United States Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

OCRWM Backgrounder

DOE/RW-0140

April 1987

CHARACTERISTICS AND INVENTORIES OF NUCLEAR WASTE

The purpose of this paper is to describe the characteristics and inventories of the various forms of nuclear waste that are generated during the production of electricity in nuclear powerplants or during the production of nuclear materials for national defense.

Radioactive waste is broadly classified as spent nuclear fuel, high-level radioactive waste, transuranic (TRU) waste, low-level waste, and uranium mill tailings.

Nuclear fuel that has been removed from a nuclear reactor core because it can no longer sustain an efficient chain reaction is referred to as "spent nuclear fuel." At this point, the spent nuclear fuel is highly radioactive and thermally hot. Spent fuel is stored temporarily in water pools adjacent to the power reactors. The water removes heat generated by the spent fuel and keeps the fuel cool. It also serves as an effective shield to protect workers at the reactor site from radiation.

High-level radioactive waste is generated from the reprocessing of spent nuclear fuel. Reprocessing is a chemical separation process that can extract plutonium, which is formed during the fission process, and the remaining usable uranium from the spent fuel. Although in some other countries reprocessing is a means of extracting usable fissile material for subsequent use in new fuel elements, in the United States reprocessing is only utilized in the production of nuclear materials for national defense.

Transuranic waste is material contaminated with certain alpha-emitting radionuclides in concentrations greater than 100 nanocuries per gram. Transuranic waste is generated primarily from defense reprocessing and fabrication operations. Almost all of the existing inventory of TRU waste was generated under the Nation's atomic energy defense programs. TRU waste is further classified as either "contact handled" waste in which little or no shielding is required, or as "remote handled" waste in which shielding and remote handling are required.

Low-level waste is defined by the U.S. Department of Energy (DOE) Order 5820.2 as all wastes which are not classified as spent nuclear fuel, high-level radioactive waste, TRU waste, or byproduct material. Low-level wastes, which are produced by many commercial, industrial, and medical processes, may require special handling although extensive shielding is not usually required. The U.S. Nuclear Regulatory Commission (NRC), which regulates the commercial low-level waste, has developed a classification system that groups part of the low-level waste into three separate categories, depending on the level of radioactive contamination. These categories are designated as Class A, B, or C.

The Low-Level Radioactive Waste Policy Amendment Act of 1985 has directed DOE to provide for the disposal of greater than Class C low-level waste and has directed that a report of recommendations for implementation be developed by DOE and presented to the Congress within one year of the passage of the Act. This report, which was submitted to Congress in February 1987, concludes that "Until the time that greater than Class C low-level wastes can be disposed, DOE plans to accept such wastes as necessary, after adoption of appropriate waste acceptance criteria, and to safely manage such wastes until disposal options are developed."

Uranium mill tailings are radioactive rock and soil that are the byproducts of uranium ore mining and milling. Tailings are produced in very large volumes and contain low concentrations of naturally occurring radioactive materials.

The following table depicts current and projected quantities of nuclear waste.

Published by the Office of Policy and Outreach
To provide current background information on program facts, issues, and initiatives. For further information write to: Information Services Division, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Mail Stop RW-40, Washington, DC 20585, Telephone (202) 586-5722.

Table 1. Quantities of Nuclear Waste[1] (in Thousands of Cubic Meters)

Type	Year			
Defense Waste	1985[2]	2000	2010	2020
High-Level[3]	355	346	370	379
Transuranic[4]	286	376	437	497
Low-Level	2,181	4,043	5,159	6,256
Commercial Waste[5]				
Spent Nuclear Fuel[6]	5	16	25	39
Low-Level[7]	1,160	2,441	3,545	4,972
Mill Tailings	100,000	146,500	197,300	265,900
High-Level[8]	2	8	8	8

The Nuclear Waste Policy Act of 1982 (NWPA) authorizes activities leading to the safe, permanent disposal of commercial spent nuclear fuel and of commercial and defense high-level waste. These forms of waste[9] contain relatively high concentrations of elements that remain radioactive for thousands of years and are potentially harmful and, hence, require isolation from the public and the environment for very long periods of time. Therefore, spent nuclear fuel and high-level waste will be disposed of in deep, geologic repositories that will be licensed by the NRC.

Defense-generated TRU waste will be sent to the Waste Isolation Pilot Plant (WIPP) in New Mexico for the demonstration of safe disposal. Low-level waste may continue to be disposed of by shallow land burial, although alternative methods, including engineered facilities and waste treatment, will be considered. Uranium mill tailings will be treated, stabilized, and stored near the uranium mines.

This paper focuses on the two forms of nuclear waste that will be disposed of in the civilian repositories authorized by the NWPA.

[1] DOE, *Spent Fuel and Radioactive Waste Inventories, Projections and Characteristics* (DOE/RW-0006, Rev. 2), September 1986.
[2] Actual. Subsequent data are projections.
[3] Includes future immobilized and other forms of waste.
[4] Includes previously disposed suspect transuranic waste and stored waste.
[5] Assumes no reprocessing of spent nuclear fuel.
[6] Volumetric data for intact assemblies calculated from data contained in referenced document. Cubic meters are used for convenience and consistency. However, spent nuclear fuel quantities are usually expressed in terms of metric tons of uranium (MTU). See Table 2. In 1984, the inventory of spent nuclear fuel reached about 13,000 MTU.
[7] Includes waste from the decommissioning and decontamination of nuclear reactors, which may have higher than Class C concentrations of radioactivity. Exclusive of reprocessing.
[8] Less than 200 cubic meters of solidified high-level waste will be produced from reprocessing waste stored at a facility near West Valley, New York.
[9] For brevity and convenience, the term "waste" may be used in this paper to mean both spent fuel and high-level waste from reprocessing.

