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INVENTORY AND CHARACTERISTICS OF CURRENT AND PROJECTED LOW-LEVEL RADIOACTIVE MATERIALS AND WASTE IN THE UNITED STATES

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The Integrated Data Base (IDB), under U.S. Department of Energy (DOE) funding and guidance, provides an annual update of compiled data on current and projected inventories and characteristics of DOE and commercially owned radioactive wastes. The data base addresses also the inventories of DOE** and commercial spent fuel. These data are derived from reliable information from government sources, open literature, technical reports, and direct contacts. The radioactive materials considered are spent nuclear fuel, high-level waste (HLW), transuranic (TRU) waste, low-level waste (LLW), commercial uranium mill tailings, environmental restoration wastes, and mixed-LLW. This paper primarily focuses on LLW inventory and characterization. The definitions for various waste classifications [1] are:

Spent Fuel: Irradiated fuel discharged from a nuclear reactor. The fuels are assumed to be permanently discharged and eligible for repository disposal. Spent fuel to be processed from government production reactors for national defense is not part of this inventory.

HLW: Highly radioactive material resulting from the reprocessing of spent nuclear fuel. These wastes are mainly liquid wastes resulting from the recovery of uranium and plutonium in a fuel reprocessing plant. They contain fission products that require heavy shielding and provisions for decay-heat dissipation.

TRU: Radioactive wastes that contain more than 100 nCi/g of alpha-emitting isotopes with atomic numbers greater than 92 and half-life greater than 20 years.

LLW: Radioactive waste not classified as spent nuclear fuel, HLW, TRU waste, or by-product uranium mill tailings. In the United States, there are four classes of LLW as defined by the U.S. Nuclear Regulatory Commission (NRC). These are Class A, Class B, Class C, and Greater than Class C (GTCC), and each requires varying degrees of confinement and monitoring.

Commercial Uranium Mill Tailings: Earthen residues that remain after the extraction of uranium from the ores. The isotopes of major concern are ^{226}Ra and ^{222}Rn.

Mixed LLW: Wastes containing both low-level radioactive materials and hazardous chemicals. The hazardous chemicals might be polychlorinated biphenyl (PCB),

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**For Revision 9 of the IDB, quantities of DOE production reactor spent fuel that will not be reprocessed will be included; these data will be included in the February 1994 presentation to the International Atomic Energy Agency (AEA).

asbestos, any other U.S. Environmental Protection Agency (EPA) listed or characteristic waste, or any wastes deemed hazardous by state regulations.

Table I shows the summary of all the current and projected low-level and mixed wastes [except GTCC and Special Case wastes (SCW), which are discussed later] shown in the latest revision of the annual IDB spent fuel and radioactive waste inventory report [1]. The inventory does not include any LLW-contaminated soils or any contaminated liquid/gas in storage. The data show a large quantity of radioactive wastes that will have to be disposed. The DOE and NRC are currently addressing the packaging and transportation issues relative to such large quantities of waste.

Table I. Current and projected cumulative quantities of U.S. radioactive waste and spent fuel [1].
(Quantities are expressed as volume ($1 \times 10^3 m^3$) unless otherwise indicated.)

Waste categories	Actual waste volume 1991	Projected waste 2000	Projected waste 2010
U.S. Government owned:			
LLW (buried and stored)	3,000	3,787[a]	4,769[a]
Mixed LLW	101	Not available	Not available
Environmental Restoration: LLW	Not available	920	18,000
Commercially owned:			
LLW	1,423	1,722	2,055
Mixed LLW	2.1[b]	Not available	Not available

[a]Projections exclude contributions from stored LLW and wastes presently managed as TRU wastes which may be eventually reclassified as LLW.
[b]Stored volume for 1990.

The remainder of this paper will address specifically the inventory and characterization of GTCC and SCWs. As noted above, LLW is classified as Class A, B, C, or GTCC, as defined by the NRC. Wastes in the GTCC category are defined as commercially generated wastes that exceed the definition of Class C wastes and are therefore not suitable for near-surface land disposal. GTCC-like wastes that are generated by the U.S. government (DOE) are called SCWs. The enactment of Public Law 99-240 (Low-Level Waste Policy Amendments Act of 1985) by the U.S. Congress made DOE responsible for disposal of both commercial GTCC LLW and U.S. DOE-owned or generated LLW. Individual states in the United States are responsible, either individually or in cooperation with other states, for the disposition of Class A, B, and C LLW generated from commercial sources. DOE is responsible for the disposal of Special Case wastes.

The U.S. regulations that determine waste classification for near-surface disposal involve two considerations: (1) the concentrations of long-lived radionuclides (and their shorter-lived precursors) whose potential hazard will persist long after precautions such as institutional controls, improved waste form, and deeper disposal have ceased to be effective, and (2) the concentration of shorter-lived radionuclides for which requirements on institutional controls, waste form, and disposal methods are well defined. Waste classes A, B, and C have well-defined near-surface land-disposal requirements. The most stringently regulated class, Class C, must be disposed so that the top of the waste is at a minimum of 5 m below the top surface of the cover or must be disposed using intruder barriers that are designed to protect against an inadvertent intrusion for at least 500 years. LLW exceeding the limits for Class C is not generally acceptable for near-surface disposal. In the absence of specific regulatory requirements, wastes exceeding Class C must be disposed in a geologic repository unless other disposal sites are approved by the NRC.

