PhD offer

From wetlands to municipal landfills: monitoring contaminant-mineral interactions with time-lapse geophysics

Summary

The PhD project addresses the major challenge of observing and modeling the reactive processes controlling the fate of invisible subsurface contaminants. The aim of the thesis is to define the added value of time-lapse hydrogeophysics (Figure 1), including induced polarization (IP), as a complementary set of methods to standard geochemical observations, for understanding subsurface contaminant storage and discharge. Since the interactions between contaminants and minerals are similar in the case of wetlands and municipal landfills, these two contexts are investigated and put into perspective.

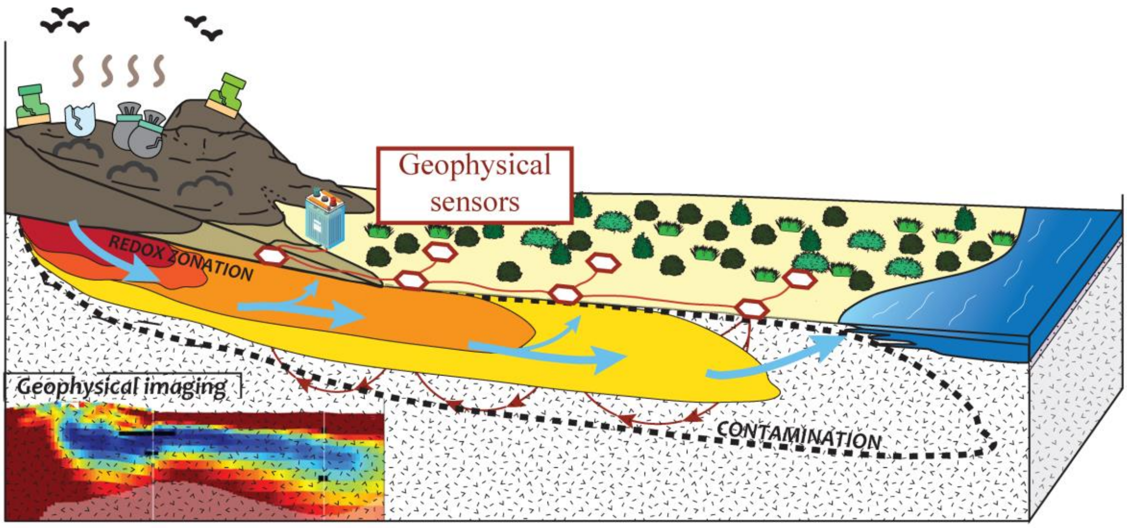

Figure 1. *Illustration of a leachate plume forming under a municipal landfill upon interaction with groundwater flow & geophysical imaging results by electrical resistivity tomography obtained by Maurya et al., 2017.*

Supervision

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Keywords

Hydrogeophysics, Induced Polarization, Wetlands, Landfills, Contaminants, Minerals

Project description

Subsurface environments are used to exploit resources and dispose of waste. While these two uses are thought of and managed separately, they are connected through groundwater flow. Contaminants may thus be transported over long distances, as well as stored in the solid matrix. They may spread into deeper levels or converge towards surface ecosystems.

Subsurface contaminants interact with water, minerals, microorganisms and, more generally, with natural biogeochemical cycles. In wetland and landfill environments, interactions with minerals such as sulfides and metal oxides play a central and complex role in contaminant mobility. However, our understanding of the key reactive processes in a given environment remains limited, posing difficulties for decision-making on preservation and remediation strategies.

Geophysical imaging can make subsurface contamination visible (Figure 1). It is particularly effective for spatializing local information obtained through detailed biogeochemical characterization. Time-lapse hydrogeophysics, including the induced polarization (IP) method, offers new opportunities for imaging reactive processes in subsurface environments, particularly those involving metal sulfides and oxides. Laboratory experiments on metal sulfides have shown that the IP method is highly sensitive to these minerals and to their evolution over time (nucleation, growth, oxidation, passivation). However, many questions remain as to the origin of the signals recorded in the field (types of mineralization, role of micro-organisms, etc.). The IP response needs to be documented in different contexts to be able to better understand it and model it.

