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An Initial Safety Case for disposal of Dutch radioactive waste

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Introduction

Nuclear technologies are used in electricity generation, medicine, industry, agriculture, research and education. These technologies generate radioactive wastes that must be managed in a safe and secure way. For materials that remain hazardous for hundreds of thousands of years, the acknowledged approach to long-term isolation and confinement is disposal in a stable geological environment beneath the Earth's surface, by emplacement in a geological disposal facility.



Fig. I) Interim storage of Dutch nuclear waste is currently facilitated at COVRA.

OPERA Initial Safety Case

The Netherlands has chosen to store radioactive waste at the surface (Fig. 1) for a period of about 100 years before disposal in a geological disposal facility (Fig. 2). This 100 years allows flexibility in case other options become available, such as a multinational geological disposal facility and gives the opportunity to do thorough research on geological disposal. OPERA is the most recent Dutch programme on geological disposal facility and focuses on clay formations and more specifically on the Boom clay. It provides an overview of the arguments and evidence that can lead to enhancing technical and public confidence in the levels of safety achievable in an appropriately designed and located geological disposal facility. Furthermore, it provides a road map to guide future research. Here we will present the possible evolution of a geological disposal facility in the Boom's clay envisioned and the road map to future

research.					
Waste Category	In storage (2130)		Packaged for disposal (2130)		
	Volume [m3]	Weight [tonne]	Number of containers	Volume [m3]	Max weight [tonne]
				45000	150000
Processed LILW	45000	150000	152000	45000	150000
Processed LILW Depleted uranium	45000 34000	150000	9060	40000	182000

volume in storage and their mass and volume when packaged for disposal. LILW: Low and Intermediate Level waste, HLW: High-Level Waste.

How does a geological disposal facility work?

The basis of a geological disposal facility is established on the concept of a multibarrier system, whereby series of natural and engineered barriers act in concert to isolate the wastes and contain the radionuclides within the geological disposal facility. The natural barrier encompasses the host rock of the geological disposal acility and the overlying geological formations. In case a geological disposal facility will be constructed in the Boom's clay, the clay will be the principal (natural) barrier. It will provide long-term containment of radionuclides by ensuring that their transport away from the geological disposal facility can only occur by the extremely slow process of diffusion due to the low permeability of the Boom's clay.

A key feature of the OPERA disposal concept is the amount of cementitious material (Fig. 6). Cementitious

aterials (tunnel liner, backfill, buffer, waste conditioning matrices) dominate the overall volume of materials in

the geological disposal facility. They are however assumed to have no physical containment role after closure of

the geological disposal facility but will provide a substantial chemical buffer that favours chemical containment of

