Reconstruction of operational parameters of a nuclear reactor based on characteristic ratios of radionuclide activities ("fingerprints") in radioactive waste

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The radiological characterization of the former Soviet Union land-based training centre of nuclear reactors of submarines, located near the city of Paldiski in Estonia, was performed. The activities included investigations of the main technological building with two submarine nuclear reactor compartments, other (mostly medical) radioactive waste and the territory of the former military base. The Soviet military base have operated two training stands: from 1968 to 1994 the first-generation Soviet nuclear submarine simulator with a working nuclear reactor VM-A 70 MW (Echo II Class, Project 658) operated and was refuelled once in 1981; the second one - VM-4 90 MW reactor (Delta I-IV class, project 667) operated in 1983-1994. The nuclear fuel was removed from both reactors in 1994 and shipped to Russia. The sections of the reactor were hermetically welded and reinforced concrete sarcophagi were built around them, work was completed in 1995. The military base was transferred to Estonia. The available information about the reactors and nuclear fuel used, composition of construction materials was very limited, also the operational history was not well known. For the radiological characterization of sarcophagi and buildings, it was necessary to create the experimentally based model of generation and transport of radionuclides due to fuel evolution in both reactors. This model was used for determination of possible neutron activation and contamination limits and estimation of uncertainties due to incomplete information on reactor structure and operating parameters. By varying the material composition and operational parameters, the range of nuclide activities was evaluated, from which the highest activity values corresponding to conservative radioactive waste management scenarios were selected. The experimental validation of the contamination source was complicated due to high background of industrial and medical radioactive wastes stored in the main technological building. We succeeded to separate the radioactive contamination part determined by the operation of nuclear reactors from other radioactive waste by using nuclear and mass spectrometry analysis of samples collected on site, in-situ gamma spectrometry measurements and characteristic isotopic ratios of the nuclides from modelling. The nuclide vector was determined for all waste streams. The obtained results are very important not only for practical solutions of decommissioning of nuclear reactors and safe further management and utilization of radioactive waste, but also for deeper fundamental knowledge about the processes that determine the evolution of nuclides in the neutron flux and their transport in the environment.