UNIVERSITY OF MISSOURI SOUTH AFRICAN EDUCATION PROGRAM
UMSAEP
UM/UWC LINKAGE PROGRAM
Final Report- Visit to UWC July 01-July 14, 2017
Extraction of Rare Earth Elements from Coal Ash

Submitted by: Dr. Lana Alagha
Assistant Professor, Department of Mining and Nuclear Engineering
Missouri University of Science and Technology
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UWC Host: Professor Leslie Petrik
Department of Chemistry, University of Western Cape

1. SUMMARY

The PI wants to express her sincere appreciation to the UM/UWC linkage program for the financial support to visit the University of Western Cape, South Africa. During my two-week visit, I got the chance to visit the research facilities in the Department of Chemistry, UWC and work closely with the members of the Environmental Nanoscience group (ENS) on different relevant projects. I also got the chance to attend their semi-annul group meeting and learnt about all the projects that are going on. The majority of these projects are related to rare earth elements, their characterization and extraction routes. I also delivered two presentations; one to the ENS research group and one to the Department of Chemistry. I also worked with professor Leslie Petrik on two grant proposals (to NSF and DOE) and one UM/UWC linkage proposal for one of her graduate students who I am co-advising (Mr. Jean Luc Mokaba). During my visit to Cape Town, I also visited the High Performance Computing Center for the purpose of collaboration on modeling of Rare Earth elements-related extraction processes. Overall, the visit was very successful and I think my host and I achieved so many good things during this very short visit.

2. PROPOSED OBJECTIVES OF THE VISIT

The US Department of Energy has identified REEs as critical materials for securing a sustainable source of energy in the future (US DOE, 2011).

Rare earth elements (REEs) are a group of seventeen elements in the periodic table as shown in **Figure 1**. Due to their unique magnetic, luminescent, and electrochemical properties, REEs have become the foundation for several technologies and have been used extensively in many industries such as modern electronics, green energy, health care and transportation and defense. As these industry sectors are growing, the global consumption of REEs is going to increase dramatically.

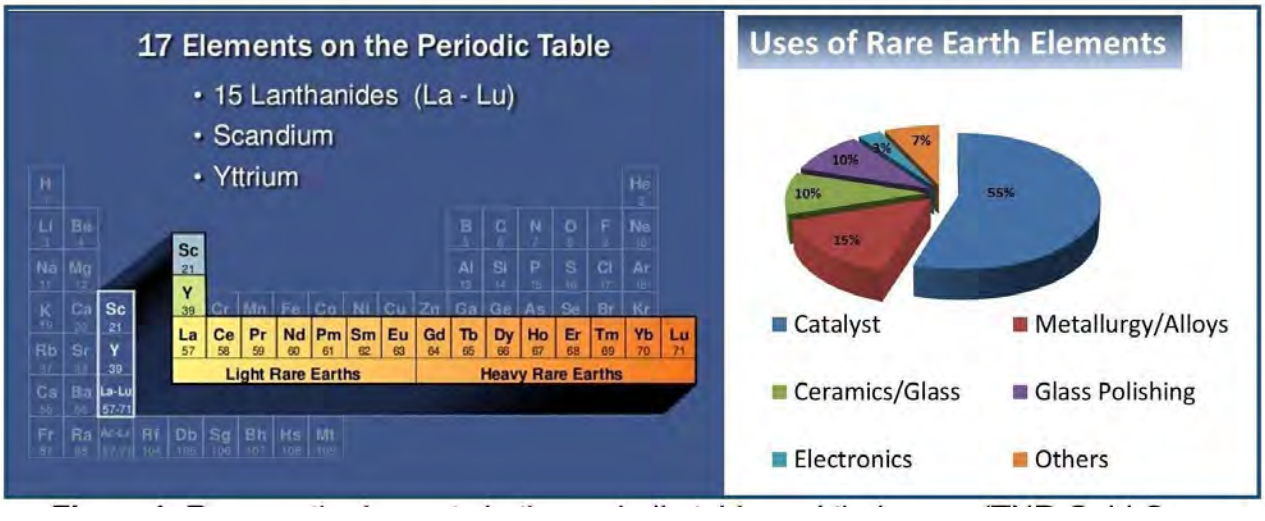

Figure1. Rare earth elements in the periodic table and their uses (TNR Gold Corp., 2017)

