NUCLEAR WASTE: WHAT IS IT? WHERE IS IT?

The large powerplants that supply our energy needs today create wastes as byproducts of using primary and secondary energy sources. These wastes can range from the solid ash produced in coal-burning plants to exhaust gases that contribute to air pollution and acid rain. Waste that results from using radioactive materials is nuclear waste. The U.S. Government has programs underway to provide for the safe permanent disposal of all types of nuclear waste.

1.11 Sources and Types of Nuclear Waste

Where does nuclear waste come from?

Nuclear waste comes from five major sources:

1. all steps involved in using nuclear energy to produce electricity;*
2. defense activities;
3. hospitals, universities, and research labs;
4. industry; and
5. mining and milling of uranium ore.

What are the four main categories of nuclear waste?

There are four basic types of nuclear waste: high-level waste, low-level waste, transuranic waste, and mill tailings. Classification of waste depends on its source, its level of radioactivity, and its potential hazard (or how likely it is to cause harm).

High-Level Waste

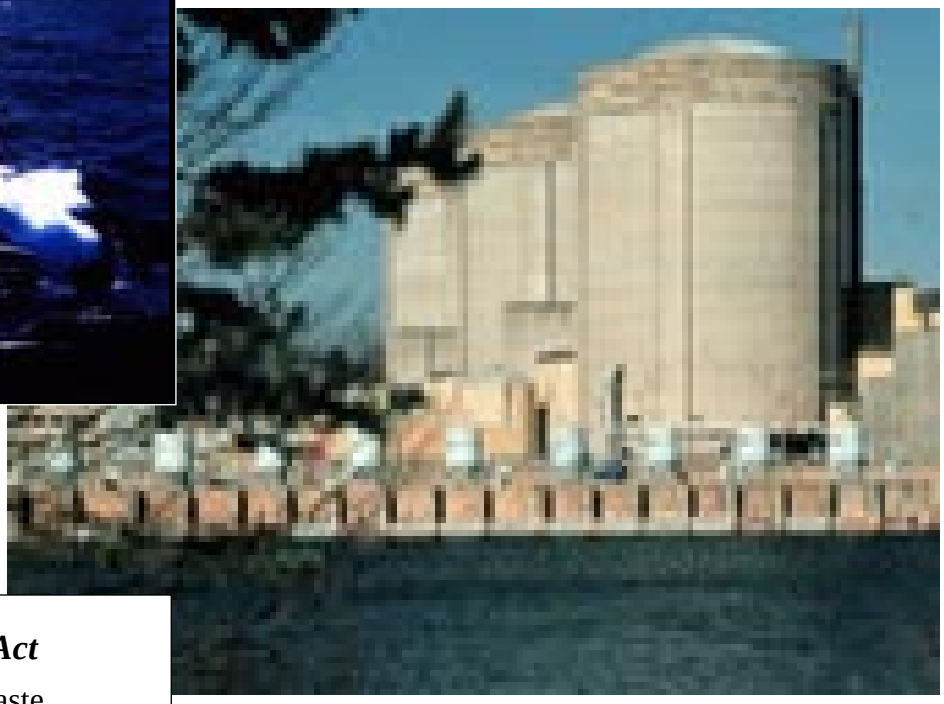
Radioactive — Giving off energy in the form of particles and rays by changes in the nucleus of an atom. *Radioactive materials emit energy when they undergo decay.*

What is high-level waste?

High-level nuclear waste is the most radioactive category of nuclear waste. It includes *spent fuel* (used fuel) from nuclear powerplants and some wastes from our Nation's defense activities. Both spent fuel and high-level defense waste are now in storage awaiting disposal. Some radioactive elements in high-level waste lose radioactivity (decay) rather quickly. Others remain radioactive for thousands of years.

**the nuclear fuel cycle*

High-level waste is handled using remote control equipment. Operators of the equipment work behind heavy protective shielding. This type of waste is transported in heavily shielded containers.



Defense activities and nuclear powerplant operations produce nuclear waste.

