Science Highlights from the NanoFASE Consortium Meeting - Malta 2019

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In March 2019, H2020 NanoFASE researchers came together in Malta for the 42nd Month Consortium Meeting of our four-year project *"Nanomaterial Fate and Speciation in the Environment"*. We shared progress and set our final targets: consolidating our Exposure Assessment Framework with clickable online access; preparing a NanoSafety Cluster environmental White Paper to inform the EC and ECHA on the knowledge we have developed; and our public Concluding Conference to be held in conjunction with ICEENN 2019 in Vienna next September!

One of NanoFASE's key aims has been to develop models to describe the arrival and transformations of engineered nanomaterials (ENM) in a number of major environmental compartments: air, soils, waters, sediments and managed waste systems, all conceived as "reactors". Experimental advances delivered through the project have built understanding that have contributed to the structuring and validation of these models, as well as to the development of protocols and international guidance documents. In this way the NanoFASE scientific developments and discoveries are having a wider impact on the field.

- Particular developments include a spatially resolved, Europe-wide atmospheric model that can provide concentrations and deposition of ENM on an hourly basis. Best-guess information on particle properties (size, density in the atmosphere…) was underpinned by empirical data collected during a field campaign.
- Modelling of the fate and transformations of engineered nanomaterials in soils has led to several successes, including good correspondence of field measurements of zero valent iron nanomaterial movements to the model outputs, and methodological development of soil column tests that will inform an OECD guidance document.
- NanoFASE demonstrates soils to be more than a mere "sink" in emissions and fate modelling, as the growing importance of detachment and transport over longer timescales becomes apparent.
- NanoFASE modelling of fate and transformations in these various environmental compartments has taken a novel dynamic approach, tracking both nano form and mass over time. In this way the NanoFASE modelling goes beyond the "steady state" concepts and capacity of many models for traditional chemicals that are used in risk assessment.
- Some key methodological developments lie in the use of single particle ICP-MS to measure the biological fate of complex core-shell structured nanomaterials upon uptake by organisms, and detailed examination of the fate and transformations of nano-pesticides in the rhizosphere, a hitherto poorly understood zone in soils in terms of engineered nanomaterial fate.

Understanding of nanomaterial flows (life cycle analyses), releases and environmental emissions (scenarios, models) has been advanced through incorporating waste treatment infrastructure as a set of reactors (including waste water treatment plants, incinerators, recycling processes, etc.) acting as a gatekeeper to the environment. These waste treatment reactors are the setting for key transformative processes that change the physicochemical properties of nanomaterial. As such, their inclusion is an essential component for the effective modelling of the mass flows of nanomaterial forms being released to other environmental compartments; in particular, work in this area improves our understanding of the exposure-relevant form of the nanomaterials leaving the waste stream and to which organisms may become exposed.

- This conceptual advance has led to the development of improved emission models for a range of metal and metal oxide nanomaterials at the European scale and with forecasts for the next 20 years.
- The transformation processes undergone by nanomaterials in waste reactors as well as emissions outputs have also been explored experimentally, with case studies at pilot scale including fate, speciation and structuring of Ag-NPs in waste water treatment plants, and the assessment of Cu and Zn transformations during sewage sludge incineration.

NanoFASE has been at the forefront of delivering some advances to the field and sharing them in a transparent manner, including:

- An integrated Model and Framework providing a comprehensive approach to the exposure assessment of engineered nanomaterials in the environment, to support risk assessment.
- Clickable open access allowing the user to explore the processes, models, methods and data required for understanding the fate of nanomaterials in a range of relevant environmental compartments.

NanoFASE's interdisciplinary approach to the science behind understanding the environmental fate of engineered nanomaterials highlights the need for meta-level integration of terminology and data. Technical words may have multiple meanings and a lack of harmonisation between scientific disciplines or even between projects can hinder the transfer of ideas between fields and potentially limit the efficient linkage and enhancement of data and knowledge. This issue has been addressed by e.g. eNanoMapper and the Bioportal by building a shared ontology of relevant terms. NanoFASE references eNanoMapper glossary terms in our Clickable Framework, and additionally contextualizes important terms and concepts, improving access by making them easily searchable and cross-referenced.

- So far such ontological efforts within nano environment/health/safety research have mainly focused on the toxicological and material sciences fields. NanoFASE has worked closely with the US Center for the Environmental Implications of NanoTechnology (CEINT) to build the extra terminology for referencing the different issues and processes relevant to the environmental fate and transformation science we have done. This work will provide an exemplar and a template for the terminology used in future nano projects dealing with environmental fate and uptake.
- A workshop in Malta, led by CEINT scientist Jaleesia Amos and the University of Birmingham's Anastasios (Tassos) Papadiamantis, trained NanoFASE researchers on data entry to contribute our part to the NanoInformatics Knowledge Commons https://ceint.duke.edu/research/nikc.
- NanoFASE is working to ensure that this part of its legacy remains available to the field in the future, by collaborating closely with the NanoCommons e-infrastructure
- Look out as well for the White Paper in September 2019 environmental White Paper to inform the NanoSafety Cluster, the EC and ECHA on the knowledge we have developed.