KÄRÄHDE

Spent fuel characterization and source term

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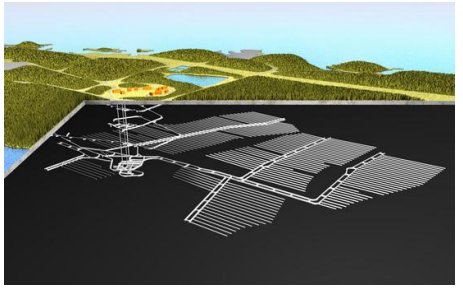
KÄRÄHDE motivation



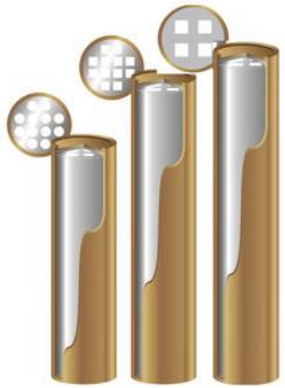
- Decay heat and reactivity determine the volume of repository space required for SNF disposal.
- Nuclide inventories are needed e.g. for safe handling of SNF and estimates of dose released to the biosphere.
- Accurate knowledge of SNF properties (source term) and associated uncertainties yield savings in repository space and enhanced safety.

Problem to be solved

- Computational characterization of SNF involves numerous uncertainty sources such as uncertainties in nuclear data, impurities, irradiation history, etc.
- SNF properties (source term) are also dependent on fuel type and burnup.
- There are no universally accepted instructions or knowledge on how to computationally determine the source term taking into account the associated uncertainties.
- Only approximate analysis exist on the effect of different fuel types and burnup used in Finland on the source term.

KÄRÄHDE in brief

- KÄRÄHDE is a four-year project funded by the Finnish Research Programme on Nuclear Waste Management (KYT). It studies
  - computational uncertainties related to the determination of the spent fuel source term and
  - effect of different fuel types and burnups on the source term.
- Assembly level calculations in 2D with Serpent 2 [1]
- Source term = decay heat, nuclide inventory, etc. Essential properties of spent nuclear fuel



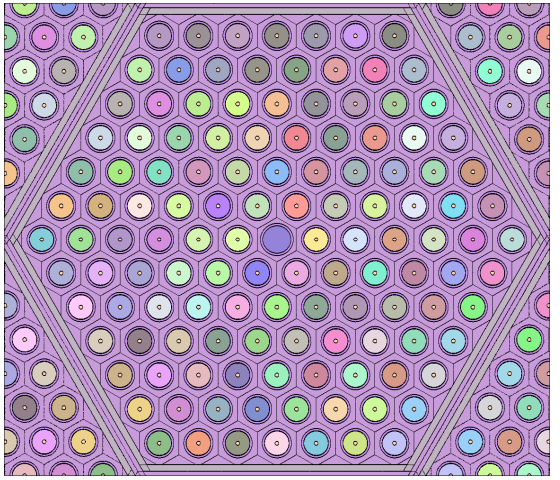
[1] Leppänen, J., et al. (2015) "The Serpent Monte Carlo code: Status, development and applications in 2013." Ann. Nucl. Energy, 82 (2015) 142-150.

KÄRÄHDE goals

- To recognize how different uncertainty components effect the source term and to write instructions on how the source term should be determined with Serpent taking into account the studied uncertainty components.
- To study and understand how different fuel types, significant in Finland, and discharge burnups effect the source term. The studied fuel types include different types of BWR, EPR, VVER-440, VVER-1200 (and SMR) fuel assemblies.

  - Also, supports VTT's participation in EURATOM project EURAD WP SFC (Spent Fuel Characterization and Evolution Until Disposal

KÄRÄHDE content



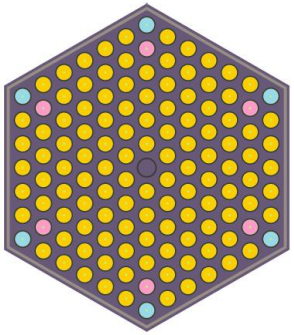
- Physical uncertainties
  - Uncertainties related to impurities in fuel and structural materials
  - Uncertainties related to nuclear data
- Uncertainties related to methods of calculation
  - Uncertainties in operation history
  - Participation in SKB led benchmark on uncertainties in operation history
  - Choice of parameters in the calculation
  - Surroundings of the fuel assembly
- Effect of fuel type and burnup
  - Fuel types: BWR, EPR, VVER-440, VVER-1200, (SMR)
  - Various burnups