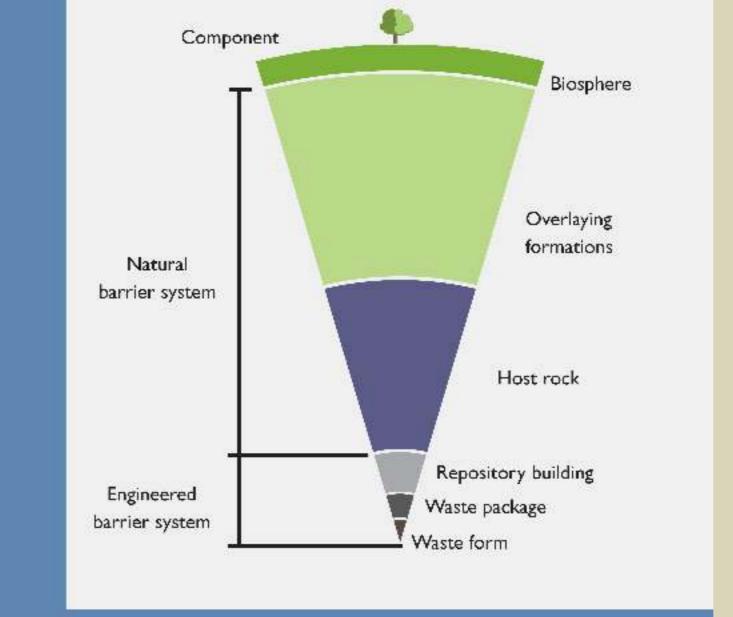


Fig. 4) The multibarrier basis of the geological disposa

The engineered barrier encompasses the containers in which nuclear waste will be packaged for geological disposal and the geological disposal facility itself. Figure 5 shows the different containers used in a geological disposal facility. Top left shows the supercontainers for vitrified high level waste and CSD-C containers. Top right is showing the supercontainer for spent research reactor fuel and other high level waste (Fig. 6). For both the supercontainers, it is assumed they will fail 35,000 years after closure of the geological disposal facility. The bottom left shows the 1000 litre concrete or magnetite containers holding 200 litre containers of low and intermediate waste level. It is assumed they will fail immediately after closure of the geological disposal facility. The bottom right shows two Konrad Type II containers for depleted uranium. This container is assumed to fail 1500 years after closure of the geological disposal facility.

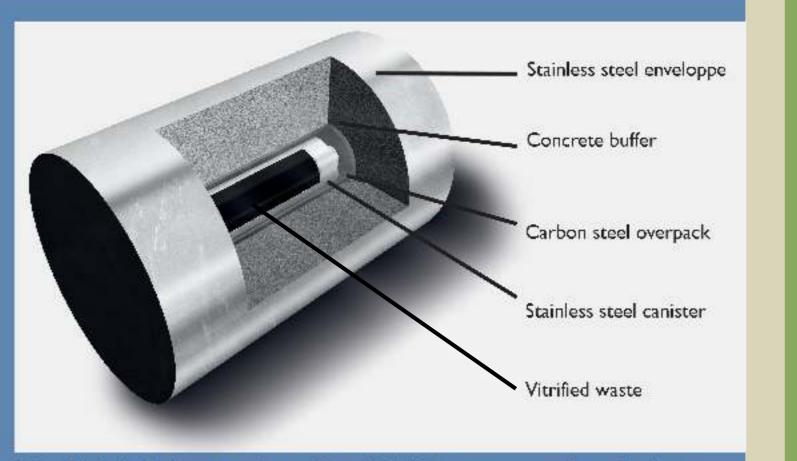


Fig. 6) Artist's impression of the OPERA supercontainer for heat generating high level waste. Note the amount of cementitious mat

Safety Case to steer future research

The safety case is used as an instrument to steer research and manage the knowldge over decades. In the OPERA safety case, current knowledge on the performance nd evolution of compartments and their contribution to safety was assessed. Based on that assessment the key topics for future research were extracted (Fig. 13).

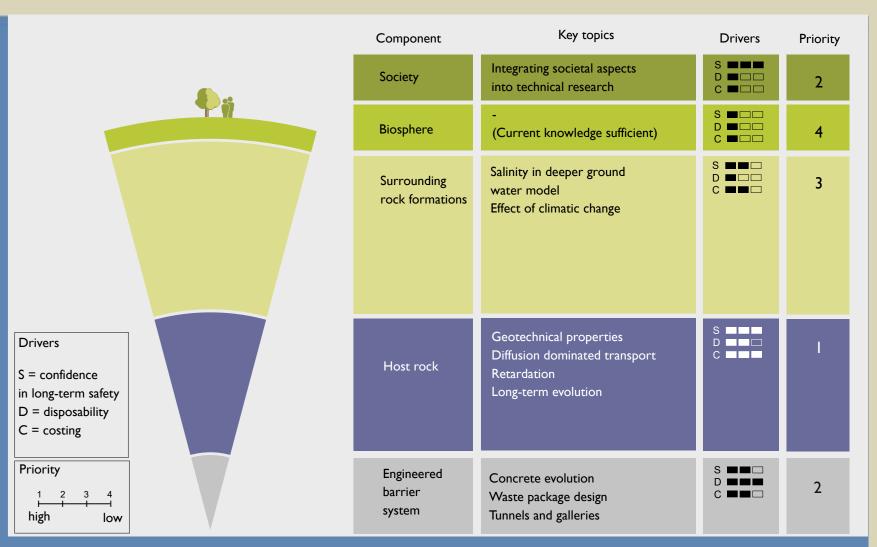


Fig. 13) Key topics for research into geological disposal organized according to con

