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ABSTRACT

Section 114(d) of the Nuclear Waste Policy Act of 1982, as amended (NWPA), limits the overall capacity of the first repository to 70,000 metric tons of heavy metal (MTHM). Current DOE policy is to allocate DOE spent fuel and high-level waste (HLW) at 10 percent of the total, or 7,000 MTHM. For planning purposes, 4,667 MTHM will be allocated for HLW. While the NWPA provides a technical basis for determining the MTHM equivalence of HLW, it does not address the significant technical differences between DOE HLW and commercial spent nuclear fuel (SNF). Although more than 170,000 MTHM of DOE fuel has been reprocessed to produce the inventory of HLW, the amount of radioactive waste generated per metric ton of DOE fuel is only a few percent of that in a metric ton of commercial fuel.

This study compares the results of four methods for determining the MTHM equivalence of DOE HLW. These methods include (1) using the actual weight of heavy metal in reprocessed DOE fuel, (2) assuming the historical equivalence of 0.5 MTHM/canister of vitrified DOE HLW, (3) comparing the total radioactivity in DOE HLW to the radioactivity of commercial SNF, and (4) comparing the total radiotoxicity of DOE HLW, as defined for those radionuclides identified in 10 CFR 20, with SNF at 1,000 and 10,000 years. This study concludes that either of the last two options would meet Congress's stated purposes of the NWPA, which are to (1) provide "reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository," and (2) to "define Federal policy for the disposal of such waste and spent fuel."

1. INTRODUCTION

The Nuclear Waste Policy Act of 1982, as amended (NWPA), established provisions for safety and protection of the environment from the hazards inherent to spent nuclear fuel (SNF) and high-level radioactive waste (HLW) disposed in a repository. According to Section 114(d) of the NWPA, the overall capacity of the first repository is restricted as follows:

> The Commission decision approving the first such [license] application shall prohibit the emplacement in the first repository of a quantity of spent fuel containing in excess of 70,000 metric tons of heavy metal or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent fuel until such time as a second repository is in operation.

In addition, the NWPA directed the President to issue a decision on whether DOE HLW should be disposed in a civilian repository. Subsequently, the Secretary of Energy recommended, and the President approved, allocating the necessary repository capacity for DOE HLW in accordance with the NWPA.[1] Current DOE planning assumes that the repository capacity limit of 70,000 MTHM includes 63,000 MTHM commercial spent fuel and 7,000 MTHM DOE SNF and HLW, divided as 2,333 and 4,667 MTHM for SNF and HLW, respectively.

About 170,000 MTHM of DOE fuel has been reprocessed to produce the current inventory of HLW.[2] A small part of the HLW inventory came from reprocessing commercial fuel (about 261 MTHM commercial fuel and 379 MTHM of DOE N-Reactor fuel from West Valley Nuclear Services during 1966-1971). In subsequent actions, title for all HLW from West Valley has been taken by the former owner, Nuclear Fuel Services, and then by the State of New York. That fuel is now classified as commercial HLW. Unless otherwise stated, this report will include this small amount of West Valley "commercial" HLW under the category of "DOE HLW."

The NWPA language does not distinguish between the origins of or address the significant technical differences between DOE HLW and commercial spent nuclear fuel. The technical basis used in Section 114 (d) for determining the metric tons of heavy metal (MTHM) equivalence of DOE HLW is unnecessarily restrictive in that it could severely limit disposal of DOE HLW. This report summarizes alternative methods that can be used to determine the MTHM equivalence of DOE HLW, including the impacts of the repository capacity limits.

2. DETERMINING MTHM EQUIVALENCE

Four methods exist for determining the MTHM equivalence of HLW:

1. SNF Reprocessed Method. Use the actual weight of heavy metal in the reprocessed DOE fuel, as compiled from site processing records, without any correction for burnup.

2. Historical Method. Assume 0.5 MTHM/canister of vitrified DOE HLW. (This was the assumption used in DOE/DP/0020/1.[1])

3. Total Radioactivity Method. Compare the radioactivity in DOE HLW[3] to the radioactivity of commercial SNF.[2,4]

4. Radiotoxicity Method. Compare total radiotoxicity (as defined for those radionuclides identified in 10 CFR 20[5]) with SNF at 1,000 and 10,000 years, respectively.

