Regulatory Change in Low Level Waste Disposal: Why Something Should be Done

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Abstract

The corner-stone of the NRC regulation of low level waste disposal is the three tiered classification system provided in 10 CFR 61.55 which was developed in 1980 through 1982. The classification system was intended to accommodate the broad range of site conditions attendant to 8-10 new regional disposal sites. It really didn't account for any particular site, although conditions and operating practices at the Barnwell site at the time served as an important reference. The regulation was also developed without a clear definition of what constitutes low-level waste. Low level waste continues as a definition of exclusion; that is, it's waste that's not high level waste or TRU waste.

Since the development of the regulation, no new LLW disposal sites have been opened. The Low Level Waste Policy Act was amended (in 1985) to encourage further site development but ultimately failed to produce the intended network of regional disposal sites. In addition, new research has updated the dose and risk factors for several radionuclides important to waste classification. The U.S. Nuclear Regulatory Commission (NRC) issued SECY 2007-180 describing the Commission's priorities on Low Level Radioactive Waste (LLRW) Policy. Task #4 states that the NRC will update the Branch Technical Position on Concentration Averaging and Encapsulation. Task #6 states that the NRC will develop Guidance Document(s) on Alternative Waste Classification (10 CFR 61.58). This comes in response to observations by the Advisory on Nuclear Waste as well as the US general accounting office that the current regulatory approach was "not risk-informed".

Generally, most power plant waste falls into the category of material contaminated with short half-lived radioactivity which would be acceptable for uncontrolled release after 300-500 years of isolation. Such waste is considered to be acceptable for near surface burial – at least, within the context of U.S. Regulations and should be the stated definition of Low Level Waste. Using this more definitive definition of LLW, this paper will examine how the various power plant waste streams conform to this definition and how using it would impact regulatory acceptance criteria for waste disposal.

INTRODUCTION

In a strategic assessment of practices and obligations toward the management of LLRW, the NRC placed high priority on two (out of seven) tasks that are of particular interest relating to the disposal of nuclear power plant generated radioactive wastes. These are 1) Update Branch Technical Position on Concentration Averaging and Encapsulation and 2) Develop Guidance Document on Alternate Waste Classification (10 CFR 61.58). The first of these items was addressed in EPRI Report 1016120, "An Evaluation of Alternative Classification Methods for Routine Low Level Waste from the Nuclear Power Industry" published in 2008. Highlights of this study were presented to the NRC in a meeting in June of 2008 and the study itself was provided to the NRC in January of 2009. The second of these items will be addressed in an upcoming EPRI report.

A Little History

The central premise of 10CFR61[1] was drawn from the direction of the Low Level Waste Policy Act of 1982 to promulgate regulations for the development for a series of regional disposal sites envisioned by the Act. In support of the regulations, model sites were theorized representing the four distinct US regions with varying populations, annual rainfall, transportation distances, etc. Using the anticipated source terms of the radioactive generators that would be expected to use the respective regional sites, model performance assessments were carried out to determine the effects on various population groups such as facility operators, waste transporters, people living along transportation routes, and persons living in the vicinity of the site.

There were three basic considerations to the NRC's evaluation:

- Protection of occupationally exposed workers and the public during operation of the facility
- Long-term environmental protection
- Protection of an inadvertent intruder

A fourth consideration was that the changes imposed by the regulatory initiatives should have a modest impact on disposal costs and disposal site operations. The cost estimates that were developed for the analysis assumed that significant changes to waste form or disposal practices would generate disposal costs that would be intolerable to the industry. Therefore, a waste classification system that accounted for large quantities of waste with minimal activity that could be disposed with minimal waste form restrictions at a minimal cost.

Up to this point there were no specific requirements for stabilization or for segregation of unstable wastes. Disposal practice at the time was to emplace waste in unlined trenches with minimal cover. The study determined that at least some of the waste required additional protection including deeper disposal and specific stabilization. Rather than place a blanket requirement for cover depth and stability (this was considered to be overly burdensome to the disposal sites operating at the time), lower activity waste was allowed to be disposed without stabilization under two meters of cover. The unstable waste had to be segregated from the higher activity wastes which were required to be physically stable. This led to the 3 tier classification system identified in 10 CFR §61.55.

