Report on research visit to Missouri University of Science and Technology, Rolla, USA

By Prof. L.F. Petrik and Dr. O.O. Fatoba

1. Introduction

In June 2012, Dr. Kwame Awuah-Offei visited Environmental and Nano Science (ENS) research group at the University of the Western Cape, South Africa for research collaboration. During his visit, there was discussion on different research areas where ENS group and his research group at MST can collaborate. The two groups identified some research areas which include determination of radionuclides in South African fly ashes, identification and quantification of rare earth elements (REEs) in South African fly ashes and conducting life cycle impact assessment (LCA) of South African fly ash and fly ash based products. In order to strengthen our collaboration, an application for research visit was submitted to University of Missouri South African Education Program (UMSAEP) to visit Dr Awuah-Offei's facilities in MST for research activities. Due to many years experience and good understanding of South African fly ash, its utilization and beneficiation, Dr O.O. Fatoba was chosen from the ENS group to visit Dr. K. Awuah-Offei at MST. The visit to Dr Awuah-Offei at MST in USA was for a period of four (4) months starting from 5th of March to 8th of July, 2013.

Dr Fatoba at Missouri University of Science and Technology

2. Research activities at MST

2.1 Background

The combustion of coal by South African power utilities to generate electricity has resulted in the production of fly ash. South African power utilities use more than 100 million tonnes of low grade bituminous coal annually to produce cheap electricity thereby generating huge amounts of fly ash as waste each year.

Fly ash is a fine-grained powdery particulate material that leaves the furnace in the flue gas stream and is collected by means of an electrostatic precipitator, baghouse, or mechanical collection device such as a cyclone. Fly ash is composed of minerals which can be divided into acidic (SiO_2, Al_2O_3, Fe_2O_3 and TiO_2) and basic (MgO, CaO, Na_2O

and K_2O). The chemical composition and the properties of fly ash are a function of the origin and type of feed coal, combustion sequence and method of collection, storage and climate. The chemical composition of fly ash is typically made up of elements such as Si, Ca, Al, Fe, Mg and S, along with various trace elements like Co, Cd, As, Se, Zn, Mo, Mn, Pb, B, Cu and Ni. Apart from these elements, studies have shown that some REEs are present in fly ash. These elements are found in the ash because of their high melting points and the short time the ash particles actually remain in the furnace during combustion. The disposal of fly ash has been a major concern to the world because of its potential environmental impact due to the possible leaching of the toxic elements contained in fly ash.

The objectives of the visit was to determine the concentration of the rare earth elements (REEs) present in different South African fly ashes, and model the South African fly ashes to determine the life cycle impact assessment of the waste material and fly ash-based products.

2.2 Identification of Radionuclides and REEs

On arrival at MST, Rolla, Dr. Fatoba visited the Nuclear reactor facility in the Mining & Nuclear Engineering Department where he was introduced to Dr. A.B. Alajo (Assistant Professor) and Mr. Craig Reisner (Reactor Technician) on 10th March, 2013. There was a brief meeting where discussions took place on the required training for the use of NAA to analyse the fly ash samples brought from South Africa. On the 18th March 2013, Dr Fatoba started the training with Mr. Reisner (Reactor Technician) on how to irradiate samples using the reactor and how to count the irradiated sample for the identification of radionuclides and other elements. After the 2-week training, he started the NAA analysis where some radionuclides such as 238U, 234U, 235U, 232Th, 228Th, 228Ra, 226Ra, 210Pb, and 40K were identified in the fly ash samples. Unfortunately, the quantification of the radionuclides was not possible due to lack of expertise and guidance on how to do the calculations. The REEs in the fly ash could not be identified due to inability to irradiate the sample to the required energy for the identification of the elements. The technician noted that the requested energy for the identification of the

REEs created too much heat and melted the vial that held the sample. The team was unable to find a solution to this problem during the period of the visit. Thus, the characterization concentrated on identifying the presence of radionuclides using NAA.

