NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Ensuring safety: Multiple-barrier system

Within a deep geological repository, a series of engineered and natural barriers will work together to safely contain and isolate used nuclear fuel from people and the environment. Each of these barriers provides a unique and stand-alone level of protection. If any of the barriers deteriorates, the next one comes into play. Safety is the top priority in implementing Canada's plan for the long-term management of used nuclear fuel.

Canada's current fleet of nuclear generating stations runs on CANDU reactors. When used nuclear fuel is removed from a CANDU reactor, it is radioactive and requires careful management. Although its radioactivity decreases with time, for practical purposes, used nuclear fuel remains hazardous, essentially indefinitely.

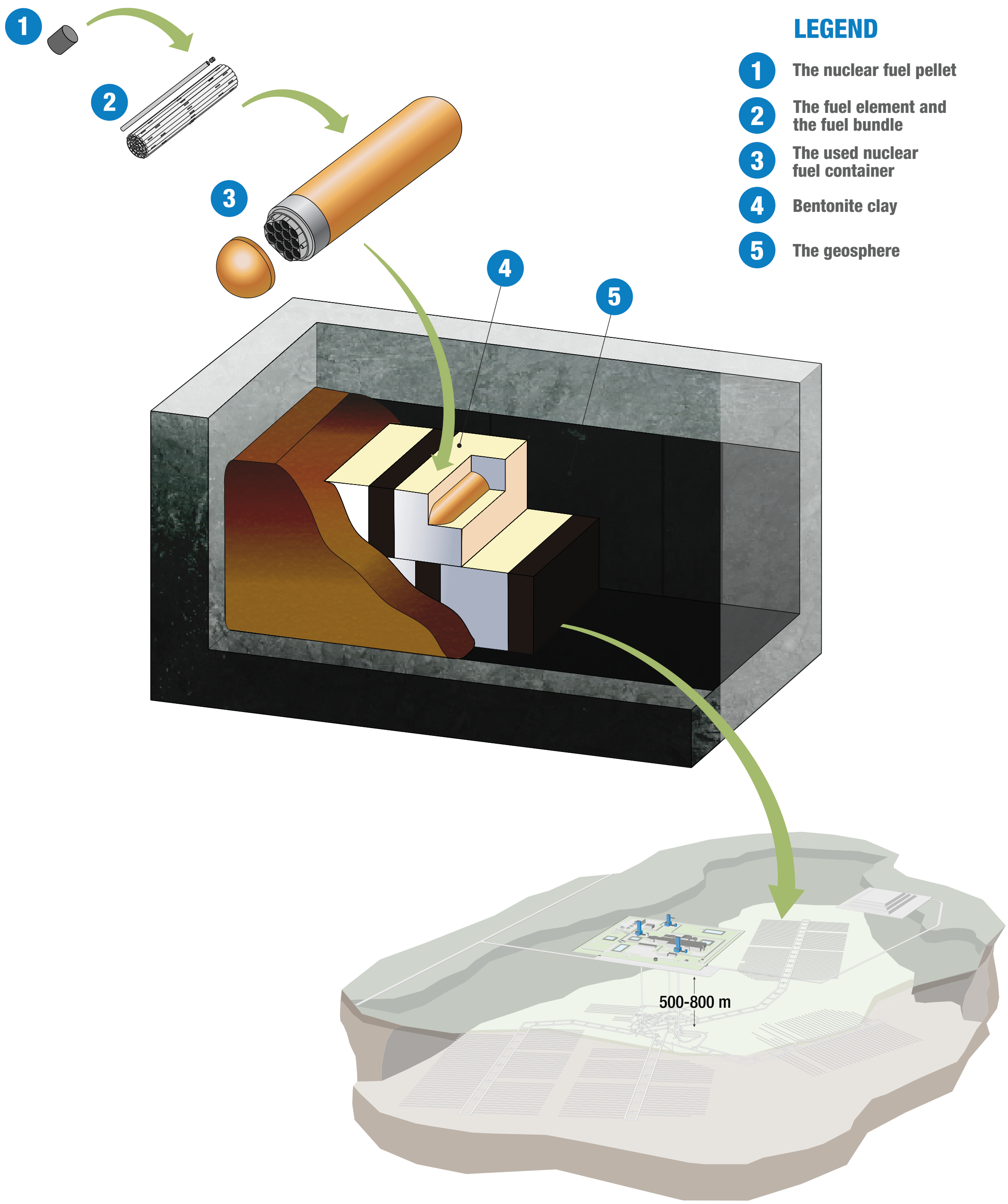
Used nuclear fuel is a solid material. It is largely made of uranium dioxide. Uranium is a naturally occurring chemically hazardous element. The used fuel also contains small amounts of other hazardous elements that were either in the original uranium ore or produced in the reactor.