Nuclear Waste Policy Act

Congress passed the Nuclear Waste Policy Act of 1982 and the Nuclear Waste Policy Amendments Act of 1987 to provide for safe disposal of high-level nuclear waste. These laws require the U. S. Department of Energy (DOE) to dispose of this kind of nuclear waste in a deep underground facility called a geologic *repository.* In the 1987 law, Congress directed DOE to perform an intense study (called *site characterization*) of Yucca Mountain, Nevada. The purpose of site characterization is to determine whether Yucca Mountain is suitable for a repository.

Low-Level Waste

What is low-level waste?

Low-level nuclear waste usually contains only a small amount of radioactivity within a relatively large amount of material. It is far less hazardous or dangerous than high-level waste. Most low-level waste does not require extensive protection. However, for certain low-level waste, some shielding may be necessary.

Where does low-level waste come from?

Hospitals, nuclear powerplants, research labs, and many industries produce low-level waste. Also, some of the waste produced by defense activities is low-level waste. Low-level waste from research and medical activities may include commonly used equipment such as empty containers, rags, papers, filters, broken tools, and used protective clothing. These are examples of the kinds of things that become low-level waste from energy production activities.

Low-level radioactive waste from a nuclear powerplant includes such things as filters, clean-up rags, lab supplies, and discarded protective clothing.

How is low-level waste disposed of now? Where?

Low-level wastes are placed in containers and then buried at special landfills licensed by the Federal Government. Two sites were in use by 19 States on September 30, 1994: Barnwell, South Carolina, and Hanford, Washington. Federal law allows these sites to limit access for disposal to regional wastes. Other States are to develop disposal capabilities, but some have not met a January 1, 1993, deadline. Barnwell is scheduled for closure on December 31, 1995.

Who will be responsible for disposal of low-level waste in the future?

Low-Level Radioactive Waste Policy

The amended Low-Level Radioactive Waste Policy Act of 1980 set the policy for disposal of low-level nuclear waste. By law, each State is responsible for providing for the safe disposal of the low-level waste produced within the State. (The Federal Government will be responsible for any low-level waste resulting from Federal activities.) The State may form a *compact* with other States to provide a regional facility for every member State to use. Congress must approve these compacts. Once approved, a compact can refuse to accept low-level waste from non-members. If it prefers, a State may operate its own disposal facility with the right to exclude waste from other States.

Transuranic Waste

What is transuranic waste?

Like low-level waste, transuranic waste is mostly discarded clothing, rags, equipment, containers, tools, etc. Like low-level waste, it emits less penetrating radiation than high-level waste. In fact, some transuranic waste has no more radioactivity than certain low-level waste. However, unlike low-level waste, transuranic waste contains elements with very long half-lives. Therefore, these elements decay (lose radioactivity) slowly and remain radioactive for thousands of years.

Where will transuranic waste be disposed of?

This cutaway view of barrels of transuranic waste shows how clothing, equipment, and solidified sludge are packaged in a dry, solid form.

Most transuranic waste results from reprocessing nuclear fuel and making plutonium weapons as part of the Nation's defense activities. Some of this kind of waste is now being stored in facilities located above ground, but plans call for it to be disposed of in a repository deep under ground. The U.S. Government plans to test geologic disposal of transuranic waste at the Waste Isolation Pilot Plant (WIPP) facility in New Mexico. The type of rock at the WIPP facility is bedded salt.

Mill Tailings

What are mill tailings? Are they hazardous?

The fuel used at a nuclear powerplant comes from uranium ore, which is found in the ground. Ore containing uranium is mined and then milled (crushed and treated to separate and remove the uranium). The leftover rocks and soil are mill tailings. The tailings contain a small amount of radium that decays to radon, a radioactive gas. Radon can be harmful to our health if we are exposed to it in concentrated amounts. For this reason, the mill tailings are covered over with enough soil to protect the public and the environment.

1.12 Spent Fuel

The fuel for nuclear powerplants is uranium oxide formed into ceramic pellets. Each pellet is about 3/8-inch in diameter and 1/2-inch long—about the size of the tip of your little finger. The pellets are stacked and sealed in fuel rods—hollow metal tubes about twice the thickness of a pencil and about 12 feet long. Groups of fuel rods are spaced and bolted together to form a fuel assembly. A fuel assembly contains about 200 fuel rods. Finally, fuel assemblies are loaded into the reactor. The number of fuel assemblies varies and depends on the design of the reactor.

