Analytical Tools and Techniques for Assessing Uranium Sources and Mobility along a Mine Value Chain: A Case Study of an Iron Ore Mine in Northern Sweden

Vimbainashe L. Dzimbanhete[a], Lena Alakangas[b], Oscar Paulsson[c], and Torbjörn Karlsson[d]

[a,b,c]Department of Civil, Environmental, and Natural Resources Engineering, Luleå University of Technology, Luleå, Sweden, vimbainashe.dzimbanhete@ltu.se; [d]Luossavaara Kiirunavaaara AB, Kiruna, Sweden

Elevated concentrations of uranium (U) can be of environmental concern due to U's nephrotoxic and carcinogenic properties. U can be released into the environment through various anthropogenic activities including the nuclear fuel cycle starting from U mining and milling to the disposal of spent nuclear waste, as well as military operations, phosphate fertilizer application, and coal combustion. While environmental studies related to U have primarily focused on U ore mining and milling operations, U can also be found in trace quantities above typical crustal abundance levels within other ore types, such as iron ores. When U-bearing minerals within these ores are exposed through mining and milling, they become susceptible to weathering and oxidation, potentially mobilizing U into groundwater and surface water.

This study emphasizes the different tools and methodologies that can be used for the identification of trace element contaminant sources and the assessment of trace element mobility along a mine value chain, with a focus on U, using an iron ore mine site in Northern Sweden as a case study. Solid (rock, tailings, and ore) and water (groundwater, process water from the processing plant, and surface water) samples were collected at different points along the mine value chain. Total element concentrations were determined through Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) to identify U sources. Additionally, geochemical modeling using PHREEQC was performed to calculate U speciation within the water samples. After determining the U speciation, conditions that could potentially influence the release of U into the water at different points along the mine value chain were identified.

In the solid sample analysis, sequential extraction tests were conducted to distinguish mobile U present in highly soluble minerals that could potentially leach and release U into the water at various points along the mine value chain, from stable U residing in insoluble minerals which require prolonged contact time and mild to acidic pH conditions for U release. Furthermore, hydroseparation tests were carried out on solid samples to concentrate U-bearing minerals in heavy mineral concentrates. The heavy mineral concentrates were subsequently mineralogically characterized using a Zeiss Sigma 300 VP Scanning Electron Microscope with Energy Dispersive Spectroscopy (SEM-EDS) to identify the U-bearing minerals.

The preliminary findings of this study revealed the significance of mine water pumped from an open pit at the mine site as a crucial U source. Subsequent investigations into potential U sources in the open pit were carried out. The minewall technique (Mend, 1995) was employed to assess U leaching rates, measured in $\mu g/cm^2$/week from various rock types within the open pit. The different U minerals leached from these rock types were concentrated through hydroseparation, followed by mineral characterization using the SEM.

This study highlights a diverse set of tools and techniques available for identifying trace element contaminant sources and understanding their behavior in mining value chains. Early recognition of potential contamination sources along the mine value chain is essential for the implementation of targeted management and mitigation measures, thereby reducing contamination mobility and the risk of downstream environmental pollution.

References

Mend. (1995). Minewall 2.0: Literature Review and Conceptual Models Mend Project 1.15.2b Mine Environment Neutral Drainage Program Welcome Screen Search Report List. Sudbury '95 Conference on Mining and the Environment.