

An integrated ecosystems approach to the design of safer nanomaterials for a nano-enabled society (EcofriendlyNano)

- A Marie Curie Career Integration Grant



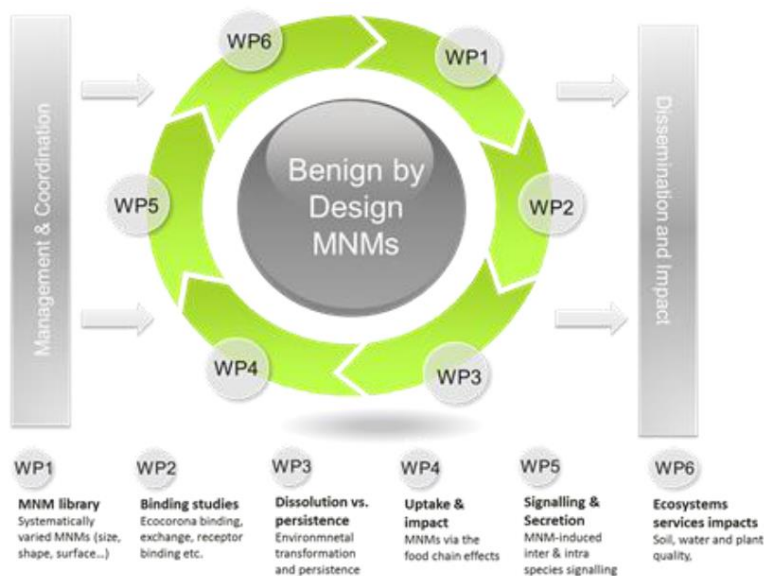
Publishable Summary – Period 1

Nanotechnology is a rapidly evolving enabling technology with the potential to revolutionise modern life. However, an increasing body of scientific evidence would suggest that some materials in their nano-form may induce harmful biological or environmental effects through a variety of potential mechanisms, not all of which are fully understood or quantified as yet. A key confounding factor is that nanomaterials (NMs), unlike conventional chemicals, are highly affected by their surroundings, transforming chemically, agglomerating, and/or acquiring an evolving coating of environmental or biological macromolecules, which provides them with an “environmental” identity that is derived from their initial “synthetic” identity. Factoring this context-dependence into assessment of the fate, behaviour and impacts of NMs is essential to move forward in terms of ensuring the safe implementation of nanotechnologies, and to facilitate the widespread application of NMs in environmental applications and for the improvement of ecosystems services, i.e. the processes by which the environment produces resources utilised by humans such as clean air, water, food and materials.

The aim of the EcofriendlyNano proposal is thus to resolve a key bottleneck in the commercial application of NMs, by re-framing the entire approach to safety-by-design as a value chain issue focussing on recovery and recycling of NMs, and understanding where additional value-add can be obtained via boosting ecosystems services such as soil, water and food quality. The overall goal is to reduce considerably the currently regulatory uncertainty regarding NMs, which is more costly to industry than increased regulatory testing due to the difficulty of evaluating (quantifying the cost of) uncertainty and the cost associated with loss of time in bringing a product to market.

Work performed to date:

Work in the first 2 years focussed on aspects of all 6 research WPs. Some highlights include assessment of strategies for cleaner or benign-by-design synthesis of carbon nanotubes (WP1), assessment of nanoparticle interactions with the proteins secreted by the sentinel organism *Daphnia magna* (WP2 and WP5) and uptake of the particles in the absence and presence of a secreted protein corona (WP4). An interesting (and somewhat unexpected) finding from this research was that the nanoparticles coated by the secreted biomolecule corona were more toxic to the *Daphnia* than the uncoated particles, in part due to increased uptake and retention (persistence) of the particles (WP5) as a result of partial agglomeration in the presence of the secreted proteins. Other highlights include broadening out the domains of interest for nanosafety and nanoregulation, including addressing the hydrogeology communities, including a presentation at the British Hydrology Conference 2014 and a resulting publication addressing water governance and the potential presence of nanomaterials in river catchments and the consequences for implementation of the Water Framework Directive (WP6).



