A novel methodology to study nanomaterial stability using single particle ICP-MS

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Project description: Current and future exploitation of nanomaterials in a wide variety of products and applications means that they are released in the environment despite uncertainties about their potential toxicity. Dissolution and consequent release of toxic ions is a well-known mechanism of toxicity, however assessing the details, such as the kinetics of nanoparticle dissolution and the influence of media composition are not trivial. Other factors that likely influence dissolution are nanoparticle size and shape, since both properties control surface area, as well as the nature of capping agents and presence of a coating of organic molecules derived from the environmental media. To date, a major challenge in all studies of nanomaterial dissolution has been how to distinguish the ionic from the particulate form, as chemical analysis methods cannot differentiate between the two, and characterisation methods that provide information on the presence (size) of nanoparticles cannot distinguish the ionic form. Recent advances in the analytical method Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to allow detection and quantification of single particles (sp) as well as total mass of a metallic species offer an exciting new direction for the detailed analysis of the intrinsic nanoparticles and extrinsic or environmental factors that drive nanomaterial (NM) dissolution. This PhD project will apply sp-ICP-MS to assess the kinetics of dissolution of silver, zinc oxide and copper oxide nanoparticles under various environmental conditions to assess the drivers of dissolution and identify factors that could be modified to control dissolution potential and thus toxicity.

The overarching hypothesis being assessed in this project is whether it is possible to utilise sp-ICP-MS to characterise NM dissolution kinetics, and the effects of various solution conditions (e.g. ionic strength, pH, presence of environmentally relevant macromolecules) and NM characteristics (e.g. size and size distribution, shape, surface coating etc.) on the dissolution kinetics. In sp-ICP-MS, liquid samples / extracts containing metal-based NMs are introduced into the ICP-MS producing a plume of metal ions in the plasma torch. This plume is detected as a signal spike in the mass spectrometer from which the particle concentration in the sample can be calculated and the particle size can be estimated (although no information is available about the actual particle shape). Performing this method in a time-resolved or temporal manner will allow changes in the particle concentration and particle size to be plotted as a function of time, and comparison of the rates of change (dissolution) under different exposure conditions to be made. Comparative temporal imaging data, e.g. via Transmission Electron Microscopy and particle shape determination (e.g. via Atomic Force Microscopy), will provide a complete description of how the NMs dissolve and the factors influencing dissolution, for example, whether one crystal "face" or shape/dimension is particularly vulnerable to dissolution (e.g. for rods if dissolution occurs from the ends or along the whole length). This information will provide valuable information for re-design of NMs that facilitate or prevent dissolution depending on the desired application (so-called safer by design NMs) and will also provide valuable input to regulation of NMs by enabling prediction of dissolution rates as a function of the physic-chemical properties of the NM and the exposure conditions.

The project combines NM characterisation using ICP-MS with imaging via TEM and AFM and thus a strong physical / physic-chemical background is preferred.

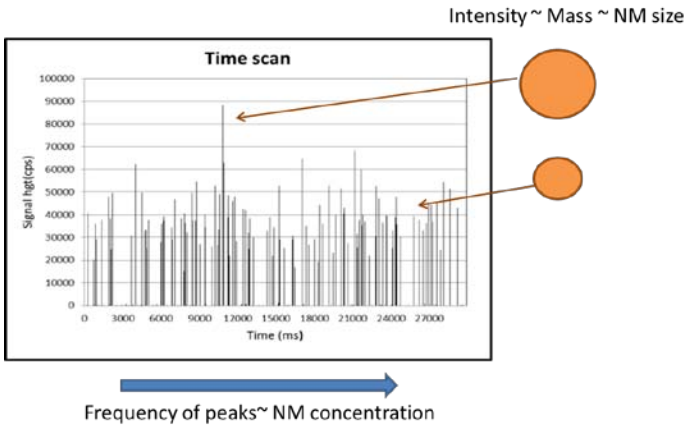

Figure: Schematic of sp-ICP-MS and the extraction of particle concentration and particle size from the spectrum.

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