# NRC Staff
# Request for Additional Information
# on
# Electric Power Research Institute Report 3002005564, "Development of Generic Scaling Factors for Technetium-99 and Iodine-129 in Low and Intermediate Level Waste"

In an email dated June 19, 2018 (EPRI, 2018), the Electric Power and Research Institute (EPRI) submitted the publicly available report, No. 3002005564 entitled, "Development of Generic Scaling Factors for Technetium-99 and Iodine-129 in Low and Intermediate Level Waste", dated November 2015 (hereafter EPRI Report No. 3002005564; EPRI, 2015), for U.S. Nuclear Regulatory Commission (NRC) staff's review and endorsement. On July 19, 2018, the NRC staff notified EPRI that the staff had accepted the report for detailed review (NRC, 2018).

The NRC staff has reviewed EPRI Report No. 3002005564 and developed this request for additional information (RAI) to obtain sufficient information to decide whether to approve for use the findings documented in EPRI Report No. 3002005564. To conduct its detailed review, the NRC staff considered the following regulations (and related NRC guidance) from Title 10 of the *Code of Federal Regulations* (10 CFR) in its evaluation:

- 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste"
- 10 CFR Part 20, Appendix G, "Requirements for Transfers of Low-Level Radioactive Waste Intended for Disposal at Licensed Land Disposal Facilities and Manifests"
- Branch Technical Position (BTP) on Radioactive Waste Classification (NRC, 1983)
- Information Notice (IN) 86-20, "Low Level Radioactive Waste Scaling Factors, 10 CFR Part 61" (NRC, 1986)
- Regulatory Information Summary (RIS) 2015-02, "Reporting of H-3, C-14, Tc-99, and I-129 on the Uniform Waste Manifest" (NRC, 2015)
- Draft NUREG-2175, "Guidance for Conducting Technical Analyses for 10 CFR Part 61" (NRC, 2016)

The NRC staff will document its evaluation in a technical evaluation report. The NRC staff has summarized background information to give context to the RAI and demonstrate why the additional information is needed to complete the NRC staff's detailed review.

NRC regulations in 10 CFR 61.55(a)(8) states:

> "the concentration of a radionuclide may be determined by indirect methods such as the use of scaling factors which relate the inferred concentration of one radionuclide to another that is measured, or radionuclide material accountability, if there is reasonable assurance that the indirect methods can be correlated with actual measurements".

The NRC's regulations in 10 CFR Part 20, Appendix G, require licensees to complete a uniform waste manifest (NRC Forms 540, 541, and 542) when transporting or offering for transportation low-level radioactive waste (LLW) that is intended for ultimate disposal at a licensed LLW disposal facility. Appendix G of 10 CFR Part 20 further specifies that the activity of certain radionuclides (i.e., H-3, C-14, Tc-99, and I-129) contained in the shipment must be reported on the manifest.

According to NRC guidance in the BTP on Radioactive Waste Classification (NRC, 1983), the NRC staff considers concentrations that are accurate to within a factor of 10 as a reasonable target for determining measured or inferred radionuclide concentrations. The NRC staff also notes in the guidance that a detailed analysis should be performed periodically for difficult-to-measure radionuclides to confirm the correlation of measurements made from gross radioactivity measurements. Analyses should also be performed whenever there is reason to believe that facility or process changes may have significantly altered (e.g., by a factor of 10) previously determined correlations.

The NRC staff provides guidance on the use of scaling factors for LLW in IN 86-20 (NRC, 1986). In report IN 86-20, the NRC staff describes problems with the use of scaling factors. These problems were identified during NRC inspections in the mid-1980s. The problems observed included poor correlation between generic radionuclide concentration data and actual sample data at some nuclear power plants. In addition, some plants with multiple waste streams were using the same scaling factors for different waste streams despite more than a factor of 10 difference in radionuclide concentrations in the waste streams. The NRC staff, in IN 86-20, states that continued use of scaling factors that produce estimates differing from actual measurements by more than a factor of 10 may constitute noncompliance with 10 CFR 61.55(a)(8).

In RIS 2015-02 and its attachment (NRC, 2015), the NRC staff provides additional clarification on the use of indirect methods for determining the activity of these radionuclides for reporting on the uniform waste manifest when a radionuclide is present at a concentration less than its lower limit of detection. In RIS 2015-02, the NRC staff noted that "accurately reporting the activities of these radionuclides is important for better decision-making regarding the disposal of LLW. Overestimation of disposal site inventory could lead to premature loss of disposal system capacity, whereas underestimation of inventory could lead to public health and safety concerns." The NRC staff further notes "Although licensees may report conservative values for radionuclides on the uniform [waste] manifest, there may be benefits for disposal facilities if more accurate and less conservative numbers are used". In the appendix to RIS 2015-02, the NRC staff summarizes guidance on the use of scaling factors. This appendix states that:

> Scaling factors should be developed on a facility and waste stream specific basis. If a site has multiple units, separate scaling factors may need to be developed for the waste streams from each unit. Generic information can be used as a basis for these scaling factors provided there is sufficient data demonstrating that these scaling factors are expected to be accurate to within a factor of 10. The use of generic information may be the most appropriate for similar waste streams (e.g., similar resins performing the same function from the same type of power plant). If generic information from other sites is used in the development of the scaling factors, it is important to consider whether the information is applicable to the specific facility and waste streams and to understand the range of conditions under which the information is applicable. For example, if a power reactor has a higher amount of fuel failure than usual, generic information may not be applicable. Additionally, if generic information is used as the basis for scaling factors, an assessment should be performed periodically to evaluate whether there have been any changes in the system that might cause the generic information to no longer be applicable (e.g., changes to coolant chemistry). The scaling factors should be periodically assessed to confirm that the values used remain appropriate.