Due to the supply challenges and increasing demand in various areas of production, extensive efforts have been devoted to tackle the supply sources, chain and risks associated with finding secure resources. Utilization of mining wastes and other byproducts of mineral-coal processing should offer sustainable and less expensive alternatives. For example, when utilizing REEs from mining operations, larger component of the cost is borne by the mining and concentration processes. This will substantially reduce the cost of separating REEs from by-products. Waste

products from coal, such as finely mixed clays, coal partings and fly and bottom ash (after combustion) have been recently considered as a potential sources of REEs (Peramaki, 2104). The proposed objectives of the visit were to:

1. Help to prepare a draft proposal to be submitted to the department of Energy (DOE)
2. Learn about the best techniques that are currently used for characterization of coal by-products.
3. Initiate discussion and training on different methods that can be used for effective sepataon of rare earth.

Below is the status of the three objectives

3. STATUS OF THE PROPOSED OBJECTIVES

3.1 Objective # 1: Help to prepare a draft proposal to be submitted to the department of Energy (DOE)

During my two-week visit to UWC-Department of Chemistry, I was able, with the help of Dr. Leslie Petrik, to prepare a proposal entitled: "A Sustainable Approach for the Recovery of Rare Earth Elements from Coal By-Products." This proposal was submitted to the Department of Energy under the funding opportunity announcement DE-FOA-0001718, CFDA# 81.089. The proposal was submitted on July 18, 2017. Dr. Leslie Petrik helped me with the chemistry part of the proposal (Chemical Dissolution of Coal Ash to Enrich REE). Total budget of the proposal was $447,089.00

3.2 Objective # 2: Learn about the best techniques that are currently used for characterization of coal by-products.

Dr. Leslie Petrik's research group has done a great job with fly ash characterization. During the semi-annual group meeting on July 4th, 2017, there were many presentation about REE characterization techniques. In addition, Dr. Petrik shared with me two M.S. theses written by her students about the characterization and potential extraction of REE from coal ash. The two theses were very beneficial to me when I wrote the DOE proposal.

3.3 Objective # 3: Initiate discussion and training on different methods that can be used for effective sepataon of rare earth.

The ENS research group has done extensive work on the chemical dissolution of fly ash to extract REE. ENS group uses a variety of techniques that include high pressure waterjet dissolution, conventional acid leaching and sequential chemical extraction procedure to pre-concentrate
REE in coal by-products. Dr. Petrik's work was on the South African coal ash which has less coal (carbon) as compared to US coal ash. We discussed a pre-concentration step using a froth flotation process to remove the combustible carbon material prior to leaching and we included that in the DOE proposal (**Figure 2&3**).

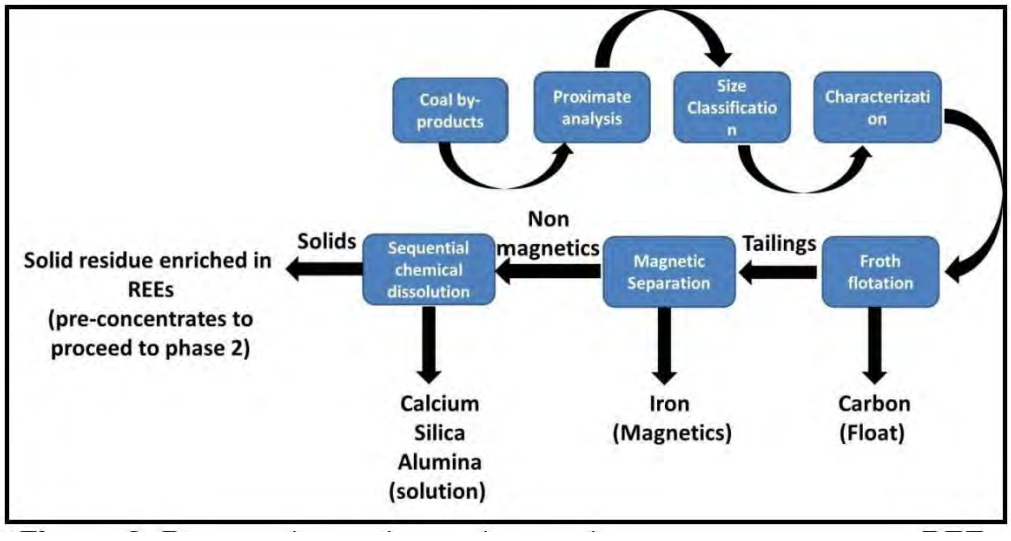

Figure 2. Proposed experimental procedure to pre-concentrate REEs in coal by-products (Objective 3)

