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Review of MACCS DCF Files for Computation of Total Effective Dose Equivalent (TEDE)

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Definition of TEDE

- Total effective dose equivalent (TEDE) is defined in 10 CFR 20.1003 as the sum of the effective dose equivalent (EDE) for external exposures and the committed effective dose equivalent (CEDE) for internal exposures.
- 10 CFR Part 50 and 10 CFR Part 20 refer to various dose-based criteria and limits based on dosimetry methodologies defined in ICRP Publication 26 and ICRP Publication 30
- ICRP 26 tissue weighing factors are directly codified by §20.1003

Computation of TEDE

- Acceptable practices for computing design-basis accident radiological consequences in terms of TEDE are to apply
  - the exposure-to-committed effective dose equivalent factors for inhalation of radioactive material found in Table 2.1 of FGR-11.
  - the exposure-to-effective dose equivalent factors for external exposure of radioactive material apply FGR-12.
- Compliance with the dose-related regulations of Parts 50 and 20 are demonstrated when applying the exposure-to-dose conversion factors of FGRs 11 and 12

Problem Statement

- Which MACCS DCF files may be used to compute TEDE?
- The methodology is as follows:
  - Identify DCF files that are commonly supplied with MACCS or its preprocessor codes;
  - Identify sources for dose coefficients that are consistent with definitions provided in 10 CFR Part 20;
  - For each DCF file, and for the 60 nuclides identified as potentially significant for LWR consequence analysis in NUREG/CR-4467 (and their short-lived progeny), verify the consistency of the effective dose coefficients by computing the ratio between the dose coefficient values identified in Step 1 and the dose coefficient values identified in Step 2.

MACCS/WinMACCS DCF Files

Filename	Date	Type	EDE pseudo-organ	Supplied with	References
DOSDATA.INP	06/25/1992	-	EDEWBODY	MACCS2 1.13.1	Runkle and Ostmeyer, 1985; Kocher 1981; ICRP 30
DOSDATA.INP	11/19/2013	DOSFAC2	EDEWBODY	DOSFAC2	Young and Chanin 1997; DOSD87 (1988); DOE/EH-0070
dosdata20organs.inp	03/27/1997	DOSFAC2	EDEWBODY	WinMACCS 3.11, WinMACCS 4.0	
Dosd60.inp[1]	01/12/2004	FGRDCF	EFFECTIVE	MACCS2 1.13.1, FGRDCF	Chanin and Young 1998; RSIC 1994; FGR-11; FGR-12
Dosd825.inp	01/12/2004	FGRDCF	EFFECTIVE	MACCS2 1.13.1, FGRDCF, WinMACCS 3.11	
FGR13DCF.INP	07/13/2007	FGR13DF	Not available. The effective dose pseudo-organ is provided by "ICRP60ED"	WinMACCS 3.11, WinMACCS 4.0	Haaker and Bixler 2019
FGR13GyEquiv_RevA.inp	05/23/2018	FGR13DF		WinMACCS 4.0	

[1] The *DOSD60.INP* file supplied with MACCS2 is dated 01/12/2004, whereas the *Dosd60.inp* file supplied with FGRDCF is dated 11/19/2013. Comparison of the text of the two files shows that the only difference is in the run date; all other text, including the dose coefficients, are identical.

Sources for TEDE Dose Coefficients

MACCS Dose Coefficient	Source	DLC-167 Data Source
CLOUDSHINE	FGR 12 Table III.1, column headed "Effective"	FGR12T31.SUB
GROUND SHINE 8HR	*not needed when using MACCS2 and above*	
GROUND SHINE 7DAY	*not needed when using MACCS2 and above*	
GROUND SHINE RATE	FGR 12 Table III.3, column headed "Effective"	FGR12T33.SUR
INHALED ACUTE	*not used for computation of TEDE*	
INHALED CHRONIC	FGR 11 Table 2.1, column headed "Effective"	FGR11T21.INH
INGESTION	FGR 11 Table 2.2, column headed "Effective"	FGR11T22.ING

