Can we reduce waste from and around nuclear installations by analysing long-lived radionuclides?

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Long-lived radionuclides are undesirable by-products resulting from the operation of nuclear installations. These radionuclides are also produced in situ in construction and building materials by a variety of processes, including (thermal) neutron capture, fission, spallation, as well as other nuclear reactions. Concentrations of the radionuclides must be monitored while the installations are in operation, after shut-down and most crucially, throughout the decommissioning phase. In the event of an accident, these radionuclides can be found in higher concentrations in the immediate and wider environmental surroundings, necessitating their analysis also in soil, water, flora and fauna.

Accelerator mass spectrometry (AMS) is a highly sophisticated analytical technique that can be used to detect three of the important but traditionally difficult-to-measure radionuclides (DTMRs) important in decommissioning: ^{14}C [1], ^{41}Ca and ^{90}Sr. Carbon-14 ($t_{1/2}$=5.7 ka) analysis is relatively straightforward and can be performed at >150 AMS facilities world-wide. Until recently, however, it was considered favourable or necessary to use one of the rare accelerators with higher ($\geq$5 MV) terminal voltage for ^{41}Ca ($t_{1/2}$=0.1 Ma) and ^{90}Sr ($t_{1/2}$=29 a) AMS analyses. However, time-consuming and cost-intensive sample preparation to reduce the sample matrix and other interferences, was preventing routine and high-sample through-put AMS measurements, which would be absolute requirements for clearance measurements to recycle building materials and soil.

The world-wide unique Ion-Laser InterAction Mass Spectrometry (ILIAMS) [2] setup at the 3 MV Vienna Environmental Research Accelerator (VERA) allows now for the very first time an isobar suppression in the order of 10^{11}-10^{12} for isobaric interferences such as ^{41}K and ^{90}Zr at these low ion energies. Under these conditions, i.e. lowering detection limits and necessary sample masses, chemical separation can be largely simplified or eliminated at all, e.g. for ^{41}Ca or ^{90}Sr in concrete, the latter being subject to very low clearance levels (e.g. 2 mBq/g soil), which are challenging to meet with radiometric methods. This development signifies a paradigm shift in the realm of AMS technique, substantiating its viability as a cost-effective modus operandi for the analysis of nuclear waste and fostering there a more circular economy.