While the amount of radioactivity in used fuel decreases quickly at first, it takes a very long time to decrease to a level that would be safe for direct exposure.

The radioactive atoms in used fuel emit radiation in the form of electromagnetic waves and high-speed particles. Exposure to these waves or particles can be controlled through distance from the source of radiation — in this case a fuel bundle — as well as through shielding or barriers.

With new types of reactors — including small modular reactors — being explored by governments across Canada, the NWMO understands that new nuclear may result in different types of waste. Even though that waste won't be produced for decades, we continue to actively engage with proponents of new technologies to ensure any potential new fuel waste will be able to meet the safety criteria for long-term management in a deep geological repository.

The NWMO's multiple-barrier system: Containing and isolating used nuclear fuel



LEGEND

1. The nuclear fuel pellet
2. The fuel element and the fuel bundle
3. The used nuclear fuel container
4. Bentonite clay
5. The geosphere

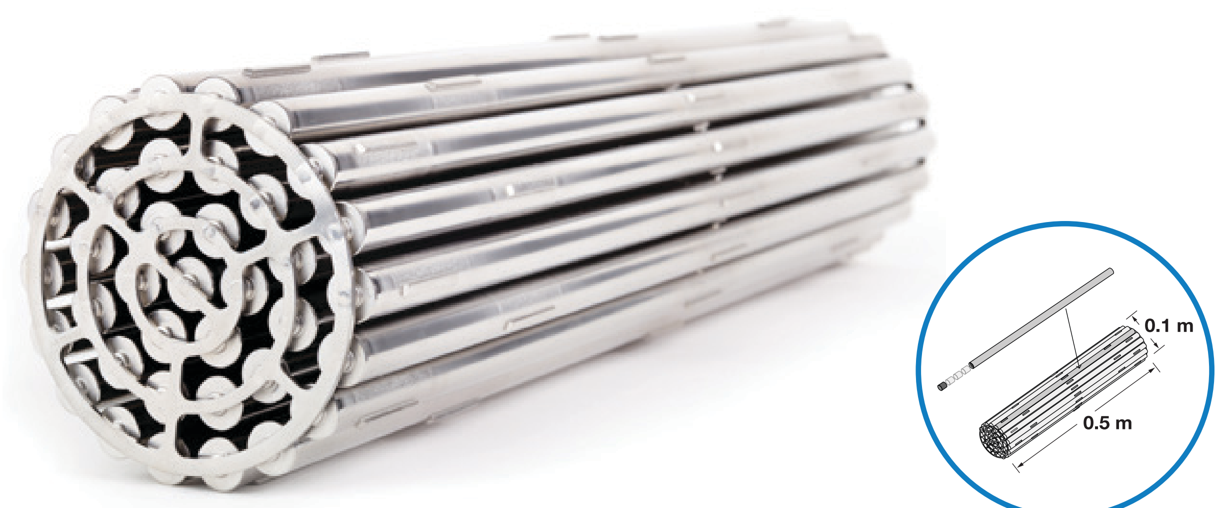
1 THE NUCLEAR FUEL PELLET

The first barrier in the multiple-barrier system is the CANDU fuel pellet. Fuel pellets are made from uranium dioxide powder, baked in a furnace to produce a hard, high-density ceramic. Ceramics do not readily dissolve in water, and their resistance to wear and high temperatures makes them one of the most durable engineered materials.

Uranium fuel pellets are used to power CANDU nuclear reactors in Canada.

2 THE FUEL ELEMENT AND THE FUEL BUNDLE

Each CANDU fuel bundle is composed of a number of sealed tubes called fuel elements. Fuel elements contain the fuel pellets and are made of a strong, corrosion-resistant metal called Zircaloy. The function of each element is to contain and isolate the fuel pellets.



Each fuel bundle contains sealed tubes called fuel elements, which hold the fuel pellets.

3 THE USED NUCLEAR FUEL CONTAINER

The used nuclear fuel bundles will be placed into large, very durable containers. The Used Fuel Container is a key part of the engineered-barrier system.

The container will prevent radionuclides in the used nuclear fuel from escaping into the underground environment. It is engineered to remain intact and keep the used fuel completely contained and isolated until its radioactivity has decreased to the level of natural uranium.

The container has three components: a steel body that is mechanically strong, a copper coating to protect against corrosion, and an inner structure that holds 48 CANDU fuel bundles.

The cylindrical steel body has a rounded lid welded to each end. The container is designed to withstand the pressure from the rock above it and from three-kilometre-thick glaciers during a future ice age.

The steel materials and copper coating technology for this container design are based on proven technology that is readily available in Canada. The Used Fuel Containers and supporting components will be manufactured at a container manufacturing plant, which could potentially be located in one of the host communities for the repository or the surrounding region, depending on interest.

The NWMO's Used Fuel Container holds 48 fuel bundles, and has a corrosion-resistant copper coating.