MACCS Radionuclides

Element	Isotopes	Element	Isotopes
Cobalt	58 60	**Iodine**	131 132 133 134 135
Krypton	85 85m 87 88	**Xenon**	133 135
Rubidium	86	**Cesium**	134 136 137
Strontium	89 90 91 92	**Barium**	139 140
Yttrium	90 91 92 93	**Lanthanum**	140 141 142
Zirconium	95 97	**Cerium**	141 143 144
Niobium	95	**Praseodymium**	143
Molybdenum	99	**Neodymium**	147
Technetium	99m	**Neptunium**	239
Ruthenium	103 105 106	**Plutonium**	238 239 240 241
Rhodium	105	**Americium**	241
Antimony	127 129	**Curium**	242 244
Tellurium	127 127m 129 129m 131m 132		

Source: Table 1 of NUREG/CR-4467

Short Lived Decay Progeny

Parent	Progeny	Progeny Half-life (from NUREG/CR-4467)	Branching Ratio (from NUREG/CR-4467)
Ce-144	Pr-144	17.3 min	0.985
Ce-144	Pr-144m	7.2 min	0.015
Cs-136	*Ba-136m	0.31 sec	0.15
Cs-137	Ba-137m	2.55 min	0.946
Kr-88	Rb-88	17.7 min	1
Ru-103	Rh-103m	56 min	0.9975
Ru-105	*Rh-105m	38 sec	0.28
Ru-106	Rh-106	29.9 sec	1
Sr-91	Y-91m	49.7 min	0.57
Zr-97	Nb-97	73.6 min	0.027
Zr-97	Nb-97m	54 sec	0.973
Te-131m	Te-131	25.0m†	0.222†
I-135	Xe-135m	15.3m†	0.154†
‡Te-129m	Te-129	69.6m†	0.65†

* Nuclide not listed in INDEXR.DAT

† Nuclide not listed in NUREG/CR-4467. Values from INDEXR.DAT

‡ Te-129 is not included as implicit progeny in NUREG/CR-4467 or in dosdata20organs.inp but is identified as an implicit progeny in FGRDCF DCF files

MACCS Radionuclide Metabolic Assumptions

Element	ICRP-30 Clearance Class*	f1†	Element	ICRP-30 Clearance Class*	f1†
Cobalt	Y - nitrates, halides, oxides, hydroxides	0.05	**Iodine**	D - all compounds	1
Krypton	n/a	n/a	**Xenon**	n/a	n/a
Rubidium	D - all compounds	1	**Cesium**	D - all compounds	1
Strontium	D - chlorides, all others (SrTi03 = y)	.3	**Barium**	D - all compounds	0.1
Yttrium	Y - oxide, hydroxide	0.0001	**Lanthanum**	W - oxides, hydroxide, chloride	0.001
Zirconium	W - oxide, hydroxide, halides, nitrates (carbide = Y)	0.002	**Cerium**	Y - oxide, hydroxide, fluorides	0.0003
Niobium	Y - oxide, hydroxide	.01	**Praseodymium**	Y - oxide, hydroxide, carbides, fluorides	0.0003
Molybdenum	Y - oxides, hydroxides, molybdates	0.05	**Neodymium**	Y - oxide, hydroxide, carbides, fluorides	0.0003
Technetium	W - oxide, hydroxide, halides, nitrates (pertechnetate = D)	0.8	**Neptunium**	W - all compounds	0.001
Ruthenium	Y - oxides, hydroxides	0.05	**Plutonium**	Y – oxides	0.00001
Rhodium	Y‡	0.05	**Americium**	W - all compounds	0.001
Antimony	W - oxides, hydroxides, sulfides, sulfates, nitrates	0.01	**Curium**	W - all compounds	0.001
Tellurium	W - oxides, hydroxides, nitrates	0.2			

* From NUREG/CR-4185 Table 2

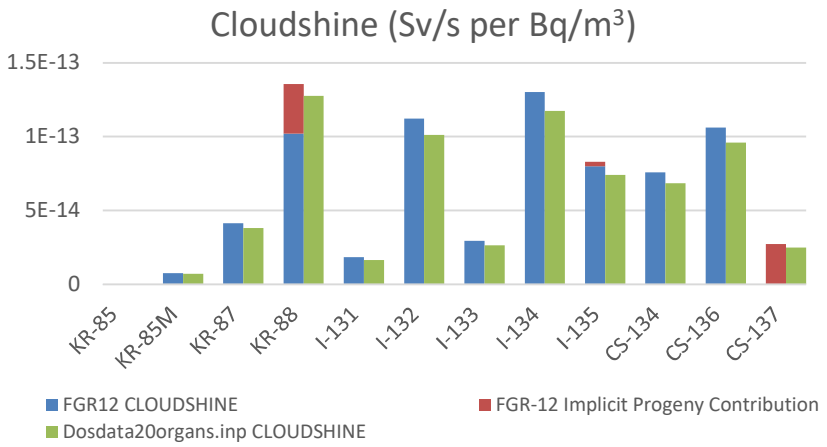
† f1 value corresponds to the f1 value given in FGR-11 Table 2-1 for the recommended clearance class

