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***Foreword***

# Bioavailability and toxicity of manufactured nanomaterials

More than a decade of research has been conducted on the ecotoxicology of manufactured nanomaterials (MNMs), or econanotoxicology. Early studies in the field suffered from a lack of basic characterisation data for MNMs being tested, confounding effects from impurities, differences observed among model organisms, lack of awareness of the importance of MNM transformations, and a paucity of techniques for quantifying MNMs in biological samples and other complex media.[1,2] As a result, early studies failed to reach consensus on which fundamental processes were governing bioavailability and toxicity. We have now reached a point where the field has begun to mature and an expanded repertoire of analytical techniques and model systems have been developed and disseminated to address some of the difficulties encountered in the earlier studies. Consensus about the basic principles governing MNM bioavailability is beginning to emerge. Importantly, we now know that it is not necessarily the properties of the manufactured materials that govern their toxicity, but how these properties evolve as the materials are transformed in ecosystems and within organisms.[3] Thus the environmental and biological history of the MNMs will in part determine their subsequent fate and effects. This Research Front contains some of the most recent developments in econanotoxicology and highlights the most pressing research needs as the field enters its second decade.

Schultz et al.[4] outline some of the challenges presented by transformations of MNMs and make recommendations for future toxicity testing. They review the toxicity data for the three most commonly studied metal-based MNMs ($TiO_2$, Ag and ZnO) and highlight the emerging themes in the aquatic toxicology of these materials. Choi et al.[5] discuss how the use of different model organisms results in somewhat different conclusions regarding the most important factors controlling MNM bioavailability and toxicity. They discuss the advantages and disadvantages of using *Caenorhabditis elegans* as a model for MNM toxicity studies and review the wealth of information these studies have provided on the mechanisms of MNM uptake and toxicity. Lahive et al.[6] provide some of the first toxicity data for $CeO_2$ MNMs in natural soil. Although they observed only subtle adverse effects in the earthworm *Eisenia fetida*, the $CeO_2$ MNMs were actually bioaccumulated to a greater extent than dissolved Ce, which contradicts classical free-ion activity paradigms. That study is representative of a greater focus on bioavailability and bioaccumulation of nanomaterials in the literature. Methodological advances such as stable isotope tracing techniques are helping to increase our ability to quantify and model bioaccumulation of MNMs. Croteau et al.[7] demonstrate how the use of stable isotope labelled Ag MNMs allows for quantification of bioaccumulation at more environmentally realistic concentrations than has been possible in previous studies. Their study showed that the relative importance of uptake of dissolved Ag released from the MNMs at low, environmentally relevant, concentrations was greater than that at high Ag MNM concentrations. Hotze et al.[8] examined the role of particle coating on attachment to silica surfaces, and demonstrated that both the surface chemistry of the particle core and adsorbed organic coatings influenced attachment efficiency. These properties of MNMs could critically affect the efficiency with which they attach to media such as soil and sediment as well as biological surfaces, and thus they might, play an important role in determining MNM bioavailability from solid media.

As this collection of papers demonstrates, considerable progress is being made addressing the complexities of predicting the toxicity of MNMs in ecosystems. This progress is reflected in a greater awareness of the importance of environmental transformations and of methodological considerations, the use of powerful model organisms, and development of new assays and methods to predict and quantify exposure and bioavailability. As a consequence of these hard won successes, the field of econanotoxicology is now poised to enter a mature phase and increase its ability to address the scientific and practical challenges necessary for a scientifically sound regulatory approach to MNMs in the environment.

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## References

[1] R. D. Handy, G. Cornelis, T. Fernandes, O. Tsyusko, A. Decho, T. Sabo-Attwood, C. Metcalfe, J. A. Steevens, S. J. Klaine, A. A. Koelmans, N. Horne, Ecotoxicity test methods for engineered nanomaterials: practical experiences and recommendations from the bench. *Environ. Toxicol. Chem.* **2012**, *31*, 15. doi:10.1002/ETC.706

[2] F. von der Kammer, P. L. Ferguson, P. A. Holden, A. Masion, K. R. Rogers, S. J. Klaine, A. A. Koelmans, N. Horne, J. M. Unrine, Analysis of engineered nanomaterials in complex matrices (environment and biota): general considerations and conceptual case studies. *Environ. Toxicol. Chem.* **2012**, *31*, 32. doi:10.1002/ETC.723

[3] G. V. Lowry, K. B. Gregory, S. C. Apte, J. R. Lead, Transformations of nanomaterials in the environment. *Environ. Sci. Technol.* **2012**, *46*, 6893. doi:10.1021/ES300839E

[4] A. Schultz, D. Boyle, D. Chamot, K. Ong, K. Wilkinson, J. McGeer, G. Sunahara, G. Goss, Aquatic toxicity of manufactured nanomaterials: challenges and recommendations for future toxicity testing. *Environ. Chem.* **2014**, *11*, 207. doi:10.1071/EN13221

[5] J. Choi, O. Tsyusko, J. Unrine, N. Chatterjee, J.-M. Ahn, X. Yang, L. Thornton, I. Ryde, D. Starnes, J. Meyer, A micro-sized model for the in vivo studies of nanoparticle toxicity: what has Caenorhabditis elegans taught us? *Environ. Chem.* **2014**, *11*, 227. doi:10.1071/EN13187

[6] E. Lahive, K. Jurkschat, B. Shaw, R. Handy, D. Spurgeon, C. Svendsen, Toxicity of cerium oxide nanoparticles to the earthworm Eisenia fetida: subtle effects. *Environ. Chem.* **2014**, *11*, 268. doi:10.1071/EN14028

[7] M.-N. Croteau, A. D. Dybowska, S. N. Luoma, S. K. Misra, E. Valsami-Jones, Isotopically modified silver nanoparticles to assess nanosilver bioavailability and toxicity at environmentally relevant exposures. *Environ. Chem.* **2014**, *11*, 247. doi:10.1071/EN13141

[8] E. M. Hotze, S. M. Louie, S. Lin, M. R. Wiesner, G. V. Lowry, Nanoparticle core properties affect attachment of macromolecule-coated nanoparticles to silica surfaces. *Environ. Chem.* **2014**, *11*, 257. doi:10.1071/EN13191