Acceptability of geological disposal and confidence in the (longm) performance of a geological disposal facility will remain key pics for the next decades.

Host rock

Research should be focused on thermal and mechanical properies, quantifying diffusion through clays and evaluating the potentially lisruptive processes like transport of corrosion gases, retardation nd solubility of radionuclides and the long-term evolution of the ost rocks.

Surrounding rock formations

Incorporation of salinity in deeper groundwater models would result in a more realistic estimate of radionuclide releases. Furthermore, research should also be focused on the effect of climate change and particularly ice ages and associated erosion and meltwa-

Engineered-Barrier System

Research should be focused on waste package design, layout of he repository and the evolution of concrete and specifically on the nature and rates of interactions between the host rock and the con-

From the list of key topics to be further investigated (Fig. 13), it is important

for planning and budgeting reasons, to identify specific objectives for the next

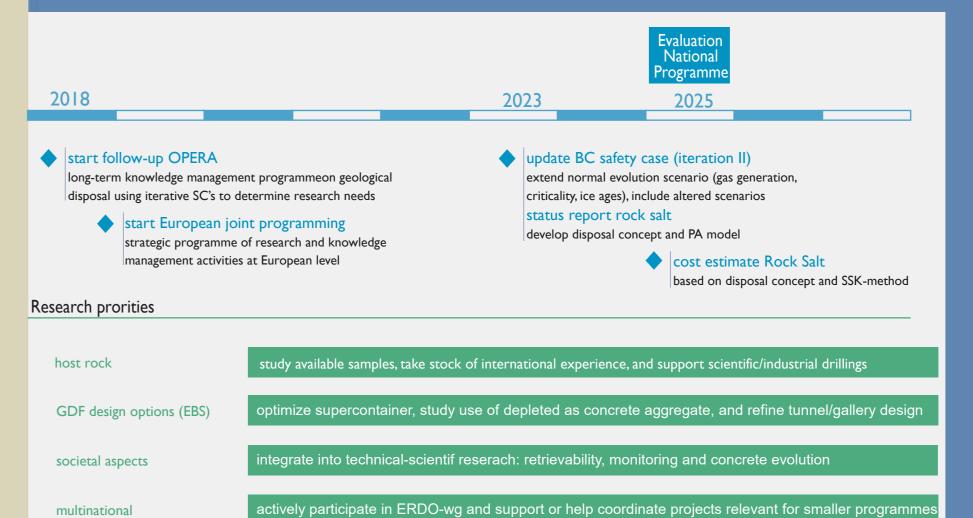


Fig. 14) Milestones for COVRA for the next decade.

decade (Fig. 14). These are to (further) develop the performance assessment capacity and to work on the key topics that have been allocated highest priority i.e. host rock, society and engineered barrier system. COVRA will start working on host rock formations for which most information is available, Boom clay and Zechstein salt, and will work on Ypresian clay later. The most important mile stones are:

- 2023 An update of Boom Clay safety case.

- 2023 An outline of a disposal concept and a first performance assessment model for rock salt.

- 2024 A cost estimate for a geological in rock salt will be developed.

How much radioactive waste?

Before a geological disposal facility can be build, one has o know how much waste is expected to be destined for geological disposal. The OPERA waste inventory is based on the Dutch base case nuclear scenario: no new nuclear power plants and operation of the present nuclear powerplant until 2033. Based on this scenario, the expected eventual inventory of wastes from all sources destined for geological disposal is shown in figure 3.

