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APPLICATION OF OPTIMIZED NUCLIDE VECTOR FOR RADIOACTIVE WASTE MANAGEMENT

CENTER FOR PHYSICAL SCIENCES AND TECHNOLOGY

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Introduction

The management and disposal of Radioactive Waste (RW) are critical issues for countries operating Nuclear Power Plants (NPPs) or decommissioning them. Most of the waste from decommissioning and dismantling consists of radiologically unrestricted material, known as exempt waste. However, about one-third of the waste contains radioactive material of different activity levels [1]. This RW must be collected, characterized, treated, stored, and ultimately disposed of in special facilities.

Characterizing of RW follows a consistent methodology across all reactors, focusing on determining the Nuclide Vector (NV). An essential part of the characterization of RW during dismantling are measurements applying non-destructive and destructive techniques. Discrimination of surface and volume activity helps to identify the best way of RW management, especially if surface contamination prevails [2]. In this case the decontamination procedure can significantly reduce the final RW volume.

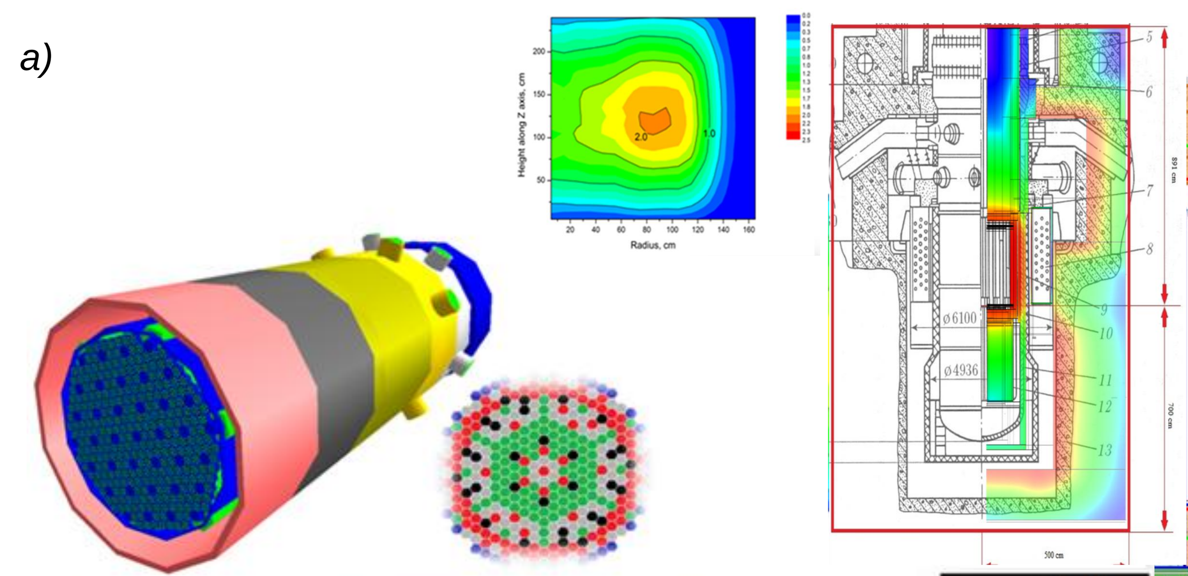
An optimized NV for specific waste streams is achieved by analyzing information about RW streams. This involves identifying key radionuclides, describing inter-correlations between easy-to-measure (ETM) nuclides and difficult-to-measure (DTM) nuclides including multivariate analysis of the already measured data at the sites, alongside with numerical evaluations of activation and contamination parts in the waste streams. Optimizing the NV can be enhanced through improved sampling methods, data grouping, bias reduction in modeling and measurements, utilizing multiple key nuclides, applying modeling ratios between DTM nuclides for scaling factor analysis.

Here we provide FTMC examples of successful scaling factor optimization and evaluation of nuclides vectors in different nuclear reactors.

