How Low Can You Go? - 14669

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ABSTRACT

The Electric Power Research Institute (EPRI) is a non-profit organization with a mission to conduct research and develop and demonstrate advancements related to key issues and challenges facing commercial electricity generators on behalf of our members, energy stakeholders, and society.

Over the past two decades, EPRI has conducted research and identified innovative solutions that have substantially aided the industry in reducing the volume of low level-radioactive waste (LLW) generated during the operation of commercial nuclear power plants. Reduced LLW generation rates conserves precious disposal site space and provides continuity to our commitment to environmental stewardship. For waste that cannot be mitigated, EPRI has also provided comprehensive, detailed guidance to the industry on both the design and operation of interim LLW storage facilities supporting safe and event-free storage of LLW. Currently EPRI research is focused on the development of a technical basis to support implementation of updated, risk informed disposal regulations and guidance to increase disposal flexibility that facilitates safe disposal in lieu of long-term interim storage.

WASTE MINIMIZATION

EPRI uses a collaborative research model. That means the Institute uses input from engineers, scientists, professionals, and others across the industry to add depth, perspective and experience to our research and guidance. In the case of the guidance that was developed for waste minimization, oftentimes the original ideas had been implemented at one or more reactor sites when they came to the Institute's attention for consideration. EPRI members advised the Institute to evaluate and collate these industry best practices resulting in proven, detailed guidance for broader industry implementation. This was accomplished using a committee of industry subject matter experts to ensure that the best practices and lessons learned represented a broad and comprehensive experience base and to vet the recommendations for their potential impact and practical implementation.

The cumulative impact of this effort cannot be attributed to one single source or activity. Leading industry professionals were ultimately responsible for implementation of the practices that led to the volume reduction that has been observed. Economic factors were and continue to be a key factor in volume reduction efforts in concert with a robust industry effort to develop and implement generation and post-generation volume reduction options. The net effect is that the EPRI guidance and technical support coupled with industry input has resulted in widespread implementation of technology and process improvement options at both the domestic and international level.

DRY AND WET SOLID (CLASS A) MINIMIZATION

During the 1990's EPRI conducted research that targeted reduction of the volume of dry and wet solid LLW (Nuclear Regulatory Commission (NRC) Class A) that was generated by commercial nuclear power plants. The research resulted in a number of varying recommendations for reducing the generated volume of Class A LLW.

Key recommendations applied to both solid waste management and liquid purification system management. One-time use items such as plastic bags, shoe covers, duct tape and plastic floor coverings were generally replaced (at that time) with launderable or dissolvable items that generated less waste per use. Even plastic bags used to collect waste and laundry were replaced with launderable bags. Point-of-generation segregation of waste to facilitate the most optimized processing options was encouraged. Improved floor coatings that reduced the challenges with area decontamination efforts were applied, reducing the need for plastic floor coverings.

In the liquid waste area, leak control was central to reducing the volume of water that was generated requiring future processing. That, combined with more aggressive chemical use controls in the plant, resulted in lower resin generation associated with wastewater processing while simultaneously reducing the volume and activity for liquid effluent releases.

Technology transfer is another part of EPRI's mission. Site assessments for assistance with implementation of the recommendations continue to be conducted both within and outside the US. The graphic below depicts some of the assessments that were performed in the US. Assessments and related technical support have also been provided to plants in the United Kingdom, Korea, Japan, Spain, Brazil, Mexico, Germany, Canada, and South Africa.