Reactor — The part of a nuclear powerplant where fission takes place. *Fission takes place in a reactor, which is basically a machine that heats water.*

What is spent fuel?

Over time, as the reactor operates, the fuel becomes less efficient. After about three years in the reactor, the fuel assemblies are no longer doing their job. At this point they are called spent fuel. Spent fuel must be removed and disposed of in a safe way.

1.13 Fission

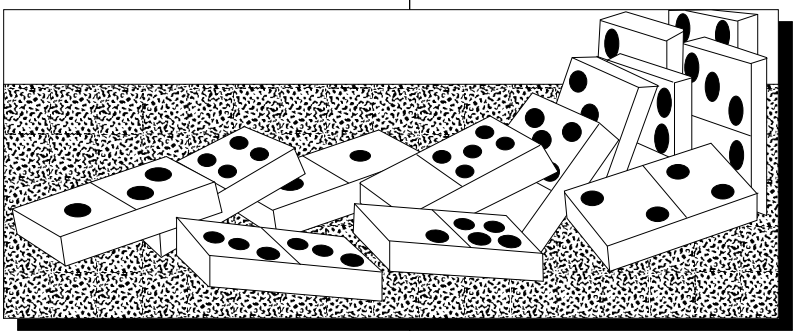
What is fission?

Coal, oil, and natural gas burn. Nuclear fuel does not burn. So how does nuclear fuel get "used up"? How does it produce the energy in a nuclear powerplant? The answer is by a chain reaction. Uranium atoms in nuclear fuel produce the energy needed for a nuclear powerplant by splitting (or "fissioning") into smaller atoms. In the process, they release a great deal of heat. In fact, one ton of nuclear fuel will provide about 100,000 times as much electrical power as that provided by burning one ton of coal.

