Campagne des contrats doctoraux LUE
PhD Proposal Position - Ecole Doctorale SIReNa 2024

LUE – Géochimie et Ecotoxicologie de deux Métaux stratégiques dans un continuum terre-mer : MODélisation des processus
LUE – Geochemistry and Ecotoxicology of two strategic Metals in a land-sea continuum: Process MODeling

Etablissement : Université de Lorraine
École doctorale SIReNa - SCIENCE ET INGENIERIE DES RESSOURCES NATURELLES
Spécialité Ecotoxicologie, Biodiversité, Ecosystèmes
Unité de recherche : Laboratoire Interdisciplinaire des Environnements Continentaux (LIEC) UMR 7360 CNRS, Université de Lorraine

Encadrement de la thèse :
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Mots-clés : Gd-Li ; Terre-Mer ; Géochimie ; Ecotoxicologie ; Modélisation TKTD
Keywords: Gd-Li; land-sea continuum; Geochemistry; Ecotoxicology; TKTD modelling

Description de la problématique de recherche- Project description
L'objectif de neutralité carbone, fixé à 2050 par la loi énergie-climat, pour répondre à l'urgence climatique nécessite la sortie progressive des énergies fossiles et le développement des énergies renouvelables à faible émission de carbone. Ceux-ci sont plus intensifs en matériaux que les technologies traditionnelles et génèrent une augmentation de la consommation de ressources minérales telles que les métaux critiques (CM) terres rares (ETR) et le lithium (Li). Les exigences accrues pour ces MC ont déjà augmenté leur extraction, entraînant inévitablement une augmentation de leurs rejets et des pressions qui en résultent, les obligeant à être considérés comme des contaminants émergents. Malgré un nombre croissant d'études, les connaissances restent limitées sur les nombreux processus géochimiques et leurs comportements écotoxicologiques, leur spéciation, leur biodisponibilité, leur accumulation dans le biote d'eau douce et marin et leur organotropisme. La connaissance de leurs effets (éco)toxicologiques est fragmentée et pas nécessairement concluante, souvent exposome, CM et espèces dépendantes. Dans un contexte environnemental d'expansion de l'utilisation des ETR et des rejets croissants, le projet propose d'évaluer leur devenir et leurs impacts environnementaux sur deux espèces emblématiques des milieux aquatiques, ultime réceptacle de contaminants. Le projet interdisciplinaire se concentrera sur le continuum terre-mer, réunissant, croisant les perspectives des chercheurs des disciplines de la géochimie environnementale, de l'écotoxicologie et de la modélisation. L'objectif est de caractériser et d'étudier les relations entre exposome et reactome au Gd et Li chez deux bivalves : un dulçaquicole (*Dreissena polymorpha*) et un marin (*Mytilus galloprovincialis*) et d'anticiper les risques environnementaux et éventuellement de consommation humaine dans un contexte de vide juridique concernant les seuils autorisés et les niveaux toxiques vis-à-vis des

organismes vivants. Afin de valider des approches expérimentales en milieu naturel, nous étudierons la relation entre l'exposome dans des situations complexes in situ dans des sites post-minier au Canada (minéralisation Li, géochimie) et le reactome (bioaccumulation, organotropisme, fractionnement isotopique, écotoxicologie). L'étude en milieu naturel permettra de mieux comprendre l'homéostasie de ce métal dans les populations naturelles, et ainsi aider à élucider les mécanismes d'action du lithium.

The objective of carbon neutrality, set for 2050 by the energy-climate law, in order to respond to the climate emergency requires the gradual exit of fossil fuels and the development of low-carbon renewable energies. These are more material intensive than traditional technologies and generate an increase in the consumption of mineral resources such as the so-called critical metals (CM) rare earths (ETR) and lithium (Li). The increased requirements for these MCs have already increased their extraction, inevitably leading to an increase in their releases and resulting pressures, forcing them to be considered as emerging contaminants. Despite a growing number of studies, knowledge remains limited regarding the many geochemical processes and their ecotoxicological behaviours, from their speciation to their bioavailability, their accumulation in freshwater and marine biota and their organotropism. Knowledge about their (eco)toxicological effects is fragmented and not necessarily conclusive, often exposome, CM and dependent species. In an environmental context of expansion of the use of REE and Li and increasing releases, the project proposes to evaluate their fate and environmental impacts on two emblematic species of aquatic environments, ultimate receptacles of contaminants. The interdisciplinary project will focus on the land-sea continuum, bringing together, crossing the perspectives of researchers from the disciplines of environmental geochemistry, ecotoxicology, and modelling. The objective is to characterize and study the relationships between Gd and Li exposome and reactom in two bivalves: a dulçaquicole (*Dreissena polymorpha*) and a sailor (*Mytilus galloprovincialis*) and to anticipate environmental and possibly human consumption risks in a context of legal vacuum concerning authorised thresholds and toxic levels vis-à-vis living organisms. In order to validate experimental approaches in the natural environment we will study the relationship between the exposome in complex in situ situations in post-mining sites in Canada (Li mineralization, geochemistry) and the reactome (bioaccumulation, organotropism, isotopic fractionation, ecotoxicology). The study in the natural environment will provide a better understanding of the homeostasis of this metal in natural populations, and thus help elucidate the mechanisms of action of lithium.

