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eurad
European Joint Programme on Radioactive Waste Management

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EURAD WP8/Subtask 2.1: Status

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EURAD WP8 annual meeting, 19-21 September 2022, Calmar Stadthotel, Sweden

Summary

- Subtask 2.1: short recall (what and which participants)
- Current short status for each participants
- Conclusions
- Future plans

EUropean Joint Programme on RADioactive Waste Management

EURAD

5-year implementation phase 1 – EURAD-1

This project receives funding from the Euratom research and training programme under grant agreement No 847593.

Subtask 2.1: short recall

- Subtask 2.1: Theoretical study of SNF source terms
- Subtask leader: PSI
- Subtask contributors: CIEMAT, JSI, NAGRA, PSI, SCK.CEN, VTT, KIT, JRC-Geel, ENRESA
- Main responsible persons:
  - CIEMAT: Francisco Alvarez
  - JSI: Marjan Kromar
  - NAGRA: Ahmed Shama
  - PSI: Dimitri Rochman
  - SCK.CEN: Luca Fiorito
  - VTT: Silja Häkkinen
  - KIT: Ron Dagan
  - JRC-Geel: Peter Schillebeeckx
  - ENRESA: Ana Muñoz

Subtask 2.1: short recall

- Activities:

1. Select representative assemblies
2. Calculated quantities: isotopic concentrations, decay heat, gamma/neutron emissions
3. Cooling time: up to 1e5 years
4. Perform calculations (nominal and uncertainties/sensitivities/biases)
5. Identify relevant parameters
6. Summary of results

Subtask 2.1: General view

Institute	Code	Samples
PSI	CASMO, CASMO/SIMULATE/SNF	GU1, GU3, BM1, ENRESA, GE, HEDL, “SKB-2006”, SKB-50,
JSI SCK.CEN JRC Geel	SERPENT2 ALEPH2 SCALE (TRITON/NEWT) POLARIS DRAGON	S1.PWR, NPP Krško fuel, SF95-5 SKB-50
KIT	MCNP/CINDER, Nucleonica	SF95-5
NAGRA	SCALE (TRITON) POLARIS	SF95-5, BM1, ENRESA Gundremmingen-7 (B23) “SKB-2006”, GE SKB-50
VTT	SERPENT2	Gundremmingen-7 (B23)
CIEMAT	EVOLCODE, MCNP/CINDER	SF95-5
ENRESA/ENUSA	Define a BWR case (8 PIE) + POLARIS	Report, ENRESA

Subtask 2.1: short recall

- <u>Time frame:</u>
- Activities delayed in 2020 and 2021 (+ 1 year) due to COVID and late request for new decay heat values to SKB
- Reporting: summary paper sent to EPJ/N, September 2022

	Month 3 (Aug. 2019)	Month 7 (Dec. 2019)	Month 11 (April 2020)	Month 15 (Aug. 2020)	(2020-2021)	Month 40 (Sep. 2022)
Task Definition	PSI					
Simplified calculations		All				
Advanced calculations			All			
Sensitivity				All		
Uncertainties					All	
Report						PSI

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Reporting final results

- Summary paper sent to EPJ/N, September 2022

On the estimation of nuclide inventory and decay heat: a review from the EURAD European project

D. Rochman[1], F. Álvarez-Velarde[2], R. Dagan[3], L. Fiorito[4], S. Häkkinen[5], M. Kromar[6], A. Muñoz[7], S. Panizo-Prieto[2], P. Romojaro[4], P. Schillebeeckx[9], M. Seidl[8], A. Shama[10] and G. Žerovnik[6]

[1] Reactor Physics and Thermal hydraulic Laboratory, Paul Scherrer Institut, Villigen, Switzerland
[2] Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT, Madrid, Spain,
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[6] Reactor Physics Division, Jožef Stefan Institute (JSI), Slovenija
[7] Empresa Nacional de Residuos Radiactivos, ENRESA, Madrid, Spain
[8] PreussenElektra GmbH, Hannover, Germany
[9] European Commission, Joint Research Centre - JRC, Geel, Belgium
[10] National Cooperative for the Disposal of Radioactive Waste (Nagra), Wettingen, Switzerland

