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Overview of Post-Closure Criticality Safety – RD&D Topics in Switzerland

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Overview of Post-Closure Criticality Safety RD&D Topics in Switzerland

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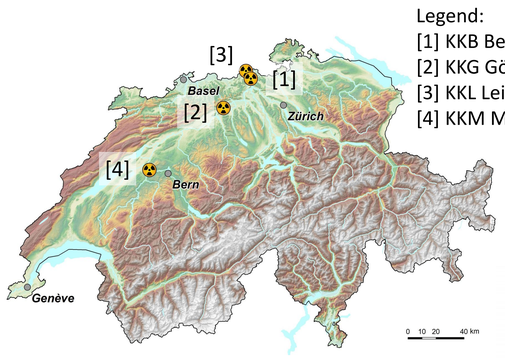
Introduction & Context

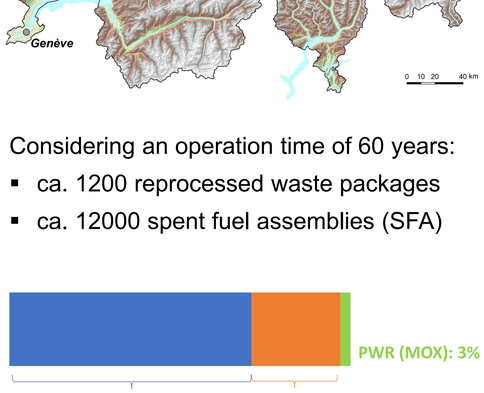
Foreseen high-level waste (HLW) inventory



Legend:
[1] KKB Beznau I & II: PWR (UO_2 & MOX)
[2] KKG Gösgen: PWR (UO_2 & MOX)
[3] KKL Leibstadt: BWR (UO_2)
[4] KKM Mühleberg: BWR (UO_2)

Considering an operation time of 60 years:

- ca. 1200 reprocessed waste packages
- ca. 12000 spent fuel assemblies (SFA)



Part of the current Nagra disposal concept: final disposal canisters for BWR (left) and PWR (right) SFA

- Nagra is presently preparing the general licence application for its current disposal concept.
- The assessment of post-closure criticality safety of HLW in a deep geological repository is a regulatory requirement in Switzerland and in many other countries.

Post-closure criticality safety analysis

- Main focus: final disposal of spent nuclear fuel
- The time scale considered for post-closure criticality safety (PCCS) analysis is one million years after emplacement.
- Goal: evaluate the reactivity of the SFA filled final disposal canister over the entire PCCS timeframe.
- One of the main challenges is that the reactivity assessment, i.e. the determination of the effective neutron multiplication factor, k_{eff}, must take into account the system's time evolution over such a long time scale.

Approach to PCCS assessments

- An essentially deterministic and staged (multi-step) approach, relying on the development of scenarios, which includes:
  I. Consideration of the most conservative case
  II. If an unlikely critical event cannot be excluded with enough confidence for the most reactive scenario, the level of realism is increased and the reactivity is re-evaluated.
- The scenario definition aims to consider conservative boundary conditions for probable configurations.
- Developing scenarios that capture adequately the evolution of the SFA disposal canister and nearfield system over the entire timescale of one million years represents a challenge.
- An additional challenge stems from the fact that the PCCS analysis requires a high level of detail for the description of the system under consideration; otherwise, highly conservative and potentially unrealistic assumptions have to be taken into account. The general license application in contrast considers simply a general technical concept.

Definition & preliminary analysis of conservative case

Conservative scenario definition

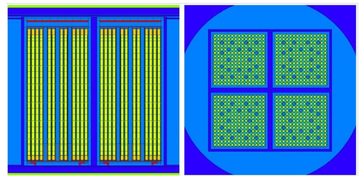
- Fresh nuclear fuel, with initial enrichment
- SFA disposal canister intact, but breached and flooded with pure water at room temperature

Preliminary analysis for BWR fuel

Axial (left) and radial (right) sections of the computational model for the BWR final disposal canister with twelve fuel assemblies. Figure taken from ref. [1]

- The criticality safety model of the final disposal canister filled with fresh BWR fuel assemblies was implemented with the KENO-VI Monte Carlo code [2].
- The preliminary results [1] indicate that this configuration is not critical (k_{eff} = 0.92443 ± 0.00039).

Preliminary analysis for PWR fuel

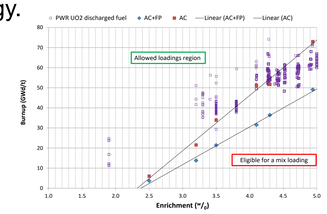


Axial (left) and radial (right) sections of the computational model for the PWR final disposal canister with four fuel assemblies. Figure taken from ref. [3]

- The criticality safety model of the final disposal canister filled with fresh PWR (UO_2) fuel assemblies was implemented with the MCNP Monte Carlo framework [4].
- The preliminary results [3] indicate that this configuration is critical (k_{eff} = 1.09513).
- Higher degree of realism to be considered in the reactivity evaluation.

Burnup credit - preliminary considerations

- The irradiation history of the nuclear fuel can be taken into account by using the burnup credit methodology.
- Canister loadings based on a determined loading curve can ensure a subcritical system.
- Considering burnup credit is a key aspect in the determination of loading curves.



Preliminary loading curve for PWR UO_2 SFAs. Figure taken from ref. [3]

Additional RD&D aspects under consideration

- Development of canister and fuel degradation scenarios and assessing their impact on the loading curve determination.
- Refinement of uncertainty quantification in the loading curve determination.
- Burnup credit application.

References

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[4] Los Alamos National Laboratory, "*MCNP 6 User's Manual*", Version 6.1 (2014).

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