Comparison of Regulatory Guide 1.109 and ICRP-72 Carbon-14 Dose Conversion Factors

Ken Sejkora
Entergy Nuclear Northeast – Pilgrim Station

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Regulatory Guide 1.109

- The NRC recognized “cookbook” for how to perform effluent dose assessments
- Revision 1 issued in 1977
- Internal dose calculated as the product of the usage factor for various environmental media (air, drinking water, vegetables, etc.), multiplied by the concentration in the media, multiplied by a dose conversion factor

Regulatory Guide 1.109
Dose Conversion Factors

- Internal dose conversion factors derived from ICRP-2 metabolic models and methodologies
- ICRP-2 issued in 1959; 50-years old by today's standards – outdated compared to more modern standards established by the ICRP
- Two exposure/intake pathways: ingestion, inhalation
- Four age classes: infant, child, teen, adult
- Seven critical organs: bone, liver, total body, thyroid, kidney, lung, GI-LLI; *non-stochastic dose approach*

Regulatory Guide 1.109
C-14 Dose Conversion Factors - Inhalation

- Inhalation dose factors only address one chemical form; RG-1.109 and ICRP-2 are not specific as to chemical form
- Critical organ for all age classes is bone, with a separate, single DCF applied to all other organs
- Bone DCF is 5.0 to 5.3 times higher than other organs

Regulatory Guide 1.109
C-14 Dose Conversion Factors - Inhalation

Age Class	C-14 DCF: mrem/pCi Inhaled		Bone:Other Ratio
	Bone	Other Organs	
Adult	2.27E-6	4.26E-7	5.33
Teen	3.25E-6	6.09E-7	5.34
Child	9.70E-6	1.82E-6	5.33
Infant	1.89E-5	3.79E-6	4.99

Regulatory Guide 1.109
C-14 Dose Conversion Factors - Ingestion

- Single ingestion dose factors irrespective of chemical form
- Critical organ for all age classes is bone, with a separate, single DCF applied to all other organs
- Bone DCF is 4.7 to 5.0 times higher than other organs

Regulatory Guide 1.109
C-14 Dose Conversion Factors - Ingestion

Age Class	C-14 DCF: mrem/pCi Ingested		Bone:Other Ratio
	Bone	Other Organs	
Adult	2.84E-6	5.68E-7	5.00
Teen	4.06E-6	8.12E-7	5.00
Child	1.21E-5	2.42E-6	5.00
Infant	2.37E-5	5.06E-6	4.68

ICRP-72
Dose Conversion Factors

- ICRP-72 issued in 1996; 14-years old by today's standards – standard guidance used by international radiation protection community, and by EPA in Federal Guidance Report 13
- Internal dose conversion factors derived from updated metabolic models and methodologies
- Effective Dose Equivalent (EDE) approach derived from summation of individual organ dose multiplied by organ weighting factor; *stochastic dose, similar to ICRP-30*
- Two exposure/intake pathways: ingestion, inhalation
- Six age classes: Newborn, 1yr, 5yr, 10yr, 15yr, Adult
- 25 organs, each with differing DCFs and weighting factors

ICRP-72
C-14 Dose Conversion Factors - Inhalation

- Inhalation dose factors address seven chemical forms: dioxide, monoxide, methyl/organic, elemental vapor, 3 particulate: fast, medium, slow
- All organs and EDE have the ~same DCF for gaseous forms... there is no “critical” organ... all organs receive ~equal dose, much like tritium

ICRP-72

C-14 Dose Conversion Factors - Inhalation

Age Class	C-14 DCF: mrem/pCi Inhaled			
	Dioxide	Monoxide	Organic	*C-Vapor*
Adult	2.30E-8	2.69E-9	1.07E-8	*2.15E-6*
15-yr	2.33E-8	3.67E-9	1.07E-8	*2.11E-6*
10-yr	3.30E-8	6.30E-9	1.48E-8	*2.93E-6*
5-yr	4.07E-8	1.04E-8	1.81E-8	*3.59E-6*
1-yr	7.04E-8	2.11E-8	2.89E-8	*5.93E-6*
Newborn	7.04E-8	3.37E-8	2.44E-8	*4.81E-6*

