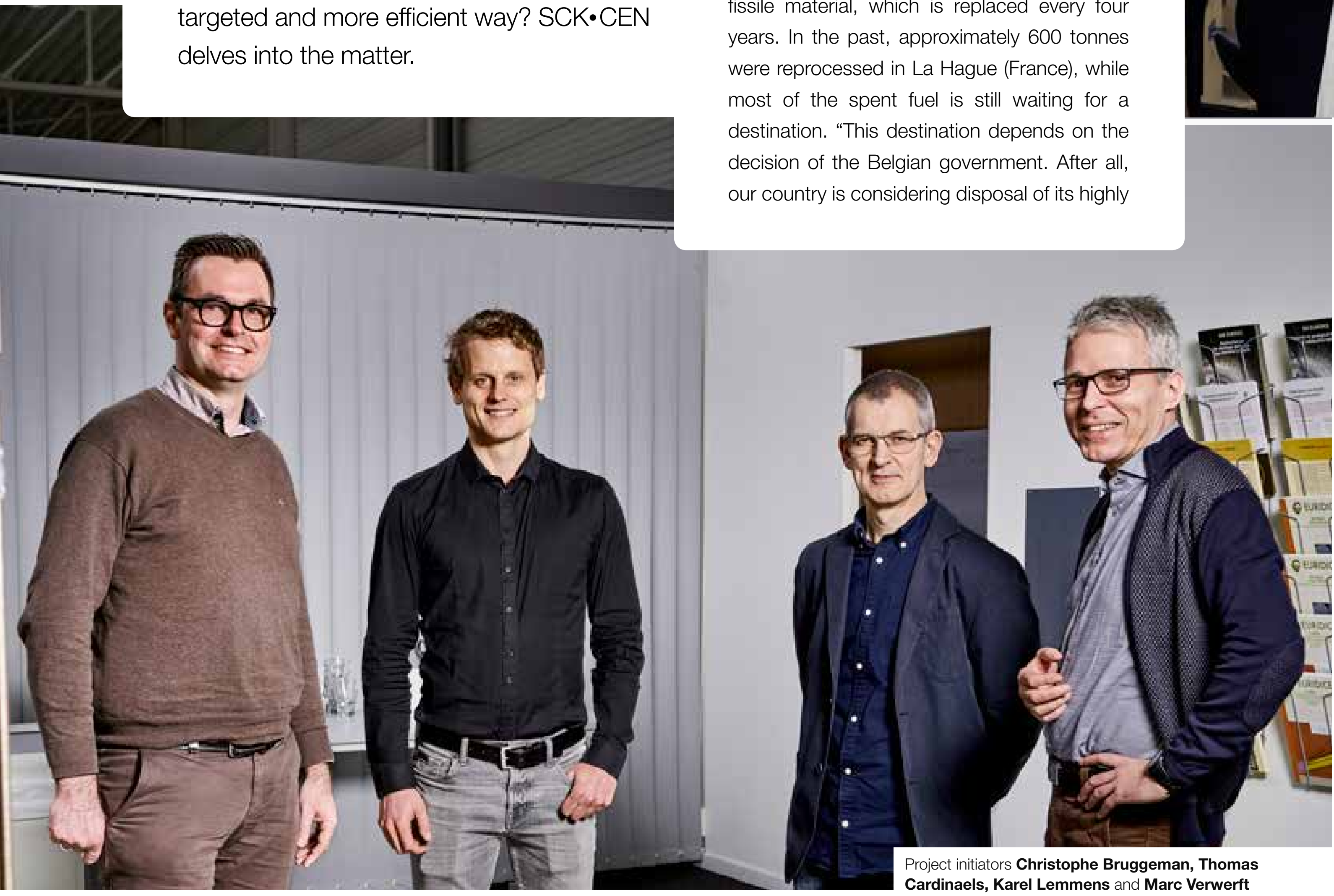
Caring for future generations

How does spent fissile material from nuclear reactors – so-called *spent fuel* – react with its environment, if we store it immediately underground? Can we separate the different radionuclides into different fractions, so that these fractions can be managed in a better targeted and more efficient way? SCK•CEN delves into the matter.



