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# Improving Trace Element "Fingerprinting"of Uranium Ore Concentrates

The Canadian Nuclear Safety Commission (CNSC) Laboratory, working within the Nuclear Material Signature and Provenance Assessment Capability Development Project (NMS/PAC), has developed a laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) method for rapid bulk trace element analysis of uranium ore concentrate (UOC) suitable for both national nuclear forensics library (NNFL) maintenance and analysis of intercepted nuclear forensics samples (1). The method enables rapid, accurate and precise trace element analysis of UOC with almost no radioactive waste generated and minimal sample consumption, which is ideal for nuclear forensics.

The LA-ICP-MS method provides a measurement of 48 element concentrations. Limits of quantification range from $1.7 \times 10^{-7}$ to $2\times 10^{-3}$ mg/mg Uranium, reflective of uncertainties that vary depending on the measured element. The applicability of LA-ICP-MS in attribution of UOCs was tested by performing a provenance assessment exercise using a selection of 28 samples comprising:

1. Three standard reference UOC samples obtained from the International Atomic Energy Agency (IAEA): IAEA8745, from Olympic Dam; IAEA8747, from Ranger mine; and IAEA 9449, an artificial sample made of a mixture of an old CRM and UOC from the Rössing mine,
2. 22 UOC samples randomly selected from the Canadian NNFL, representing 20 manufacturers from 8 distinct geographical locations and four types of UOCs, and
3. Three samples of unknown origin.

The origin of each sample was determined using classification models developed under the NMS/PAC and trained using the Canadian NNFL. To assess the effects of measurement specific uncertainty, the models were trained on different subsets of elements. The element subsets were chosen based on:

1. Prior measurements and geochemical subject matter expertise (published in (2));
2. Identification of elements with high variability and low measurement uncertainty in the dataset; and
3. Inclusion of the full suite of rare earth elements into the high variability subset.

The subset of elements included during the model-training phase is found to be crucial for reliably successful UOC attribution. Method 2 provided the best results: the ranges of concentrations of the elements were sufficiently broad to allow for clear discrimination between producers. In addition, it appears that the uncertainties in element concentrations play a significant role. Classification based on elements with lower uncertainties provided higher confidence in provenance assessment. The inclusion of rare earth elements in the training subset resulted in a decrease in the confidence of attribution, as already reported (2).

The significance of these results for the characterization and provenance assessment of UOC and interrogation of NNFL will be discussed.

**References**

1. Trace Analysis of Uranium Ore Concentrates Using Laser Ablation Inductively Coupled Plasma Mass Spectrometry for Nuclear Forensics. S. V. Jovanovic, T. Kell, J. El-Haddad, C. Cochrane and A. El-Jaby. 2019, J. Radioanal. Nucl. Chem. (submitted).
2. Discrimination of Uranium Ore Concentrates by Chemometric Data Analysis to Support Provenance Assessment for Nuclear Forensics Applications. J. El-Haddad, A. Harhira, A. Blouin, M. Sabsabi, S. Jovanovic, T. Kell and A. El-Jaby. 2018, J. Radioanal. Nucl. Chem., Vol. 317, pp. 625-632.

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