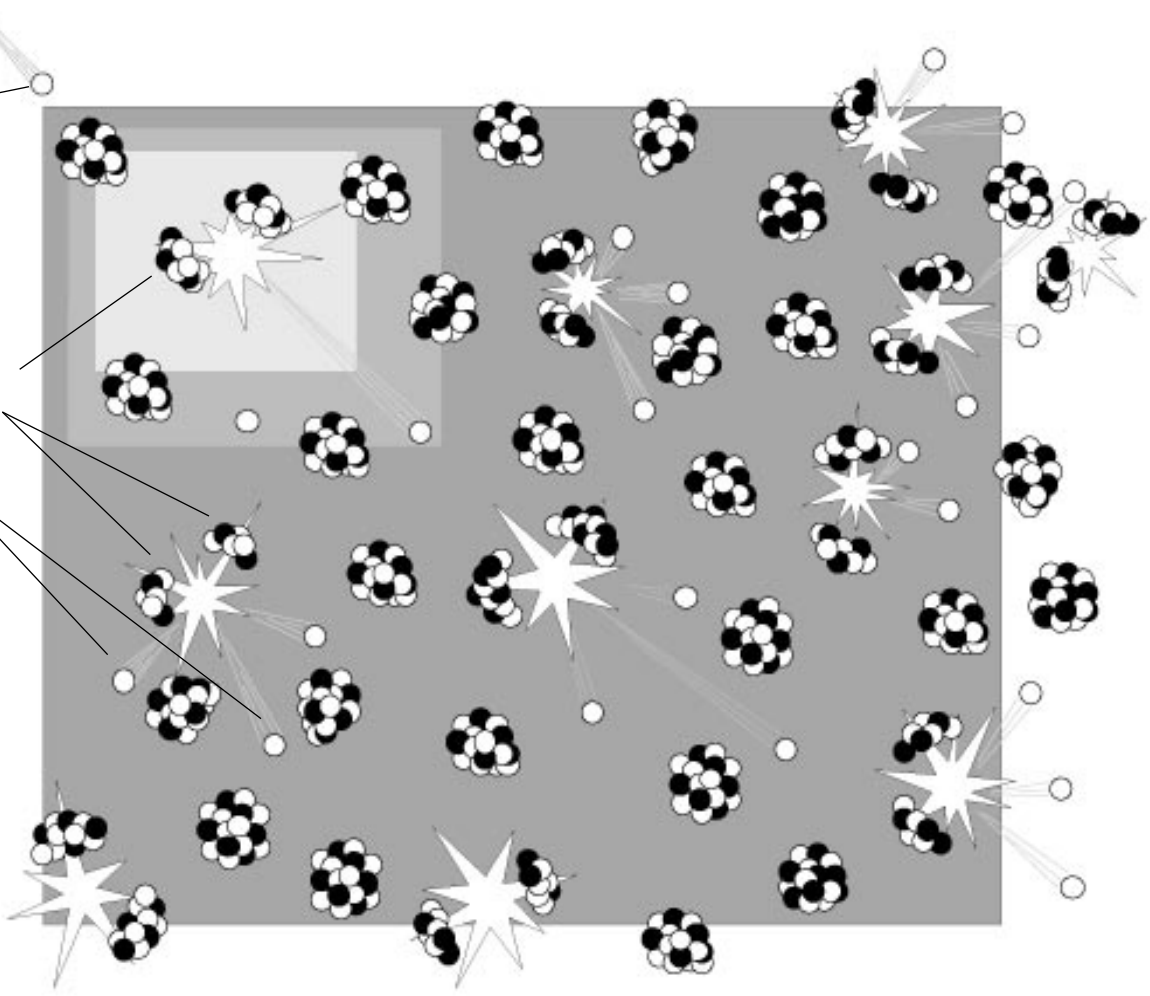
A Chain Reaction

If you knock over the first domino in a line of standing dominos, the second one will fall as the first one hits it. Then the next one will fall as the second one hits it...and so on down the line.

Fission is the process in which a uranium atom absorbs a *neutron* and then splits into two smaller atoms, releasing a relatively large amount of energy and one or two neutrons. These neutrons in turn can cause other uranium atoms to fission, releasing more energy and still more neutrons. Eventually, a nuclear reaction is achieved in which only one neutron from each uranium atom



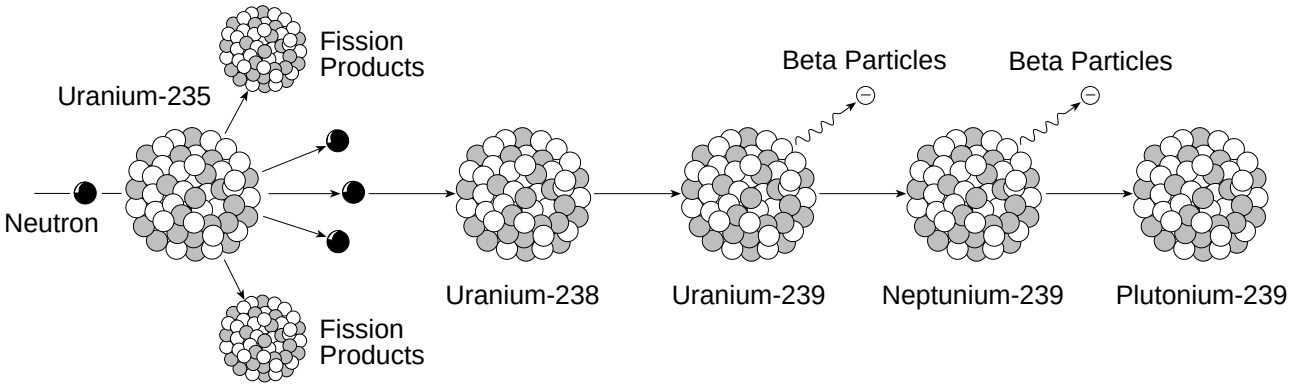
that fissions causes another uranium atom to fission. Such a nuclear reaction is a "nuclear chain reaction." The nuclear chain reaction produces the energy that is converted to electricity at a nuclear powerplant.



What are fission products?