Project initiators **Christophe Bruggeman, Thomas Cardinaels, Karel Lemmens** and **Marc Verwerft**

In the 70's, Belgium started its own nuclear programme with the construction of four reactors in Doel and three reactors in Tihange. In 1975, the first ones went on-line. Since then, those seven reactors have been producing approximately 50% of the power supply in our country. The energy is generated by irradiating fissile material, which is replaced every four years. In the past, approximately 600 tonnes were reprocessed in La Hague (France), while most of the spent fuel is still waiting for a destination. "This destination depends on the decision of the Belgian government. After all, our country is considering disposal of its highly radioactive waste and spent nuclear fuel. Several options are available: the spent fuel may be stored directly and permanently in geological layers, but it may also be split up in fractions. By doing so, the total volume that must be stored can be reduced. SCK•CEN is exploring two possibilities in two multidisciplinary projects", explains Christophe Bruggeman, one of the project initiators. "Both projects have the same aim: reducing the load for future generations."

DIRECT STORAGE

SCK•CEN has been carrying out experiments for a while, commissioned by the National Institute for Radioactive Waste and Enriched Fissile Materials (NIRAS), which will support the safety studies concerning the possible direct geological disposal. "The SF-ALE project, which we run in cooperation with the German research centre Jülich (FZJ), is part of the NIRAS research programme", says Karel Lemmens, project manager at SCK•CEN. The project started in 2018 and tests one specific safety aspect of the current, proposed disposal concept.

Groundwater

"In the current design, the irradiated fissile elements are put in heavy, protective concrete containers. These containers slide into underground tunnels, which are also made of concrete. The irradiated fissile elements can enter into contact with groundwater seeping through the concrete and become alkaline as a result", explains Karel. "The groundwater then adopts the typical characteristics of cement pore water: high pH value and high concentration of alkali metals and calcium. What is the chemical stability of the 'spent fuel' in this environment? That is the main information on which the safety assessment of the disposal system is based."

To test the concept, SCK•CEN submerges representative nuclear fuel rods for at least eighteen months in cement water with a high pH. "The pH value of cement water is 13.5, while groundwater usually has a pH of around 7.4. The aim is to monitor the release of radionuclides over time", explains Karel.

Reproducing real-world conditions

In their experiments, researchers aim at imitating real-life circumstances of underground disposal as accurately as possible. "We have planned a long test period, because the release of radionuclides in these circumstances is expected to occur slowly. The experiment was launched in 2018, and the first phase runs until 2020. In this phase, we focus on the most soluble radionuclides found in the structures that are in direct contact with cement water", says Gregory Leinders, who follows up cooperation with the German centre JFZ. "If the results are satisfactory and with the necessary funding, the tests will be extended in the period 2020-2021."

BETTER MANAGEMENT

With the other multidisciplinary project ASOF, SCK•CEN investigates possible leads for a more optimal management of irradiated fissile material in Belgium. "ASOF stands for *Advanced Separation for Optimal management of spent nuclear Fuel*. You can guess from the name that this project focuses on the option of enhanced separation of the different radionuclides in irradiated fissile materials. The different resulting fractions can then be management in a more targeted and more efficient way. Compare this with household waste: before, everything was dumped in one big heap and then burnt, now we sort it. This offers the opportunity to follow the best way for the processing of each fraction", illustrates Thomas Cardinaels, expert in radiochemistry.

> *"With the ASOF project, we are looking for an alternative scenario aimed at reducing the load and risks of geological disposal for future generations."*

Separating more is disposing less

In this context, ASOF want to develop a method to separate americium. This element, in particular the Am-241 isotope, has a high radiotoxicity, a long half-life (432 years) and generates a lot of heat. "When we reprocess the separated americium into a target that can be irradiated in a reactor such as MYRRHA, it can be transformed into short-lived radionuclides", explain Thomas Cardinaels and his project co-initiator Marc Verwerft. "We are also researching a method to separate fission products caesium-137 and strontium-90. These are short-lived and generate a lot of heat. By separating them and then conditioning them separately, we prevent this fraction from ending up with the highly radioactive waste."

This means separation has an impact on the final disposal footprint. "In fact, our project is a search for an alternative scenario aimed at reducing the load and hazards for future generations", concludes Thomas. The first results of this study are expected in five years' time.

Knowledge

Keep investing

Even after an eventual closing of the power reactors in Belgium, we must keep investing in order to preserve and deepen our nuclear knowledge. This knowledge is useful to manage nuclear waste safely, dismantle nuclear power plants and ensure the production of theranostic radioisotopes (for therapeutic treatment or diagnostic research).

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