IMPACT OF ADVANCED FUEL CYCLES ON RADIOACTIVE WASTE DISPOSAL IN A CLAY FORMATION

Background

During the last 15 years the EC (European Commission) has initiated several research projects on the possibilities of introducing partitioning and transmutation techniques in nuclear fuel cycles in order to reduce the amount of long-lived isotopes present in the radioactive waste. One of these projects, Red-Impact (impact of partitioning, transmutation and waste reduction technologies on the final nuclear waste disposal) started in 2004; its main objective was to assess the impact of partitioning and transmutation on radioactive waste management and geological disposal.

Objectives

The main objective of SCK•CEN's contribution to the Red-Impact project is to evaluate the impact of some representative advanced fuel cycles, making use of partitioning and transmutation techniques, on radioactive waste disposal in a clay formation.

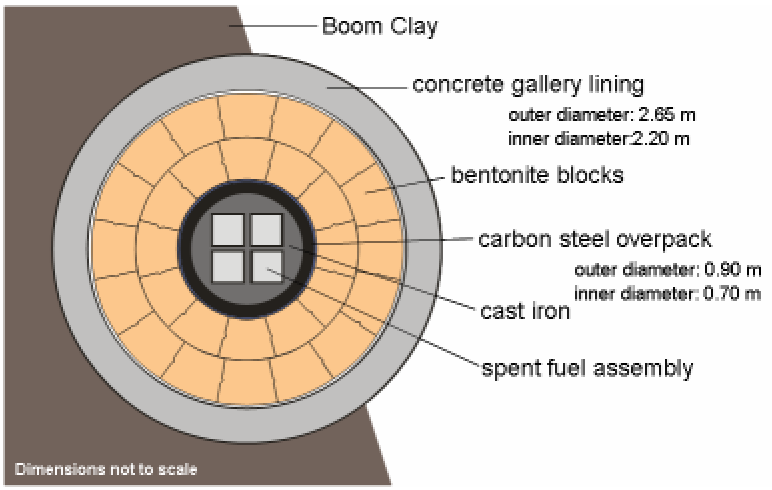
Principal results

The Red-Impact project started with the identification of a number of representative fuel cycle scenarios. Five basis scenarios are considered in the evaluations: three "industrial" scenarios, which are based on presently available technologies, and two innovative scenarios, which assume the availability of new reactor types and reprocessing techniques. The five analysed fuel cycles are:

- A1: the reference fuel cycle, which is an open cycle based on LWRs (light water reactor) with low enriched uranium oxide fuel;
- A2: fuel cycle based on LWRs with single recycling of Pu as MOX (mixed oxide) fuel;
- A3: fuel cycle based on FRs (fast reactor) with multi-recycling of Pu as MOX fuel;
- B1: fuel cycle based on FRs with infinite recycling of Pu and minor actinides;
- B2: double strata fuel cycle based on a combination of LWRs, FRs and ADS (accelerator driven system).

For each basis fuel cycle mass flow schemes were prepared and the corresponding neutronic calculations were made. On the basis of a number of assumptions on the reprocessing losses, the amounts and composition of the HLW (high level waste) and ILW (intermediate level waste) radioactive waste streams arising from the basis fuel cycles were estimated.

Starting from repository concepts considered by ONDRAF/NIRAS in its SAFIR 2 report for disposal of high level and intermediate level waste in the Boom Clay formation, we have evaluated the impact of the advanced fuel cycles on the dimensions of the repository and on the long-term radiological consequences of the radioactive waste disposal.