In 1993, the U.S. DOE Transportation Management Division established the GTCC Packaging and Transportation Working Group to address packaging and transportation issues related to both GTTC LLW and Special Case wastes. The initial key element of this effort is to characterize and quantify both waste categories. The next phase will develop an action plan with recommendations on packaging and transporting of such wastes. Over the past few years, a number of DOE-sponsored reports have been prepared to describe, locate, and quantify low-level radioactive wastes held in both the commercial and government (DOE) sectors. References 2 and 3 document the known commercially generated GTCC. These reports, which were based on several sources, are the most complete available documentation currently for the characterization and quantification of GTCC LLW.

Special Case wastes include a wide variety of forms, sources, and isotopic mixtures. Characterization of these wastes is incomplete, and published documentation has not yet been issued. In this paper, SCWs are divided into the following categories [2]:

Non-Certifiable Defense TRU. Defense-program-generated TRU wastes that are not certifiable for disposal at the Waste Isolation Pilot Plant (WIPP) or for transport in the TRUPACT-II shipping container. Without WIPP acceptance, these wastes currently have no disposal alternative.

Non-defense TRU. DOE-titled TRU wastes generated by DOE Energy Research (ER) Programs, Nuclear Energy (NE) Programs, or an NRC licensee. Currently, WIPP will only dispose of DOE Defense Programs (DP) generated wastes. Therefore, DOE non-defense TRU wastes currently have no disposal alternative.

Specific Performance Assessment Required (SPAR). DOE-titled wastes that contain radionuclides in concentrations greater than those specified for NRC-defined Class C wastes. These are Special Case wastes because they are not generally acceptable for near surface disposal.

Performance Assessment Limiting (PAL). Absorbed tritiated liquids waste, hot-cell wastes from destructive examination of fuels, sludges containing mixed fission products, ion-exchange resins containing transuranics, gauges and dials containing ^{226}Ra, and uranium solids with associated decay products.

Fuel and Fuel Debris. Primarily include DOE-titled fuel and fuel debris used for research and development. These wastes are similar in some respects to waste destined for the spent-fuel and HLW repository. However, most of these wastes are in packaging configurations that are unlike normal commercial fuel elements and may not meet repository waste acceptance criteria (WAC). These wastes are SCWs because of undefined disposal and facility acceptance criteria.

Uncharacterized Wastes. Any containers of waste with unknown contents. These wastes are believed to contain nuclear materials at or near the limits of SPAR or TRU wastes. Further characterization of these wastes will determine their material forms, approximate mass, and levels of radioactivity.

Excess Nuclear Materials. Nuclear materials above the economic discard level (EDL) that either are no longer useful to the current custodians or require processing that is not available because of a lack of capabilities or capacities to recover the useable nuclear materials. Excess nuclear materials include unirradiated nuclear materials, irradiated nuclear materials, and nuclear materials containing decay products. Some of the materials contain Resource Conservation Recovery Act (RCRA)-regulated constituents, which preclude processing because recovery facilities are not permitted by the Act.

Sealed sources. Encapsulated radioactive material whose main purpose is to generate known amounts of radiation. These sources are of special interest because the concentrations of their radioactive material usually make them SPAR waste at the time of disposal.

DOE-Titled, Held by Licensees. Includes wastes or materials that are DOE-titled but held by NRC licensees. These wastes or materials include sealed sources and spent fuel. DOE has provided nuclear materials to licensees through a variety of mechanisms, including contracts, loans, leases, and grants for use in nuclear-research-related fields.

Because of the responsibilities given to it under the Low-Level Waste Policy Amendments Act of 1985, DOE established the National LLW Management Program (NLLWMP) to develop best estimates of GTCC LLW volumes and radioactivities to use in planning for the disposal of this waste. In its report of August 1991, the NLLWMP grouped GTCC LLW into the following generator categories [3]:

Nuclear Utilities: Operators of light water reactors (LWRs) (pressurized-water reactors and boiling-water reactors) are GTCC LLW generators. Operating procedures of LWRs vary from reactor to reactor. Different operating practices and manufacturing designs of individual reactors dictate the potential GTCC LLW that may be produced. These wastes include metals from standard operation procedures, ion-exchange resins and cartridge filters from decontamination efforts and other decommissioning wastes.

Sealed Sources: Sealed sources are small capsules, generally stainless steel, that contain high concentrations of a single nuclide. Sealed sources are used in a wide range of industrial and medical applications and become waste when they are no longer usable. These sealed sources include well-logging devices, moisture gauges, and medical therapy and calibration devices.

DOE-Held GTCC Waste: Several commercial facilities have generated GTCC LLW, and through contractual agreements DOE has taken possession of those wastes and currently stores them at various DOE sites. It has not been completely determined whether an NRC-licensed facility will be required for disposition of these wastes.