Methods:

- Accumulation of historical data of the system (routine measurements, failure events etc.)
- Modelling (3D reactor simulation with SCALE, MCNP, etc.);
- Validation of the models according to available measurements;
- Sampling and analysis (gross measurements, gamma spectrometry, destructive analysis) of experimental results;
- Application of statistical methods for scaling factors evaluation for separate waste streams
- Optimized determination of NV - describing inter-correlations between the RW streams

a)



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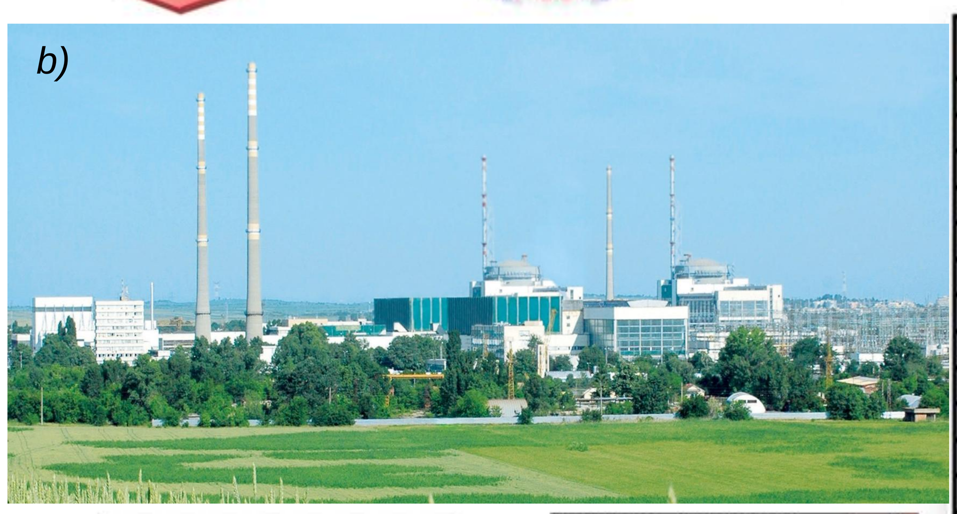


Nuclide	Scaling factor
C-14	5.9E-02
Fe-55	2.2E-01
Co-60	1.0
Ni-63	1.6
Sr-90	7.6E-02
Nb-94	1.2E-03
Tc-99	6.3E-03
I-129	1.1E-05
Cs-134	6.3E-01
Cs-137	4.0
U-233	5.0E-12
U-234	4.1E-07
U-235	1.2E-08
U-238	8.6E-08
Pu-238	3.0E-02
Pu-239	7.4E-05
Pu-240	6.1E-05
Pu-241	7.9E-03
Pu-242	1.4E-07
Am-241	5.5E-04
Cm-242	7.0E-07
Cm-244	1.8E-03

c) d)

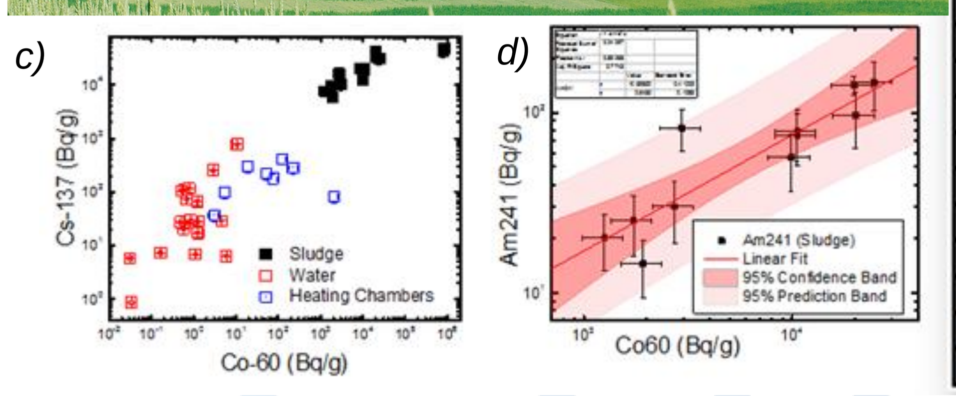
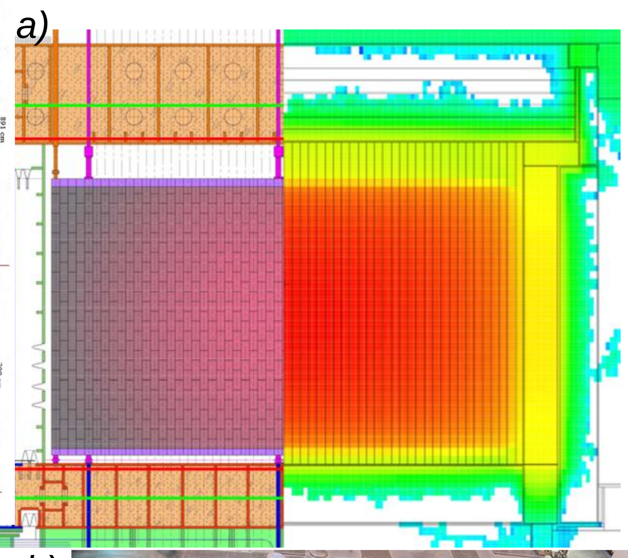


