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The Phantom 4
Manifesting
³H, ¹⁴C, ¹²⁹I & ⁹⁹Tc:
Preliminary Findings for
¹²⁹I & ⁹⁹Tc

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Quantifying the ³H, ¹⁴C, ⁹⁹Tc & ¹²⁹I
Key Take Aways

- Accurate quantification of these highly mobile nuclides is challenging, but important for correct performance assessment
- There are better and more accurate methods to quantify and manifest the Phantom Four in reactor LLW:
 - ³H follows moisture fraction and should not be scaled to other nuclides
 - ¹⁴C method perhaps adequate: look a little harder
 - lowering required Table 1 LLD values by 10 times should resolve the ¹⁴C data (a further lowering is not practical)
 - ⁹⁹Tc and ¹²⁹I should be scaled as real when non-detect result is received
 - Use of non-positive LLD values results in manifested values for ⁹⁹Tc & ¹²⁹I that are 100-1,000 times higher than actual -- could adversely impact that disposal site capacity

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Over-Reporting of ⁹⁹Tc and ¹²⁹I in LLW

- Multiple references have documented the positive bias in current reporting of these nuclides and the adverse impact on disposal site capacity, a few are listed below:
 - NUREG-1418 "Roles Report", 1990
 - DOE/EH-0332P, LLW & MW Disposal During 1990, 1993
 - NUREG/CR-6567, LLW Classification, Characterization and Assessment, 2000
 - NCRP 152, LLW Performance Assessment, 2005
 - EPRI 1019222, LLW Disposal Practices, 2009
 - ML13260A075, EPRI Letter to Staff, August 1, 2013
- There are better and more accurate methods to quantify and manifest ⁹⁹Tc and ¹²⁹I such as scaling generically as real when not detected by radiochemistry measurements

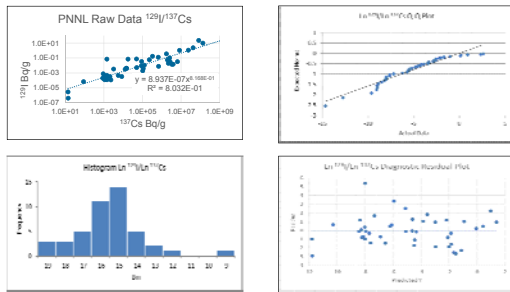
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Scaling Factor Development - Approach

- Sample data from NUREG / CR-6567 Table 7-8 for ⁹⁹Tc and ¹²⁹I spectroscopy measurements by PNNL* were evaluated
- For ¹²⁹I:
 - Direct measurements of ¹³⁷Cs and ¹²⁹I were transformed to their natural log
 - The log transformed data was checked for normality using three graphical depictions of the data
 - a histogram of the natural logarithm of the ratios of ¹²⁹I/¹³⁷Cs for frequency distribution
 - a quantile-quantile (Q-Q) plot showing the distribution of the data against the expected normal distribution
 - and a plot of residuals for randomness
 - Fuel conditions were considered by taking into account the Cs/Co ratio
- Same approach applied with ⁹⁹Tc in comparison to ¹³⁷Cs & ⁶⁰Co

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Validity Checks for Log Transformed ¹²⁹I Data

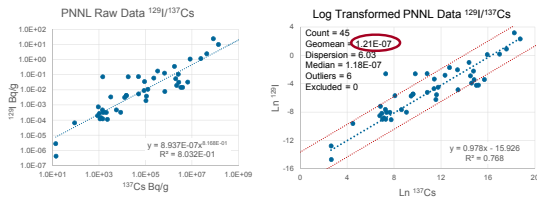


Validity Checks Considered Satisfactory

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¹²⁹I Mass Spec Data Evaluation

- Raw PNNL ¹²⁹I/¹³⁷Cs power regression exhibits very good correlation and could reasonably be used as is.
- The log transformed data validates the log-mean and log-mean dispersion provide good correlation as well.



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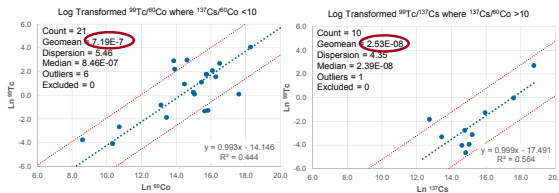
Preliminary Results – ¹²⁹I

- ¹²⁹I should be scaled to ¹³⁷Cs
- A scaling factor of 2.0E-07 should scale within a factor of 10 with a 80% confidence factor
- This value is the most conservative and it bounds the “all fuel clad integrity” data by a factor of ~2 and the “poor fuel clad integrity” data by a factor of ~5.
- The use of detection limit (non-positive) values has been shown to be incorrect by a factor of 100-1,000 or more

	All Ru ¹⁰⁶ Cs	All Ru ¹⁰⁶ Cs where Cs/Co <10	All Ru ¹⁰⁶ Cs where Cs/Co >10
Sample Count	45	32	13
Geometric Mean	1.2E-07	2.0E-07	3.5E-08
LMD 68%	6.03	4.89	5.62
LMD 80%	9.98	7.62	9.11
LMD 90%	19.4	13.7	17.3
LMD 95%	33.9	22.4	29.5

**⁹⁹Tc Mass Spec Data – Preliminary Results
Log Transformed Data**

- Two scaling factors for ⁹⁹Tc emerged from this analysis
 - ⁹⁹Tc is scaled to the activated corrosion product ⁶⁰Co when ¹³⁷Cs/⁶⁰Co <10
 - ⁹⁹Tc is scaled to the fission product ¹³⁷Cs when ¹³⁷Cs/⁶⁰Co >10



– These results suggest that the production mechanism for ⁹⁹Tc under high fuel integrity conditions is dominated by activation of ⁹⁹Mo, while fuel leaks have a greater influence when the leak is large enough to result in a ¹³⁷Cs/⁶⁰Co >10

**Scaling Factor Conclusion - Preliminary
Proposed Indirect Method**

- The PNNL mass spec datasets for ⁹⁹Tc and ¹²⁹I in LLW:
 - Provide a reasonable basis for generic scaling factors
- Proposed Indirect Method
 - Perform analysis for ⁹⁹Tc and ¹²⁹I in waste to required sensitivity (1% 61.55 Table 1 A-Priori at a minimum)
 - When ⁹⁹Tc and/or ¹²⁹I results are at the detection limit (LLD) in lieu of using the detection limit value - use a scaling factor from this research to calculate a value as applicable and treat as a positive measurement:
 - ¹²⁹I should be scaled to ¹³⁷Cs
 - ⁹⁹Tc should be scaled to ⁶⁰Co when the ¹³⁷Cs/⁶⁰Co <10
 - ⁹⁹Tc should be scaled to ¹³⁷Cs when the ¹³⁷Cs/⁶⁰Co >10



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