Nickel-63 Dose Conversion Factor Anomalies and Implications to RETS and Groundwater Monitoring Efforts

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Presented at the 22nd Annual RETS-REMP Workshop

Orlando, FL / 25-27 Jun 2012

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Recent OE Involving Ni-63

- OE34998 - Nickel 63 Activity Not Quantified in Liquid Effluents (Prairie Island)
  - Nickel 63 activity levels in high level/low level radioactive resin were found to be 10 times higher than Cobalt 60 activity levels.
  - Despite the elevated activity levels of Ni-63 in the Solid Effluent Waste, the Chemistry department has not been analyzing the liquid effluent waste for Ni-63
- Identified during NRC effluent inspection

Regulatory Guidance

- Standard ODCM guidance in NUREG-1301/1302 does *not* require Ni-63 analysis for liquid effluents; only requires Fe-55, Sr-89, and Sr-90
- Verbal guidance from NRC at recent RETS-REMP Workshops has been to use 10CFR61 waste analyses to determine additional analyses for hard-to-detect nuclides in liquid effluents
  - Parallel approach to “principal radionuclide” concept in Revision 2 to Regulatory Guide 1.21

Reason for Concern - 1

- Ni-63 can be a major contributor to total activity, especially at PWRs – activation of stable nickel from stainless steel in steam generators
- Ni-63 characteristics
  - Neutron activation of Ni-62, 3.66% abundance, 15 barn cross-section
  - Half-life = 100.1 years
  - 100% beta decay -- 65.9 keV max, 17.1 keV average; no gamma; relatively low dose compared to gamma emitters

Reason for Concern - 2

- Ni-63 can be a major contributor to total activity, raising potential for occurrence in liquid effluents and groundwater
  - Proper assessment of dose consequence
  - Proper derivation of LLDs for analysis
  - Proper selection of 10CFR61 waste stream for assessment of fractional activity

Dose Conversion Factor Anomalies - EPA Drinking Water Standard - 1

- EPA drinking water guidelines (40CFR141.66) do not list limit specifically for Ni-63; would be grouped under Gross Beta concentration limit of 50 pCi/L = 4 mrem/yr dose
- EPA water guidelines based on NBS Handbook 69, Maximum Permissible Body Burden for Occupational Exposure, circa 1963... similar to ICRP-2 methodology
- Occupational exposure, adult male
- Assuming 50 pCi/L will result in 4 mrem/yr dose consequence, 2 liter/day consumption rate equates to 3.65E4 pCi/yr intake
- Effective DCF becomes 1.10E-4 mrem/pCi

Dose Conversion Factor Anomalies - EPA Drinking Water Standard - 2

- 40CFR141.66 specifies that for radionuclides not specifically listed in §141.66 Table 1, the DW concentration limit should be based on 4 mrem/yr dose resulting from drinking water at a rate of 2 liters/day containing the 168-hour MPC value listed in NBS Handbook 69
- 168-hour MPC value for Ni-63 is 3E-4 uCi/mL, resulting in a dose consequence of 5000 mrem/yr
- Scaled MPC value: (4 mrem/yr / 5000 mrem/yr) * 3E-4 uCi/mL = 2.4E-7 uCi/mL, or 240 pCi/L
- Assuming 240 pCi/L will result in 4 mrem/yr dose consequence, 2 liter/day consumption rate equates to 1.75E5 pCi/yr intake
- Effective DCF becomes 2.28E-5 mrem/pCi

Dose Conversion Factor Anomalies – Regulatory Guide 1.109

- Regulatory Guide 1.109 Dose Factors based on ICRP-2 methodology from late 1950s
- Dose conversion factors – mrem/pCi ingested

Organ	Adult	Teen	Child	Infant
Bone	1.30E-4	1.77E-4	5.38E-4	6.34E-4
Liver	9.01E-6	1.25E-5	2.88E-5	3.92E-5
T.Body	4.36E-6	6.00E-6	1.83E-5	2.20E-5
Thyroid	No Data	No Data	No Data	No Data
Kidney	No Data	No Data	No Data	No Data
Lung	No Data	No Data	No Data	No Data
GI-LLI	1.88E-6	1.99E-6	1.94E-6	1.95E-6