Thématique / Domaine / Contexte Objectifs

The Energy-Climate Act adopted in 2019 sets ambitious targets for France's climate and energy policy. The law sets a target of carbon neutrality by 2050, in response to the climate emergency and the Paris Agreement, one of whose four pillars is the gradual phase-out of fossil fuels and the development of renewable energies. Low-carbon technologies are more material-intensive than traditional technologies, and energy efficiency linked to the development of renewable energies is also accompanied by increased consumption of mineral resources, including so-called critical metals (CM) or strategic metals for geological or economic reasons. Whether for electrified vehicles (cobalt, lanthanum, lithium), catalytic converters or fuel cells (platinum, palladium, rhodium), wind power (neodymium, dysprosium, terbium, etc.), civil aeronautics (neodymium, dysprosium, terbium, etc.) or energy efficiency (cobalt, lanthanum, lithium), civil aeronautics (titanium consumer) or solar photovoltaics (cadmium, indium, gallium consumer), all the innovations developed to achieve the energy transition depend on the availability of certain ores and refined metals, such as rare earths (REE) and lithium (Li).

REEs are a group of 17 elements (scandium, yttrium and 15 lanthanides), which have become essential for many cutting-edge industries in the military and medical fields, as well as for low-carbon technologies (wind turbine magnets). In line with the expected increase in installed capacity, the results show an almost 2.5-fold increase in total rare earth consumption in a 4° C scenario, and a more than 10-fold increase in a 2° C scenario by 2050 (Hache et al 2021b, IFPEN 2020).

As for lithium, in addition to being very light, it has a very low electronegativity, making it the material of choice for batteries that enable reversible energy storage. With the development of Li-ion technologies, it has found a strong outlet in this sector, whether for portable electronics (notably cell phones and laptops) or, more recently, for electric vehicles. Global Li production has increased 3-fold in the space of a decade, from 25,000 t in 2010 to over 82,000 t in 2020. In recent years, demand for Li has grown at a steady rate of around 20% a year. Demand for Li is set to increase by a factor of 5 to 7 over the next decade, with demand estimated at over 680 kt in a zero-emission scenario.

The growing demand for these two MC has already led to an increase in their extraction, inevitably leading to an accentuation of their discharge and the resulting pressures, which obliges/allows these metals to be considered as emerging contaminants. Despite industrial practices and processes that

seek to be more respectful of the environment, and the promotion of more responsible development of mineral resources (Plante et al., 2023), the environmental footprint of mining is not negligible.

In an environmental context of expansion of the use of REE and lithium and increasing releases, the project proposes to evaluate their fate and environmental impacts on two species of invertebrates emblematic of aquatic environments. The interdisciplinary project associated with the PhD proposal will focus on the land-sea continuum, bringing together researchers from the fields of environmental geochemistry, ecotoxicology, molecular biology and modeling. The aim is to characterize and study the relationships between the exposome, metallome, metabolome and reactome in two bivalves: one freshwater (*Dreissena polymorpha*) and one marine (*Mytilus galloprovincialis*), and to anticipate environmental risks. This type of project, which is highly integrated in disciplinary and spatial terms, does not exist or exists only to a limited extent for other, more conventional metals, and is therefore completely innovative for REE and Li, for which no environmental standards have yet been established. The main challenge is to describe, characterize and formalize the links between exposure to contaminants (physico-chemical characterization of environments, geochemistry, speciation, bioavailability, bioaccumulation, organotropism, cellular distribution) and the biological responses observed in organisms. Laboratory experiments will provide answers to the following questions:

1. What is the fate and bioavailability of Gd-AC and Li in fresh and marine waters?
2. What is their transfer, bioaccumulation and distribution in biota?
3. What are the molecular and cellular mechanisms and effects induced in exposed organisms?
4. How can we predict the exposure of aquatic organisms to Gd-AC and Li, and the transfer levels at risk for bivalves, by developing mathematical and statistical approaches?

Field experiments will provide answers to the following questions:

1. What is the potential risk associated with the transfer of Li from various mineralisations to biota and its potential biomagnification?
2. What is the anthropogenic impact of Li in areas of exploitation and industrial use?

Méthode/Methods

The project will comprise 5 interconnected tasks involving the highly complementary partners from France, Canada and Italy. The combination of the different approaches developed will provide a systemic view of the interaction between Gd-AC and Li - aquatic organisms, and will lead to a better understanding of their ecotoxicity, toxicokinetics and toxicodynamics, improved environmental risk assessments, predictive modeling and the development and implementation of more targeted management measures.

Task 1: Characterization of the exposome of the two bivalve species

The fate, speciation and bioavailability of the 2 CM will be studied and modeled.

