EPRI Research Results: International Nuclear Power Plant Waste Classification – 17444

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ABSTRACT

Different countries around the globe use varying schemes for the classification of radioactive waste. Many countries develop country specific waste classification schemes based on the International Atomic Energy Agency (IAEA) waste classification framework. The United States of America use the Class A, B, and C waste classification. Additionally, some countries use concentration limits to classify wastes while others use dose rate limits or a combination of concentration and dose rate limits. General comparisons have been made between the IAEA and the United States classification schemes, but a clear and well researched comparison of the international schemes was not evident in the available research data sets.

In 2013 Electric Power Research Institute (EPRI) initiated the *Comparison of Global Low and Intermediate Level Waste Management Methods* project. The objective of the project was to understand how six countries managed their low and intermediate level wastes from generation to disposal. A major task of this project was to conduct a comparison of the international waste classification schemes. EPRI developed a set of reference waste volumes that are representative of nuclear power plant low-level radioactive waste in form and radioactivity concentrations (e.g. dry active waste, high activity resin, low activity resin, high activity filters and low activity filters). These waste volumes were then classified using the waste classification systems in place in several countries around the world. In 2016, EPRI presented a paper providing a status update on this research. This 2017 paper provides the final results of that research, show where comparisons and correlations can be made, and provide a discussion on how this information might inform international radioactive research and development and benchmarking of radioactive waste management strategies, operational experiences, best practices, and technology implementation.

INTRODUCTION

In 2013 EPRI initiated the *Comparison of Global Low and Intermediate Level Waste Management Methods* project. The objective of the project was to understand how six countries managed their low and intermediate level wastes from generation to disposal. The six countries selected were Canada, France, Republic of Korea, Spain, Sweden and the United States (U.S.) A major task of this project was to conduct a comparison of the international waste classification schemes. The comparison of the international waste classification schemes was conducted in order to understand the differences and commonalities between the various classifications of wastes (especially when similar terminology was used.) This understanding would support international radioactive research and development and benchmarking of radioactive waste management strategies, operational experiences, best practices, and technology implementation.

The International Atomic Energy Agency (IAEA) provides the following general radioactive waste categories in their *Safety Standard, General Safety Guide No. GSG-1, Classification of Radioactive Waste*: Exempt waste (EW), Very Short Lived Waste (VSLW), Very Low Level Waste (VLLW), Low Level Waste (LLW), Intermediate Level Waste (ILW), and High Level Waste (HLW). The U.S. uses the categories LLW and HLW. While the U.S. does not use the VLLW and clearance (exempt) categories, there are regulatory process that can be used in order to dispose of wastes with undetectable or very low levels of radioactivity at hazardous waste disposal sites. The scope of this research focuses on those wastes that fall into the categories of Low and Intermediation Level Waste (LILW) and does not include HLW or clearance/exempt level wastes.

Whether using the IAEA or U.S. classification frameworks, each country develops their own specific criteria for defining and further separating the different classes of LILW. In fact, the IAEA General Safety Guide No. GSG-1 provides the general framework and guidance for various approaches for classification, but directs each country to develop their own criteria based on disposal facility design and its waste acceptance criteria. The U.S. country specific classification system is aligned with the general framework provided in the IAEA guidance.

The country definitions and classifications depend on and determine how these various wastes will be packaged, conditioned or stabilized, transported, and how and where they will be disposed of (i.e. disposal site design and waste acceptance criteria.) These country specific waste classification criteria may be radionuclide concentration based and/or package dose-rate based. Some countries use package surface or near surface dose rates (Canada, Sweden), other countries rely on activity limits for individual waste packages (U.S., Republic of Korea), while other countries use a combination of both approaches (France), or rely solely on the concentration of a few easy-to-measure nuclides (such as ^{60}Co and ^{137}Cs) in the waste (Spain).

In general terms, TABLE I identifies the waste classification system used for low and intermediate level waste in the six countries studied. TABLES II and III identify the process used by each country to classify their waste. TABLE III identifies those countries that use a package surface or near surface dose limit.

TABLE I. Waste Classification by Country

Waste Class	Canada[1]	France[2]	Republic of Korea[3]	Spain[1,2]	Sweden[1,2]	U.S.
Low Level Waste (LLW)	LLW	LLW	LLW[4]	Level 1	BLA[5]	*Class A* *Class B* *Class C*
Intermediate Level Waste (ILW)	ILW	ILW	ILW	Level 2	BTF[6] BMA[6] Silo[6]	-

[1] Has clearance.

[2] Has Very Low Level Waste (VLLW) disposal facility(ies).

