Characterizing surface-area of airborne nanostructured particles

Sébastien Bau, Olivier Witschger, François Gensdarmes, Dominique Thomas

CHARACTERIZING SURFACE-AREA OF AIRBORNE NANOSTRUCTURED PARTICLES

Sébastien Bau[1,2,3*], Olivier Witschger[1], François Gensdarmes[2], and Dominique Thomas[3]

[1] Institut National de Recherche et de Sécurité, Laboratoire de Métrologie des Aérosols
Avenue de Bourgogne, BP 27, F-54501 Vandoeuvre Cedex — France
Tel: +33-383509890; Fax: +33-383508711; E-mail: sebastien.bau@inrs.fr,
Tel: +33-383509838; Fax: +33-383508711; E-mail: olivier.witschger@inrs.fr
[2] Institut de Radioprotection et de Sûreté Nucléaire, Laboratoire de Physique et de Métrologie des Aérosols, BP 68, F-91192 Gif-sur-Yvette — France
Tel: +33-169085506; Fax: +33-160193061; E-mail: françois.gensdarmes@irsn.fr
[3] Laboratoire des Sciences du Génie Chimique, Groupe Sisyphe,
1, rue Grandville BP 20451, F-54001 Nancy Cedex — France
Tel: +33-383175197; Fax: +33-383322975; E-mail: dominique.thomas@ensic.inpl-nancy.fr

Keywords: *nanostructured particle; surface-area*

Nanostructured particles (NP) are particles having structures with a characteristic length below 100 nm which exhibit nanostructured-influenced properties [1]. For some materials, studies have shown that NP are more harmful than micro-scale particles at similar mass concentrations. Consequently, conventional exposure monitoring methods that typically rely on characterizing the mass of airborne particles do not seem appropriate to NP. The characterization of airborne exposure to NP is currently hampered by the lack of suitable and validated instruments and methodologies. Their development to assess exposure to engineered airborne NP is among the top research needs within the next few years [2].
Although there is not yet sufficient evidence to clearly identify which aspect of airborne NP should be measured (mass, number, surface-area concentration or something else) to determine health effects, current published informations show that surface-area could be an appropriate property for exposure characterization when lung inflammation is involved [3].
As a first step, the present paper attempts to explore the different approaches that might be applicable for characterizing surface-area of airborne NP. Figure 1 shows the different theoretical ways that have been identified.
In the BET method, the specific surface-area a_M, defined by the ratio of the geometric surface-area to the mass of particles, is derived from the gas adsorption characteristic on the particles. Nitrogen is widely used as the adsorbed gas. The surface-area characterized is the one accessible to the nitrogen molecules. This method does not offer on-line capabilities and is not well suited for characterizing airborne surface-area of NP at low concentrations. However, it is used extensively in toxicological studies for the characterization of powders.
Electron microscopy analysis provides different off-line methods through the detailed information of collected NP (primary particle size d_{pp}, number of primary particle N_{pp}, fractal dimension D_f, projected area diameter d_{AP} etc.). However, electron microscopy analysis is time consuming and has stringent collection and preparation requirements.
Another approach is based on a combination of integral and independent measurements obtained simultaneously by direct-reading instruments (i.e. mass, number, current etc.). By assuming some of the distribution parameters the surface-area can be estimated with some knowledge of the response of the instruments.
From size distribution measurements, the surface-area weighted distribution can be calculated. However, the transformation of the size distribution requires assumptions about particle morphology and/or density.

Few on-line techniques have been designed to measure surface-area of airborne particles. These techniques all rely on attachment rate of airborne markers (unipolar ions or radioactive atoms) to particles. The measured property is the fraction of the geometric surface-area, which interacts with the airborne markers. For this reason, the term of active surface is used.

