An effort towards understanding the sources of impurities in generating nanoparticles via liquid-phase methods

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Introduction: Generating nano-sized materials of a controlled size and chemical composition is essential for the manufacturing of materials with enhanced properties on an industrial scale, as well as for research purposes, such as toxicological studies. Among the generation methods for airborne nanoparticles (also known as aerosolisation methods), liquid-phase techniques have been widely applied due to the simplicity of their use and their high particle production rate. The use of a collison nebulizer is one such technique, in which the atomisation takes place as a result of the liquid being sucked into the air stream and injected toward the inner walls of the nebulizer reservoir via nozzles, before the solution is dispersed. Despite the above-mentioned benefits, this method also falls victim to various sources of impurities (Knight and Petrucci 2003; W. LaFranchi, Knight et al. 2003). Since these impurities can affect the characterization of the generated nanoparticles, it is crucial to understand and minimize their effect.

This study aims to quantify the impurities and determine their sources through the physical characterization of nebulized water nanoparticles.

Methods: We designed an experiment in which different metrics of the nebulized water nanoparticles, including size, number concentration and volatility, were assessed. Deionised (DI) water was chosen for this study because the size distribution of the nebulized particles measured by a Scanning Mobility Particle Sizer (SMPS) confirmed that this water carried the least level of impurities compared to the two other pure water types available (distilled and HPLC-grade water).

Firstly, the residues from the nebulizer reservoir and nozzle were studied as a potential source of contaminants. For this purpose, the reservoir and the nozzle were washed with DI water several times and sonicated for ten minutes to determine if this could reduce the impurities.

To investigate the role of the volatile organic content of nebulized DI water nanoparticles in determining the level of impurity, we designed a second experiment in which a thermodenuder was used to study the effect of temperature on the size distribution and number concentration of the nebulized water particles. To do so, a Condensation Particle Counter (CPC) and a SMPS were used to measure the number concentration and size distribution of the particles before and after they passed through the thermodenuder.

Results: Comparison of the size distributions, both before and after the washing and sonicating of the nebulizer, showed a decrease in the median diameter (from 22 to 17 nm) and number concentration (from 1.52e4 to 6.1e3 particles/cm^3) of the impurities.

In the second experiment, an incremental increase in temperature from 25 ˚C to 260 ˚C led to a decrease in number concentration, as a result of the evaporation of small water particles. However, not all of the particles evaporated, even at high temperatures. According to Figure 1, although both total number concentration and mode diameter of the nebulized water particles decreased due to the high temperature (from 963 to 508 p/cm^3 and from 42.9 to 37.2 nm, respectively), it can also be seen that a number of these particles were not volatile organic particles and did not evaporate.

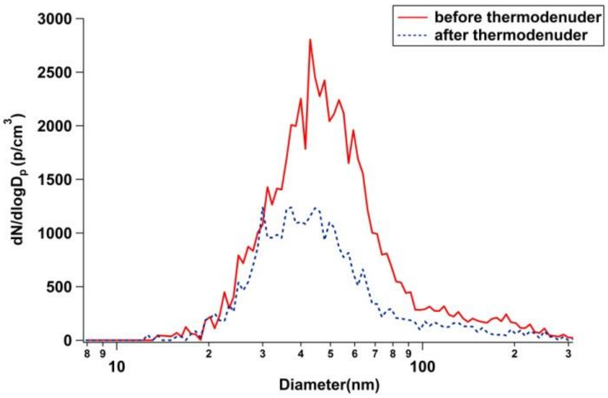

Figure 1- Size distribution measured before and after the thermodenuder at 200 ˚C

Conclusions: The results confirmed that not all of the impurities were volatile organics stemming from the nebulized water. The other possible sources of contaminants were residues inside the nebulizer, which could be removed by washing and sonicating the nebulizer reservoir and nozzle (in this case, a 23% decrease in size and 60% decrease in total number concentration) and also leaching from the inner walls of the container used to keep and carry the DI water.

Knight, M. and G. A. Petrucci (2003). "Study of Residual Particle Concentrations Generated by the Ultrasonic Nebulization of Deionized Water Stored in Different Container Types." Analytical Chemistry **75**(17): 4486-4492.

W. LaFranchi, B., Knight, M. et al. (2003). "Leaching as a source of residual particles from nebulization of deionized water." Journal of Aerosol Science **34**(11): 1589-1594.