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High-Level Radioactive Waste, Seventy Years On...

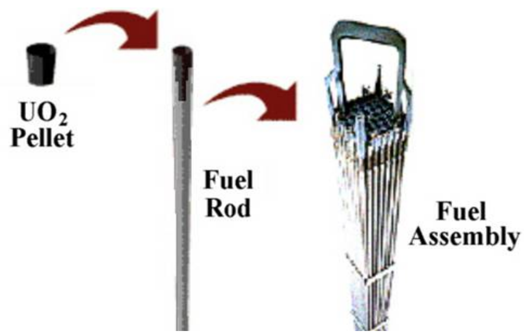
History

The first nuclear "chain reaction" was accomplished in Chicago on December 2, 1942 with a pile of uranium big enough to make a "critical mass." Sub-atomic particles called neutrons were generated that split the nucleus of uranium atoms, which is called fission. The spontaneous fission of other atoms continued that day until the researchers shut it down, thus the term "self-sustaining." The goal was heat, released when the atomic nucleus breaks. In an atomic bomb fission is not limited and quickly forms a massive fireball. Atomic power reactors are designed to control the rate of fission, capturing the same heat to boil water. Electricity is generated with the resulting steam. The loss of control is an "accident."

Arguably, that December day marks the first generation of high-level radioactive waste. Since then the fuel has been greatly refined. Reactor cores have thousands of pencil-thin fuel rods containing uranium pellets--bound together in hundreds of assemblies. The assemblies are rotated during refueling since the most intense fission is in the center of the core.

Definition

High-Level Radioactive Waste is defined in the Nuclear Waste Policy Act as nuclear fuel rods that have been removed after use in the reactor core (also called "spent nuclear fuel" or SNF) and liquids, solidified waste and residues from the reprocessing of SNF. Reprocessing is the separation of plutonium from the nuclear fuel.



Fission produces fragments: the remnants of the uranium nucleus are smaller, lighter elements. Not present in nuclear fuel to begin with, these elements are millions of times more radioactive than the original fuel and include cesium, strontium, iodine, xenon, krypton (and many more). In addition to ionizing radiation, these elements generate thermal "decay" heat. If released to our environment, whether by nuclear explosions, routine releases from nuclear reactors, or major reactor accidents, ionizing radiation from fission products harm living organisms, including us.

Uranium and Plutonium

Uranium (U) has been mined on every continent. Pit and underground mines and in situ leaching have all been used to extract uranium, causing dangerous radiation exposure to miners, their families and surrounding communities.[i] U ore is primarily **U-238**, while a rarer form (typically 0.1% of ore) is **U-235** which will fission. **Plutonium** (Pu) is a byproduct of fission of uranium (U). It is not found on our planet naturally except in very small traces in some uranium deposits--

indication of natural fission in the past. When a neutron hits a U-238 atom (96% of typical fuel rods) sometimes the uranium will absorb the neutron in its nucleus, resulting in transmutation of the U-238 into Pu-239. Irradiated nuclear fuel is about 1% plutonium.[ii] Pu-239 is the fuel in much of the world's nuclear weapons stockpile. *Every electric power reactor makes highly radioactive waste that also contains fuel for a bomb factory.*

How Long?

2012 marked 70 years of human-made fission. The waste from fission will last much, much longer than the electricity that it made!

A **half-life** is the time it takes for 1/2 of any radioactive material to decay to another form.

U-238:	4.5 billion years.
U-235:	703,800,000 years
Pu-239:	24,110 years
Cesium-137:	30.7 years
Strontium-90:	28.79 years

The **period of hazard** is defined as 10-20 times the half-life in order to lower the total activity significantly.

How Much Waste?[iii]

As of 2011, operation of atomic reactors in the USA had resulted in 174,000 irradiated fuel assemblies, weighing in at 67,000 metric tons of uranium (MTU). Today's nuclear reactors add about 2000 MTU to the pile each year.

The waste is currently located at 77 sites, which includes commercial nuclear reactors and four sites owned by the Department of Energy. Eighty percent is located east of the Mississippi River, and with only a few exceptions, on the site where it was generated, including those where reactors have now closed.