Spent Nuclear Fuel

Nuclear fuel is the heart of the reactor. For a commercial, light-water nuclear powerplant, the fuel consists of pellets of ceramic uranium dioxide that are sealed in hundreds of metal rods bundled together within a rigid metal structure called a "fuel assembly." The fuel rods are carefully spaced in the fuel assembly to allow coolant to flow between them as they irradiate during the fission process. Each assembly is about 14 feet long and weighs about 1,200 pounds. It is designed to be readily handled with suitable hoists and cranes at the reactor site. After about 3 years of use, the fuel assembly is removed, or discharged, from the reactor.

DOE uses forecasts of commercial spent fuel discharges published annually by the U.S. Energy Information Administration (EIA) as one of the principal planning variables in the formulation of waste management program and funding requirements. These projections are generated from predictive macroeconomic computer models and other data sources, including industry surveys. These data sources are used by EIA to assess the status of commercial nuclear powerplants as they move from the planning phase to operational status.

In developing its waste acceptance schedules for program planning purposes, DOE uses EIA's "Upper Reference Case"[10] forecasts of commercial spent fuel discharges that assume "increasing burnup" of fuel assemblies. Under this assumption, the irradiation levels[11] of fuel assemblies removed from reactor cores increase gradually, exceeding the 1979-1983 historical average levels by 30 percent in 1998 and then stay constant thereafter. The following table depicts cumulative projections of inventories of commercial spent fuel discharges from 1986 through 2020.

Table 2. Projections of Cumulative Commercial Spent Fuel Discharges - EIA Upper Reference Case[12]

Year	Extended Burnup	
	Metric Tons	Cubic Meters
1986[13]	13,800	5,900
1990	21,200	8,500
1995	31,500	12,500
2000	41,600	16,200
2005	52,400	20,200
2010	66,600	24,800
2015	85,600	31,300
2020	106,000	38,200

[10] The "Upper Reference Case" is one of four projection series devised by EIA. The others are the "No New Orders Case," "Lower Reference Case," and "Optimistic Case." DOE selected the Upper Reference Case series as its reference planning case because it typified a moderate growth condition in which projected demand for additional nuclear power is satisfied by new orders of light-water reactors, as well as taking into account industry practice to extend the fuel cycle.
[11] Fuel assembly irradiation (or burnup) is measured in units of megawatt-days thermal per metric ton of uranium (MWDT/MTU).
[12] EIA, *World Nuclear Fuel Cycle Requirements 1986* [DOE/EIA 0436(86)], September 1986. The post-1985 volumetric data computed by OCRWM were based on the projected mix of commercial boiling water and pressurized water reactors.
[13] Data are projections.

High-Level Radioactive Waste

Radioactive waste produced from the reprocessing of either commercial or defense spent fuel accounts for the other type of nuclear waste that DOE is required to accept and dispose of under the provisions of the NWPA and subsequent Presidential actions. High-level waste is distinguished from spent nuclear fuel by its much greater volume, substantially lower radioactivity, and variety of forms ranging from liquids to solids.

A small quantity of liquid high-level radioactive waste was generated during the commercial reprocessing of power reactor spent fuel at a facility near West Valley, New York, from 1966 through 1972. No additional commercial liquid high-level waste from reprocessing is being generated in this country. The liquid waste stored at the West Valley facility is scheduled to be solidified into glass and encapsulated in stainless steel canisters for eventual disposal in a geologic repository.

The preponderant share of immobilized high-level waste from reprocessing that is scheduled to be emplaced in geologic repositories comes from the Nation's nuclear defense materials production.

Defense high-level waste is generated and stored at three DOE sites: (1) the Savannah River Plant (South Carolina), (2) the Idaho National Engineering Laboratory (Idaho), and (3) the Hanford Reservation (Washington).

Neutralized defense high-level waste in the form of liquid, salt, and sludge is stored in underground tanks at the Hanford and Savannah River Plant sites. At the Idaho National Engineering Laboratory site, acidic liquid high-level waste is stored in stainless steel tanks. It is routinely converted to a dry, granular solid called calcine for storage in bins in underground concrete vaults. As a result of the President's decision in April 1985 to accept the Secretary of Energy's recommendation that defense waste be emplaced in a civilian geologic repository, high-level waste stored at the three DOE sites will be converted to a solid waste form for ultimate disposal in a combined defense-commercial repository. The ultimate disposal of waste at Hanford is the subject of a draft *Environmental Impact Statement*. The following table depicts cumulative inventories of defense high-level waste from 1986 through the year 2020.

Table 3. Inventories of All Forms of High-Level Defense Waste[14]

Year	Cubic Meters (in Thousands)
1986[15]	340
1990	342
1995	340
2000	343
2005	361
2010	365
2015	371
2020	374

[14] DOE, *Spent Fuel and Radioactive Waste Inventories, Projections and Characteristics* (DOE/RW-0006, Rev. 2), September 1986. The changes in volume reflect DOE's program to convert quantities of defense waste to an immobile solid form for eventual geologic disposal, which will reduce the volume of waste.

[15] Data are projections and exclude high-level waste incorporated in borosilicate glass.

— DOE —