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Capacity Report on Low-Level Radioactive Waste

Report to the 87th Texas Legislature

Radioactive Materials Division
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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Capacity Report on Low-Level Radioactive Waste

A Report to the 87th Texas Legislature

Prepared by

Radioactive Materials Division

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Abbreviations and Acronyms

AEA – Atomic Energy Act

AEC – Atomic Energy Commission

ALARA – As Low as Reasonably Achievable

BWR – Boiling Water Reactor

Ci - Curies

CFR – Code of Federal Regulations

COL – Combined Operating License

CWF – Compact Waste Disposal Facility

DAW – Dry Active Waste

D&D – Decontamination and Decommissioning

DOE – Department of Energy

FR – Federal Register

FWF – Federal Facility Waste Disposal Facility

GTCC – Greater than Class C

HB – House Bill

HLW – High Level Waste

LAW – Low Activity Waste

LLRW – Low-Level Radioactive Waste

LLRWPA – Low-Level Radioactive Waste Policy Act of 1980

LLRWPAA – Low-Level Radioactive Waste Policy Amendments Act of 1985

MCC – Modular Concrete Canister

nCi - Nanocuries (one-billionth of a Curie)

NORM – Naturally Occurring Radioactive Material

NRC – Nuclear Regulatory Commission

PA – Performance Assessment

PWR – Pressurized Water Reactor

RCRA – Resource Conservation Recovery Act

RIA – Radiological Impact Assessment

SAFSTOR – Safe Storage

SB – Senate Bill

TAC – Texas Administrative Code

TCEQ – Texas Commission on Environmental Quality

TDSHS – Texas Department of State Health Services

TH&SC – Texas Health and Safety Code

TLLRWDA – Texas Low-Level Radioactive Waste Disposal Authority

TLLRWDCC – Texas Low-Level Radioactive Waste Disposal Compact Commission

TNRCC – Texas Natural Resource Conservation Commission

VLLW – Very Low-Level Waste

WCS – Waste Control Specialists, LLC

Executive Summary

Study on the Available Volume and Curie Capacity

In 2011, the Texas Legislature passed Senate Bill (SB) 1504 (82nd regular session). This bill charged TCEQ with conducting “a study on the available volume and curie capacity of the Texas Compact Waste Disposal Facility (CWF) for the disposal of party state compact waste and nonparty state compact waste” (referred to in this report as the “2012 Capacity Study”).

In 2013, the Texas Legislature passed Senate Bill 347 (83rd regular session). SB 347 amended Texas Health and Safety Code (TH&SC) Section 401.208 to require an updated capacity study by the end of 2016 (referred to in this report as the “2016 Capacity Study”).

In 2017, the Texas Legislature passed House Bill (HB) 2662 (85th regular session) which amended TH&SC Section 401.208 to require an updated capacity study every four years, starting in 2020 with this report. As codified in Chapter 401, Section 401.208, TCEQ is required to consider and make recommendations on the following topics[1]:

1) The future volume and curie capacity needs of party state and nonparty state generators and any additional reserved capacity necessary to meet those needs.

2) The calculation of radioactive decay related to the CWF and radiation dose assessments based on the curie capacity.

3) The necessity of containerization of the waste.

4) The effects of the projected volume and radioactivity of the waste on the health and safety of the public.

5) The costs and benefits of volume reduction and stabilized waste forms.

In considering these topics, TCEQ focused primarily on projections for future volume and curie capacity needs and on some of the new developments since 2016 affecting those needs. The five topics mentioned above were previously discussed in the 2012 and 2016 Capacity Studies. These topics remain unchanged and are updated to reflect any new information that has developed since the publication of the 2016 Capacity Study.

This report serves as an update to the 2016 Capacity Study and includes revised Low-Level Radioactive Waste (LLRW) volume and curie estimates from the Texas Compact facilities (references to Texas Compact comprise waste generated by both Vermont and Texas facilities). Information contained in this report for volume and curie estimates for nonparty utility generators is derived from effluent reports required by the Nuclear Regulatory Commission (NRC) from each utility and from

[1] Information collected for the initial capacity study in 2012 and in the subsequent 2016 study is used in this update based on its relevance and accuracy.

actual disposals that have occurred at the CWF since 2012. This data has been extrapolated over the assumed 35-year disposal site license period (15 years for initial license and two renewals of 10 years each) to provide annual estimates from nonparty utility generators.

In 2009, the CWF was licensed for an initial 15-year period, until 2024, with the possibility for one or more additional 10-year renewal periods. For purposes of the 2020 Capacity Study, the time period used was the initial 15-year period plus two renewal periods, extending the license until 2044. This was consistent with the CWF operator's original license application. The originally licensed volume and radioactivity were 2,310,000 cubic feet (ft^3) and 3,890,000 curies, respectively.

In August of 2014, TCEQ authorized an increase in volume capacity to 9,000,000 ft^3. The currently approved curie amount remains at 3,890,000 curies. However, the CWF operator has been authorized to "decay correct" the radionuclide inventory annually, allowing more overall curie disposal. Even though the CWF operator is authorized to decay correct their inventory, the total curies of the disposed (at time of manifest) waste at any time is not allowed to exceed the currently authorized amount of 3,890,000 curies at any time during operation or at closure. The CWF operator's license allows for requests for additional curie capacity as needed, up to a decay-corrected amount of 8,000,000 curies.

Volume and Curie Estimates

Volume and curie estimates from the Texas Compact nuclear utilities include both as-generated operational waste and decommissioning waste. These estimates were used to determine that approximately 852,509 ft^3 and 21,640 curies[2] of as-generated operational waste will be generated at Texas Compact nuclear power plants by 2044. As-generated operational waste estimates assume license extensions for the four operating nuclear power plant units generating operational LLRW at Texas Compact nuclear utilities through 2044. The Texas Compact nuclear utilities also provided estimates that approximately 1,894,737 ft^3 and 563,205 curies of decommissioning waste will be generated by Texas Compact nuclear utilities by 2044.

The total as-generated volume in cubic feet and the radioactivity in curies estimated to be generated in the Texas Compact by 2044 is less than the currently authorized volume and curie limits of the LLRW disposal license. This is indicated by updated information obtained from Texas Compact generators, along with four additional years of disposal information since the 2016 report. The disposal needs of the Texas Compact are presented in Table 1-1. The as-disposed volume is lower than the as-generated volume since a portion of the as-generated waste is eligible for:

[2] These volume and activity values are substantially lower in the 2020 report compared to the 2016 report because the operational waste generated by two planned reactors, which were included in the 2016 report, are not included in the 2020 report because the plans for these reactors have been cancelled.

- Disposal outside of the Texas Compact if an export petition for this waste is approved by the Texas Low-Level Radioactive Waste Disposal Compact Commission (TLLRWDCC).
- Disposal in a Resource Conservation Recovery Act (RCRA), Subtitle C hazardous waste disposal unit if the waste meets specific criteria.
- Volume reduction before disposal (discussed in Section 2).

Table 1-1. Future Capacity Needs of the Texas Compact Generators through the Year 2044

	As-generated Volume (ft^3)	As-generated Radioactivity (Ci)	As-disposed Volume (ft^3)
Utility Operational	852,509	21,640	193,093
Utility Decommissioning	1,894,737	563,205	752,447
Non-utility	166,513	6,206	37,715
Total	**2,913,759**	**591,051**	**983,256**

Nuclear Utilities

Based on the utility operational and utility decommissioning estimates for the Texas Compact Generators, the nuclear utilities generate in excess of 90% of the Texas Compact LLRW volume and more than 95% of the Texas Compact LLRW radioactivity (curies). The volume and curie percentage of LLRW generated by nuclear utilities for nonparty states is presumed to be the same as the percent values derived from the LLRW generation information for the Texas Compact states. This suggests nuclear utilities in nonparty states will likely be a majority of the LLRW in the United States, as opposed to academic, medical, or industrial sources.

As of the end of 2019, there were 77 nuclear power plant units operating and generating operational LLRW in nonparty states without a disposal site within their respective compacts. Table 1-2 shows the average annual generation rate of the primary waste streams and the total annual volume estimated to be generated by these nuclear utilities in nonparty states. The volumes presented in Table 1-2 are as-generated.

Due to the variability in volumes of waste generated from year to year, the annual generation rate was averaged for a 14-year period from 2005 through 2018 for estimating current annual volume generation rates and for volume projections through 2044. The span from 2005 to 2018 includes the ten years used (2005 to 2014) in the 2016 Capacity Report. The volumes represented in Table 1-2 include all classes of LLRW and combine both types of reactors: Pressurized Water Reactors (PWR) and Boiling Water Reactors (BWR).

Table 1-2. U.S. Industry Average Annual Operational LLRW Generation Rate for Nonparty Nuclear Utilities

LLRW Type	Annual Operational Volumes (ft^3)	Annual Operational Curies	Data Source
Spent Resins, Filter Sludges	123,490	70,610	NRC Radioactive Effluent Reports From 2005-2018
Dry Compressible Waste, Contaminated Equipment	1,301,714	6,687	
Irradiated Components	1,905	191,627	
Large Components, Other	247,338	2,759	
Total	**1,674,447**	**271,683**	

Using these totals and assuming all nonparty utilities remain in operation through 2044, nonparty states' nuclear utilities are estimated to produce roughly 42,000,000 ft^3 of operational LLRW by 2044. This represents roughly 93% of all as-generated LLRW in the U.S. between 2016 and 2044. This is a highly variable estimate and may be considered conservative given the uncertainty in license renewals, a utility's decision to decommission sooner than expected, and new technologies contributing to volume reduction.

Volume Reduction and Containerization

In 1981, the NRC identified volume reduction as a possible solution to the lack of disposal options. Since then, generators have applied various volume reduction techniques. In 2015, the NRC revised this position with its volume reduction policy statement. The effect of implementing volume reduction techniques on the LLRW generated in the Texas Compact should increase the unused capacity of the CWF for accepting nonparty waste.

Texas SB 347 amended TH&SC Section 401.207 during the 83rd legislative session to require that eligible nonparty compact waste be volume reduced by at least a factor of three. Volume reduction techniques greatly increase the available capacity for nonparty waste thereby preserving capacity for compact waste generators. Processing eligible waste typically involves volume reduction techniques that can result in volume reduction between a 3-to-1 ratio and a 100-to-1 ratio, depending on the waste and technique used.

This study also examines the necessity of containerization of LLRW. Containerization helps maintain the structural stability of the waste form leading to site stability. TH&SC Section 401.218 relating to Disposal of Certain Waste requires that Class B and Class C waste be disposed within a reinforced concrete container that is within a reinforced concrete barrier or within containment structures made of materials technologically equivalent or superior to reinforced concrete. The same requirement applies to nonparty compact Class A waste imported for disposal. Second, containerization provides shielding for workers from radiation during operations. Shielding allows the CWF to accept higher activity LLRW while keeping the radiation dose incurred by the workers as low as reasonably achievable (ALARA). Finally, containerization prevents and limits the possible movement of radionuclides into the environment.

Performance Assessment

Federal and Texas regulations require a Performance Assessment (PA) to evaluate the effects on human health and the environment in relation to volume and radioactivity to be disposed of in the CWF. A PA is a quantitative analysis used for demonstrating compliance with the following performance objectives:

- Protection of the general population from releases of radioactivity.
- Protection of individuals from inadvertent intrusion.
- Protection of individuals during operations.
- Stability of the disposal site after closure.

The evaluation of the long-term performance of the CWF included 110 radionuclides. The PA evaluated short-term (i.e., 30 years) exposure for workers and long-term (i.e., 1,000,000 years) exposure to the public. As part of the long-term evaluation, the modeling accounted for decay of radionuclides over the 1,000,000-year period of analysis. Note that the decay of radionuclides was not considered for the short-term worker evaluation because waste containing radionuclides may be accepted for disposal at any time during the operational period. The results from the PA long-term analyses demonstrate that the dose from the waste inventory (with decay accounted for) is well below regulatory limits.

Low Activity Waste

In certain cases, some portions of LLRW may fall into the category Low Activity Waste (LAW) often referred to as Very Low-Level Waste (VLLW). In July 2013, TCEQ amended the CWF operator's license to authorize the disposal of certain low activity Class A LLRW in their RCRA, Subtitle C hazardous waste disposal unit. The license amendment allowed the CWF operator to receive Class A LLRW and to make the determination if the waste would be eligible for disposal in the RCRA disposal unit using a TCEQ approved, concentration-based dose limit of one millirem per year to a member of the public up to 1,000 years after closure. This authorization allows a percentage of eligible LAW destined for the CWF to be disposed in the RCRA disposal unit, therefore preserving additional capacity in the CWF.

1. Introduction

1.1. Background

The history of Low-Level Radioactive Waste (LLRW) management in the United States (U.S.) is essential to understanding the concepts associated with CWF capacity in Texas. Prior to 1954, the U.S. Government controlled all atomic energy activities and facilities. However, the Atomic Energy Act (AEA) of 1954 created a framework for civilian participation in the atomic field and the industrial use of radioactive materials by private industry (including medical and academic) to be regulated by the U.S. Atomic Energy Commission (AEC). Under the AEA framework, many private entities began using radioactive materials in industry, medicine, science, and research. Because of the now widespread use of radioactive materials, the AEA also authorized the AEC to enter into an agreement with any state or group of states to perform regulatory inspections or other regulatory functions on a cooperative basis, as the Commission deemed appropriate. The State of Texas entered into such an agreement with the NRC (AEC's successor in 1975) and became an Agreement State in 1963.

