IMPACT OF ADVANCED FUEL CYCLES ON DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE

Background

During the last decade various international initiatives have been taken to investigate the role and feasibility of advanced nuclear energy systems. Such advanced nuclear systems aim at optimizing the utilisation of natural resources and minimizing the generation of long-lived radioactive waste. In the framework of the NEA project *"Impact of Advanced Nuclear Fuel Cycle Options on Waste Management Policies"* SCK•CEN studied the impact of advanced fuel cycles on the geological disposal of high-level radioactive waste in a clay formation.

Objectives

The main objectives of the study are assessing the impact of advanced fuel cycles on the design of repositories for the disposal of high level radioactive waste and on their long-term radiological consequences.

Principal results

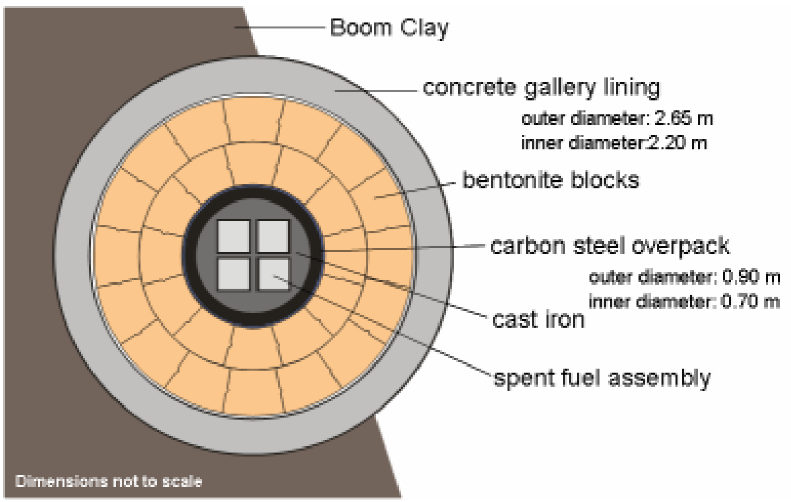
The NEA project identified 10 representative fuel cycle scenarios and 3 variants, of which 4 scenarios were selected for detailed quantitative analyses. The considered fuel cycle scenarios are divided into 3 categories: (1) cycles based on current industrial technologies and extensions, (2) partially closed cycles, in which selected actinides are recycled, and (3) fully closed cycles, in which all actinides are recycled.

The four analysed fuel cycle scenarios are:

- 1a: reference fuel cycle: "once through" cycle based on PWR plants with uranium oxide fuel;
- 1b: fuel cycle based on PWR plants with uranium oxide fuel and the generated Pu is recycled once as mixed oxide (MOX) fuel;
- 2a: fuel cycle based on PWR plants with uranium oxide fuel and the generated Pu is continuously recycled as mixed oxide (MOX) fuel;
- 3c-v1: fuel cycle based on a gas cooled fast neutron reactor with carbide fuels, in which all the actinides are recycled.

To illustrate the potential impact on waste disposal of separation of fission products from the high-level waste, a variant of scenario 3c-v1, in which it is assumed that Cs and Sr are separated, is also considered.

Starting from repository concepts that have been developed within the Belgian national radioactive waste management programme for disposal of vitrified high-level waste and spent fuel in a clay formation, we evaluated the impact of the innovative fuel cycle scenario on the repository dimensions.

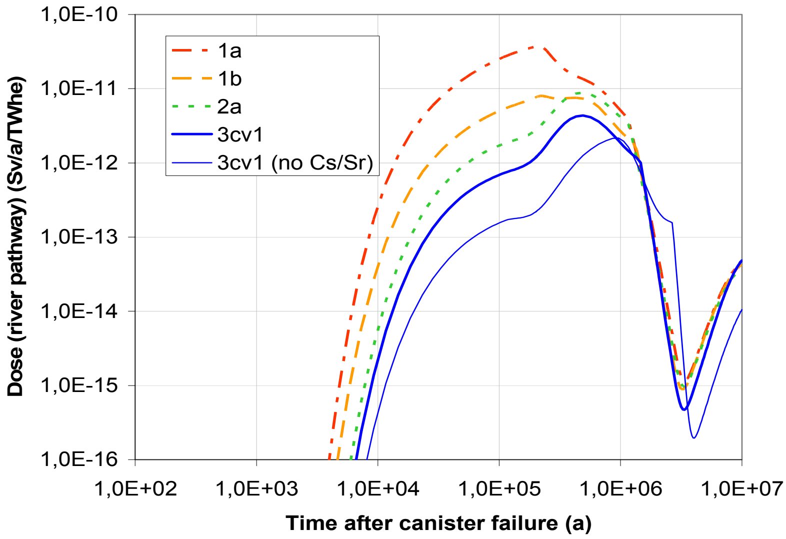


Repository concept considered for the disposal of uranium oxide spent fuel

Thermal calculations determine the maximum allowable disposal density: a temperature limit of 100 °C at the interface between the gallery lining and the clay has to be respected. The following table gives the resulting relative lengths of the galleries required for the disposal of the high level radioactive waste for a 50 years cooling time.

Fuel cycle	Relative length of required disposal galleries (cycle 1a is taken as reference)
1a	1.000
1b	0.963
2a	0.947
3c-v1	0.287
3c-v1 (removal of Cs and Sr)	0.107

The second step of the analyses consists of an evaluation of the radiological impact of the HLW disposal. We made simulations of the transport of radionuclides contained in the disposed high-level waste types through the main components of the geological repository system for the case of the expected evolution of the disposal system. The following figure gives the total doses calculated for the 4 considered fuel cycle scenarios and the variant considering removal of Cs and Sr.



Doses standardized per produced electricity calculated for the 4 considered fuel cycle scenarios and the variant considering removal of Cs and Sr

The calculated doses are strongly influenced by the amount of iodine that is remaining in the disposed waste. The more compact disposal configuration in case of advanced fuel cycles strengthens the contribution of solubility limits to the confinement of radionuclides. Doses due to actinides occur after 3 million years, they are at least 2 orders of magnitude lower than the doses due to fission products.

The results obtained show that the introduction of innovative fuel cycle scenarios can result in a considerable reduction of the needed size of the geological repository. However, the impact on the radiological consequences is rather limited. Indeed, the maximum dose, which is expected to occur a few tens of thousands of years after the disposal of the waste, is essentially due to fission products such as ^{129}I, ^{79}Se and ^{126}Sn, and their amount is about proportional to the heat generated by nuclear fission.

Future work

In the framework of the Red-Impact (Impact of Partitioning, Transmutation and Waste Reduction Technologies on the Final Waste Disposal) project of the European Commission, SCK•CEN will make in 2006 analyses for a larger set of fuel cycle scenarios, including transmutation and partitioning scenarios.

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Main reference

J. Marivoet and E. Weetjens, *Assessment of the disposal of HLW from advanced fuel cycle scenarios in the Boom Clay formation*. Appendix H in *Advanced Fuel Cycles and Waste Management*. OECD/NEA, Paris.