[3] VLLW classification implemented 2014, disposal facility planning and development will be initiated when LLW disposal facility is available.

[4] Disposal facility planning for construction is underway.

[5] BLA is the low level waste caverns in the SFR disposal facility. (See TABLE III)

[6] BTF, BMA (two BTF caverns and one BMA cavern) and Silo intermediate level waste packages with lower to higher surface dose rates (10, 100 and 500 mSv/h) respectively. (See TABLE III)

TABLE II. Waste Classification Using of Activity Limits

Waste Class	France	Korea	Spain	U.S.
LLW	100 – 20,000 Becquerel/gram (Bq/g)	Activity concentration > than 100 times the IAEA clearance levels but < Low Level Waste activity levels (10 radionuclides including) < 3.70E+3 Bq/g total alpha <1.11E+6 Bq/g tritium	Maximum activity /unit mass < 1.85E+02 Bq/g per total alpha at 300 years < 7.40E+03 Bq/g tritium < 3.70E+04 Bq/g total beta/gamma activity; nuclides	*Class A* 10 CFR Part 61 Class A Concentration limits *Class B* 10 CFR Part 61 Class B Concentration limits *Class C* 10 CFR Part 61 Class B Concentration limits

			with half-life > 5 years	
ILW	20,000 – 1,000,000 Bq/g	Greater than LLW but less than High Level Waste: 4,000 Bq/g of alpha emitting nuclides with half-lives longer than 20 years, with a heat generation rate of less than 2 kW/m^3.	More detailed limits and limits per package for those nuclides in the Reference Inventory ^{60}Co activity below 3.70E+05Bq/g ^{90}Sr activity below 3.70E+05Bq/g ^{137}Cs activity below 3.70E+05Bq/g	Not a U.S. classification Note - Class C (even though defined as LLW by U.S. regulations)[1] and Greater than Class C (GTCC) more closely approximate ILW in the IAEA scheme

[1]10 Code of Federal Regulations (CFR) Part 61 Class C Concentration Limits

TABLE III. Waste Classification Method – Dose

Waste Class	Canada	France	Sweden
LLW	Type 1 < 2 millisievert/hour (mSv/h)	< 2 mSv/h	BLA – 2 mSv/h
ILW	Type 2 2 to 150 mSv/h Type 3 > 150 mSv/h	$\geq$ 2 mSv/h	BTF[1]– 10 mSv/h BMA – 100 mSv/h Silo - 500 mSv/h

[1] By classification (i.e. 10mSv/h) the BTF is an intermediate level waste cavern. However, much of the waste disposed is dewatered low level resins.

The 2007 EPRI Report 1016120, *An Evaluation of Alternative Classification Methods for Routine Low Level Waste from the Nuclear Power Industry* analyzed over 8,500 waste package records from 41 pressurized water reactors (PWR) and 24 boiling water reactors (BWR) over a four-year time period. The data from this 2007 EPRI report was sorted and used to develop reference waste streams that could be applied uniformly among the various global waste classification systems within this study.

EPRI classified these References Wastes using the classification systems of the six countries being studied. In some cases, this classification exercise involved theoretically packaging, conditioning, or processing the wastes as they would be in each country. For those countries that use radionuclide concentration limits as the basis for the waste classification, the concentrations in the Reference Wastes were compared against the radionuclide concentration limits to classify the waste. For those countries that uses package dose rates as the basis for the waste classification, the waste packages were modeled using Microshield™ to determine the package dose rates and classify the waste as appropriate.

COUNTRY SPECIFIC WASTE CLASSIFICATION DETAILS

The following describes the waste classification criteria for the six countries included in this study as they were used in the classification of the Reference Wastes. Each country and the utilities therein have various strategies for waste segregation, stabilization and conditioning, packaging, and disposal (including disposal site waste acceptance criteria and design) that were developed to provide protection of the public and the environment following the disposal of the radioactive wastes. These details were researched and incorporated into the classification of the Reference Wastes, however, they are not discussed in detail in this paper (they are fully documented in the EPRI report.)

United States

The U.S. radioactive waste classification criteria are defined in 10 Code of Federal Regulations (CFR) 61.55 “Waste Classification.” LLW is separated into Classes A, B, and C based on the concentrations of certain radionuclides in the waste. There are more rigorous requirements for stability and protection against inadvertent intruders as the waste classification progresses from A to C. The U.S. also has a class of waste called “Greater than Class C” that is still considered LLW exceeds the criteria of Class C wastes. Table 1 of 10CFR61.55 shows limits for long-lived nuclides, and Table 2 of 10CFR61.55 shows limits for short-lived nuclides. These tables are reproduced below (TABLE IV and TABLE V), and have been converted into Becquerel/gram (Bq/g) (assuming a waste density of 1 grams/cubic centimeter) to more easily enable comparison to other countries' limits. A summary of the classification method is as follows:

The radionuclide concentrations in the waste are compared to the Class A values in 10CFR61.55, Table 1 and Table 2.