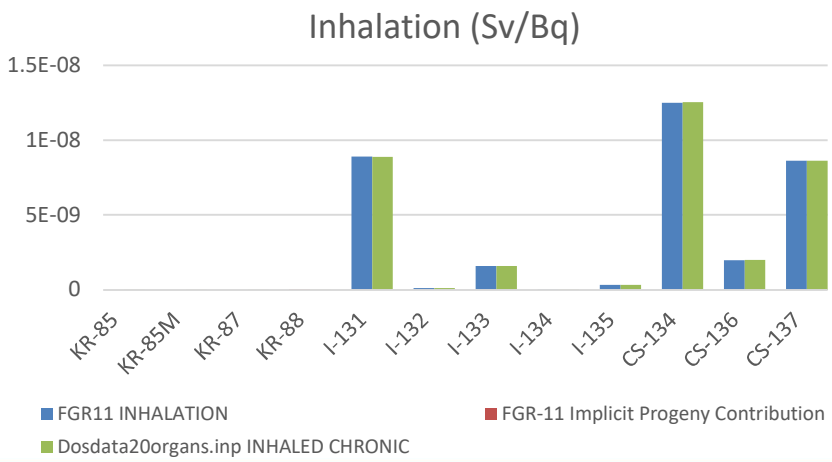
‡ No value provided in NUREG/CR-4185. Recommended value from NUREG/CR-4691 Volume 2 Table D.4

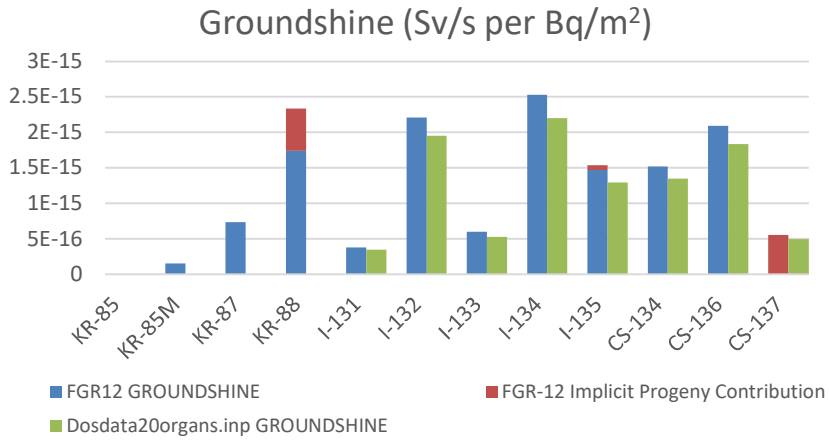
Comparison of Effective Dose Coefficients

dosdata20organs.inp

- DOSFAC2 DCF file dose coefficients include dose contributions from short-lived progeny
- External (cloudshine and groundshine) dose coefficients generally slightly less than progeny-corrected FGR-12 values
  - 29% within 10%
  - 83% within 30%
- Internal (inhalation and ingestion) dose coefficients generally very close to progeny-corrected FGR-11 values
  - 96% within 10%
  - 98% within 30%