Two field sites are investigated in the PhD project : a natural wetland and a former landfill, both of them located on the south coast of the Brittany region (France), where the Ploemeur-Guidel critical zone observatory has also been inactivity for the past 30 years (see more: SNO H+, IR OZCAR).

Methodology

The PhD candidate will work at the interface between geophysics, hydrogeology, geochemistry and mineralogy. The work will include inversion of electrical and electromagnetic data, as well as modelling of transport in fractured media and of the interactions between contaminants and minerals. The proposed research will be based in Rennes (central Brittany, France) and will take place over three years.

The first part of the PhD involves the analysis of geophysical signals recorded since 2018 at the Guidel natural wetland (Figure 2), by a new high-resolution IP monitoring system developed in-house. The goal is to understand iron and sulfur transformations and their impacts on geophysical signals. A natural resurgence of deep, iron-rich water at this site creates a wetland within which metal sulfide precipitation-dissolution cycles can exist. Controlled in situ experiments between piezometers, at a scale equivalent to that of laboratory columns (~1m), will be set up to stimulate the reactivity and observe the associated geophysical responses. These field experiments may be supplemented by laboratory experiments, such as IP measurements on micro-fluidic chips. The aim will be twofold: (i) refine the observation method to deploy it later on at a coastal landfill (see second part) and (ii) explore fundamental questions about the response of wetlands to contamination (such as fertilizers or heavy metals), a topic of interest for many scientific communities.

Figure 2. *Guidel critical zone observatory, belonging to Ploemeur commune, in south Brittany. Groundwater resurgence.*

The second part involves the deployment of geophysical monitoring systems at Kerloret coastal landfill (also belonging to Ploemeur commune), in order to contribute to decision-making on management strategies. The aim will be to monitor the evolution of the subsurface contaminant plume and reaction fronts over the hydrological cycle, and to develop a conceptual understanding of the contaminant fluxes observed in rivers and piezometers. Several geophysical methods will be combined. Electrical resistivity tomography (ERT) and towed transient electromagnetics (tTEM) will be used to define the current extent of the subsurface contamination plume. Self-potential measurements will be combined with IP measurements to identify redox interfaces, image biogeochemical hot-spots, and monitor their evolution over time. This part will help define how hydrogeophysics may contribute to understanding subsurface contamination in the context of coastal landfills, and to monitoring it over time.

Pre-requisite

You hold a master’s degree in geosciences, preferably in geophysics, hydrogeology or mineralogy. You are ready to carry out fieldwork and ideally already have some experience in the field. You have knowledge of geophysical inversion methods and a good command of numerical processing tools (Python or MATLAB). GIS skills are also valued. In addition, good command of written and spoken English is required for interpreting, synthetizing and presenting results. Fluency in French is an asset but not necessary.

Salary and available support

Monthly gross salary: 2100 €, fully funded for three years.

In addition to monthly remuneration, the PhD project benefits from funding recently obtained from the French National Research Center (CNRS). Part of this budget is specifically dedicated to geophysical and geochemical measurements. A first round of ERT and IP data acquisition at the Kerloret landfill took place in May 2024, as part of master internship. These results show considerable variability over the landfill site, confirming the need for further data acquisition and complementary types of measurement, as well as a major effort on modelling. In addition, the IP monitoring prorotype instrument, already installed at Guidel wetland, will be replicated for installation at Kerloret landfill, as part of the PIA3 EQUIPEX+ TERRA FORMA instrumental development program (WP2.7).

You will benefit from the support and expertise of experienced geophysicists, as well as ongoing collaborations with local water resources managers (site access, knowledge transfer) and with the ECOBIO laboratory for microbiology questions.

Recruitment process

Application period is until September 15th. To apply, candidates should send to the three email addresses given above: their resume, statement of interest and names of three reference scientists we can contact. We will review all applications and contact selected candidates for a first round of interview.

Starting date is January 1st, 2025 at the latest.