Current Regulations and Guidance - New Approaches for Risk-Informed Low-Level Radioactive Waste Management[1]

M.T. Ryan Ph.D., C.H.P.[2]
Advisory Committee on Nuclear Waste & Materials
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

ABSTRACT

This paper presents the historical foundations and future challenges for commercial low-level radioactive waste (LLRW) management in the United States. LLRW has been managed at government facilities since the beginning of the nuclear age and in the commercial sector since the early 1960's. Over the intervening years many technical, management and regulatory changes have occurred. Significant progress has been made in waste form, waste packaging and in recognizing radionuclides important to performance of disposal technologies and disposal facilities. This presentation will examine approaches using existing regulations and risk-informed approaches to improve guidance, licensing and management of LLRW.

INTRODUCTION

In the United States, tens of thousands of establishments, both government and private, are authorized (or licensed) to use radioactive materials. The volume and level of radioactive material in wastes produced varies. Historically, the greatest proportion by volume of radioactive waste produced domestically is what is classified as LLRW, although LLRW only accounts for less that 1 percent of the total quantity of radioactive material being disposed [1].

The term "low-level radioactive waste" or "LLRW" has carried a changing meaning over the years. At the time the U.S. Nuclear Regulatory Commission (NRC or the Commission) promulgated the LLRW disposal regulations found in Title 10, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," the term LLRW was exclusionary. It included all radioactive wastes that were not high-level radioactive waste (HLW) including spent nuclear fuel (SNF), intermediate-level radioactive waste with concentrations of transuranic (TRU) elements greater than 100 nanocuries per gram (nCi/g), and LLRW with radioactive material concentrations greater-than-Class C (GTCC) LLRW limits found in 10 CFR Part 61.

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[1] The author wishes to acknowledge the collaboration and contributions of M.P. Lee and H.J. Larson and their work in preparing the "History and Framework of Commercial Low-Level Radioactive Waste Management in the United States" [2], on which this paper is largely based. Readers may find there a more detailed review of the topics discussed in this paper.

[2] The opinions expressed in this paper are the sole responsibility of the author and do not reflect the views or opinions of the Nuclear Regulatory Commission or its staff.

LLRW is currently defined in 10 CFR Part 61 in the same way that it is defined in the Low-Level Waste Policy Act of 1980 (LLWPA – Public Law 96-573) and the Nuclear Waste Policy Act of 1982, as amended – specifically, radioactive waste that is not classified as HLW, TRU waste, SNF, or byproduct material as defined in Section 11e.(2) of the Atomic Energy Act of 1954 (AEA – i.e., uranium or thorium tailings and waste).

COMMERCIAL LLRW

The radioactive material concentration in LLRW can range from just above background levels found in nature to, in certain cases, very high concentrations of radioactive material, such as stainless steel items replaced during maintenance inside of a nuclear power plant reactor vessel. Sites used for the disposal of LLRW are assessed for performance for periods of 100-300 years since this is the time interval when nearly all of the disposed radioactive material decays, although a very small percentage of longer lived radionuclides such as uranium persist without decay for much longer periods of time. Licensees that typically use only short-lived radionuclides store LLRW on site until it has decayed and can be disposed with regard to other non-radiological requirements (e.g., ordinary municipal or medical wastes). Longer-lived wastes are often accumulated until enough is accumulated for economical shipment to an approved LLRW disposal site. The NRC has historically discouraged the use of onsite storage of LLRW as a substitute for permanent disposal.[3]

The NRC classifies commercial LLRW as Class-A, Class-B, and Class-C. In addition to radionuclide half-life and concentration, the requirements for disposal include waste form, waste packaging, depth of burial, and site characteristics and engineered features of the site. All these features are aimed at the physical and chemical stability of the waste form and packaging. In any year, the amount of commercial LLRW generated can vary. Generally, the annual volume is approximately 10^6 cubic feet (ft^3). For example, in 2004 about 3.8×10^6 ft^3 of LLRW was generated, representing about 3.4×10^5 curies (Ci) of radioactive material. The majority of the volume (more than 99 percent) was Class-A LLRW. Although Class-A LLRW is the greatest in terms of volume of material generated, Class C wastes contain most of the activity – averaging between 69 and 97 percent of all of the curies disposed of over the last ten years.[4]

Technological advances, as well as significant improvements in normal operational practices at nuclear power plants over the past several decades, have contributed to a significant decrease in the quantities of LLRW generated. However, the volume of

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[3] In Generic Letter 81-38 [3], the NRC staff first noted that no nuclear facility should be built to store waste for longer than 5 years under a licensee's 10 CFR 50.59, "Changes, Tests and Experiments," evaluation. The licensee should obtain specific NRC approval. This limitation was based in part on safety considerations, but was aimed at encouraging the development of permanent LLRW disposal facilities. However, recognizing that the 5-year limit has not influenced the development of new waste disposal facilities and that the states continue to make slow progress, the NRC has eliminated any language in its guidance to suggest that the 5-year term is a limit beyond which storage would not be allowed.