ICRP-72
C-14 Dose Conversion Factors - Ingestion

- Single ingestion dose factors irrespective of chemical form
- “Critical” organ for all age classes is stomach, with all other organs having ~same DCF
- Stomach DCF is only 1.1 to 1.4 times higher than EDE DCF; ***much lower ratios than ICRP-2***

ICRP-72

C-14 Dose Conversion Factors - Ingestion

Age Class	C-14 DCF: mrem/pCi Ingested			Stomach-to-EDE Ratio
	Stomach	Other Organ	EDE	
Adult	2.33E-6	2.11E-6	2.15E-6	1.08
15-yr	2.37E-6	2.07E-6	2.11E-6	1.12
10-yr	3.30E-6	2.89E-6	2.96E-6	1.11
5-yr	4.44E-6	3.56E-6	3.67E-6	1.21
1-yr	7.04E-6	5.56E-6	5.93E-6	1.19
Newborn	7.41E-6	4.81E-6	5.19E-6	1.43

RG-1.109 & ICRP-72 DCF Comparison

C-14 Inhalation Exposure Pathway

Age Class	C-14 DCF: mrem/pCi Inhaled				
	RG-1.109 Non-Bone	Dioxide	Monoxide	Organic	C-Vapor
Adult	*4.26E-7*	2.30E-8	2.69E-9	1.07E-8	*2.15E-6*
Teen/ 15-yr	*6.09E-7*	2.33E-8	3.67E-9	1.07E-8	*2.11E-6*
10-yr	*--*	3.30E-8	6.30E-9	1.48E-8	*2.93E-6*
Child/ 5-yr	*1.82E-6*	4.07E-8	1.04E-8	1.81E-8	*3.59E-6*
1-yr	*--*	7.04E-8	2.11E-8	2.89E-8	*5.93E-6*
Infant/ Newborn	*3.79E-6*	7.04E-8	3.37E-8	2.44E-8	*4.81E-6*

RG-1.109 & ICRP-72 DCF Comparison

C-14 Ingestion Exposure Pathway

Age Class	C-14 DCF: mrem/pCi Ingested			
	RG-1.109 Bone	RG-1.109 Other	ICRP-72 Stomach	ICRP-72 EDE
Adult	2.84E-6	5.68E-7	2.33E-6	2.15E-6
Teen/ 15-yr	4.06E-6	8.12E-7	2.37E-6	2.11E-6
10-yr	--	--	3.30E-6	2.96E-6
Child/ 5-yr	1.21E-5	2.42E-6	4.44E-6	3.67E-6
1-yr	--	--	7.04E-6	5.93E-6
Infant/ Newborn	2.37E-5	5.06E-6	7.41E-6	5.19E-6

Effective Dose Equivalent Approach

- EDE approach has been the ICRP model since ICRP-26/30, circa 1970s
- Each organ is given a risk-weighting factor, and effective whole body dose is established as summation of the product of individual organ dose multiplied by the weighting factor
- ICRP-72 methodologies and DCFs are the standard among the international community for radiation protection of the public

Effective Dose Equivalent Approach

- NRC “adopted” the EDE approach when they revised 10CFR20 in early 1990s, at which time ICRP-30 was used to derive effluent concentration limits in 10CFR20 Appendix B
- In bases to 10CFR20 Appx.B values, NRC states that non-stochastic (i.e., “critical organ”) doses are assumed to not be applicable in the case of the low doses anticipated from effluents, and ECLs were based on stochastic (“EDE”) dose consequence
- Based on this precedence, EDE dose factors should be considered the most technically-correct and preferential means to calculate C-14 dose

Summary

- ICRP-2 dose conversion factors in RG-1.109 are outdated and inconsistent with current ICRP radiation protection guidance used by the international community
- RG-1.109 inhalation DCFs for C-14 appear to be based on the elemental vapor chemical form, and are inappropriate/invalid for calculation of inhalation dose from gaseous forms of C-14 anticipated
  - Only technically-correct option is to use ICRP-72 DCFs

Summary

- RG-1.109 ingestion DCFs for C-14 in bone are overly conservative compared to more modern ICRP guidance; modern ICRP guidance has no true “critical organ” with appreciably higher dose
  - If ICRP-72 DCFs are used for inhalation dose calculations, similar approach should apply for ingestion dose
- Use of ICRP-72 EDE DCFs is consistent with the stochastic EDE concept endorsed by the NRC in establishing 10CFR20 Appendix B effluent concentration limits

Questions?