Fig. 2) Artist's impression of a geological disposal facility in the Boom clay, The Nether-

Waste Category	0 ()		1 dettaged 131 disposal (2133)		
	Volume [m3]	Weight [tonne]	Number of containers	Volume [m3]	Max weight [tonne]
Processed LILW	45000	150000	152000	45000	150000
Depleted uranium	34000	110000	9060	40000	182000
Vitrified HLW	93	191	478	3388	9560
Spent research reactor fuel	104	99	75	638	1800
Other HLW	256	600	700	5104	14400

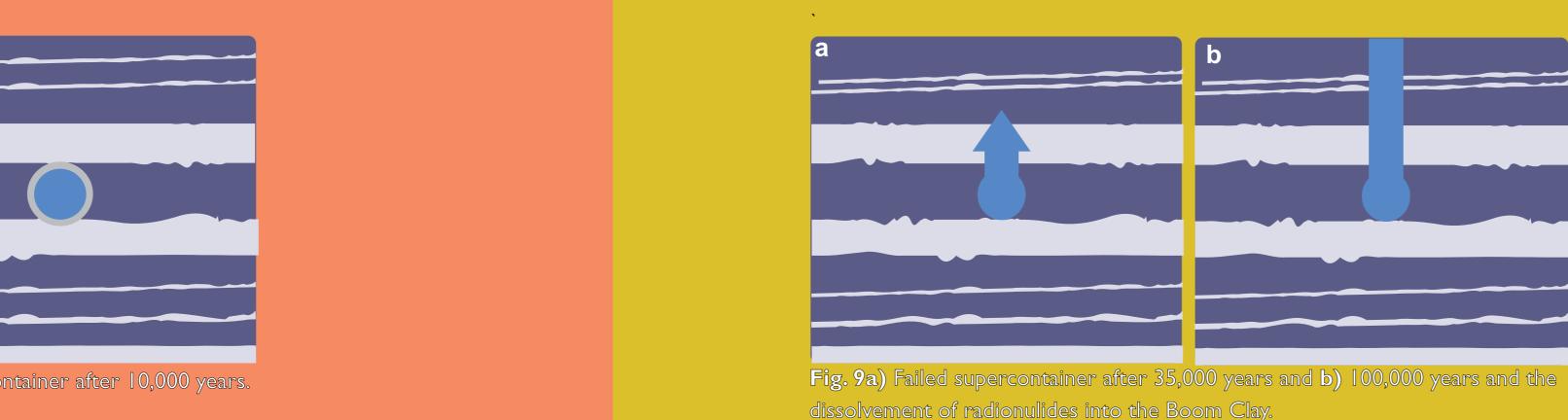
Fig. 3) Expected eventual inventory of wastes for disposal, showing their mass

10,000 to 100,000 years

nany radionuclides by reducing their solubilities and promoting sorption.

Different containers for radioactive wastes.

During this period, the liner, backfill and buffer are likely to begin to lose their distinct individual identity to form a more continuous mass of cementitious materials. Around the end of this period, the radiotoxicity of the spent fuel from research reactors will be close to that of the original uranium ore from which it was manufactured (Fig. 11). At 35,000 years after closure of the geological disposal facility, it is assumed that the supercontainers will fail. The high level waste from the supercontainers will then instantly dissolves and diffuses into the Boom clay (Fig. 9a and b). An exception is the vitrified high level waste that starts to dissolve gradually and is gradually released into the Boom clay.



100,000 to 1,000,000 years

By the end of this period, the physical strength and chemical containment nctions of the concrete will have broken down completely. Consequently, obile radionuclides will be mobilised and start to diffuse through the legraded concrete, the Boom clay and subsequently into the aquifer system rithin the overlying sediments but only in extremely small concentrations. owever, many radionuclides diffuse so slowly through the natural barrier ystem with respect to their half-lives that they will decay to insignificance uring transport through a thick clay formation. Immobile and long-lived radionuclides will still remain within the degraded engineered barrier system. U-238, for example, will remain within the geological disposal facility until he inexorable processes of geological erosion disperse it into new sediments and rocks. It will behave like a naturally occurring ore body.