[4] Estimates obtained from the U.S. Department of Energy's Manifest Information Management System (MIMS) LLRW data base. The MIMS web site can be found at *http://mims.apps.em.doe.gov/*.

material being disposed has recently increased as a result of the decommissioning of the first generation of commercial nuclear power plants [4]. To address the increase in disposal volume, some very low level radioactive wastes are being disposed at facilities permitted for the disposal of chemical wastes under Subtitle C and Subtitle D of the Resource Conservation and Recovery Act (RCRA) of 1976. Consequently in 2003, the U.S. Environmental Protection Agency (EPA) published an advance notice of proposed rulemaking requesting comment on the suitability of using RCRA Subtitle-C disposal technology (and regulations) for disposing of certain "unimportant quantities" of mixed low-activity radioactive waste (LAW) [5].[5]

Generators have undertaken volume reduction and waste minimization efforts in response to increased disposal costs (taxes, surcharges and disposal charges) for LLRW. These efforts include segregation, decontamination, and minimizing waste generation by careful work planning as well as limiting contaminated materials in the environment to only that needed for carefully planned tasks. Some of the most effective volume reduction strategies are compacting, consolidating, and monitoring waste streams to reduce the volume of LLRW requiring storage and to reduce the exposure of routine equipment to the reactor environment [6, 7, 8, 9, 10, 11, 12]. [6]

Despite these changes and new developments, there still remains a very fundamental concern that little new LLRW disposal capacity has become available since the passage of the LLWPA. Of the six disposal sites in operation at the time LLWPA was passed, four of the sites − Beatty, Maxey Flats, West Valley, and Sheffield − are now closed. One new disposal facility in Clive, Utah, opened to Class-A waste generators in 2000. A disposal facility in Andrews County, Texas, has been proposed to serve members of Texas Compact. That license application is currently undergoing a review. The Energy Solutions disposal facility in Barnwell, South Carolina, is scheduled to close to generators outside of the Atlantic Compact in June 2008, leaving 36 states with no disposal access for Class-B and Class-C wastes, as described in Table I. Even though there is adequate disposal capacity at the remaining disposal facilities for those with access for the foreseeable future, the plan for final disposal for Class-B and -C wastes being generated in the remaining 36 states is less certain. The industry has indicated it will safely store wastes at generating sites until disposal access is available.[7]

To further illustrate this concern, of the 104 nuclear power plants currently in service, only 12 are in states with an operating LLRW disposal facility (i.e., South Carolina and Washington). The remaining 92 are in states that have will not have access to LLRW

[5] "Unimportant quantities" is a legal term that applies to source material defined in 10 CFR Part 40 ("Domestic Licensing of Source Material"). It refers to uranium- and/or thorium-bearing materials, in concentrations less than 0.05 percent by weight, that are deferred from regulation.
[6] The materials in the Introduction from its beginning through this paragraph has been taken and summarized from Ryan, M.T., M.P. Lee, and H.J. Larson, "History and Framework of Commercial Low-Level Radioactive Waste Management in the United States," NUREG-1853, U.S. Nuclear Regulatory Commission, Advisory Committee on Nuclear Waste (January 2007).
[7] Source: R. Andersen/Nuclear Energy Institute, Presentation to the Advisory Committee on Nuclear Waste & Materials (ACNW&M) at its 182nd meeting entitled "Near-Term Issues and Opportunities in LLW Management," dated September 18, 2007.

disposal for Class-B and -C wastes. Most new nuclear power reactors being proposed will not have access to either existing or proposed disposal sites (see Table II).

Table I. Existing LLRW Disposal Capacity vs. Future Need. Source: Adopted from J. Kennedy/NRC, presentation to the ACNW&M at its 185th meeting entitled "Strategic Assessment of NRC's Low-Level Radioactive Waste Regulatory Program," dated December 18, 2007.

