Update of MACCS Dose Coefficients to US EPA FGR 15

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MACCS Users Group Meeting 2021

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Introduction

- Dose coefficients are key input for radiological consequence assessments

- Objectives
  - Summarize background/history of dose coefficients
  - Compare new US EPA FGR15 external dose coefficients to FGR13 coefficients used in MACCS
  - Show potential impact of similar evolution on internal dose coefficients

Background

- MACCS dose coefficients are based on US EPA FGR13
  - ICRP 38 Radionuclide Transformations (1983)
  - ICRP 60 The 1990 Recommendations of the ICRP (1991)
- US EPA FGR15 (2019) brings significant updates to external dose coefficients:
  - ICRP 103 The 2007 Recommendations of the ICRP (2007)
  - ICRP 107 Nuclear Decay Data for Dosimetric Calculations (2007)
  - Modelling capabilities, age dependent phantoms, soil roughness effect

History

Year	Source	Scope	Tissue Weighting Factors	Radionuclide Decay
1988	US EPA FGR11	Internal Dose (Inhalation, Ingestion)	ICRP 26	ICRP 38
1993	US EPA FGR12	External Dose (Cloudshine, Groundshine)	ICRP 26	ICRP 38
1995	ICRP 72	Age Dependent Ingestion and Inhalation Dose	ICRP 60	ICRP 38
1996	DCFPAK	Dose coefficient package for FGR11 and FGR12	ICRP 26/60	ICRP 38
1999	US EPA FGR13	Internal and External Dose	ICRP 60	ICRP 38
2012	ICRP 119	Compendium of Dose Coefficients based on ICRP Publication 60	ICRP 60	ICRP 38
2013	DCFPAK3	Dose coefficient package based on ICRP 60 and ICRP 107	ICRP 60	ICRP 107
2019	US EPA FGR15	External Dose	ICRP 103	ICRP 107

- Driver 1 - Tissue weighting factors, definition of effective dose
  - ICRP 26 The 1977 Recommendations of the ICRP (1977)
  - ICRP 60 The 1990 Recommendations of the ICRP (1991)
  - ICRP 103 The 2007 Recommendations of the ICRP (2007)
- Driver 2 – Nuclide decay data
  - ICRP 38 Radionuclide Transformations (1983)
  - ICRP 107 Nuclear Decay Data for Dosimetric Calculations (2007)

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Evolution of tissue weighting factors

Table II.1. Tissue Weighting Factors According to ICRP (1977, 1991).

Organ/Tissue	Weighting Factors	
	w_T (ICRP 26)	w_T' (ICRP 60)
Gonads	0.25	0.20
Breast	0.15	0.05
Colon		0.12
Red Marrow	0.12	0.12
Lungs	0.12	0.12
Stomach		0.12
Urinary Bladder		0.05
Liver		0.05
Esophagus		0.05
Thyroid	0.03	0.05
Bone Surface	0.03	0.01
Skin		0.01
Remainder	0.30[1]	0.05[2,3]

[1] The value 0.30 is applied to the average dose among the five remaining organs or tissues receiving the highest dose, excluding the skin, lens of the eye, and the extremities.
[2] The remainder is composed of the following tissues and organs: adrenals, brain, small intestine, upper large intestine, kidney, muscle, pancreas, spleen, thymus, and uterus.
[3] The value 0.05 is applied to the average dose to the remainder tissue group. However, if a member of the remainder receives a dose in excess of the highest dose in any of the twelve organs for which weighting factors are specified, a weighting factor of 0.025 is applied to that organ and a weighting factor of 0.025 is applied to the average dose in the rest of the remainder.

Table 3-1. ICRP Publication 103 (2007) tissue weighting factors for calculating effective dose rate coefficients.