- If the comparison to each value is < 1.0 of the Class A values, and the sum of the ratios in each table is also less than 1.0, then the waste is considered Class A.
- If greater than Class A, then comparison to Class C (Table 1 and Table 2) and comparison to Class B (Table 2 only) is necessary to determine the classification. The sum of the ratios is used to determine if the limit is reached.
- If any comparison is greater than Class C, then 10CFR61.55 states that the waste is "not generally acceptable for near-surface disposal."

TABLE IV. 10CFR61.55 Table 1 for Long-Lived Nuclides Converted to Bq/g.

Nuclide	Class A Limit (Bq/g)*	Class B Limit (Bq/g)	Class C Limit (Bq/g)
C-14	3.0E+04	N/A	3.0E+05
C-14 (Act)*	3.0E+05	N/A	3.0E+06
Ni-59 (Act)*	8.1E+05	N/A	8.1E+06
Nb-94 (Act)*	7.4E+02	N/A	7.4E+03
Tc-99	1.1E+04	N/A	1.1E+05
I-129	3.0E+02	N/A	3.0E+03
Alpha >5 year half life (Bq/g)	3.7E+02	N/A	3.7E+03
Pu-241 (Bq/g)	1.3E+04	N/A	1.3E+05
Cm-242 (Bq/g)	7.4E+04	N/A	7.4E+05

Notes:

** Bq/g assuming that density = 1.0 g/cc*

*** (Act) = in activated metal*

Class A limits are 10% of 10CFR61.55 Table 1

Class B is not defined for Long-lived nuclides
Class C limits are from 10CFR61.55 Table 1

TABLE V. 10CFR61.55 Table 2 for Short-Lived Nuclides Converted to Bq/g.

Nuclide	Class A Limit (Bq/g)*	Class B Limit (Bq/g)	Class C Limit (Bq/g)
All nuclides <5 year half life	2.6E+07	No limit	No limit
H-3	1.5E+06	No limit	No limit
Co-60	2.6E+07	No limit	No limit
Ni-63	1.3E+05	2.6E+06	2.6E+07
Ni-63 in Activated Metals	1.3E+06	2.6E+07	2.6E+08
Sr-90	1.5E+03	5.6E+06	2.6E+08
Cs-137	3.7E+04	1.6E+06	1.7E+08
** Bq/g assuming that density = 1.0 g/cc*			
If the nuclide mix is within Class A for long-lived nuclides, then the mix must meet Class A - Table 2 for short-lived nuclides.			
If the nuclide mix is within Class C for long-lived nuclides, then the mix must meet Class C - Table 2 for short-lived nuclides.			

The Republic of Korea

The Republic of Korea (ROK) defines VLLW as radwaste that contains radionuclides at concentrations of a 100 times the IAEA Clearance Levels (IAEA Safety Guide RS-G-1.7). For example, Ni-63 VLLW limit is 1.0 E+4 Bq/g, Co-60 VLLW limit is 10 Bq/g. The ROK defines LLW as radwaste that contains radionuclides in concentrations exceeding VLLW limits but do not exceed LLW concentration limits. LLW concentration limits are presented in TABLE VI. The ROK defines ILW as radwastes with radionuclide concentrations that exceed LLW limits but less than High Level Waste. HLW is defined as wastes contains 4,000 Bq/g alpha with half-lives >20 years, and heat generation >2 kilowatt/cubic meter (kW/m^3.)

TABLE VI. Republic of Korea Waste Classification Concentration Limits.

Radionuclide	LLW Concentration Limit (Bq/g)
^{3}H	1.11E+06
^{14}C	2.22E+05
^{60}Co	3.70 E+07
^{59}Ni	7.40 E+04
^{63}Ni	1.11E+07
^{90}Sr	7.40 E+04
^{94}Nb	1.10E+02
^{99}Tc	1.11E+03
^{129}I	3.70E+01
^{137}Cs	1.11E+06
Gross Alpha	3.70E +03

Spain

Spain defines VLLW as radwaste that contains <100 Bq/g for each radionuclide, and <30 Bq/g Cs-137, mean value for disposal units. LLW is divided into LLW Level 1 and LLW Level 2, as defined in TABLE VII.

