UNIVERSITY OF BIRMINGHAM

NERC SCIENCE OF THE ENVIRONMENT

Project title: Single particle ICP-MS applications in nanomaterial safety
Project code: SP-ICP-MS & nanosafety
Host institution: University of Birmingham (UoB)
Theme: Environmental Health Sciences
Key words: single particle ICP-MS, nanomaterials; physico-chemical properties
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Overview:

Nanotechnology offers incredible opportunities, in the form of novel materials and processes capable of solving problems such as energy capture and storage, climate change mitigation, minimisation of the use of finite resources, but also significant challenges due to the potential of these novel materials to present unknown and unforeseen behaviour and toxicity. Limitations in a full assessment of the environmental safety of nanomaterials (NMs) stem from analytical difficulties, in relation to identification, characterisation and tracking of engineered nanosized objects in aqueous media and particularly in complex environmental matrices (sediment & soil) containing naturally occurring particles of similar sizes. A further level of complexity is introduced by the need to trace NMs within individual organisms, or even cells.

Single Particle ICP-MS is emerging as a method with enormous potential to address the need for fast characterisation of nanomaterials where both chemical and physical (particularly particle size and particle numbers) characteristics are essential; there is a major drive to fully develop methodologies capable of addressing the European Commissions regulatory definition of NMs. SP-ICP-MS is an extremely novel method, which has emerged in the past five years, and although robust, it is currently only tested with a small number of NMs. Further development will expand and augment the capability of SP-ICP-MS and transform it into a powerful analytical tool for assessing and potentially monitoring, nanomaterials in real environmental matrices.

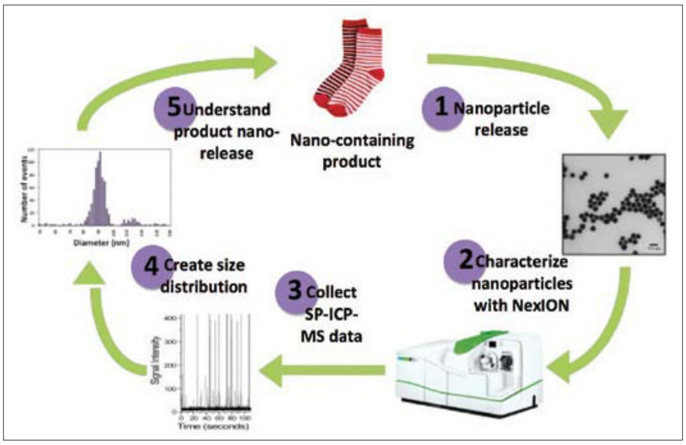

Figure 1: *Principles of characterizing nanoparticles using single particle ICP-MS analysis with NexION 300Q system.*

Methodology:

Novel approaches designed within the project will revolve around bio-nano interactions and advanced, complex characterisation as follows :

Task 1) Advancement of SP-ICP-MS towards single cell-ICP-MS, where the ICP-MS technology is used to enable quantification of NMs in individual cells and potentially even in specific sub-cellular organelles; this is a risky and novel approach that has never previously been tested. For this task reference cell lines (primarily A549, widely used as an in vitro model for a type II pulmonary epithelial cell model) and Au and Ag nanoparticles in a range of sizes, will be tested. In house synthesis methodologies that offer good size control are likely to be used to minimise project costs and offer the student additional training.

Task 2) Comparisons of SP-ICP-MS with other particle quantification techniques, such as FFF (field flow fractionation) with emphasis on comparative size and mass detection limits, and with other methods for quantification of nanoparticle uptake such as Flow cytometry and microscopy (EM/confocal), and investigation of the effects of different environmental matrices on sensitivity. Reference Au and Ag nanoparticles will be used for this task.