2.3 Life cycle modelling

After the training on the use of the for the analysis of radionuclides, the life cycle impact assessment modelling software (SimaPro 7) was purchased by Dr. Kwame Awuah-Offei. The modelling software was used to carry out a comparative study on the life cycle inventory (LCI) for the production processes of Zeolite A in Europe and the production of South African fly ash-based zeolite-A. The purpose of the study was to generate and publish an authentic LCI for the production of fly ash-based Zeolite A using a "cradle-to-factory-gate" approach. The processes comprised the raw materials, flow of energy, emissions to air and water and solid waste generation. The raw materials for the European zeolite A production were sand, sodium chloride and bauxite. The sodium chloride was electrolysed to produce caustic soda (NaOH), which was used to convert bauxite to sodium aluminate and sand to water glass (sodium silicate). In the fly ash-based zeolite A production, the processes of converting bauxite to sodium aluminate and sand to sodium silicate were by-passed due to the composition of fly ash. The by-pass of some of these processes would have advantages on the input and output of the process. Details of the LCI are contained in the manuscript “in preparation” which is yet to be published.

3. Other activities

3.1 Visit to other collaborators

As part of the efforts to extend the collaboration of the ENS group to other researchers at MST, Rolla, Dr. Fatoba visited Dr. Jonathan Kimball in the Electrical and Computer Engineering Department at MST. There was a discussion on the proposal submitted by ENS group to US National Science Foundation's (NSF's) Partnerships for Enhanced Engagement in Research (PEER) program, where Dr. Kimball and Dr Burken Joel were included as US collaborators. The possibility of future collaboration apart from the

PEER funding proposal was also discussed. Dr. Fatoba, with the arrangement by Dr Awuah-Offei, met with Dr Lana Alagha of Missouri University of Science and Technology–Department of Mining & Nuclear Engineering, Rolla. There was discussion on research collaboration which led to the writing of a joint proposal titled “Ash Depression in Fine Coal Flotation Using Novel Polymeric Nanoparticles” submitted to Illinois Clean Coal Institute (ICCI) for funding. The proposal, if funded, will strengthen the research collaboration between UWC and MST researchers.

3.2 Visit to tourist centres

During the 4-month research visit to MST, Rolla, some tourist centres were visited by Dr. Fatoba. These include visits to Meramec Spring in Rolla, St Louis Zoo and St Louis Science Center *(photos inserted)*.

Dr Fatoba at Meramec Spring in Rolla

Dr Fatoba at St Louis Science Center

3.3 Presentation at MST

On the 19th April, 2013, Dr Fatoba made a presentation to the Rock Mechanics & Explosives Research Center (RMERC) at MST where he was hosted during the research visit. The presentation which was titled “An overview of research work at Environmental and Nano Sciences (ENS) group in South Africa” gave an overview of the research work carried out by ENS research group at the University of the Western Cape. The presentation was well attended by Faculty members and postgraduate students, and this gave the opportunity for the researchers to have an insight into the type of research being carried out at ENS and the possible areas of future collaboration.

3.4 Return trip (Missed flight)

On the return trip to South Africa, Dr. Fatoba missed his flight from Washington-Dulles to Johannesburg, South Africa, as a result of the delayed flight from St. Louis to Washington-Dulles. The missed flight led to spending extra 2 days before arriving in South Africa. The delay added extra cost which was paid by the ENS group. Unfortunately, none of the airlines were ready to take responsibility for the additional cost. This reason for this was as a result of the way the travel agency booked the ticket. Instead of connecting all the flights from Cape Town to St Louis, Missouri, a flight was booked from Johannesburg to Washington-Dulles, while local flights were booked separately from Cape Town to Johannesburg and Washington-Dulles to St Louis with no connection with the international flight. In order to avoid the repeat of this incident, it is advised that in future a direct international flight be booked instead of booking both local and international flight that may end up creating problems in case anything happens.

4. Comments

The research visit was an interesting and educating one. Dr O. Fatoba would like to greatly thank and express his appreciation to the University of Missouri-South African Education Program (UMSAEP) for the opportunity.