To address the issue of the disposal of LLRW, Congress passed the Low-Level Radioactive Waste Policy Act (LLRWPA) (Public Law 96-573) (42 U.S.C. Sections 2021b-2021j) of 1980 and, as amended, in 1985. This act created a regional approach to LLRW disposal by providing that LLRW produced by non-DOE activities would be managed on a state or regional level. It encouraged the formation of regional compacts and in each compact one state would be designated as the host state for siting and constructing a LLRW disposal facility. Find a map of the NRC regional compacts. [3]

1.2. History of LLRW Disposal in Texas

In 1981, the Texas Legislature created the Texas Low-Level Radioactive Waste Disposal Authority (TLLRWDA) to site, develop, operate, close, and decommission a Texas LLRW disposal facility. In 1993, Texas, Vermont, and Maine approved legislation for the formation of the Texas Compact. By 1998, the TLLRWDA had chosen a site along with a design of the facility to dispose of LLRW. The Texas Natural Resource Conservation Commission (TNRCC) was given the authority to review the application but denied the license to the TLLRWDA in 1998. By 2000, the TLLRWDA was abolished. In 2002, the Maine Legislature passed emergency legislation to repeal the enactment of the Texas Compact, due to the early closing and decommissioning of the state's only nuclear reactor, Maine Yankee. The Texas Compact is now comprised of Texas and Vermont.

In 2003, the Texas Legislature passed HB 1567, amending TH&SC to allow privatization of the siting and operation of commercial LLRW disposal facilities for the Texas Compact and for federal facility waste. The legislation allowed for the creation of two privately run waste disposal facilities to be licensed by TCEQ. One facility, the Federal Facility Waste Disposal Facility, or FWF, disposes of federal facility waste, as defined by the LLRWPA of 1980 and its 1985 amendments, subject to certain specified conditions. The other adjacent facility, the CWF, disposes of commercial LLRW from Texas

[3] www.nrc.gov/waste/llw-disposal/licensing/compacts.html

Compact generators and nonparty compact generators. After five years of technical review, TCEQ Executive Director offered a draft license and the draft Environmental Analysis for public comment and opportunity for a public hearing. On September 10, 2009, TCEQ Executive Director issued a LLRW disposal license to Waste Control Specialists, LLC (WCS). The CWF was licensed in 2009 for 15 years until 2024; however, the total lifespan of the facility is 35 years, the original 15-year term plus two 10-year renewal periods. Construction of the CWF was completed in 2012 and TCEQ authorized the commencement of disposal operations at the CWF on April 25, 2012 with the first waste shipment being received on April 27, 2012.

As a result of SB 1504, TH&SC Chapter 401, Section 401.207 allows for a system of importation of nonparty waste into the CWF. The TLLRWDCC was established primarily to oversee importation and exportation of LLRW in and out of the Texas Compact. The TLLRWDCC promulgated revised rules (2015) in 31 Texas Administrative Code (TAC) Chapter 675 regarding its authority for importation and export of LLRW. In conjunction with the TLLRWDCC, TCEQ reviews proposed import petitions and provides written certification that imported LLRW is authorized for disposal under the disposal site license. In 2013, the Texas Legislature passed SB 347 (83rd regular session) amending Section 401.207, providing for the license holder of the CWF to dispose of not more than the greater of:

1) 1,167,000 curies of nonparty compact waste; or

2) an amount of nonparty compact waste equal to 30% of the initial licensed capacity of the facility; and

3) not more than 275,000 curies of nonparty compact waste in any fiscal year.

Additionally, SB 347 also amended Section 401.207 to require that the license holder of the CWF not accept nonparty LLRW unless it has been volume-reduced by, at least, a factor of three.

1.3. History of LLRW Disposal Outside of Texas

The first commercial site for the disposal of LLRW opened in Beatty, Nevada, in 1962 and closed in 1992. Within the next ten years, five more sites opened in Washington, Illinois, South Carolina, New York, and Kentucky. Between 1975 and 1979, three of the six commercial LLRW disposal sites in the U.S. closed. The site at Sheffield, Illinois, was closed when it was at capacity and the site operator withdrew an application for site expansion. Two other sites, located at West Valley, New York and Maxey Flats, Kentucky, were closed because of operational and water management problems.

The states hosting the three remaining sites, located in Beatty, Nevada; Richland, Washington; and Barnwell, South Carolina, grew concerned over the volumes of LLRW being sent for disposal. Over time, these states closed or restricted the use of the commercial LLRW facilities to generators within their respective compacts or jurisdictions. In 1990, Envirocare of Utah began operations accepting only Class A waste. In 2004, Envirocare was sold and ultimately became Energy Solutions after several acquisitions. Prior to the CWF opening and the recent changes in law and rules regarding importation of nonparty LLRW, most facilities throughout the United States that generate LLRW had few to no options for safe disposal of their LLRW.

1.4. Definition and Classes of Low-Level Radioactive Waste

LLRW is defined by what it is and by what it is not in TH&SC, Section 401.004.

LLRW is radioactive material that is:

- discarded or unwanted and is not exempt by board rule adopted under TH&SC, Section 401.106;
- waste as defined by Title 10, Code of Federal Regulations (10 CFR) Section 61.2;
- subject to concentration limits established under 10 CFR Section 61.55, or compatible rules established by the Texas Department of State Health Services (TDSHS) or TCEQ, as applicable; and
- disposal criteria established by 10 CFR or established by the department or commission as applicable.

LLRW is not:

- high-level radioactive waste;
- spent nuclear fuel;
- by-product material as defined by paragraph (20)(B) - (E) of 30 TAC §336.2;
- naturally occurring radioactive material (NORM) waste; or
- oil and gas NORM waste.

LLRW is classified for disposal according to waste classification tables set forth in 10 CFR Section 61.55. Regulatory classification of LLRW is comprised of Class A, Class B, Class C, and Greater Than Class C (GTCC). Class A LLRW accounts for approximately 91%[4] of LLRW volume generated in the U.S. and contains the lowest levels of radioactivity. Classes B and C make up the remaining 9% percent with Class B being approximately 7% percent and Class C approximately 2% percent of the LLRW volume. Conversely, Classes B and C contain the highest levels of radioactivity making up roughly 75% of the total radioactivity for all classes. Subsequently, Class A with the largest volume, accounts for 25% of the total radioactivity. Figure 1-1 illustrates the comparison between class volumes of waste and total radioactivity per class. LLRW that exceeds the radionuclide concentration limits specified for Class C waste is not generally acceptable for near-surface disposal unless specific authorization is obtained. Such waste, usually referred to as GTCC, is waste for which waste form and disposal methods must be different and, in general, more stringent than those required for Class C waste. GTCC makes up less than 1% of the volume but also has higher concentrations of radioactivity. Currently, GTCC is not allowed for disposal in

[4] These percentages are based on utility waste from the NRC Radioactive Effluent Reports from 2005-2018. Waste from utilities have a higher percentage of Class B/C waste than non-utilities. However, since non-utility waste is only 5% of the activity of all of the LLRW generated, using the data from utilities does not have a significant effect on the final average values of the amount of Class A and Class B/C waste.

the State of Texas and will not be evaluated in this report. All classes of LLRW may contain either short-lived or long-lived radionuclides, or a combination of both.

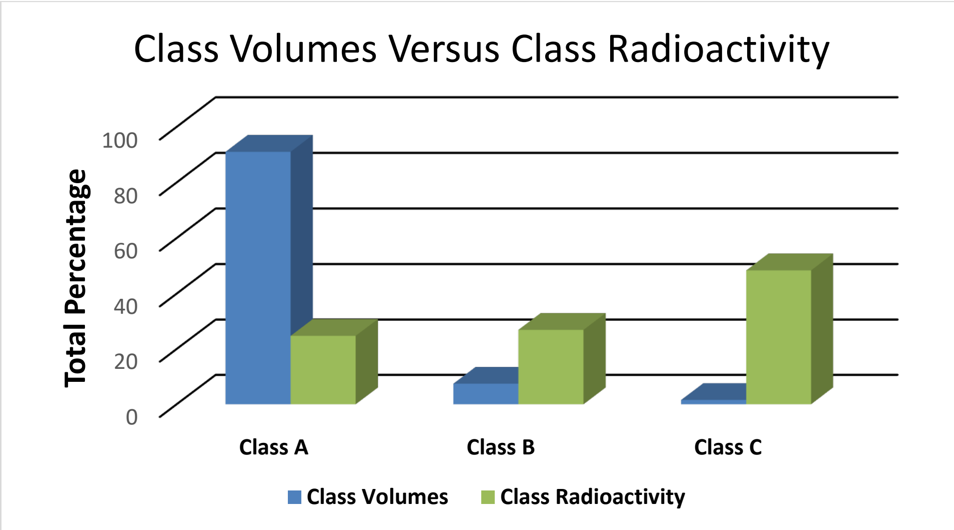


Figure 1-1. Comparison of Waste Class Volumes to Waste Class Radioactivity

TCEQ has adopted similar LLRW classification requirements and radionuclide concentration limits for each class. The NRC classification method was based on analyses in which doses to an inadvertent intruder were used to develop concentration limits for certain radionuclides. Hence, the waste classification scheme using limiting concentrations provides safeguards to protect an inadvertent intruder. TCEQ has adopted LLRW classification requirements that are equivalent to the NRC's with one exception; the NRC waste classification tables do not include radium-226 (^{226}Ra). The Class C limit for ^{226}Ra in 30 TAC Section 336.362, Appendix E is 100 nanocuries per gram (nCi/g). The purpose of inclusion of a ^{226}Ra concentration limit in the TCEQ waste classification tables was to provide an additional layer of safety for inadvertent intrusion and to meet performance objectives over the long-term.

The various classes of LLRW require increasing controls commensurate with their increasing radioactivity as required by TCEQ statutes, rules, and the CWF license conditions. Class A LLRW is only required to meet the minimal institutional control requirements because it is of a lower concentration. Class B LLRW has a higher concentration of key radionuclides than that of Class A LLRW and its waste forms must meet more rigorous requirements to ensure stability after disposal. The physical form and characteristics of Class B LLRW must meet both the minimum and additional stability requirements intended to ensure that the waste does not degrade and affect the overall stability of the site through slumping, collapse, or other failure of the disposal unit, thereby leading to an increase in water infiltration. Further, Class B waste must be placed in a reinforced concrete canister or an equivalent alternative for disposal.

Class C LLRW has the highest concentration of key radionuclides acceptable for near-surface disposal and its waste forms not only must meet the more rigorous requirements to ensure stability, but also requires additional measures at the disposal facility, such as burial depth and engineered barriers, to protect against inadvertent intrusion. The physical form and characteristics of Class C LLRW must meet both the minimum and additional stability requirements. Like Class B LLRW, Class C LLRW must be placed in a reinforced concrete canister or a technologically equivalent alternative for disposal.

LLRW is generated from various economic sectors and activities that involve radioactive materials in locations such as:

- Nuclear power plants (not including spent fuel);
- Hospitals;
- Laboratories;
- Industries that manufacture and use radioactive materials;
- Institutions of higher learning; and
- State and local governments.

1.5. LLRW Volume and Radioactivity Projections

In 2011, The Texas Legislature passed SB 1504, which charged TCEQ with conducting "a study on the available volume and curie capacity of the CWF for the disposal of party state compact waste and nonparty compact waste.[5]" TH&SC Chapter 401, Section 401.208 requires TCEQ to consider and make recommendations on:

- the future volume and curie capacity needs of party state and nonparty state generators and any additional reserved capacity necessary to meet those needs;
- a calculation of radioactive decay related to the CWF and radiation dose assessments based on the curie capacity;
- an investigation of the necessity of containerization of waste;
- the effects of the projected volume and radioactivity of the waste on the health and safety of the public; and
- the costs and benefits of volume reduction for LLRW and stabilized waste forms.

The 2012 Capacity Study was published in November 2012. In 2013, the Texas Legislature passed SB 347 (83rd regular session) amending Section 401.208 to require an updated capacity study by the end of 2016. The 2016 Capacity Study was published in November 2016. In 2017, the Texas Legislature passed HB 2662 (85th regular session) amending Section 401.208 to require an updated capacity study every four years, starting in 2020 with this report. In addition to the statutory elements of the capacity study stated above, this report also discusses other topics having a direct effect on capacity, such as volume reduction and alternative disposal options for LAW or VLLW.

Volume and radioactivity projections for this report were based on relevant data from the 2012 and 2016 capacity studies and updated information provided by the compact

[5] Party state compact waste means LLRW generated within the Texas Compact and nonparty compact waste means LLRW imported into the Texas Compact from nonparty states by approval from the TLLRWDCC.

utilities. The nonparty utility updates were obtained from each individual utility's annual Radioactive Effluent Reports which are required by the NRC and available on the NRC's website. These effluent reports span a fourteen-year period from 2005 to 2018. Additional data was obtained from waste disposal at the CWF that has occurred between 2012 and 2020.

Four active nuclear utility units generate in excess of 90% of the Texas Compact LLRW volume and more than 95% of the Texas Compact LLRW radioactive inventory as compared to non-utility generators.

2. Future Volume and Curie Capacity Needs

2.1. Current Nuclear Utility Landscape

There are currently 96 operating power reactor units in the U.S., which includes two new units that have begun construction since the 2016 capacity report. The 96 operating units consist of 64 PWRs and 32 BWRs. There are fifteen operating units in states within other compacts that have a disposal site available within their respective compacts. There are four operating units within the Texas Compact that have the CWF for disposition of waste. The remaining 77 operating units will have only two options for disposal of operational waste, the CWF in Texas and the disposal site in Clive, Utah.

As of the end of December 2019, and to provide perspective on future volume considerations, 18 units are still operating on their original license and 78 units have been granted license renewals. By 2044, all but 20 licenses of the currently licensed units are set to expire. This includes both Texas Compact and nonparty state utilities. License renewals may or may not be granted based on further evaluation by the NRC. Due to the uncertainty in whether license renewals will be granted, no estimates for decommissioning wastes from nonparty utilities will be presented.

Currently, there are 18 units going through various phases of decommissioning. Two units were not included in this count since they are expected to be decommissioned by the end of 2020. Six of the units are currently, or will soon be, undergoing dismantling and decommissioning. Twelve of the 18 units are in Safe Storage (SAFSTOR). This is a decommissioning method in which the unit is placed and maintained in a condition that allows for the safe storage of radioactive components of the plant and subsequent decontamination to levels that support license termination. Of the 18 units, 13 are planning for license termination prior to 2044.

