Post-doctoral contract offer

Multivariate Population Balances for the Multiscale Modelling of Bioleaching Processes to Recycle Electronic Waste

General information

Workplace: Nancy, France
Type of contract: FTC Scientist
Contract period: 18 months
Expected date of employment: 2024
Proportion of work: Full time
Remuneration: 2190 €/month net salary (2773 €/month gross salary)
Desired level of education: PhD
Experience required: -

Motivation

Among the different types of secondary waste or so-called “post-consumer” waste, electronic waste shows the strongest growth at the global level. The efficiency of their recycling is considered by the United Nations Program for the Environment as a major issue regarding their impact on the environment (landfill or incineration), the prevention of illegal exports as well as complementary supply of metallic raw materials [1]. Many components of this waste, especially certain metals, are considered critical because of their use in energy transition and digital technologies. However, the complexity of these products in terms of structure and composition is such that it is not always possible to fit e-waste into conventional recycling chains [2]. Printed Circuit Boards (PCBs) are the part of Waste Electrical and Electronic Equipment (WEEE) which contains the majority of non-ferrous metals.

Biohydrometallurgy relies on the use of microorganisms in extractive hydrometallurgy to allow in situ formation of reactants at limited costs and is based on flexible processes, which can adapt to variations of recycling demand. This process is known as showing lower environmental costs than pyrometallurgy due to lower operating temperatures. In recent years, some works have been devoted to the development of bioleaching processes for the treatment of electronic waste, and more particularly of PCBs. It allows indeed on the one hand to dissolve base metals as well as certain high-tech metals (Ga, In, W ...) and on the other hand to produce a solid concentrate of precious metals (Au, Ag, Pt ...) which can then be upgraded by conventional processes (pyro or hydro) in existing sectors (smelters Umicore, Aurubis or Boliden) [3-4].

Multiscale modelling is complementary to experimental campaigns. The main scientific bottlenecks raised by the development of this type of model are linked to the couplings of the various phenomena in a three-phase environment (gas, liquid, solid/microorganisms), associated with different populations and internal properties (age for the microorganisms, size and composition for the other types of particles). It is thus necessary to model the behavior of these populations over time in the bioreactor in order to simulate both the concentration heterogeneities linked in particular to particle segregation, and the temporal changes due to biochemical reactions.

Missions / Activities

The CFD modelling and simulation of the bioleaching reactor will be conducted by project partners (LRPG and BRGM, find details in the following section). The work at Insitut Jean Lamour will focus on modelling the evolution of the PCB recycling process over time based on a multivariate population balance.

The first step consists in describing the populations of solid PCB particles according to two internal variables, namely their size and chemical nature. The dissolution kinetics (studied by LRGP and

BRGM) governs the evolution in size of each population. Since the possible interactions between particles are neglected in this first approach, the population balance are explicitly independent. The second step takes into account interactions between populations, since the attachment of bacteria onto solid particles may depend on the chemical nature of the particles [5]. These interactions make PBEs more complex by bringing in non-linear terms that make PBEs dependent. Particular attention must therefore be paid to the efficiency and dynamics of aggregation between the different phases.

While fully-resolved hydrokinetic description of bioleaching process remain reachable at the 50 L pilotscale, its extension to possible industrial reactors will have to be simplified using a compartmental approach [6]. Mass balances, implementing the PCB bioleaching kinetic model will be applied to a reasonable number of compartments, in close collaboration with LRGP partners to design the size and interconnecting liquid and gas flowrates of the model based on their dedicated CFD simulation.

Work context

The research will be conducted at Institut Jean Lamour in Nancy and is part of larger project that involves two partners, the Reactions and Process Engineering Laboratory (LRGP) in Nancy and the “Bureau des Ressources Géologiques et Minières” in Orléans.

Institut Jean Lamour (IJL, UMR CNRS University of Lorraine, Nancy)

The 301 team of the Jean Lamour Institute specializes in the engineering of processes for the production of metallic materials, which calls on skills in thermodynamics, transport phenomena, continuous media and numerical simulation techniques. The IJL has more than twenty years of experience in solving PBEs and their coupling to CFD simulations in industrial metallurgical reactors [7]. In addition, IJL has worked on establishing fine models for particle aggregation at the mesoscopic scale [8], so that a similar approach would allow capturing the aggregation dynamics in the bioleaching reactor.

Reactions and Process Engineering Laboratory (LRGP, UMR CNRS University of Lorraine, Nancy)

The Bioprocédés Biomolécules team of LRGP has been dedicating part of its research activities for the past fifteen months to the numerical simulation of multiphase flows (gas-liquid and liquid-solid) within bioreactors and to the modeling of biological kinetics of the scale of the cell to that of the bioreactor. Recently, the numerical simulations developed have made it possible to improve the design of mechanically stirred bioreactors using a solid phase in suspension [9-10] and to describe the hydrodynamics of bioreactors of bioleaching of ores [6].

Bureau des Ressources Géologiques et Minières (BRGM, Orléans)

BRGM is a public geoscience research institution. It has recognized expertise in the field of biotechnology for the treatment of primary and secondary resources, and has been involved for nearly 30 years in the development and improvement of bioleaching processes, as well as knowledge of the microorganisms involved.

About Institut Jean Lamour

The Institut Jean Lamour (IJL) is a joint research lab of CNRS and Université de Lorraine. Specializing in materials science and engineering and processes, its scope includes materials, metallurgy, plasma, surfaces, nanomaterials and electronics. IJL regroups 183 researchers, 91 engineers and support staff, 150 PhD students and 25 post-doctoral fellows. It maintains industrial collaborations with more than 150 partners and its academic collaborations cover 30 countries. Its experimental facilities are located in 4 sites, its main site being in Nancy on the Artem campus.

Skills

The candidate will need a strong experience with population balances (ideally multivariate, but not necessarily), either as a developer or as an advanced user. They must hold a PhD degree on a research subject that is related to population balances. They should also be proficient in numerical methods and scientific computation. The candidate must have some practice of at least one or more programming language(s) (C, C++, Fortran, Python+NumPy, Matlab/Octave or any other) and a will to strengthen their programming skills.

Constraints and risks

The position you are applying for is located in a sector relating to the protection of scientific and technical potential. It therefore requires, in accordance with the regulations, that your arrival be authorized by the competent authority of the Ministry of Higher Education, Research and Innovation.

Application

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Please apply by e-mail. Describe you motivation for this offer in the content of your e-mail and attach a resume, preferably in PDF.

References

[1] Reuter et al. (2013). Metal Recycling: Opportunities, Limits, Infrastructure, A Report of the Working Group on the Global Metal Flows to the International Resource Panel.

[2] Hubau et al. (2019a). Waste Management 91, 62–71.

[3] Guezennec et al. (2015). Minerals Engineering, 75, 45-53.

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[5] Hubau et al. (2018). Hydrometallurgy 180, 180–191.

[6] Cheron et al (2020), Hydrometallurgy 197, 105490

[7] Castro-Cedeno et al. (2019), Metall. Res. Technol. 116, 5.

[8] Kroll-Rabotin et al. (2020), Metals 10, 517.

[9] Delafosse et al. (2018). Chem. Eng. Sci., 180, 52-63.

[10] Loubière et al. (2019). Chem. Eng. Sci., 203, 464-474.