September 13, 2022

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Reporting final results

- Overview

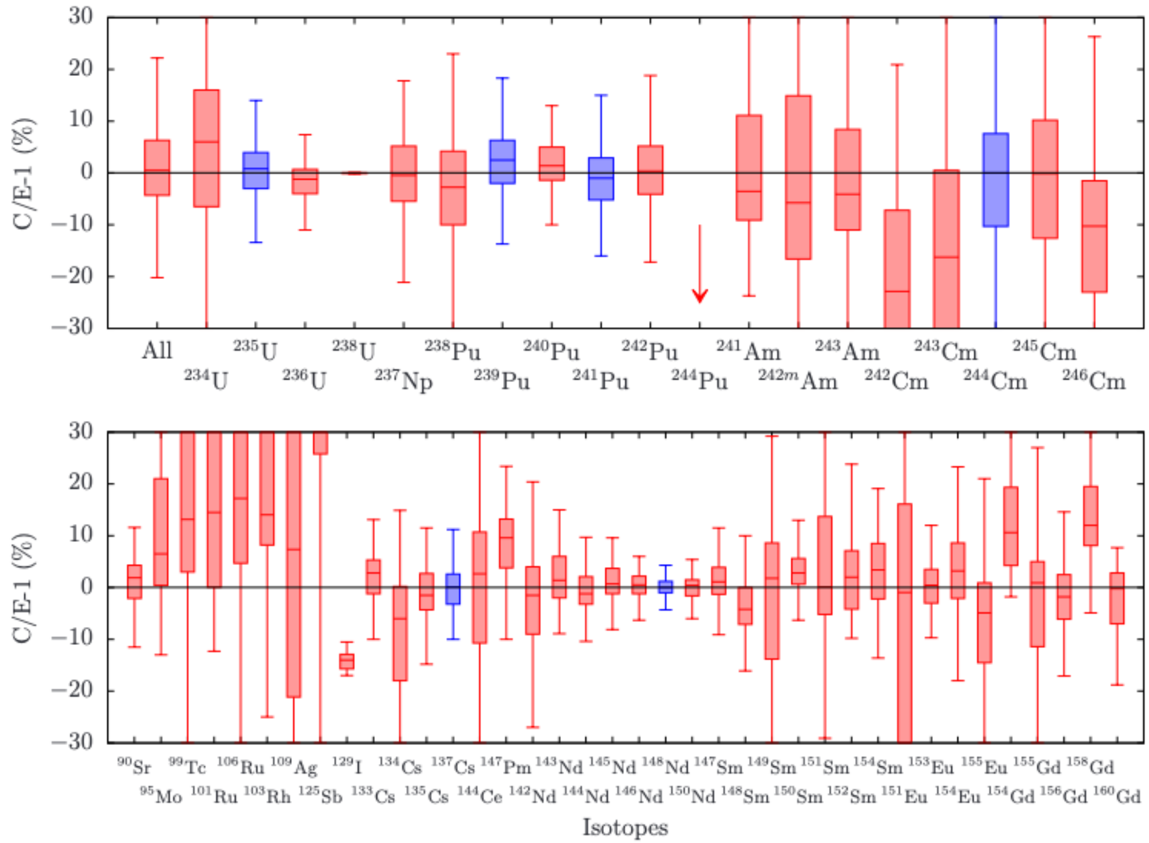


Fig. 4. Interquartile ranges for the $C/E-1$ nuclide concentrations, considering a total of more than 12 000 measured concentrations. The blue color is given to important nuclides. See Tables 3 and 4 for numerical values.