Other Generator Waste: These are generated wastes that do not belong in the previous three categories. These waste generators include Carbon-14 users, fuel fabricators, nuclear research/test reactors, and sealed source distributors.

Table II presents a summary of the current inventory of GTCC LLW and Special Case waste based on refs. 2 and 3 and on unpublished data obtained from the Idaho National Engineering Laboratory (INEL).

Special Case Waste Classification Under Safety Series No. 6

Effort is underway to classify SCW under the Safety Series No. 6 guidelines for Low Specific Activity (LSA). Safety Series No. 6 1985 edition (amended 1990) classifies LSA materials into 3 groups:

(a) **LSA-I**
- (i) Ores containing naturally occurring radionuclides (e.g., uranium, thorium), and uranium or thorium concentrates of such ores;
- (ii) Solid unirradiated **natural uranium** or **depleted uranium** or natural thorium or their solid or liquid compounds or mixtures; or
- (iii) **Radioactive material**, other than **fissile material**, for which the A_2 value is unlimited.

(b) **LSA-II**
- (i) Water with tritium concentration up to 0.8 TBq/L (20 Ci/L) or
- (ii) Other material in which the activity is distributed throughout and the estimated average **specific activity** does not exceed 10^{-4} *A_2/g for solids and gases, and 10^{-5} A_2*/g for liquids

(c) **LSA-III**

Solids (e.g., consolidated wastes, activated materials) in which
- (i) The **radioactive material** is distributed throughout a solid or a collection of solid objects, or is essentially uniformly distributed in a solid compact binding agent (such as concrete, bitumen, ceramic, etc.);
- (ii) The **radioactive material** is relatively insoluble, or it is intrinsically contained in a relatively insoluble matrix, so that, even under loss of **packaging**, the loss of **radioactive material** per **package** by leaching when placed in water for seven days would not exceed 0.1 A_2; and
- (iii) The estimated average **specific activity** of the solid, excluding any shielding material, does not exceed 2×10^{-3} A_2/g.

Table II shows that for all SCW categories, gross volume (m^3) and overall radioactivity (Ci) content are the only two parameters that are known. To classify the wastes as LSA, the following additional information will be required:

(a) Radionuclide(s) present in the various waste streams;
(b) Activity levels (Ci) for each waste stream; and
(c) Mass of the waste stream.

This information will determine the LSA classification (I, II, or III) and the required packaging (IP-1, IP-2, or IP-3).

SUMMARY

Table II indicates that approximately 1.08×10^6 m^3 of DOE SCW and 3,240 m^3 of GTCC LLW waste could potentially exist in the U.S. inventory. INEL has estimated that the quantity of SCWs could increase by approximately 12,000 m^3 during the 5-year period 1991–1995. Most of the SCW is uncharacterized waste from underground storage tanks at the Hanford, Washington, site. This inventory is expected to rise as more waste is characterized at various government sites as a result of environmental restoration efforts. The inventory of SCW far exceeds the quantity of GTCC LLW; therefore the GTCC Packaging and Transportation Working Group will concentrate on updating the inventory and characterization of SCW. The characterization will help determine the waste classification (i.e., LSA type) under IAEA regulations. This classification will be instrumental in defining packaging and transportation requirements to transport such large quantities of waste to a future disposal site. This characterization effort can also provide valuable input to IAEA in its evolving definitions of LSA/surface-contaminated objects (SCO) based upon the impact to GTCC/SCW packaging requirements.

REFERENCES

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2. *Greater-Than-Class C Low-Level Radioactive Waste Packaging and Transportation Elements Report*, DOE/LLW-116, Idaho National Engineering Laboratory, Idaho Falls, Idaho, October 1991.

3. *Greater-Than-Class-C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics, Greater-Than-Class C Low-Level Waste Management Program*, DOE/LLW-114, Idaho National Laboratory, Idaho Falls, Idaho, August 1991.

Table II. Summary of estimates of commercial GTCC LLW and DOE-generated/owned SCWs through 1990 [1,3].

Waste category	Volume (m^3)	Number of items	Radio-activity (10^6 Ci)
SCW summary:			
Non-Certifiable Defense TRU	35,500		0.580
Non-Defense TRU	850		0.117
SPAR	34,200		122.0
PAL	5,600		0.08
Fuel And Fuel Debris	8,300		21.6
Uncharacterized	871,000		201.0
Excess Nuclear Materials	125,000		0.796
Sealed Sources	NA[a]	2,570	1.02
DOE Titled, by Others	NA[a]	4,160	0.013
Subtotal	**1,079,450[b]**	**6,730**	**347.0**
Commercially Generated GTCC LLW			
Nuclear Utility Wastes	1,853		65.0
Sealed Sources	6	27,000	0.303
DOE Held GTCC Waste	1,076		0.538
Other Generator Waste	307		0.003
Sub-Total	**3,242**	**27,000**	**66.0**
Total	**1,082,692**	**33,730**	**413.0**

[a]NA = not available

[b]INEL has estimated that the quantity of SCWs could increase by approximately 12,000 m^3 during the 5-year period 1991–1995.