Figure 1. *a) 3D model of PWR reactor; core fuel loading pattern; relative neutron flux inside and outside the reactor core; b) Kozloduj NPP site; c) experimental data of nuclear spectrometry; d) Experimental/modeling data analysis and scaling factors for RW*

a)



b)

Figure 2. *a) MCNP6 modelling of neutron activation zones in RBMK-1500 reactor [3], b) Photo of RBMK-1500 core*

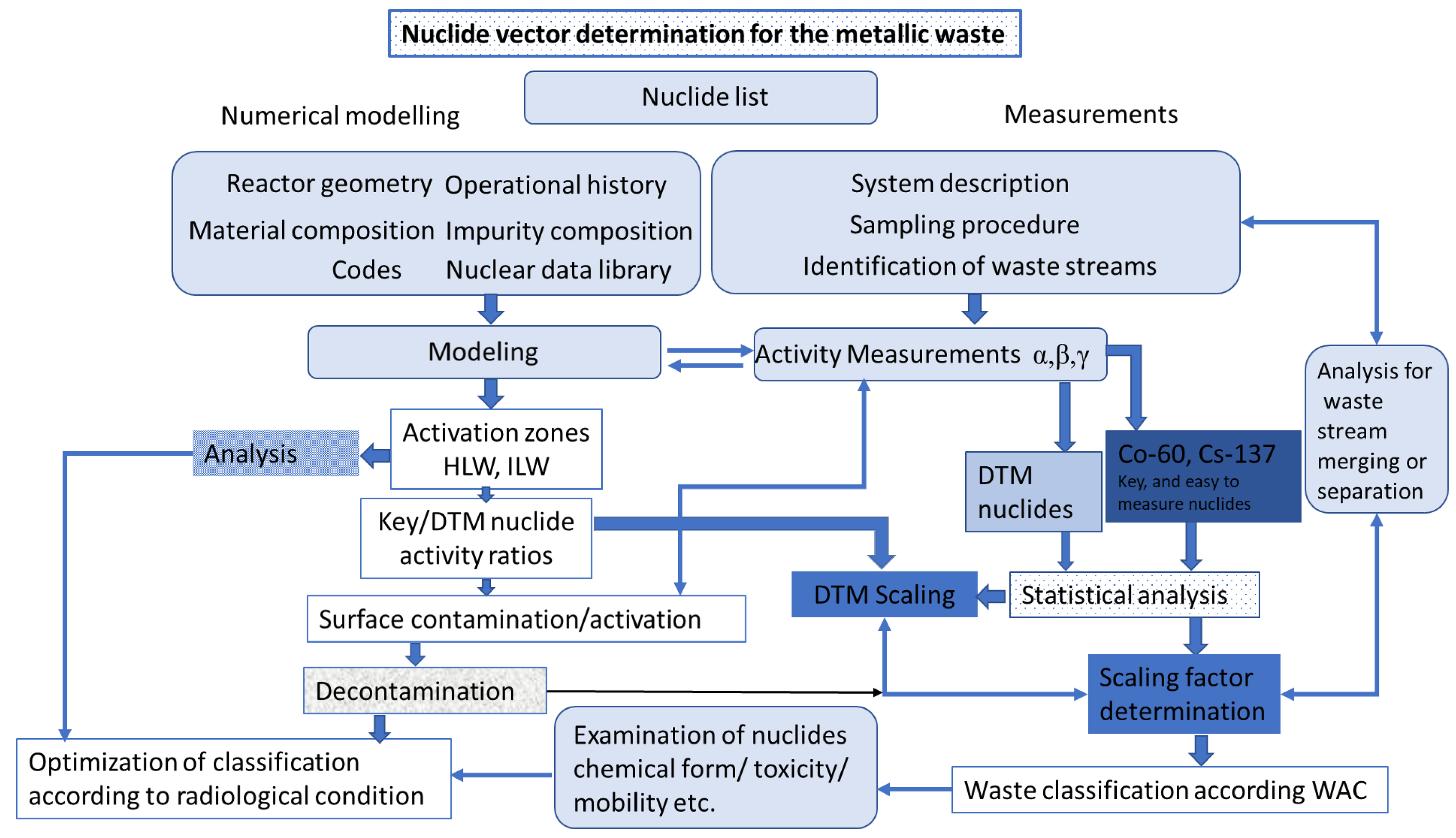


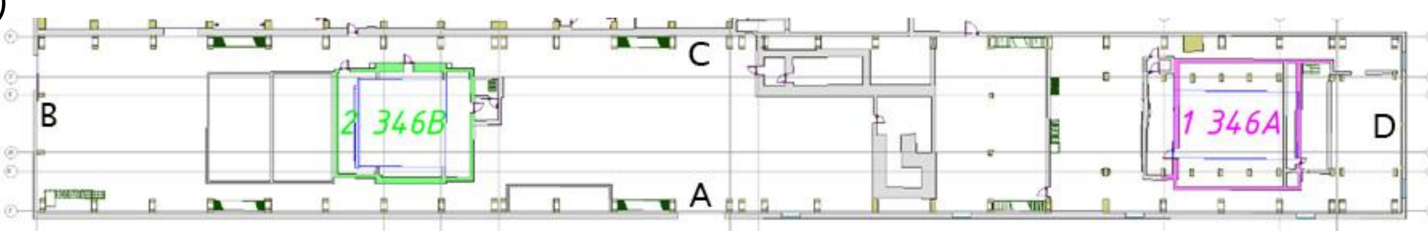
Figure 4. *Nuclide Vector determination scheme*

Examples of scaling factor application :

