WASTE DISPOSAL

The elusive search for a long-term nuclear disposal solution

Much of the debate around nuclear power revolves around fears of leakage of radioactive material and accidents leading to a reactor meltdown. But a fire in a cooling pool – where large quantities of spent nuclear fuel is stored – could be worse. So why can't the world's nuclear-powered nations agree on a more secure storage solution? *Jennifer Johnson* reports.

It has been more than six decades since the first nuclear power stations began producing electricity – and there's now a global stockpile of almost 250,000 tonnes of highly radioactive spent fuel distributed across 14 countries. Each year of commercial reactor operation produces an additional 12,000 tonnes of used nuclear fuel, the majority of which is stored – for the present – in deep cooling pools at reactor sites.

According to a new report from Greenpeace, *The Global Crisis of Nuclear Waste*, many of these pools lack crucial safety infrastructure, such as secondary containment and independent back-up power – see box. Most countries have yet to decide on a final destination for their spent fuel, meaning that prolonged storage in cooling pools is likely. As quantities of spent fuel accumulate, the need to expand and secure storage facilities grows more urgent.

Pools that are densely packed with fuel present a greater fire risk if water and cooling levels are compromised. A 2016 report by the US National Academy of Sciences (NAS) found that a fire in a spent fuel pool was only narrowly avoided in the wake of the 2011 Fukushima disaster. In this case, a fortuitous water leak kept used fuel from being exposed to the open air. Had the hot fuel been uncovered and caught alight, the NAS warned there could have been 'large radioactive material releases into the environment.'

Naoto Kan, Japan's President at the time of the disaster, said he feared such a fire would have forced the evacuation of 50mn people and brought about 'the end of the state of Japan'. While incidents like Fukushima highlight the need for robust defences around spent fuel facilities, they also underline the need to develop secure storage solutions for the long-term – for many thousands of years. It's generally believed that disposal deep in geological formations is the answer, and though a handful of countries are pursuing such projects, most are still decades away from being realised.

Nordic approach

Finland is likely to be the first country with an operational geological repository, with disposal at its Onkalo facility scheduled to begin in the 2020s. Located adjacent to the Olkiluoto nuclear power stations (including Olkiluoto 3, which is due to start generating electricity next year), Onkalo is being built using the KBS-3 method – a Swedish design based on barriers of copper canisters, bentonite clay and bedrock.

The facility will be able to hold about 6,500 tonnes of spent fuel, with shafts and tunnels excavated to a final depth of roughly 450 m. The final disposal canisters containing the radioactive waste will then be placed in holes from inside the tunnels. According to current plans, the repository would be sealed, and then the radioactive waste will be left to decay *in situ* for tens of thousands of years.

Under the KBS-3 method, waste

An artist's impression of SKB's planned geological disposal concept.

Photo: SKB

is kept in intermediate storage for 30 years before being encapsulated in cast iron canisters. These canisters are then placed in copper capsules, which are deposited in a layer of bentonite clay and stored underground. The method will also be used at another planned geological repository near the Forsmark nuclear power plant in Sweden.

However, there is ongoing debate about the long-term security of such a facility in the country's Land and Environment Court. In January 2018, following a formal review process, the court said it could not guarantee that the planned repository was safe. In particular, the investigation showed that there were uncertainties about the ability of the copper canisters to resist corrosion and contain the nuclear waste in the long term.

'The big risk is that if the copper and other facilities corrode and degrade with time, then circulating groundwater will carry away the isotopes if they come into solution,' explains Dr Herbert Henkel, Associate Professor Emeritus at the KTH Royal Institute of Technology in Stockholm and a specialist on nuclear waste in Sweden. 'That is why the KBS-3 method has all these different barriers to prevent the isotopes from coming into solution. In Sweden, and the Baltic Sea as a whole, there is fresh, circulating groundwater down to a depth of about 1 to 2 km.'

In early April, SKB – the company developing the geological repository at Forsmark – submitted additional documentation in response to the concerns of the Land and Environment Court. According to a statement from the firm, its new reports confirm that the copper canisters will be durable in the repository environment and that the facility itself will be safe after it is sealed up. Ultimately, the Swedish government will decide whether the project can go ahead as planned, but Henkel believes that there might be designs better-suited to the demands of spent fuel storage.

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> **Robert Alvarez, IPS**

'The alternatives are deep drill holes where you can store a lot of radioactive waste, and you can store it at depth, where it is not in contact with the circulating groundwater,' he explained. 'Of course, the depths at which groundwater is stagnant depend very much on the local geology. That must be determined by some method, but the technology to make deep drillings is well established in the oil industry, so it wouldn't be a technical problem.'

Henkel, and several other Swedish geoscientists, have also expressed concerns about the long-term geological stability of the Forsmark project. When selecting a potential site for spent fuel disposal, earthquake risk is one of the more obvious considerations. In theory, a facility should be built in an area that has been, and appears likely to remain, geologically inactive for many thousands of years. But in practice, they'll probably be located in communities already comfortable with nuclear power – because they are more likely to consent to construction.

According to Henkel, it's no coincidence that both Onkalo and the Forsmark project are in close proximity to existing nuclear power stations: 'There was a very strong reaction from the public wherever SKB tried to study the feasibility of different types of bedrock,' he recalled. Regardless of whether Sweden eventually builds the Forsmark facility, continuing to store spent fuel in pools is not a permanent solution.

