News, Podcast & Blog. Nuclear Energy for a Cleaner, Safer, More Prosperous Tomorrow.

This Week in Nuclear

This Week in Nuclear #77:"What nuclear waste problem?"

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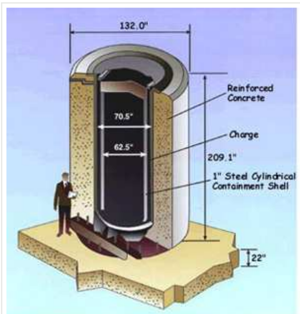
I have a family member that I love dearly and have an infinite amount of respect for. She is a fantastic mother, a caring person, respected in her chosen profession, and a good friend. She would do anything she could to help someone in need. When we first met she was strongly opposed to nuclear energy. Over the years we have discussed it from time to time and I've had some influence on her perspective. She's not totally won over yet, but we're making progress. Not too long ago she asked me, "But what about the waste? That really worries me!" She really didn't believe me when I said "There's no such thing as a nuclear waste problem. That's nothing but a myth."



Spent Fuel Storage Cask

Let me explain.

Used nuclear fuel is very safely stored in earthquake proof storage pools and dry storage casks at nuclear plants around the USA. It can stay there until we're ready to recycle it, and we WILL recycle it eventually because it would be a waste not to do so. When we remove used fuel from a reactor more than 90% of the potential energy is still in the fuel. It would be wasteful to even consider putting it in a hole a mile underground! Also, when we do recycle it, the left over material is much smaller and is much easier to handle, but we'll talk about that in a few minutes.

First we need to look at the components of used power reactor fuel, and recognize that with recycling each of the components can be separated from one another. A typical batch of used nuclear reactor fuel is made up of the following materials (not counting the structural materials):

	% Composition (approx)
Uranium	93%
Plutonium	1.5%
Minor Actinides	0.2%
Fission Products	5.3%

When the fuel is new the concentration of the isotope U-235 is about 4% and U-238 is the rest. After the fuel is burned in a reactor the uranium is mostly U-238 (very close to the isotopic mix of natural uranium) because most of the U-235 gets burned out by absorbing neutrons and fissioning. There is also a small but important amount of plutonium that is formed when uranium atoms capture neutrons but do not fission. This is called "breeding" and in fact at the end of life of a reactor fuel load more than 20% of the heat generated is from the fission of plutonium atoms formed by breeding. All of this plutonium and uranium can be mixed back together to make new nuclear fuel. This is what is commonly referred to as mixed oxide fuel, or MOX fuel. MOX fuel is currently used in commercial reactors in the United Kingdom, France, Germany, Switzerland, and Belgium.

Risk of Diverting Used Power Reactor Fuel for Weapons

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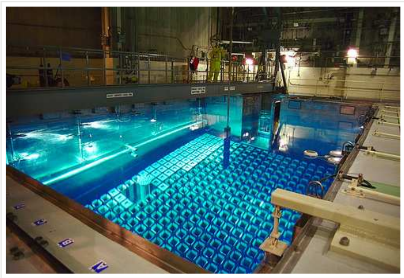

This is a good time to discuss a common misperception about reprocessing and the risk that a rogue nation would use commercial nuclear fuel reprocessing as a source for weapons grade plutonium. It turns out this really is not an issue. The plutonium from used fuel is a mixture of five isotopes, Pu-238 through Pu-242.

Let's take a look at how each plutonium isotope would affect a nuclear weapon:

Pu-238, 240, and 242 all spontaneously fission which produces neutrons and a lot of heat. If used in a bomb, the material would heat up and melt the high-explosive material used to trigger the device. The neutrons can also cause an early detonation which would lower the yield of the bomb. Pu-241 decays to an undesirable isotope americium-241. Americium-241 emits intense alpha particles and gamma rays. If used in a weapon it would cause a high radiation fields that would make handling the device very difficult. It would also make the weapon easier to detect. Only Pu-239 is good for weapons. In weapons grade plutonium, the Pu-239 makes up more than 90% of the total, but in reactor grade plutonium only about 53% of the material is Pu-239. The rest made up of the other undesirable plutonium isotopes.

So while it is *technically* possible to create a nuclear explosion using reactor grade plutonium, in the real world with real world limitations and constraints it would be virtually impossible to create a deployable nuclear weapon from reactor grade plutonium. The US NRC agrees with me in this. On the safety of MOX fuel fabricated from down-blended weapons grade plutonium after it has been used in a nuclear power plant the NRC says,

> *Using the plutonium in the reactor as MOX fuel makes using it for any other purposes difficult.*

Of all of the nations that have developed nuclear weapons, none have ever obtained their plutonium from used nuclear fuel from a power reactor. Usually it comes from special kind of test or research reactor called a "fast reactor" that makes mostly Pu-239.

This raises a logical question; if reactor grade plutonium is unsuitable for building bombs, why did the USA ban reprocessing commercial fuel in the mid-1970's? The basis for the commercial fuel reprocessing ban was political and was NOT supported by sound science or engineering. Even though President Reagan later overturned the ban, the damage was done. Now, thirty years later, companies like Areva and GE are proposing new fuel recycling facilities in the USA but those are years away from being a reality. In the mean time, this is yet another area where the USA has lost it's technological lead. Canada, Russia, France, and the UK all went on to develop reprocessing industries and now sell MOX fuel to customers around the world.