These four methods will be described in the following sections. Table 1 provides the results of calculated equivalent MTHM using the above methods.

2.1 SNF Reprocessed Method

This method uses the MTHM equivalence language of Section 114 (d), "a quantity of solidified high-level waste resulting from such a quantity of spent fuel…" Under the planning basis of 4,667 MTHM for DOE HLW when compared to over 170,000 MTHM of DOE fuel reprocessed, just three percent of DOE's inventory of vitrified HLW, would be allowed into the repository. Thus, even though the NWPA enacted in 1982 originally intended to dispose of all SNF and HLW in more than one repository, in the NWPA Amendments Act of 1987, Congress ordered the Secretary of Energy to terminate all activities to develop alternative sites than the Yucca Mountain site and to report only after January 1, 2007, on the need for a second repository. This, combined with the 70,000 MTHM limit on the first repository, effectively prohibited the disposal of almost all DOE HLW until well into the 21st century. Perhaps Congress was only aware of the amount of commercial SNF and was not aware of how much spent fuel was actually reprocessed to produce the existing DOE HLW inventory. Using this extremely strict interpretation would impose significant impacts on DOE-EM, the HLW producer, in providing extensive interim HLW storage capacity.

This methodology is not completely reasonable, since most "spent" DOE fuel is much less radioactive than spent commercial fuel. The typical burnup rates for reprocessed DOE fuel were between 0.7 and 2 gigawatt days (GWd) per MTHM. In contrast, commercial fuel burnup rates are between 25 and 40 GWd/MTHM.[2] This results in a much lower rate of total fission products being generated per MTHM of DOE fuel.[2,4] For example, reprocessing approximately 100,000 MTHM of fuel at Hanford between 1944 and 1990 generated 399 million curies of HLW. This is approximately 0.004 MCi/MTHM. Typical commercial fuel contains approximately 0.3 MCi of radioactive material per MTHM, or 75 times as much as an equivalent amount of typical DOE fuel.[3]

2.2 Historical Method

The 1985 report to the President, which allocated the necessary repository capacity for DOE HLW, also estimated that a canister of vitrified DOE HLW would be equivalent to the amount of HLW generated from reprocessing 0.5 MTHM of commercial fuel.

This method has some credibility in that it was used as a basis in a report directed by the NWPA. It is based on using a radioactivity approach such as described in Section 2.3, Total Radioactivity Method. This was done by comparing the curie content of a "typical DOE HLW canister" (assumed to contain 0.15 MCi) with the curie content of a "typical commercial HLW canister" (assumed to contain 0.658 MCi from reprocessing 2.28 MTHM of commercial SNF, or about 0.3 MCi/MTHM).[1,2] Thus, by dividing 0.15 MCi/canister by 0.3 MCi/MTHM, a value of 0.5 MTHM/canister is obtained.

However, the Historical Method is valid only for HLW canisters with the high radionuclide content of 0.15 MCi assumed in DOE/DP/0020/1. As is pointed out in the Hanford example above, much DOE waste has significantly less radionuclide content than this option assumes, and most DOE HLW canisters are expected to contain much lower radionuclide levels than 0.15 MCi. A new value of MTHM equivalence must be calculated in the same way for the canisters with lower curie loading. For example, for a canister containing 0.03 MCi of HLW, the correct equivalence value should be 0.03 MCi/canister divided by 0.3 MCi/MTHM, or 0.1 MTHM/canister. Thus, the Historical Method overestimates the MTHM for the canister with lower radioactivity by a factor of 5 if 0.5 MTHM/canister is assumed for a canister containing 0.03 MCi of HLW.

By using the Historical Method, only 46 % of DOE's HLW would be accepted under the allocation of space established by DOE.

Table 1. Total MTHM equivalence ($MTHM_{eq}$) for HLW at each site.