How Hot? Temperature

Uranium fuel rods in the reactor core are very hot in temperature, as well as being highly radioactive. During fission inside a fuel pellet it is well over 1000° F. The rod surface temperatures are controlled by moving coolant taking the heat away to generate steam; if the coolant pumps stop, as at Three Mile Island and Fukushima, the temperatures inside the pellets rise quickly (less than an hour) to the melting point which is over 3300°F.[iv] Stopping fission reduces the temperature, but the heat of radioactive decay of the fission products cannot be shut off. Fuel rods removed from the core, now waste, must be stored in pools with moving coolant for the first five years at the site of generation.

How Radioactively "Hot?" From:
http://www.state.nv.us/nucwaste/trans/radexp.htm
Referring to unshielded irradiated fuel: "...5-year old SNF has a very high surface dose rate, as high as 25,000 to 50,000 rem/hour at one meter in air. Even 10-year old SNF has a dose rate of 10,000 to 20,000 rem/hour."

Generally 500 rems to an individual is fatal. While touching irradiated fuel is very unlikely. it is important to note that being anywhere close to this material when it is not shielded is dangerous, and if in the range of feet, quickly lethal.

Storage

While hot rods must be stored in liquid initially, most fuel pools at U.S. reactors are overfilled and packed tight with far more waste than they were designed to hold. Pools typically are outside reactor containment structures and also are not consistently supplied with emergency back-up power to ensure the coolant will move at all times. An accidental drain-down or boil-off could result in fuel rods melting or burning and massive radiological releases.[v] Unfortunately the federal Nuclear Regulatory Commission (NRC) allows this situation to continue.

In 2012 a federal court mandated the NRC to conduct a study of the environmental impacts of storing radioactive waste on reactor sites. An environmental impact statement may be completed by late 2014. In the interim, for the first time ever the NRC's authority to license any further waste production has been put on hold.

Waste that has been cooled in fuel pools for 5 years may be transferred to **dry "casks,"** containers made of concrete and steel. The casks are placed on an outdoor concrete pad on the reactor site, rather like bowling pins. "Hardening" these casks would help protect them from extreme weather or attack.[vi] Estimates put the cost of addressing the pool problem at $5-$7 billion nationwide.[vii] Unfortunately the waste generators view dry storage as an unnecessary expense since the NRC allows overly full pools.

Approximately 73% of commercial atomic power waste is in pool storage, and the remaining 27% is stored in dry casks. 27 reactor sites had no dry casks in use in 2012.[viii]

Off-Reactor-Site Storage

Some nuclear advocates want to put the casks on trucks, trains or barges and ship them to consolidated or centralized "interim" storage sites. Dubbed a "parking-lot dump" by activists in the 1990's, a consolidated storage site would be technically identical to dry storage on the reactor site, save for the transportation[ix] between the two sites, and ostensibly a third, permanent site in the future.

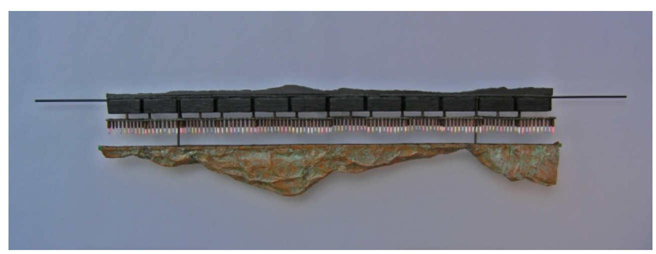
Another key difference is the concentration of waste, which poses both a security concern and also a social challenge. A single Congressional District versus the seventy-seven where the waste is located today presents a serious barrier for future appropriations and other federal attention, raising concerns that any off-reactor-site could become de facto a permanent site.

Off-site storage proposals have been defeated by local prospective "host" communities in Tennessee, Utah, New Mexico, 27 Native American Reservations, and the proposed Yucca Mountain site in Nevada.

Disposal?

Nuclear reactors have operated in this country for more than 50 years, and yet there is no "final destination" for permanent isolation of reactor waste from our environment--a little like building a skyscraper without bathrooms!