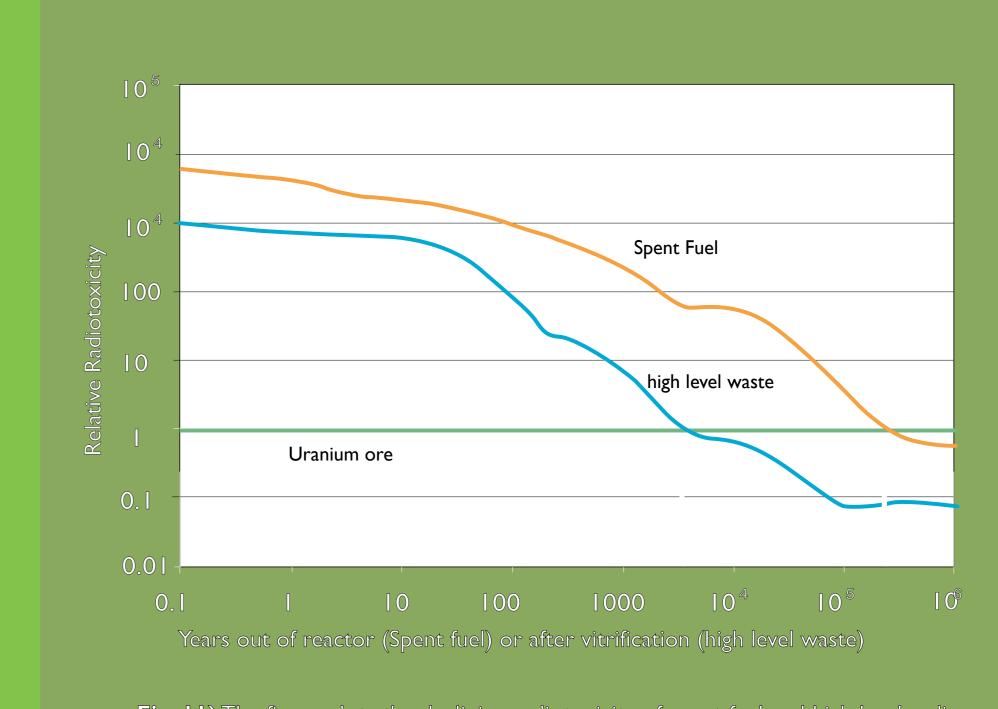


Fig. II) The figure plots the declining radiotoxicity of spent fuel and high level rad active waste as a function of time after the fuel has been taken out of the reactor or for high level radioactive waste, after it was manufactured, following the reprocessing of the equivalent quantity of spent fuel. These curves are shown normalised to the radiotoxicity of the amount of uranium ore that was originally used to make the fu (the horizontal line). Note that radiotoxic diminishes significantly over a period of a ome hundred years.