Method	WVDP[b]	Savannah River	Hanford	INEEL	TOTAL
IDB Total HLW Inventory, MCi[a]	24.1	502.2	399.8	49.3	915.4
IDB Projected Number of Canisters[a]	276	5,944	12,444	570	19,234
MTHM from SNF Reprocessed	640[b]	70,000	99,411	44	170,095
$MTHM_{eq}$ from Historical Method (0.5 MTHM per Canister)	640	2,972	6,222	285	10,119
$MTHM_{eq}$ from Total Radioactivity					
10-yr Decay	66	2,140	1,524	241	3,971
1,000-yr Decay	10.7	138	161	34.5	344
$MTHM_{eq}$ from Radiotoxicity[c]					
1,000-yr Decay	9.9	117	147	16.4	290
10,000-yr Decay	5.2	168	7.8	18.7	200

[a]Integrated Data Base - Reference 3.

[b]Commercial HLW from West Valley – Reference 6.

[c]10 CFR Part 20 – Reference 5

2.3 Total Radioactivity Method

This method compares the total radioactivity in DOE HLW estimated from the Integrated Data Base[3] with commercial fuel. The commercial fuel is assumed to have a burnup of 39 GWd/MTHM and to contain 0.359 MCi/MTHM at 10-yr cooling. By dividing the total radioactivity of HLW by this factor, the equivalent MTHM can be calculated. In Table 1, the HLW radioactivity was calculated at 10- and 1,000-year decay times and was compared with the comparable values per MTHM of spent fuel to arrive at the equivalent MTHM values of 3,971 and 344, respectively. The difference is primarily due to the much higher concentration of long-lived isotopes, such as plutonium, in spent fuel compared to HLW.

By using the Total Radioactivity method, all of DOE's HLW can be disposed under the DOE allocation limit.

2.4 Radiotoxicity Method

The radiotoxicity method is an extension of the radioactivity method and compares the relative radiotoxicity of HLW with that of commercial fuel at 1,000 and 10,000 years. The standard commercial spent fuel at a burnup of 39 GWe/MTHM, containing 0.359 MCi/MTHM radionuclides, was used for comparison. Radiotoxicity indices were calculated from the inventory of specific radionuclides in the

HLW[7] or SNF and their allowable 10 CFR 20[5] release limits. These calculations resulted in totals of 290 and 200 equivalent MTHM for DOE HLW at 1,000 and 10,000 years, respectively.

By using the Radiotoxicity Method, all of DOE's HLW can be disposed under the DOE allocation limit.

3. CONCLUSIONS AND DISCUSSION

Four methods for comparing the MTHM equivalence of DOE HLW to commercial fuel have been evaluated. By using the SNF Reprocessed Method established in the NWPA and the allocation of space established by DOE, less than three percent of the total inventory of DOE HLW could be disposed in the first repository. This method does not put DOE HLW and commercial SNF quantities on a common total system performance basis.

The Historical Method is not strictly valid for HLW resulting from reprocessing of low-burnup fuel, including the large amount of Hanford and SRS fuel. By using this method, the equivalent MTHM would be over-estimated and would allow 46% of the HLW to be disposed under the DOE allocation limit.

Thus, if either the SNF Reprocessed Method or the Historical Method is used, Congress's intent to dispose of DOE HLW will be significantly delayed well into the 21st century. If most of the HLW is excluded from disposal in the repository, it could result in less efficient emplacement layouts, which are highly dependent on heat from commercial SNF.

By using the Total Radioactivity Method or the Radiotoxicity Method to estimate the MTHM equivalence, all of the DOE HLW could be disposed in the first repository within the allowable limit. Similar quantities of radionuclides would be disposed per MTHM as compared to commercial spent fuel. By using these methods, DOE HLW is placed on a common radioactive waste constituent basis with commercial SNF. These methods also meet common total system performance goals. Such a common basis supports the purpose of the NWPA, to provide "reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository." It also supports the NRC repository licensing criteria in 10 CFR 60,[8] which are based on radionuclide containment. Such an efficient use of repository space allows disposal of HLW with minimal impacts on total system performance.

4. REFERENCES

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