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Exploring Spectroscopic and Morphological Data as New Signatures for Uranium Ore Concentrates

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Nuclear Forensics is a relatively new discipline that emerged as a response to illicit nuclear material trafficking. From measurable parameters such as chemical and isotopic composition of major and minor elements, the aim of the analysis is to determine the origin of the 'lost' or 'found' nuclear material. The task of attributing materials remains to be multi-faceted and the search for new signatures (i.e. measurable parameters) continues. In this study, the material of interest is a class of uranium compounds known as uranium ore concentrates (UOCs) or colloquially termed as yellow cakes. These are pre-cursors of nuclear fuel and various chemical compositions are available industrially due to the use of different precipitating reagents upon mining and milling of uranium deposits.

The first part of the study involves the use of Raman spectroscopy for measuring these samples. The technique is of interest as it is capable of providing fast analysis without destruction of the samples and henceforth samples can be further preserved for other analysis. The applicability of Raman spectroscopy to UOCs for nuclear forensics purposes has been demonstrated1.

Upon the Raman measurement of the samples, principal component analysis (PCA) would be used to analyze the data. Primarily a pattern recognition/data reduction technique, PCA is a form of chemometrics that has gained importance in the analysis of huge dataset. It is useful in data such as spectroscopy which has typically a few thousand variables. In essence, PCA finds the correlation between variables (in this context, the variables are the wavenumbers) and presents the data using principal components (PCs). Normally, only a handful of PCs suffice to explain most of the variance in a dataset, therefore PCA also leads to data reduction while at the same time, it reveals the relationship between the samples (known as 'score plot') as well as that among the variables (known as 'loadings plot'). Similar samples will thus be located close to each other in a score plot and hence groups or clusters are concurrently highlighted. On the other hand, outliers can also be readily identified.

PCA was successfully applied to the Raman spectra after some pre-processing was carried out. The usefulness of Raman spectroscopy in the analysis of UOCs shall be discussed in details along with its complementary nature to Infrared spectroscopy (IR)2.

In the second part of the study, the morphology expressed in terms of particle sizes or particle size distributions of the different compositions of UOCs was investigated. Scanning electron microscopy (SEM) is used to obtain images of dispersed particles while characterization is done with image processing software.

While at its infancy, the particle size analysis using SEM poses challenges. A reliable and reproducible method of dispersal is currently under development. It is necessary to disperse the particles such that their sizes and shapes could be properly evaluated or characterized. It is subsequently envisaged that the SEM images of well dispersed samples be evaluated with image processing software.

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