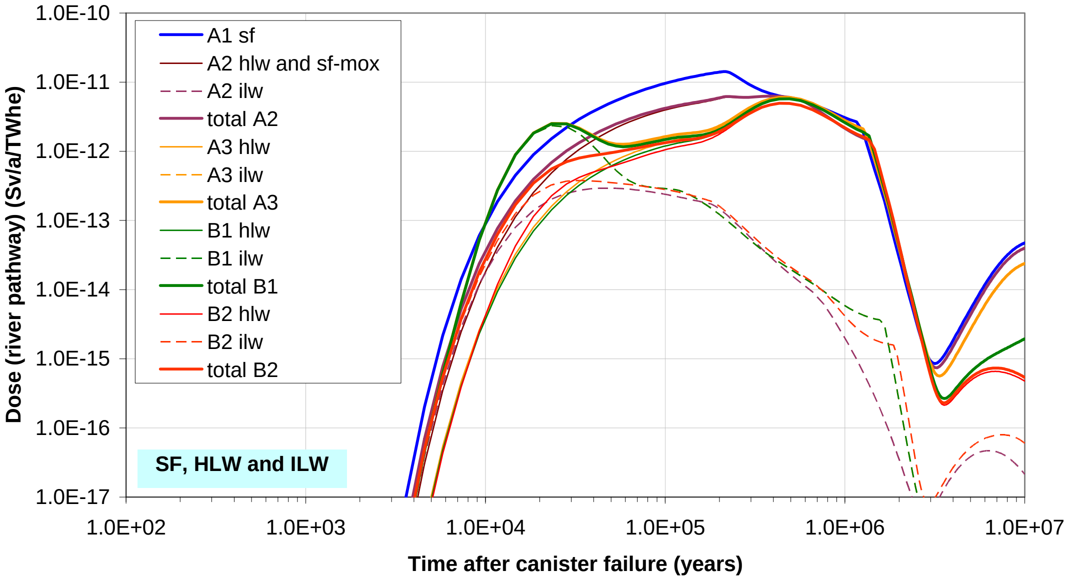
Cross-section of the repository concept considered for the disposal of uranium oxide spent fuel

The minimum needed length of the galleries for spent fuel and HLW disposal is determined by the thermal output of that waste. The main temperature limitation in the SAFIR 2 repository concept is that the temperature at the interface between the gallery lining and the Boom Clay has to remain below 100 °C. As the thermal output of ILW is about negligible, the length of the ILW galleries is determined by the number of waste packages. For the disposal of intermediate level waste it is assumed that 19 canisters are placed in a gallery section. The estimated lengths of the disposal galleries per produced electricity are given in the following table. The results show that the introduction of fast reactors or ADSs in the fuel cycle results in a reduction with a factor 2 to 3 of the length of the galleries needed for the disposal of spent fuel and HLW. The length of the galleries needed for the disposal ILW is for all considered fuel cycles much smaller than the one needed for spent fuel and HLW disposal.

Fuel cycle		A1	A2	A3	B1	B2
Spent fuel and HLW gallery length	(m/TWhe)	5.92	5.74	3.48	1.88	2.89
ILW gallery length	(m/TWhe)	0	0.08	0.18	0.18	0.11

Estimated needed length of the galleries for disposal of HLW (after a 50 years cooling time) and ILW arising from the 5 basis fuel cycles

To estimate the radiological consequences of the radioactive waste disposal, we make simulations of the transport of the radionuclides released from the disposed waste through the main components of the repository system. We consider a river draining the aquifer overlying the host formation as pathway to the biosphere. The following figure gives the doses (per produced electricity) due to the disposal of HLW and ILW in a repository in clay. The results show that the introduction of advanced fuel cycles has only a limited impact on the resulting doses. This is explained by the fact that the doses are mainly due to long-lived fission and activation products that are mobile in the geosphere. On the other hand transmutation strongly reduces the amount of actinides disposed of in the repository, but because of their low solubility in groundwater and their strong sorption on clay minerals, the actinides do not give a considerable contribution to the total doses. The doses due to ILW are for some fuel cycles of the same order of magnitude as the doses due to HLW; this is because the ILW contains relatively high amounts of mobile fission and activation products.



Doses via the river pathway due to disposal of HLW and ILW arising from the 5 basis fuel cycles in a repository in clay

Future work

In the framework of the Raphael project an analysis of the impact of a fuel cycle based on another type of advanced fuel cycle, i.e. a high-temperature reactor, on waste disposal will be made.

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Main reference

W. Von Lensa, R. Nabbi, M. Rosbach (Eds.), "Red-Impact: Impact of Partitioning, Transmutation and Waste Reduction Technologies on the Final Nuclear Waste Disposal", Synthesis report (2008) FZ Jülich, Energy & Environment Series, Vol. 15.