Also, the NRC staff noted in RIS-2015-02 (NRC, 2015):

> "the licensee should determine the range of conditions under which the indirect method is appropriate and the situations that could lead to a change in the correlation or cause the indirect method to no longer be appropriate. This is particularly important when the indirect method is based on an empirical relationship that does not have a physical basis. For example, indirect methods involving the correlation of radionuclides with different production mechanisms (e.g., activation products versus fission products) or different transport properties (e.g., H-3 and C-14 versus cobalt-60 [Co-60] or cesium-137 [Cs-137]) would not be expected to correlate well over a range of conditions."

The NRC staff provide additional guidance for the estimation of inventory using indirect methods, such as scaling factors, in Draft NUREG-2175 (NRC, 2016). This guidance states that: "Licensees may use indirect methods of estimating the inventory of some radionuclides when direct methods are not available, are not technically feasible, or are cost prohibitive. Indirect methods of estimating inventory have additional uncertainty that should be reflected in inventory estimates. When using indirect methods to estimate the inventory, the licensee should describe where the waste has been generated and what isotopes are used or created in the associated processes."

In EPRI Report No. 3003005564, EPRI developed constant scaling factors for I-129 and Tc-99 that depend on the presence of Co-60 or Cs-137 in LLW samples from power reactors. Given the NRC guidance discussed above, the NRC staff reviewed EPRI's report to determine whether EPRI had provided adequate justification for constant scaling factors for all waste streams from power reactors considering the potential variability in relative ratios of radionuclides between specific waste streams (e.g., resins, dry active waste, etc.). Likewise, the NRC staff evaluated EPRI's approach to determine whether EPRI provided adequate justification for constant scaling factors for use across all power reactors given the potential for plant-to-plant variability. Finally, the NRC staff reviewed the report to determine whether adequate justification was provided for constant scaling factors given the potential for changes in power reactor operation over time and associated effects on waste streams.

The NRC is responsible for ensuring public health and safety. Though the use of overly conservative activity estimates may have other impacts (e.g., disposal facility capacity), it would not pose a health or safety concern with respect to dose to a member of the public from waste at a disposal facility. Therefore, in its review, the NRC staff focused its evaluation on whether there was reasonable assurance that the proposed scaling factors would not underestimate the radionuclides by more than a factor of 10.

In summary, based on the above regulations and guidance, key criteria the NRC staff is using to evaluate the applicability of the scaling factors proposed in EPRI Report No. 3002005564 include:

- Is there reasonable assurance that the indirect method (i.e., scaling factors) can be correlated with actual measurements?
- Are the scaling factors accurate to within a factor of 10 (i.e., is there reasonable assurance that the activity will not be underestimated by more than a factor of 10)?
- Are the range of conditions under which the scaling factor is applicable well understood, particularly for radionuclides that have different production mechanisms and/or different transport properties?
- Is there sufficient information to demonstrate that the generic information used to develop the scaling factors are applicable to a specific facility and waste stream?
- Have the scaling factors been periodically assessed to confirm the values remain appropriate?

## RAI 1

**Comment:**

EPRI Report No. 3002005564 (EPRI, 2015) needs more justification that the data from NUREG/CR-6567 (NRC, 2000) are applicable to LLW generated today.

**Basis:**

The LLW samples analyzed and described in NUREG/CR-6567, “Low-Level Radioactive Waste Classification, Characterization, and Assessment: Waste Streams and Neutron-Activated Metals” (NRC, 2000) that served as the basis for the scaling factors generated in EPRI Report No. 3002005564 were taken in the late 1980s and 1990s. Improvements have been made in the nuclear power industry between that time and today that likely affect the relative ratios of the radionuclides considered in EPRI Report No. 3002005564. For example, the performance of fuel cladding has likely improved and there is probably much less fuel failure than in the past. A reduction in the amount of fuel failure would decrease the amount the fission products (e.g., Tc-99, Cs-137, and I-129) that are released into the reactor coolant system. There could be differences between the release and transport of the radionuclides formed by fission products in failed fuel and tramp fuel and the ratios between the radionuclides might not be constant even if the mechanism of formation is the same. In addition, there may have been changes to reactor coolant system chemistry that could affect the relative ratios of radionuclides. For example, changes in the chemistry that could affect the rate of corrosion or other properties of the radionuclides (e.g., solubility, amount of sorption) could also affect the relative ratios of the radionuclides in the reactor coolant and in associated LLW.

Similarly, valves containing the cobalt-chromium alloy stellite, a potential source of Co-60, have been replaced with other materials that do not result in the generation of Co-60, potentially resulting in a decrease in the activity of Co-60 formed. These changes could have led to the relative ratios of these four radionuclides changing, which could cause the scaling factors provided in EPRI Report No. 3002005564 to no longer be accurate to within a factor of 10 (i.e., the use of the scaling factor would not result in the underestimation of the radionuclide by more than an order of magnitude). This is because the scaling factors in the report are based on the relative ratios of Tc-99 and/or I-129 to the amount of Co-60 and/or Cs-137 detected in the sample. For example, Page 1-3 of EPRI Report No. 3002005564 notes, “The key radionuclide for scaling Tc-99 was found to be highly dependent on the ratio of fission to activation products (represented by the ratio of Cs-137 to Co-60) in the sample”.

There may also have been other changes to power reactor operations, such as amount of tramp fuel present, amount of molybdenum (a Tc-99 precursor) in plant components, or changes to the reactor coolant system (RCS) operation or components (e.g., resin) that could lead to changes in the relative ratios of these radionuclides (i.e., Tc-99, Co-60, Cs-137, and I-129).

