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Measurement of Organic Residues of Uranium Ore Concentrates (Yellow cakes) for Nuclear Forensic Investigations

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As a response to the illicit trafficking of nuclear materials starting from the 1990s a new scientific topic has emerged, commonly referred to now as nuclear forensics.1 The aim of the nuclear forensic investigations is to identify the hazard and origin of the confiscated or found nuclear materials and ultimately strengthen security measures and prevent nuclear terrorism thereafter. Over the last few years several signatures of nuclear materials have been investigated and developed to establish the links between the measurable parameters of the unknown material in question and the source of the nuclear materials. These measurable parameters or signatures include e.g. elemental or anionic impurities, isotopic composition, structural analysis, morphology and age determination.1 This complex dataset can give information about the source of uranium ore or feed materials, process and the production facility. Uranium ore concentrate (commonly known as yellow cake) has a special role among the investigated nuclear materials, as it is the first purified industrial product of nuclear fuel fabrication, and thus it is highly useful to identify the source and propagation of various applicable signatures.

In the last years several signatures of the inorganic constituents have been investigated in details, such as the concentration of common metallic impurities (transitions metals or lanthanides) or their isotopic compositions.1 On the contrary, organic traces of nuclear materials have been rarely studied for nuclear forensic or safeguards purposes, probably due to the fact that traditionally inorganic analytical techniques are applied in this field. Though several intermediate products of the nuclear fuel cycle potentially contain high amount of organic materials, especially if organic solvents and reagents are present in the process flow, their systematic study and application have not been performed yet. Firstly, Kennedy et al. reported the possible use of gas chromatography mass spectrometry (GC-MS) for the measurement of non-volatile constituents in uranium ore concentrates.2 They applied Twister® stir bars to extract the organic traces qualitatively, and several organic constituents could be identified (e.g. dioctylamine and trioctylamine), which were assumed to be indicative of the used metallurgical processes. The study, however, used only selected samples and did not give details on the origin of the studied material.

The aim of the present study is to evaluate the feasibility of GC-MS for the origin assessment of unknown uranium ore concentrates. The work comprises the method development for the extraction of trace-level organic constituents, followed by the high sensitivity GC-MS analysis. The first target analytes in our study are tri-n-octylamine, tri-n-octylphosphine oxide and tri-n-butyl phosphate, which are the most important extractants used for solvent extraction in uranium production. The developed method and the results of uranium ore concentrates of world-wide origin are presented.

References

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2. A. K. Kennedy, D. A. Bostick, C. R. Hexel, R. R. Smith and J. M. Giaquinto, Journal of Radioanalytical and Nuclear Chemistry, 2013, 296, 817-821.

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