- Similar order of magnitude (xE-4 mrem/pCi) to EPA DW standard; bone dose 15-70 times higher than other organs

Dose Conversion Factor Anomalies – 10CFR20 Appendix B Effluent Limits

- 10CFR20 Appendix B Effluent Concentration limits based on ICRP-30, circa 1970s; new dose models
- 10CFR20 Appendix B EC limit based on CEDE dose consequence of 50 mrem/yr
- Table 2, Column 2 EC for Ni-63 = 1E-4 uCi/mL
- Assuming 1E-4 uCi/mL will result in 50 mrem/yr dose consequence, 730 L/yr consumption rate equates to 7.3E+7 pCi/yr intake
- Effective DCF becomes 6.85E-7 mrem/pCi

Dose Conversion Factor Anomalies – ICRP-30 Dose Factors

- ICRP-30 CEDE dose factors used as basis for 10CFR20 Appendix B EC limits
- Dose factors for occupational exposure, adult "standard man"
- Dose conversion factors – mrem/pCi ingested
  - CEDE = 5.78E-7 mrem/pCi
  - Bone = 3.15E-7 mrem/pCi
  - Maximum Organ (LLI Wall) = 3.40E-6 mrem/pCi
- Bone is not critical organ as in RG-1.109; maximum organ dose only ~6X higher than EDE

Dose Conversion Factor Anomalies – ICRP-72 Dose Factors

- Current international standard for member of public, circa late 1996; multiple age groups as in RG-1.109
- Dose conversion factors – mrem/pCi ingested

Age Class	CEDE	Bone	LLI
Adult	5.56E-7	3.22E-7	3.41E-6
15-yr	6.67E-7	3.52E-7	4.07E-6
10-yr	1.04E-6	4.81E-7	7.41E-6
5-yr	1.70E-6	8.15E-7	1.22E-5
1-yr	3.11E-6	1.30E-6	2.41E-5
Infant	5.93E-6	3.07E-6	3.70E-5

Dose Conversion Factor Anomalies – Comparison

- Dose conversion factors – mrem/pCi ingested

EPA DW Standard Gross Beta (adult)	1.10E-4
EPA DW Standard Ni-63 NBS (adult)	2.28E-5
RG-1.109 Infant Bone	*6.34E-4*
RG-1.109 Infant Total Body	2.20E-5
10CFR20 Appendix B (adult CEDE)	6.85E-7
ICRP-30 CEDE (adult)	5.78E-7
ICRP-30 Bone (adult)	3.15E-7
ICRP-72 Infant CEDE	5.93E-6
ICRP-72 Infant Bone	*3.07E-6*

- EPA drinking water standard and RG-1.109 ***significantly overestimate*** dose consequence; 200X ICRP-72 values

Derivation of LLDs - 1

- Ni-63 analyses are not required by NUREG-1301/1302, therefore no LLD “requirements” or guidance exist
- Necessary to derive equivalent LLDs commensurate with those in ODCM
  - Effluent LLDs for liquid effluent composites
  - (Effluent LLDs for gaseous effluent composites)
  - REMP-equivalent LLDs for groundwater

Derivation of LLDs – 2a Liquid Effluent LLD

- Cs-137 is a commonly-accepted surrogate in radiological scaling applications
- Use Cs-137 as scaling factor, yielding equivalent dose consequence to Cs-137 LLD
  - ODCM Liquid Effluent LLD for Cs-137 = 5E-7 uCi/mL
- Scale Cs-137 liquid LLD based on ratio of water EC limit values from 10CFR20 Appendix B:
  - Cs-137 water EC Limit = 1E-6 uCi/mL (~50 mrem/yr dose)
  - Ni-63 water EC Limit = 1E-4 uCi/mL (100X Cs-137)
  - Derived Ni-63 Liquid LLD: 5E-7 uCi/mL * (1E-4 ÷ 1E-6) = *5E-5 uCi/mL liquid* (~21 mrem/yr dose)