**Path forward:**

(a) Provide additional information on significant changes in power reactor components or operations in the past 20 to 30 years that could have affected the relative ratios of Tc-99, I-129, Cs-137, and Co-60, including any changes to: the amount of tramp fuel, materials that could affect the formation of activation products, the RCS operation or components, and the management of LLW at the power plants.

(b) Provide justification for the use of sample data from 20 to 30 years ago for current LLW by either of the following methods:

(i) Provide additional basis and justification for the applicability of the sample data from 20 to 30 years ago to current LLW considering changes in fuel performance, reduction in the use of cobalt containing alloys in reactor components, and any other significant changes identified in part (a) of this RAI.

or

(ii) As an alternative to part (i) above, provide the results of analyses from recent power reactor LLW samples that demonstrate that improvements and changes to nuclear power plants in the last 20 to 30 years have not resulted in a significant change to the scaling factors (i.e., a change that could result in the underestimation of the activity of a radionuclide by more than a factor of 10).

## RAI 2

**Comment:**

Adequate justification is needed that the data from NUREG/CR-6567 (NRC, 2000) used in EPRI Report No. 3002005564 (EPRI, 2015) are sufficient to generate generic scaling factors for all LLW from commercial nuclear power reactors.

**Basis:**

EPRI Report No. 3002005564 contains an extensive statistical analysis of the data from NUREG/CR-6567, but the report does not have a justification that the number and types of samples taken for the NUREG/CR development, as well as the analytical methods used for the measurements, is adequate for the development of generic scaling factors for use with all nuclear power station LLW.

NUREG/CR-6567 documents research performed by Pacific Northwest National Lab (PNNL) and funded by the NRC[1]. The goal of this study was to provide regulatory agencies, nuclear

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[1] NUREG/CR-6567 was generated by an NRC contractor and contains the following disclaimer: "NUREG/CR-6567 is not a substitute for NRC regulations and compliance is not required. The approaches and/or methods described in this NUREG/CR are provided for information only. Publication of this report does not necessarily constitute NRC approval or agreement with the information contained herein."

utilities, and LLW managers with more information on the radionuclide source terms. As part of this study, researchers measured the activity of Tc-99, I-129, Co-60, and Cs-137 in LLW samples from commercial nuclear power stations. Data from previous EPRI reports and unpublished data collected at PNNL was also compiled in this report. The relative ratios of the radionuclides (i.e., I-129 to Cs-137, I-129 to Co-60, Tc-99 to Cs-137, and Tc-99 to Co-60) were determined for each sample in the dataset and the geometric mean of these ratios for calculated to determine scaling factors. NUREG/CR-6567 does not include a description of the specific waste types and conditions under which their calculated scaling factors would be applicable. The geometric standard deviations of the ratios in the dataset were also not evaluated.

**A total of 45 samples were reported in the dataset in NUREG/CR-6567 that served as the basis for the scaling factors developed in EPRI Report No. 3002005564. Most of the samples were of resin, but a small number of samples of dry active waste (DAW), filters, and other materials were also analyzed (Table 1.** Types of Samples Reported in NUREG/CR-6567 that are referenced in EPRI Report No. 3002005564

). EPRI does not provide a basis demonstrating that a sufficient number of samples was included in the dataset. As is seen in the table below, very few samples were taken of most of the types of waste. The sorption or other aspects of the behavior of the radionuclides considered in EPRI Report No. 3002005564 (Tc-99, I-129, Cs-137, and Co-60) could differ for different materials and kinds of waste and the relative ratios of the radionuclides might not be constant across the different waste types and conditions. The analysis currently included in EPRI Report No. 3002005564 is not sufficient to demonstrate that the proposed scaling factors are appropriate for all the expected power reactor LLW types and conditions.

**Table 1.** Types of Samples Reported in NUREG/CR-6567 that are referenced in EPRI Report No. 3002005564

| **Type of Sample** | **Number of Samples** | | |
|---|---|---|---|
| | **PWR** | **BWR** | **Total** |
| Resin | 21 | 11 | **32** |
| DAW | 3 | 2 | **5** |
| Filter | 4 | 0 | **4** |
| Charcoal | 1 | 0 | **1** |
| Soil | 0 | 1 | **1** |
| Oil | 0 | 1 | **1** |
| Coolant | 1 | 0 | **1** |
| **Total** | **30** | **15** | **45** |

Based on the data reported in Table 7.8 of NUREG/CR-6567

Additionally, as noted above, the measurements compiled in Table 7.8 of NUREG/CR-6567 included measurements made as part of that project as well as measurements previously published in EPRI reports (e.g., Vance, et al. 1992) and other studies by Robertson, et al. 1990, and Robertson, et al. 1997, as well as from previously unpublished measurements made at PNNL. It is not clear which of the samples in the dataset are from which study and if the analytical method described in NUREG/CR-6567 was used for all these studies.

Finally, NUREG/CR-6567 notes that some of the resin samples were taken from scaled-down versions of the reactor primary coolant demineralizer that were built to sample the primary coolant at several different power stations and were installed in-line with the primary coolant sampling line. It appears some of the resin samples represent samples taken from the in-line samplers and some represent samples taken from the actual resins used in the plant. The researchers designed the in-line samplers to represent the conditions of the real system, but there may still be some differences in the behavior of the radionuclides in the real system versus the scaled-down test columns. Information on whether the individual samples represent resin from the in-line sampler or from the real system was not provided in NUREG/CR-6567. However, the NRC staff expects that EPRI might have access to this information as much of the dataset reported in NUREG/CR-6567 came from EPRI research reports.

**Path forward:**

(a) Provide a justification that the analytical methods used to generate the dataset in Table 7.8 of NUREG/CR-6567 (including the analytical methods described in the NUREG/CR as well as the analytical methods used to generate the EPRI data) are appropriate for the development of generic scaling factors.