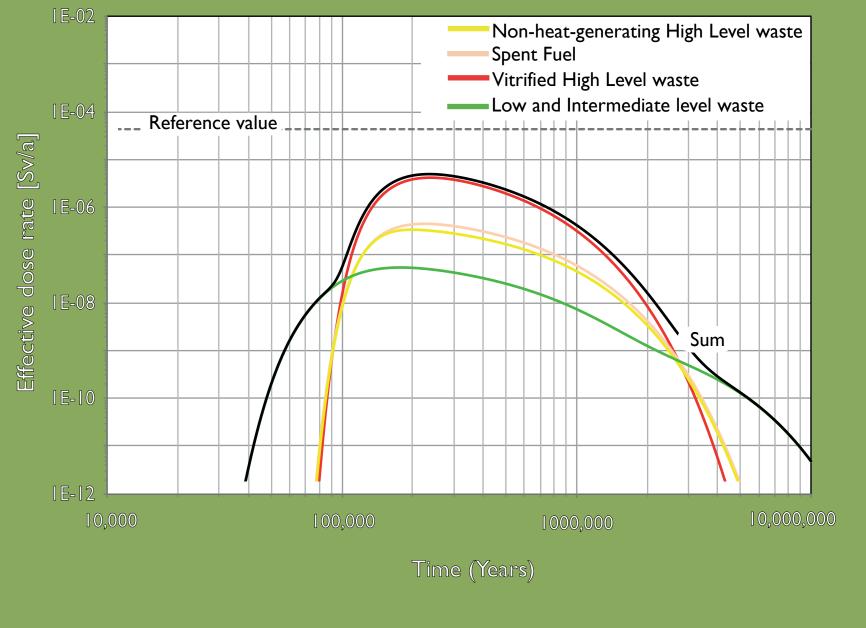
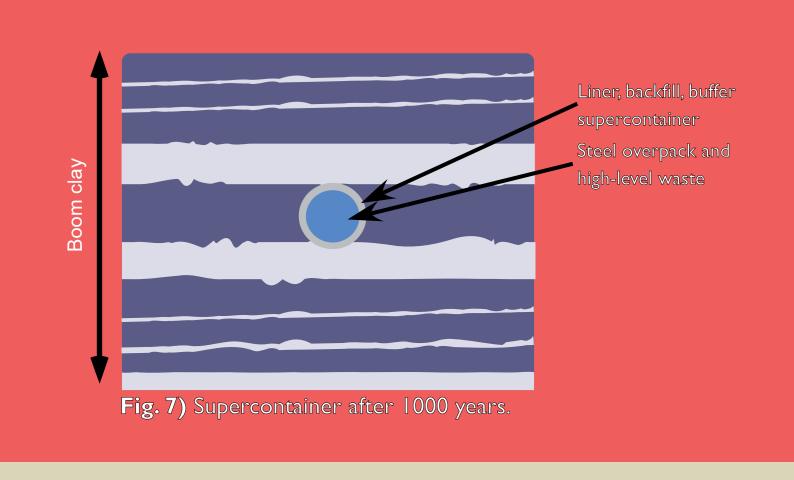


Fig. 12) The wastes that dominate the calculated exposures are vitrified high level waste and spent research reactor fuel, even though the volumes of these wastes are relatively small compared to other wastes (see fig. 3). Th calculated peak exposure is about 10 µSv per year, at about 200,000 years into the future. This peak is about 150 times lower than average natural background radiation exposure

How does the geological disposal facility evolve?

0 to 1000 years

1000 years after closure of the geological disposal facility, it is expected that the properties and geometry of the tunnels will have changed very little althought there will be limited chemical interaction between the clay pore waters and the cementitious materials. The high radiotoxicity of high-level waste will have reduced considerably during this period (Fig. 11). The supercontainers (Fig. 7) will remain intact throughout this period. Also the Konrad Type II containers will remain intact throughout this period. In contrast, the low and intermediate level waste steel packages are assumed to fail immediately after closure of the geological disposal facility.



1000 to 10,000 years

At the end of this period, concrete components like the tunnel liner of the engineered barrier system may have lost some strength due to some decalcification. Furthermore, most of the short-lived radioactivity will have decayed in-situ, the long-lived radionuclides will remain in (or in the vicinity of) the waste containers, and the hazard potential of all classes of high-level waste will have diminished considerably (Fig. 11). The supercontainers will remain intact throughout this period and thus do not release radionuclides (Fig. 8). In contrast, the Konrad Type II containers for depleted uranium, are assumed to fail 1500 years after closure of the geological disposal facility releasing the radionuclides into the Boom clay. The release of uranium into the Boom clay limited by its low solubility.

Fig. 8) Supercontainer after 10,000 years.