We have not completely overcome our national irrational aversion to MOX fuel. NRC rules make it very difficult for commercial reactors in the USA to take advantage of MOX fuel. It is not enough for plant operators to prove MOX fuel will perform as expected based sophisticated computer modeling and hundreds of reactor years of experience around the world. Any operator who wants to take advantage of MOX fuel must

1. Amend their operating license to allow using MOX fuel, a process that includes public comment and inevitable interference by anti-nuclear groups,
2. Operate with test fuel assemblies for "a few years"
3. Analyze the performance of the fuel, then submit a report to the NRC
4. Finally, the NRC must review and approve the final application.

Utilities are in the business to make electricity, not perform research and development. Unless the rules are streamlined to allow the thoughtful application of international experience it is unlikely many utilities will choose to use MOX fuel. The Catawba nuclear plant in South Carolina went through this process as part of a US DOE funded program. They ran a test from 2005 through 2008 with several MOX test assemblies. The MOX fuel in the test was fabricated from down-blended weapons grade plutonium, not from reprocessed reactor fuel, and was part of a government program to dispose of excess weapons grade material.

Let's Finish Recycling Our Used Nuclear Fuel

After we remove the uranium and plutonium and recycle it back to other reactors to be burned again we are left with a combination of actinides and fission products making up about 5.5% of the original mass. Within this mixture there are several highly valuable isotopes that can be extracted and sold commercially. Many like strontium, cesium, iodine, chromium and iron have medical uses such as treating various kinds of cancer and perform special tests. There are also many industrial uses for isotopes like californium, americium, and krypton. These materials can fetch hundreds or even thousands of dollars per gram!

Recycling Nuclear Fuel is a Good Idea

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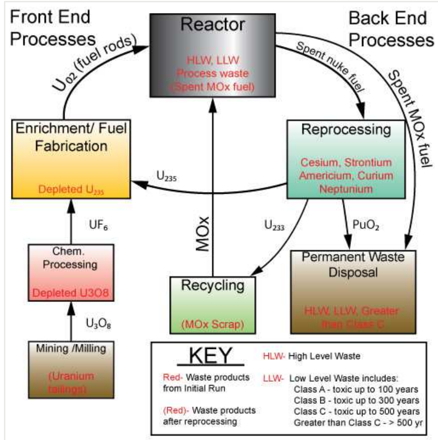
Including structural materials and other factors, with reprocessing the volume of waste requiring long term disposal is only about 25% of the original volume. This can be safely vitrified (mixed with glass) as is done in France, or encased in corrosion resistant containers, then monitored while the radiation decays to near background levels. Also, when the MOX fuel is returned to the reactor we are greatly increasing the amount of energy extracted from the original uranium. This means we need to mine less uranium ore (creating less environmental impact) and we greatly extend our fuel supply. It does cost more to reprocess fuel compared to the current once-through fuel cycle, but because the price of uranium is such a small component of the total electricity costs from nuclear plants, the financial impact is very low.



The chemical / mechanical process used to recycle reactor fuel is called the PUREX process. In this process the used fuel is first dissolved in aqueous nitric acid. Then kerosene and tributyl phosphate, an organic solvent are added. The Pu and U stay together and separate out from the minor actinides and fission products.

What is "Depleted Uranium" and Is it toxic?

Anti-nuclear activists often try to make a big deal out of how "depleted" uranium is handled. When dug out of the ground, natural uranium ore contains three isotopes, U-238 (99.27%), U-234 (0.001%), and U-235 (0.2%). To prepare the uranium for use as a reactor fuel the percentage of U-235 is raised to anywhere from about 1% to about 4% of the total. This is accomplished by removing some of the U-238 from the mixture to increase the relative amount of U-235. This process is called "enriching" the uranium. The left over U-238 that is removed during the enrichment process is called "depleted" because it is depleted of U-235.

Because the U-235 is more radioactive than the left over U-238, **depleted uranium is less radioactive than natural ore**. If we chose to, we could put the depleted uranium back into the hole in the ground where we extracted the ore, and we would be leaving the encironment less naturally radioactive than it was in its natural state. Of course, environmental regulations won't allow that. That's no worry; there's a good market for depleted uranium because of its unique physical and chemical properties. It is very dense (about twice as dense as lead) so it makes great counter weights for aircraft. Depleted uranium (DU) is a very good radiation shield, so it is used as safety shielding for medical personnel who work in nuclear medicine around x-ray machines and other imaging devices. Also, DU is very tough so it is used by the military as armor for vehicles and in armor piercing rockets.

According to the World Health Organization, the health risks of exposure to depleted uranium are extremely low.

> *Under most circumstances, use of DU will make a negligible contribution to the overall natural background levels of uranium in the environment. Probably the greatest potential for DU exposure will follow conflict where DU munitions are used.*

With this in mind, the WHO inspected sites where DU weapons were used in Kosovo and concluded there was very little risk of exposure to people who live nearby.

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