IMPACTS AND RAMIFICATIONS OF DEFINING HIGH-LEVEL WASTE

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ABSTRACT

The Nuclear Regulatory Commission (NRC) is considering rulemaking to provide a concentration-based definition of high-level waste (HLW) under authority derived from the Nuclear Waste Policy Act (NWPA) of 1982 (1) and the Low Level Waste Policy Amendments Act of 1985 (2). The Department of Energy (DOE), which has the responsibility to dispose of certain kinds of commercial waste, is supporting development of a risk-based classification system (3,4) by the Oak Ridge National Laboratory (ORNL), to assist in developing and implementing the NRC rule. The system is two-dimensional, with the axes based on the phrases "highly radioactive" and "requires permanent isolation" in the definition of HLW in the NWPA. Defining HLW will reduce the ambiguity in the present source-based definition by providing concentration limits to establish which materials are to be called HLW. The system allows the possibility of greater-confinement disposal for some wastes which do not require the degree of isolation provided by a repository. The definition of HLW will provide a firm basis for waste processing options which involve partitioning of waste into a high-activity stream for repository disposal, and a low-activity stream for disposal elsewhere. Several possible classification systems have been derived and the characteristics of each are discussed. The Defense High Level Waste Technology Lead Office at DOE - Richland Operations Office (RL), supported by Rockwell Hanford Operations (Rockwell), has coordinated reviews of the ORNL work by a technical peer review group and other DOE offices. The reviews produced several recommendations and identified several issues to be addressed in the NRC rulemaking.

INTRODUCTION

The definition of High Level Waste (HLW) has been developing over the past few years from the early qualitative basis of its source as the first cycle solvent extraction system in a fuel reprocessing plant toward a quantitative concentration-based definition.

The early definition in Appendix F to 10 CFR 50 (5) states: "For the purpose of this statement of policy, 'high-level liquid radioactive wastes' means those aqueous wastes resulting from the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuels." Later modifications added solids derived from such liquids and spent fuel, if disposed of without reprocessing. The Nuclear Waste Policy Act (NWPA) of 1982 (1) provided a modified definition in 2 parts:

(A) The highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in suffient concentration; and

(B) other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation.

The Nuclear Regulatory Commission (NRC) considered rulemaking (6) and prepared a staff technical paper (7) to assist in interpreting the phrases "highly radioactive", "in sufficient concentrations", and "requires permanent isolation". The NRC had earlier issued 10 CFR 61 (8) for land disposal of radioactive waste, which provided concentration limits for Class A, B, and C low-level waste (LLW), as well as provisions for case-by-case consideration of disposal requirements for LLW above Class C. The staff paper (7) proposed concentrations of 30 times the Class C limits for Sr-90, Cs-137, Pu-241, and alpha-emitting transuranic (TRU) nuclides as appropriate to define materials which would require permanent isolation.

The Low-Level Waste Policy Amendments Act (LLWPAA) of 1985 (2) gave the responsibility for disposing of commercial LLW above Class C to the Federal Government (to be implemented by DOE), and required NRC licensing of the facility used for disposal of those commercial wastes. Thus both DOE and NRC have a substantial interest in determining what wastes are to be included and the disposal requirements. It was recently reported (9) that the NRC will soon announce initiation of the rulemaking to define HLW. The DOE has been supporting studies (3,4) by the ORNL to develop a risk-based waste classification system as a source of technical data for the NRC rulemaking. The Defense HLW Technology Lead Office at DOE-RL, supported by Rockwell, has coordinated reviews of the ORNL work by a technical peer review group and other DOE offices.