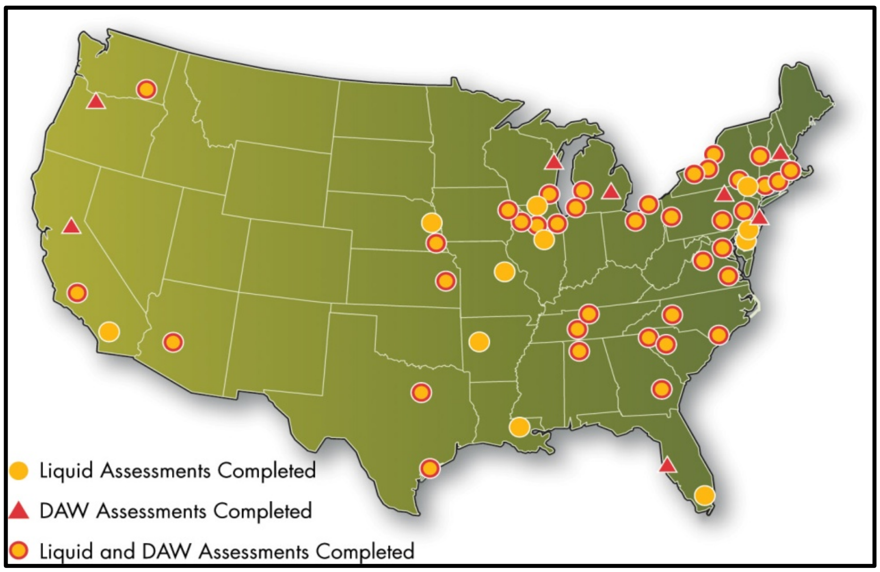
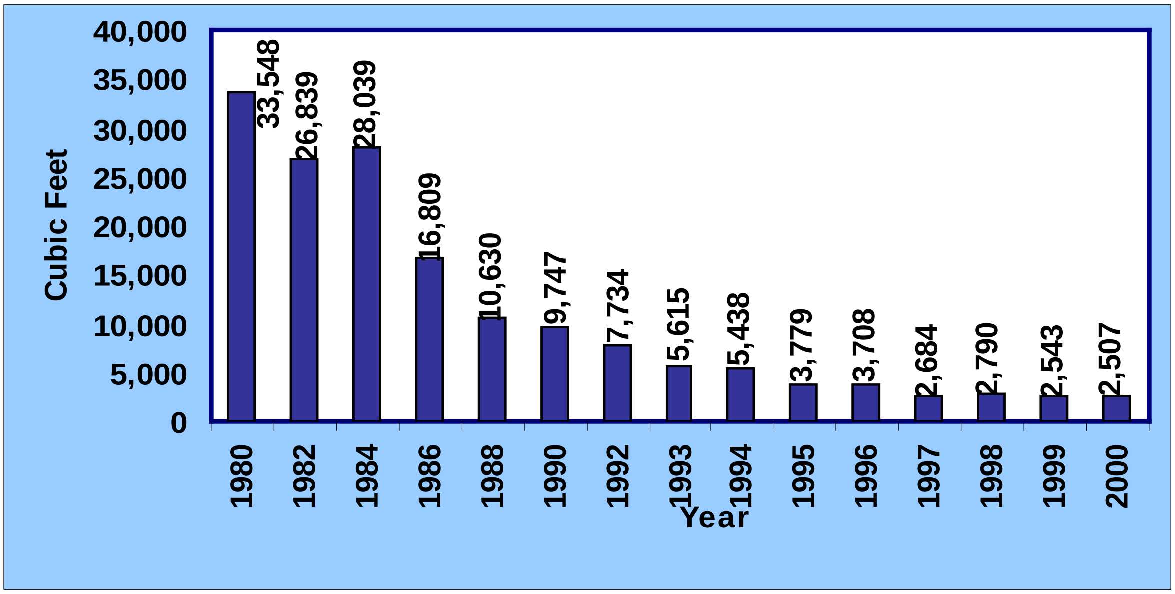


Fig. 1. EPRI US Solid and Liquid Waste Assessments.

