Multimodality Scanner for Advanced Radioactive Waste Characterization

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Radioactive materials used in human activities, such as power generation, industrial processes, and medical applications, can generate radioactive waste. During the early stages of nuclear technology development, radioactive waste was conditioned in waste drums that, in many cases, lack partial or complete information about their origin, contents, and activity. In Sweden, thousands of drums containing this so-called legacy radioactive waste are currently stored in temporary facilities. These drums must be characterized and classified to meet the acceptance criteria of the Swedish final repository system, which is currently under construction.

Non-destructive radioanalytical methods are generally preferred for characterizing this type of waste, as sampling may be difficult [1]. We have developed a multimodality scanning system that enables comprehensive passive non-destructive assay (NDA) of shielded waste drums. The system combines three complementary imaging techniques: Neutron-Gamma Emission Tomography (NGET) [2], 3D gamma-ray transmission computed tomography (CT), and spectrometric gamma-ray Single Photon Emission Computed Tomography (SPECT).

Each modality provides distinct but complementary information about the drum contents. NGET detects and localizes special nuclear materials and other actinides, while SPECT identifies and localizes gamma-ray-emitting radionuclides. Transmission CT reconstructs the distribution, shape, and dimensions of passive materials within the drum, providing the structural information required to interpret the radiological measurements. By integrating information from all three modalities, the system enables comprehensive characterization of the waste drum that would not be achievable using any single technique alone.

The three imaging modalities are integrated into the Automatic Radwaste Characterization (ARC) machine [3], which incorporates a precision positioning system with continuous 360° rotation and 1 m vertical scanning capabilities, enabling full-volume imaging of standard waste drums.

The ARC machine was evaluated using representative waste matrices and a mock-up drum designed to replicate the physical characteristics of a typical Swedish legacy waste package. The mock-up consisted of three nested drums of different diameters separated by a thick concrete layer. The system successfully localized point-like ^{252}Cf sources, a natural uranium bar, and point gamma-ray sources such as ^{60}Co and ^{137}Cs, while also reconstructing the positions, shapes, and relative densities of passive materials within the drum. This work presents the first measurements and reconstructed images obtained with the complete ARC system and compares the results with detailed GEANT4 simulations of the full experimental setup.

[1] Bornhöft M. C., Millot, L. (2024): ROUTES – Review of characterisation of legacy and historical wastes. Final version as of 15.04.2024 of deliverable D9.8 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

[2] J. Vasiljević, V. Peters, A. Puranen, and B. Cederwall, Sensitive imaging of actinide materials in shielded radioactive waste. Sci. Rep. 14, 26798 (2024). https://doi.org/10.1038/s41598-024-78027-9.

[3] B. Cederwall, A novel 3D-imaging and characterisation technique for special nuclear materials in radioactive waste, EPJ Nuclear Sci. Technol. 9, 8 (2023) https://doi.org/10.1051/epjn/2022037.