Reporting final results

- Overview

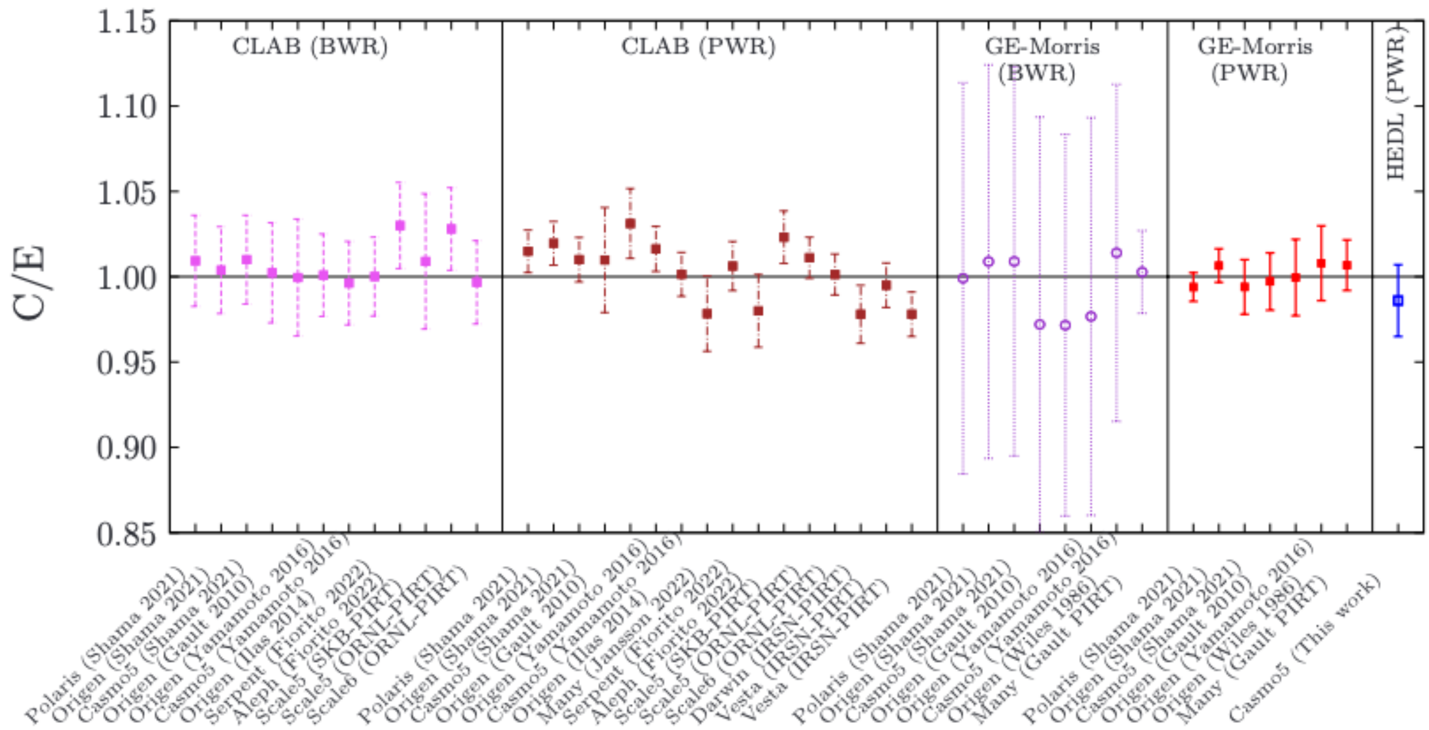
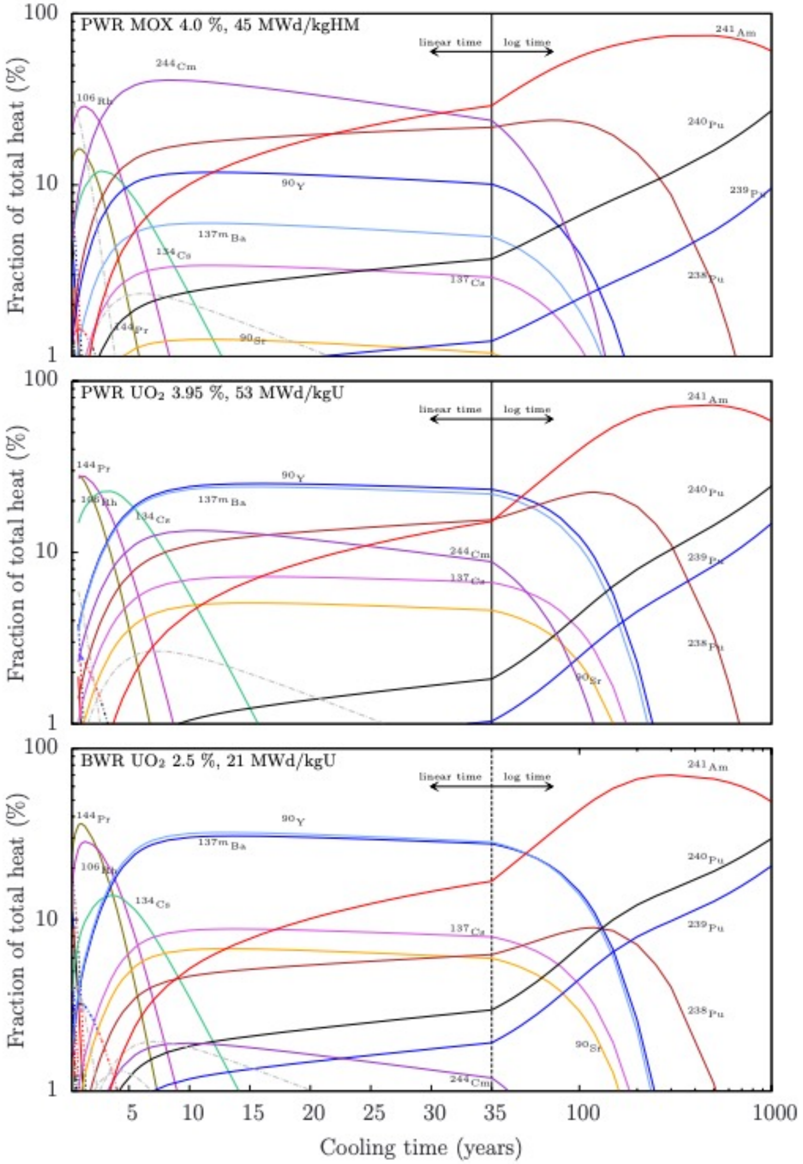