First results

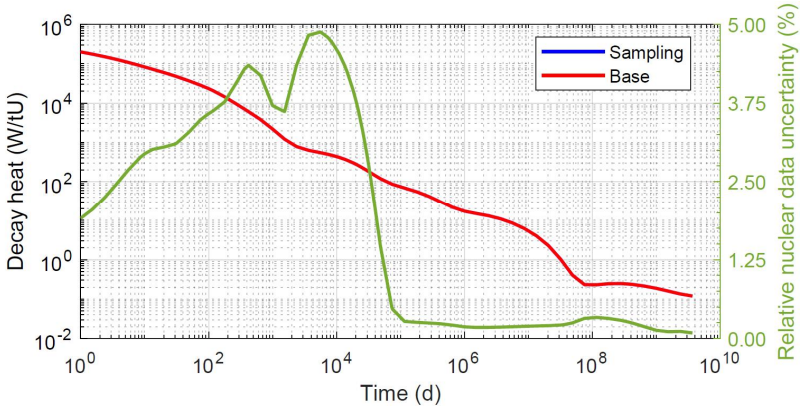
- Uncertainties in fission product yield and radioactive decay data → effect on the source term
- Burnup and different fuel assembly types → effect on the source term

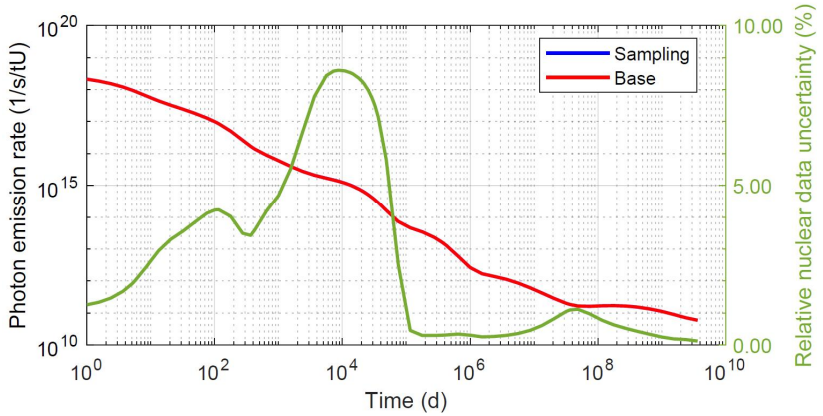
Fission product yield and radioactive decay data, method 1/4

- ENDF-6 files contain 1 standard deviation uncertainty estimates for fission product yield and radioactive decay data.
- Serpent 2.1.31 was extended to sample these values from normal distribution.
- Calculations with uncertainty sampling on (100) and off (10).
- Calculated assembly: VVER-440 with 6 Gd-rods and 4.4 % average enrichment.
- Burnup 20 MWd/kgU and decay 1d → 1E7 y.