(b) Provide additional information on the applicability of the generic scaling factors for all nuclear power station waste by either of the following methods:

   (i) Provide a justification that the number and types of samples in the dataset is adequate for the development of generic scaling factors for use with all nuclear power station LLW under all conditions. If additional samples are added to the dataset in response to RAI 1, the new data can be considered in this evaluation.

   or

   (ii) As an alternative to part (i) above, provide a description of the types of waste and the conditions under which these scaling factors are expected to be applicable and the bounds of when the scaling factors can be used.

(c) Provide a list of which samples from Table 1 above were evaluated in the previous EPRI studies (e.g., Vance, et al. 1992) and other unpublished studies, if this information is available. Describe any differences in the analytical methods used in the different studies, if applicable.

(d) If available, provide information on which resin samples were taken from the in-line samplers and which were taken from the real system if this information is available in the previous EPRI reports.

(e) If available, provide information on analytical uncertainty and uncertainty propagation in the analyses used to develop the scaling factors. Similarly, provide information on the quality of the unpublished data used to develop the scaling factors.

## RAI 3

**Comment:**

The proposed scaling factor for quantifying the activity of I-129 based on a measured activity of Cs-137 potentially underestimates the activity in waste from Boiling Water Reactors (BWRs).

**Basis:**

The scaling factor proposed in EPRI Report No. 3002005564 (EPRI, 2015) for I-129 based on Cs-137 was developed based on the geometric mean of the data points in NUREG/CR-6567 (NRC, 2000) for samples that had a ratio of Cs-137 to Co-60 that was less than 10 (i.e., the samples from systems in which the fuel cladding performance appeared to be good). The geometric means of the entire NUREG/CR-6567 dataset and the samples with ratios of Cs-137 to Co-60 of more than 10 (i.e., the samples from systems in which there was failed fuel) were also calculated. The scaling factor calculated based on the samples from plants with intact fuel was higher (more conservative) than the one calculated based on the entire dataset and the one calculated based on samples from plants with failed fuel, so it was selected as the proposed scaling factor for all fuel conditions.

However, an independent evaluation of the NUREG/CR-6567 data by the NRC staff found that calculated ratios of I-129 to Cs-137 were generally higher for the BWR samples than samples from Pressurized Water Reactors (PWRs) (**Error! Reference source not found.**). The geometric mean of the I-129-to-Cs-137 ratio from all BWR samples was $4.2 \times 10^{-7}$ while the geometric mean from all PWR samples was $6.5 \times 10^{-8}$. Based on the data in NUREG/CR-6567, it appears that the use of the proposed scaling factor could result in the underestimation of the activity of I-129 in LLW from BWRs.

Additionally, this scaling factor would have resulted in the underestimation of the I-129 by more than an order of magnitude in two of the NUREG/CR-6567 BWR samples (Figure 2). It is not clear if these samples are representative of typical BWR LLW or if there is a known explanation for why the relative ratio of I-129 to Cs-137 might differ for these samples. If the samples are believed to be representative of typical BWR LLW, then the data from these results indicate that there is not reasonable assurance that the proposed scaling factor would result in a predicted activity of I-129 that is within a factor of 10 of the actual activity. However, if the samples are not representative of BWR LLW, then the proposed scaling factor could be restricted to waste streams that do not have the same properties as those samples.

