Environmental toxicity and aquatic food chain transfer of metallic nanoparticles

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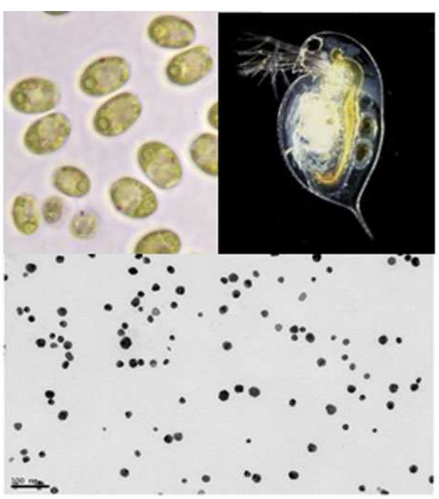
Introduction:
Engineered nanoparticles (NPs) are used widely in many commercially available products and their use is increasing rapidly worldwide. Exposure of the consumer and the environment to these materials is therefore increasing, yet the environmental impacts of such exposure are not clear. Although there is an increasing number of studies on the bioavailability and toxicity of aqueous NPs, such ecotoxicological research has focused on the exposure of individual organisms, often at environmentally unrealistic concentrations. Critically, there has been no in depth examination of the movement, behaviour and toxicity of NPs through a food chain. The expected and predicted exposure of humans is highest for silver (Ag)-NPs, which are the most commercially produced and widely used NP type, particularly due to their potential anti-bacterial properties. Contamination of wastewater with Ag and Ag-NPs has been detected confirming that NP release into the environment is already a problem. Recently, work by us demonstrated that Ag derived from Ag-NPs can be transferred via diet in an aquatic food chain, from green algae to grazing Daphnia (McTeer et al 2014). We also found that Ag exposure inhibited the feeding rate of the animal due to release of ionic Ag, and results indicated that chemical speciation of the metal is an important determinant to toxicity. In addition to such chemically/physically synthesised NPs, metallic NPs can be generated by biological activity. Specifically, metal-reducing bacteria are a source of metal oxide NPs that can be produced in commercially viable quantities (Lloyd et al 2011; Pattrick et al 2013) and research at Manchester has characterised the generation of these microbial NPs (Byrne et al 2011). Different NPs from different sources will vary in their physico-chemical properties therefore there is a need to examine the potential environmental impacts of these various types of metallic NP.



The green microalga *Chlamydomonas reinhardtii* (top left) and the zooplankton grazer *Daphnia magna* (top right). Electron microscopy image of silver nanoparticles (bottom).

Project Summary
This project will build on our previous work by characterising the mechanisms of NP accumulation in detail in order to assess the potential environmental risks and provide an understanding of the movement of such metallic pollutants through an aquatic ecosystem. The project will focus on a model aquatic food chain starting with NP uptake into algae through to fish via grazing zooplankton. Secondly, the project will compare different NP types (including Ag-NP, TiO_2-NP, Fe_3O_4-NP etc) which vary in physico-chemical property and in method of manufacture, either produced chemically or biologically. The student will use commercially available NPs and biologically generated NPs made in the lab, at environmentally relevant concentrations and conditions to perform exposure experiments. These studies will utilise model algal, zooplankton and fish species, under controlled water chemistry parameters, to quantify uptake of NPs, metal dissolution, and toxicity. Feeding experiments will determine diet-borne accumulation and toxicity of NPs. Techniques such as ICP-MS/ICP-AES coupled with filtration, dynamic light scattering and electron microscopy will be used to determine NP characteristics, and quantification and localisation of NPs into cells and tissues. In

addition to the facilities at Manchester, the student will make use of external facilities such as FENAC (Facility for Environmental Nanoscience Analysis and Characterisation) and the Diamond Light Source for further localisation and chemical analysis of NPs. Finally, in addition to physiological indicators of toxicity, the student will use molecular and metabolomic techniques to develop and test novel biomarkers of NP exposure which could be used as alternative toxicology indicators to reduce the need of empirical testing.

The student will receive training in a wide range of multidisciplinary approaches and skills including physiology, microbiology, microscopy, spectroscopy, and molecular biology. The student will be based within the Faculty of Life Sciences (FLS) but will also work with researchers based in the Williamson Research Centre for Molecular Environmental Science in the School of Earth, Atmospheric and Environmental Sciences (SEAES). The main supervisor will be Jon Pittman, who currently supervises a number of algal and plant biotechnology/metal stress-related projects (BBSRC- and international-funded PhD studentships, NERC-funded postdoc). He will provide training in analytical techniques, algae growth, physiology and molecular biology. Expertise will also be provided by co-supervisors Keith White (FLS), Holly Shiels (FLS), Richard Pattrick (SEAES) and Jon Lloyd (SEAES) on, respectively, zooplankton physiology/toxicology, fish biology, NP chemical analysis and microbiology. The project will also link into existing on-going projects in this area, including the NanoRem EU project and a related NERC project. Students at the University of Manchester obtain tailored skills as part of their postgraduate research, including courses in research management, project design and scientific communication, as well as laboratory skills. All the associated labs currently have PhD students and postdoctoral scientists working on related projects and using relevant techniques, and together the labs will provide an excellent training environment for the student to gain a unique set of cutting edge, multidisciplinary skills.

References

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