Radiation exposure from the inadvertent intruder scenario were found to dominate the risk from Class A waste disposal and formed the basis for isotopes and concentration limits for Class A waste. Environmental factors dominated the risk from Class B and Class C waste primarily through groundwater

[1] Code of Federal Regulations, Title 10 Part 61, Licensing Requirements for Land Disposal of Radioactive Waste

pathways. Exposure modeling at the time gave no credit for waste form or disposal site design as a barrier to radionuclide entry into the environment. As a concession in the framing of the criteria, Cs-137 concentration limits were determined on the basis of a factor of 20 dilution across the segregated (Class A) trench. While this may be realistic in context of the actual radioactivity content, it is contrary to later restrictions on averaging placed by the NRC and fails to recognize that Cs-137 dominates risk following the end of the institutional control period. This dilution credit responded to disposal site practice and concerns expressed about the economic impact if a tighter rule was imposed.

The current classification criteria were developed as generic values that envelop the conditions that may be encountered at various disposal sites and were based on the most conservative site model. If the proposed disposal sites followed criteria as presented in §61.55 and could demonstrate that the protection levels sought in the regulations would be met through site selection, the classification system would assure safe operation. Furthermore, a standardized system of classification would reduce confusion both for the generator as well as for the disposal site operator. The generator would not have to be concerned with varying disposal requirements and the disposal site operator would be able to automatically determine how to disposition each package.

Directive to Change

While this classification system may offer some convenience, it is not "risk informed" which is the current standard for regulatory decision-making. The phrase "risk-informed decision-making" has been defined for NRC as follows:

A "risk-informed" approach to regulatory decision-making represents a philosophy whereby risk insights are considered together with other factors to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to health and safety.[2]

However, it is uncertain how a risk-informed approach could be applied toward the issue of waste classification and disposal. To be risk informed the classification system would have to be subjected to a quantitative risk assessment. Most of the radionuclide concentration limits provided to establish waste class are based on exposures to a hypothetical subsistence intruder who excavates into the site, exposing the waste, to construct a foundation for a house. The intruder remains to build the house, spread the excavated material, maintain gardens, and grow livestock for food and milk on the site. Therefore, the intruder analysis is a deterministic analysis. That is, it isn't evaluated as a probability of occurrence; it's assumed that it will happen. The intruder scenario is also completely dependent on the specific disposal model (unstabilized waste, thin 2 meter cover) used in developing the concentration limits. Furthermore, a risk based analysis could not be conducted on a universe of disposal sites as 10CFR61 was intended to apply. It would require focusing on a specific site with all of its attendant parameters and disposal configuration. This opens the prospect of site specific evaluation and the

[2] Nuclear Regulatory Commission (U.S.),"White Paper on Risk-Informed and Performance-Based Regulation," SECY-98-144, June 22, 1998

setting of site specific disposal conditions independent of following 10 CFR §61.58. The paragraph is reproduced here for convenience.

> **§ 61.58 Alternative requirements for waste classification and characteristics**.
>
> The Commission may, upon request or on its own initiative, authorize other provisions for the classification and characteristics of waste on a specific basis, if, after evaluation, of the specific characteristics of the waste, disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives in subpart C of this part.

This provision would allow an applicant to redefine concentration limits corresponding to a specific site and disposal configuration as long as the general performance requirements of 10CFR61 are met (i.e. 25 mrem/year whole body, 75 mrem/year to thyroid, and 25 mrem/year to any other organ).

While the §61.58 provision stands out in the regulation, it has not been used to develop an alternative disposal criteria for any commercial disposal site development. Classification in accordance with §61.55 is required for transfer of radioactive wastes per Appendix G of 10CFR20. Agreement states potentially licensing a disposal site must treat compliance with §61.55 as a "matter of compatibility"[3]. Notwithstanding these impediments, the NRC eschews the possibility of revising 10 CFR 61 directly and believes that clearer guidance toward implementing an application in accordance with §61.58 would facilitate new site development.

Regardless, the existing set of regulations contain a level of both ambiguity and specificity that does not provide for a risk-informed approach nor does it take into account the latest data on radiation risks.

What is Low Level Radioactive Waste?

Low-level radioactive waste (LLRW) for lack of a better definition is legally defined as waste that is not "high level radioactive waste, spent nuclear fuel, or byproduct material"[4]. This begs the larger question. What is low-level waste – really?