TABLE VII. Spain Waste Classification Concentration Limits

Radionuclide	LLW Level 1 Activity Limits (Bq/g)	LLW Level 2 Activity Limits (Bq/g)

H-3	7.40E+03	1.00E+06
Na-22	2.00E+04	
Mn-54	3.70E+04	
Fe-55	3.70E+04	
Co-60	3.70E+03	5.00E+07
Zn-65	1.00E+04	
Sr-90	3.70E+03	9.10E+04
Ru-106	9.00E+03	
Ag-110m	2.00E+04	
Sn-119m	3.70E+04	
Sb-125	3.70E+04	
Cs-134	3.70E+03	
Cs-137	3.70E+03	3.30E+05
Ce-144	9.00E+03	
Pm-147	3.70E+04	
Eu-152	3.00E+04	
Eu-154	2.00E+04	
Tl-204	3.70E+04	
Pb-210	3.70E+01	
Ac-227	1.00E+01	
C-14	3.70E+03	2.00E+05
Ni-59	3.70E+03	6.30E+04
Ni-63	3.70E+03	1.20E+07
Zr-93	2.60E+03	
Mo-93	3.70E+02	
Nb-94	1.20E+02	1.20E+02
Tc-99	1.00E+03	1.00E+03
Pd-107	3.70E+03	
I-129	4.60E+01	4.60E+01
Cs-135	1.00E+04	
Sm-151	3.70E+03	
Total Beta-gamma with >5 year half-life	3.70E+04	
Total Alpha at 300 year	1.85E+02	3.70E+03

France

France has specific activity limits, per container, for Centre de L'Aube for a variety of radionuclides. However, for the purposes of this analysis a set of gross radionuclide concentrations, available in the literature, were used to classify their radioactive waste. These data are presented in TABLE VIII. In addition, France uses the value of 2 mSv/hr as the boundary between Low Level Waste (LLW) and Intermediate Level Waste (ILW).

TABLE VIII. Waste Classification System for France.

Classification	Concentration Limit
Very Low Level Waste (VLLW)	≤ 100 Bq/g
Low Level Waste (LLW)	100 - ≤ 20,000 Bq/g
Intermediate Level Waste (ILW)	20,000 - ≤ 1,000,000 Bq/g
High Level Waste (HLW)	> 1,000,000 Bq/g

Canada

Canada uses a waste classification system based on three sets of dose rates. For the purposes of this analysis, the dose rates used to determine where the waste will be stored at their centralized storage facility (the Western Waste Management Facility), were used:

- Low Level Waste (LLW - Type 1): < 2 mSv/hr
- Intermediate Level Waste (ILW - Type 2*): 2 - 150 mSv/hr
- Intermediate Level Waste (ILW - Type 3): > 150 mSv/hr

* Note, there are exceptions when these wastes may qualify as Low Level Wastes.

Sweden

Sweden uses a waste classification system based on dose rate:

- Low Level Waste (BLA): < 2 mSv/hr
- Intermediate Level Waste (BTF): ≥ 2 - 10 mSv/hr
- Intermediate Level Waste (BMA): > 10 - 100 mSv/hr
- Intermediate Level Waste (Silo): > 100 - 500 mSv/hr

The acronyms in the parenthesis indicates the disposal cavern at the SKB (the Swedish disposal facility) that the different class of wastes are disposed in.

DEVELOPING REFERENCE WASTE STREAMS

The 2007 EPRI Report 1016120, *An Evaluation of Alternative Classification Methods for Routine Low Level Waste from the Nuclear Power Industry* analyzed over 8,500 waste package records from 41 pressurized water reactors (PWR) and 24 boiling water reactors (BWR) over a four-year time period. The data from this 2007 EPRI report was sorted and used to develop reference waste streams that could be applied uniformly among the various global waste classification systems within this study. Reference waste streams were developed for the following waste types:

A. PWR High Activity Ion Exchange Resin (typifies reactor coolant and spent fuel pool purification resins),
B. PWR Low Activity Ion Exchange Resin (typifies waste liquid processing media, deborating and delithiating resins),
C. PWR Cartridge Filters,
D. BWR High Activity Resin and Filter Media (typifies reactor water clean-up media),
E. BWR Low Activity Resin and Filter Media (typifies condensate and radwaste media),
F. BWR Cartridge Filters (typifies filters from submersible clean-up systems and primary process filters),
G. Dry Active Waste-Low Level (e.g. Class A) (compactable, non-compactable [metal] sometimes referred to as combustible and non-combustible except that compactable wastes containing chlorides such as PVC are also not combustible),
H. Dry Active Waste - High Level (e.g. Classes B and C), and
I. PWR Evaporator Concentrates

A summary of the total concentration in each Reference Waste stream is shown in Fig. 1, with the range from a low of 1.6E+04 Bq/g (PWR Evaporator Bottoms) to a high of 3.4E+06 Bq/g for BWR High Level Resin. Each Reference Waste stream also has their own detailed radionuclide concentration spectrum. The reference waste stream for PWR High Activity Resins is shown in TABLE IX as an example.

