ASSEMBLY OF FIRST NATIONS

Nuclear Waste Technical Backgrounder Series

Part Two: ***Used Nuclear Fuel and Long-Term Storage***

Introduction:

There are different kinds of nuclear waste in our society, from what is characterized as low and intermediate-level wastes to high-level waste. Most nuclear wastes produced in our society is low-level. Compared to other industrial activities, nuclear power generation produces a relatively small amount of waste. While this waste is hazardous to living creatures and the environment, it is highly regulated and has been shown to be well-managed in Canada.

Although used nuclear fuel is well-managed and regulated and there have been no notable accidents in Canada, it still creates a great deal of concern in our society. This background paper is intended to provide some important facts about used nuclear fuel and Canada's plan for its long-term safe storage and management. Details about the different types of nuclear waste will be provided as a background, followed by an overview of the entire nuclear fuel cycle. Finally, this paper will explain the current and future measures for safely storing used nuclear fuel in Canada.

I. Nuclear Waste & Used Nuclear Fuel

What is Nuclear Waste?

As mentioned, there are different types of nuclear waste ranging from low and intermediate-level to high-level waste. Low-level waste, rather than being defined in terms of what it is, is defined in terms of what it is *not.* Nuclear wastes that are not classified as intermediate or high-level waste are usually considered low-level waste. The definition of low-level waste does not include any references to its radioactivity.

While waste in this category can still contain highly radioactive elements, it is typically in quantities small enough that it can be handled safely using normal industrial practices without any special radiation protection. Examples of low-level waste are mop heads and cloths used to clean nuclear reactor areas and medical facilities, cooling water from nuclear reactors, and equipment used in uranium mining.

Intermediate-level wastes make up about 5% of the total volume of waste produced at nuclear power plants (excluding used nuclear fuel). It contains levels of radioactivity that require special shielding for workers handling it, and is harmful to anyone standing close without protection. This waste mostly contains cooling water filters and irradiated reactor core components.

High-level waste is a form of radioactive waste produced from nuclear fuel in nuclear power reactors. It is the most hazardous level of nuclear waste due to the high amounts of radiation it emits. In Canada, high-level waste is almost exclusively used nuclear fuel, which consists of pellets of processed natural uranium encased in bundles of zirconium-alloy tubes. There are currently over 2 million bundles of used nuclear fuel in Canada, which grows by approximately 85,000 bundles every year.

When used nuclear fuel is removed from the reactors where it was used, it is highly radioactive and remains so for hundreds of thousands of years. The Nuclear Waste Management Organization (NWMO) is responsible for the long-term, safe storage of this waste, which will be discussed later in this paper.

Clearly, the term "nuclear waste" is fairly general and can include anything from low-level to high-level waste. However, this backgrounder is intended to provide technical information surrounding radiation and health so that First Nations can be involved in the dialogues surrounding the long-term storage of used nuclear fuel, or high-level waste.

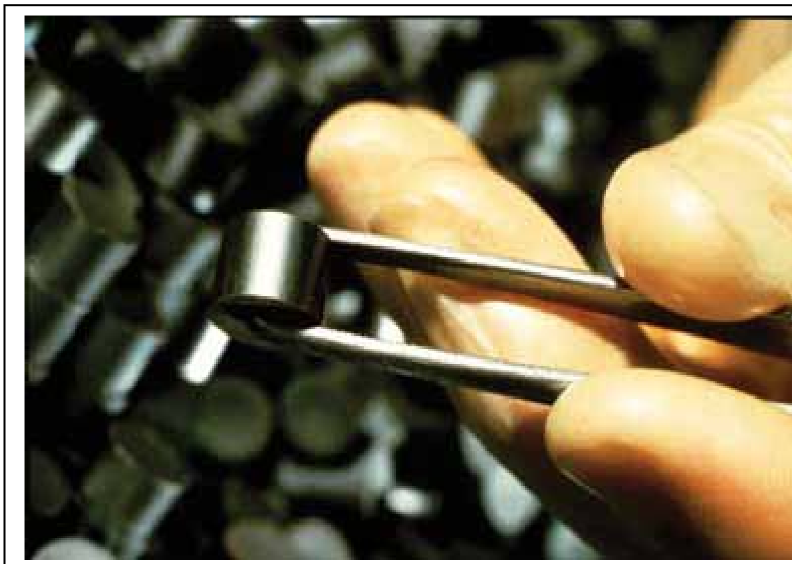
Where does Used Nuclear Fuel come from?