Main outputs to date:

EcofriendlyNano has resulted in 6 peer reviewed publications and 2 book chapters so far, as follows:

1. Trompeta, A.-F., Koklioti, M.A., Perivoliotis, D.K., Lynch, I., Charitidis, C.A. Towards a holistic

environmental impact assessment of carbon nanotube growth through chemical vapour deposition. *J Cleaner Production*, 2016, 129, pp. 384-394

2. Lynch, I. Water governance challenges presented by nanotechnologies: Tracking, identifying and quantifying nanomaterials (the ultimate disparate source) in our waterways. *Hydrology Research*, 2016, 47:552-568.
3. Baalousha, M., Cornelis, G., Kuhlbusch, T.A.J., Lynch, I., Nickel, C., Peijnenburg, W., Van Den Brink, N.W. Modeling nanomaterial fate and uptake in the environment: Current knowledge and future trends. *Environmental Science: Nano*, 2016, 3: 323-345.
4. Kendall, M., Lynch, I. Long-term monitoring for nanomedicine implants and drugs. *Nature Nanotechnology*, 2016, 11: 206-210.
5. Nasser F, Lynch I. Secreted protein eco-corona mediates uptake and impacts of polystyrene nanoparticles on *Daphnia magna*. *J Proteomics*, 2016, 137: 45-51.
6. Lynch I, Feitshans IL, Kendall M. 'Bio-nano interactions: new tools, insights and impacts': summary of the Royal Society discussion meeting. *Philos Trans R Soc Lond B Biol Sci*. 2015, 370(1661):20140162.
7. Lynch I, Dawson KA, Lead JR, Valsami-Jones E. (2014) Macromolecular Coronas and Their Importance in Nanotoxicology and Nanoecotoxicology. In *Frontiers of Nanoscience*. 2014.
8. Mahapatra, I., Dobson, P.J., Lead, J.R., Lynch, I., Owen, R., Clark, J., R.A. (forthcoming October 2016): "Re-imagining Responsible Innovation for Nanomedicines: Stakeholder Perspectives" In: Bowman, D.M., A Dijkstra, C Fautz, J Guivant, K Konrad, H van Lente and S Woll (eds), *Responsibility and Emerging Technologies: Experiences, Education and Beyond*, Berlin: AKA Press, 2016.

Expected final results and their potential impact and use:

A significant challenge faced by Europe compared to the US is the lack of clear centres of excellence for nanosafety and nanoregulation. The establishment of Dr. Lynch (now Prof. Lynch) at the University of Birmingham adds to the critical mass of internationally competitive researchers active on the topic of environmental implications of NMs, and is contributing significantly to making University of Birmingham an internationally recognised centre of excellence for this field. This is recognised by the numerous EU Horizon2020 nanosafety-related projects with UoB partners, including NanoFASE, Marie Curie RISE project NanoGenTools, the newly starting EC4SafeNano and the in-negotiation project ACEnano. Prof. Lynch is also coordinating the development of the Stage 2 proposal for a Starting Community research infrastructure on nanosafety data (called NanoCommons) which will be submitted in March 2017.

The project opens new research opportunities within the area of environmental applications of NMs, in addition to the deepening understanding **of safe design, implementation and recovery of NM**, contributing to the scientific excellence, and leadership, of Europe in these important areas. Europe has always been a global leader in the management and protection of the environment, and indeed has taken a leadership role in ensuring the safe implementation of nanotechnologies, via its code of conduct for responsible nanosciences and nanotechnologies research, and via the development of the REACH regulations which are now being reviewed in light of the rapid emergence of NMs in myriad application sectors.

EcofriendlyNano has enabled Prof. Lynch to increase the capacity of the School of Geography, Earth and Environmental Sciences to cooperate with stakeholders from industry, policy and regulatory bodies on event research (International Environmental Agencies, Local Authorities, European Environmental Agency, DEFRA, Health & Safety Executive etc.). Indeed, via the project, Dr. Lynch was able to establish the UK Nano-Environment Academics and Regulators Group, which has subsequently received funding from the UK Natural Environment Research Council as part of the Pathways to Impact of the CEH-UoB NERC funded Highlight Topic project on the "Tracking relevant nanomaterial transformations, exposure, uptake and effects in freshwater and soil systems" project.

Project Website: <http://www.birmingham.ac.uk/research/activity/environmental-health/areas/enviro-nanoscience/index.aspx>

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