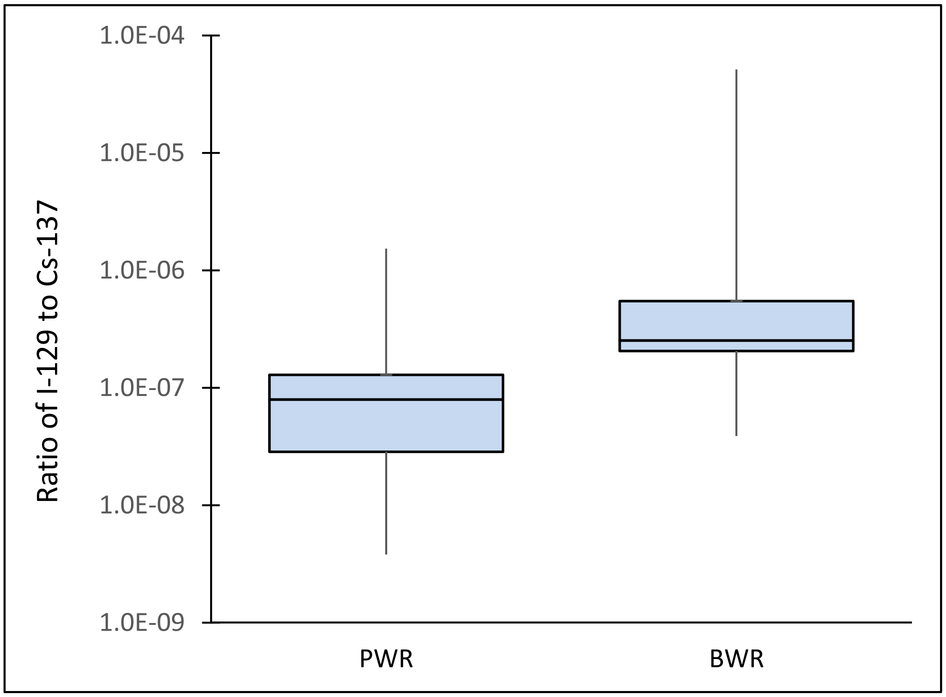


**Figure 1.** Ratio of I-129 to Cs-137 in Samples Analyzed in NUREG/CR-6567

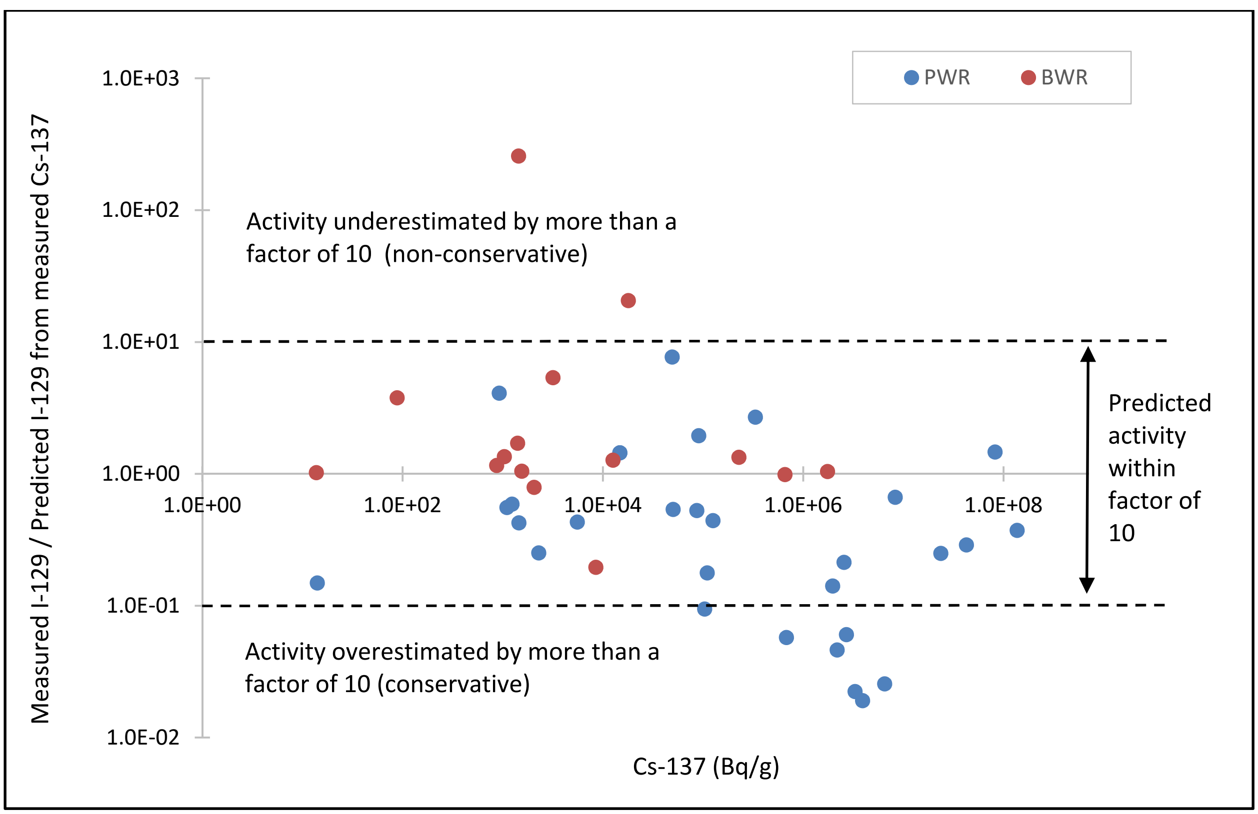

**Figure 2.** Ratio of measured I-129 to predicted I-129 based on the proposed scaling factor

**Path forward:**

(a) Provide justification that the proposed scaling factor for I-129 based on the measured Cs-137 activity is appropriate for all LLW from BWRs. Alternatively, provide a description of and basis for the specific conditions under which it would be appropriate to use the proposed scaling for LLW from BWRs.

(b) Provide information on the representativeness of the two samples for which the use of the proposed I-129/Cs-137 scaling factor would result in more than a factor of 10 underestimation in the activity of I-129. If the samples are determined to be not representative of BWR LLW, provide a description of what properties of the waste and/or plant conditions caused the samples to not be representative.

## <u>RAI 4</u>

**Comment:**

Insufficient information was provided to conclude that there is reasonable assurance that the use of the proposed scaling factor for I-129 based on measured Co-60 activity when Cs-137 is not present above the detection limit will result in the activity in the waste being accurately estimated.

**Basis:**

A scaling factor was proposed for determining the activity of I-129 based on the measured Co-60 activity when Cs-137 is not present above the detection limit. Co-60 and I-129 have different mechanisms of formation in power reactors. Co-60 is formed from activation of Co-59 corrosion products from plant components, while I-129 is a fission product that is released from fuel pellets or from tramp fuel. Because I-129 and Co-60 are not formed from the same process, there does not appear to be a mechanistic basis for these two radionuclides to have a constant ratio and the ratio might vary over the range of conditions expected in commercial nuclear power plants.

Additionally, as described in RAI 1, the activities of Co-60 generated in nuclear power plants may have changed between when the samples were taken and are different now due to improved industry practices, such as reducing the amount of cobalt in plant components. Similarly, improvements to fuel performance and possible changes in the amount of tramp fuel could also cause changes in the relative amounts of Co-60 and I-129 present. Also, improved fuel cladding performance might lead to more waste that does not have an activity of Cs-137 that is above the detection limit.

EPRI Report No. 3002005564 does not include a description of the situations in which the use of the I-129/Co-60 scaling factor would be appropriate, per the guidance discussed earlier from

RIS-2015-02 (NRC, 2015), other than a statement that this scaling factor should only be used when Cs-137 has not been detected in the sample.