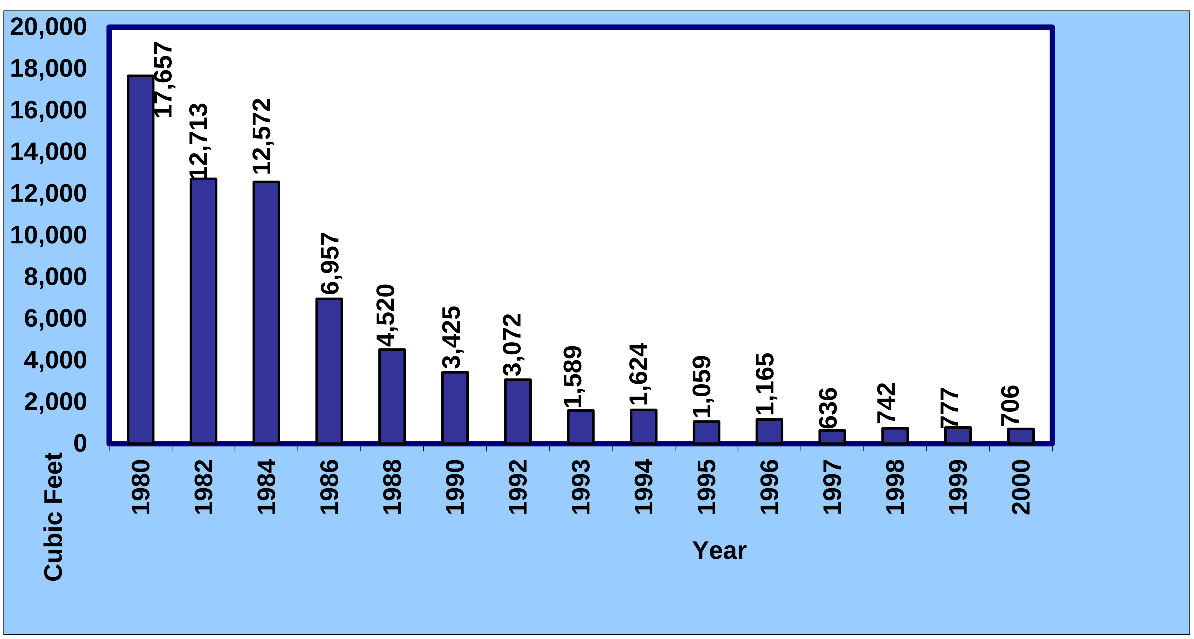
While performing these assessments, EPRI and industry experts participated in a weeklong site visit, during which site practices in the generation and management of LLW were reviewed against the recommendations in EPRI guidance. During these visits, many in the industry performed the illuminating task of "dumpster diving." Though not glamorous, it was always revealing to see exactly what comprised the largest volumes in the dry active LLW streams. This gave plant staff insight into which waste streams were contributing the most to dry active waste volumes so program improvements could be prioritized to target the highest impact items. The results of the site liquid and solid waste assessments were summarized and prioritized in a report for the site's use.

As the attached graphs demonstrate, implementation of the recommendations, along with economics and many independent efforts undertaken by the nuclear power plant staff, have had a very significant impact.



Source: Institute of Nuclear Power Operations (INPO) 01-003 & 96-002, World Association of Nuclear Operations (WANO) Performance Indicators for US Nuclear Utility Industry.

Fig. 2. Volume of Disposed Low-Level Solid Radioactive Waste – US Boiling Water Reactors (BWR)



Source: INPO 01-003 & 96-002, WANO Performance Indicators for US Nuclear Utility Industry

Fig. 3. Volume of Disposed Low Level Solid Radioactive Waste – US Pressurized Water Reactors (PWR)

INTERMEDIATE LEVEL (CLASS B & C) WASTE MINIMIZATION

Intermediate level waste (ILW)(NRC Class B and Class C) is generally comprised of ion exchange and filter media used for treating reactor coolant and spent fuel pool water or for reactor coolant shutdown crudburst cleanup efforts during refueling outages. While these waste streams had a high per unit disposal cost, the generated volume of these waste streams was relatively low. Also, these resins and cleanup efforts can affect outage schedules and duration, including critical path, and have widespread implications on the plant's source term and area dose rates. Because of these factors, ILW (Class B & C) generation rates were not closely examined in the 1990's.

The closure of the Barnwell Disposal Site to out-of-compact waste eliminated disposal options for this waste stream for 85% of the US generators. This created an immediate need to build and then operate interim on-site storage facilities for an unknown period of time and represented an unknown future disposal cost. The fear was the storage period could be long, requiring significant capital costs for construction of appropriate facilities and that disposal cost, when it became available, could be quite high. Further it was not known what the final disposal site waste acceptance criteria would be, thereby challenging definition of "best" interim storage waste form criteria.

