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MCNP modeling of impurity activation in graphite moderator and reflector of a L-54M-type nuclear research reactor

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The CeSNEF L-54M was a homogeneous nuclear research reactor fueled by a uranyl sulfate aqueous solution enriched by 19.94% 235U. It was commissioned by Politecnico di Milano to Atomics International in the late '50s. After 20 years of operation, in 1979 the reactor was definitely shut down. Since then, Politecnico di Milano decided to manage the entire structure according to in-situ safe storage strategy, so as to take advantage of short-lived radionuclides decay by reducing the total amount of radioactive material to be removed and allowing safer dismantling operations. Recently, Politecnico di Milano decided to restore the unrestricted re-use status, thus L-54M decommissioning has been launched. During the last years, preliminary environmental radiological characterization of the surrounding topsoil has been performed [1]. At the same time, analysis of few samples of irradiated graphite and concrete evidenced the presence of gamma emitting radionuclides (above all 60Co and 152Eu), 3H and 14C, even though a more extended radiological characterization would be required for implementing L-54M decommissioning.
In this work, a Monte Carlo N Particle (MCNP) 3D model of the reactor has been developed and validated in order to accurately assess the activation of the reflector graphite stack. This study is aimed at better addressing the future radiological characterization efforts and reducing the associated analytical costs. In order to build an accurate MCNP model, rigorous geometrical and materials information about the main reactor components were required and collected from blueprints, security and safety reports, as well as from experimental and academic works published in the 1960s. The L-54M reactor pile has been modeled in detail up to the outer boundary of the concrete shielding. In order to verify the model and ascertain its accuracy, several simulated data have been compared with available experimental ones with satisfactory agreement. In particular, neutron flux profiles in the experimental irradiation channels, criticality condition, control rods inventory and calibration have been considered. Afterwards, a superimposed fine mesh has been used to obtain the neutron fluence in the graphite reflector. For each radionuclide of interest, the main production reactions have been considered and the activation precursors have been assessed thanks to a detailed elemental characterization of virgin graphite by ICP-MS analyses following a suitably developed oxidation and acid digestion procedure. The MCNP data have been properly elaborated and converted to activity concentration values, taking into account the exponential decay up to the measurement date.
A satisfactory accordance between MCNP simulations and preliminary experimental data has been highlighted. Following this promising study, further samples have already been collected at different positions within the graphite stack in order to better corroborate the model outcomes.

Reference:
[1] Mossini E. et al., Topsoil radiological characterisation of L-54M reactor surroundings preliminary to decommissioning operations. J. Environ. Radioact. (2017) DOI: 10.1016/j.jenvrad.2017.11.026

Primary authors: Mr PARMA, Giorgio (Politecnico di Milano); Mr ROSSI, Filippo Maria (Politecnico di Milano); Dr MOSSINI, Eros (Politecnico di Milano)

Co-authors: Mr GIOLA, Marco (Politecnico di Milano); Dr MACERATA, Elena (Politecnico di Milano,); Prof. PADOVANI, Enrico (Politecnico di Milano); Prof. CAMMI, Antonio (Politecnico di Milano); Prof. CAMERA,

Franco (INFN - Section of Milano); Prof. ALIMONTI, Gianluca (INFN - Section of Milano); Prof. MARIANI, Mario (Politecnico di Milano)

Presenter: Dr MOSSINI, Eros (Politecnico di Milano)

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