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Tracking down Tc-99 in the environment

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Concentrations of the anthropogenic radionuclide ^{99}Tc ($t_{1/2}$ = 2.1× 10^5 yrs) have been extensively studied in the Irish Sea, where the Sellafield reprocessing plant is responsible for high concentrations of 2× 10^9 atoms/ml. However, a comprehensive understanding of its global distribution and physico-chemical behavior in the environment remains limited. The accurate determination of ^{99}Tc concentrations in samples distant from contamination sources requires detection methods with exceptionally high sensitivities of better than 10^7 atoms/sample or prohibitively large sample volumes.

In AMS of ^{99}Tc effective suppression of the stable isobar ^{99}Ru and establishment of a reliable normalization method are imperative. Various strategies can be employed for the suppression of ^{99}Ru: at the Vienna Environmental Research Accelerator (VERA), we investigate an approach using a 3 MV tandem accelerator coupled with the Ion-Laser InterAction MS (ILIAMS) setup. It has been shown that because of different detachment energies, $^{99}RuF_5^-$ can be suppressed by a factor of up to 105 using a 532 nm-laser, making extraction of $^{99}TcF_5^-$ a viable option for ILIAMS [1]. For normalization to $^{93}NbF_5^-$ extracted from the same sample, the reproducibility of the method was significantly improved by a factor of 3 by optimization of ion source parameters.

At AMS-facilities equipped with large accelerators that can reach >10 MV terminal voltage, another approach can be pursued. The Australian National University (ANU) uses a 15 MV tandem accelerator, so that the ions are accelerated to ~190 MeV and ^{99}Ru and ^{99}Tc are separated in an 8-anode ionization chamber. The minute differences in their energy loss characteristics are only observable at these high ion energies [2]. Normalization to $^{93}NbO^-$ current extracted from the sputter matrix [3] achieved a precision of 10%. Technical details of this technique are presented in the contribution from Stefan Pavetich.

Implementing this latter approach, we not only met the criteria for sensitivity and reproducibility but also marked a significant milestone by effectively analyzing a comprehensive set of samples from different environmental reservoirs. Among these were 1 g peat bog samples and 10 L water samples from the Pacific Ocean and European rivers. By employing chemical preparation techniques and subsequent AMS measurement we successfully determined ultra-trace levels of ^{99}Tc.

References:
[1] Martschini et al. Radiocarbon 64(3) (2022), doi: 10.1017/RDC.2021.73
[2] Wacker, et al., Nucl Instrum Methods Phys Res B 223-224 (2004), doi: 10.1016/j.nimb.2004.04.038
[3] Koll et al., Nucl Instrum Methods Phys Res B 438 (2019), doi: 10.1016/j.nimb.2018.05.002

Student Submission

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