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Laboratory Investigation for Critical Minerals, Including REE and Lithium in an Unconventional Source – Oil Sands Tailing

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Summary

Critical minerals, including Rare Earth Elements (REE), lithium, and other elements, are of rapidly increasing interest for their applications in advanced technology and energy systems. Canada has potentially substantial critical mineral resources. One potential source of critical minerals is oil sands tailings. Detailed quantitative information on the baseline and elevated concentrations of REEs in oil sands tailings generated from mining activities in Alberta are required for sustainable critical mineral development. Canada is well known as a resource rich nation with the highest environmental standards for exploration and extraction. Considering the importance of securing reliable critical mineral supplies, this study investigates 100 tailing samples by XRD and four selected samples by WDXRF, ICP-OES/ICP-MS technique to assess the critical minerals contents. The REE content ranges from 1662 ppm to 2681 ppm and the lithium content varies from 114 ppm to 139 ppm. The REE component is primarily associated with monazite and Li is often present within the structure of illite clay.

Introduction

Critical minerals are essential components for the transition from conventional energy systems to green energy technologies. Through oil sands and hard rock mining operations, past studies have shown elevated concentrations of critical minerals present in the mine solid waste. In general, for the reasons of economic significance and demand, only one or a few value added critical minerals have been mined from a mine site and other valuable minerals (if any) are left in the solid waste. At the time of extraction, the left-over minerals were not considered 'critical' and significant in terms of usefulness. For example, Canada has extracted oil from the oil sands deposits for decades and did not consider other mineral resources that may have been present in the oil sands and the processed tailings. Past studies indicate that Alberta oil sands tailings contain significant amounts of heavy minerals such as zircon, rutile, anatase, apatite, monazite, ilmenite, and tourmaline. Among these minerals, monazite [$(REE,Y,Th)PO_4$], is one of the main minerals for rare earth elements. In addition, the crystal structure of zircon and apatite can accommodate rare earth elements (REEs) to some extent. There is a great indication that some other prospective critical minerals such as zirconium and titanium may be present in unconventional sources such as oil sands and will add considerable value.

Rare earth elements (REEs) are a group of 14 chemically similar metallic elements consisting of the lanthanide series (Ln) in the Periodic Table. Yttrium (Y) and scandium (Sc) are sometimes considered REE as they have similar physical and chemical properties. Major application of rare earth elements (REEs) is in manufacturing permanent magnets for electricity generators, electric vehicles, wind turbines, and motors. Other uses include airplane components, vehicle components, flat screens, touch screens, LED lights, electronic parts, EV drive trains, speakers, steel manufacturing, battery anodes, chemical catalysts, glass manufacturing, and specialized glass lenses. Lithium (Li) is a soft alkali metal and is the least dense and highly reactive element. The main use of Li is in the manufacturing of rechargeable batteries.

The aim of this study is to investigate the concentrations of critical minerals using modern analytical techniques, such as Rietveld X-ray diffraction, WDXRD, QEMSCAN, and ICP-OES/MS. The results will

be important for overcoming the technical, economic, and environmental challenges in the critical mineral resource development of oil sands tailings.

Method

One hundred oil sands tailing samples have been collected and analyzed by the following sequences:

1. Semi-quantitative mineral analysis by powder X-ray diffraction in order to determine the relative abundance of heavy and light minerals.
2. Quantitative mineral assessment for selected samples by Rietveld X-ray diffraction in conjunction with WDXRF and QEMSCAN analyses to observe the presence of REE bearing mineral phases.
3. Selected samples have been analyzed by sodium peroxide fusion – ICP-MS/ICP-OES techniques to find the concentrations of critical minerals, including REEs and Li.

Results, Observations, Conclusions

Semi-quantitative X-ray diffraction analysis shows that the average abundance of heavy minerals in the tested tailings samples is 10 wt.%. These heavy minerals include zircon, rutile, anatase, ilmenite, and tourmaline. However, the quantitative analyses by Rietveld method of high-resolution XRD data indicate that the heavy mineral fraction of tailing samples also contains monazite, xenotime, garnet, and magnetite. The presence of these heavy minerals has been confirmed by major and trace element analyses using WDXRF and ICP-OES/ICP-MS. Heavy minerals particularly monazite, xenotime, and zircon often incorporate radioactive elements (uranium and thorium) and critical minerals, such as REEs, Y, Sc, etc. The concentrations of rare earth elements are shown in Figure 1. The ICP-MS/ICP-OES analysis also indicates that the tailing samples contain elevated amounts of lithium (114 to 139 ppm). Thus, the oil sands tailings in Alberta are rich in critical minerals (REEs, Li, Ti, and Zr) and can be considered a valuable resource.

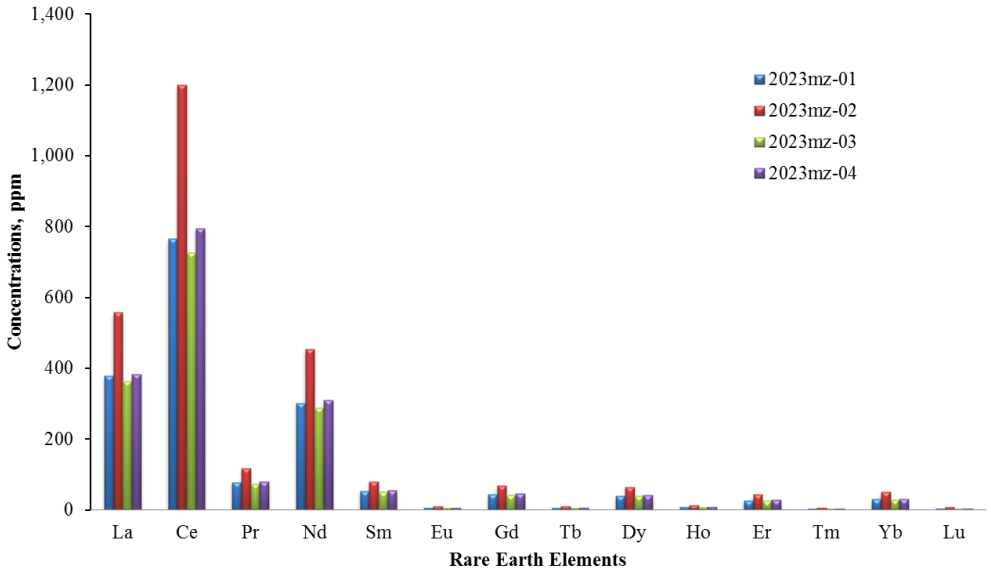

Figure 1: Concentrations of rare earth elements in four oil sands tailing samples measured by sodium peroxide fusion ICD-OES/ICP-MS.