Focus on
High Level Waste and Deep Geological Disposal

Multiple natural and artificial barriers work together to protect people and the environment from harmful radiation.

When nuclear fuel is discharged from a nuclear reactor, it is highly radioactive. After cooling, it can be treated as waste to be disposed of or it can be recycled, through reprocessing. The spent fuel and fission products separated from the spent fuel (when reprocessed) make up most of what is termed high level waste. This waste poses a sufficiently high enough radiological risk that a high degree of isolation from the biosphere is required for a long period of time. Because of radioactivity and the heat it generates, high level waste has to be shielded and cooled.

Spent fuel

The useful life of a fuel assembly is 3–6 years. About once a year, 25–30% of the fuel in a reactor is unloaded and replaced by fresh fuel. The spent fuel, immediately after removal from the reactor, is very hot and radioactive; therefore it is kept under water for a year or more in a pool close to the reactor. Water provides both effective cooling and radiation shielding.

Within a year, the radioactivity is reduced to a hundredth of the original level and after a few years it has cooled sufficiently to allow it to be transported into an interim storage facility. In 40 years, the radioactivity level is down to a thousandth of the level at discharge.

The amount of spent fuel produced in a year is relatively modest. A 1000 MW(e) reactor generates about 27 tonnes of spent fuel per year, which requires about 20 m^3 of space in a pool.

High level waste from reprocessing

Reprocessing spent nuclear fuel, to recycle the plutonium and/or uranium, involves dissolving the fuel in acid and separating the highly radioactive fission products and transuranic waste from the reusable plutonium and uranium. The resulting high level liquid waste is stored in stainless steel tanks equipped with cooling systems.

Since solid material is more convenient to manage, store, transport and dispose of, the high level liquid waste is dried and incorporated into molten borosilicate glass which is solidified inside a stainless steel canister. This process is known as vitrification.

A fresh nuclear fuel assembly does not emit harmful radiation.

After removal from the reactor, the fuel is highly radioactive. After a few years of cooling, the spent fuel can be transported to the interim storage facility.

The heat and radioactivity of spent fuel decrease over time, thus making it easier to handle.

IAEA
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Vitrification produces a stable glass that has the high level waste incorporated within its structure. If the 27 tonnes of spent fuel produced in a year by a 1000 MW(e) reactor is reprocessed, only 3 m^3 of vitrified high level waste will be produced. This waste can be placed into about 12 canisters 1.3 metres high and 0.4 metres in diameter, which can be transported and stored, with appropriate shielding, before final disposal.

There are just over a hundred interim storage facilities for high level waste in the world.

Interim storage

High level waste, whether spent fuel or vitrified waste from reprocessing, requires isolation from the biosphere for thousands to hundreds of thousands of years. Before disposal, it needs to be temporarily stored so that the heat and radioactivity decrease significantly, which makes the waste easier to handle.

Interim storage facilities may be at one central place, as in Sweden, or, as in many cases, at the reactor site. The interim storage may be wet storage or dry storage. In dry storage, circulating air removes the heat generated by the spent fuel. The structure and design of both the building and the containers protect the 'outside world' from radiation exposure and the fuel from potential outside hazards.

Deep geological disposal

At present, there are no final disposal facilities in operation in which high level waste can be disposed of; all high level waste is temporarily in interim storage facilities.

However, research, technical development and demonstration of the viability of deep geological disposal are being conducted in many countries using nuclear power.

The principle of geological disposal is to isolate the waste deep inside a suitable host formation, e.g. granite, salt or clay. The waste is placed in an underground disposal facility hundreds of metres beneath the surface, designed to ensure that a system of multiple natural and multiple artificial barriers work together to prevent radioactivity from escaping.

The release barriers are the original waste matrix (ceramic spent fuel pellet or borosilicate glass); the disposal canister made, for example, of stainless steel or copper; the bentonite clay surrounding the canister; the tunnel backfill and the host rock. A defect in the functionality of one release barrier will not jeopardize safety in the long run.

The most advanced countries to implement final disposal of spent fuel are Finland, France and Sweden.

The host rock is carefully studied to ensure its suitability for final disposal of spent fuel. At the Finnish disposal site, the excavation of the access tunnel reached the final disposal depth 420 metres in 2010.

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