Continuing work by Kocher and Croff (4) led to a revised system in which the highly radioactive boundary was defined as 50 W/m^3 (the approximate Class C limit for Sr-90), or 1 C/kg-h[a] (100 R/h) external exposure rate (the approximate Class C limit for Cs-137). The only other boundary used was a modified Class C limit line which again combined Tables I and II from 10 CFR 61 into a single table, but also added several nuclides by calculations from other sources, and expressed TRU nuclide concentrations on a volume rather than mass basis, which effectively reduced the limit line below the Class C limits. All waste above this modified Class C limit line was called TRU waste if below the highly radioactive boundary, or HLW if above the highly radioactive boundary. Thus some Class C waste would become TRU waste and some TRU waste would become HLW.

The potential for greater-confinement disposal of some waste above the modified Class C limit line, but below the CGD boundary, was left as an option for future development.

REVIEWS AND RECOMMENDATIONS

The Defense High-Level Waste Technology Lead Office coordinated reviews of the ORNL work, including a technical peer review by a group of experts in the field and programmatic reviews by DOE-Headquarters (HQ) and Field Offices. The technical peer review group agreed with the two-dimensional representation and several other key features, but made the following recommendations.

1. Focus on the HLW definition and define only HLW (no other classes) using the "highly radioactive" (HR) and "requires permanent isolation" (RPI) boundaries, to be applied at the time of disposal. The pictorial representation is given in Fig. 2.

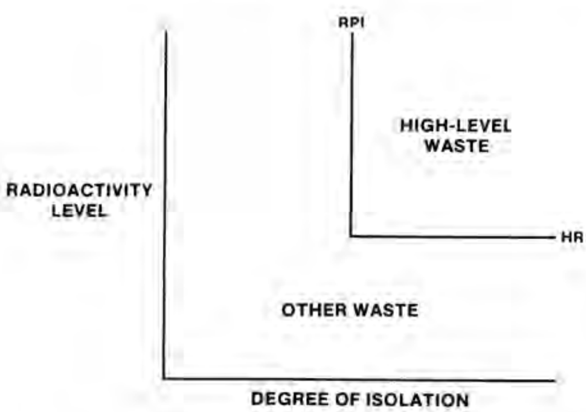


Fig. 2. Pictorial representation of peer review group recommendation for defining HLW.

This recommendation was based on the fact that adding other limit lines, or extending these lines to either axis, raised extraneous issues about other waste classes. Since those issues need not be resolved in order to define HLW, their inclusion would only complicate and delay rulemaking.

Classification at the time of disposal was specified because the definition and concentrations are intended to be applied to the final waste form for disposal. Operations involving volume reduction, mixing, and partitioning will change the concentrations and could change the classification.

2. Set the HR boundary at a power density of 100 W/m^3 or a radiation level of 1 C/kg-h (100 R/h), not coupled to the Class C limits. An option of raising the limit to the 300 W/m^3 used by WIPP was offered, if a rationale to justify the higher limit could be found.

3. Define the RPI boundary through generic scenarios appropriate to GCD, and use the boundary for defining HLW only. Consider applying the scenarios at 1000 years instead of 500 years (corresponding to the "hot waste facility" discussed in Section 7 of Ref. 10).

4. Hold a workshop to develop scenario parameters and the resulting concentration limits.

5. Concentrations should be determined by averaging over the volume of the waste package if less than 1m^3, or over the volume of waste in the waste package if over 1m^3.

   This recommendation recognizes that small concentrated sources may have high concentrations even with relatively low radioactivity content, and that averaging over stabilizing or shielding material in the package is reasonable, but not beyond 1m^3.

Several ramifications result from the above recommendations.

1. HLW is defined by the HR and RPI boundary, in agreement with the NWPA, and disposal in a licensed repository is clearly intended.

2. The lower limit for TRU waste is retained. Disposal technology is not specified. The upper limit is not the same as given in the WIPP acceptance criteria (300 W/m^3 or 850 MBq/m^3), so some accomodation may be needed.

3. LLW is defined, by exception, as radioactive waste which is not spent fuel, HLW, TRU waste, or mill tailings, thus permitting some waste above the Class C limits to be LLW. Disposal technology is not specified. Different wastes may require different degrees of isolation, but the determination is left to site-specific limits for GCD and shallow land burial.