LLRW Disposal Site	LLRW Generators	Future Need[a]
Barnwell (SC)	Atlantic Compact (3 states)	Class A: 300,000 ─ 800,000 ft^3/yr Class B/C: 4,000 ─ 12,000 ft^3/yr
Hanford (WA)	Northwest Compact and Rocky Mountain Compact (11 states)	Class A/B/C: 20,000 ─ 86,000 ft^3/yr
Clive (UT)	Remaining 36 States	Class A: 2,500,000 ─ 3,300,000 ft^3/yr
Site-not-identified	Remaining 36 States	Class B/C: 10,000 ─ 35,000 ft^3/yr

[a] Generation rate based on last 5 years of data

Table II. Proposed New Nuclear Power Plants, by State. Adopted from Nuclear Energy Institute Fact Sheet, dated December 2007.

State	Site	Number of Units/Design Type
Alabama	Bellefonte	2/AP1000
Florida	Levy Co. Turkey Point	2/AP1000 2/tbd [a]
Georgia	Vogtle	2/AP1000
Idaho [b]	Bruneau	1/EPR
Illinois	Clinton	1/tbd
Louisiana	River Bend	1/ESBWR
Maryland	Calvert Cliffs plus 2 other sites	3/EPR
Michigan	Fermi	1/tbd
Mississippi	Grand Gulf	1/ESBWR
Missouri	Callaway	1/EPR
North Carolina	Davie Co.	1/tbd
	Harris	2/APWR
Pennsylvania	Susquehanna	1/tbd
South Carolina [b]	Cherokee Co. Oconee Co. Summer	2/AP1000 1/tbd 2/AP1000
Texas [b]	Amarillo Bay City Comanche Peak Victoria Co.	1/EPR 2/ABWR 2/APWR 1/ESBWR
Virginia	North Anna	1/ESBWR

[a] Design to be determined.

[b] Note: Plants in South Carolina, Idaho, and Texas will have access to existing or proposed disposal facilities.

THE ADVISORY COMMITTEE ON NUCLEAR WASTE AND MATERIALS

For many decades, the NRC (and its predecessors) have relied on independent advisory committees such as the Advisory Committee on Nuclear Waste (ACNW) to review its regulatory activities.[8] In May 2006, the ACNW held a Working Group Meeting to obtain current information on commercial LLRW management practices and identify emerging LLRW management issues and concerns that might have a bearing on or improve the management of commercial LLRW. These issues and key questions addressed by the Committee during its Working Group Meeting were as follows:

- **Alternative Waste Classification.** *10 CFR Part 61.58 provides for the development of alternative systems for LLRW classification considering the characteristics of the wastes, disposal sites, and methods of disposal so long as there is reasonable assurance that the principle protection criteria are met.* ***Are there approaches to alternative classification that better accommodate the types and quantities of wastes being produced and disposed today?***

- **Metrics for Risk Assessment.** *Concentration and quantity are both important to any risk assessment. Concentration alone does not determine risk nor does quantity. Concentration is a convenient metric that is useful as a surrogate over a wide range, but for very dilute and very concentrated sources, it may not be as useful.* ***Are there better approaches to assessing risk at very low and high concentrations?***

- **Risk-Informed Regulation.** *Risk-informed regulation takes into account three significant questions related to risks:[9] (1) What can go wrong?, (2) How likely is it?, and (3) What are the consequences?* ***Can the approaches for risk-informed regulation be used to better classify, treat, and dispose wastes today? Can risk-informed approaches be used to better assess success and failure modes for key components, features, events processes and systems used to manage LLRW? Can deterministic approaches be thus avoided?***

To this end, two recent reports summarize possible directions forward to make commercial LLRW management better. For example, in their 2006 report, The National Academies [17] recommended:

[8] Before 1988, the Advisory Committee on Reactor Safety (ACRS) Waste Management Subcommittee reviewed the NRC's LLRW activities [13]. In April 1988, the Commission established the ACNW as a separate advisory committee to continue this oversight. In May 2007, the ACNW's name was revised to be the ACNW&M to reflect additional Committee oversight responsibilities in the area of nuclear materials licensing. The ACRS issued its first letter report on commercial LLRW management in April 1976. The ACNW issued its first letter report on LLRW in August 1988. Collectively, the ACRS, the ACNW, and the ACNW&M have commented on various LLRW management issues as well as the implementation of the NRC's LLRW regulatory framework in more than 40 letter reports. NUREG-1125 [14] and NUREG-1423 [15] contain copies of these letter reports and the exact text of the Committees' recommendations.