The smaller atoms produced by the fissioning uranium atoms are called "fission products." Fission products are very radioactive. They make up the part of high-level waste that loses radioactivity relatively fast.

The Formation of Plutonium



1

A uranium-235 atom absorbs a neutron and splits into two lighter atoms called fission products, releasing heat energy and two or more neutrons.

2

If a uranium-238 atom absorbs a neutron, fission rarely occurs.

3

Instead, it forms uranium-239. Through the process of radioactive decay...

4

It transforms first to neptunium-239, and then through an additional decay to...

5

plutonium-239. The transformation takes about 2 days.

There are two types of uranium atoms in nuclear fuel. When a uranium-235 atom absorbs a neutron, it fissions. Uranium-238 does not. When a uranium-238 atom absorbs a neutron, it is converted into a radioactive element called a *transuranic* element (a transuranic element has a higher atomic number than Uranium on the periodic table of elements). As uranium-238 atoms absorb neutrons, more and more of these transuranic elements form. The transuranic elements make up the portion of high-level waste that loses radioactivity very slowly. They cause spent fuel and high-level waste to remain radioactive for thousands of years.

What are transuranics?

Where does all this activity take place? It takes place inside the fuel rods. Fission products and transuranic elements accumulate within the fuel rods. Gradually, the uranium-235 in the nuclear fuel is almost used up and the nuclear chain reaction becomes less efficient. That's when the fuel assemblies (now spent fuel) must be removed and replaced with fresh fuel.

Why does the fission reaction become less efficient?

1.14 Spent Fuel Storage

More that 20 percent of the Nation's electricity is produced by more than 100 nuclear powerplants located around the country. As of 1993, nearly 28,000 metric tons (27,552 tons) of spent fuel were in storage.

Where is spent fuel stored?

Spent fuel is stored in specially treated water in a deep, steel-lined, concrete pool inside a building at the powerplant. Here it begins to cool and becomes less radioactive as it decays.

Commercial Spent Fuel Storage – 1993* and 2003

State	1993	2003
	(Metric Tons of Uranium)	
Alabama	1,334	2,130
Arizona	430	1,125
Arkansas	554	884
California	1,263	2,181
Colorado	15	15
Connecticut	1,169	1,752
Florida	1,320	2,048
Georgia	915	1,713
Idaho	51	51
Illinois	4,154	6,701
Iowa	231	360
Kansas	194	420
Louisiana	318	790
Maine	426	580
Maryland	578	882
Massachusetts	431	489
Michigan	1,149	1,951
Minnesota	610	930
Mississippi	299	590
Missouri	242	470
Nebraska	350	610
New Hampshire	63	295
New Jersey	1,080	1,855
New York	1,792	2,588
North Carolina	1,460	2,311
Ohio	395	810
Oregon	358	859
Pennsylvania	2,284	4,250
South Carolina	1,684	2,923
Tennessee	409	1,066
Texas	360	1,155
Vermont	365	502
Virginia	1,088	1,804
Washington	191	363
Wisconsin	779	1,128
Total	**28,312**	**48,045**

**Most recent data available at time of printing.*
Source: Nuclear Fuel Data: Form RW 859 (1993). *U.S. Department of Energy, Washington, DC. (Sum of entries may not equal totals due to rounding process.)*

Some utilities are now using dry storage to increase their storage space. (Dry storage is discussed further in Unit 4.)

How does spent fuel change during storage?

During the first three months of storage, spent fuel loses about 50 percent of its radioactivity. In one year, it loses about 80 percent. In 10 years, radioactivity is reduced by 90 percent. But the remaining 10 percent ***could be*** a danger to health and the environment for thousands of years. (Some countries reprocess their spent fuel. The U.S. reprocessed a small amount of commercial spent fuel in the early 1970's, but currently does not do so.)

1.15 Storage of Defense High-Level Waste

How much defense waste is there?

As part of our country's national defense program, nuclear materials are used for nuclear weapons. About 9,000 metric tons (8,856 tons) of defense high-level waste are stored temporarily at three U.S. Department of Energy sites: Savannah River Plant in Aiken, South Carolina; Idaho National Engineering Laboratory in Idaho Falls, Idaho; and U.S. Hanford Reservation in Richland, Washington.