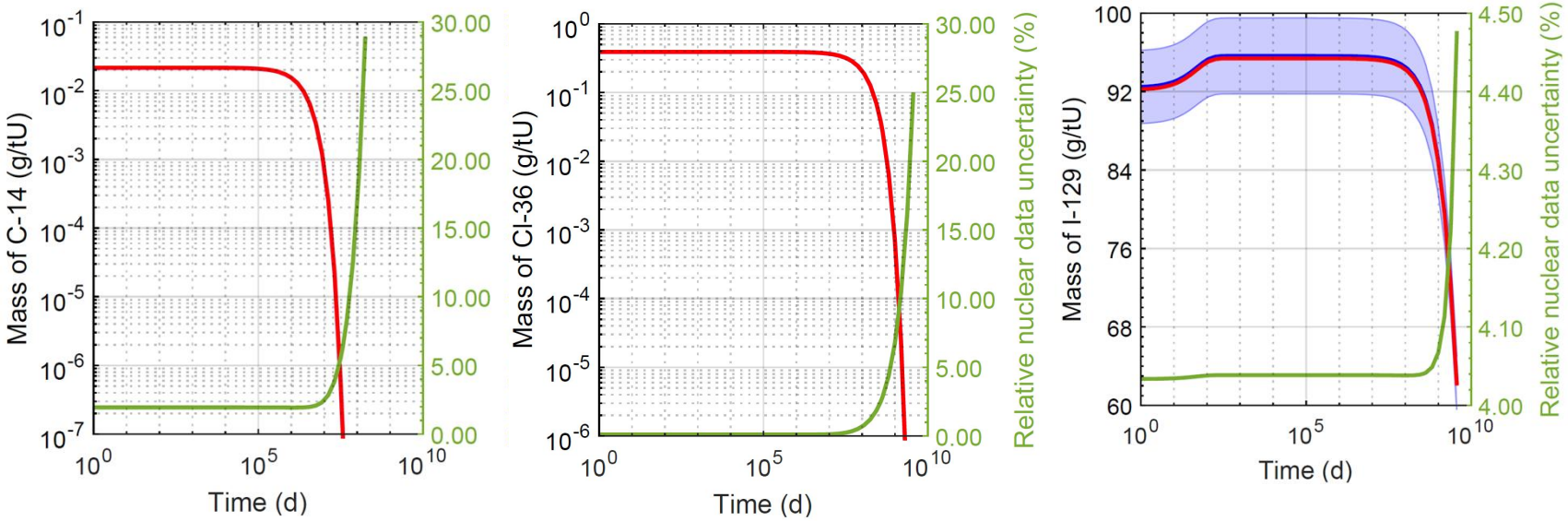


Fission product yield and radioactive decay data, results 2/4





Fission product yield and radioactive decay data, results 3/4



Fission product yield and radioactive decay data, future work 4/4

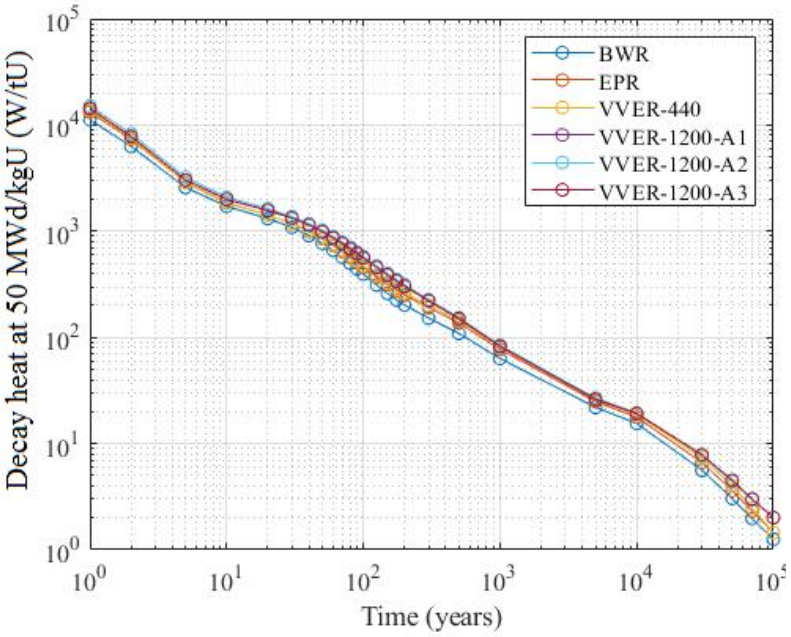
- Identification of the most important components in the fission product yield and radioactive decay data:
  - Separate sampling of fission product yield and radioactive decay data
  - Separate sampling of individual nuclides
- Tests with a different fuel assembly type, e.g. BWR

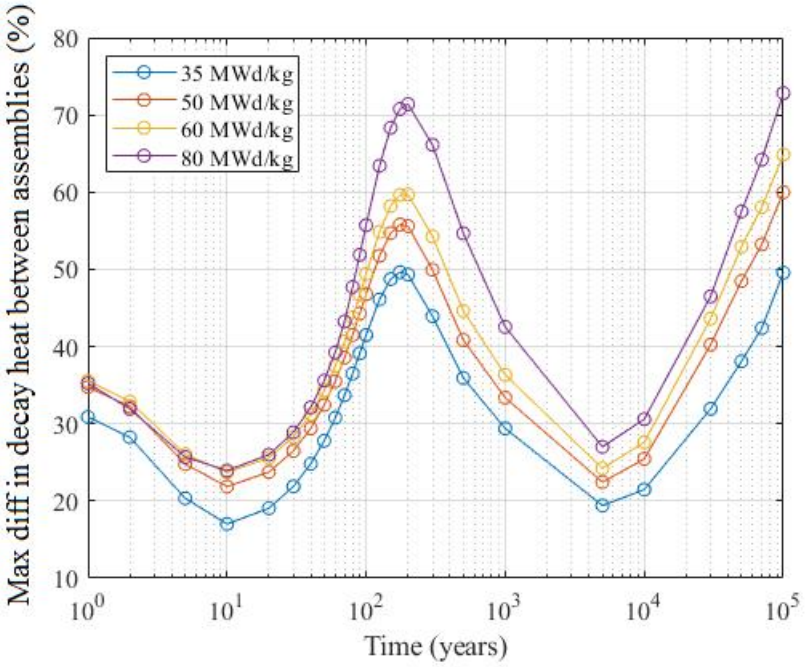
Burnup and different fuel assembly types, calculated assemblies 1/4

- 2D assembly burnup calculations up to 80 MWd/kgU.
- Fresh VVER-1200 fuel contained 0.7 % U-236