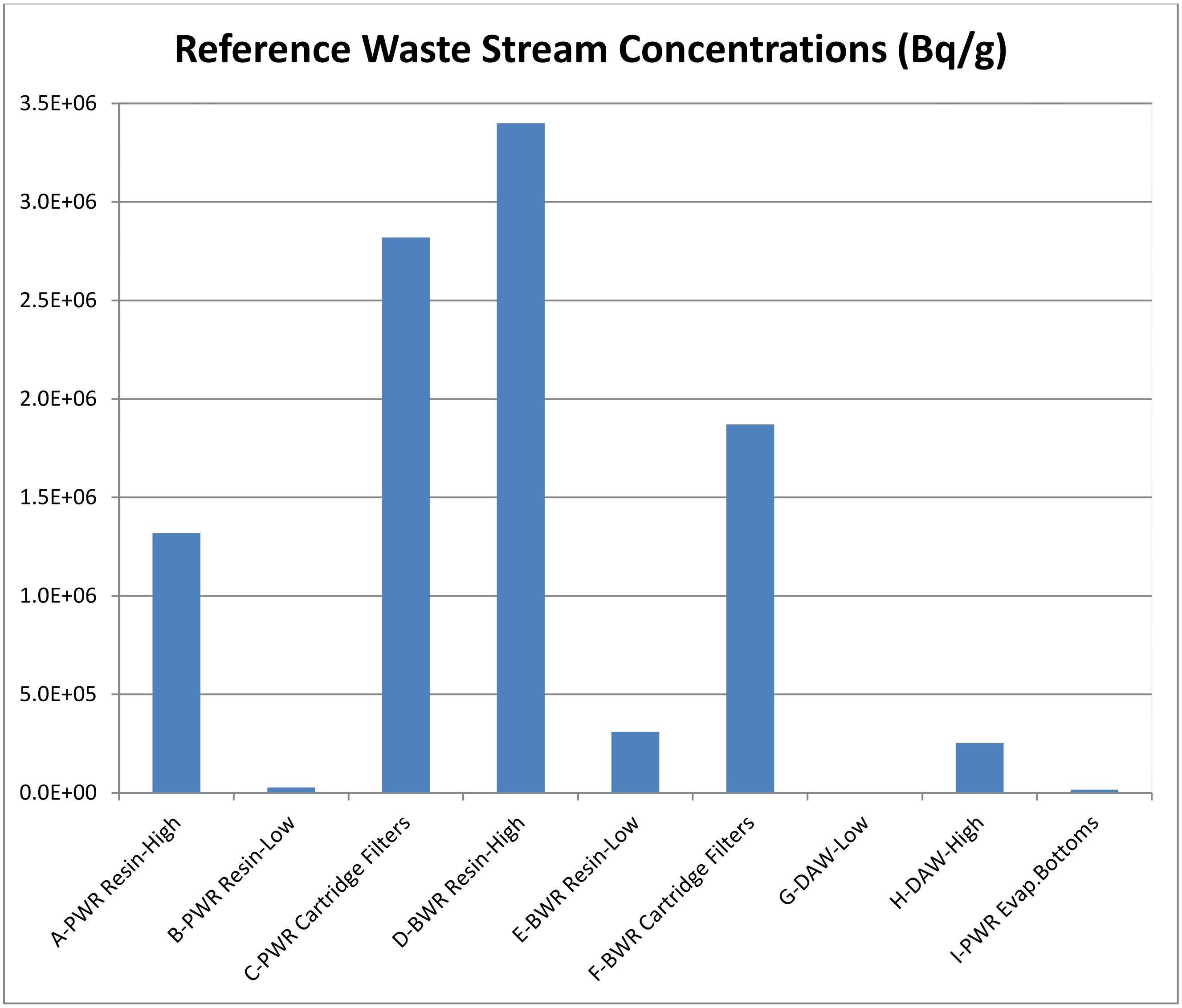

Fig. 1. Comparison of Reference Waste Stream Concentrations.