Task 3) Effects of shape and surface functionalization on the accuracy of detection by SP-ICP-MS. Other than the reference particle mentioned above, TiO2 and CuO NMs in sphere and rod shapes will be tested and a range of surface modifications (giving both positive and negative surface charge and both steric and electrostatically stabilised Ag NMs will be tested).

Training and skills:

The University of Birmingham (UoB) offers doctorate students a well structured experience, by placing them under an experienced lead supervisor and one or more co-supervisors, the latter offering significant additional technical expertise. UoB requires all external supervisors to be qualified scientists having a relevant PhD or MSc with significant research experience. Case partner policies and supervisor selection herein reflect this. UoB monitors supervision quality through both informal and formal means (regular student/supervisor(s) meetings and biannual supervisory boards involving a committee assessment of student progress) with remedial action taken as necessary.

Training in core methods for the project, such as synthesis and characterisation of nanomaterials, will be provided from the supervisory team at UoB. Advanced training in imaging and chemical analysis will be provided in house (UoB) and single particle ICP-MS by the CASE partner (see below).

Where synergies are possible (e.g. in recruitment) this CASE studentship will be promoted and managed in parallel with CENTA, Central England NERC Training Alliance: (http://www.birmingham.ac.uk/generic/centa/about/index.aspx), a NERC funded doctoral training consortium.

Partners and collaboration (including CASE):

The case partner is PerkinElmer (PE), a major international manufacturer of scientific instrumentation. PE is committed to scientific innovation and has helped to significantly improve human and environmental health around the world. PerkinElmer holds 3,300 patents and operates over 25 centres of excellence committed to R&D. Using critical knowledge and expertise, the company's innovations support their customers to make better decisions. The company offers extensive training solutions based on their instrumentation, see: http://www.perkinelmer.co.uk/training/default.aspx

Further reading:

PerkinElmer offer a number of free access documents on single-particle ICP-MS at their web site:

http://www.perkinelmer.com/CMSResources/Images/44-157257NanoSingleParticleICPMSTheory.pdf

http://www.perkinelmer.com/CMSResources/Images/44-140557APP_NexION300Q-GoldNanoparticlesSP-ICPMS.pdf

http://www.perkinelmer.com/CMSResources/Images/44-158789APP_NexION-350Q-Silver-Nanoparticles-Dissolution-Kinetics_011750_01.pdf

A short selection of high impact papers from the academic supervisors:

Croteau, M.-N.; Dybowska, A. D.; Luoma, S. N.; **Valsami-Jones, E.**, A novel approach reveals that zinc oxide nanoparticles are bioavailable and toxic after dietary exposures. Nanotoxicology 2011, 5 (1), 79-90.

Khan, F. R.; Laycock, A.; Dybowska, A.; Larner, F.; Smith, B. D.; Rainbow, P. S.; Luoma, S. N.; Rehkämper, M.; **Valsami-Jones, E.,** Stable Isotope Tracer To Determine Uptake and Efflux Dynamics of ZnO Nano-and Bulk Particles and Dissolved Zn to an Estuarine Snail. Environmental science & technology 2013, 47, 8532-8539.

Lynch, I., Weiss, C, **Valsami-Jones, E.**, A strategy for grouping of nanomaterials based on key physicochemical descriptors as a basis for safer-by-design NMs. Nano Today 2014, 9, 266-270.

Misra, S. K.; Dybowska, A.; Berhanu, D.; Croteau, M. N. l.; Luoma, S. N.; Boccaccini, A. R.; **Valsami-Jones, E.,** Isotopically modified nanoparticles for enhanced detection in bioaccumulation studies. Environmental science & technology 2011, 46 (2), 1216-1222.

Monopoli, M.P., Walczyk, D., Campbell, A., Elia, G., **Lynch, I.,** Baldelli Bombelli, F., Dawson, K.A. Physical-Chemical aspects of protein corona: Relevance to in vitro and in vivo biological impacts of nanoparticles, Journal of the American Chemical Society, 2011, 133, 2525-2534.

Further details:

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