Tissue	w_T	Representation in Phantom
Red marrow	0.12	Multiple trabecular bone regions
Colon	0.12	Multiple segments represented
Lung	0.12	Both left & right lobes
Stomach	0.12	Contents excluded
Breast	0.12	Both male & female
Gonads		
Testes	0.04	Male tissue
Ovaries	0.04	Female tissue
Bladder	0.04	Contents excluded
Esophagus	0.04	Explicit tissue region
Liver	0.04	Explicit tissue region
Thyroid	0.04	Explicit tissue region
Bone surface	0.01	Trabecular & cortical bone regions
Brain	0.01	Explicit tissue region
Salivary glands	0.01	Explicit tissue region
Skin	0.01	Explicit tissue region
Remainder		
Adrenals	0.00923	Explicit tissue region
Extrathoracic region	0.00923	Explicit tissue region
Gall bladder	0.00923	Contents excluded
Heart	0.00923	Contents excluded
Kidneys	0.00923	Explicit tissue region
Lymphatic nodes	0.00923	Soft tissue surrogate
Muscle	0.00923	Explicit tissue region
Oral mucosa	0.00923	Explicit tissue region
Pancreas	0.00923	Explicit tissue region
Prostate	0.00462	Male tissue
Small intestine	0.00923	Contents excluded
Spleen	0.00923	Explicit tissue region
Thymus	0.00923	Soft tissue surrogate
Uterus/cervix	0.00462	Female tissue