The long-standing concept for permanent disposition is to dig a mined geologic repository and transport the waste to the site in casks. If these are "compatible" with the site the same containers would be placed in the tunnels underground. Otherwise the waste would be "recontainerized" prior to burial. Here is a representation of the concept by artist Gerry Moll:



The concept is then to close the repository. This sort of project has not been accomplished anywhere in the world. There is discussion in Finland, the one site under advanced construction, about whether such a site should be well marked with warnings (as has been assumed in the U.S.) or carefully concealed from future generations.

Such a site retains the potential for continued problems--inadvertent intrusion, intentional mining for plutonium, possible seismic, vulcan and other natural disturbance, leakage to either ground water or gaseous release.

The Department of Energy has made one attempt at a geologic repository: Yucca Mountain. Yucca is a compacted Tuff formation near the Nevada Test Site in Nevada; a site considered sacred, and part of their traditional and treaty lands by the Western Shoshone Nation.

Yucca Mountain would very likely have failed to meet the goal: isolation of the waste for 10-20 half-lives. The conjunction of salt in the base rock, seismic activity that cracked that rock allowing both water and air flow, heat from the waste, moisture from the sponge-like retention of torrential dessert rains by the rock, steel containers and a very, very long time period conspire to project a high probability of waste container failure. Indeed, the Department of energy evaluated the rock of Yucca Mountain as an overall negative factor in the isolation of radioactivity from our environment.

The people of both Nevada and the Western Shoshone Nation rejected this plan. In 1998 more than 200 US NGOs petitioned the Department of Energy to disqualify the Yucca site from further consideration; it took another seven years for federal action by President Obama to stop that site; it should not be "revived" now.

At the same time reactor sites are not suited for permanent isolation: so many are on coasts, shores, islands and other unstable ground. A scientific basis for permanent isolation is needed. It is not clear that mined geologic repositories are the "best bet." Some independent experts say that isolation is viable, but there has not been sufficient research on exactly how.

Reprocessing

Reprocessing is the recovery of plutonium from SNF. Highly radioactive fuel rods are chopped up, dissolved in acid; the plutonium is then isolated using chemical separations. Plutonium is about 1% of the fuel rod; and it is only this part that can be "re-used." None of the original radioactivity is reduced, it is simply spread out over a larger volume. Liquid caustic wastes and vast amounts of so-called "low-level" radioactive waste are hard to contain. Ninety-three percent of the rod is uranium but it is not pure since the highly radioactive fission products and plutonium are mixed in.

Some claim this uranium is still useable; in practice none of it reused and has to be stored as highly radioactive waste. When re-use of such uranium was tried in the U.S. during the Cold War the Paducah enrichment factory became contaminated by fission products and plutonium, causing a huge, expensive mess and much higher worker exposures since no disclosure was made to them. Likely the by-products from that facility (Depleted Uranium, DU) were also contaminated.

Recovered plutonium may fuel reactors, or nuclear weapons. Plutonium as a fuel in reactors is much harder to control than uranium, and if control is lost will inflict twice as many long-term cancer deaths on any exposed population compared to the results if the same accident were to happen with uranium fuel.[x]

The good news is that 21st Century electric power generation from wind, sun, waves, and geothermal does not use fuel, and so does not make waste. The only real solution is to stop making this waste. *March 2013-- Mary Olson, maryo(at)nirs.org*

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[i] Info on uranium: http://www.wise-uranium.org/
[ii] See: http://ieer.org/resource/testimony/spent-fuel-and-reprocessing-myths-and-realities/
[iii] USA Spent Fuel Storage, James Werner: http://www.fas.org/sgp/crs/misc/R42513.pdf
[iv] melting temp http://energy.gov/sites/prod/files/M3LW-12IN0502028_Tradeoff_study_report.pdf
[v] 2003 MacFarlane, Thompson, Alvarez, et al http://www.princeton.edu/sgs/publications/sgs/pdf/11_1Alvarez.pdf
[vi] http://www.nirs.org/radwaste/policy/hossprinciples3232010.pdf
[vii] See Alvarez http://www.issues.org/28.2/alvarez.html
[viii] see iii
[ix] Updated NIRS transport info: http://www.nirs.org/radwaste/hlwtransport/mobilechernobyl.htm
[x] Edwin S. Lyman, "Public Health Risks of Substituting Mixed-Oxide for Uranium Fuel in Pressurized-Water Reactors," Science & Global Security, Volume 9, 2001, pp. 33-79.