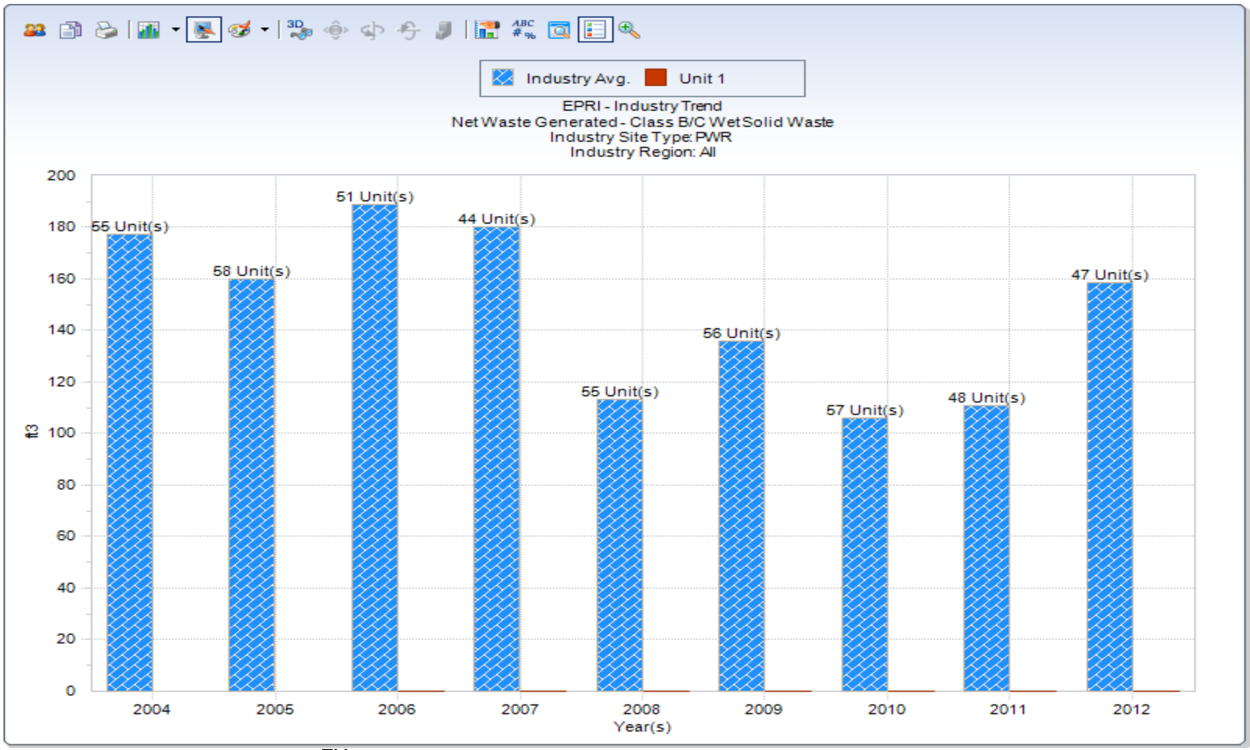
In the early 2000's, EPRI began conducting research on changes in operational practices that could reduce ILW or Class B and Class C waste generation. At the time, many in the industry viewed limiting the generation of Class B and Class C waste and satisfying chemistry and operational objectives as competing priorities. It was acknowledged that saving a few cubic feet (hundred liters) of resin, but having insufficient shutdown crudburst cleanup or on-line Reactor Coolant System (RCS) purification capabilities was an unacceptable trade-off.

Again, using the collaborative model, industry experts collected and analyzed best practices. The resulting best practices that were identified did in fact lead to lower generation of Class B and Class C waste or ILW while still supporting successful execution of chemistry and operational goals.

Some of the techniques that were identified included:

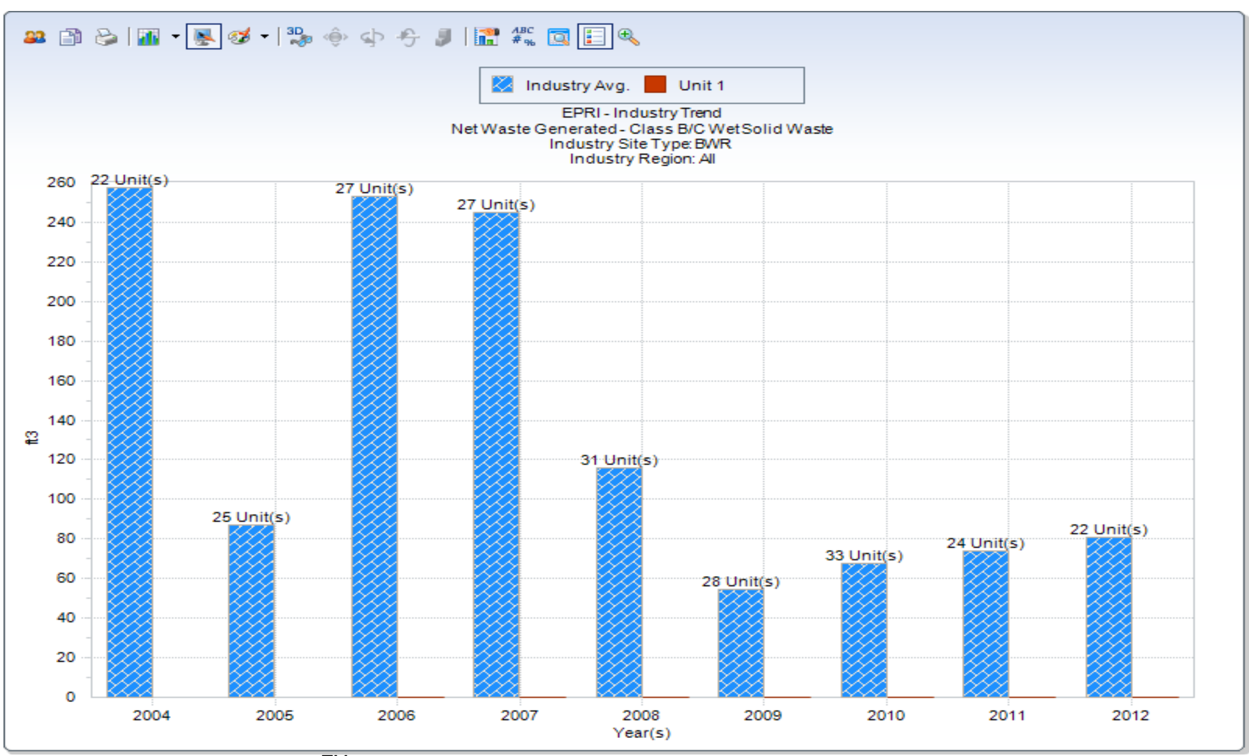
- reducing the volume of ion exchange media loaded into individual demineralizer vessels,
- on-line lithiation strategies for reactor coolant purification demineralizers,
- careful segregation of Class A (LLW) resin and filters from Class B&C (ILW) media,
- intermittent usage of some demineralizers instead of continuous usage (spent fuel pool),
- shortening the run time of some demineralizers and filters so that media change out occurred before the activity levels drove it to exceed Class B limits, and
- more effective implementation of the 10 CFR 61 classification guidance.

Similar to the efforts related to reduction of Class A waste, site assessments for assistance with evaluation of industry guidance and implementation of the recommendations were widespread in the US. Again, as illustrated in the following figures, implementation of the EPRI recommendations by nuclear power plants resulted in a significant decrease in the generation of Class B and Class C waste. This simultaneously had a very significant reduction in the associated waste disposal costs, often representing millions or tens of millions of dollars in cost savings over the plant life.



Source: EPRI RadBench™

Fig. 4. Class B&C (ILW) Waste Generation Trend – US PWR.



Source: EPRI RadBench™

Fig. 5. Class B&C (ILW) Waste Generation Trend – US BWR.

EPRI LEADERSHIP IN WASTE MINIMIZATION TECHNOLOGY DEVELOPMENT

In addition to the low and intermediate level waste (LILW) assessments and tech transfer activities described above, it should be noted that EPRI also continues to lead the development of LILW minimization technologies that have provided essential tools to the industry for reducing waste generation and disposal volumes. For example, EPRI's Decontamination for Decommissioning (DFD) process, which effectively removes surface contamination from large components, can dramatically reduce disposal volumes of these wastes. The EPRI DFD process has been widely used by the US and international industry. EPRI has also led the development and testing of selective radionuclide removal techniques, which have the capability to concentrate waste class driving radionuclides such as cesium, thus reducing overall disposal volumes.

In fact, one of the selective media that EPRI tested was utilized for Fukushima liquid waste volume reduction. Another example is the use of dissolvable clothing by the industry. EPRI was instrumental in the economic and technical evaluation of dissolvable clothing applications for the industry, fostering a major acceleration in the use of this solid waste volume reduction option. EPRI is continuing to research innovative technologies which can further reduce industry LILW volumes.

INTERIM ON-SITE LLW STORAGE IN THE US

Although Barnwell did not permanently close to out-of-compact generators until 2008, the potential for this to happen was recognized much earlier on. It was estimated that this would result in greater than 85% of the US industry with no access to a Class B and Class C waste disposal path, and interim storage of the waste would be required.