An independent analysis by NRC staff found that the use of the I-129/Co-60 scaling factor consistently resulted in an acceptable prediction of the I-129 activity for the waste streams in the NUREG/CR-6567 (NRC, 2000) dataset when the ratio of Cs-137 to Co-60 was less than 0.1 (Figure 3), which would be expected to be true when Cs-137 is not present in detectable quantities. However, Cs-137 was detected in all these samples and there are no sample measurements that can be used to confirm that the scaling factor is appropriate when the activity of Cs-137 is below the detection limit.

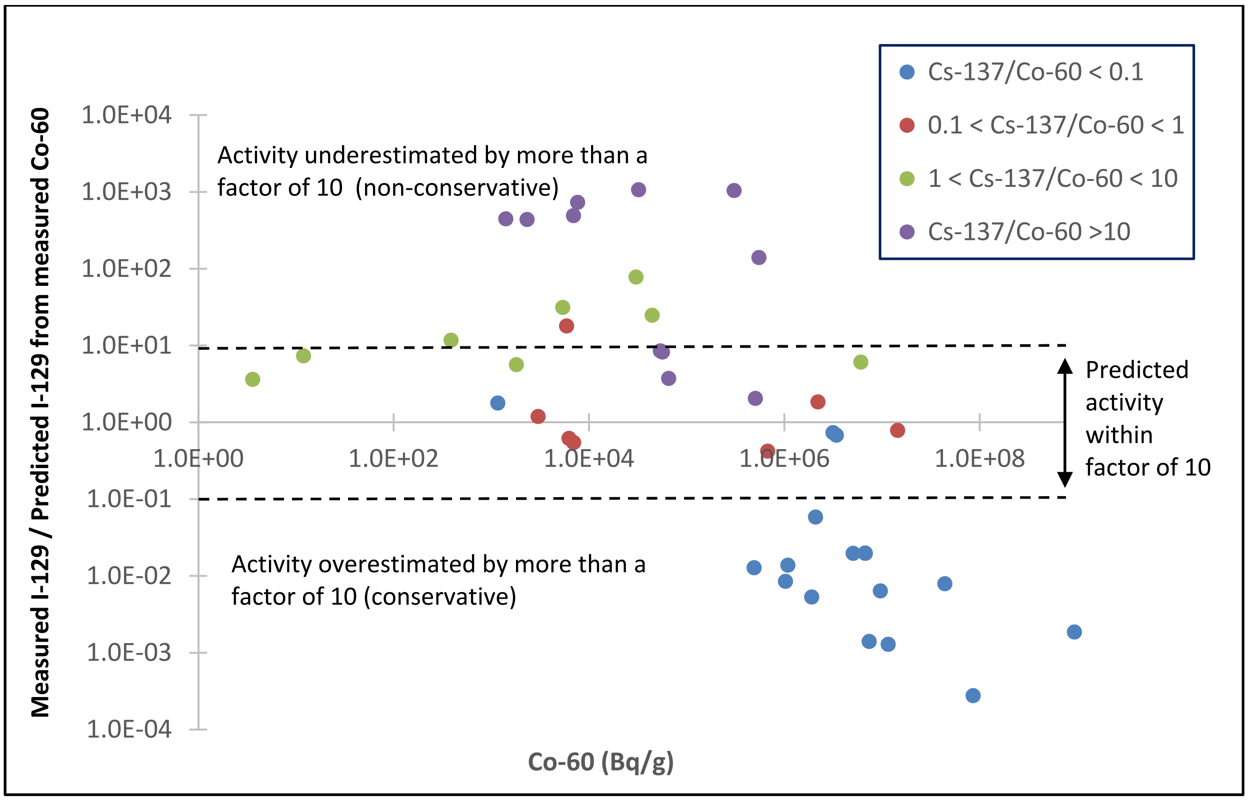


**Figure 3.** Ratio of measured I-129 to predicted I-129 based on the proposed I-129/Co-60 scaling factor

EPRI Report No. 300200556 notes that it could be appropriate to conclude that I-129 is not present (or not present in quantities of concern) if Cs-137 is not present. Both Cs-137 and I-129 are fission products and are formed through the same mechanism, so it is reasonable to expect that samples with low Cs-137 activities would also have low I-129 activities. However, even if Cs-137 was not detected in a sample, it could still be present in small amounts and I-129 could also be present in small amounts. The risk from I-129 primarily comes from the use of contaminated water at the disposal facility over the long term, while Cs-137 poses a risk over the short term. The relative risk from I-129 per unit activity can be higher than the relative risk from Cs-137. Therefore, the potential risk from I-129 from a given waste stream cannot be assumed to be negligible based only on the lack of Cs-137 detection. However, an analysis of the potential dose at the disposal facility from I-129 in waste streams that do not have detectable level of Cs-137 could be performed to evaluate the potential I-129 risk. If this risk is found to be negligible, it might be possible to make a more robust argument that I-129 does not need to be considered when Cs-137 is not detected. Such an analysis would need to consider the potential activity of I-129 when Cs-137 is at or below the detection limit (including uncertainty) and the potential dose at a range of disposal facilities (e.g., including both disposal facilities with and without a groundwater pathway).

**Path forward:**

For the NRC staff to conclude that it is appropriate to estimate the I-129 concentration based on the concentration of Co-60 when Cs-137 is not present in detectable quantities, EPRI should do either of the following (a or b):

(a) Justify that the I-129/Co-60 scaling factor is appropriate when Cs-137 is not present above the detection limit by providing the following information:

   (i) A description of the range of conditions under which the use of the I-129/Co-60 scaling factor is appropriate and the situations that could lead to a change in the correlation or cause the indirect method to no longer be appropriate; and

   (ii) Additional information to demonstrate that the data used to generate the I-129/Co-60 scaling factor is applicable when Cs-137 is not present above the detection limit given that Cs-137 was detected in all the samples considered in EPRI Report No. 3002005564.

or

(b) Alternatively, demonstrate that there is reasonable assurance that a reasonably bounding activity of I-129 that could be present when Cs-137 is not detected would not cause a significant long-term risk at a disposal facility.