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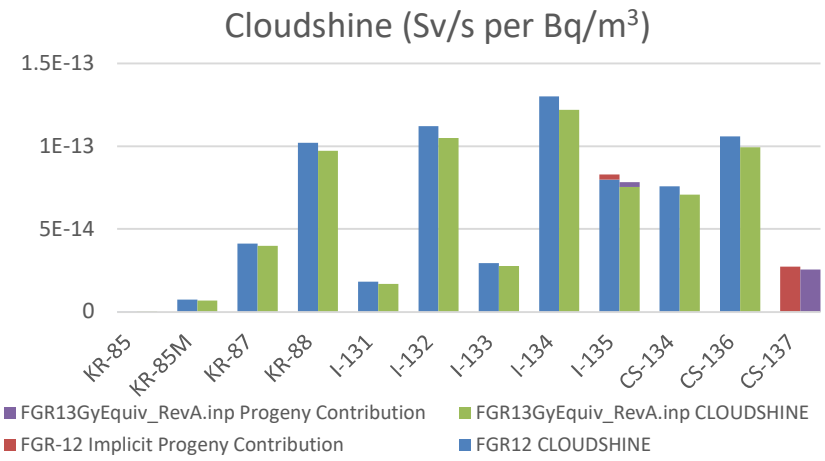
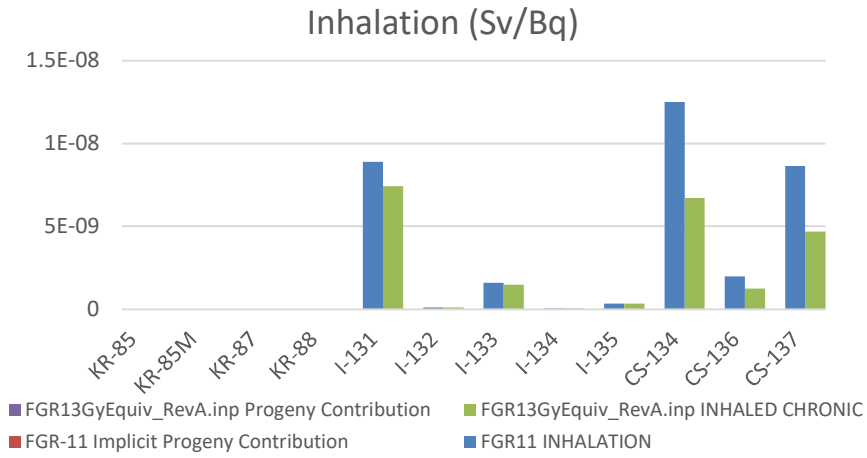
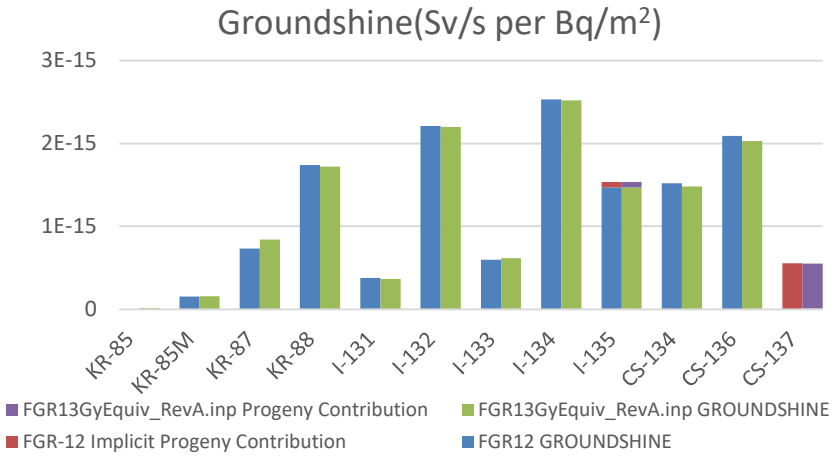
Comparison of Effective Dose Coefficients

FGR13DCF.inp

- FGR13DF DCF file dose coefficients do not include dose contributions from short-lived progeny
- External (cloudshine and groundshine) dose coefficients generally similar to FGR-12 values
  - 58% within 10% of FGR-12 values
  - 79% within 30% of FGR-12 values
- Inhalation dose coefficients generally less than FGR-11 values
  - 41% within 30% of FGR-11 values
  - 38% are more than 30% less than FGR-11 values
- Ingestion dose coefficients generally similar to FGR-11 values
  - 52% within 10% of FGR-11 values
  - 70% within 30% of FGR-11 values