Task 2: Bioaccumulation, organotropism and cellular distribution of the metals Gd and Li

The study of bioaccumulation enables us to understand the link between exposure concentration and the toxic effects engendered. Bioaccumulation involves various processes grouped together under the term ADME (Absorption, Distribution, Metabolization, Elimination) which depend on the physico-chemical properties of the contaminants, the species under consideration and environmental conditions.

Task 3: Determination of the toxic mode of action of Gd and Li and integrated assessment of biological effects at molecular, cellular and individual levels

Task 4: Lithium-Health-Environment: Establish the basic geochemical and environmental conditions and trophic transfer of lithium in freshwater ecosystems.

The aim is to validate experimental approaches in the natural environment by studying the relationship between the exposome in complex in situ situations (Li mineralization, geochemistry) and the reactome (bioaccumulation, organotropism, isotopic fractionation, ecotoxicology).

Task 5: Remediation trajectories: Cross-reflection and synthesis

Précisions sur l'encadrement - Details on the thesis supervision

The consortium formed by the 4 partners has all the skills to carry out interdisciplinary and innovative research in the field of environmental sciences, on the whole life cycle of the two strategic metals and on two abiotic and biotic continuums, first land-sea for the spatial approach and then Exposome-Réactome (via metalloma and metabolioma) for the ecotoxicological approach. The 4 partners will be also involved in the PhD project.

Partner 1: UMR 7360 LIEC, Université de Lorraine, France. L. Giamberini, L. Minguez et al.

Partner 2: University of Naples Federico II. Laboratory of Hygiene: Water, Food and Environment. G. Libralato et al.

Partner 3 : Université du Québec en Abitibi-Témiscamingue (UQAT - Canada). Institut de recherche en mines et en environnement (IRME). Benoît Plante et al.
Partner 4 : Université Lyon 1 Claude Bernard & CNRS, France. Laboratoire de Biométrie - Biologie Évolutive (LBBE) UMR 5558. Christelle LOPES et al.

Conditions scientifiques matérielles et financières du projet de recherche
Thèse en co-direction avec les 4 partenaires, localisée principalement sur le site du LIEC à Metz, secondairement sur le site du LIEC à Nancy. Missions de court et moyen termes chez les 3 autres partenaires. Missions plus longues à l'université de Naples

Thesis in co-direction with the 4 partners, located mainly on the LIEC site in Metz, secondarily on the LIEC site in Nancy. Short and medium-term assignments with the other 3 partners. Longer assignments at the University of Naples

Ouverture Internationale. International
Projet en collaboration avec l'Université de Naples (Italie) et l'Université du Québec en Abitibi-Témiscamingue (Québec, Canada)
Project in collaboration with the University of Napoli (Italy) and the University of Quebec in Abitibi-Témiscamingue (Quebec, Canada)

Objectifs de valorisation des travaux de recherche du doctorant : diffusion, publication et Profil et compétences recherchées
Promotion in the form of scientific publications, presentations at national and international conferences and scientific mediation to different stakeholders

Profil et compétences recherchées / Profile and skills required
Ce projet interdisciplinaire nécessitera d'avoir un candidat ou une candidate curieux, ouvert aux différentes approches menées entre géochimie, écotoxicologie et modélisation et déjà bien formé sur les diverses méthodologies. Le candidat devra en particulier posséder de bonnes qualités techniques (connaissances de bases des concepts en écotoxicologie, en écotoxicologie expérimentale et modélisation géochimique ou écotoxicologique) et rédactionnelles. De bonnes qualités relationnelles sont également attendues pour assurer les interactions avec les différents interlocuteurs de ce projet interdisciplinaire et international.

This interdisciplinary project will require a curious candidate, open to different approaches between geochemistry, ecotoxicology and modeling and already well trained on the various methodologies. In particular, the candidate must possess good technical (experimental ecotoxicology and geochemical or ecotoxicological modelling) and writing skills. Good interpersonal skills are also expected to ensure interactions with the various partners of this interdisciplinary and international project.

Candidature/ Application AVANT LE 30 SEPTEMBRE 2024
Les candidatures se font préférentiellement en ligne via Adum via le lien ci-contre : http://doctorat.univ-lorraine.fr/fr/les-ecoles-doctorales/sirena/offres-de-these
Le dossier de candidature du candidat doit comporter à minima les éléments suivants :
• le CV du candidat et la lettre de motivation,
• les notes obtenues au diplôme conférant le grade de master et copie du diplôme s'il est disponible,
• 2 lettres de recommandations émanant du Responsable de la filière de formation et du tuteur de stage de fin d'études,
• des éléments tangibles sur l'initiation à la recherche (mémoire de recherche, publication, ...).

Applications are preferably made online via Adum via the link : http://doctorat.univ-lorraine.fr/fr/les-ecoles-doctorales/sirena/offres-de-these **BEFORE SEPTEMBER 30th 2024**
The candidate's application must include at least the following elements:
• the candidate's CV and cover letter,
• test scores obtained on the degree conferring the master's degree and a copy of the diploma if available
• 2 letters of recommendation from the Head of the training course and the final traineeship tutor of studies,
• tangible elements on initiation to research (research thesis, publication, ...).

Contacts Université de Lorraine, LIEC

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