0.12

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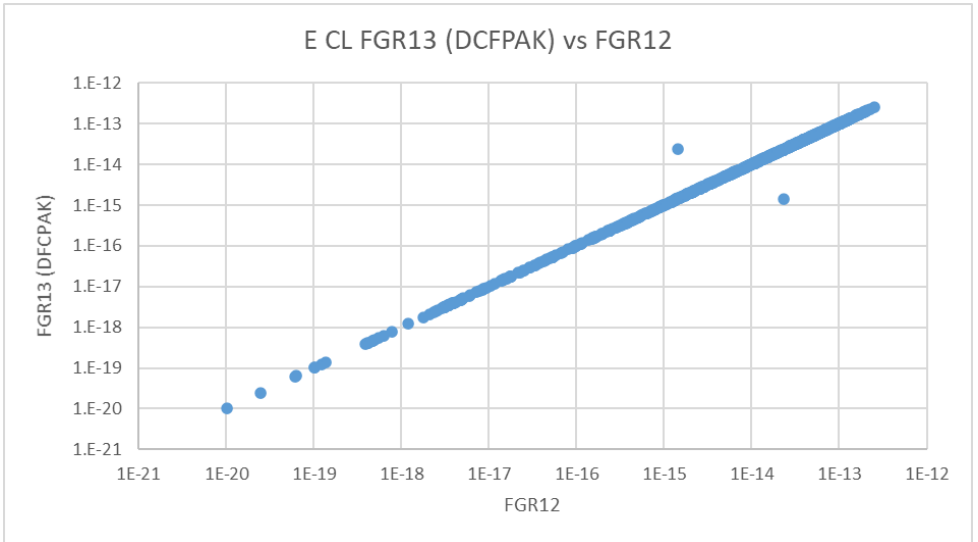
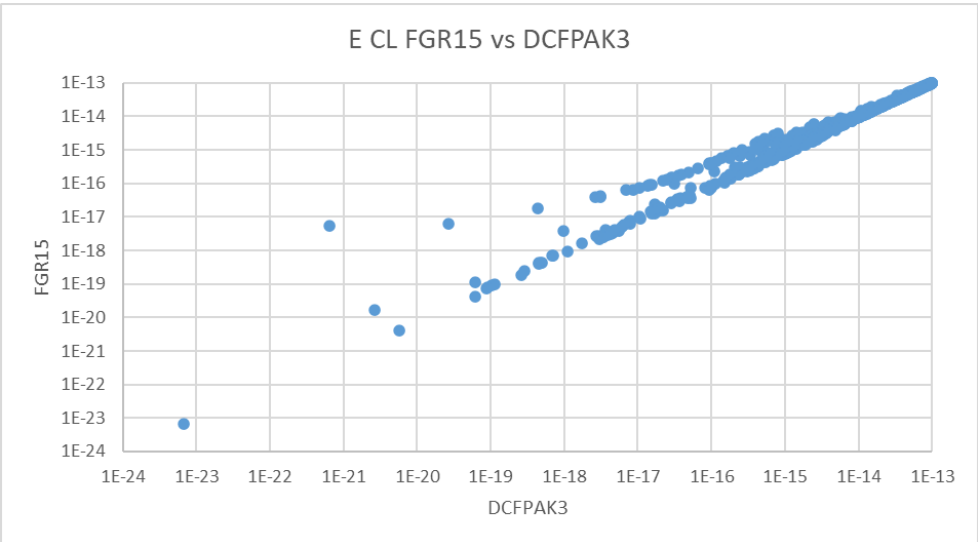
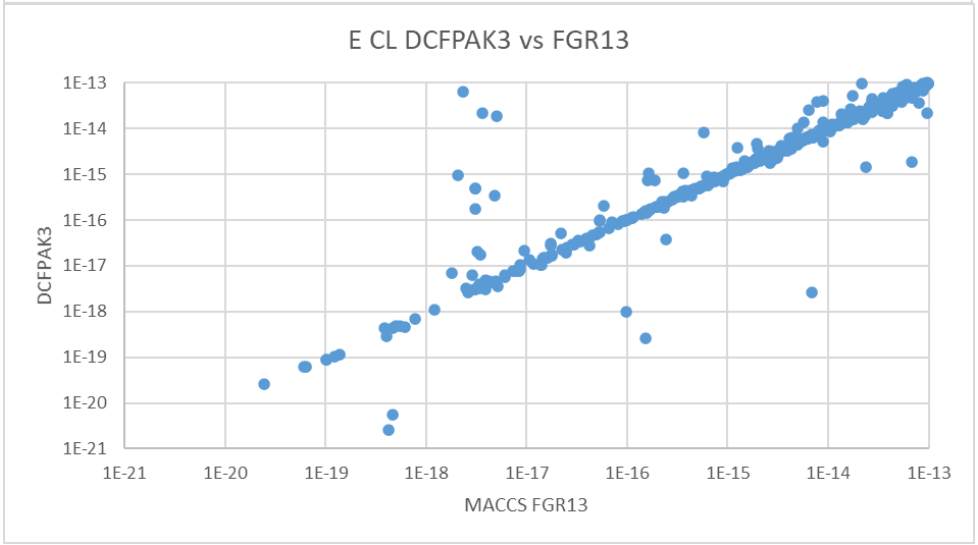
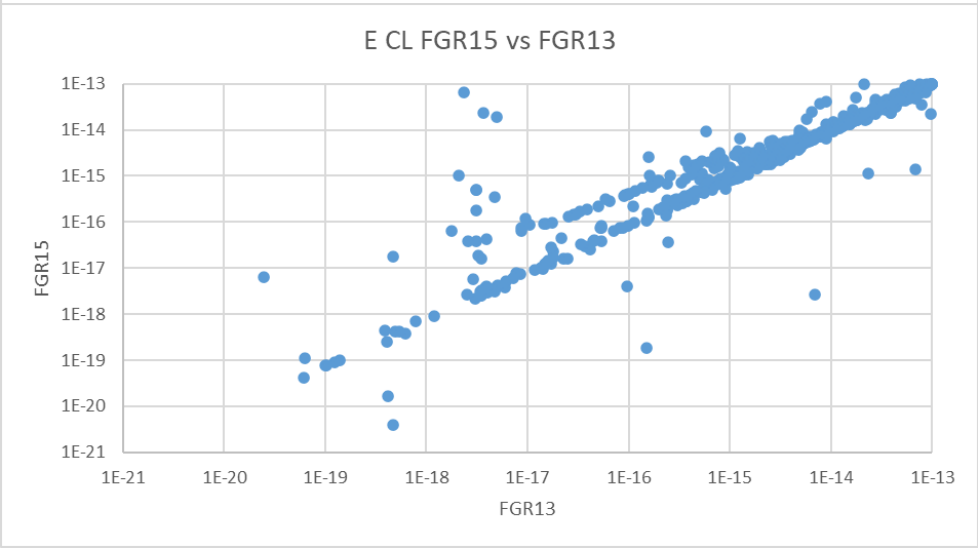
Impact on Cloudshine Effective Dose Coefficients









