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Abstract

Radiological characterization of low-and intermediate level (LL/IL) radioactive waste

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In the framework of maintenance, upgrades and dismantling activities of particle accelerators, a number of activated components are removed from the accelerator complex and require radiological characterization before their disposal as radioactive waste. This thesis introduces a methodology for the radiological characterization of radioactive waste produced in the particle accelerators at the European Organization for Nuclear Research (CERN). In particular, we focus on the characterization of Low level/Intermediate level (LL/IL) metallic waste, in view of its disposal after melting.

The aim of the characterization is the identification of the radionuclides produced inside the waste packages, along with the evaluation of their activity concentration. The characterization relies on extensive analytical calculations, which allow us to predict what radionuclides can be produced due to interactions between the incident particles and the accelerator structures and their surroundings. The predicted radionuclides can be classified as Easy-to-measure (ETM), Difficult-to-measure (DTM) or Impossible-to-measure (ITM). The ETM radionuclide activity concentrations are evaluated via gamma spectrometry measurements of the waste items, the activities of DTM radionuclides by experimental scaling factors (using representative samples of the waste) and the activities of ITM radionuclides by analytical scaling factors.

The radiological characterization presents several challenges. Items of waste which are candidates for elimination as LL/IL have dose-rate levels higher than 100 μSv/h, a radiation level which is challenging in terms of radiation protection during the phases of handling and measurement. In addition, these waste items often exhibit highly heterogeneous activity distributions. Hence, it can be difficult to obtain accurate results from *In-Toto* gamma spectrometry, especially if the analyses are performed under the simplistic assumption that the activity distribution is uniform. In order to overcome such difficulties, we propose a novel Non-Destructive Assay (NDA) technique that estimates the uncertainties introduced by this assumption. We use geometry model optimization to quantify the expected activity concentration values to the best of our knowledge using multi-line and multi-count consistency constraints. The thesis also describes the quantification of activity concentration levels of DTM and ITM radionuclides. The scaling factor formalism relies on an existing activity correlation established between the Key Nuclide (KN) and DTM radionuclides from a set of samples representing the waste population. Therefore, the Difficult-to-measure radionuclides activity concentrations of a given waste item or package belonging to this population can be evaluated using the geometric mean scaling factor value from the sample's log normal distribution. The entire process to establish the scaling factors for the DTM radionuclides may be long and challenging, in order to collect a sufficient number of samples that represent the waste population. In the case of Impossible-to-measure radionuclides, we apply the analytical Correlation factor (CF) from the analytical activation calculations.

In addition, we propose a new methodology that predicts the total beta-gamma specific activity based on the average dose rate measurements for LL/IL waste produced at CERN in an operationally efficient manner for waste packages production purposes. The methodology is validated using gamma spectroscopy techniques with a geometry model optimization formalism.

The thesis describes the characterization methodology in full details, along with practical examples and benchmarks. At the moment of writing, such methodology has already been approved by French National Agency for Radioactive Waste Management (ANDRA) and it is being applied to the first batch of LL/IL waste to be disposed of. We expect that this methodology can be successfully applied to radioactive waste produced in other particle accelerators outside CERN.