2.2. Nuclear Utility Waste Types and Streams

Utility waste types can be divided into three general categories: dry waste, process waste, and decommissioning waste. Dry and process waste are considered operational waste, so the waste types analyzed in this report will be operational LLRW and decommissioning LLRW. Waste types with similar characteristics generally can be managed in a similar manner. For the purposes of this report, party and nonparty utility operational waste information was categorized as:

- Spent resins, filter sludges, evaporator bottoms, etc.
- Dry compressible waste, contaminated equipment, etc.
- Irradiated components, control rods, etc.
- Other (large reactor components and associated equipment)
- Low activity exempt quantities of secondary resins, sludge, and oily sludge.

It is expected that wastes assigned to these waste streams are likely to exhibit similar physical and chemical characteristics regardless of the generator.

2.2.1. Operational Waste

The dry active waste category consists of four waste streams:

- Compactible trash
- Non-compactible trash
- Non-fuel reactor components
- Sealed Sources

Process wastes (or wet wastes) are those generated from processes common to nuclear utilities. Under both federal and TCEQ disposal regulations and as required by the CWF license, any wastes from wet processes would have to be treated to remove free liquids before they could be accepted at the CWF for disposal. Examples of process or wet wastes are:

- Various types of spent resins
- Various types of filter sludges
- Process filters
- Evaporator bottoms
- Absorbed liquids

2.2.2. Decommissioning Waste

Decommissioning waste is generated when facilities cease operations, decontaminate, and dismantle structures and equipment. Decommissioning enables other beneficial land uses once the site is released for unrestricted use. For example, when a nuclear power facility permanently ceases operations, any waste that cannot be decontaminated must be disposed of as decommissioning waste. This waste stream is called Decontamination and Decommissioning Waste (D&D) and can consist of piping, tanks, ancillary components, steam generators, reactor vessels, pumps, and valves. This equipment can vary dramatically in size. For example, a typical BWR vessel is cylindrical in shape and is approximately 73 feet in height and 22 feet in diameter. Similarly, a typical reactor vessel for a PWR also is cylindrical in shape and is approximately 41 feet in height and 15 feet in diameter. Decommissioning volumes vary between a BWR and a PWR, with a BWR generating a larger volume of D&D due to the design and functionality differences as compared to a PWR.

2.3. Non-Utility Waste Types and Streams

Non-utility LLRW makes up a relatively small percentage of all LLRW generated. Non-utility LLRW is generated from activities in the academic, industrial, and medical sectors. Non-utility waste streams are primarily composed of, but not limited to, the following:

- Dry active waste (DAW), which includes:
    - compactible waste, e.g., personal protective clothing, paper, plastic, glass
    - non-compactible waste, e.g., concrete, soil, contaminated tools, organic material
    - sealed sources
- Biological waste

- Absorbed liquids
- Machine parts and equipment
- Gauges
- Medical items that have been in contact with radioactive material

2.4. Low Activity Waste

LAW or VLLW is a subset of LLRW that represents approximately 10% of all Class A waste. LAW does not have a statutory or regulatory definition, but generally identifies wastes that contain some residual radioactivity, including naturally occurring radionuclides, which can be safely disposed of in authorized hazardous or municipal solid waste landfills. Such waste possesses a small fraction of the hazard of waste at the Class A limits in 10 CFR Part 61. The CWF licensee was granted authorization on January 17, 2014, to exempt LAW specifically for disposal in their RCRA disposal unit. The waste concentration limits for this exemption were determined by conducting a radiological impact assessment (RIA) to demonstrate that a member of the public would not be exposed to more than one millirem per year for 1,000 years after closure, assuming the RCRA disposal unit was completely filled with waste at the concentration value determined for each radionuclide. The RIA was incorporated into the licensee's PA model which is used to calculate dose to members of the public after closure of the CWF. The RIA sub-model was used for these calculations but modified to account for the differences in the two disposal facilities. The concentration limits for LAW disposed in the RCRA facility are not allowed to exceed 10% of the Class A limit with the exception of radium-226, which is set at 50% of the Class A limit. This option provides a lower cost alternative to LLRW disposal. The volume and activity data of LAW disposed by WCS at their RCRA facility cannot be used in this study since it contains radioactive waste that is not eligible for disposal at the CWF.

2.5. Texas Compact Utility Operational Volume and Radioactivity Estimates

To calculate the estimated party state volumes and activity of LLRW, information was gathered from the 2012 and 2016 Capacity Studies, updated volume and curie generation rates from Texas Compact utilities, and current disposal data from disposals that have occurred at the CWF since 2012. Estimates through 2044, the life span of the CWF, were based on updated annual generation rates and decommissioning data from the Texas Compact utilities.

There are currently two operating Texas Compact utilities consisting of four PWR units and one Texas Compact utility consisting of one BWR unit that is in decommissioning. The non-operating unit has ceased generating operational waste and is only generating decommissioning waste now and in the future.

The licenses for one of the nuclear utilities (two units) within the Texas Compact are set to expire prior to 2044. The last of the two licenses expires in 2033 and it is assumed that each utility will operate until their license expires and then commence with decommissioning.

Table 2-1 provides the total operational as-generated volume in cubic feet and curies estimated to be generated between 2020 and 2044 for both Texas Compact utilities. One of the Texas Compact utilities has two different licenses that will expire for each individual unit in 2030 and 2033. For this study and preservation of capacity, it is anticipated that operational waste and curies would be generated up to those dates and decommissioning would begin after 2030 and 2033. The other Texas Compact utility has two operating unit licenses set to expire in 2047 and 2048. Again, it is expected that operational waste and curies would be generated up to those dates and decommissioning would begin after 2047 and 2048. Operational waste generated after 2044 is not included in the values of Table 2-1. The possibility does exist that a Texas Compact utility may request license extensions from the NRC. To capture these potential operational volumes and curies through 2044 the current annual average generation volume and annual average curies was used to estimate future volumes and curies. One of the utilities has an annual generation rate of 10,503 ft^3 and 264 curies. The other utility has an annual generation rate of 23,904 ft^3 and 387 curies. The Texas Compact utilities also provided estimated total volume and activity values, which are shown in the tables. Table 2-2 provides total operational as-generated volumes and curies up to 2044 assuming the utility whose licenses expires in 2030 and 2033 receive license renewals for operations beyond 2044. The data provided in Table 2-2 serves as a bounding estimate of Texas Compact utility operational waste that could be potentially generated throughout the life of the CWF. All operational volumes and curies represent waste classes A, B, and C combined.

Table 2-1. Texas Compact Utility Operational Volumes and Radioactivity through 2044 without License Extensions

Type	Operational Volumes (ft^3)	Operational Curies
Utility One[6]	120,780	5,691
Utility Two[7]	597,604	9,674
Totals	**718,384**	**15,365**

Table 2-2. Texas Compact Utility Operational Volumes and Radioactivity through 2044 with License Extensions

Type	Operational Volumes (ft^3)	Operational Curies
Utility One[8]	254,905	11,966
Utility Two[9]	597,604	9,674
Totals	**852,509**	**21,640**

[6] Total reflects volumes and curies for two operating units through 2030 and 2033
[7] Total reflects volumes and curies for two operating units through 2044
[8] Total reflects volumes and curies until 2044 for two operating units with license extensions
[9] Total reflects volumes and curies until 2044 for two operating units

All data presented in Tables 2-1 and 2-2 represent as-generated volumes and not as-disposed volumes. It is important to note that more than 90% of all operational volumes presented in Tables 2-1 and 2-2 are comprised of Class A LLRW. The volume of Class A is approximately 775,783 ft^3. The volume of Classes B and C combined is approximately 76,726 ft^3. Several factors, in terms of volume, may play a key role in greatly reducing operational volumes. First, Texas Compact utility operational Class A LLRW may have other disposal pathways besides the CWF. In some cases, Texas generators have sought export authorization for disposal pathways outside of the Texas Compact. Second, Class A LLRW is the most amenable for volume reduction and, in some cases, treatments can achieve reductions as great as 100 to 1 (100:1). Last, 10% of all Class A LLRW contains low enough radioactivity or concentrations that it can be considered LAW and would be eligible for disposal at a RCRA disposal site.

As an example, and to provide context for as-disposed volumes, a waste generator may apply some or all the previous volume reduction factors mentioned above. To illustrate this point, assume a hypothetical case presented in Table 2-3 which uses information from Table 2-2. Conservative assumptions are that 50% of the Class A LLRW is shipped to a disposal site outside the Texas Compact, volume reduction achieved a 3:1 efficiency, and 10% is eligible for disposal in a RCRA disposal unit. The result indicates nearly an 85% reduction from as-generated volumes of Class A LLRW over the term of the CWF license. Class B and C waste stream reductions are possible but limited based on the waste stream composition. Volume reduction will be discussed further in Section 6. Because Class A waste has relatively lower levels of radioactivity it was conservatively assumed that curie totals for as-generated and as-disposed will remain the same.

Table 2-3. Hypothetical Case - As-Disposed Volumes of Texas Compact Utility Operational Class A LLRW through 2044

Factor Affecting Volumes	As-Generated Operational Volumes (ft^3)	Remaining Volumes (ft^3)
Initial Volume of Class A	775,783	775,783
Low Activity Waste (10%)	775,783	698,205
Disposed Outside Texas Compact (50%)	698,205	394,102
Volume Reduction (3:1)	349,102	116,367
As-disposed Total		**116,367**

2.6. Texas Compact Utility Decommissioning Volume and Curie Estimates

For the 2016 Capacity Study, updated decommissioning waste volume and curie estimates were provided by all Texas Compact utility generators for the term of the CWF license extending until 2044. The licenses for each of the four units that are currently in operation are set to expire in 2030, 2033, 2047, and 2048. The possibility exists that the utility with a license set to expire before 2044 may seek license extensions from the NRC prior to expiration of the current licenses. These utilities may also decide to cease operations before the license expiration date. Due to the difficulties in predicting estimates because of those unknown factors, it was presumed for this study that all four currently operating utilities will cease operations and decommission prior to 2044. The one BWR in the Texas Compact has ceased operations, and is currently being decommissioned, scheduled to be completed by 2030. Some of the decommissioning waste from the BWR has already been disposed.

All four of the units in operation are PWRs. Typically, BWRs produce a larger volume of LLRW upon decommissioning because steam is produced directly within the reactor pressure vessel itself. The steam is then capable of spreading radioactive activation and fission products throughout the system including piping, turbine housing, steam condenser units, pumps, and anywhere else water can accumulate. Conversely, PWRs typically produce less waste because of the separate steam generation loop; this allows contaminated water within the core loop to remain separate from the overall system.

Two of the PWRs in the Texas Compact have a unique design which produces an additional volume of decommissioning waste that some other power plants do not have. The volume reported by this non-conventional utility is pre-volume reduction. The reported estimated decommissioning volumes and curies through 2044 are presented in Table 2-4.

Table 2-4. Texas Compact Utility As-Generated Decommissioning Volumes and Radioactivity Estimates through 2044

Unit	Decommissioning Volume (ft^3)	Decommissioning Curies
Utility in Decommissioning	27,252	27,190
Utility One	579,574	246,657
Utility Two	1,287,911	289,358
Total	**1,894,737**	**563,205**

Based on historic decommissioning of nuclear power plants, it is important to note that approximately 5% of all structures and equipment will be sufficiently contaminated to require disposal as LLRW or LAW. This is dependent on the type of reactor, the amount of secondary waste generated during decommissioning, and efforts in decontamination and contamination control by each individual utility. Radioactivity is normally higher in a limited number of components because radiation interaction with certain metals makes them radioactive. It should also be noted that past decommissioning efforts indicate that, in some cases, significantly large volumes of decommissioning waste generated would be eligible for disposal as LAW in an authorized RCRA disposal facility. Volume reduction techniques applied to decommissioning waste are limited due to the composition and structure of the waste forms. To illustrate potential as-disposed volumes of decommissioning waste through 2044 a hypothetical case is presented in Table 2-5. It was conservatively assumed that

10% of the Texas Compact utility decommissioning waste would be eligible for disposal as LAW at a RCRA disposal site, 25% would be disposed of outside the Texas Compact, and a volume reduction of 2:1 is achieved. Because Class A waste has relatively lower levels of radioactivity it was conservatively assumed that curie totals for as-generated volume and as-disposed volume will remain the same.

Table 2-5. Hypothetical Case - As-Disposed Volumes of Texas Compact Utility Decommissioning Class A LLRW through 2044

Factor Affecting Volumes	As-Generated Decommissioning Volumes (ft^3)	Remaining Volumes (ft^3)
Initial Volume of Class A	1,724,211	1,724,211
Low Activity Waste (10%)	1,724,211	1,551,790
Disposed Outside Texas Compact (25%)	1,551,790	1,163,842
Volume Reduction (2:1)	1,163,842	581,921
As-disposed Total		**581,921**

2.7. Texas Compact Non-Utility Volume and Radioactivity Estimates

LLRW from Texas Compact non-utility generators is primarily from the three economic sectors: medical, academic, and industry. Volume and curie data for non-utility generators is presumed to remain unchanged from the 2012 Capacity Study. As illustrated in Figure 2-1, the Texas Compact non-utility operational waste comprises approximately 12% of all volume generated within the Texas Compact while the remaining 88% is operational utility volume. Similarly, the Texas Compact non-utility curies amount to roughly 5% of all curies generated within the Texas Compact while utility curie amounts make up the other 95%. The data gathered for non-utilities represents total as-generated volumes and curies by summing an estimated annual generation rate from Texas Compact non-utility generators through 2044. The totals are provided in Table 2-6.

