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Monte Carlo optimization of shielding for novel industrial free-release measurement facility

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Content

A novel industrial radionuclide-specific free-release measurement facility (FRMF) is being designed, constructed and tested within the scope of a 3-years joint research project "Metrology for Decommissioning Nuclear Facilities" (MetroDecom). The facility is modular and reusable, allows its site-specific optimization including installation of multi-detector modular arrays matching end-user needs, and provides high throughput using a flow-through configuration without movable doors. High sensitivity of the FRMF is realized by gamma-spectrometric High-Purity Germanium (HPGe) detectors installed inside a construction from unique bricks made of concrete with low mass activity of natural radionuclides (uranium and thorium decay series and potassium-40). The aim of the construction is to minimize the radiation background inside the FRMF that originates outside – primarily in the material of walls and floor of the hall where the FRMF is located, allowing to significantly decrease the minimum detectable activities of materials inspected by the FRMF. The presented paper describes the optimization of the design of this concrete shielding by means of Monte Carlo (MC) simulations. The optimization was performed for a monoenergetic source of 1461 keV photons (emitted by K-40) originating inside the floor within 12 m from the FRMF vertical axis. The scored quantity was the fluence of 1461 keV photons at the position of the HPGe detectors. Study focused on the thickness, width and length of FRMF concrete walls and floor, including the floor below conveyer belts and side-walls protecting against radiation that could come inside the FRMF through its open entrances. As the weight of the shielding may easily reach up to 100 tons, the goal was to suggest one or several shielding configurations with the balance between the shielding weight and the decrease of natural background. In addition, the shielding configuration was considered appropriate, if the fluence rate of 1461 keV photons inside the FRMF originated in the floor, per Becquerel, varied at the level of the fluence rate of 1461 keV photons originated in the concrete shielding. To assess this condition, the mass activity of K-40 in the floor was set to a quite high value of 500 Bq/kg while the mass activity of the FRMF shielding was expected to be 6 Bq/kg as determined by a gamma-spectrometric measurement. As resulted from MC simulations, this K-40 mass activity in concrete results in the full-energy peak and total count rate of about 1.3 counts/min and 5.8 counts/min per one HPGe detector IDM-200-V^{TM} (ORTEC), respectively. The final configuration of the FRMF concrete shielding was selected from suggested configurations based on the complexity of the technical solution and shielding weight. The simulated relative decrease of the 1461 keV full-energy peak count rate will be compared with the one measured at the experimental site once the industrial FRMF is constructed and put into operation in late spring 2016.

About the Presenter

Jaroslav Solc is a metrologist at the Czech Metrology Institute working at the Department of Fundamental Metrology of ionizing radiation. He has long experience with Monte Carlo simulations in the code MCNP. He participates in international scientific projects, primarily in European projects on ionizing radiation metrology EMRP and EMPIR focused on industry, environment and health.

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