Yucca Mountain

The spent fuel situation is perhaps most acute in the US, where pools are currently holding three or four times more waste than their original designs intended. Almost one-third of the global inventory of spent fuel is located in the US, with roughly 80,000 tonnes stored at 125 reactor sites, of which 99 are still in operation. Much of the waste was never intended to be kept in pools for this long. In fact, it was meant to be stored inside the long-delayed Yucca Mountain repository in Nevada.

The site, located 80 miles northwest of Las Vegas, was first selected by the US Congress in 1987. The Department of Energy (DoE) was then scheduled to start accepting spent fuel at Yucca Mountain at the start of 1998. Decades of policy indecision, and downright opposition, have brought the project to a halt several times. To date, the government has spent $15bn studying the site and drilling test tunnels, but permission to begin construction in earnest has never been granted.

In 2008, the DoE began pursuing a license to build the facility, but the Obama administration abandoned the project three years later amid intense opposition from residents and political leaders in Nevada. Failure to provide a secure site for the storage of spent reactor fuel is what has led to the widespread practice of 'dense compaction' at reactor sites nationwide.

According to Robert Alvarez, a Senior Scholar at the Washington DC-based Institute for Policy Studies and former Senior Adviser in the DoE, these sites also lack defence in-depth in case of acts of malice or natural disasters. 'A fire in a pool with several irradiated cores in it would tend to release far more radioactivity than a mere meltdown,' Alvarez warned.

Is it imperative, then, to try to get the construction of Yucca Mountain back on the US policy agenda? In light of serious issues with its

Is there a global crisis of nuclear waste?

The report, from Greenpeace France, focused on seven major nuclear countries (Belgium, France, Japan, Sweden, Finland, the UK and the US). It suggests that no government has yet resolved how to safely manage the volumes of nuclear wastes produced in stages of the nuclear fuel cycle, and that underground repository research has failed to find a solution.

The environmental organisation's experts identified hazards with plans for underground geological disposal, both during the operational phase (during the first 100 years in which the repository is built and filled-up with waste), and the very long term, including:

- fire risks, including explosion, failure of containers and venting of radioactive gases into the environment;
- water migration and flooding risks impacting the container system and risking environmental contamination;
- technical challenges in storage containers robustness and corrosion resistance;
- unknown and escalating costs, with future generations to be burdened.

For Greenpeace, the first step for high-level waste, including spent fuel, is to downscale the problem, which means halting its production at the earliest opportunity through a planned nuclear reactor phase out. For existing spent fuel, dry, above-ground or near-surface temporary storage remains the least threatening option over the coming decades. This would keep all options open for future generations and it is an easier way to monitor waste. But it offers no solution for the long timescales required to safeguard the waste.

geological suitability, the answer is almost certainly no. The International Atomic Energy Agency (IAEA) has stipulated that any potential geological storage sites must have 'stable geochemical or hydro chemical conditions at depth...and long-term (millions of years) geological stability, in terms of major earth movements and deformation, faulting, seismicity and heat flow.'

In the seismically volatile Western US, Alvarez said, these conditions are not met.

'Because Yucca Mountain is in a desert area where the US exploded several bombs, both above and underground, it was assumed that this was a safe space to store waste over a period of time that transcends the geologic epoch defining human civilisation,' Alvarez explained. 'What the scientists discovered is that this is not a dry repository. In a matter of hundreds of years there is enough moisture that could creep down into the repository that would jeopardise the integrity of the containers.'

Interim storage

With plans for a permanent geological disposal facility in the US on hold for the foreseeable future, the nuclear industry must begin finding alternative storage arrangements. One option is to keep spent fuel in dry cask storage, in which spent fuel that has been cooled in a pool for at least a year is surrounded by inert gas inside a steel cylinder. The cylinder is then welded or bolted shut and encased in steel, concrete or another material to provide protection from radiation.

'I think we're looking at a default scenario of decentralised, indefinite surface storage,' Alvarez said. 'There are different types of dry casks out there, the Germans tend to have perhaps the most durable. The walls of their canisters are approximately one foot thick, whereas those that are in widespread use in the US are about five-eighths of an inch (1.5 cm) thick.'

One company, Holtec International, believes it may have found a medium-term fix for the country's nuclear waste woes. The US Nuclear Regulatory Commission is currently considering a proposal by the firm to build an interim storage facility in a remote part of southeast New Mexico with an initial capacity of 10,000 storage canisters, or 120,000 tonnes, of used fuel.

The project, known as HI-STORE CIS, is designed to keep the waste in an inert environment in what Holtec calls a 'subterranean configuration.' The waste would then be stored safely for more permanent disposal once suitable technologies and facilities have matured.

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No matter where the nuclear industry tries to build a spent fuel storage facility, public opposition is sure to follow. The UK, for instance, has been grappling with these tensions since 1976, when it first began the search for a deep geological disposal site. Now, after five failed attempts, Radioactive Waste Management (RWM), a subsidiary of the Nuclear Decommissioning Authority, has again initiated the search for a UK site and community willing to host a disposal facility.

The process of finding, developing and constructing such a project will take decades – if RWM manages to identify a suitable location at all. But the consequences of keeping spent nuclear fuel in vulnerable pools at the surface could be dire. It's incumbent upon the countries with nuclear power programmes to agree and implement plans for the management of their spent nuclear fuel. It's a challenge that will persist far beyond the lifetimes of anyone living today. ●