Used nuclear fuel is created during the nuclear fission process inside a nuclear reactor.

Nuclear fission is the nuclear chain reaction involving fissile material (in this case, uranium) which produces great amounts of energy in the form of heat and ionizing radiation. In order to understand used nuclear fuel a little better, it is important to look at the whole nuclear fuel cycle, from beginning to end.

First, uranium ore is mined from northern Saskatchewan in the Athabasca Basin. The ore, which contains the uranium, is crushed and processed in mills using chemicals in order to separate the uranium from the ore. The result is a fine, yellow or black powder called "yellowcake", which is about 80% uranium. The yellowcake is refined at a refinery in Blind River, Ontario, where it is further processed to remove impurities and prepared for conversion. The conversion facility is located in Port Hope, Ontario, and this is where the uranium is chemically transformed into uranium dioxide, a form of uranium suitable for use as fuel in Canada's nuclear reactors.

The uranium dioxide is sent to one of two facilities, either in Port Hope or Peterborough, Ontario, where it is pressed and heated to extreme temperatures to form ceramic pellets. These pellets do not dissolve in water, and are highly resistant to wear and extreme temperatures, making them very durable. The pellets are placed into long tubes made of zirconium alloy, which are in turn bundled together into an assembly called a fuel bundle. The fuel bundle is about the size and shape of a fireplace log, and weighs approximately 53lbs. Now that the fuel bundle is created, it is sent to one of the nuclear power generating stations (located in Ontario, Quebec, or New Brunswick) for use as fuel in a nuclear reactor.



Uranium dioxide is pressed and heated to extreme temperatures to produce ceramic fuel pellets, like the one shown here. These pellets are extremely durable and strong.

What happens to the nuclear fuel?

When the fuel bundles are placed in a nuclear reactor, the energy given off by the nuclear fission process produces intense heat, which is used to turn water into steam which drives giant turbines, creating electricity. The nuclear reactions that take place inside the reactor, as well as the natural radiation given off by the uranium, cause small amounts of other radioactive elements to form. Some of these are radioactive for hundreds of years, some for millions of years. When the bundles are taken out of the reactor, they "decay" into other elements by giving off radioactive energy. This radioactivity decreases over time, and reaches the level of natural uranium after approximately one million years. To learn more about radiation, see the backgrounder on *Radiation and Health*.

After about 18 months, the fuel bundles are removed from the reactor and placed in water-filled pools to reduce its heat and radioactivity. About 8 feet of water is sufficient to keep radiation levels acceptable, although in practice the pools are much deeper to provide an added degree of protection. After about 7-10 years in the cooling pool, the bundles are then placed in large containers with heavy shielding and stored at the facility where they were used. These containers are so effective at containing the radiation that any person without protective clothing can walk up and touch them without getting exposed to radiation.

These storage sites are only temporary, since the bundles remain radioactive for many thousands of years. This is why the NWMO is currently developing a plan for the safe, permanent storage of all of Canada's used nuclear fuel deep underground in a facility called a deep geological repository, which will be discussed in the next section.