The validated Nuclide Vector technology for decommissioning of NPP's was implemented in Ignalina (LT) and Kozloduj (BG) NPP's. Also the model of radionuclide generation and transport at nuclear reactors of the Submarine Training Centre (EE) at the Paldiski military base was developed. The full radiological characterization of the 2 reactor sarcophagi, reactor compartments and equipment, buildings and the entire territory of the Paldiski site was performed.

Territory of Paldisky Submarine Operator Training Center

a)



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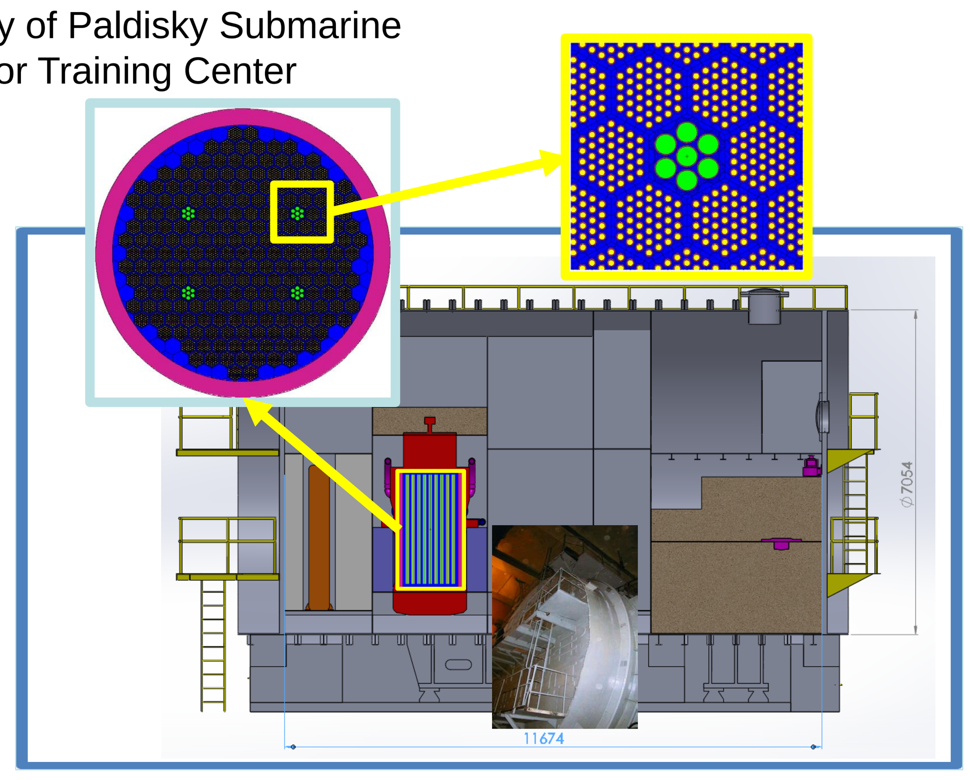
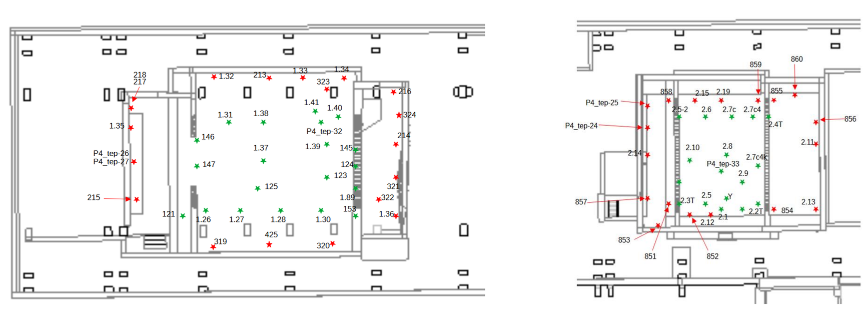