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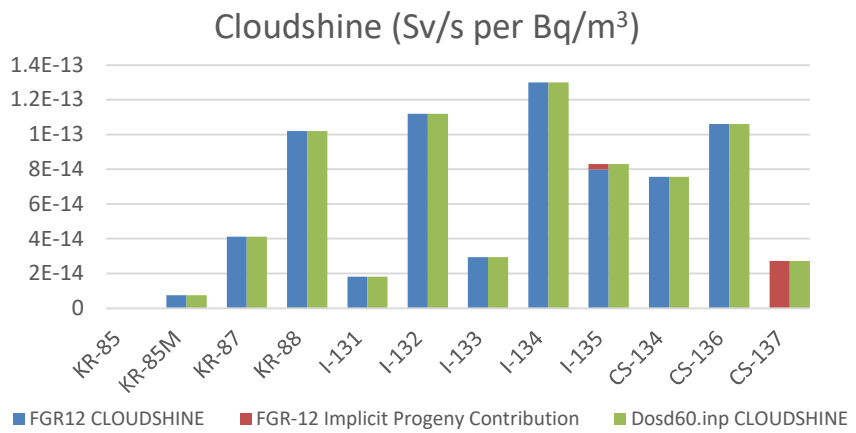
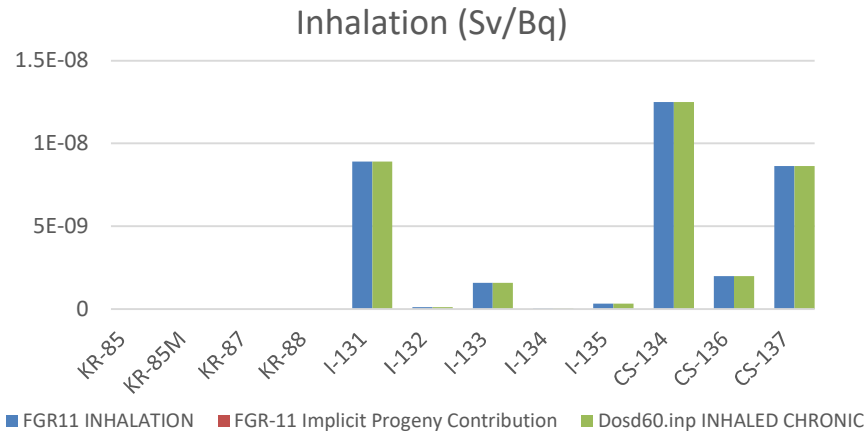
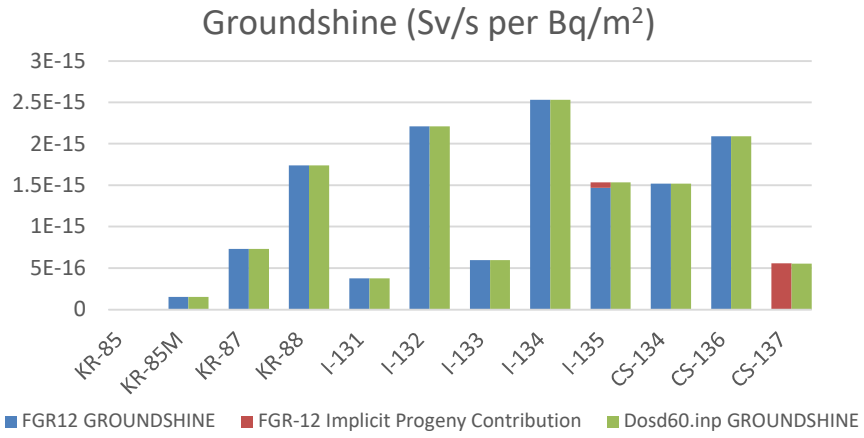
Comparison of Effective Dose Coefficients

Dosd60.inp

- FGRDCF DCF file dose coefficients include dose contributions from short-lived progeny
- Rb-88 not included as decay progeny of Kr-88
- External (cloudshine and groundshine) dose coefficients identical to progeny FGR-12 values
- Internal (inhalation and ingestion) dose coefficients identical to progeny-corrected FGR-11 values
- For *Dosd825.inp* DCF file, slight discrepancies for Zr-97, Sb-127, and Sb-129







Potential Reason for Difference in Effective Dose Coefficients

- Differences in tissue weighting factors
- Updates to external dose computations used to compute organ doses from external radiation
- Updates to metabolic models used to compute organ doses from intakes

Conclusions

- FGRDCF files, such as *Dosd60.inp* and *Dosd825.inp*, have been developed to be consistent with FGR-11 and FGR-12 and provide the most accurate computations for estimating TEDE
  - Note that FGRDCF files include doses from short-lived progeny; however, contributions from Rb-88 are not included in doses from Kr-88
- Other current DCF files, such as *dosdata20organs.inp* or *FGR13DCF.inp*, contain dose coefficients that are relatively close to FGR-11 and FGR-12 values for some radionuclides but not for other radionuclides.

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