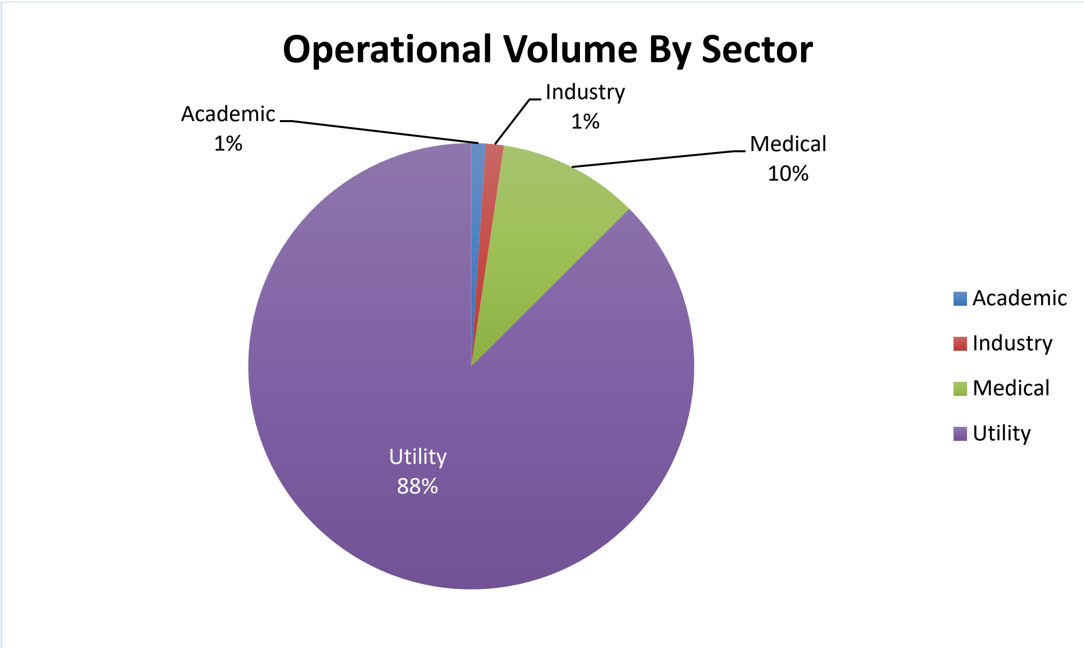


Figure 2-1. Texas Compact LLRW Generated by Each Economic Sector

Table 2-6. Texas Compact Non-Utility As-Generated Volumes and Radioactivity Estimates through 2044

Sector	Volume (ft^3)	Radioactivity (Ci)
Academic	13,677	17
Industry	17,530	5,249
Medical	135,306	939
Total	**166,513**	**6,206**

The totals presented in Table 2-6 represent as-generated waste volumes. Using conservative assumptions, a hypothetical case for volume reductions is presented in Table 2-7. The same waste class variability illustrated in Figure 1-1 applies to Texas Compact non-utility waste with 91% being Class A and the remaining 9% being Class B and C. The hypothetical case assumes that of the 91% of Class A, 10% will be eligible for disposal as LAW, 50% will be disposed outside the Texas Compact, and an applied volume reduction technique achieves a 3:1 reduction. Again, these volume reduction factors result in nearly an 85% volume reduction of all Class A Texas Compact non-utility waste generated. Because Class A waste has relatively lower levels of radioactivity, it was conservatively assumed that curie totals for as-generated volume and as-disposed volume will remain the same.

Table 2-7. Hypothetical Case - As-Disposed Volumes of Texas Compact Non-Utility Class A LLRW through 2044

Factor Affecting Volumes	As-Generated Volumes (ft^3)	Remaining Volumes (ft^3)
Initial Volume of Class A	151,527	151,527
Low Activity Waste (10%)	151,527	136,374
Disposed Outside Texas Compact (50%)	136,374	68,187
Volume Reduction (3:1)	68,187	22,729
Remaining Volume Disposed		**22,729**

2.8. Texas Compact Volume and Radioactivity Totals

The estimated LLRW volume and curie needs of Texas Compact generators through 2044 was obtained from the previous table values by simply summing utility operational volumes, utility decommissioning volumes, and non-utility volumes. The total as-generated and as-disposed volume and curie estimates are provided in Table 2-8. The as-disposed estimate totals include volume-reduced Class A with Classes B and C volumes added back into the totals. The Class B and C waste is not expected to be volume-reduced. The results indicate that the Texas Compact volume and curie needs are well below the current license limits of 9,000,000 ft^3 and 3,890,000 curies.

Table 2-8. Texas Compact Volume and Radioactivity Totals through 2044

	As-Generated Volume (ft^3)	As-Generated Radioactivity (Ci)	As-Disposed Volume (ft^3)
Utility Operational	852,509	21,640	193,093
Utility Decommissioning	1,894,737	563,205	752,447
Non-utility	166,513	6,206	37,715
Totals	2,913,759	591,051	983,256

2.9. Disposed Volumes and Radioactivity at the Compact Waste Disposal Facility

The CWF began accepting waste in April 2012. The data presented here represents disposed volume and curies from 2012 to present. The volume and activity, as reported on the waste manifests, of waste disposed at the CWF since the first waste shipment in April 2012 are shown in Tables 2-9 and 2-10 and sorted by Texas Compact and imported, respectively. The values were obtained from a database maintained by WCS which contains disposal data up to the end of 2019. This was compared with similar data obtained from the monthly and quarterly receipt and disposal activities report, through the end of 2019, that WCS is required to submit to TCEQ. The data from the database is used in Tables 2-9 and 2-10 because the monthly receipt and disposal activities report only contains total volume and activity data and is not broken down by waste class.

Table 2-9. Texas Compact and Imported LLRW Volume Disposed at the CWF

Compact Volume (ft^3)

Year	Class A	Class B	Class C	Annual Totals
2012	2,472	4	8	2,484
2013	4,361	974	12	5,347
2014	3,234	1,805	256	5,295
2015	1,378	1,030	155	2,563
2016	2,591	509	704	3,804
2017	2,054	639	291	2,984
2018	2,221	999	539	3,759
2019	9,246	744	148	10,138
Totals (ft^3)	27,557	6,704	2,113	36,374

Import Volume (ft^3)

Year	Class A	Class B	Class C	Annual Totals
2012	0	4,981	3,125	8,105
2013	488	6,470	2,239	9,298
2014	22,338	6,362	6,086	34,786
2015	11,557	8,621	1,743	21,920
2016	2,893	4,030	2,096	9,018
2017	2,693	3,954	2,504	9,151
2018	845	6,658	2,315	9,818
2019	19,080	3,219	1,931	24,230
Totals (ft^3)	59,894	44,295	22,039	126,325

Table 2-10. Texas Compact and Imported Radioactivity Disposed at the CWF

Compact Activity (Ci)

Year	Class A	Class B	Class C	Annual Totals
2012	590	0.7	11	602
2013	142	462	2	606
2014	151	1,083	396	1,630
2015	49	492	264	805
2016	198	171	24,318	24,687
2017	28	122	416	566
2018	9	909	1,471	2,389
2019	181	526	49	756
Totals (Ci)	1,348	3,766	26,927	32,041

Import Activity (Ci)

Year	Class A	Class B	Class C	Annual Totals
2012	0	18,739	36,563	55,302
2013	10	28,292	92,022	120,324
2014	2,052	10,824	37,854	50,730
2015	1,356	6,156	34,883	42,395
2016	288	4,637	97,512	102,437
2017	100	4,183	34,625	38,908
2018	60	9,735	199,107	208,901
2019	581	5,782	88,415	94,778
Totals (Ci)	4,447	88,348	620,981	713,775

For disposals outside the Texas Compact, Energy Solutions operates a disposal facility in Clive, Utah that is available for Class A LLRW disposal. The export petitions to the TLLRWDCC are available online and contain volume and activity data for LLRW generated in the Texas Compact that was requested to be exported for disposal outside of the Texas Compact. Table 2-11 contains the volume and activity of all Texas Compact waste for which the TLLRWDCC granted an export petition for disposal. The volume and activity in the petitions may be greater than the amounts disposed. The estimated volumes of Texas Compact waste disposed outside of the Texas Compact, as determined by the export petitions, are roughly double the volumes presented by the hypothetical cases presented in Tables 2-3 and 2-7. However, the amount of overestimation in the export petitions is not known. The estimated hypothetical volume disposed through 2044 outside the Texas Compact is 417,286 ft^3 while the actual estimated volume disposed extrapolated for an additional 25 years to 2044 is 1,137,815 ft^3.

Table 2-11. Texas Compact Waste Volume Approved for Disposal Outside of the Texas Compact

Year	Total Volume (ft^3)	Activity (Ci)
2015	54,359	N/A[1]
2016	46,589	2.8
2017	29,905	0.8
2018	46,352	7.4
2019	50,358	9.6
Total	**227,563**	20.6[2]

1. Total activity values are not available for export petitions issued in 2015.
2. This value is the total activity only for the years 2016 to 2019.

The volume and manifested radioactivity data from WCS' monthly receipt and disposal activities report was plotted monthly in Figures 2-2 and 2-3, respectively. The figures illustrate that the waste disposed contains a waste stream in which the volume or activity for some months deviate significantly from the average value. The eight-year span of data shown in the figures is sufficient to obtain a reasonably approximate average LLRW disposal rate despite these large volume or large activity waste disposal events, which are usually waste generated from decommissioning activities.

Roughly 80% of the total volume of LLRW disposed in the CWF to date is nonparty compact volume while the remaining 20% is Texas Compact volume. Also, 96% of the total radioactivity disposed in the CWF is nonparty compact curies while the remaining 4% is Texas Compact curies. Figure 2-4 illustrates the volume and radioactivity comparison between Texas Compact and nonparty compact LLRW disposed between 2012 and the end of 2019.

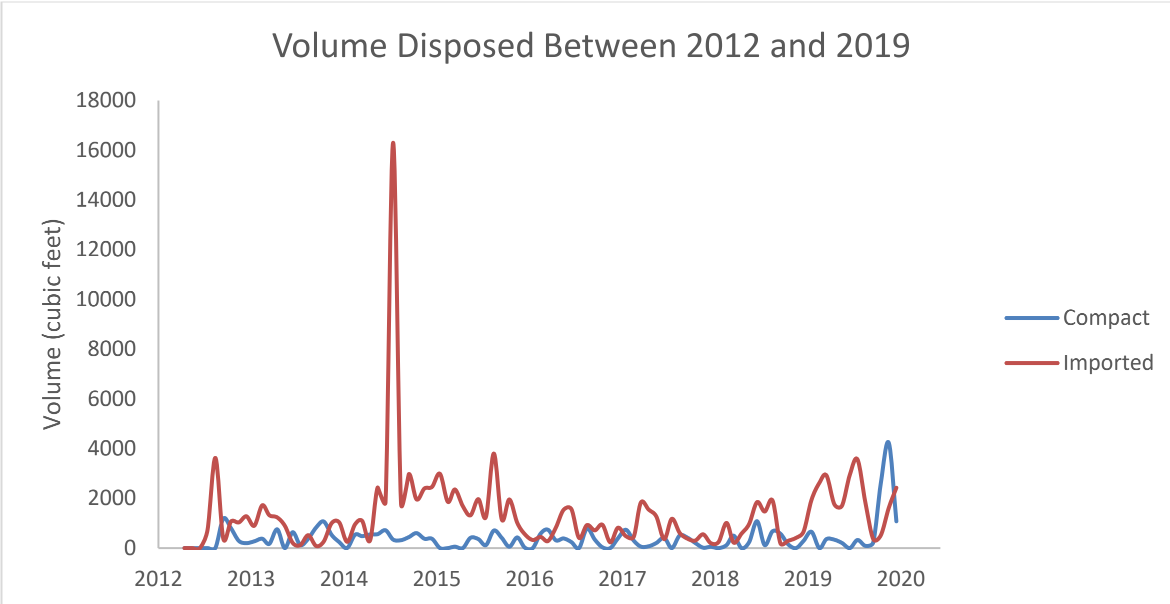


Figure 2-2. Volume of Texas Compact and Nonparty Compact LLRW Disposed at the CWF Between 2012 and 2019

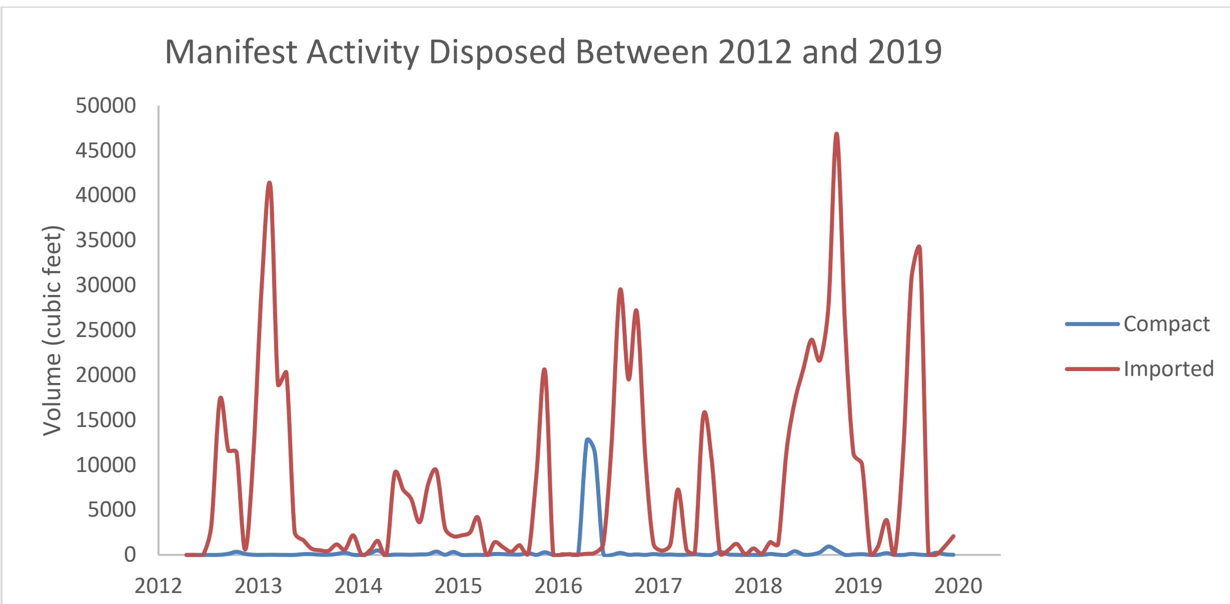
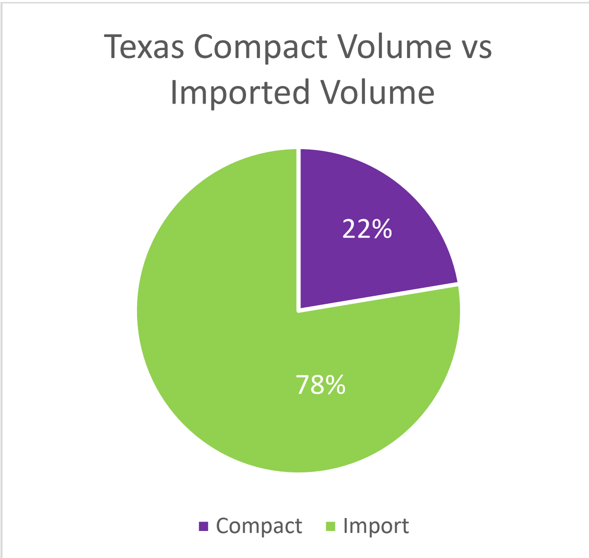


