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#08-137 Advanced Sectorial Gamma Scanning of Radioactive Waste Drums with Spatial Reconstruction of Activity Distributions and Quantification of Uncertainties

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The non-destructive assay based on radiation detection techniques is cost-effective measure to characterize radioactive waste and serves to verify the conformity with safety requirements for waste packages. Gamma scanning is a standard widespread measurement technique for the non-destructive assay of radioactive waste drums to determine the nuclide-specific activity content of the waste product. In the past decades, the predominantly used method is segmented gamma scanning (SGS), which is based on simplifying assumption of a uniformly distributed activity and a homogeneous waste matrix. The simplification leads to large model-error for a non-uniformly distributed activity distribution which reduces the accuracy of the measurement. The deviation from the calibration condition of SGS adds to the measurement uncertainty which in turn increases the upper limit of the confidence interval used to quantify the conservative estimate of the activity content. In some cases, this leads to a significant overestimation of the true activity, the difference constituting 'virtual activity'which is not actually present in the waste drum. The virtual activity caused by the large measurement uncertainties results in an excessive and inefficient exhaustion of activity limits for waste packages resulting in higher costs for disposal.
The companies AiNT and Mirion Technologies (Canberra) collaboratively developed a novel system named Advanced Sectorial Gamma Scanning (ASGS) for the gamma-spectrometric waste assay of waste drums with uniform and non-uniform activity distributions. The ASGS system is designed for commercial use allowing for

- high throughput,
- flexibility with respect to size of the waste drum,
- a high dynamic range with respect to the gamma radiation fields of the measured waste drum,
- a high degree of automation of the measurement and analysis procedure.

The analysis method to reconstruct the spatial activity distribution of nuclides within the waste was implemented in a software module named ECIAD (Efficiency Calculation for Inhomogeneous Activity Distributions). The software undertakes the calculation of the photopeak-efficiencies based on a geometric modeling of the measurement configuration, the waste drum, and the active matrix. The activity distribution within the active matrix is approximated with a discrete model of sources on a grid within the drum. The best estimator for the total activity is determined from the measurement data using an optimization method and considering the Poisson statistics of the counting measurement, uncertainty contributions in the self-absorption of the active matrix as well as the model uncertainty in localization of the activity distribution. The ECIAD software reports the measurement results including the uncertainties and the characteristic limits in accordance with the ISO 11929. This feature is highly relevant for the safety assessment and qualification of radioactive waste packages where a confidence level of the activity inventory needs to be declared.
An ASGS system was commissioned at the technical center of AiNT for experimental validation of the gamma scanning method and the analysis software. To this end, reference drums with three different matrix materials consisting of medium density fiberboard, polyethylene, and garnet sand with respective densities of 0.7, 0.9 and 2.3 g/cm^3 were measured with calibration sources located at various locations within the matrix. In addition, measurements using the method of segmented gamma scanning were performed for a direct systematic comparison of the measurement accuracy. The validation of the ASGS system and the ECIAD software demonstrates the capability to determine the nuclide activities of a 'hot-spot'in 1.5 hours total scanning time

with a significantly lower total measurement uncertainty than the standard method of Segmented Gamma Scanning. This paper presents the ASGS system design, the analysis procedure, the treatment of uncertainties and the results from the experimental validation.

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