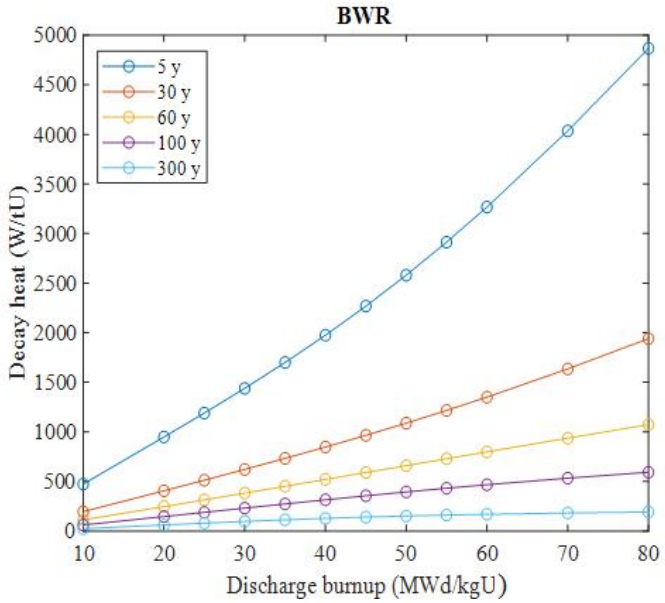
Param	BWR GE14	EPR	VVER-440 TVEL 2nd gen	VVER-1200 Asse1	VVER-1200 Asse2	VVER-1200 Asse3
U [kg/cm]	0.51	1.2	0.52	1.3		
Enr [%]	4.2	3.6	4.4	4.9	3.8	4.9
Norm rods	74	253	120	306	300	300
Gd rods	18	12	6	6	12	12
B [ppm]	-	600	500	600		

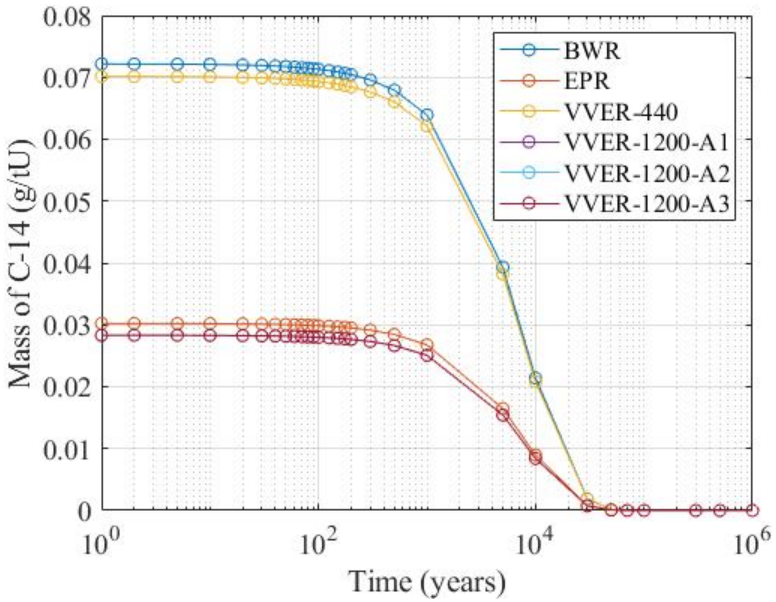
Burnup and different fuel assembly types, results 2/4





Burnup and different fuel assembly types, results 3/4





Burnup and different fuel assembly types, future work 4/4

- A closer study of the effect of selected components on the source term
  - Burnup dependence of the source term
  - Enrichment dependence of the source term
  - Source term dependence on the number of Gd rods
  - Most important sources of decay heat in different assembly types
- Calculation of more fuel assembly types

Conclusions

- KÄRÄHDE is a national research project aiming for computational characterization of spent nuclear fuel (SNF) with Serpent.
- Different uncertainty components will be identified and their effect on the source term (significant SNF properties) are studied.
- Work is carried out during 2019-2022.
- As a final result, instructions on how to characterize SNF with Serpent will be written.

Contact information and references

- Silja Häkkinen silja.hakkinen@vtt.fi (KÄRÄHDE project manager)
- Jaakko Leppänen jaakko.leppanen@vtt.fi (Serpent development)

- Antti Rintala, ”Evaluating the Effect of Decay and Fission Yield Data Uncertainty on Spent Nuclear Fuel Source Term Using Serpent 2”, Proceedings of the International Conference Nuclear Energy for New Europe, Portorož, Slovenia, September 9-12, 2019.
- Pauli Juutilainen and Silja Häkkinen, ”Impact of Fuel Type and Discharge Burnup on Source Term”, Proceedings of the International Conference Nuclear Energy for New Europe, Portorož, Slovenia, September 9-12, 2019.