4 BENTONITE CLAY

Each Used Fuel Container will be encased in a bentonite clay buffer box.

Each used nuclear fuel container will be encased in a highly compacted bentonite clay buffer box during placement in the repository. Bentonite clay is a natural material formed from volcanic ash.

Bentonite is proven to be a powerful barrier to water flow. It swells when exposed to water, making it an excellent sealing material. Bentonite is also very stable, as seen in natural formations formed millions to hundreds of millions of years ago.

In the repository, the chemical properties of the bentonite clay, backfill and sealants will also help trap any radionuclides in the unlikely event that they were to escape from the container.

Each buffer box will be placed and separated from the next with bentonite clay spacer blocks. The containers will be stacked in two layers.

After the used nuclear fuel containers are placed in the repository, all open spaces in each underground chamber will be filled with bentonite clay. Each placement room will be sealed at the entrance using a combination of highly compacted bentonite clay and a concrete bulkhead.

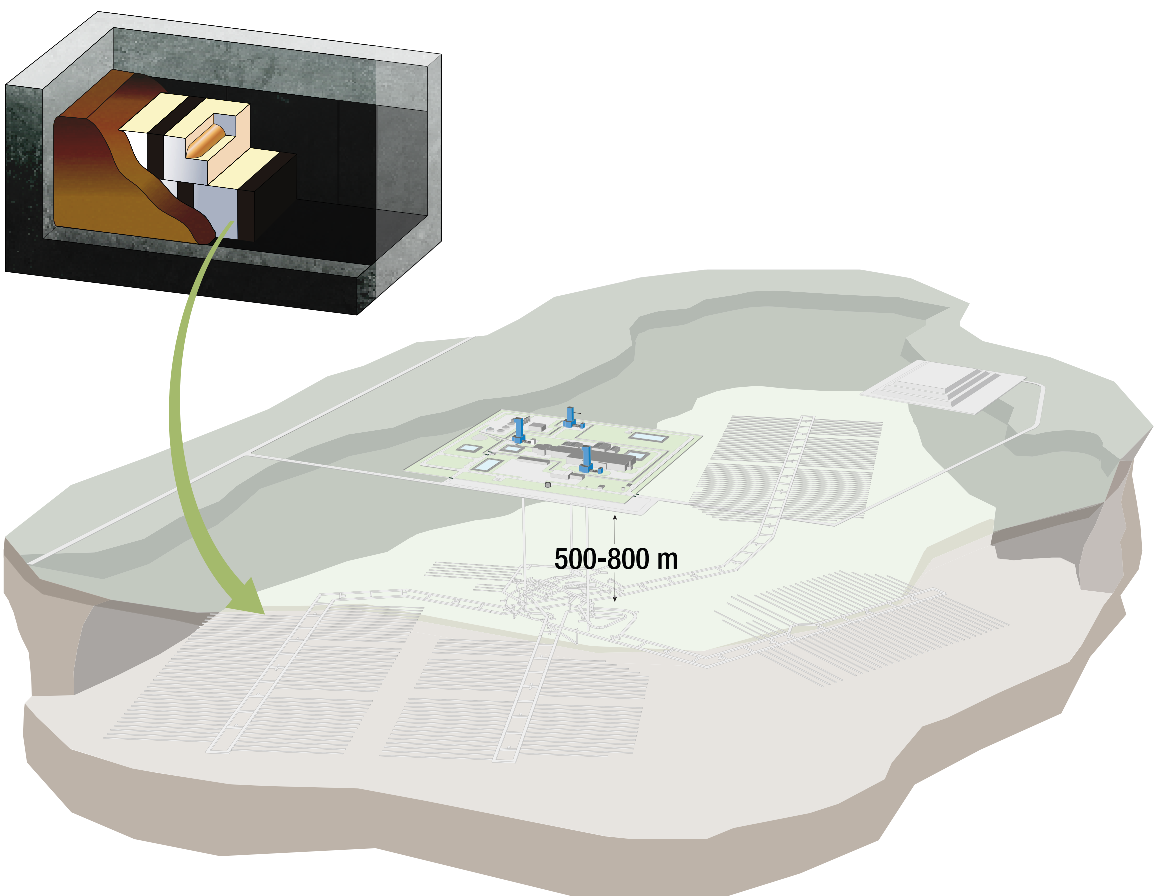
Before the repository is closed, all tunnels and shafts will be filled with similar backfill and sealants, isolating the repository from the environment. The performance of the repository will be monitored during placement operations and during an extended post-closure period.

5 THE GEOSPHERE

The geosphere forms a natural barrier of rock, which will protect the repository from disruptive natural events, water flow and human intrusion.