Figure 2-3. Manifested Radioactivity Disposed at the CWF Between 2012 and 2019



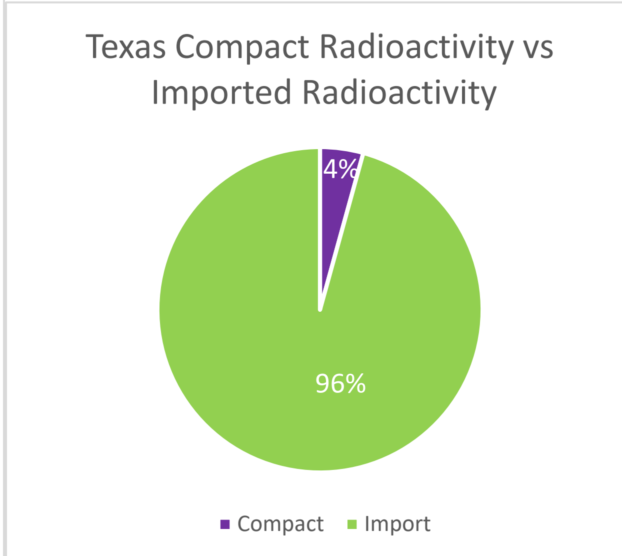


Figure 2-4. Texas Compact Volume and Radioactivity versus Nonparty Compact Volume and Radioactivity Disposed at the CWF.

2.10. Texas Compact Waste Generated Versus Actual CWF Disposals

Data from disposals at the CWF to the end of 2019 for Texas Compact LLRW was compared to data obtained from the Texas Compact generators. Texas Compact generator disposals in the CWF from 2015 through 2019 were used to obtain an average volume and curie amount disposed annually. The last five years are used since the average operational waste stream for a nuclear power plant is a five-year cycle. The Texas annual generation volumes and activities, obtained from the utilities, was used to determine the as-generated volume and activity values for Texas Compact waste. The 85% hypothetical volume reduction determined in Tables 2-3 and 2-7 for Class A LLRW was used to determine the as-disposed volume. The Texas Compact waste generation information includes utility and non-utility as-disposed volumes and curies. Since Class A LLRW accounts for the majority of volume, this category is tabulated separately. The comparison of average annual volumes and curies is provided in Table 2-12.

Table 2-12. Average Annual Comparison of Disposals at the CWF versus Texas Compact Waste Generation Based on Data from 2015 to 2019

	CWF Disposals		Texas Compact Generation		
	ft^3/yr	**Ci/yr**	**ft^3/yr as generated**	**ft^3/yr as disposed**	**Ci/yr**
Class A	3,498	93	34,522	5,178	214
All Classes	4,650	5,840	37,936	8,592	856

The data in Table 2-12 shows that the operational volume of LLRW generated annually within the Texas Compact is greater than the annual volume disposed at the CWF. The estimated as-disposed volume (calculated using a hypothetical scenario) approaches the actual disposed volume by within 50% which is acceptable given the uncertainties in the data available and assumptions made. The Texas Compact generated volumes are future estimates, not actual values, and no volume reduction was calculated for Class B and C LLRW. The curies disposed exceeds the estimated curies generated by a factor of nearly seven for all LLRW classes due to a nuclear power plant decommissioning (not included in the operational waste generation estimate) and due to the storage of Class B and C LLRW by the Texas Compact generators for several years between the closing of Barnwell to Texas Compact generators in 2008 and the opening of the CWF in 2012. The curies generated exceed the curies disposed by over a factor of two for Class A LLRW since no reduction of curies was calculated in the hypothetical scenario used to determine the volume reduction percentage of 85%. The hypothetical scenario had half of the Class A LLRW being disposed outside of the Texas Compact in another LLRW disposal facility.

2.11. Nonparty Utility Volume and Radioactivity Estimates

As stated previously, there are currently 77 nonparty nuclear power units at 53 utilities operating in the U.S. These nonparty utilities with no compact disposal site only have two disposal options: either the CWF or the facility in Clive, Utah. Nonparty utility volumes and curie data was obtained from each utility's annual Radioactive Effluent Reports as required by the NRC for years 2005 through 2018. Because the Texas Compact nuclear utilities make up greater than 90% of both the volume and activity produced in the Texas Compact states, it is anticipated that operational LLRW generated by utilities in nonparty states would similarly make up a large fraction of the total LLRW generated. Due to the uncertainty in whether license renewals will be granted by the NRC, no estimates for decommissioning wastes from nonparty utilities will be presented.

Each nonparty utility's Radioactive Effluent Report contains similar information on operational waste generated. The volume and curie information provided in these reports is as-generated and is represented in four major categories: 1) spent resins and filter sludges; 2) dry compressible waste and contaminated equipment; 3) irradiated components; and 4) large components and other. Various factors influence the variability of data presented in the effluent reports. Notably, the closing of the Barnwell, South Carolina disposal site to non-Atlantic Compact states produced higher than average volumes and curies disposed for many utilities just prior to 2008. Another factor is that several of the utilities ceased operations between 2005 and 2018 resulting in less than 14 years of volume and curie data. However, given these anomalies, 14 years of data provides a representative sample of volume and curie totals with which to project through 2044. These anomalous events make it difficult to set upper and lower bounds for volume and curie estimates in any given year. For simplification purposes, an annual average for all waste streams over a 14-year period was used to estimate potential LLRW volumes and curies generated through 2044. It is important to note that totals for volumes and curies from nonparty utility operational waste presented here anticipate that all the utilities will generate operational waste through 2044. This will likely not be the case, in reality, due to early closures or license renewals that will not occur. Additionally, the estimated totals presented below may be an overestimate of operational waste generated.

All estimates presented for nonparty utility volumes and curies represent all classes of waste combined. As stated previously, the waste class ratios remain consistent with the historically established information provided in Table 1-1. The information provided in Table 2-13 represents the four major categories of waste streams and an annual as-generated average for each based on data from 2005 through 2018. The total represents an annual as-generated average for all waste streams combined.

Table 2-13. Nonparty Utility As-Generated Annual Operational Volume and Radioactivity

Waste Type	Annual Operational Volumes (ft^3)	Annual Operational Curies
Spent Resins, Filter Sludges	123,490	70,610
Dry Compressible Waste, Contaminated Equipment	1,301,714	6,687
Irradiated Components	1,905	191,627
Large Components, Other	247,338	2,759
Total	**1,674,447**	**271,683**

The data presented in Table 2-13 indicates that a vast majority (nearly 80%) of the volume is from dry compressible waste which is normally Class A, and the majority (70%) of the radioactivity is from irradiated hardware which is normally Class B and C.

The annual operational volume in Table 2-13 for this report is lower than the corresponding value of 2,135,032 ft^3 in the 2016 Capacity Report while the annual operational activity value for this report is higher than the 247,117 curies of the 2016 Capacity Report. The 2016 report used the values for ten years (2005 to 2014) whereas this report added the values for four additional years (2015 to 2018) to the 2016 calculations. Figures 2-5 and 2-6 show the annual volume and activity of operational waste generated respectively for the years in this report of 2005 to 2018. These figures demonstrate a large variation in values per year.

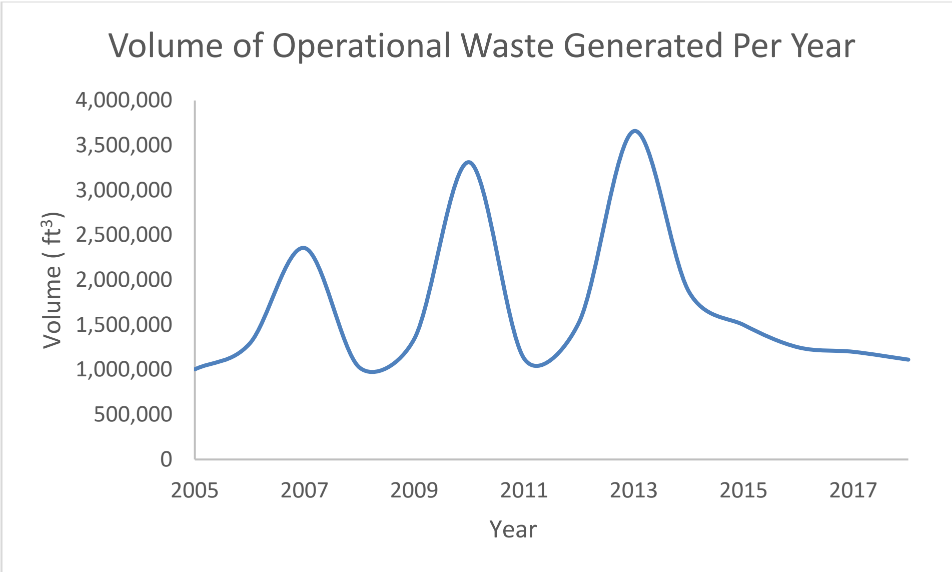


Figure 2-5. Volume of Operational Waste Generated by Nonparty Utilities that Dispose of Waste in the CWF

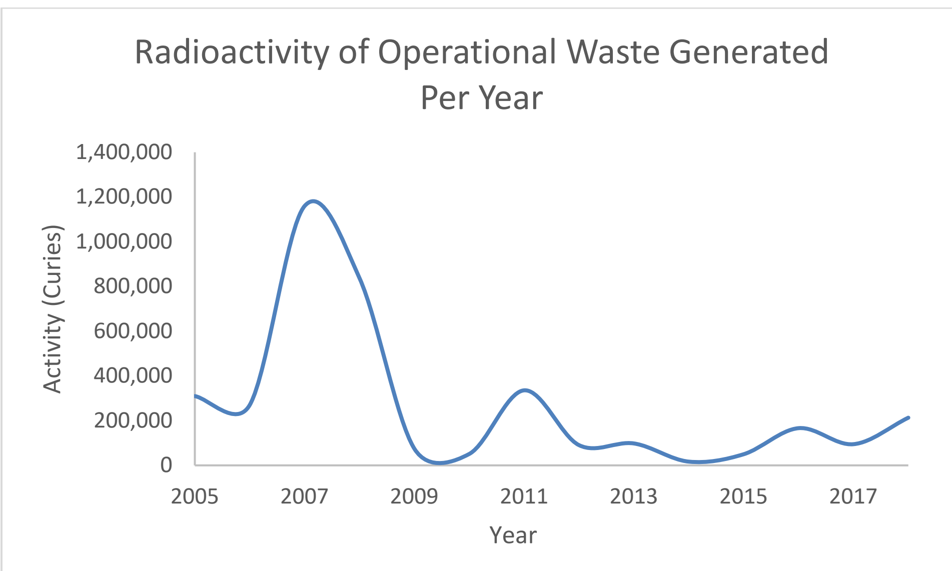


Figure 2-6. Radioactivity of Operational Waste Generated by Nonparty Utilities that Dispose of Waste in the CWF

For purposes of meeting the volume reduction requirement discussed later in Section 6 of this report, only spent resins and dry compressible waste streams listed above would be eligible for volume reduction. The volume of dry compressible waste also includes contaminated equipment, which is not eligible for volume reduction. The NRC Effluent Reports do not provide a breakdown of this category into dry compressible waste and contaminated equipment, but the volume of contaminated equipment is expected to be significantly lower compared to dry compressible waste. The hypothetical case presented in Table 2-14 assumes a conservative volume reduction of 3:1 for dry compressible waste and spent resins combined. To provide an as-disposed total annual volume, the volumes of both irradiated components and large components were added back to the volume-reduced total. The overall result is a 40% reduction in volume for as-disposed waste. It is important to note that the total volume overestimates a potential as-disposed volume since greater volume reduction efficiencies can be achieved for dry compressible waste.

Table 2-14. Hypothetical Case – Nonparty Utility As-Disposed Annual Volume Estimate

Waste Type	**Annual Operational Volumes (ft^3)**	**Annual Reduction Volume (ft^3)**
Spent Resins, Filter Sludges	123,490	41,163
Dry Compressible Waste, Contaminated Equipment	1,301,714	433,904
Irradiated Components	1,905	NA
Large Components, Other	247,338	NA
Remaining Volume for Disposal[10]		**724,310**

[10] Total includes as-generated operational volumes for irradiated components and large components

3. Radioactive Decay Effects on Curie Capacity

Radioactive decay is a decrease in the amount of any radioactive material with the passage of time, due to spontaneous emission from the atomic nuclei. As shown in Figure 3-1, the extent to which the total amount of radioactivity of a given LLRW declines over time depends upon the half-lives of the radionuclides contained in the waste. Typically, about 95% of LLRW decays to insignificant levels in less than 500 years. Radioactive constituents that could potentially be released from LLRW after disposal at a facility must not produce doses exceeding the regulatory limit of 25 millirems per year. Therefore, longer-lived radionuclides are required to be evaluated in a site-specific PA to determine the maximum amount of radioactivity allowed to be received in order to keep the peak dose below the regulatory limit.

