nwmo
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 deteriorate, 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.

When used nuclear fuel is removed from a 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 oxide. 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.

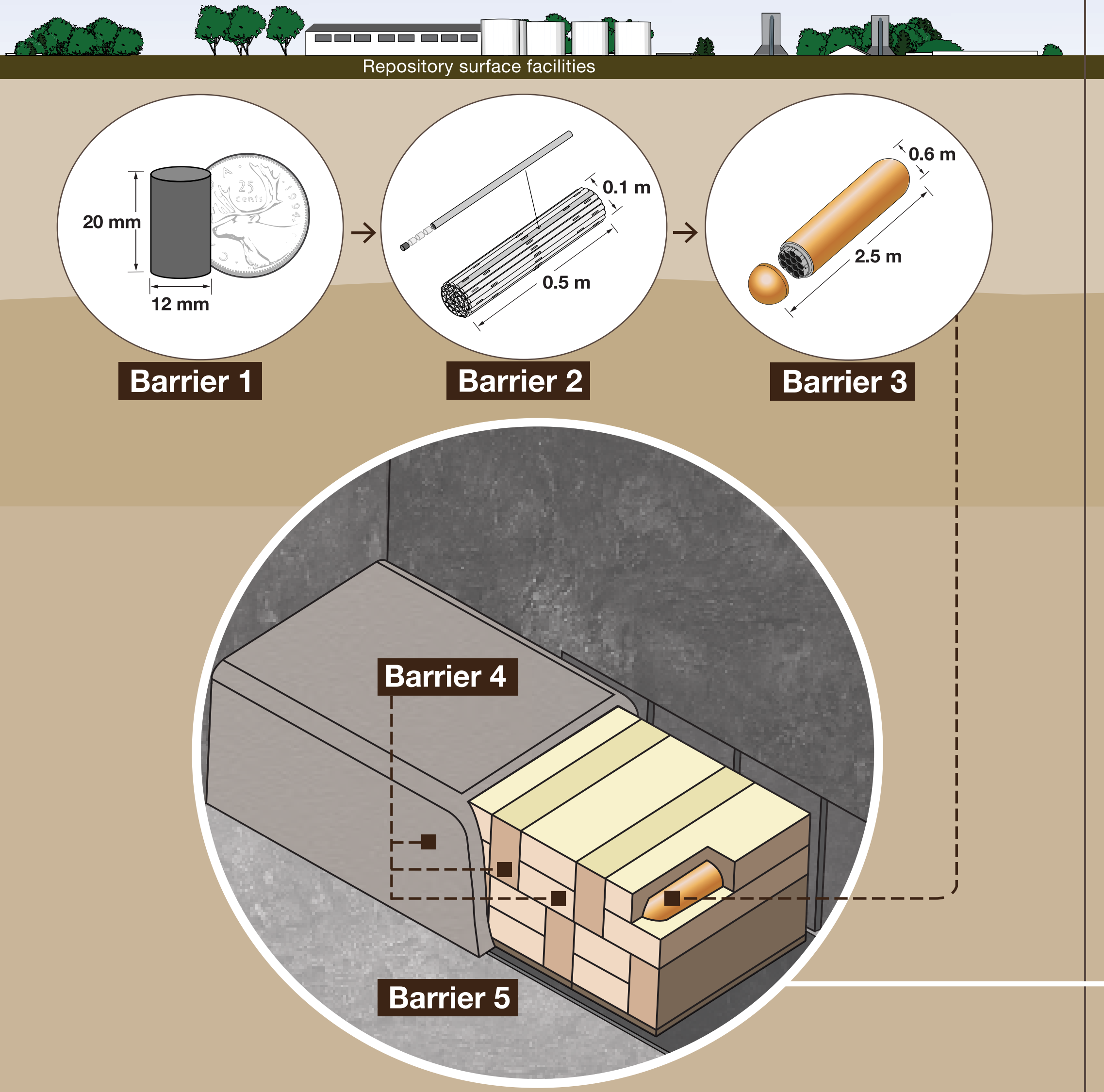
BARRIERS

#1 The Fuel Pellet

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

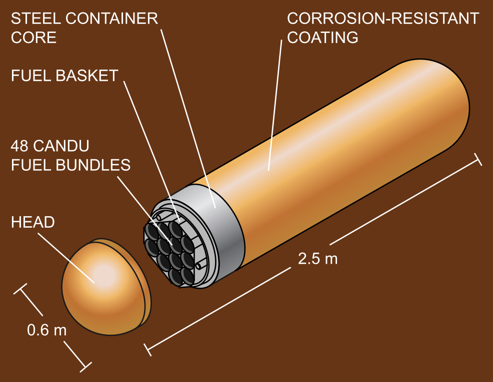
#2 The Fuel Element and the Fuel Bundle

Each 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.



BARRIERS

#3 The Used Nuclear Fuel Container



Used nuclear fuel bundles will be placed into large, very durable containers. In 2014, the NWMO refined its container design to one that is optimized for the used CANDU fuel produced by Canadian nuclear power reactors. Together with the bentonite clay buffer box (see Barrier 4), the container is a key part of the engineered barrier system.

The container prevents radionuclides in the fuel from escaping into the underground environment. It is engineered to remain intact and keep the used nuclear fuel completely isolated until the fuel's radioactivity has decreased to levels of natural uranium.

