ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT ET PHYSIQUE DE L'UNIVERS, PARIS

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Subject title: Speciation, bioaccumulation and biological feedback: towards a new predictive model for the toxicity of metals and their cocktails

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Host lab/ Team :	**IPGP- Team ACE – UMR7154**

Financing:	ANSES project: PNR EST n° EST-24-202 – TOXIMET

Presentation of the subject:

A study published in 2021 by Santé Publique France shows that 97-100% of the French population have metal levels (blood, hair, urine) higher than those found in most European countries. This situation is constantly evolving, as many new technologies use "new" metals (rare earths elements - REE, indium - In, platinum - Pt, silver - Ag, etc.), for example to limit greenhouse gases (catalytic converters, wind turbines, hybrid cars, etc.), improve medical treatments (anti-cancer), ensure the ecological transition or digital performance (electronic components). The increased use of these metals is significantly altering their natural biogeochemical cycles.[1] The growing development of these technologies is accompanied by an increase in their extraction and, consequently, their dissemination. As a result, a new "new entities" planetary limit has been crossed, showing that the increasing rate of new entities released (volume and number) into the environment is outstripping the capacity of societies to carry out safety assessments and monitoring.[2] In this context, it is vital to develop new methods for assessing the risks of mixtures of substances to ecosystems.

Ecotoxicological models estimate the toxicity of a substance, such as a metal, to a living organism. They are developed on the basis of results obtained from ecotoxicological bioassays in which the EC50 (concentration at which 50% effect on a population is observed) or EC10 (10%) is determined. Two models are mainly used in the literature: BLM (Biotic Ligand Model) and WHAM-F_{TOX}, both of which are based on a dependency between speciation (the distribution of a metal between different chemical species in a system[3]), bioaccumulation and toxicity to living organisms.[4,5] However, the models currently used have been developed *a posteriori* using data from the literature. Therefore, experimental plans have often not been developed in collaboration with speciation modellers, and the available data generally do not allow sufficient constraints to be imposed for accurate modelling of mechanisms involved. As a result, many of the available data remain difficult to use for modelling purposes. These models have therefore been developed on the basis of approximations of metal speciation, making it difficult to determine toxicity parameters. Mixtures of metals pose an additional difficulty for toxicity models, due to the complexity of toxic effects, which are more difficult to deconvolute. This adds to the complexity of correctly taking into account the toxicity of each individual metal in the presence of the living organism. However, it is necessary to model the toxicity of metal mixtures correctly, as living organisms are confronted in the environment with cocktails of metals in addition to other pollutants. Finally, the BLM[5] and WHAM-F_{TOX}[4] models fail to predict the toxicity of metal mixtures, as metal speciation and bioaccumulation are based on erroneous assumptions and are therefore inadequately modelled and parameterized. For example, some living organisms produce organic molecules in the aquatic environment. First under metal stress, thiolated organic compounds such as phytochelatins, have strong complexing capacities towards certain metals, are produced by algae and therefore metals are trapped.[6–9] However, the biological production of organic ligands under metal stress is not taken into account in the models. Second, metals bioaccumulate in different organs of a living organism. For example, (1) Cd and Ag, which are known to have a strong affinity for reduced sulphur, interact with cysteine-type thiol compounds in microalgae.[10–12] (2) Co interacts with many living molecules, including oxygen-carrying molecules,[13] and (3) REEs, which have a strong affinity for oxygen-carrying ligands, interact with acetate-type molecules.[14] Therefore, as toxicity is calculated on the basis of speciation and bioaccumulation, incorrect parameterization of these two preliminary steps prevents a good estimate of the toxicity of metals to living organisms. Furthermore, with the models currently proposed in the literature, it is necessary to carry out numerous toxicological experiments to determine the toxicity of a metal towards a living organism. There is an urgent need to propose methods for estimating metal toxicity based on existing data in the literature, particularly in view of the proliferation of new pollutants in the environment.

The aim of the PhD project is therefore to develop a new ecotoxicological model capable of better predicting the toxicity of metal mixtures using *Raphidocelis subcapitata* (freshwater algae) as model organism. It is based on a close collaboration between geochemists from the Institut de Physique du Globe de Paris (IPGP, Paris, France) and ecotoxicologists from the Laboratoire Interdisciplinaire des Environnements Continentaux (LIEC, Metz, France). Different approaches will be developed during the PhD project:

1) Modelling: a new ecotoxicological model capable of better predicting the toxicity of metal mixtures has to be developped. It will be built from the experimental data.
2) Experimental approach: ecotoxicological experiments with different metals (In, La, Ag, Cd, Co, Ni) will be carried out, first with only one metal, then with mixtures of metals.
3) Spectroscopic approach: Such approaches will be used to complement experimental approaches to determine the mechanisms involved in metal-algae interactions. In particular, they will allow us to determine in which part of the algae the metals are concentrated and to which molecules they are complexed. Especially XAS (X-ray Absorption Spectroscopy) will be used.

Financial support of the PhD Project

- Project from ANSES funding (TOXIMET, C. Catrouillet) for 3 years;
- Beamtime will be requested at the SOLEIL and ESRF synchrotrons.

Candidate profile:

- University education/engineering school in Geosciences/Geochemistry/Environment or in Biology/Ecotoxicology/Environment with an honour degree or excellent academic results;
- Knowledge in Geosciences and Biology, use of modelling software, solid knowledge in ecotoxicity, in mineralogy or geochemistry is desirable ;
- The candidate must be autonomous and rigorous ;
- Very good knowledge of spoken, read and written English is essential.

Please note that the PhD is divided into several parts: 6 months at Paris (IPGP), 2 years at Metz (LIEC) and for the 6 last months at Paris (IPGP).

Starting date: 1st of January

Contacts: *please sent emails to all three with CV, motivation letter and Master's grades*

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