TABLE IX. PWR High Activity Ion Exchange Resin

Nuclide	Activity (Bq/g)	Fractional Abundance
^{3}H	4.89E+03	3.69E-03
^{14}C	3.72E+03	2.81E-03
^{51}Cr	3.81E+02	2.88E-04
^{54}Mn	3.61E+04	2.73E-02
^{55}Fe	2.34E+05	1.77E-01
^{59}Fe	1.27E+02	9.61E-05
^{57}Co	4.00E+03	3.03E-03
^{58}Co	1.62E+05	1.22E-01
^{60}Co	1.46E+05	1.10E-01
^{59}Ni	2.30E+03	1.74E-03
^{63}Ni	5.05E+05	3.82E-01
^{65}Zn	1.61E+02	1.22E-04
^{90}Sr	7.27E+02	5.50E-04
^{95}Zr	5.17E+02	3.91E-04
^{94}Nb	2.47E+00	1.87E-06
^{99}Tc	2.69E+02	2.03E-04
^{110m}Ag	3.62E+02	2.74E-04
^{125}Sb	9.83E+03	7.43E-03
^{134}Cs	7.50E+04	5.67E-02
^{137}Cs	1.35E+05	1.02E-01
^{144}Ce	2.21E+03	1.67E-03
^{238}Pu	4.70E+00	3.55E-06
$^{239/240}Pu$	1.57E+00	1.19E-06
^{241}Pu	2.86E+02	2.16E-04
^{241}Am	3.47E+00	2.62E-06
^{242}Cm	1.11E+00	8.40E-07
^{243}Cm	4.80E+00	3.63E-06
^{244}Cm	7.08E-01	5.35E-07
Sum	**1.32E+06**	**1.00E+00**

The reference waste streams do not necessarily reflect every possible radionuclide but they do represent a large fraction of the most common radionuclides typically found in nuclear power plant waste. Similarly, the reference waste streams developed do not necessarily represent every radionuclide that is included in the classification criteria of various countries. Furthermore, some of the countries in this study do not generate the waste streams that are directly analogous to the Reference Waste Streams. For example, France does not operate any BWRs and therefore would not generate any BWR related waste streams. Canada does not operate light water reactors; CANDU waste streams radionuclide concentrations may be different from the Reference Waste Streams. However, all nuclear power plants, regardless of design, do generate various level of radioactive ion exchange resins, filters, dry active wastes, etc. The reader should bear this in mind when reviewing the results of this analysis. The purpose of this project was the analyze the classification schemes using a standard set of radioactive wastes that would be commonly generated from nuclear power plants to study.

HOW CLASSIFICATION DATA WERE COMPARED

It was important to begin with the radionuclides concentrations of raw waste streams as generated. The different waste conditioning and packaging schemes used in the countries for the various waste forms studied result in changes to the initial volumes and densities. Where applicable to the waste form and its classification (for example, ion exchange resins solidified in cement or polymer), a number of assumptions relative to the package size, the waste density and quantity, and any solidifying agent and quantity were made. These assumptions were based on information provided from waste generators where possible.

The basic method of comparison of classification criteria is as follows:

1. Obtain the Reference Waste Stream nuclide mix (e.g., as in Table IX).
2. For the U.S., convert concentrations to microcuries/cubic centimeter (uCi/cc) for comparison to the US criteria. A density of 0.8 grams per cubic centimeter (g/cc) was assumed for resin waste streams, and a density of 1.0 was assumed for all other waste streams.
3. For South Korea and Spain, use the same radionuclide mix in units of Bq/g.
4. For France and Sweden, the concentrations of radionuclides for certain waste forms were adjusted for any solidification methods used.
5. For Sweden and Canada, the package dose rates were calculated using Microshield™.
6. For each classification, compare the concentrations or package dose rates to the countries limits
7. This was performed for each of the nine reference waste streams.

RESULTS OF COMPARISON

As discussed above, each country has developed country specific classification criteria. Most countries using the IAEA classification framework as the basis of their classification criteria. In the U.S. the waste classification is strictly based on the concentration of specific radionuclides provided in regulations and disposal site licenses. Whereas, in some of countries, the distinction between LLW and ILW could be based on the surface dose rate of the conditioned package.

Fig.2 provides, as an example, the Cs-137 limits of the various countries' classification criteria and the Cs-137 concentrations in the Reference Waste Streams. While only a sample of one of the radionuclides, it provides a perspective on the differences between the limits of each countries' criteria. Fig. 3, provides a comparison of the dose rate criteria for those countries that use package dose rates as classification criteria for wastes. As can be seen, all three countries (France, Canada, and Sweden) 2 mSv/hr is the limit of LLW. Anything greater than 2 mSv/hr is considered ILW. Furthermore, in Canada and Sweden, there are additional breakdowns of the ILW categories which determine their disposal.