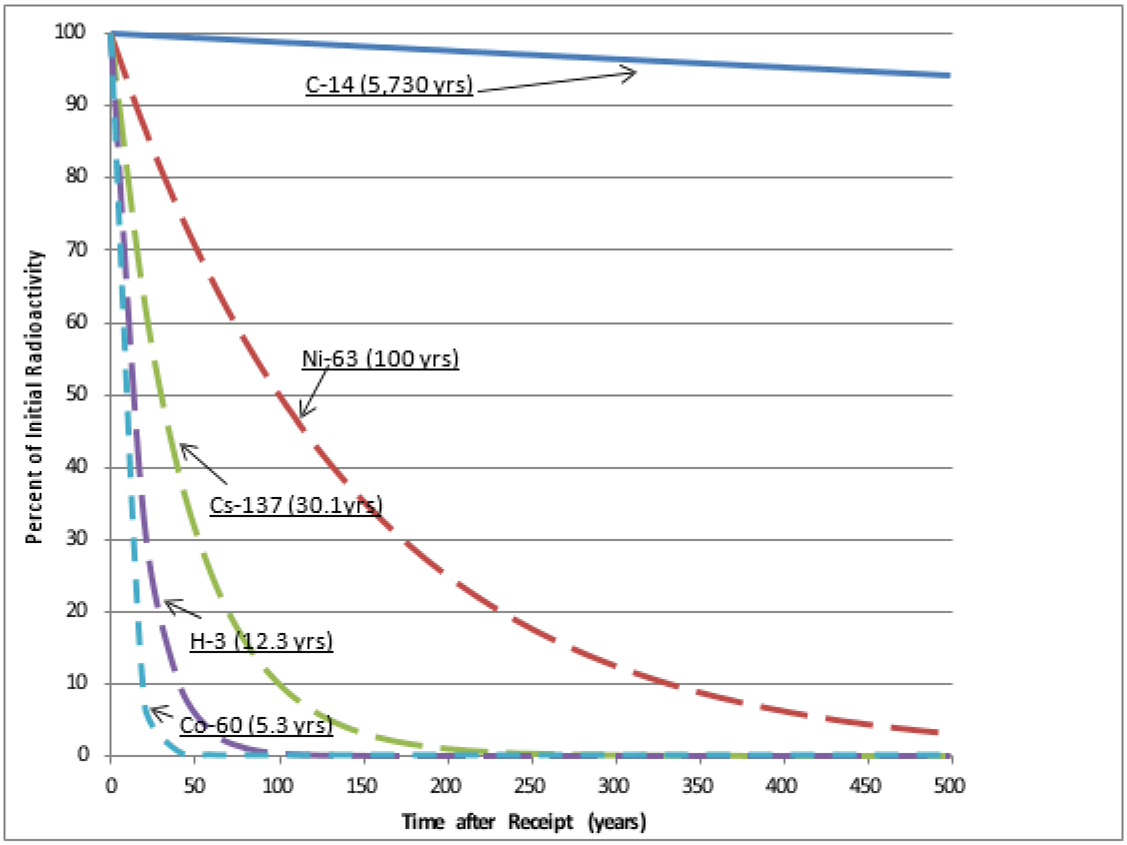


Figure 3-1. Decay of Initial Radioactivity of Common Radionuclides Over Time by Half-Life

As previously mentioned, SB 347 provided for the license holder to dispose of not more than the greater of:

- 1,167,000 curies of nonparty compact waste; or
- an amount of nonparty compact waste equal to 30% of the initial licensed capacity of the facility; and
- not more than 275,000 curies of nonparty compact waste in any fiscal year.

The current CWF operator license allows a decay corrected maximum of 3,890,000 curies. The license also contains a condition that allows the TCEQ Executive Director to authorize, through minor amendment to the license, an increase in the total decay corrected radioactivity limit in the CWF site license within the following specifications:

- Upon disposal of 2,000,000 decay corrected curies, the Licensee may request an increase in the total decay corrected radioactivity not to exceed 6,000,000 curies.
- Upon disposal of 4,000,000 decay corrected curies, the Licensee may request an increase in the total decay corrected radioactivity not to exceed 8,000,000 curies.

In 2015, the CWF site operator provided a calculation methodology for determining decay of the proposed radioactivity inventory on an annual basis extending to 2044. For future projections, the site operator used historical disposal data from past disposals at other LLRW disposal sites, specifically the disposal site in Barnwell, South Carolina.

When evaluating potential doses to members of the public by conducting long-term analyses, the radioactive inventory or source term is almost always decay corrected. This is since a site-specific analysis or PA evaluates effects over periods up to 1,000,000 years. There are a small number of radionuclides that have half-lives approaching those timeframes. Decay of the source term results in much lower to non-existent doses and decreases uncertainty in long-term analyses as it relates to protection of human health and the environment. Evaluating long-term performance of a disposal site will be discussed further in Section 5.

4. Necessity of Containerized Waste

Section 401.218 of the TH&SC requires containerization for Class B and C waste. This containerization consists of disposal within a reinforced concrete container and within a reinforced concrete barrier or within containment structures made of materials technologically equivalent or superior to reinforced concrete. In addition, certain types of Class A waste with high radiation levels must be disposed in a similar manner as Class B and C waste. The containerization used for disposal of LLRW at the CWF is a reinforced Modular Concrete Canister (MCC) as shown in Figure 4-1. The MCCs are approximately ten feet high, six feet wide, and one foot thick. The function of the MCC is threefold. First, the canisters help maintain the structural stability of the site. Second, the canisters provide shielding for workers from unnecessary radiation exposures during operations. Finally, the canisters prevent the potential movement of radionuclides into the environment. The filling of void space within the MCCs with either grout or sand is also significant as it provides additional shielding to workers and additional stability within the cell.

Figure 4-1. Cylindrical Modular Concrete Canister Used in the CWF (TCEQ, 2014)

4.1. Stability of the Modular Concrete Canisters

Long-term stability of a containment structure is essential to meeting various NRC and Texas requirements for LLRW disposal. The Texas regulations in 30 TAC §336.733(b) require the special criteria:

> "The special criteria specified in this subsection shall apply to the disposal of wastes consisting of radionuclides with half-lives greater than 35 years and wastes consisting of transuranic radionuclides which are acceptable for disposal under this subchapter, that is, transuranic radionuclides in concentrations of less than ten nanocuries/gram. All those wastes that are determined to be Class A shall be placed in reinforced concrete canisters or equivalent containment structures to provide stability after disposal or shall meet the stability requirements set forth in §336.362(b)(2) of this title. These special criteria are in addition to the minimum requirements for Class A wastes set forth in §336.362(b)(1) of this title. The executive director may consider a licensee's request for an alternative from these special criteria on a case-by-case basis."

Additional stability requirements in 30 TAC §336.362(b)(2) are:

> "The following requirements are intended to provide stability of the waste. Stability is intended to ensure that the waste does not degrade and affect overall stability of the site through slumping, collapse, or other failure of the disposal unit and thereby lead to water infiltration. Stability is also a factor in limiting exposure to an inadvertent intruder since it provides a recognizable and non-dispersible waste.
>
> Waste shall have structural stability. A structurally stable waste form will generally maintain its physical dimensions and its form, under the expected disposal conditions such as weight of overburden and compaction equipment, the presence of moisture, and microbial activity and internal factors such as radiation effects and chemical changes. Structural stability can be provided by the waste form itself, processing the waste to a stable form, or placing the waste in a disposal container or structure that provides stability after disposal."

MCCs are designed to meet these requirements by providing individualized structural stability and to contribute to maintaining the overall structural integrity of the waste disposal unit. The canisters can either be cylindrical or rectangular in shape and are designed to accommodate various load combinations, motion from seismic events, and lateral movements. The MCCs also pass certification testing to ensure they meet all the technical specifications for performance under the given conditions.

These canisters are designed in a manner that enables the placement of one stacked directly on top of another. Thus, the bottom of one canister provides the top of the canister beneath it. The canisters are designed with two options for reinforcing steel with a tensile strength of 60,000 pounds per square inch, which will enable the canisters to withstand the anticipated loads under tension. For compression loading, the concrete mix design strength is 5,000 or 4,000 pounds per square inch depending on which reinforcing steel option is used. Under this design, calculations show that the canisters should be able to ensure the waste remains containerized for at least 300 years and structural stability is maintained.

4.2. Modular Concrete Canister Role in Reducing Radiation Worker Dose

Safety is an important legal and regulatory consideration in determining the necessity of containment as it serves as shielding to protect workers from unnecessary radiation exposures. An essential component of a radiation safety program is shielding the radiation worker from the radiation source to meet ALARA requirements. The MCCs provide shielding from the emplaced LLRW and therefore greatly reduce worker doses. To demonstrate the effect of shielding, a waste container with similar dimensions and material to a high integrity liner was modeled in MicroShield® v6.02 in three configurations: unshielded, ungrouted in an MCC, and grouted in an MCC. MicroShield® is a comprehensive gamma ray shielding and dose assessment computer program that is widely used for designing shields, estimating source strength from radiation measurements, minimizing exposure to people, and teaching shielding principles.

The ungrouted MCC scenario model resulted in a decrease in dose by a factor of nearly 30 from the unshielded scenario. Additionally, the grouted MCC scenario model resulted in a decrease in dose by a factor of nearly 4,650 compared to the unshielded scenario. As evidenced by the MicroShield® simulation, the use of the MCC has a dramatic effect on keeping radiation worker doses ALARA. It is important to note that worker doses are usually kept well below regulatory limits by use of administrative controls, procedures, and specialized equipment that allows remote handling of high dose rate waste.

4.3. Modular Concrete Canister Role in Environmental Protection and Water Infiltration

MCCs are also used to provide an extra layer of protection to prevent water from encroaching into the contained waste. The low permeability concrete can decrease the flow of water into and out of the MCCs. Because the speed of the flow of water is the primary means of restricting the movement of radionuclides into the environment, reducing water infiltration is advantageous. It is important to note that the low permeability of concrete is not an ultimate barrier in preventing the mixing of water and waste. Concrete containerization remains an important factor in the protection of the environment from the potential release of radionuclides.

5. Projecting Capacity and Its Effect on Health and Safety of the Public

5.1. Public Health and Safety

In order to evaluate the effects of the estimated volume and radioactivity of the waste disposed, TCEQ requires that a site-specific PA be conducted. A PA for a LLRW disposal facility is a quantitative analysis used for demonstrating compliance with performance objectives found in 10 CFR Part 61 and 30 TAC Chapter 336. This type of analysis answers three basic questions: 1) What can happen? 2) How likely is it to happen? and 3) What is the result?

The State of Texas is required to maintain compatibility with certain federal NRC regulations. The performance objectives in Texas regulations are identical to those found in 10 CFR Part 61. The performance objectives include protection of the general population from releases of radioactivity, protection of individuals from inadvertent intrusion, protection of individuals during operations, and stability of the disposal site after closure. Currently, the requirements found in 10 CFR Part 61 are being revised to allow Agreement States more flexibility and to provide for site-specific analyses in evaluating long-term performance of a disposal site.

Demonstrating compliance with the performance objectives requires several different types of analyses. A short-term analysis is used to evaluate the protection of individuals during operations. A long-term analysis is required for evaluating the effects of potential releases to human health and the environment. Finally, an analysis is performed to evaluate long-term stability. These analyses ensure that the appropriate measures are taken to account for the various effects associated with the time-dependent nature of the waste and suitability of site characteristics.

In meeting the performance objectives, the following information is required:

- Site characterization;
- Development of conceptual model(s);
- Defining scenarios and pathways;
- Selection of appropriate mathematical model(s) and code(s);
- Sensitivity and uncertainty analyses; and
- A detailed comprehensive radionuclide inventory.

The central attribute of conducting a PA is that it is an iterative approach, whereby the aspects listed above are continuously refined as more information is gathered, until a level of certainty is reached for making defensible regulatory decisions. The process is represented in Figure 5-1.

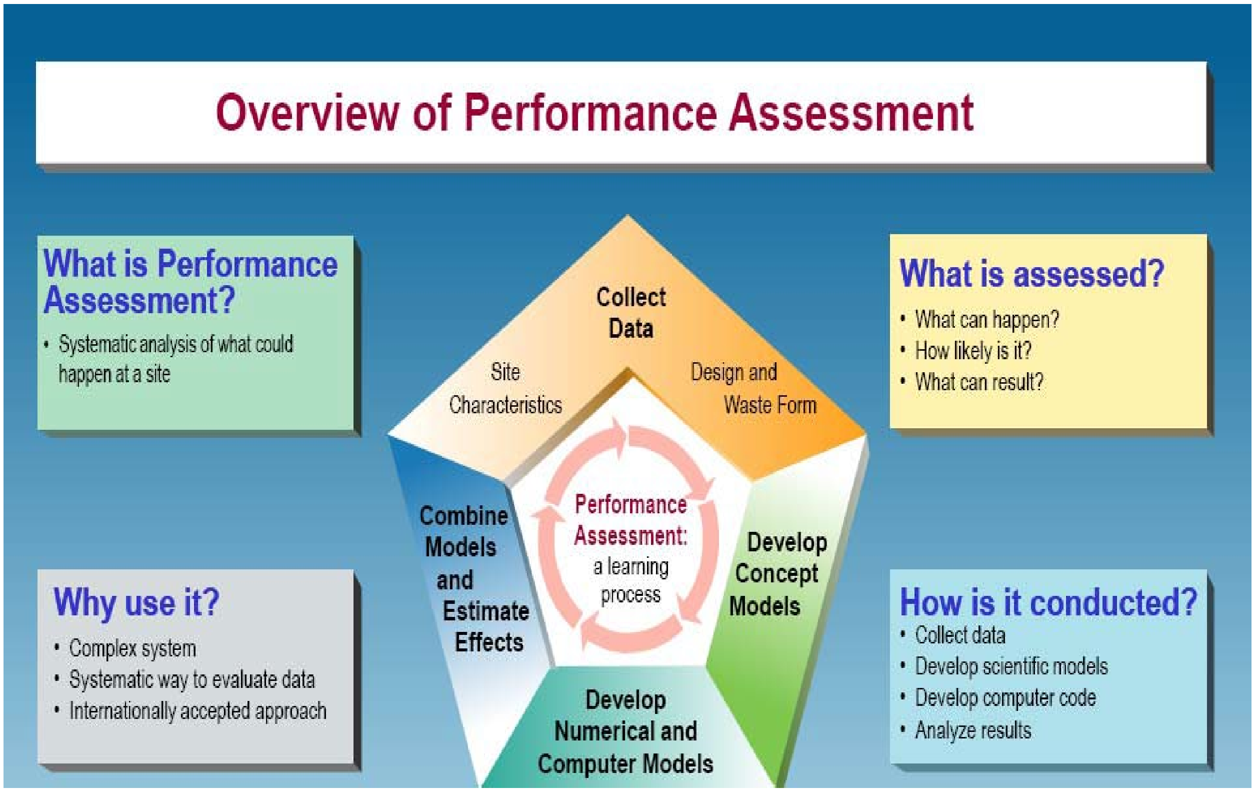


Figure 5-1. Performance Assessment Process (NRC, 2011)

As part of demonstrating that performance objectives can be met, site-specific data related to area and site characteristics are provided and include ecology, geology, seismology, soils, topography, surface hydrology, hydrogeology, air quality, natural background radiation, meteorology, climatology, and demographics. The data used for demonstrating compliance must be representative of current conditions and sufficient for modeling future conditions. Environmental monitoring data is collected in all environmental media (water, soil, air, and biota) and from characterization investigations to establish baseline conditions. Monitoring data must be collected, analyzed, and reported following the appropriate quality assurance/quality control (QA/QC) and chain of custody protocols for the given analytical method. In the absence of site-specific data, literature values may be used if they can be demonstrated to be conservative and representative of site conditions.