Fig. 7. Plots of the average C/E values for the decay heat from various references.

Reporting final results

- Overview



Reporting final results

- Overview

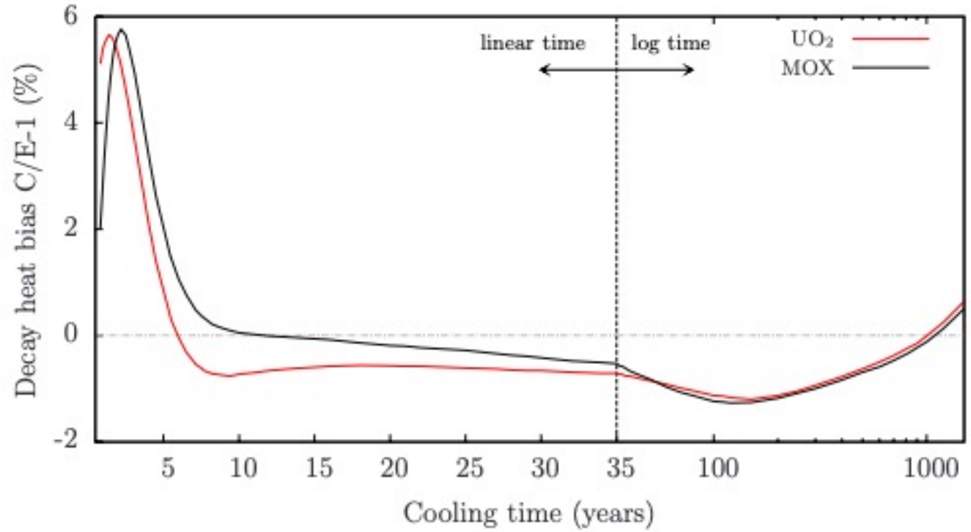


Fig. 9. Decay heat biases obtained from the mean biases on nuclide inventory.

Table 6. Summary of the recommendations concerning some SNF calculated nuclide concentrations and decay heat, for the cooling period between 1 and 1000 years. The uncertainty represents one standard deviation (1σ).

