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## **Techniques Used to Determine Rare Earth Elements (REEs) in Coal Fly Ash Generated from Three Different Power Stations in South Africa**

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Recently, the worldwide supply of rare earth elements (REE's) (i.e. Sc, Y and the so-called lanthanoids which are La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Th, Yb, and Lu) has been considered vulnerable to disruption. On the other hand, coal-derived fly ash emitted from coal-fired electric power plants occurs in abundance and may contain relatively high concentrations of REE's. The contents of REE's in coal fly ash are possibly up to several hundreds of ppm. In order to extract and recover REE's from coal fly ash particles, as a first step, techniques to determine their concentration levels have to be identified.

This study aims to identify the techniques that are commonly and appropriately used to determine the concentration of REE's in three coal-derived fly ash products generated from different power stations in South Africa. The most common techniques used in the determination of REE's are X-ray diffraction (XRD), scanning electron microscopy (SEM), inductively coupled plasma techniques (i.e. LA-ICP-MS, ICP-MS and ICP-OES), instrumental neutron activation analysis (INAA), and particle induced x-ray emission (PIXE). However in this study, only XRD, SEM, ICP-MS/OES, and INAA will be used.

XRD was used to identify minerals that are known to contain REE's such as monazite, francolite, zircon, and apatite. Since these minerals are found in very small amounts in coal fly ash, XRD was not able to detect these minerals due to its low detection limit. Thus, the minerals that were detected in all coal fly ash samples were mainly quartz ( $\text{SiO}_2$ ) and mullite ( $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ ), a minor amount of albite ( $\text{NaAl}_3\text{Si}_3\text{O}_8$ ) and hematite ( $\text{Fe}_2\text{O}_3$ ), and a trace amount of anorthite ( $\text{CaAl}_2\text{Si}_2\text{O}_8$ ), cristobalite ( $\text{SiO}_2$ ) and sillimanite ( $\text{Al}_2\text{SiO}_5$ ).

In order to analyse the coal fly ash using ICP techniques (excluding LA-ICP-MS), complete digestion is required. Different techniques, including the use of different acids, have been tried in order to identify the methods that can lead to the highest recovery of REE's using ICP-MS/OES. INAA which is non-destructive method will also be used to determine the concentration levels of these elements in the coal fly ash. SEM will be used to obtain elemental maps of these materials and possibly to determine the mineral associations of the REE.

