Bio-nano-interfacial interactions: Probing the kinetics and dynamics of nanoparticle interactions with macromolecules

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Project description: The binding of biological and environmental macromolecules to the surface of nanomaterials (NMs) is a well-established paradigm for conferring biological activity to NMs, thereby influencing their interactions with living organisms. While significant progress has been made to identify the biomolecules that bind to NMs, much less progress has been made in determining the kinetics of binding, and towards teasing out competitive binding effects, and displacement of bound biomolecules by others of potentially lower abundance but higher affinity for the particle surface. The project described here will address this important topic, and develop binding and displacement kinetics models for NMs with representative environmentally relevant macromolecules, including humic and fulvic acids, exopolysaccharides and environmental pollutants. Effects of nanomaterial physico-chemical and surface characteristics (e.g. size, surface charge, surface coating) will be assessed. The project will utilise state of the art approaches such as Quartz Crystal Microbalance (QCM) and Fluorescence Correlation Microscopy (FCS) to probe the kinetics and dynamics of macromolecule binding to NM surfaces, and to assess displacement reactions as the NMs move from one environment to another (e.g. from ground water to soil; or from the environment into an organism).

The overarching hypothesis being assessed in this project is that the coating of acquired environmental macromolecules determines the environmental fate and behaviour, and ecotoxicity of NMs. The increasingly accepted paradigm in (eco)toxicity research is that NMs must be characterised under the exact conditions in which they will be presented to organisms (i.e. in the relevant media and in the presence of likely macromolecules), in order to: (a) understand the "real" or available dose of NMs under these conditions by characterising the degree of agglomeration under the exposure conditions; and (b) to reduce the possibility for non-physiologically relevant effects such as acute toxicity resulting from strong membrane adhesion and consequent damage that would not occur during real-life exposure where NMs will have acquired a passifying macromolecule coating from the surroundings. This paradigm has yet to be fully translated to ecotoxicity and environmental fate and behaviour research, in part due to the complexity of the naturally occurring macromolecules in soil and water, and in part as a result of the traditional time-lag between toxicity and ecotoxicity research.

This gap in assessment of NMs environmental transformation and behaviour hinders the development of accurate assessment of the transformation, fate and behaviour of NMs in the environment, and especially the ability to begin to predict NM fate and behaviour in the environment, on the basis of easier to characterise physico-chemical parameters, for risk assessment. The projects vision in vision is that an improved understanding of the kinetics and dynamics of the formation and evolution of the environmental-nano interface, and its role in determining the uptake of NMs by sentinal organisms in the environment (e.g. daphnia), will provide for more accurate risk assessment studies as well as facilitating assessments of the impacts of NMs on ecosystems services, benefiting environmental health, policy-makers, regulators, and scientists. The project will combine laboratory studies of binding kinetics / displacement kinetics of macromolecules to NMs with detailed NMs characterisation in pristine and coated forms, as the basis for development of quantitative structure-activity relationships (QSARs).

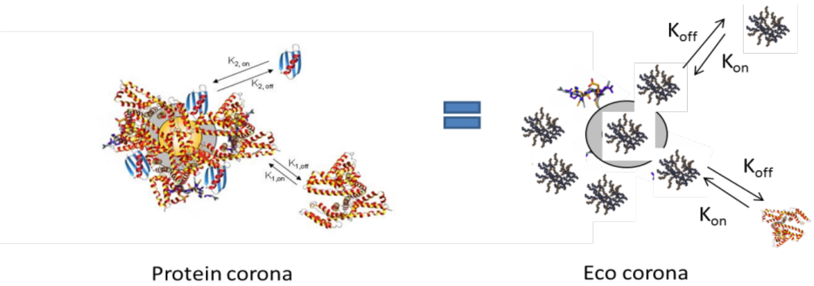

Figure: Illustration of the concept of the protein corona (left) and its translation into the concept of an Eco corona formed from environmentally relevant macromolecules, such as Natural Organic Matter.

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