The repository will be more than 500 metres underground; the exact depth will depend on the characteristics of the host rock formation. It will be excavated within a crystalline rock formation that meets the safety and technical requirements of the project. The crystalline rock formation will have low permeability, which means there will be little groundwater movement. The traces of water that exist at this depth, known as porewater, can take 1,000 years to move one metre through the rock and well over 100,000 years to reach the surface.

This natural barrier will ensure the repository safely contains and isolates the used nuclear fuel, even in extreme scenarios.



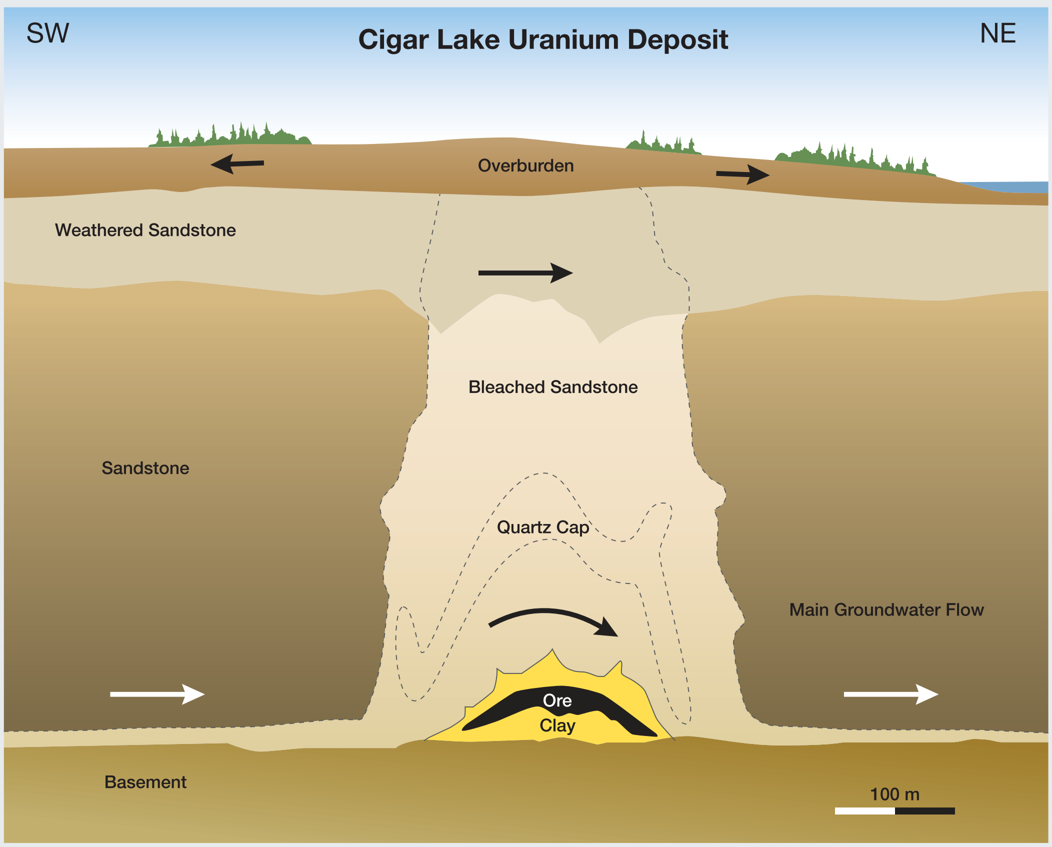
The geosphere is the final barrier that will contain and isolate the used nuclear fuel from people and the environment.

Examples in nature

Radiation

There are several locations where natural radioactivity has been contained for millions of years by the surrounding geology. These natural systems provide strong evidence supporting the concept of containment within a deep geological repository under similar conditions.

The Cigar Lake uranium deposit in Saskatchewan is one billion years old and is buried 450 metres below the surface, surrounded and protected by a layer of naturally occurring clay. There is no trace of radioactivity from the deposit at the surface. This is an example of how the deep geological repository can contain and isolate used nuclear fuel.



Uranium buried 450 metres underground for one billion years has left no trace of radioactivity at the surface.

Copper

Copper is a natural material that is known to be durable under deep rock conditions where there is no oxygen to cause corrosion. For example, naturally pure copper ore has been mined from around the Great Lakes.

Natural copper plates found in the mudstones from South Devon, U.K., provide a point of comparison for used nuclear fuel containers placed in a clay backfill. These copper plates were formed 200 million years ago and have shown little corrosion since that time, due in part to the protection of the clay-rich mudstone.

Found in clay-rich mudstone, this 12-centimetre copper plate experienced little to no corrosion for 200 million years.

Clay

The sequoia-like trees of Dunarobba forest in Italy were buried in clay for 1.5 million years. Similar to the bentonite clay that will be used in the repository, the clay minimized the flow of water to the trees, preventing them from decomposing. The trees did not fossilize; they are still made of wood.

Sequoia-like trees, buried in clay for 1.5 million years, did not decompose.

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