II. Multi-Barrier Containment

The design of the deep geological repository that will safely contain and isolate the used nuclear fuel involves many barriers to the escape of radiation, some that are engineered and some that are natural. The deep geological repository will be constructed in a stable rock formation made of sedimentary or crystalline rock, approximately 500 metres (depending on the location) underground in a location yet to be determined. We do know the deep geological repository is to be located near an informed and willing host community somewhere in one of the four provinces involved in the nuclear fuel cycle (Saskatchewan, Ontario, Quebec, or New Brunswick). A description of the natural and engineered barriers to the spread of radiation will be provided here.

Engineered Barriers:

There are several engineered barriers that work together with natural barriers to isolate the used nuclear fuel and its radiation. The engineered barriers consist of:

- The fuel pellets themselves
- The fuel element and the fuel bundle
- The used nuclear fuel container
- Bentonite clay, backfill, and sealants.

Fuel Pellet

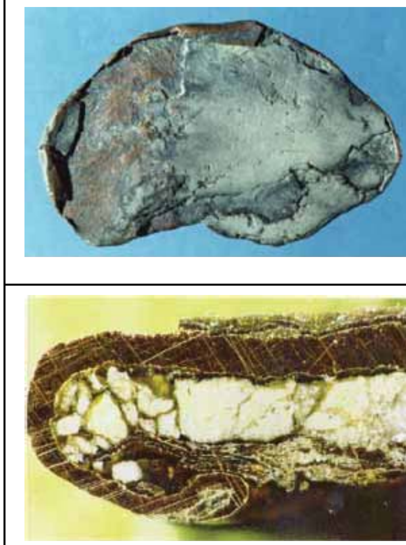
The fuel pellets, made from uranium dioxide powder, are hard and high density ceramic, making it extremely durable and hard to break. As mentioned, they do not dissolve in water and are resistant to heat and wear. This is the first barrier in the multi-barrier system, and it contains over 99.9% of the radioactivity.

Fuel Bundle

The fuel element and fuel bundle form the second line of protection. The fuel elements are the long, sealed tubes which house and isolate the fuel pellets. They are made of zirconium alloy, or Zircaloy, a metal that is strong and resistant to corrosion. Fuel bundles are made up of 28 or 37 of these elements.

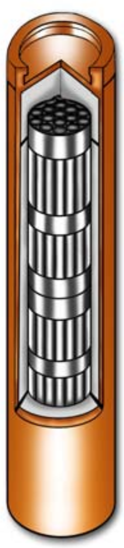
Used Nuclear Fuel Container

The used nuclear fuel container is an important barrier that will be responsible for containing and isolating the fuel bundles from the outer barriers. A design for the containers has not yet been finalized, but there is a general idea of how it will be structured. Several hundred bundles will be placed inside a support vessel made of carbon-steel, which in addition to having the ability to withstand radiation exposure, also provides mechanical strength to the used fuel container. The support vessel will sit inside a larger container made of thick copper. The used fuel containers are designed to last at least 100,000 years.



This 12-cm long piece of copper plate was found in clay-rich mudstone. It has experienced very little corrosion despite being 200-million years old.

Under deep rock conditions copper is extremely durable and resistant to various types of corrosion. Copper is one of the few metals found in its native state in the geological environment, and studies on natural copper deposits and archaeological artefacts from First Nations people and other cultures indicate excellent environmental durability. The copper plates shown in these pictures were formed about 200 million years ago and show very little corrosion.



This illustration shows what the used nuclear fuel container will probably look like. The bundles sit in a carbon steel support vessel, encased in a larger copper vessel.

Conditions within the rock at the depth of the repository will be free of oxygen. In the absence of oxygen or any other oxidants, copper doesn’t rust. It is expected any corrosion will be uniform, caused by any remaining air trapped between the rocks and the container, as well as impurities in the groundwater, clay, and/or microbial activity. It is estimated that corrosion of the container will 2mm after one million years, which would be much less than its overall thickness. Unfavourable conditions, such as corrosive chemicals in the groundwater, rapid microbial activity, and even earthquakes have been factored into storage design and site selection criteria. The container design is also intended to retain its integrity during glaciation, with a glacier up to 3-km thick above the repository. For safety purposes, it will be assumed that a few of the containers will be defective so that the possible consequences may be assessed.