Since LLRW is defined by exclusion, a starting point, then, would be to identify what is not LLRW. High level waste (which is not LLRW) is waste which requires "permanent" isolation such as that provided in geologic structures[5]. Low level radioactive waste, one would therefore assume, is waste that does not require permanent isolation and would in some defined period of time render itself harmless (within the context of other environmental risks). It has historically been supposed that sufficient isolation of this waste was achieved with near surface burial. The Low-Level Waste Policy Act and 10CFR61 were constructed around this premise. In fact, the main purpose of the LLRWPA was to delegate responsibility for LLRW disposal under the assumption that it was acceptable for near surface disposal. The Act left the NRC the responsibility to classify which radioactive waste is LLRW.

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[3] SA-200, Compatibility Categories and Health and Safety Identification for NRC Regulations and Other Program Elements, US Nuclear Regulatory Commission, Office of State Programs
[4] Title 42 §2021 (12) (A), "The Low level Radioactive Waste Policy Act"
[5] Title 42 § 10101 (12)

Table 1 lists what is commonly considered to be LLRW and what is commonly considered to be not LLRW. It should be noted that some of the "not" LLRW may also be acceptable for near surface disposal subject to a specific determination of the suitability and the conditions of disposal. Since these are not LLRW in the context of the LLRW waste policy act, acceptance for disposal would be determined by the relevant disposal authority. Disposal classification in accordance with 10CFR61 for any of these "not LLRW" waste would be generally irrelevant.

Table 1 LLRW and Not-LLRW

Not Low-Level Radioactive Waste	Low-Level Radioactive Wastes

• Spent Nuclear Fuel
• Wastes resulting from the reprocessing of spent nuclear fuel
• Byproduct Material
    ○ Mill Tailings 11e(2)[6]
    ○ Waste Incidental to Fuel Manufacturing 11e(2)
    ○ Discrete source of Ra-226
    ○ Accelerator Wastes
    ○ Other Sources developed from NARM
• Transuranic (TRU) Wastes – Wastes Containing Concentrations of TRU not exceeding 10CFR61 Disposal Limits
• Greater than Class C Wastes
• Chemically Hazardous LLRW Wastes (Mixed Wastes)
• NORM, Naturally Occurring Radioactive Material
• Some Sealed Sources
• *Exempt Waste*
	• Nuclear Power Plant Generated Wastes (excluding Nuclear Fuel)
	    ○ Process Wastes (Resins, Filter materials, DAW)
	    ○ Expendable hardware
	    ○ Decommissioning Wastes including most activated hardware
	• Government
	    ○ Dry Solids
	    ○ Trash
	    ○ Absorbed liquids
	    ○ Biological
	    ○ Solidified chelates
	    ○ Sealed Source
	• Industrial Generated Wastes
	    ○ Miscellaneous solids and absorbed liquids
	    ○ Solidified oils
	    ○ Resins and filter wastes
	    ○ Biological wastes
	    ○ Discarded manufactures products
	• Hospitals and Medical Facilities
	    ○ Laboratory Wastes
	    ○ Biological
	• Academic
	    ○ Laboratory Wastes
	    ○ Dry solids
	    ○ Biological

Defining what is LLRW is a fundamental first step in setting reasonable standards for disposal site protection objectives. A working definition offered here, that is consistent with guidance published by the International Atomic Agency and adopted by other nations utilizing near surface disposal, is:

[6] Public Law 83- , The Atomic Energy Act of 1954, Mill tailings and waste incidental to extraction and concentration for source material content would be defined as byproduct material.

Low-level radioactive waste is material whose risk is dominated by short half life activity that would be rendered acceptable for uncontrolled release following a finite period of storage. Concentrations of long-lived activity would be limited to a disposal site average concentration of <10-100 nCi/gm TRU alpha.

By this definition all LLRW would suitable for near surface disposal providing 500 years isolation.

How Do Utility Wastes Compare With This Definition?

Utility LLRW is the dominant source of radioactivity in LLRW accounting for almost 90% of it, when considered in the context of all sources. Radioactivity in utility LLRW is dominantly short half lived activity with most of it disappearing after a few hundred years. Data collected by EPRI for the 2003-2006 time period of overall waste generation and key nuclide activities of utility process wastes are summarized in the Table 2, below. The values in Table 2 represent stream wide averages as shipped. The values do not include activated metal waste (These will be examined separately). No effort was made to segregate the material by 10CFR61 class. Actual disposal site concentrations would be lower.

