**Valorising Wastewater: A Novel Approach for Critical Raw Materials Recovery from Acid Mine Drainage**

Tamlyn Naidu1, **Craig Sheridan**2 and Peter Engelund Holm1

(1)University of Copenhagen, Copenhagen, Denmark, (2)Centre in Water Research and Development, University of the Witwatersrand, Johannesburg, Johannesburg, South Africa

**Abstract Text:**

**Introduction:**

Mining wastewater and Mining Influenced Water (MIW) represent formidable environmental challenges globally. Acidic mine drainage (AMD), in particular, has gained increased attention in recent years, following the 2015 Gold King Mine spill – leading to classification by the United Nations as the second largest environmental issue worldwide. This AMD and MIW concern extends beyond mining regions, impacting global resource management due to its pervasive and enduring legacy. Traditional AMD treatment methods, often chemical or energy-intensive such as reverse osmosis, are neither economically nor environmentally sustainable. Moreover, the prevalence of AMD intensifies climate change-related issues, including soil degradation, biodiversity loss, and adverse socio-economic effects. However, recent studies have revealed a (small) silver lining: many AMD streams contain substantial quantities of rare earth elements (REEs), and other critical raw materials (CRMs) such as arsenic. These waste streams also exhibit other characteristics that can be harnessed for value extraction, such as high acidity, rich iron content, and strategic geographic locations, often near other waste sources (proximity which presents opportunities for developing a circular economy by combining various waste streams). This study considers a perspective of broader AMD valorisation research, proposing an innovative approach to extract value from AMD, focusing on CRMs, particularly REEs. By integrating various treatment methodologies – ion exchange (IX) technology in particular for REE extraction – this approach redefines AMD from a costly waste liability to a valuable secondary resource. Such a paradigm shift not only mitigates the environmental impact of AMD but also potentially enhances global access to CRMs, addressing a critical need in the context of depleting natural resources.

**Methods and Data:**

This research focussed on the extraction of REEs from coal mine AMD in the Emalahleni region of South Africa (an area that has been impacted by both the social and environmental effects of MIW for decades). The research involved a detailed characterization of AMD to identify and quantify the presence of REEs. Ion-exchange (IX) technology was then evaluated as a method to extract these CRMs from the wastewater. The efficacy of different cationic and chelating resins, specifically chosen for their high affinity for trivalent cations, was assessed. Both batch and column studies were conducted to determine the effectiveness of these resins in extracting REEs from AMD. A thorough analysis of the adsorption capacities of different resins, an examination of adsorption isotherms and kinetics, and the assessment of desorption efficiencies was undertaken in this research.

**Results:**

AMD samples revealed concentrations of REEs with a recovery value of nearly 1 Euro/m3 of AMD. It was found that both chelating and cationic resins closely followed the Langmuir adsorption isotherm model for most REE species, with the chelating resin also aligning to the Temkin model for Yttrium and Lanthanum. This indicated a strong interaction between adsorbate and adsorbent for REEs in AMD. The cationic resin displayed a greater overall adsorption efficiency (80 – 95%) than the chelating resin (33 – 45%) for the range of REEs tested – in the case of Gd, adsorbing up to 5 times more than the chelating resin. In batch kinetics studies, both resins exhibited pseudo-second order behaviour, suggesting that chemisorption is the rate-limiting step in both these systems. Findings from the breakthrough studies suggest that the cationic resin saturated with iron much sooner than with REEs – signifying that iron has a prominent effect on the performance. Desorption experiments with varying concentrations of EDTA and sulfuric acid demonstrated varying efficiencies, with higher concentrations of these eluates generally yielding better desorption results. Desorption was not entirely successful, especially with lower EDTA concentrations, indicating the need for further investigation.

**Discussion and Take-Home Message:**

This study underscores that AMD holds significant concentrations of valuable CRMs. IX technology proves effective for extracting these CRMs, with the research detailing the kinetic behaviour and efficiency of different IX systems. The presence of iron in AMD poses a challenge, affecting the efficiency of REE extraction and necessitating further research to enhance the process. Successful lab-scale results indicate potential for this method to address both wastewater treatment challenges and CRM recovery, promising transformative impacts if scaled effectively.