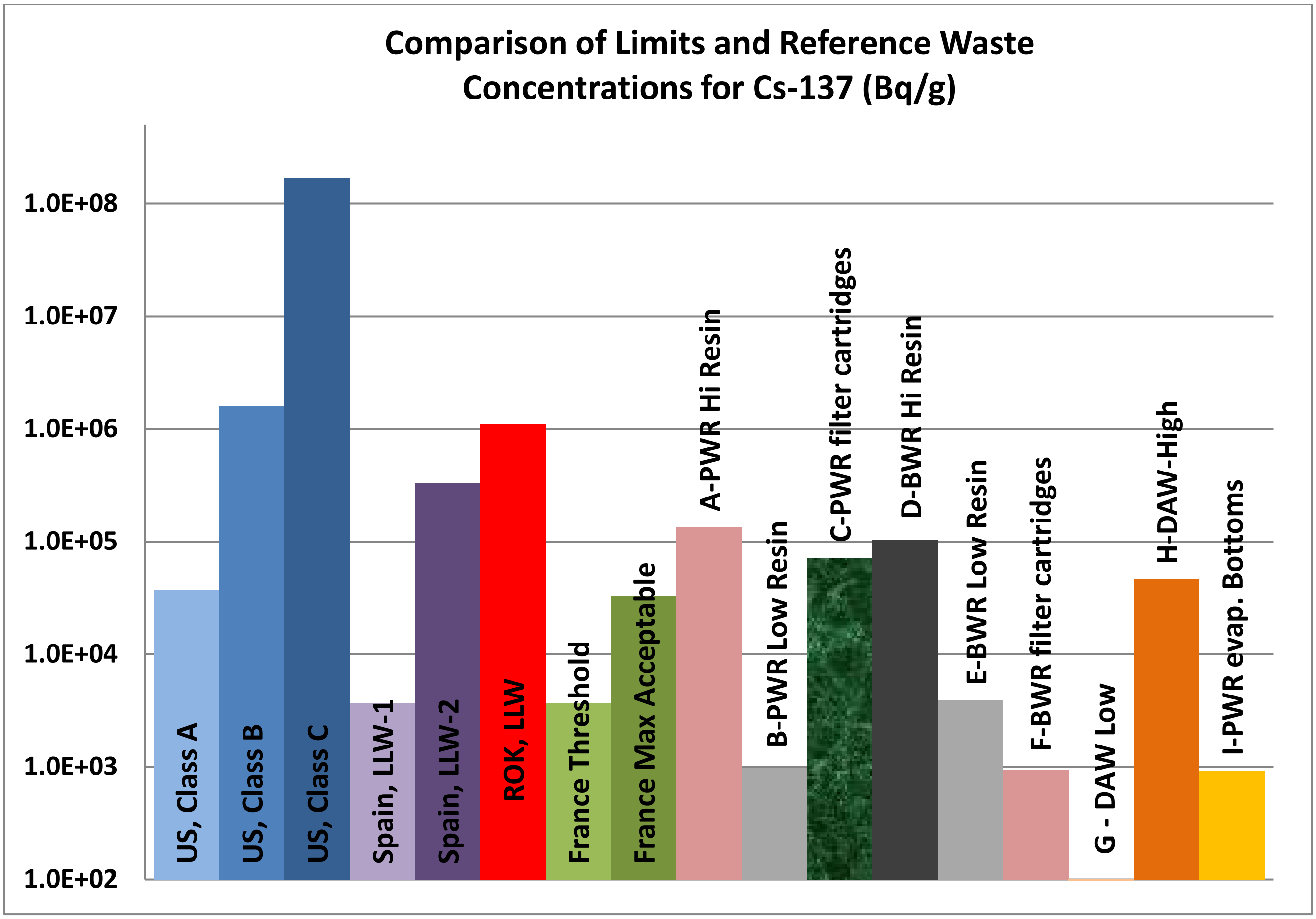

Fig. 2. Comparison of Limits and Reference Waste Concentrations for Cs-137 (Bq/g)

France	**0**	**< 2**	**≥ 2**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**	**200**	**300**	**400**	**500**
	LLW		**ILW**																			
Canada	**0**	**< 2**	**≥ 2**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**< 150**	**≥ 150**			
	LLW: Type 1		**ILW: Type 2**																**ILW: Type 3**			
Sweden	0	< 2	≥ 2	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	200	300	400	500
	LLW: BLA		**ILW: BTF**		**ILW: BMA**									**ILW: Silo**								

Fig. 3. Comparison of Package Surface or Near Surface Dose Rates Used as Classification Criteria.