   If some LLW at a specific site cannot meet the limits, even for GCD, such waste would need to be disposed of in a licensed repository.

4. No technical reasons to prevent the extension of the HLW definition to waste from reprocessing were found.

This comment relates to the fact that in Ref. 7, it was proposed to apply the concentration definition only to "other highly radioactive material" under definition in the NWPA, and not to

a. The coulomb per kilogram (C/kg) is the unit for radiation exposure in the International System of Units.

PROPOSED HLW DEFINITIONS

Croff, et al, (3) studied the history of HLW and the language in the NWPA, concluding that HLW is material which is both "highly radioactive" (HR) and "requires permanent isolation" (RPI). This led to "a two-dimensional waste categorization system in which one axis is related to whether or not the wastes require permanent isolation and is associated with long-term risk from waste disposal and the other axis is related to whether or not the wastes are highly radioactive and is associated with short-term risks from waste management and operations."

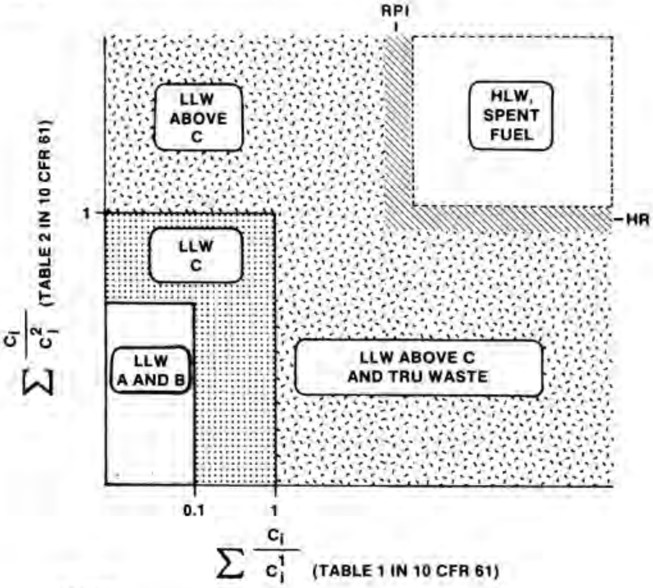
The measure chosen to relate the degree of radioactivity to short-term risks from waste management and operations was the power density of the waste. A rationale was developed to support a value of 50 W/m^3 as a level which might require additional measures in system design or operation. Then a peak-to-average ratio of 4 was used to set a value of 200 W/m^3 as the "highly radioactive" boundary for individual waste packages.

The degree of isolation required was determined in a manner similar to the development of the limits (10) for 10 CFR 61. Systems corresponding to greater confinement disposal (GCD) by engineered surface structure or intermediate depth burial were defined and treated as the "next-best disposal technology" to disposal in a deep geologic repository. The NRC exposure scenarios and pathway dose conversion factors were modified to correspond to the proposed disposal systems, and a list of concentration limits was generated (Table I of Ref. 3) to define radionuclide concentrations requiring permanent isolation, referred to as the "greater confinement limit". This completed the development of the definition of HLW in terms of the highly radioactive limit and the greater confinement (or permanent isolation) limit.

Croff, et al, then proceeded to expand the concept to define other classes of waste, by adding a third limit line based on the NRC Class C limits. In 10 CFR 61, the Class C limits are given in 2 tables. Table 1 contains limits for long-lived nuclides (C-14, Tc-99, I-129, and transuranic nuclides), and Table II contains limits for short-lived nuclides (Ni-63, Sr-90, and Cs-137). These limits are applied through a "sum-of-the-fractions" (SOF) rule, in which the ratio of each radionuclide to its limit is taken,and the resulting fractions summed for each table individually. If either sum exceeds 1, the waste is above Class C. However, Croff, et al, combined the 2 tables into a single list and applied the SOF rule to the combined list to derive their "Class C" limit line. The resulting system is shown in Fig. 1 of Ref. 3. Two new waste categories were created: high-activity waste (HAW) and intermediate-level waste (ILW). The TRU waste category was modified to include only radionuclide concentrations above the greater confinement limit (whether transuranics or fission products), but below the highly radioactive limit. Thus some waste, which is currently TRU waste, would be ILW or HAW and some Class C waste would become ILW.