To assist the industry in preparing for this eventuality, EPRI updated and enhanced earlier EPRI storage guidance related to the construction and operation of interim on-site storage facilities. Elements of this guidance have been implemented at most US nuclear power plants to ensure safe and regulatory compliant facility design and operation.

Several complementary reports were generated outlining designs that incorporated storage both outside and inside of buildings and within and outside the protected area. Waste forms and waste containers were also examined. Finally, operating guidelines were developed to outline all the pertinent requirements associated with interim storage in one place. These were reviewed by the NRC and were recognized as an acceptable method for interim storage of waste.

The industry has safely conducted interim on-site storage of LLW since Barnwell's closure to out-of-compact waste. This was done through appropriate design and construction of storage facilities, proper selection of waste forms and containers, and proper waste and container monitoring and recordkeeping while in storage. EPRI research and industry collaboration has directly and significantly contributed to this outcome. With the opening of the Waste Control Specialists (WCS) disposal site in Texas and the existing access to Barnwell for a small number of generators, all US utilities currently have potential access to Class B and Class C waste disposal sites. However, until all the stored waste is disposed of, or if a utility or the industry loses access to a disposal pathway, the EPRI guidance and tools remain in place to safely execute interim storage.

The combined impact of these efforts has helped the industry to conserve precious disposal space, and when disposal is not available, to safely store the waste on site.

DEVELOPMENT OF TECHNICAL BASIS FOR INPUT TO THE REGULATORY REQUIREMENTS

In a separate but related effort, EPRI has been highly engaged in the NRC's revision process for NRC guidance and regulations associated with the disposal of LLW. These efforts have been used to provide a technical basis that targets risk informed regulations and guidance during the ongoing revision process.

As part of this effort, EPRI research spanning eight years has technically analyzed the characteristics, activity content, and hazards of the commercial nuclear power plant waste streams. This has helped to inform the process from a scientific and technical perspective to ensure the actual hazard is more fully understood. Risk informed disposal regulations and guidance is expected to increase disposal flexibility to facilitate disposal in lieu of onsite storage which EPRI views as beneficial to society.

These efforts began with collecting and sorting over 8,500 L/ILW (Class A, Class B, and Class C) package records provided by US commercial nuclear power plants for shipments between 2003 and 2006. This extensive dataset of actual US light water reactor (LWR) waste shipments formed the foundation upon which this research was built. The characteristics and the fractional mix of radionuclides in various LWR waste streams were now well documented. Between 2007 and 2012, EPRI has relied on this waste stream database to demonstrate many differences between the actual waste and the assumptions used to develop 10 CFR Part 61, such as:

- the LWR waste stream is much different in both volume and radionuclides,
- the L/ILW disposal volumes from LWRs are approximately 25% of what was envisioned,
- the quantity of highly mobile nuclides is far lower than assumed, and
- the dose conversion factors used in the Part 61 basis are not current thus introducing artificial barriers to facilitation of disposal.

In order to fully depict disposal site inventories and accurately model disposal site performance using accurate waste stream data and modern dosimetry, EPRI took this effort a step further by mining five years worth of non-utility waste data from the Department of Energy Manifest Information Management System (MIMS).

In 2009 EPRI projected the total utility and non-utility L/ILW through the decommissioning of the current US reactor fleet out to approximately 2060. The summed volume from this effort results in nine million cubic meters of waste (approximately 10% of the volume assumed in just one 10 CFR Part 61 regional disposal site) and includes all eligible L/ILW. This representative waste stream was used in performing disposal site performance assessment modeling in both wet and dry environments considering four cases:

- a base case with minimum cover and without durable containers or barriers,
- a barrier case that assumed a cap was installed to limit infiltration of water,
- a waste form case that limited the migration rate of radionuclides from waste, and
- a waste form and barrier case combined.

The results of the wet site models (most restrictive considering a resident farmer intruder) are depicted below indicating that even in the base case (no cap to prevent water infiltration), the postulated peak dose does not exceed 4 mSv/year. Adding a water infiltration cap (a generic practice) reduces the postulated peak dose to 2.5 mSv/year and adding additional waste form barriers (common practice) results in postulated peak doses <5% of the intruder performance objective.