TABLE X provides the results of the comparison of the international waste classification criteria using the Reference Wastes.

Table X. Comparison of the Classifications of Reference Waste Streams

	Reference Waste Type	US Classification	S. Korea - Classification	Spain - Classification	Canada - Classification	Sweden - Classification	France - Classification
A	PWR High Activity IX Resin	Class B	LLW	LLW Level 2	ILW (Type 2).	ILW (BMA).	ILW
B	PWR Low Activity IX Resin	Class A	LLW	LLW Level 2	LLW (Type 1)	ILW (BTF).	LLW
C	PWR Cartridge Filters	Class B	ILW	Exceeds LLW Level 2	ILW (Type 2).	ILW (BMA).	ILW
D	BWR High Activity Resin/filter media	Class B	LLW	LLW Level 2	ILW (Type 3).	ILW (Silo).	HLW
E	BWR Low Activity Resin/filter media	Class A	LLW	LLW Level 2	ILW (Type 2).	ILW (BTF).	ILW
F	BWR Cartridge Filters	Class A	LLW	LLW Level 2	ILW (Type 2).	ILW (BMA).	ILW
G	DAW-low level (Class A)	Class A	LLW	LLW Level 1	LLW (Type 1)	LLW (BLA)	LLW
H	DAW-higher level (Class B and C)	Class B	LLW	LLW Level 2	ILW (Type 2).	ILW (BTF).	ILW
I	PWR Evaporator Concentrates	Class A	LLW	LLW Level 2	LLW (Type 1)	LLW (BLA)	LLW

Note: Color coding is as follows: green = Class A or LLW; orange = Class B or ILW, and red = HLW or greater than ILW.

It is evident that the country specific waste classification criteria are very different even a common overarching framework and similar nomenclature is used. This is because each country develops their own criteria based on a safety assessment of the disposal site where the waste will be disposed of. These safety assessments are subject to the approval of the regulatory authority in each country and the results are affected by a number of factors, including:

- Dose rate on the package
- Construction of the package
- Stability of the conditioned or solidified waste
- Half-life of the radionuclide
- Depth of disposal
- Soil characteristics
- Meteorology, e.g., rainfall
- Hydrology of the site
- Engineered solutions, such as caps, liners, vaults, or buildings
- Public/stakeholder involvement

Some of these factors are technologically based and can be common around the world (e.g. dose rate on package, construction of package, stability of the conditioned or solidified waste, half-life of radionuclide, etc.) Several of these factors (e.g. soil characteristics, meteorology, hydrology, public/stakeholder involvement, and regulatory approval) would naturally vary widely among all of the different countries studied leading to different waste management and disposal strategies.

SUMMARY AND CONCLUSION

Prior to this research effort, there has been no comprehensive effort to collect, analyze, and compare the waste management, classification, and disposal practices of different countries. EPRI worked with international utility and disposal site colleagues to compile detailed information about each country's radioactive waste regulations, classification schemes, generation, segregation, conditioning and stabilization, packaging, transportation, waste classification, and disposal facility design and waste acceptance criteria. Using this detailed information, EPRI classified a standard set of radioactive wastes, the EPRI Reference Waste Stream, to better understand how the different classification schemes of each country align to each other.

This research showed that many countries adopt the IAEA framework and guidance for waste classification. The IAEA framework and guidance provides the overall, general guidance on classifying waste based on the long term safety of waste in a disposal setting. However, the IAEA directs each country to develop criteria based on the safety assessment and waste acceptance criteria of each country's disposal site(s.) As such, each country has developed their own country specific waste classification system and criteria for VLLW and LILW. Even the U.S. waste classification scheme is compatible with the IAEA waste classification framework.

The classification of the Reference Waste Streams further demonstrated the differences in the classification schemes of each country driven by the difference in concentration limits (for those countries that use concentration limits) on various radionuclides in the radwastes.

With such variations in the classification of radioactive wastes in different countries, it may be most effective, to communicate about radioactive waste management, technologies, and research and development based on the waste forms as opposed to waste class. As discussed above, all nuclear power plants generate some levels of radioactive ion exchange resins, filters, and dry active waste. Even though there may not be easy correlations made between classes of waste in different countries, there is still much benefit to be gained from discussing research and development, technologies, and management strategies based on common waste forms and goals (e.g. volume reduction, stabilization, packaging, etc.)

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