In evaluating long-term performance, the groundwater pathway scenarios are usually given greater consideration due to the significance of this pathway as the main contributor of dose to an individual. Figure 5-2 is a depiction of a conceptual site model showing the various radionuclide transport pathways in the environment and potential exposure pathways.

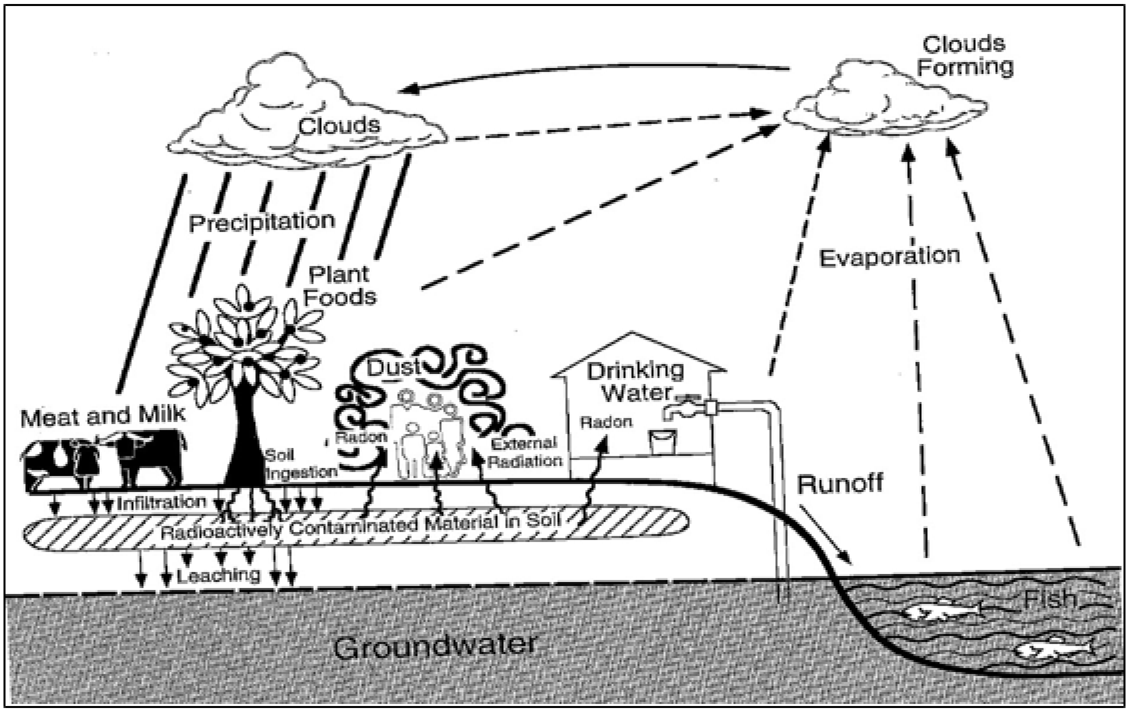


Figure 5-2. A Schematic of the Various Pathways Analyzed in a Performance Assessment (DOE, 1993)

In addition to meeting NRC compatibility requirements, the PA should be a useful tool for both TCEQ and the TLLRWDCC to make determinations on how capacity may impact the performance of the landfill, the need for expansion or limits on the type, volume, and concentration of waste to be received, and other environmental impacts.

5.2. Site Characteristics and Its Relationship to Capacity

Certain changes or information regarding the above site characteristics could impact capacity by affecting disposal cell expansion decisions and/or limitations on type of waste, concentrations, and volume. An assessment of site characteristics is essential in evaluating both dose and the resulting health effects. Dose calculations rely on site characteristics, such as meteorology, geology, hydrology data, waste inventory information, and behavioral parameters. Engineered features and site characteristics work in conjunction to ensure site suitability for the disposal activities. It is within the specific site characteristics that the transport of radionuclides to the general environment were evaluated. Transport mechanisms by air, water, and biotic intrusion were considered in the PA as well as evaluating the potential impacts from nearby facilities. The PA has been updated annually up to 2018 until TCEQ declared it complete in October of 2019, which changed the frequency of updating the PA to every five years.

5.3. Waste Inventory

Keeping an accurate waste inventory, bearing in mind the role of decay and decreasing or increasing radioactivity, will be vital in making capacity decisions. It is also a requirement in the current site operator's license. The radionuclide source term (or inventory) is characterized by the composition and magnitude of total radioactive waste received over the facility life, including chemical and physical properties of the radioactive waste.

A typical LLRW inventory would consist of approximately 110 radionuclides, all of which are evaluated in the PA. As part of that evaluation, the modeling accounted for decay of radionuclides over the 1,000,000-year period of analysis. Of those 110 radionuclides, roughly 80 (73%) would decay to insignificant levels after 500 years, the time at which engineered barriers are expected to fail. The remaining 30 (27%) radionuclides are the primary concern for evaluating mid-to-long-term effects to public health and safety, with particular attention to the more environmentally mobile radionuclides.

The decay of radionuclides was not considered for short term (i.e. 30 years or less) analyses when evaluating potential worker doses. This is due to the fact that the radionuclides may be accepted for disposal at any time during the operational period. The doses could be underestimated if a large shipment is disposed toward the end of the operational life but was considered disposed during the beginning of the operational life. Thus, the full inventory amount, and not the decayed amount, was utilized for short term analyses. Worker dose evaluations for external exposure and during accident scenarios were considered short term analyses and resulted in no adverse health and safety effects. The current projected inventory developed by the CWF site operator is based on actual waste receipts at the CWF. The inventory used in the PA is based on receipts through the first site license term ending in 2024. To ensure public health and safety through the full license term, the current disposal site license requires the site operator to provide periodic updates to the PA to reflect any changes in current and proposed inventory as well as refinements to existing data or assumptions used in the model.

The quantitative results from the CWF PA analyses indicate that the doses are below regulatory limits for all scenarios and pathways evaluated. Based on the predicted future LLRW inventory the dose results from the PA are within acceptable limits for the health and safety of the general population considering that the total activity predicted to be generated in only the Texas Compact by 2044 is less than what is currently licensed.

6. Volume Reduction

Volume reduction has been a common practice in the nuclear industry for decades. It has served as a mechanism for reducing disposal costs, for conserving limited storage space when no disposal options existed, and for preserving disposal capacity for operating LLRW disposal sites. Various techniques are used to achieve volume reductions ranging anywhere from 2:1 up to 100:1 or greater in special cases. The efficiencies will vary by the reduction technique used and by the physical properties of the waste itself. For example, dry compressible waste is much more amenable to greater reductions than irradiated hardware.

6.1. National Policy on Volume Reduction

In 1981, and subsequently revised in 2012, the NRC published a Policy Statement regarding the volume reduction of LLRW.[11] The Policy Statement addressed:

- The need for a volume reduction policy; and
- The need for waste generators to minimize the quantity of waste produced.

For 30 years, the Policy Statement has conveyed the NRC's expectations that generators of LLRW should reduce the volume of waste shipped for disposal at licensed commercial waste disposal facilities. The NRC stated that such action would:

- Extend the operational lifetimes of the existing commercial low-level disposal sites;
- Alleviate concern for adequate storage capacity if there are delays in establishing additional regional sites; and
- Reduce the number of waste shipments.

While policy statements from the NRC are not regulations, they have impacted industry standards. This policy statement clarifies that there are a variety of options for management of LLRW that are secure and protect public health and safety.

6.2. Texas Volume Reduction Requirements

Senate Bill 347 amended TH&SC Section 401.207 during the 83rd legislative session to require that eligible nonparty compact waste be volume reduced by at least a factor of three. Implementation of SB 347 in 30 TAC Chapter 336 provided the following requirements:

- The CWF license holder "may accept nonparty compact waste for disposal at the facility only if the waste has been volume-reduced, if eligible, by at least a factor of three in a manner consistent with TH&SC, Chapter 401, Subchapter F."

- "Waste has been reduced by a factor of three if the final volume of waste disposed is one-third (1/3) or less of the initial volume.

[11] 76 FR 50500 (August 15, 2011).

  - Initial volume of the waste is the volume of radioactive material generated prior to receiving any processing or operational waste volume reducing methods.
  - Final volume of the waste is the volume after the waste has been processed, whether by the generator (including any waste minimization as part of the generator's process) or by a commercial waste processor and is in the final form immediately prior to disposal. Waste packaging is not included in determining the final volume."

- "Examples of volume reduction methods include:
  - reduction of the volume of ion exchange media loaded into individual demineralizer vessels;
  - on-line lithiation strategies for reactor coolant purification demineralizers;
  - intermittent use of some demineralizers instead of continuous use (spent fuel pool);
  - reduction by compaction of dry active waste or compactible waste;
  - removal of radioactive particulates from a liquid waste stream by the use of methods such as filters, ion-exchange medium (such as resin), precipitation, flocculation, or settlement (resultant liquid, if still radioactive, would not be considered volume reduced);
  - incineration (any radioactive effluent captured in a device such as a baghouse or charcoal filter would not be considered volume reduced);
  - concentration technologies such as evaporation, crystallization, drying, or dewatering; or
  - repackaging or consolidation of waste in order to more efficiently minimize volume required for disposal in compliance with the license."

- "Examples of what is not considered volume reduction include:
  - downblending;
  - separation of radioactive waste from non-radioactive waste, such as debris or contaminated scrap metal; or
  - volume reduction based entirely on hypothetical calculations, rather than actual records of historical waste generation."

- "Waste streams that are not eligible for volume reduction include:
  - irradiated hardware;
  - solid forms, such as non-compactible metals or monoliths;
  - large components;
  - soils and demolition debris; or
  - sealed sources."

6.3. Volume Reduction Techniques

Much of the LLRW generated undergoes some form of processing before disposal. Processing provides volume reduction and, in some cases, both reduction and a stable waste form. Current volume reduction techniques vary widely from relatively simple methods, such as sorting or segregation of waste classes, to more complex techniques, such as steam reforming, requiring specialized equipment and process knowledge. As a result, waste generation volumes differ from disposal volumes. Based on the comparison of the reported as-generated volumes and the as-disposed volumes, it appears that overall, there is a volume reduction of approximately 4:1. However, this factor can vary greatly between different waste streams. In the thirty years since the 1981 NRC Policy Statement, volume reduction techniques have changed in several ways. Additional details on each of these volume reduction techniques are discussed below.

6.3.1. Sorting and Segregating

Sorting and segregating can produce significant cost savings for disposal. As discussed previously, 91% of all LLRW volume generated is Class A. The 91% is usually in the form of DAW and can be easily separated from LAW or by class either at the point of generation or prior to packaging for disposition. In most cases, it is process knowledge or actual analysis of the waste for its radioactivity content that verifies the waste is eligible for disposal as LAW in a RCRA disposal facility. Additionally, there are various regulatory provisions which allow for certain wastes to be disposed via sanitary sewer or held for decay in storage. These additional options can easily reduce the volume of Class A LLRW by 50%. For the purposes of meeting the volume reduction requirements in 30 TAC Chapter 336 for nonparty compact waste, separation of LLRW from non-LLRW is not considered volume reduction.

6.3.2. Compaction

Compaction involves compressing the waste to reduce its volume. Compaction is a relatively inexpensive and widely available option, which is used by many LLRW generators.[12] Compactors can range from low-force compaction systems (~5 tons or more) to presses with a compaction force over 1,000 tons, referred to as supercompactors. Volume reduction factors are typically between three and 10, depending on the physical properties of the waste material. Low-force compaction is typically applied to the compression of waste, in order to facilitate packaging for transport either to a waste treatment facility, where further compaction might be carried out, or to a storage/disposal facility. In the case of supercompactors, in some applications, waste is sorted into combustible and non-combustible materials. Combustible waste is then incinerated while non-combustible waste is supercompacted. In certain cases, incinerator ashes are also supercompacted to achieve the maximum volume reduction. Low-force compaction utilizes a hydraulic or pneumatic press to compress waste into a suitable container, such as a 200-liter drum. In the case of a supercompactor, a large hydraulic press crushes the drum itself or other receptacle containing various forms of solid LLRW. The drum or container is held in a mold during the compaction stroke of the supercompactor, which minimizes the drum or container outer dimensions. The compressed drum is then stripped from the mold and the process is repeated. Two or more crushed drums, also referred to as pellets, and are then sealed inside an over-pack container for interim storage and/or final disposal. A supercompaction system may be mobile or stationary in concept, supplied as a basic system manually controlled with a minimum of auxiliary equipment to an elaborated computer-controlled system which selects drums to be processed, measures weight and radiation levels, compresses the drums, places the

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[12] RER-40 How Is Low-Level Radioactive Waste Treated Prior to Disposal? Fentiman, A., Jorat, M., Meredith, J. of The Ohio State University.

crushed drums in over-pack containers, seals the over-packs, and records the drums and over-packs content via a computerized storage system.