Each container holds 48 used fuel bundles in a steel basket within a carbon steel pipe. This steel pipe has the mechanical strength to withstand pressures of the overlying rock and loading from three-kilometre-thick glaciers during a future ice age. The pipe is protected by a corrosion-resistant copper coating.

The container has a spherical head that is welded to the core of the container. This spherical shape is designed to withstand significant pressure.

The carbon steel pipe and copper coating technology for this container design are based on proven technology that is readily available in Canada. The used nuclear fuel container and supporting components will be manufactured at a container manufacturing plant which could potentially be located in the host community or surrounding region, depending on interest.

BARRIERS

#4 Bentonite Clay

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 would also help to trap any radionuclides in the unlikely event they were to escape from the container.

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

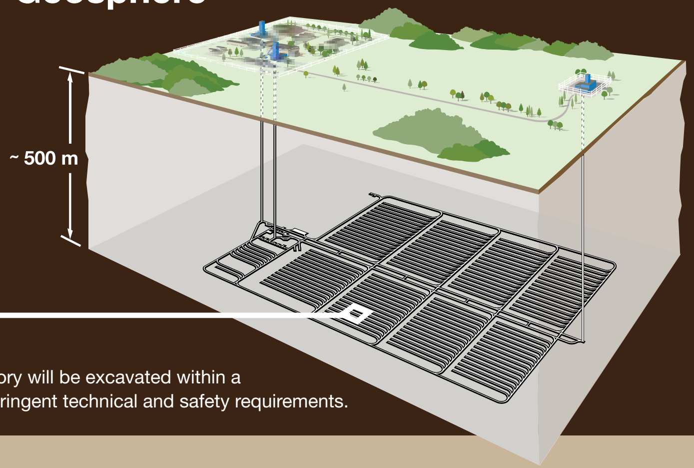
After the used nuclear fuel containers are placed in the repository, all open spaces in each underground chamber will be filled with bentonite clay.

A six- to 10-metre-thick highly compacted bentonite clay seal and a 10- to 12-metre-thick concrete bulkhead will be used to seal the entrance to each placement room.

Before closing the repository, 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 postclosure period.

Buffer box with container placed inside.

#5 The Geosphere



The deep geological repository will be excavated within a rock formation that meets stringent technical and safety requirements.

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 approximately 500 metres underground – the exact depth will depend on the site. It will be excavated within a sedimentary or crystalline rock formation that meets the technical and safety requirements of the project. The rock formation selected will have low permeability, which means there will be little groundwater movement. The traces of water that exist at 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.

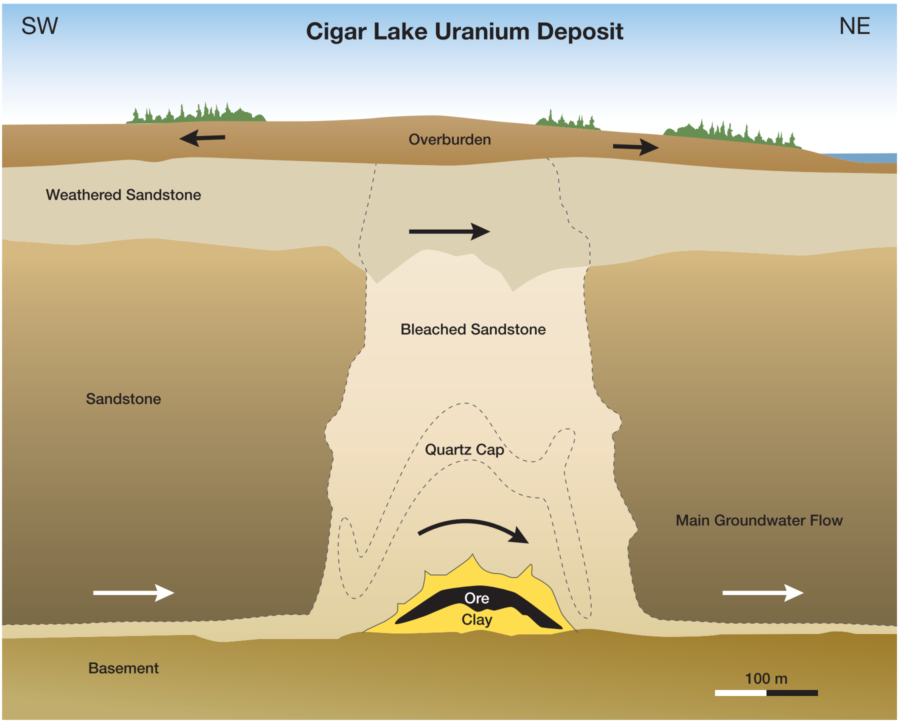
It will ensure the repository safely contains and isolates the used nuclear fuel, even under extreme scenarios.

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 radioactive components 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.

Examples in Nature

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; First Nations people in the area used surface outcrops of this copper.

Also, natural copper plates found in the mudstones from South Devon, U.K., provide an example for used nuclear fuel canisters placed in a clay backfill. These copper plates were formed 200 million years ago and show 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 in Dunarobba forest, Italy, were buried in clay for 1½ million years. 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 1½ million years, did not decompose.

For more information,
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