[9] See discussion in Kaplan and Garrick [16].

> **“Recommendation 2**
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> **The committee recommends that regulatory agencies adopt a risk-informed LAW system in incremental steps, relying mainly on their existing authorities under current statutes and using a four-tiered approach: (1) changes to specific facility licenses or permits and individual licensee decisions; (2) regulatory guidance to advise on specific practices; (3) regulation changes; or if necessary, (4) legislative changes.**
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> The committee advocates a stepwise, ‘simplest-is-best,’ approach to implementing risk-informed LAW regulation and management. Acting under their existing authorities, regulatory agencies and site operators can effect significant changes from the bottom up, beginning with changes to specific facility licenses, permits, or decisions. The balance among these approaches is best determined by the agencies with the authority for regulating LAW.
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> By changing licenses and permits, the burden of moving toward risk-informed practices is shared by generators, facility operators, and regulators. This includes characterizing waste and providing information to the public in advance of regulatory requirements. Good business practices can lead generators toward better waste prevention, minimization, and segregation if there is more flexibility in selecting options for managing and disposing wastes.
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> Effective changes can be made with regulatory guidance, regulations, and new legislation. Regulatory guidance is often developed to provide specific advice regarding practices or interpretation of regulations that define acceptable conditions or requirements. Examples include Branch Technical Positions and Regulatory Guides promulgated by the NRC staff.
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> Regulations are promulgated to implement controlling laws and statutes. Changes are often small but may occasionally result from larger initiatives. In addition, agencies can and do enter into Memoranda of Understanding (MOUs) to better align and clarify requirements where there is a shared regulatory responsibility. One example is the MOU between the NRC staff and EPA on decommissioning requirements for sites containing both radioactive and hazardous materials.
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> At the highest level of the four-tiered approach, new legislation should be targeted carefully to address a range of issues and should be balanced against the need for consistency and minimal disruption to established practices in the industry. For example, the Energy Policy Act of 2005 amended the AEA’s definition of byproduct material, which will lead to more consistent regulation of materials that pose similar risks.”

By contrast, in its 2006 letter to the Commission, the ACNW&M [18] stated the following:

"1. The Committee believes that there is no need to revise NRC's LLRW regulations found in 10 CFR Part 61 at this time. The Committee recommends that the Commission develop license conditions and regulatory guidance to better implement the provisions of 10 CFR 20.2002 and 10 CFR 61.58 which give specific authority to implement such guidance.

2. The Committee recommends that NRC develop guidance permitting management and disposal of unique and emerging waste streams. Such guidance should consider waste types and forms, packaging, and disposal site conditions in a way that is risk-informed and performance-based consistent with the performance criteria in 10 CFR 61.41 to 61.44 and 10 CFR 61.58, as appropriate.

3. The Committee recommends that NRC should encourage a more risk-informed approach to LLRW management that places greater emphasis on the radionuclide content of the waste rather than the waste source or origin.

4. The Committee recommends examining how NRC and the Agreement States are preparing to regulate potential increases in the storage of Class-B and -C LLRW if and when Barnwell closes to out-of-compact waste in July 2008 and no alternative options become available.

5. The Committee recommends that, because the waste classification provisions in 10 CFR Part 61 are referenced by and included in legislation and other regulations, it is important to identify and evaluate any unintended consequences from changes recommended in this letter. The Committee believes that the incremental changes and improvements suggested in this letter are unlikely to have such unintended consequences."

A Path Forward – Many solutions for LLRW management can be accomplished within the current licensing framework. Using a combination of license conditions, regulatory guidance, and regulations allows for risk-informed regulations that incorporate consideration of the changes in waste form and disposal technologies that have occurred since the late 1970's. These approaches offer flexible and risk-informed systematic approaches to address LLRW issues and challenges as they develop.

SOME OPPORTUNITIES TO RISK-INFORM LLRW MANAGEMENT

It is not clear when or how many new facilities will become available for the disposal of commercial LLRW. Nevertheless, as a result of its reviews, the Committee has identified several risk-informed approaches to the management of commercial LLRW that might help to alleviate the issue of disposal access for LLRW generators in the near term consistent with the existing NRC Part 61 regulatory framework.