## RAI 5

**Comment:**

Adequate justification is needed to support the use of scaling factors developed for Tc-99 based on the activities of Cs-137 and Co-60.

**Basis:**

In EPRI Report No. 3002005564 (EPRI, 2015), two scaling factors were developed for Tc-99. One of these scaling factors was based on the ratio of Tc-99 to Co-60 and is applicable when the ratio of Cs-137 to Co-60 is less than 10 (i.e., when there is good fuel cladding integrity) and the other scaling factor is based on the ratio of Tc-99 to Cs-137 and is applicable when the ratio of Cs-137 to Co-60 is less than 10. As is described in more detail in the report, Tc-99 in LLW from nuclear power reactors is generated from two different mechanisms: as a fission product (both in the fuel pellets and in tramp fuel) and from the activation of molybdenum in plant components. Fuel cladding integrity has likely improved over time. Therefore, data collected when fuel cladding was poorer may not be representative of conditions with improved fuel cladding. Waste generated during decommissioning might be affected by historic fuel failure and the Tc-99/Cs-137 scaling factor could potentially still be applicable for some waste streams.

The amount of Tc-99 released from the fuel pellets would be higher when the fuel cladding integrity is poor, and the fraction of the Tc-99 in LLW generated as a fission product would also be higher when the fuel cladding integrity is poor. Under these conditions, it is expected that the activity of the Tc-99 would correlate more with Cs-137, which is also formed from fission. It is expected that a higher fraction of the Tc-99 in LLW would be formed as an activation product when the fuel cladding integrity is good and that the activity of Tc-99 would not correlate as well with Cs-137. However, more information is needed to have reasonable assurance to support the generic use of these correlations.

Although Co-60 and Tc-99 are both formed by activation, they are formed from different elements. Co-60 is formed from Co-59 and Tc-99 is formed from Mo-98. Cobalt and molybdenum can both be present in small amounts in plant components, but there is no mechanism that would cause there to be a correlation between the amounts of them present. In Section 3 of EPRI Report No. 3002005564, the relative amounts of Co-59 and Mo-98 in certain RCS materials (i.e., 304 SS, 316 SS, Alloy 600, Alloy 690, and Alloy 800) are analyzed. The authors concluded that the mean of the ratios of Mo-98 to Co-59 generally do not vary by more than a factor of 2 to 3 for the most influential materials, though a basis is not provided for why these particular materials were selected as being the most influential sources of Co-59 and Mo-98. The report also does not provide quantitative information on what changes, if any, there have been to the Co-59-to-Mo-98 ratios with time. Further, the range of conditions for which the use of the proposed Tc-99/Co-60 scaling factor is appropriate and the situations that could lead to a change in the correlation or cause the indirect method to no longer be appropriate were not provided in the report.

An independent analysis by the NRC staff found that the use of the Tc-99/Co-60 scaling factor consistently resulted in an acceptable prediction of the Tc-99 activity for the samples in the NUREG/CR-6567 (NRC, 2000) dataset except for one sample (Figure 4). Based on this, it appears that there are some conditions under which the proposed Tc-99/Co-60 scaling factor would not adequately estimate the activity of Tc-99. A description of the conditions under which this scaling factor would not be applicable is needed.

Although there is a mechanistic reason for there to be a correlation between Tc-99 and Cs-137 when there is a poor fuel cladding integrity, additional information is needed to have reasonable assurance that the use of the proposed scaling factor will result in an appropriate predicted activity under all expected conditions. Of the 45 samples reported in NUREG/CR-6567 and subsequently used by EPRI to develop scaling factors, only 13 of the samples had a Cs-137-to-Co-60 ratio of greater than 10. Tc-99 was only measured in 10 of these samples, and all 10 of these samples were for resin from PWRs. As is noted in RAI 2, it is not clear if these resin samples are from the in-line samplers or from the actual reactor systems. Information is needed to demonstrate that the number and type of samples included in the dataset was adequate.