Where will high-level waste from defense activities be disposed of?

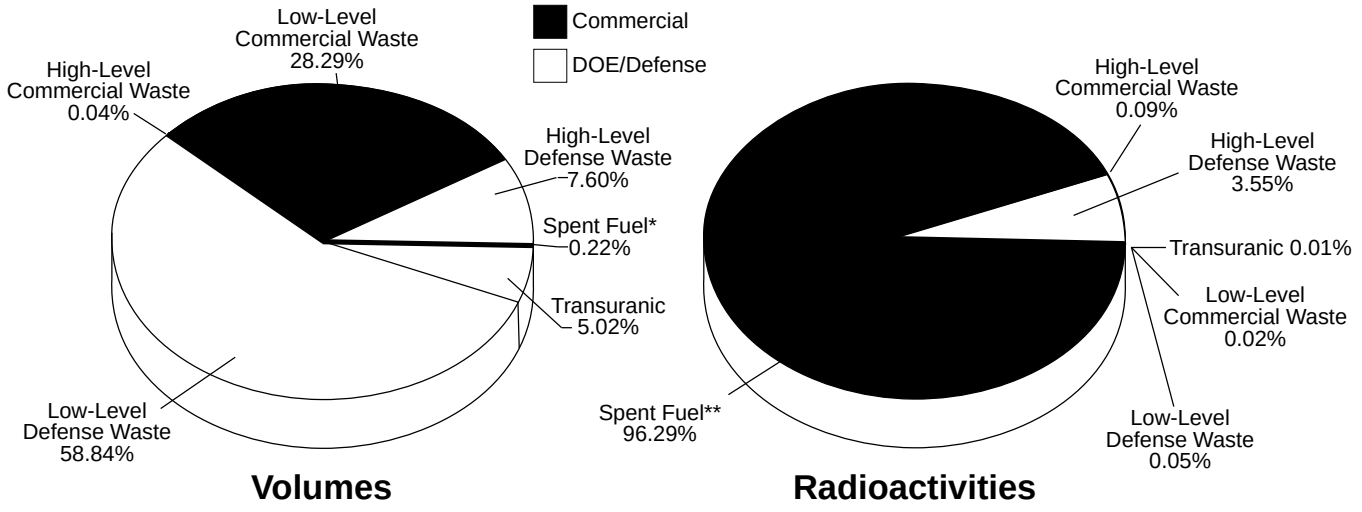
The Nuclear Waste Policy Act required the President to decide whether to dispose of defense high-level waste in the same repository as spent fuel. In 1985, President Reagan accepted the recommendation of the Secretary of Energy to dispose of defense high-level waste in the repository planned for spent fuel from nuclear powerplants.

1.16 Volumes and Radioactivities

Why is it important to consider both the volume of waste and the level of radioactivity?

The *volume* of waste does not tell you its level of radioactivity. Both the volume (space occupied) of waste and how much radioactivity it contains are important. A large volume of waste with little radioactivity presents less hazard than a smaller amount of waste with more radioactivity. For example, spent fuel is far less than 1 percent of the volume of radioactive waste, but it contains almost 95 percent of the total radioactivity. On the other hand, low-level waste is nearly 86 percent of all radioactive waste by volume, but contains less than one-tenth of one percent of the total waste radioactivity.

Radioactive Wastes: Volumes and Radioactivities (1993)



**Includes spacing between fuel assembly rods. DOE/Defense Program spent fuel to be reprocessed is not shown.*

***DOE/Defense Program spent fuel to be reprocessed is not shown.*

Source: Calculated from data presented in Table 0.3 of *U.S. Department of Energy*, Integrated Data Base Report - 1993: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics *(DOE/RW-0006, Rev. 10), December 1994*.

1.17 High-Level Waste Focus

As you now know, there are four different types of nuclear waste. Each type is stored and will be disposed of in a way that protects people and the environment. From this point on, our main focus will be on spent fuel and defense high-level waste that will be disposed of in a geologic repository.

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