The work was devoted to prepare for the final decommissioning of the Paldiski military base in 2039 by transferring all RW (2100 m^3 and 900 m^3, respectively) to a near surface and intermediate depth repository.

Table 1. *Nuclide Vector determined for reactor sarcophagi based on Cs-137 (calculated for year 2040) valid for all "reactor determined waste"*

Nuclide	Scaling factor	Upper limit
C-14	8.5E-02	1.5E-01
Ni-59	4.7E-05	1.1E-02
Co-60	7.4E-06	1.1E-05
Ni-63	3.7E-03	8.8E-01
Sr-90	7.4E-03	2.1E-02
Nb-94	4.4E-06	1.0E-03
Cs-137	1.0E+00	
Eu-152	4.4E-04	1.1E-01
Eu-154	5.9E-05	1.4E-02
Pu-238	3.4E-05	5.6E-05
Pu-239	3.4E-05	1.2E-04
Pu-240	9.8E-06	3.5E-05
Am-241	5.1E-05	7.0E-05

c)



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d)

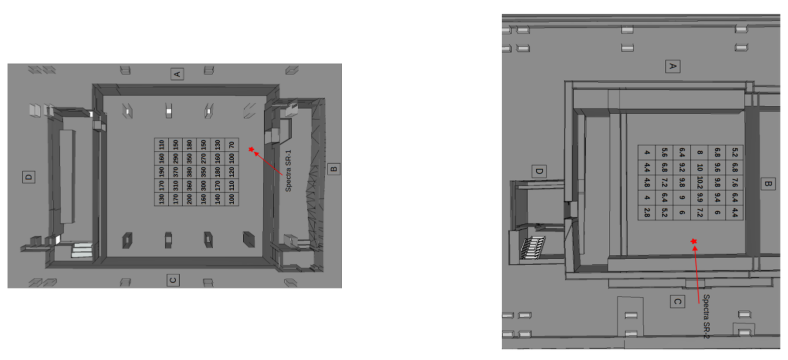

Figure 3. *a) The scheme of Main Technological Building, b) Reactor modeling, c) Locations of samples taken for destructive analysis (* smears, * bulk samples) and d) Dose rate measurements and * in-situ gamma spectroscopy places.*

Conclusions:

- Applying fundamental knowledge about the processes determining: the evolution of nuclides in the reactor (neutron flux), their transport in MCC loop and dispersion in the environment, one can solve all practical problems of decommissioning of any nuclear reactors.
- The ratios of characteristic nuclides, helps to distinguish between the activation, contamination parts in the total activity or separate the activity caused by reactor operation or other activities with radioactive materials.

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References:

1. INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, IAEA Safety Standards Series No. GSG-1, IAEA, Vienna (2009).
2. R. Plukiene et al., Report on gamma spectrometry and sampling procedure 21/07/2024 version 1.0, PREDIS Deliverable 4.6