percentage of the PM mass; in urban, dense-traffic areas their part in the mass of $PM_{2.5}$ is substantial. The ultrafines have the higher penetration in the deeper regions of the lungs and also have the higher toxicity, possibly through associations with polycyclic aromatics and metals.

She concluded that the present representation of PM in GAINS will overestimate the benefits from reductions of SIA precursors and does not assess adequately the benefits of measures which target traffic emissions. In addition, the grid resolution (50 km) of GAINS prevents that higher RR in urban areas are being addressed in calculations of optimised reduction policies.

P. Vanderstraeten (Brussels Environment) had compared monitoring data of car-free Sundays with days with normal traffic. It was observed that while PM-values could remain high during car-free days BCP-levels dropped to near-zero, supporting policies which target traffic-emissions. He confirmed that PM and particle number counts correlated poorly with BCP; NO_x and NO did much better while CO had an intermediate score. He concluded with the observation that local traffic emissions reductions, which are thought to be most effective in protecting human health, are often inadequate to reach compliance with the PM_{10} limit value.

Particles and Climate

The role of aerosols including fine particles in the climate system, in particular their impact on cloud formation, precipitation and radiation, was discussed in a keynote speech by *Andrew Ferrone* (KIT). He explained the difficulties to represent these interactions in global climate models and the resulting uncertainties for projections of the future climate. The regional model system COSMO-ART can be used to fill this gap and gain important information on the interactions with aerosols and climate parameters. Some case studies were presented and in one case the model showed that high levels of aerosols may shift precipitation patterns. This might be explained by the fact that high concentrations of fine particles renders a surplus of small cloud droplets with insufficient mass to precipitate. The analogy with the natural process in which Aitken nuclei (typical size around 10 nm) induce the condensation of water vapour suggests that the finest fractions of anthropogenic aerosols could play a major role in such a suppressive effect. However, longer time series need to be analysed in order to quantify the effects of such interactions on climate time scales.

Mr Saathoff described novel results on the atmospheric chemistry of aerosols as simulated in the big AIDA reactor at KIT. He studied the formation and properties of secondary organic aerosols (SOA), produced upon a reaction between α-pinene and ozone. In the oxidative atmosphere with OH radicals the SOA are not broken down but take up 10-35% additional mass. Adding coagulated soot particles in the system makes the coagulates of soot fall apart again and results in the coating of the SOA with the ultrafine soot. This process changes SOA from being particles with a net cooling effect in the atmosphere through scattering of radiation into being absorbers of radiation and net climate forcers.

EU Policy Review

In the Closing session *Andre Zuber* provided the timepath of the Commission within which new information will have to be fed in the policy process and presented the Workplan for the Air Pollution Policy Review that should result in proposals by the Commission in 2013. Key elements therein are:

- Review of the current air quality legislation including reasons for non-compliance
- Review of the current air quality limits and targets
  - $PM_{2.5}$ as required by Directive
  - Latest scientific evidence of air pollution impacts for ozone, PM_{10},**UFP**, heavy metals, PAHs, others? (with involvement of CLRTAP/WHO)
  - new targets
  - long term objectives (2020 – 2030 – 2050?)
- Possible new measures
- Links to climate change
  - e.g. co-benefits, short lived climate species, BC, minimise trade-offs
- Integration into sector-wise policies
  - transport, energy, vehicle emissions,etc
  - already 2011 (White Paper and 2050 roadmaps)
- Simplification - smart regulation - streamlining

In a subsequent Panel discussion Congress chairman *Karl-Friedrich Ziegahn* offered the support of EFCA and its associations and partners in the policy process to follow and expressed their interest to tune the research agenda to policy needs. He was happy to announce that a fourth EFCA-symposium on Ultrafine particles is to take place in 2013.

Conclusions

The key message of UFP-3 is that progressive knowledge has enabled scientists to provide a more robust basis for health protection against PM exposure. Various policies up to the present time have delivered major improvements with respect to particulate matter. There is now convincing evidence that adequate protection of public health against exposure to fine particles requires limit values which are source-specific. The imperfection of present PM-regulation in the EU and elsewhere may be largely overcome by introducing regulation for an additional, traffic-specific component of PM. Considering health risk evaluations, implementation criteria and traffic-specificity, black carbon particles (BCP) seems to be the most suitable component. A long history of BCP-monitoring by several different methods makes implementation feasible. The recent focus on BC (or CB, Carbon Black) as a climate forcer supports its candidacy.

The shortcomings may also necessitate an evaluation of present methodologies for estimating benefits of air quality policies.

It is obvious that a new approach requires a thorough evaluation with respect to its policy implications. The organisers will be happy when the recommendations above have been made timely to be taken into account in the process towards the proposals by the Commission.