Abstract. Assessments of nanoparticle exposure are needed to enable risk assessments which are needed to achieve a sustainable development of nanotechnology including public perception. Therefore an overview of measurement techniques, needed data quality, comparability, and measurement strategies is given. Additionally some results of exposure related studies are summarized. Overall it is demonstrated that an integrated approach towards nanoparticle exposure assessments in workplaces, but also in the environment is needed, despite the current published results indicating mainly release of nanoparticle agglomerates in the size range larger than 100 nm.

1. Introduction

Nanoparticles and nanoobjects, intentionally produced particles of nanoscale in three or two dimensions, have specific properties possibly altering the (eco-) toxicological potential when compared to larger particles or the corresponding bulk material. The detailed assessment of this potential risk is a prerequisite to accomplish sustainable nanotechnology since it directly influences the public perception. The risk is generally a function of potential hazard and exposure. The importance of the latter is given by (a) that no risk exists if no exposure, (b) the dose, leading to possible health effects, is directly linked to the exposure, and (c) correct exposure determination is also of importance for e.g. epidemiological studies. To assess exposure it is also necessary to clarify the areas (e.g. workplace, environment), subjects (e.g. humans, animals, ecosystems) and exposure media (air, liquid, solid) of interest.

This paper focuses on the human exposure mainly in workplace environments since highest exposure can be expected in these areas. Also, measurement technologies and strategies can be evaluated and tested in workplace environments since possible sources and hence particle material is known and can be differentiated from ambient nanoscale particles.
The currently discussed main exposure route of nanoparticles is via the airborne state by inhalation. Other discussed routes of exposure such as via the skin or gastrointestinal tract possibly leading to an uptake are currently seen as of minor importance [4] but still have to be investigated.

Two major pieces of information are necessary for the assessment of exposure and possible nanoparticle implications:

- The exposure leading to a dose
- The hazard, influenced by the particle properties

Hence, assessments of exposure to nanoparticles have a twofold task. One task is the general determination of an exposure and to quantify the ‘relevant’ aerosol property. The second task is the characterization of the nanoparticle properties since these may have been influenced or changed during the transport period after release. Any changes in these particle properties may have a significant influence on the possible hazard of nanoparticles. Spatial and time resolution of the measurements can therefore play a crucial role in the exposure determination and its evaluation.

This background puts certain demands onto the measurement techniques for airborne nanoparticles as well as the measurement strategies.

2. Measurement Techniques

Basically, various physical and/or chemical properties of nanoparticles and aerosols can be determined with especially particle size and concentration being physical properties of importance in the case of nanoparticles (<100 nm in three dimensions) and nanoobjects (<100 nm in two dimensions). For a decision on the instrumentation to be used for exposure measurement the scheme shown in Figure 1 was introduced in Borm et al. [2]:

This scheme indicates the different steps of possibilities when choosing the instrumentation for exposure assessment. Certainly, the ideal sampling for exposure assessment would be a personal sampler measuring and reporting continuously the physical and chemical characteristics of all single particles (agglomerates or primary particles) as well as their concentrations entering the measurement system. Since this is not possible, decisions have to be made based on the task to perform and

![Figure 1. Scheme of particle characterization for exposure measurements [2].](image-url)