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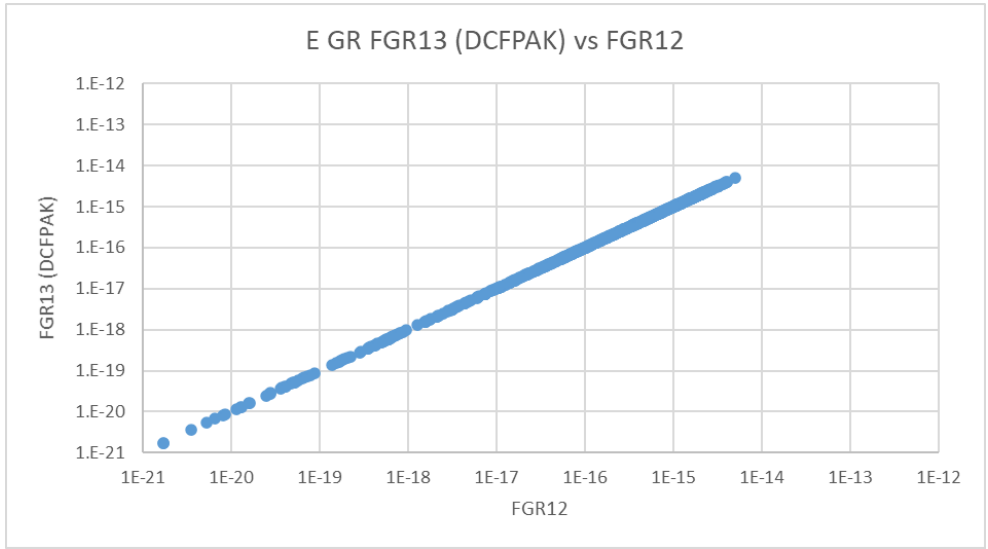
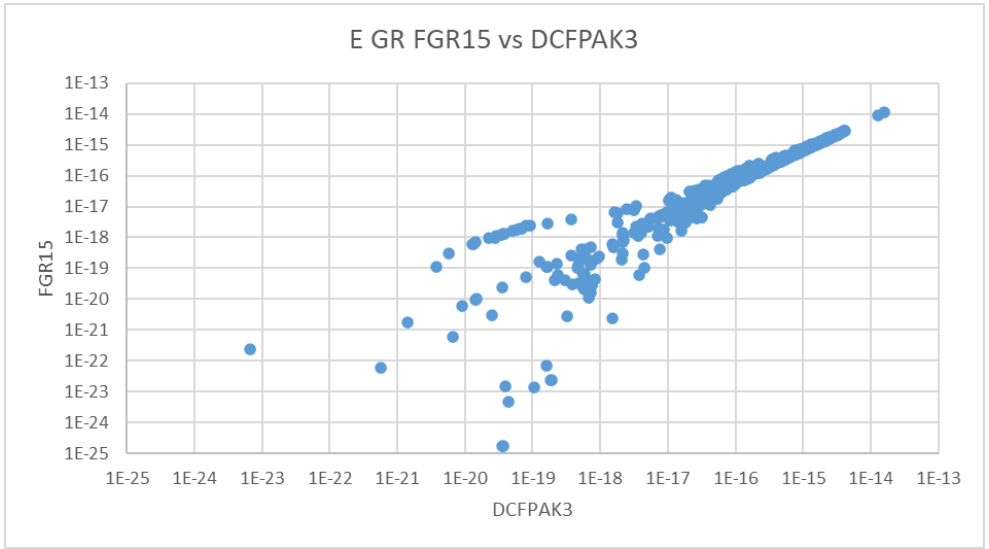