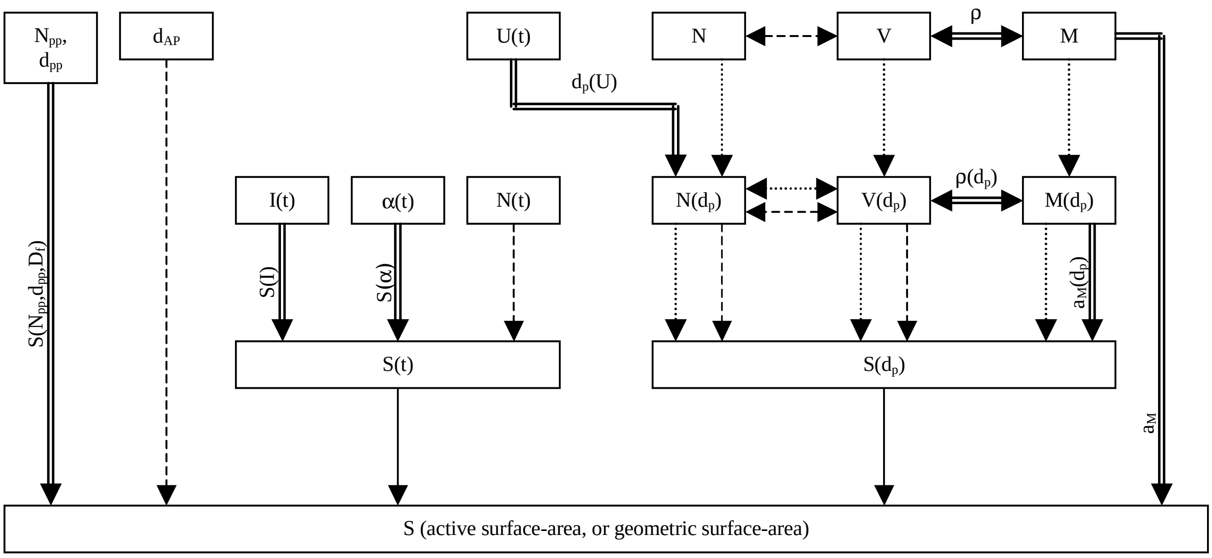

Fig. 1 : Schema of the different theoretical ways for measuring surface-area of airborne NP. Dashed lines : hypothesis on particle size and/or shape. Dotted lines : hypothesis on particle-size distribution. Double solid lines : theoretical or empirical relationship and/or experimental property between two parameters.

This analysis suggests that several approaches yield the determination of different surface-areas. However, most of them rely on strong hypotheses regarding airborne NP properties. Moreover, several methods are limited in their widespread application in the workplace. Most of the on-line techniques are recent and there is a lack of reliable data on the performance and on the parameters that could affect the response of the instruments.

A next step of this study is to experimentally explore some of the identified approaches in laboratory conditions, but relevant with the ones encountered in the workplaces (size, morphology, concentration, chemical composition etc.). Specific experiments have been designed to evaluate and to compare recent developed techniques for estimating on-line surface-area of airborne NP against surface characterization by BET method and/or electron microscopy analysis.

References

[1] Oberdörster, G., A. Maynard, K. Donaldson, V. Castranova, J. Fitzpatrick, K. Ausman, J. Carter, B. Karn, W. Kreyling, D. Lai, S. Olin, N. Monteiro-Riviere, D. Wahrheit and H. Yang, Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy, *Particle and Fibre Toxicology* **2**:8 (2005).

[2] Maynard A.D., Aitken R.J., Butz T., Colvin V., Donaldson K., Oberdörster G., Philbert M.A., Ryan J., Seaton A., Stone V., Tinkle S.S., Tran L., Walker N.J., Warheit D., Safe handling of Nanotechnology. *Nature* **444**, 267-269 (2006).

[3] Maynard, A. D., Nanotechnology: The Next Big Thing, or Much Ado about Nothing? *Ann. Occup. Hyg.* **51**(1) : 1-12 (2007).