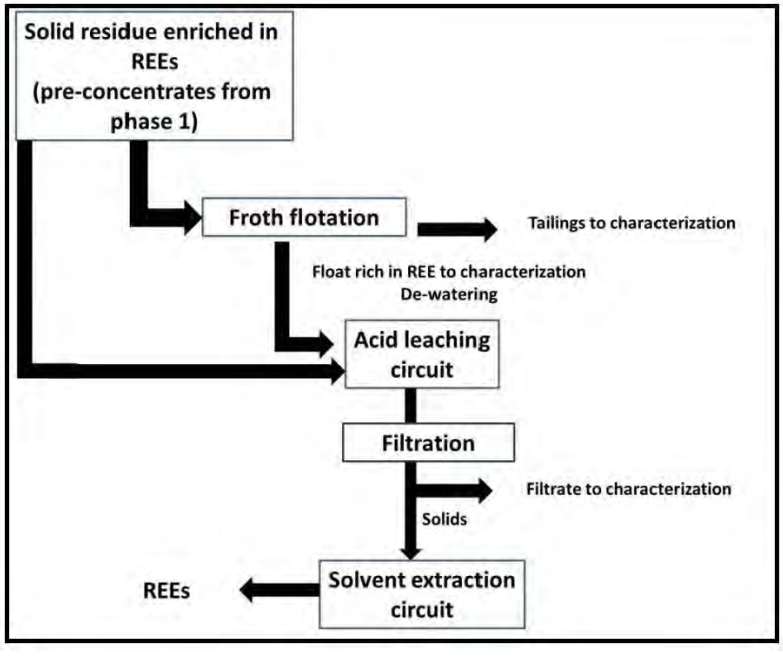

Figure 3. Proposed experimental protocol to concentrate REE (Phase II, objective 3)

4. OTHER ACCOMPLISHMENTS

During my two-week visit, I was able to submit another proposal about the use of ionic liquid membranes in rare earth extraction to the National Science Foundation (NSF). Actually, I was surprised that Dr. Petrik is currently working on a similar project. I also discussed with her the possible use of Molecular Dynamic Simulations (MDS) as a computational tool to understand the mechanism of rare earth metal extraction by liquid membranes. Dr. Petrik was excited about the idea and we visited the High Performance Computing Center in Cape Town for the purpose of collaboration on MDS. The visit and the valuable discussion helped me to submit a proposal

entitled: “Complexation and Ion Transport of Critical Metals in Ionic Liquid Membranes Systems” to NSF. The budget was $561,318.00.

Another very exciting accomplishment was the acceptance of a UWC/UM proposal that was submitted by Dr. Leslie’s PhD student, Mr. Jean Luc Mokaba. Mr. Jean-Luc was awarded a travel grant to visit the Department of Mining and Nuclear Engineering, Missori S&T, to work with my research group on rare earth extraction from tailing wastes.

5. ACTVITIES

07/04/2017: Attended the Environmental Nanoscience group (ENS) semi-annual meeting. There were about 25 different presentations on different research topics. The majority is related to rare earth elements.

07/04/207: Delivered a presentation to ENS group about my current research work at Missouri S&T.

07/08/2017: Visited and established important contacts with the High Performance Computing Center in Cape Town for the purpose of collaboration on MDS.

07/10/2017: Delivered a presentation to the Department of Chemistry/UWC about my past and current projects and potential areas of collaboration.

These are in addition to daily individual meetings with students and tours in campus and in the city of Cape Town.

6. OUITLOOK AND FUTURE COLLABORATION

As I mentioned earlier, my research interests are very similar to Dr. Petrik’s research interests, especially in the rea of rare earth elements. I was selected to serve as a co-advior of one of her PhD students whose research project is very relevant to the research project of one of my PhD students. This student, Mr. Jean Luc Mokaba,was awarded a travel grant from UM/UWC linkage program. Mr. Mokaba is going to visit Missouri S&T in spring of 2018. Mr. Mukaba’s research on the extraction of rare earth elements from phosphate processing wastes aligns very well with my current research on rare earth elements. .My research group is going to help him with the processing part of his project, which includes the mineralogical characterization and physical separation. In addition to this, Dr. Petrik and I are going to collaborate on publications.

7. REFERENCES

Peramaki, S. 2014. “Method Development For Determination And Recovery Of Rare Earth Elements From Industrial Fly Ash”, PhD Thesis: Department of Chemistry, University of Jyväskylä Research Report Series ISSN 0357-346X-ISBN 978-951-39-6001-8

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