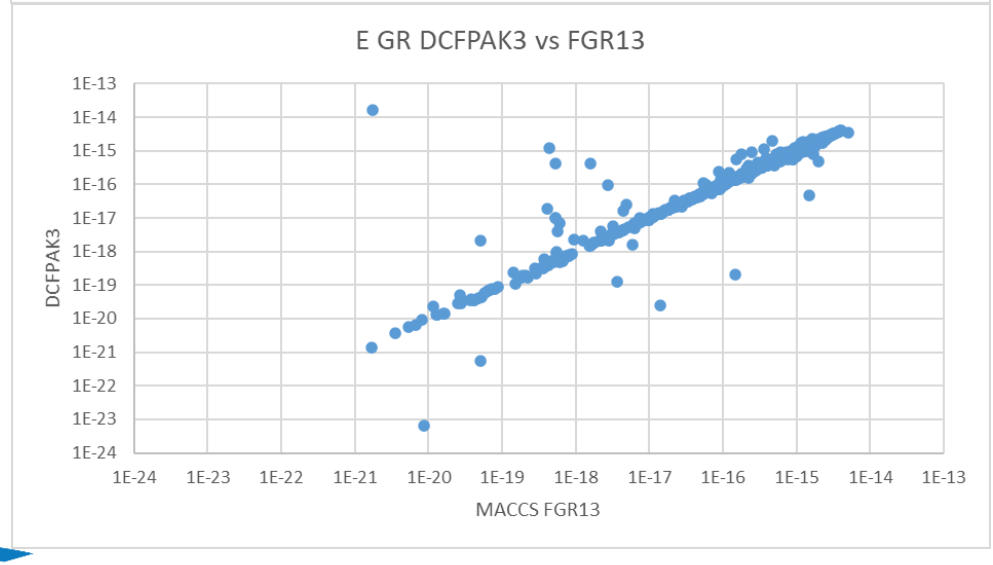
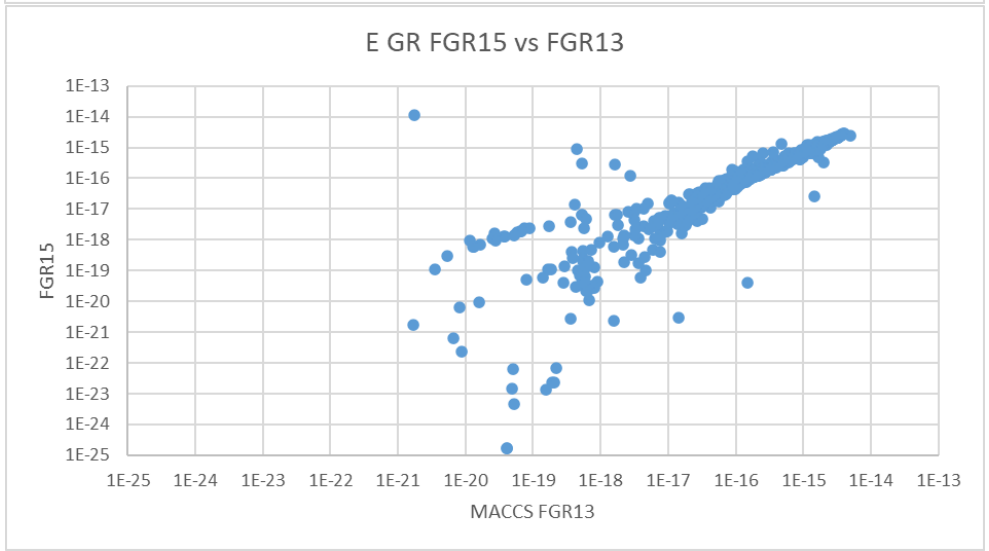
Impact on Groundshine Effective Dose Coefficients