Alternative Classification. The Commission decided to allow for the consideration of alternative LLRW classification schemes in 10 CFR 61.58, "Alternative Requirements for Waste Classification and Characteristics," on a specific (case-by-case) basis so long as compliance with the Part 61 Subpart C performance objectives can be demonstrated with reasonable assurance. In Section 61.58, the regulations acknowledge that alternative classification systems can be developed as long as the principle protection criteria are met. Such alternative classification could account for different waste types, physical forms, packaging, radionuclide concentrations and quantities not foreseen at the time the 10 CFR 61 regulations were first promulgated.

A Path Forward - The current classification system is only one approach to demonstrating compliance with the principle protection criteria. Alternate systems of classification are anticipated in current regulation. These alternative systems could take into account improvements in waste processing and waste form, waste packaging and disposal technologies.

Risk-Informed Regulation. The current 10 CFR Part 61 waste classification system relies on deterministic ultraconservative assumptions in unrealistic assessment scenarios to determine potential risks. In August 1995, well after the formulation of the 10 CFR Part 61 regulatory framework and its associated implementing guidance, the Commission published a Policy Statement on the use of probabilistic risk assessment (PRA) methods in NRC regulatory activities [19]. Can the approaches for risk-informed regulation be used to better classify, treat, and dispose wastes today?

A Path Forward – It is reasonable that the physical and chemical forms of waste, waste treatment and waste packaging, along with the site characteristics and engineering features of site design, operation, and closure can be taken into account in a manner that is risk-informed to better estimate performance. The approaches should account for realism in scenarios for performance of disposal systems site performance and intrusion after institutional controls are no longer maintained. These would improve the understanding of risks compared to the extreme bounding scenarios that currently support 10 CFR Part 61.

Metrics for Risk Assessment. Concentration is useful over a wide range, but it may not be as useful for very dilute and very concentrated sources, Are there better approaches to assessing risk at very low and high concentrations? Could small concentrated sources (that exceed Class-C limits) be disposed with robust packaging and be deemed appropriate with a risk-informed assessment of performance? In some cases, the quantities of radioactive materials in small discrete sources would be less much less than the quantities disposed in irradiated LLRW reactor hardware. Conversely, are there very low concentrations of radioactive materials, such as unimportant quantities of source material, that can be safely disposed in RCRA Subtitle-C or -D facilities without undue risk to public health and safety?

A Path Forward - Concentration and quantity are both measures of risk and need to be considered in performance assessments. Concentration is a convenient metric used in transportation and operational health physics assessments of LLRW. The risk from a disposal site is better characterized by considering the quantities of radioactive

materials disposed and the performance of the technologies used to contain them. Local concentration in given waste packages is not as useful a metric as total quantity of radioactive material disposed.

Improved Performance Assessment. In 2000, the NRC staff issued recommendations on how to conduct a LLRW performance assessment consistent with the Part 61 Subpart C performance objectives and the Commission's 1995 PRA Policy Statement. Those recommendations were published in NUREG-1573 [20] and included an extensive discussion of engineered barrier performance, including waste form.

A key feature of the Part 61 regulation is the waste form stability requirements set forth in 10 CFR 61.56(a). The Commission established these requirements to address some past performance issues at early LLRW disposal facilities. Based on past disposal experience, certain waste forms and processing options may reduce the potential for radionuclide dissolution and subsequent biosphere transport. All commercial LLRW classes are now subject to minimum waste form characteristics.

Since the publication of NUREG-1573, the durability of engineered barriers and LLRW waste forms and the credit they can be afforded in a performance assessment have improved.

A Path Forward – Performance assessments can be improved by considering realistic performance of engineered barriers, waste forms and waste packaging. Additionally, a better approach for a risk-informed performance assessment would be to consider behavior of the disposal system over a range of values for key parameters describing the features, events, and processes of a LLRW disposal site and that waste put into it and more realistic scenarios of human exposure over time.

The management of LLRW has been successfully achieved in the commercial sector in the Unites States. Additional successes can be achieved by taking advantage of past operating experiences as well as continuing improvements in LLRW treatment, packaging, and disposal technologies. Combining these successes and process improvements with risk-informed decision-making can perhaps improve the management of these wastes while at the same time making the regulatory process more transparent for practitioners, stakeholders, and the public.

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