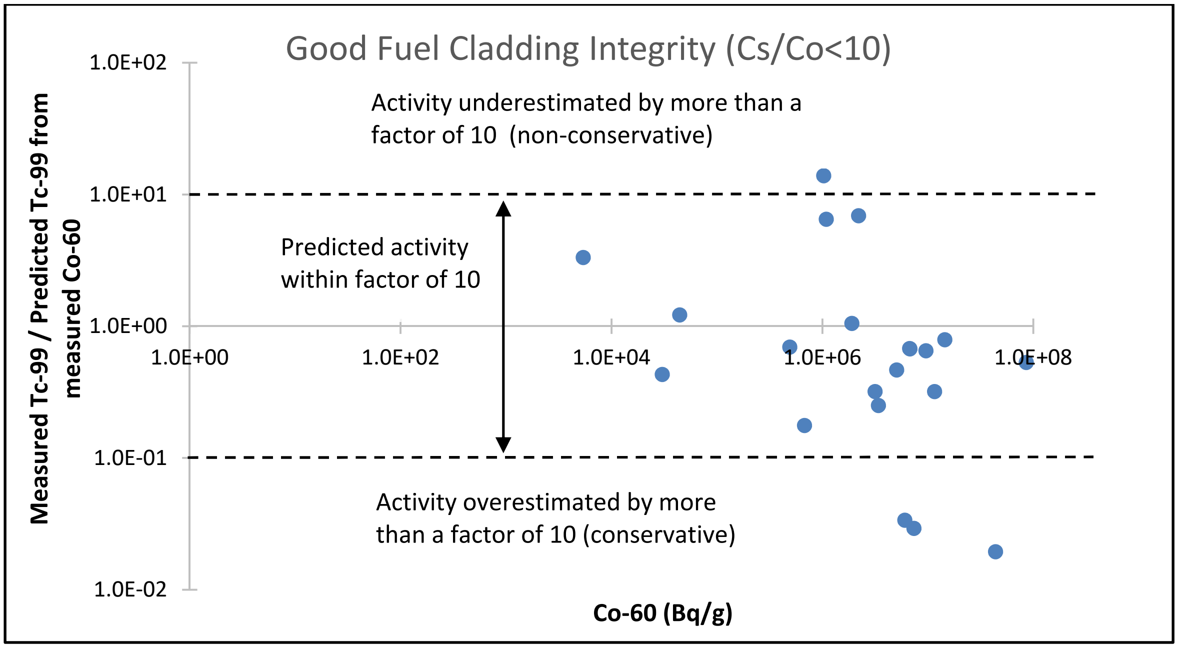


**Figure 4.** Ratio of measured Tc-99 to predicted Tc-99 based on the proposed Tc-99/Co-60 scaling factor

An independent analysis by the NRC staff found that the use of the Tc-99/Cs-137 scaling factor consistently resulted in an acceptable prediction of the Tc-99 activity for the samples in the NUREG/CR-6567 dataset except for one sample (Figure 5). Based on this, it appears that there are some conditions under which the proposed Tc-99/Cs-137 scaling factor would not adequately estimate the activity of Tc-99. A description of the conditions under which this scaling factor would not be applicable is needed.

**Path forward:**

(a) For the NRC staff to conclude that it is appropriate to predict theTc-99 activity based on the Co-60 activity, the following information is needed:

  i. Additional data to support the conclusion that the relative ratio of Co-59 to Mo-98 is relatively consistent from plant to plant and over the operating history of the power plants; and

  ii. A description of the range of conditions under which the use of the Tc-99/Co-60 scaling factor is appropriate and the situations that could lead to a significant change in the correlation that would cause the proposed scaling factor to no longer be appropriate.

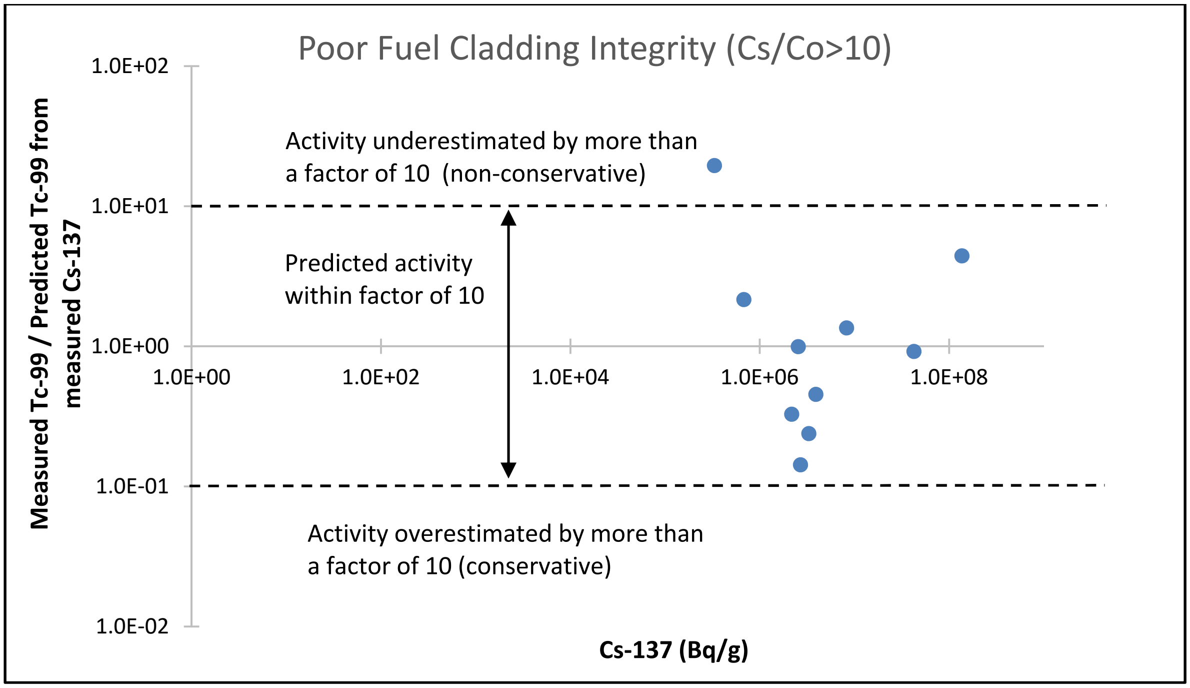


**Figure 5.** Ratio of measured Tc-99 to predicted Tc-99 based on the proposed Tc-99/Cs-137 scaling factor

(b) For the NRC staff to conclude that it is appropriate to predict theTc-99 activity based on the Cs-137 activity, the following information is needed:

i. A basis for concluding that a sufficient number of samples was collected to have reasonable assurance that the proposed Tc-99/Cs-137 scaling factor is appropriate or provide additional measurement results demonstrating that this scaling factor is appropriate;

ii. If the proposed Tc-99/Cs-137 scaling factor is intended for use for LLW other than other than PWR resin, a justification that the PWR resin data are applicable to other waste streams; and

iii. A description of the range of conditions under which the use of the Tc-99/Cs-137 scaling factor is appropriate and the situations that could lead to a significant change in the correlation that would cause the proposed scaling factor to no longer be appropriate.

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