Every year worldwide, tens of thousands of drums are volume-reduced and stored, with waste generally being reduced in volume by up to 5:1.[13]

6.3.3. Incineration

Incineration is a volume reduction option for combustible radioactive wastes. Following the segregation of combustible waste from non-combustible constituents, the waste is incinerated in a specially engineered kiln up to around 1,000 degrees Celsius. Volume reduction factors up to 100 can be achieved in incineration, depending on the density of the waste.[14] Any gases produced during incineration are treated and filtered prior to emission into the atmosphere and must conform to national emissions regulations. Following incineration, the resulting ash, which contains the radionuclides, may require further conditioning prior to disposal such as cementation or bituminization. Compaction technology may also be used to further reduce the volume, if cost-effective.

Incineration technology is subject to public concern in many countries as residents worry about what is being emitted into the atmosphere. However, modern incineration systems are well engineered, high-technology processes designed to effectively and efficiently burn the waste with minimal emissions to the environment.[15]

6.3.4. Vitrification

Vitrification is a process during which radioactive waste is blended within a borosilicate material and heated, which makes glass “beads” or disks. Vitrification alone would not provide desired results for volume reduction. Instead vitrification is the secondary treatment method for waste that has already been volume reduced in some other manner. The vitrification process has been used on High Level Waste (HLW) and LLRW to provide an extremely stable waste form. One advantage of vitrified waste is that the radioactive material is bound in the glass matrix and is not easily released, even if water comes in contact with the waste after it is placed in a disposal facility.[16]

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[13] Treatment and Conditioning of Nuclear Wastes. World Nuclear Association. Retrieved July 2012 from www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/treatment-and-conditioning-of-nuclear-wastes.aspx

[14] Treatment and Conditioning of Nuclear Wastes. World Nuclear Association. www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/treatment-and-conditioning-of-nuclear-wastes.aspx

[15] Treatment and Conditioning of Nuclear Wastes. World Nuclear Association. Retrieved July 2012 from www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/treatment-and-conditioning-of-nuclear-wastes.aspx

[16] RER-50 What Is Being Done to Reduce the Volume of Low-Level Radioactive Waste? Fentiman, A., Karam, P., Meyers, R. The Ohio State University.

6.3.5. Steam Reforming

Steam reforming is a thermal treatment technology classified as "pyrolysis," which differs significantly from an open-flame incineration/combustion process. When used for reduction of nonmetal filter cartridges in a tank conversion reformer, this process is referred to as "conversion reforming." Steam reforming uses temperatures elevated just enough to release the organic gases and water vapor from the waste without it combusting. The resultant waste residue appears as a dry granular media which can be disposed in liners or high integrity containers. A benefit of this type of processing is that it greatly reduces the water content of the wet waste, which, if not reduced, can lead to stability issues in the future. The volume reduction efficiency of the as-generated waste is between 5:1 and 33:1.

Steam reforming uses a dry (high quality) steam to reform or reduce waste to small gas-size particles which can then be burned in a special reactor void of oxygen. Therefore, it is a two-stage process in which hydrocarbons are vaporized from the waste in one chamber and injected into a secondary reaction chamber with superheated steam. Within the reaction chamber, organics are converted to CO_2, CO, and H_2 and the remaining waste product consists primarily of metal oxides, salts, and other impurities removed from the waste generator/processors in-plant coolant and liquid waste systems. Steam reforming is ideally suited for processing mixed wastes and wastes exhibiting high activity levels, such as resin and nonmetal filter media. Steam reforming can accept wastes up to (and, in special cases, exceeding) a dose rate of 100 R/hr (1 Sv/hr).

Steam reforming is the preferred method for volume reduction of high activity wet waste, which can be very costly to ship unprocessed due to poor packing efficiencies and void spaces. Another benefit of this type of processing is that it greatly reduces the water content of the wet waste, which can lead to stability issues in the future. The volume reduction efficiency of the as-generated waste is primarily dependent upon the inorganic content of the waste, the higher the inorganic fraction, the greater the final disposed waste volume and the lower the net volume reduction efficiency. For steam reforming of resin, the volume reduction efficiency is directly proportional to the activated corrosion and wear product deposited in the resin and the percentage of inorganic media. Most spent resin contains from 3% to 20% metal oxides, salts, and other impurities which originate in the nuclear plant liquid process stream. Unlike resin, most filter cartridges are constructed using a combination of organic and inorganic materials. For example, nonmetal filters commonly employ some type of plastic as the construction media. Plastic is essentially solidified oil (or more accurately, a polymerized hydrocarbon), so it results in a 100% volume reduction efficiency. Conversely, some filters contain fiberglass, which is not normally reduced by steam reforming. Construction materials which do not perform well in the pyrolysis process will increase the volume of the product, thereby reducing the net volume reduction efficiency. Thus, one challenge in determining the net disposal volume reduction efficiency for conversion reforming of filters is to determine the additional contribution from filter construction materials to the reformed end product. However, the potential remains for concentrating the waste so as to produce a waste form which exceeds the acceptance criteria of disposal facilities due to certain nuclide concentrations (i.e., could produce waste that is greater than Class C (GTCC) waste.)

Typically, this limitation is mitigated by blending high and low activity wastes from the same waste classification prior to steam reforming to ensure a disposable end product.

6.3.6. Costs and Benefits of Volume Reduction

When deciding whether to use volume reduction techniques, a generator must consider the cost per cubic foot for disposal at the disposal facility, cost of transportation, and the cost for the processing.

Volume reduction provides two benefits. First, it allows for more waste to be placed in the disposal facility. Second, steam reforming of wet waste streams greatly reduces the water content of the waste, which will improve the stability of the waste.

However, reducing waste volumes does have the potential to result in a change in waste classification due to increasing or over-concentrating the radioactivity of the waste. Further, blending waste to a lower classification cannot be used to prevent this inadvertent over-concentrating because dilution is prohibited in TCEQ rules in 30 TAC §336.229.

Another consideration when deciding if to use volume reduction is commingling Texas compact waste with nonparty compact waste. Commingling is defined as any process that combines radioactive substances from two or more generators resulting from the commercial processing of radioactive substances. Per 30 TAC §336.745, a licensee may not dispose of LLRW that contains Texas Compact waste that has been commingled at a commercial processing facility with waste from other sources unless the commingling was incidental to the processing of the waste and processing has not altered the waste class and follows TCEQ commingling guidelines. Further, while some nonparty compact generators might find it not economically feasible to volume reduce, recent revisions to TH&SC Chapter 401 and 30 TAC Chapter 336 require volume reduction of at least 3:1 for eligible imported LLRW destined for disposal in the CWF.

Historically, many generators in the Texas Compact have used volume reduction techniques due to the lack of LLRW disposal options. However, volume reduction activities may decline in the future as generators and processors weigh the potential risk of concentrating LLRW volumes into a form that exceeds waste acceptance criteria and the prohibition on dilution per 30 TAC §336.229. In addition, the costs for disposal, transportation, and processing will play a key role in whether a generator of LLRW decides if it is economically feasible to use volume reduction techniques prior to disposal.

7. Conclusion

House Bill 2662, amending Chapter 401, tasked TCEQ with conducting a study on the volume and curie capacity of the CWF for the disposal of Texas Compact LLRW and nonparty compact LLRW. Based on updated information from Texas Compact generators and disposals at the CWF, TCEQ has estimated that the LLRW generators in the Texas Compact are likely to generate no more than 2,913,759 ft^3 as-generated LLRW and potentially 983,256 ft^3 as-disposed LLRW with 591,051 curies of as-generated operational and decommissioning waste by 2044. These estimates are less than the volume (9,000,000 ft^3) and curies (3,890,000 Ci) currently allowed in the disposal site license, representing for as-generated waste about 32% of the authorized volume and 15% of the authorized activity.

When evaluating the future volume and curie capacity needs, consideration should be given to the impact of high curie amounts from Class B and C waste, primarily from nuclear utility irradiated hardware. The information gathered for this 2020 study suggests that a relatively large number of nuclear utilities outside of the Texas Compact are storing Class B and C waste onsite. One reason for this may be related to the historical lack of disposal options for this type of waste prior to the opening of the CWF. It is presumed that storage is a result of economic considerations and budget constraints related to processing, packaging, transportation costs, and disposal costs. Some uncertainty still exists with volumes and curies of nonparty non-utility LLRW generated. However, it is safe to assume, based on import disposals to date at the CWF, that most of the imported waste is from utilities. Additional consideration should be given to the fact that since the terrorist attacks of 9/11, the federal government has made a concerted effort, along with Agreement States, to secure certain radioactive material and to encourage disposal of certain high-risk material. As this effort continues, a larger volume of waste may present itself over time that will need to be stored and/or disposed.

The health and safety effects of the licensed volume and activity were evaluated and were found acceptable. Calculations of radioactive decay and radiation dose assessments as part of the PA indicate that the estimated volume and radioactivity throughout the license period provide reasonable assurance that doses to workers and members of the public will continue to be below regulatory limits both in the short-term and for a period of 1,000,000 years. As the volume and curie inventory evolves over time, updates to the PA have been performed annually by the site operator up to 2018 to reflect that evolution. The PA has since been declared complete by TCEQ in October 2019 and now only requires the PA to be updated every five years.

The containerization of waste is not only a regulatory requirement but a sound scientific approach to providing assurance for long-term stability, protection from inadvertent intrusion, protection of workers, and it serves as a barrier to radionuclide migration. Containment structures must meet certain technical and engineering specifications to be considered “certified” for their intended purpose. MCCs used in the CWF meet the technical specifications for disposal of LLRW. In addition, the MCCs, through seismic analysis, have been shown to withstand the stresses associated with a seismic event.

A new alternative for volume reduction of LLRW potentially destined for the CWF uses an approach to segregate a percentage of Class A waste and dispose of it as LAW. LAW is determined using a performance-based concentration limit equal to one millirem. The concentrations are developed by conducting an RIA. This could potentially provide an alternative disposal option for the lower 10% of Class A which makes up approximately 91% of the volume of all LLRW classes. The costs and benefits of volume reduction will have different effects on different generators. Performing volume reduction is consistent with the NRC's policy statement. As this is only a policy statement, generators are encouraged to make every effort at minimizing waste. However, Texas regulations require that eligible nonparty compact waste be volume-reduced by, at least, a factor of three.

The choice to utilize volume reduction and other processing techniques is primarily economically driven. Prior to 2012, generators in compact states without a regional disposal site had no choice but to store their waste or use techniques such as volume reduction in order to preserve storage space. It is in the best interest of the State of Texas to preserve as much capacity as possible in the CWF while not diminishing the economic attractiveness of a disposal option.

Glossary

Activated Hardware – non-fuel reactor components that have been exposed to neutron radiation and made to be radioactive. Synonymous with irradiated hardware.

As Low As Reasonably Achievable (ALARA) – making a reasonable effort to keep exposure to ionizing radiation as low as possibly achievable using techniques such as decreasing the exposure time, increasing distance from the source of radiation, and shielding.

Bituminization – the process of mixing particles with asphalt (or bitumen) to reduce the risk of inadvertent inhalation of the particles.

Commingling – the act of mixing two or more sources of radioactive waste. In the Texas Compact this applies specifically to compact waste and non-compact waste.

Containerization – the act of emplacing waste within a canister or a rectangular or cylindrical reinforced concrete container.

Curie – a unit or measure of radioactivity from a certain element or radionuclide. (One Curie equals the amount of radioactivity from one gram of ^{226}Ra. One curie equals 3.7×10^{10} Becquerel or undergoes 3.7×10^{10} disintegrations per second).

Decommissioning – the act of removing from service any facilities that were used to store, process, dispose, or stage radioactive materials.

Decontamination – the act of removing radioactive contamination from equipment, structures, or other materials that have been in contact with radionuclides.

Dose – a measure of the energy deposited in a medium by ionizing radiation per unit mass.

Downblending – the blending or mixing of LLRW with higher concentrations of radionuclides with LLRW with lower concentrations of radionuclides to form a final homogeneous mixture of a lower class of waste.

Flocculation – the process by which individual particles of clay aggregate into clot-like masses or precipitate into small lumps. Flocculation occurs as a result of a chemical reaction between the clay particles and another substance, usually saltwater.

Irradiate – the process of exposing materials to ionizing radiation. If the radiation is a neutron beam, the resulting exposed material can become radioactive.

Irradiated Hardware – non-fuel reactor components that have been exposed to neutron radiation. Synonymous with Activated Hardware defined above.

Lithiation – to combine or impregnate with lithium or a lithium compound.

Low Activity Waste (LAW) – the lowest 10% of Class A waste, synonymous with Very Low-Level Waste, that may have alternative disposal options such as disposal in a RCRA site.

Millirem – A unit of radiation dose equivalent to 0.001 Rem.

Performance Assessment (PA) – a quantitative analysis that addresses what can happen, how likely it is to happen, what the resulting impacts are, and how these impacts compare to regulatory standards as it relates to the disposal of LLRW.

Permeability – a hydrologic characteristic of soils or other porous materials. The permeability is an indication of the ability of a liquid to move through the porous material.

Pyrolysis – the decomposition of organic material in the presence of superheated water or steam.

Radiological Impact Assessment – a quantitative evaluation of impacts from disposal of Low Activity Waste (LAW) in a RCRA disposal site.

Radionuclide – an element from the periodic table that is capable of spontaneously emitting its constitutive particles and thereby changing into another element. Such an element is termed radioactive and the emitted particle is called radiation.

Rem – a unit of radiation dose.

Texas Compact – the name of the LLRW disposal compact that includes the states of Texas and Vermont.

Transuranic – a term usually referring to radionuclides (or elements) with the number of protons greater than that of uranium. These radionuclides are typically not found in nature.

Volume Reduction – the process of reducing the volume of LLRW by methods such as compaction, incineration, or pyrolysis.