Natural Barriers:

Bentonite Clay & Backfill

Once the used fuel containers are placed in boreholes in the deep geological repository, they will be surrounded by compacted pellets of bentonite clay, a natural clay that can absorb up to 10 times its weight in water. If moisture were to approach the used fuel containers, the bentonite clay would absorb it and swell up, forming an effective seal. The placement rooms where the containers will be buried will also be filled in with backfill and sealants made up of a mixture of clay, sand, and rock to impede the flow of moisture.

If a used fuel container ever did fail, the chemical properties of the bentonite clay, backfill and sealants would seriously impede the flow of radiation. Once the DGR is full, the remaining tunnels and shafts will be filled in with more backfill and sealants, isolating the repository from the outside world.

To illustrate the long-term protection that clay can provide, take the ancient forest of Dunarobba, near Umbria, Italy, as an example. The trees there have been buried for about 1.5 million years, and what is remarkable is that they have essentially been mummified in clay during that time, and the trunks remain in an upright position. The oldest of these

This picture shows the remains of trees from the ancient forest of Dunarobba, near Umbria, Italy. These trees were buried in clay for about 1.5 million years, which preserved them and protected the wood from decomposition by minimizing the flow of water.

trees are actually about 3000 years old, but a protective barrier of clay minimized water flow to the trees, preventing them from decomposing. Unlike fossilized trees, these trees are still made of wood.

Geology

The surrounding geology, one of the natural barriers in the multi-barrier containment system along with the natural bentonite clay, is often referred to as the biosphere and is the final barrier. The repository will be located in a rock formation that will likely be stable over a very long period and will not be substantially affected by natural disturbances such as seismic activity, geothermal activity (such as geisers) and glaciation. It will also be required to have no groundwater resources at the repository depth, and must contain no naturally exploitable resources that we know of today, so that the repository will unlikely be disturbed by future generations. The engineered barriers as well as the natural barriers are designed to be more than sufficient to prevent dangerous levels of radiation from reaching the surface or contaminating the environment.

There are places in the environment where natural radiation has been contained by the surrounding geology. There is a radioactive uranium deposit 450 meters underground in Cigar Lake, Saskatchewan, which is considered the largest undeveloped high grade uranium deposit in the world. This 1 billion year old deposit, covered in a protective layer of natural clay, has left no traces of radioactivity at the surface. It remains an excellent example of the biosphere's ability to contain radiation.

Construction and Operation of the DGR:

Construction and operation of the deep geological repository and its above-ground facilities will involve ongoing review and reassessments until a future society determines when the facility shall be closed, as well as the form and duration of post-closure monitoring. Throughout this process, regulatory standards would apply and regulatory approval and licenses would be required at various points. Monitoring of the project by scientists and government agencies will be extensive, beginning with the site selection and screening process.

Once the repository is filled to capacity with used nuclear fuel, it will be staffed by technicians who will monitor radiation levels and ensure the deep geological repository is safe and secure for an extended period of time. The facility will be closed and filled in with backfill and sealants, and a future society will make a decision on the manner of final closure of the facility. Until then, the used nuclear fuel containers will remain retrievable if the need ever arose to do so.

Radiation Fields for Used Nuclear Fuel Bundles:

It is difficult to understand the danger used nuclear fuel bundles pose to human health without having an idea of how radioactive they are. The following examples should provide some clarification. After only 50 years, at a distance of 0.3 m, it would only take 3 seconds for the used fuel bundles to give you a radiation dose roughly equal to one third the annual average dose from natural sources. In 200 years, that dose would be achieved in approximately 97 seconds. In one million years, it would take 110 hours. Also, after 50 years the bundle would deliver a potentially fatal dose after 4 hours of exposure at the same distance of 0.3 m.