The current authors found the two-dimensional representation and the GCD concept attractive, but suggested a modification to align the categories more closely with existing definitions and the NRC system.

The modification, shown schematically in Fig. 1, uses Table I (long-lived nuclides) of 10 CFR 61 for the degree of isolation axis and Table II (short-lived nuclides) for the degree of radioactivity axis, recognizing that the long-lived nuclides have low specific activity and contribute very little to the total activity of most waste streams. At first the Table 1 limit line was used to separate TRU waste from LLW (Class C and above). However it was recognized that Table I includes long-lived radionuclides other than transuranics, so the dividing line is not sharp. Thus the schematic representation of Fig. 1 shows a region of "LLW above C and TRU waste". This is also consistent with the Low Level Waste Policy Amendments Act, which does not exclude TRU waste from the definition of LLW, in contrast with other LLW definitions, which do exclude TRU waste. Thus, by omission, TRU waste becomes a subclass of LLW above Class C for purposes of the Act.



where:

Ci is the concentration of radionuclide i in the waste,

C_i^1 is the concentration of radionuclide i in Table I of 10 CFR 61, and

C_i^2 is the concentration of radionuclide i in Table II of 10 CFR 61.

Fig. 1. Proposed modification to the waste classification system of Ref. 3.

The highly radioactive (HR) boundary was originally suggested as the Table II limits in 10 CFR 61. However it was later recognized that the only real application of that boundary was to separate defense TRU waste, destined for the Waste Isolation Pilot Plant (WIPP), from HLW destined for a licensed repository. Thus the HR boundary could logically be chosen as the WIPP Waste Acceptance Criterion of 300 W/m^3 (about 45000 Ci/m^3 for Sr-90). This criterion is a few times higher than the Class C limits, but not as high as the limits suggested by Fehringer (7).

The GCD concept to define the permanent isolation boundary was retained, but it was suggested that only the radionuclides listed in Table I of 10 CFR 61 (rather than all nuclides in both tables) be used to define the boundary. An in-depth peer review of the scenarios and parameters was recommended as a method to achieve consensus on the limit values.

waste from reprocessing under Part A. The peer review group felt that a concentration-based definition should apply to both parts.

Parallel reviews by DOE-HQ and Field Offices identified many of the same issues, as well as some site-specific needs for better identification and clarification of waste classes. The primary issues are listed below.

1. The role of GCD in the overall disposal program, and development of consensus scenarios and parameters.

2. Application of the system to waste from reprocessing.

3. Change in the definition of TRU waste, if any.

4. What waste can reasonably be designated as above Class C, but not HLW or TRU waste.

5. Disposal technology for long-lived transportable nuclides (C-14, Tc-99, and I-129).

6. Existing disposal plans may be changed if the categories or definitions change. Ground rules are needed.

These issues need to be accomodated within the framework of the NRC rulemaking. In fact, the existence of these issues is a good indication that the rulemaking is needed as an appropriate forum for resolution.

The primary impact of the definition would be to remove uncertainty by providing a firm quantitative basis for classifying waste according to the degree of hazard represented by the waste. Types of wastes affected by the uncertainty include 1) irradiated hardware, such as in-core instruments and parts from fuel rod consolidation, 2) concentrated gamma and neutron sources for radiography, radiation processing, and industrial measurements, 3) radionuclides concentrated by ion exchange or filtration, and 4) reprocessed waste which has been further processed or partitioned to remove or concentrate radionuclides. Another impact will be to expedite development of a new disposal system (or modification of an existing system) to dispose of LLW above Class C. Additional impacts may be seen as the NRC rule develops.

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