Table 2 Annual Generation Rates of Radionuclides
Important to Classification Per 1000 MWe (Values Excluding Activated Hardware)

Parameter	BWR	PWR	Units
Volume	17264	8603	ft^3
H-3	5.9E+05	1.9E+05	mCi
C-14	7.0E+02	1.0E+03	mCi
Co-60	1.3E+05	1.6E+04	mCi
Ni-63	6.2E+03	5.5E+04	mCi
SR-90	2.3E+02	1.4E+02	mCi
Cs-137	1.7E+04	2.9E+04	mCi
TRU*	1.6E+01	3.8E+00	mCi

*Excludes Pu-241 and Cm-242

Wastes included in Table 2 generally contain a mixture of contaminant radionuclides including fission products, activation products, and TRU contaminants. Not included in the list are Technetium 99 (Tc-99) and Iodine 129 (I-129). These generally appear at such low levels that they are not reliably measured using radiochemistry. There is no evidence that any radiochemistry laboratory has reported anything other than a detection limit for I-129. In the case of Tc-99, while it is sometimes reported as a positive value in the radiochemistry reports, it is clear that unrealistically high values have been included in the database. Investigations sponsored by EPRI included mass spectroscopy measurements of I-129 and Tc-99, and C-14 of sample drawn from test columns installed at six PWR and four BWR power plants. Results[7] from these measurements were compared with industry averages reported from routine sampling and radiochemical analysis. These measurements indicated that reported concentrations for these radionuclides were 3 to 5 orders of magnitude higher than what was measured in the controlled

[7] D.E. Robertson, et al., "Concentrations and Behavior of 129I, 99TC, and 14C in Low-Level Radioactive Wastes from Nuclear Power Stations", Waste Management '91 Proceedings, Volume II, pp287-294

experiments. These high values significantly bias any treatment based on the database results. I-126 and Tc-99 are discussed in 10CFR61 specifically in relation to radionuclide risk. It is demonstrated that there cannot be sufficient release of these isotopes in solid waste streams to figure prominently in disposal risk. Even using higher values, however, these two radionuclides do not figure strongly in the risk assessment and averages remain well below the Class A limits.

The 10 CFR 61 concentration limits were derived to correspond to a common level of risk (i.e. that concentration that would result in 500 mrem/year to an inadvertent intruder). Using the activities from Table 2, values were decayed for varying time periods out to 10,000 years which is the maximum time period for evaluation of LLRW disposal facilities[8]. Concentration values calculated from Table 2 are divided by the Part 61 Class A limiting concentration and plotted on Figure 1. Note that in these waste streams, which include a composite of all utility waste streams, there are no other radionuclides that figure prominently in the classification calculation. For the first 300 years disposal risk is driven almost entirely by Cs-137 and Ni-63. After 500 years, only C-14 and TRU continue to stand as dominant risk contributors. Neither C-14 nor TRU in this mixture are ever more than about 10% of the Class A limits. We should remind ourselves that we are evaluating risk on the basis of an intruder scenario which is a short term exposure issue. Both C14 and TRU are evaluated in the context of long term risks to the general public. This analysis does not take into account site-specific factors that may affect dose.