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Internal dose coefficients

- ICRP 119 is a minor modification of ICRP 72
  - Still based on ICRP 60 Recommendations and ICRP 38 Nuclear Data
- Independent work by K. Manabe, A. Endo and K. F. Eckerman shows the impact of ICRP 107 as replacement for ICRP 38 nuclear decay data
- Internal dose coefficients have not been updated by ICRP

Impact of ICRP-107 vs ICRP-38 on ICRP-72 Inhalation DCF

Table 2. Nuclides with significantly large positive D_e values.

Nuclide	Absorption type	$D_{E_{tot}}$ (%)	D_e (%)	Cause of D_e
^{114}In	M	+0.284	+226	d
^{194}Tl	F	+86.7	+134	a, c
^{189}Pt	F	+54.4	+59.3	a
^{202}Pb	F	+306	+59.3	a, c
^{193}Hg (Organic)	F	+178	+50.6	a, c
^{173}Lu	S	+42.2	+46.0	a
^{192m}Ir	M	+4.53	+44.4	c
^{236}Np	M	+17.2	+44.4	a, c
^{114m}In	M	−5.05	+39.4	d[a]
^{99}Rh	S	−3.96	+37.3	c
^{80}Br	M	−0.299	+35.6	d
^{135}Cs	F	+32.8	+32.9	a
^{185}Ir	F	+37.1	+29.0	a
^{121}I	F	−0.701	+28.5	c
^{186m}Ir	F	+16.9	+28.5	a, b
^{155}Tb	M	+27.6	+27.0	a
^{162}Yb	M	+73.0	+24.6	a
^{124m}Sb	F	+25.2	+23.9	a
^{188}Ir	F	+30.8	+23.7	a
^{149}Gd	F	+24.6	+22.4	a

Causes are a: change in E_{tot}, b: change in half-life, c: change in radiation type and decay mode and d: change in shape of beta particle spectrum.
[a] D_e of ^{114m}In was caused by the change in the shape of the beta particle spectrum data of its daughter nuclide: ^{114}In.

Table 3. Nuclides with significantly large negative D_e values.

Nuclide	Absorption type	$D_{E_{tot}}$ (%)	D_e (%)	Cause of D_e
^{123}Te	M	−88.5	−70.3	a
^{135}Ce	S	−57.8	−68.5	a
^{190}Ir	S	−13.4	−36.8	a, c
^{190m}Ir	S	−7.63	−35.8	b
^{195m}Ir	F	−30.2	−33.8	a
^{173}Ta	M	−20.3	−31.9	a, b
^{120m}I	F	−32.2	−28.3	a
^{199}Pb	F	−28.2	−21.8	a
^{205}Po	M	−0.303	−21.1	b
^{234}Np	M	−22.8	−20.0	a
^{240}Np	M	−15.1	−19.2	a, b
^{234}Pa	M	−22.3	−18.5	a
^{178m}Hf	M	−7.72	−17.6	a
^{189}Re	F	−6.70	−16.4	a
^{189m}Os	F	+3.26	−16.3	b
^{120}I	V	−7.78	−15.1	a
^{170}Hf	M	−20.5	−14.1	a
^{179}Ta	M	−17.5	−13.8	a
^{207}At	M	+33.7	−13.2	c
^{81}Sr	S	−1.01	−11.0	b

Causes are a: change in E_{tot}, b: change in half-life and c: change in radiation type and decay mode.

Source: K. Manabe,A. Endo and K. F. Eckerman, Impact of the New Nuclear Decay Data of ICRP Publication 107 on Inhalation Dose Coefficients for Workers. Radiation Protection Dosimetry (2010), Vol. 138, No. 3, pp. 245–250

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Conclusion

- Implementation of US EPA FGR15 external dose coefficient in MACCS would align MACCS with
  - Latest radionuclide decay data
  - Latest ICRP Recommendations
  - Latest modelling
- Consideration should be given to ICRP 72 modified internal dose coefficient based on ICRP 107
- Age-dependent dose coefficient files could be built from these two sources

Questions?

Thank You!

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