Derivation of LLDs – 2b
Gaseous Effluent LLD

- Use Cs-137 as scaling factor, yielding equivalent dose consequence to Cs-137 LLD
  - ODCM Gaseous Effluent LLD for Cs-137 = 1E-11 uCi/mL
- Scale Cs-137 gaseous LLD based on ratio of air EC limit values from 10CFR20 Appendix B:
  - Cs-137 Air EC Limit = 2E-10 uCi/mL (~50 mrem/yr dose)
  - Ni-63 Air EC Limit = 2E-9 uCi/mL (10X Cs-137)
  - Derived Ni-63 air LLD: 1E-11 uCi/mL * (2E-9 ÷ 2E-10) =
    1E-10 uCi/mL air (~0.8 mrem/yr dose)

Derivation of LLDs - 3 Groundwater LLD

- Use Cs-137 as scaling factor, yielding equivalent dose consequence to Cs-137 LLD
  - ODCM REMP LLD for Cs-137 = 18 pCi/L
- Scale Cs-137 LLD based on ratio of water EC limit values from 10CFR20 Appendix B:
  - Cs-137 water EC Limit = 1E-6 uCi/mL
  - Ni-63 water EC Limit = 1E-4 uCi/mL (100X Cs-137 EC)
  - Derived Ni-63 water LLD: 18 pCi/L * (1E-4 ÷ 1E-6) = *1800 pCi/L* (~0.8 mrem/yr dose)

Derivation of LLDs - 4
EPA Drinking Water LLD

- Standard practice in EPA drinking water standard is to set LLD at 10% of limit
- EPA DW Limit for Gross Beta = 50 pCi/L; however, ***this limit is based on erroneous dose factors that are grossly over-conservative***
- Resulting DW LLD would be *5 pCi/L*, approximately 360-times lower than LLD of 1800 pCi/L derived from equivalent dose consequence; corresponding dose ~0.0025 mrem/yr
- Due to flawed approach, EPA Gross Beta DW limit should not be used to establish target LLD for Ni-63

Selection of Proper 10CFR61 Waste Stream - 1

- Screening of Ni-63 to determine fractional activity contribution based on 10CFR61 waste disposal analyses
- Two major categories of waste defined in Regulatory Guide 1.21 Rev. 1
  - Spent resins, filter sludges, evaporator bottoms, etc.
  - Dry Compressible Waste, contaminated equipment, etc.

Selection of Proper 10CFR61 Waste Stream - 2

- Resins have different affinities for different chemical species (anions, cations, etc.) – may not be representative of radionuclide mix in liquid waste streams or radionuclides released to environment from leaks
- DAW radionuclide profile likely represents materials that have been in contact with or leaked out of contaminated systems – may be more representative of materials in liquid effluents and material released to the environment from leaks
- 10CFR61 profile for DAW is most likely the best choice to determine fractional Ni-63 activity contribution

Summary

- Ni-63 can qualify as a “principal radionuclide” relative to total activity; likely not “principal” related to dose, but overly-conservative dose factors may inflate fractional dose contribution
- Dose factors from RG-1.109 are overly conservative and will result in overestimating maximum organ dose by more than 100-times
- EPA drinking water limit of 50 pCi/L for gross beta is inappropriate for Ni-63

Summary (continued)

- 10% of EPA drinking water limit should *not* be used to establish Ni-63 LLDs for groundwater
- Recommended target LLDs for Ni-63 scaled from equivalent ODCM Cs-137 LLDs:
  - Liquid Effluent LLD = 5E-5 uCi/mL
  - Gaseous Effluent LLD = 1E-10 uCi/mL
  - REMP/Groundwater LLD = 1800 pCi/L
- 10CFR61 nuclide profile for Dry Activated Waste is likely most representative for determining if Ni-63 constitutes a major fraction of total activity

Questions?