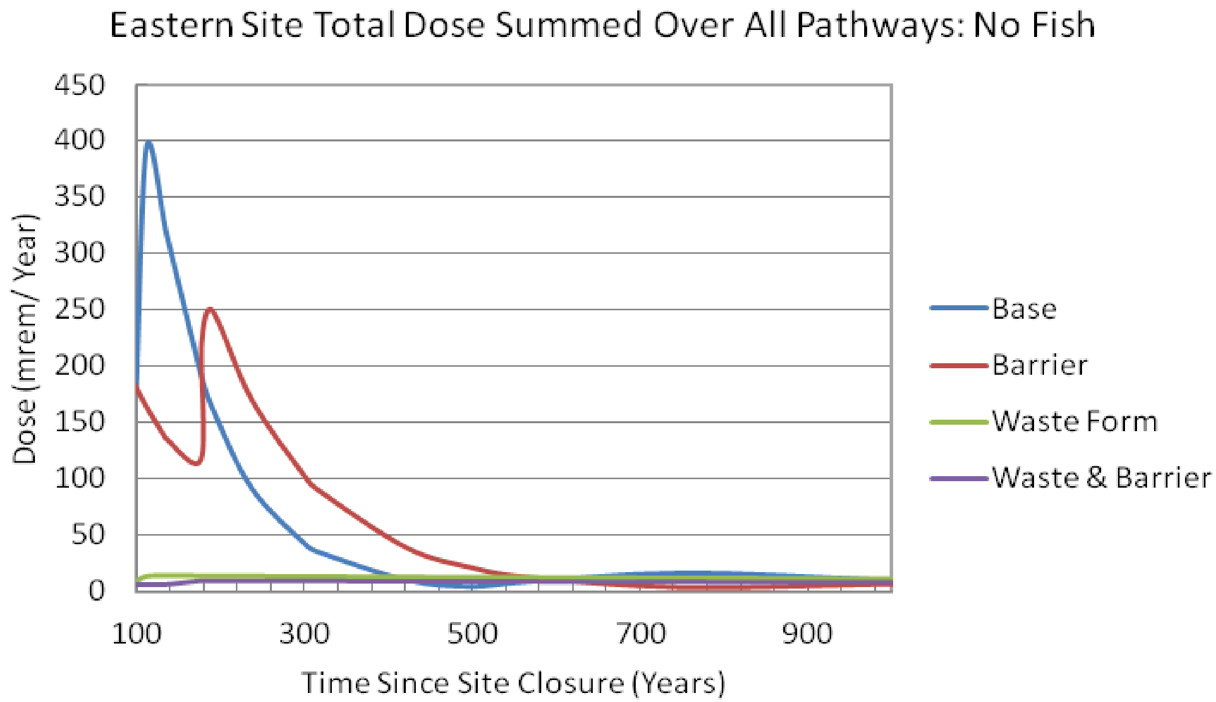


Fig. 6. Results of Wet Site Models.

This realistic yet conservative humid site resident farmer intruder model demonstrates that even with all the LILW from 48 years of disposal placed in one site, when using existing disposal practices of impervious trench caps (barrier) and some form of isolation (waste form), the peak postulated dose would be <5% of the 5 mSv/year performance objective. A similar semi-arid site model resulted in doses of far less than 0.01 mSv/year in all cases and is not depicted here.

More recent LILW research efforts have been focused in three subject areas. The first is improving the accuracy of LILW characterization through the use of constant scaling factors for some hard to measure radionuclides instead of using detection limit values as real numbers. The second area of research is investigating reasonable time frames for evaluating the risks presented by LILW as compared to international LILW practices and other hazards. And the third area is a comprehensive analysis of very low-level waste (VLLW) and how it might be applied more effectively in the US regulatory environment.

SUMMARY

Over two decades of EPRI research has been conducted related to L/ILW NRC Regulated (Class A, Class B, and Class C). The research has been designed with a three-prong approach.

First, generate as little of the waste as possible. The industry responded to guidance in this area with quite astonishing volume reduction results.

Second, for waste that is generated but does not have a disposal pathway, store it safely with no events. EPRI guidance has contributed to the industry doing just that since 2008.

Finally, development of a technical basis to help risk informed disposal regulations to increase disposal flexibility and reduce the need for interim storage of waste. This process is still ongoing, but EPRI research has directly contributed to both the revision of the NRC Branch Technical Position on Encapsulation and Concentration Averaging (expected to be published later this year in 2014) and to the ongoing revision of 10 CFR Part 61.