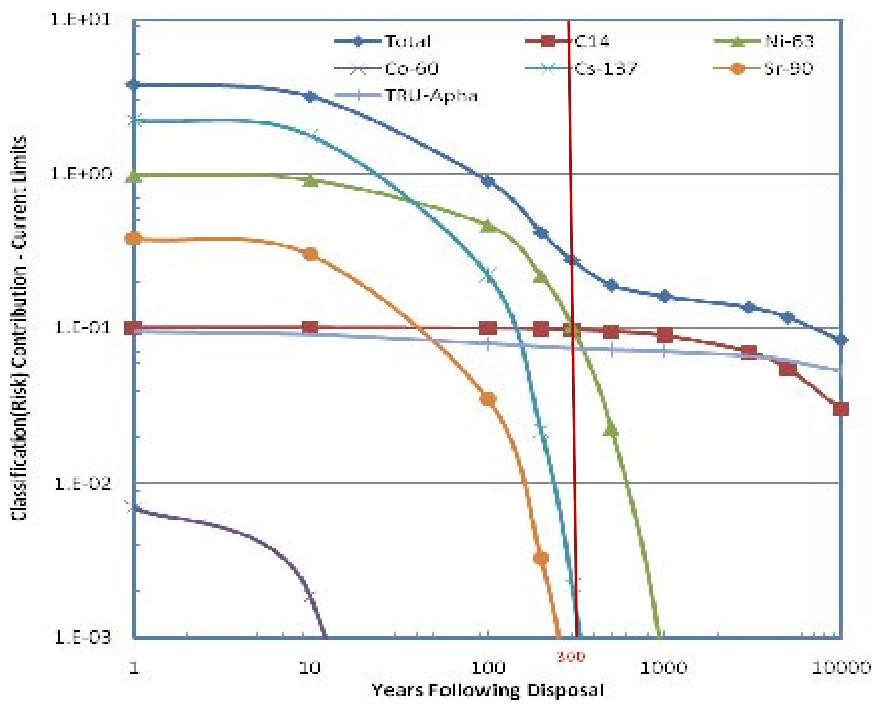

Figure 1 Relative Risk Versus Time for Classification-Limiting Radionuclides

[8] NUREG-1573 A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities, October 2000.

The first 100 years of the graph are within the expected institutional control period of the disposal site during which no public land use or inadvertent intrusion is expected. The next period, out to 300 years, is the time period for isolation of the waste from inadvertent intrusion based on waste form (stability) and deeper cover. [9] Given 300 years of isolation, which can reasonably be achieved with current disposal practices, overall risk is attributed almost entirely to C-14 and TRU alpha both of which are evaluated based on transport scenarios which are highly site dependent. Our source investigations have also shown that C-14 is systematically over-reported with the solid waste source term exceeding annual generation estimates before accounting for retention and alternate pathways.

What to Change and Why

The NRC, through the recommendations from GAO and ACNW, has opened a discussion of 10CFR61 that just a few years ago we would have thought extremely unlikely. Changing anything in the nuclear arena brings out competing interests and arguments from all corners. Establishing a rational, technically correct, and economically viable disposal policy provides a better foundation for progress even if all of those weighing in don't agree with it. If the nuclear industry, itself, doesn't weigh in on this opening, we simply leave it to industry opponents to define the policy. Even from within the industry there's a lot of trepidation to advancing this discussion. However, there are some issues with the 10 CFR 61 classification system that should be addressed.

<u>Inadequate Definition of Waste</u>

The lack of a definitive identification of what LLRW is creates a regulatory morass where it becomes difficult at best to develop true risk-based requirements that can be consistently applied because the source term is unknown. By defining radioactive waste by source or process allows radionuclides with similar hazards and dose consequences to be treated differently and inconsistently. A change to the regulations that defined LLRW based on level of hazard would make the development of risk and performance-based analyses easier, clearer, and assures public protection.

<u>Faulty Application of Generic Rules.</u>

The effort undertaken by the NRC to develop regulations for the disposal of LLRW was a landmark effort. The studies and the regulations established a framework that served as a model for the rest of the world. Aspects of the regulation are reflected in every program outside of the US that followed. However, generic rules intended to apply to everything generally don't particularly apply to anything.

The waste classification system described in §61.55 was meant to apply to the lowest common denominator as far as U.S. sites were concerned. The limits were based on what was believed would be the most restrictive disposal conditions and the least restrictive waste form conditions. Class A waste limits were based on an intruder scenario that assumed waste would be distributed in and indistinguishable from soil and that the initial disposal method would involve a minimum of cover (2 meters). The remaining waste classes required additional stability or deeper cover to achieve the same

[9] NUREG-0782 Draft Environmental Impact Statement on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste", USNRC, September 1981.

dose consequences. Given current disposal facility practices and designs, most of the intruder assumptions no longer apply and therefore the distinction between waste classes is essentially irrelevant with regard to the performance objective.

In order to ensure that limits written into law are applicable to a specific situation, the regulations should be modified to allow the flexibility to apply scientific and technical criteria to the final waste form and disposal environment to achieve the performance objectives (as originally intended). This disconnect is strongly visible in disposal site development that exceeds the base conditions of 10CFR61. The §61.55 limits are only relevant to the case of minimum cover and stability, which is not used at any of the current disposal facilities.