	^{148}Nd	^{137}Cs	^{235}U	^{239}Pu	Average burnup	Decay heat
Uncertainty	4 %	5 %	4 %	4 %	5 %	> 4 %
Bias	−0.1 %	−0.4 %	+0.2 %	+2.5 %	-	see Fig. 9

Reporting final results

- Needs

Based on the existing international efforts, the availability of measurements and databases, the following needs are identified in order to improve the estimation of the important SNF quantities (nuclide concentrations and decay heat):

1. The number of SNF decay heat measurements is extremely limited, and based on a small number of experimental facilities (only one still exists nowadays). This is limiting the validation capabilities, and therefore the confidence in the predictive power of existing simulation codes. New SNF decay heat measurements are therefore recommended, overlapping with the characteristics of existing SNF (high burnup, high enrichment, large range of cooling time). If possible, measurements of the decay heat and of nuclide concentrations should be performed for the same assemblies. Only these sources of independent experimental information can validate at the same time calculated compositions and calculated decay heat.

2. Experimental uncertainties for nuclide concentrations are often not covering the full aspect of the experimental knowledge (often leading to small reported uncertainties). The consequence is that such uncertainties are left aside during the simulation process, leading to a possible under-estimation of recommended uncertainties. It is therefore suggested to perform more complete uncertainty assessment during the measurement procedure.
3. Calculated quantities such as SNF nuclide concentrations and decay heat can be affected by the normalization procedure (*e.g.* to ^{148}Nd) and by the boundary conditions. It is therefore recommended to perform simulations based on the maximum information regarding the irradiation history, and, as much as possible, to avoid power normalization through the ^{148}Nd content.
4. The normalization of the sample power to the measured ^{148}Nd content present advantages, but it does not disentangle between fission contributors (such as ^{235}U or ^{239}Pu). The use of a ratio such as ^{90}Sr over ^{150}Nd, with different fission yields for the two main fission contributors, can help to better assess if individual contributions are correctly captured during the simulation.
5. Finally, specific needs for nuclear data can also be expressed: necessity of providing fission yield correlations in the evaluated libraries, better knowledge of the ^{242}Pu(n,γ) cross section (for the estimation of ^{244}Cm), of the independent fission yields of isotopes of mass 134 (for the estimation of ^{134}Cs), of the ^{134}Cs(n,γ) cross section (also for the estimation of ^{134}Cs), and of the production and disappearance chain of ^{240}Pu.

Plans/conclusions

- All participants have started their calculations and publications
- We follow a delayed schedule (+ 1 year)
- Collection of all results: 2022
- Joint publication: 2022
- Future plans: see next slides

Future plans for EURAD-2 1/3

- Goals:
  - provide to the users recommendations regarding source terms & derived quantities
  - develop measurement methods which can be routinely applied.

- EURAD(-1):
  - Provide DH biases and uncertainties, covering well specified cases.
  - Global estimate for nuclide concentrations

- Current limitations:
  - existing integral/local measurements
    - Limited integral measurements for DH (high correlation, not in phase with current fuel and SNF specifications, no blind values)
    - Less limited measurements for concentrations, but questions about bias sources, uncertainties
  - existing calculation capabilities
    - Separate effect of codes, irradiation histories, assumptions (geometry, environment)
    - Nuclear data

Future plans for EURAD-2 2/3

- EURAD-2: motivated by
  - safety
  - cost efficiency of short, medium and long term storage

- Towards user’s needs:
  - Help Waste Management Organizations
  - Operators
  - Safeguards
  - Safety Authorities and public (current and future threads)

Future plans for EURAD-2 3/3

- Technically: for source terms, cladding, fuel behavior:

- address limitations due to calculations
  - Effect of irradiation history,
  - Effect of nuclear data (we still don't know which data are missing, especially for short cooling periods)
  - From core simulator: impact of the estimation of BU, thermal power, boron curves (uncertainties due to core simulator: 5-2-2)
  - From lattice codes: effect of boundary conditions
  - For reactivity (BU credit): what is the estimation at low BU (top, bottom of SNF), effect of gas release and accumulation

- EURAD-2: address limitations due to measurements
  - Limitations due to existing measurements and non-existing measurements (lessons learned from EURAD-1).
  - Needs: systematic measurements ? If yes, for what ? How ?

Wir schaffen Wissen – heute für morgen