Title of the thesis subject : **Mobility and transfer of rare earth elements from soil to plants by arbuscular mycorrhizal fungi**

Reare earth elements are nowadays strategic metals in many modern technolologies, but their toxicicity and accumulation in terrestrial ecosystems is still poorly known (Gonzalez et al., 2014). Rare earth elements are not toxic in natural soils where concentrations are low, and their transfer to plants limited (Tyler 2004). But it is not the case in soils where rare earth are exploited, such as for example in China, where 50% or rare earth ressources can be found, and where intensive exploitation lead to high concentrations in soils, water and sediments (Kinycki et al, 2012). Rare earth concentrations in abandoned mining soils can reach 150 to 800 mg/kg (Chao et al. 2016). In contaminated soils, phytotoxicity can be observed. Areas where rare earth elements have been exploited need to be rehabilitated for example using adapted plants (phytomanagement). Few studies have been performed on the effect of rare earth elements on bacterial community (Chao et al. 2016), but nothing has been done on fungi. Arbuscular mycorrhizal fungi have a beneficial role on plant growth in stressed environments, especially in soils contaminated by metallic trace elements. Such fungi might contribute to plant growth and tolerance on soils contaminated with rare earth elements, and possibly contribute to reduce the transfer of rare earth elements to the plant.
The objectives of the pH-D thesis will be to precise the toxicity of rare earth elements (REE) towards root symbiotic fungi and to study the role of these fungi in the transfer of REE to plants. The hypothesis is that arbuscular mycorrhizal fungi play a role of filter towards toxic metallic elements (Redon et a. 2008). Binding of REE at the hyphae level, as previously observed for metallic trace elements such as Cd, could contribute to a better fitness of plants in the presence of high concentrations of REEs. Arbuscular mycorrhizal fungi might then be considered to inoculate the plants used for phytomanagement of REE contaminated soils.
More specifically, the pH-D candidate will study the mobility of REE and its transfer to plants via arbuscular mycorrhizal fungi. Experiments will be performed with Samarium (Sm) as model REEs. Adsorption kinetic experiments will be first performed with different soils. Experiments with plants inoculated or not with a mycorrhizal fungus will then be performed with soil spiked with Sm at different concentrations, and plant growth and Sm uptake will be analysed. The use of compartment devices (Joner et Leyval, 1997), and of radioactive Sm probing (^{151}Sm) will allow to follow the transfer of this REE from soil to plant through the fungus hyphea, in comparison to a nutrient element such as phosphorus (^{33}P). NanoSIMS technique will also be used to precise the localisation of the spiked Sm in the rhizosphere and its availability (Ayadi et al. 2012 ; Cennerazzo et al, 2017).

Skills : the pH-D candidate should have skills in soil science and soil microbiology, and have a good practice in english langage. He/She will be trained to be allowed to use radio-elements.

Starting period : September 2017

Laboratory : LIEC, Laboratoire Interdisciplinaire des Environnements Continentaux, UMR 7360 Université de Lorraine, CNRS, Faculté des Sciences et technologies, BP70239, 54506 Vandoeuvre-les-Nancy Cedex, FRANCE

Supervision : Dr Corinne Leyval (director of the thesis), corinne.leyval@univ-lorraine.fr
Dr Alexis De Junet (co-director), alexis.dejunet@univ-lorraine.fr
Dr Thierry Beguiristain, thierry.beguiristain@univ-lorraine.fr

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Contact:
ed-rp2e-secretariat@univ-lorraine.fr
Isabelle.abildtrup@univ-lorraine.fr