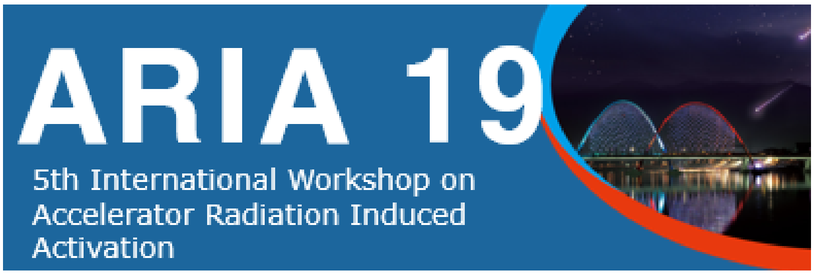

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Radiological characterization of radioactive magnets at CERN

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The radiological characterization is an essential requirement for the disposal of radioactive waste in national repositories. At the same time, such characterization can be particularly challenging in the case of radioactive waste produced in particle accelerators like the ones operated at the European Organization for Nuclear Research (CERN) –where most of the accelerator components are unique prototypes and the radiation environment includes neutrons, protons, photons and pions with a wide range of energies and fluences. More specifically, accelerator components can also include electromagnets, which are used to guide and focus charged particle beams. As a consequence of the accelerator complex operation, those electromagnets become radiologically activated and hence referred to as radioactive magnets. After the decommissioning of a particular accelerator, the electromagnets are temporarily stored at CERN awaiting radioactive decay and characterization for an adequate definition of a waste elimination pathway.

The characterization of CERN radioactive magnets is particularly challenging. Firstly, their dimensions can be several meters in length and their masses are typically above one ton. Secondly, they are composed of different types of metals (e.g. cast iron and copper) in different proportions. Thirdly, they present heterogeneous activity distribution. Finally, the magnets' physical geometry does not lend itself easily to radiation dose profile measurements due to hardly accessible surfaces (e.g. inside the vacuum chambers).

In this paper, we present a characterization method which is based on a prior extensive study using the analytical code ActiWiz [1], in order to define the expected radionuclide inventory and activity levels over hundreds of possible activation scenarios. By normalizing the activity levels of all the radionuclides to the activity level of the dominant gamma emitter, one can infer the so-called "fingerprints": a list of radionuclides with the associated activity ratios. We then performed a series of Monte Carlo simulations with Fluka [2,3] and In-Situ HPGe (High Purity Germanium) gamma spectroscopy measurements, in order to define the ratio between a contact dose-rate measurement and the specific activity of the dominant gamma emitter. By combining the fingerprints with the dose-to-activity ratios, we obtained the so-called "conversion factors", which provide the radiological characterization of the magnet from the dose rate map.

The French National Radioactive Waste Management Agency (ANDRA) approved the proposed based on the conversion factors and dose rate map. A pilot phase was successfully carried out using this method, which has now reached an operational phase at CERN. In addition, we performed an experimental validation by comparing results from this characterization method with those from In-Situ HPGe gamma spectroscopy measurements. Thanks to this study and to the experience gained in the pilot elimination campaigns, we could identify the number of dose-rate measurements and how to choose representative measurement points in order to obtain the most accurate activity evaluation.

The conversion factors method can be applied to radioactive waste from other particle accelerators, in particular to large accelerator components with a non-homogeneous activity distribution. The propose method has a clear advantage over the In-Situ HPGe gamma-spectrometry and sampling techniques. It can be performed with a hand-held radiation detector, and does not require destructive analyses.

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[2] T.T. Böhlen, F. Cerutti, M.P.W. Chin, A. Fassò, A. Ferrari, P.G. Ortega, A. Mairani, P.R. Sala, G. Smirnov and V. Vlachoudis, The FLUKA Code: Developments and Challenges for High Energy and Medical Applications,

Nuclear Data Sheets 120, 211-214 (2014).

[3] A. Ferrari, P.R. Sala, A. Fasso‘, and J. Ranft, FLUKA: a multi-particle transport code, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773

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