Cost/Benefit Overcome by Reality

The cost benefit analyses performed to justify the disposal model for 10CFR61 are completely disconnected from the current disposal reality. At that time, disposal site operating costs were the driving factor in the disposal analysis. Overall disposal costs were assessed to be on the order of $223 per cubic meter ($6.32 per cubic foot). A number of alternative disposal technologies were considered in the original environmental impact study (DEIS)[10]. The incremental costs associated with these technologies are shown in Table 3, below:

Table 3 Summary of Incremental Barrier Costs For Facility Design and Operation (Table S.7 from NUREG -0782, Volume I)

	Additional Disposal Costs (1980	
Type of Barrier	$/m3	$/ft3
No Barrier	0	0
Thicker cap - 3m of soil	1.59	0.05
Thicker cap - 3m of compacted clay	10.89	0.31
Layered waste disposal	37.73	1.07
Slit trench (10% of waste)	91.49	2.59
Caisson disposal (10% of waste)	216.45	6.13
Walled trench (10% of waste)	256.09	7.25
Walled trench (100% of waste)	160.99	4.56
Grouting—cement	60.46	1.71
Grouting--low-strength cement	46.86	1.33
Engineered intruder barrier	59.17	1.68
Intermediate depth burial	53-159	1.50-4.50
Mined cavity	327-654	9.26-18.52
Ocean disposal	710-2200	20.11-62.31
Space disposal	2,000,000.00	56,600.00

[10] NUREG-0782, "Draft Environmental Impact Statement on 10 CFR Part 61, 'Licensing Requirements for Land Disposal of Low Level Radioactive Waste'", US Nuclear Regulatory Commission, Washington, DC, Sept. 1981

A lot of attention was paid to disposal costs. Effectively it was decided to minimize the amount waste that would have been subject to additional barriers, so that the bulk of the volume would be disposed with no added barrier. Only a small volume, <10%, would then be subject to the additional cost. If we took the $6.32/ft^3 as the average disposal cost at the time of preparation of the DEIS, it would be equivalent to paying ~$60/ft^3 today (assuming 10% inflation rate). This compares with $400-500/ft^3 average disposal cost today (over $3000/ft^3 for some wastes). Today's costs are driven largely by the imposition of enhanced barrier requirements by Agreement State regulations; a situation that under current authorities and responsibilities will continue to exist regardless of any changes to 10CFR61. Furthermore most of the enhanced barriers are in current use at the disposal sites exist despite the fact that no benefit is credited. The actual cost drivers have little to do with the original cost/benefit analysis. In addition, the industry has been able to survive LLW disposal costs far in excess of the original estimates.

Individual Nuclide Limits Inconsistent with Dose Conversion Factors

Using fixed activity limits in a regulation doesn't admit improved technical knowledge (coming from either direction). DCF's and risk assessment factors have changed significantly since 10 CFR 61 was issued. The use of the more recent ICRP 72 and Federal Guidance Report (FGR) 13 dose and risk factors would result in considerably different activity concentrations that would result in the target dose limits of the regulation. Most radionuclides important to classification would have much higher limits. This particularly affects Ni-63 and Sr-90 which are often found to bear significantly on classification for nuclear power plant LLRW.

The DEIS placed great amount of importance on tracking certain highly mobile radionuclides which would readily be carried in groundwater. These included H-3, C-14, Tc-99, and I-129. 10 CFR 20 Appendix G requires that these radionuclides be reported on the waste manifest regardless of their activity or concentration. Dose and risk factors used now for these nuclides are much different than those used in 1980. In addition, a review of industry shipping data indicates that the reported concentrations are far below the regulatory limits for these nuclides. It makes no sense to set mandatory reporting requirements for radionuclides whose concentrations are orders of magnitude below their estimated limiting concentrations.

The NRC has been more responsive to DOE interests with respect to regulatory barriers, site-specific evaluations and concentration averaging rules than to the nuclear utilities. It would be fair, and technically defendable, to apply the same principles across the board and re-write the rules to remove the political compromises of the past.

Conclusion

LLRW disposal in the United States is at a crossroads. The current regulatory scheme was developed to solve the problem given a particular set of circumstances and the best scientific knowledge available at the time. Legislation in the years since the development of 10 CFR 61 has failed to produce the LLRW disposal sites envisioned at the time and the industry and the Country is left with a new reality and a new set of circumstances.

The NRC recognizes that these circumstances have changed and has taken on the challenge to review the existing set of regulations and potentially develop new ones. The development of new standards and regulations has some risk since the LLW disposal problem has roots in politics as much as technical issues. However, regulations based on the latest science and technology would have the benefit of truth without which no political victory can be achieved.

It's clear that the situation has changed, the science has progressed and the problem remains. Maintaining the status quo achieves nothing but to allow the political arguments to continue to dominate the discussion and risk further erosion of cost-effective disposal capability. Supporting changes to the disposal regulations has at least the potential to make change for the better.