SAND2003-1072P
Unlimited Release

FRMAC ASSESSMENT MANUAL

TABLES, CHARTS, WORKSHEETS, GLOSSARY, REFERENCES

VOLUME 2

The Federal Manual for Assessing Environmental Data During a Radiological Emergency

April 2003

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

SAND2003-1072P
Unlimited Release

FRMAC Assessment Manual

Tables, Charts, Worksheets, Glossary, References

Volume 2

William G. Rhodes III
Authorized Derivative Classifier
Assessment Working Group Chair
Sandia National Laboratories

Harvey W. Clark
Former Assessment Working Group Chair
Remote Sensing Lab, Bechtel/Nevada

Colleen T. O'Laughlin
CM/FRMAC Program Manager

Donald M. Daigler
Director
Emergency Management Division

Deborah A. Wilber
National Response Program Manager
Office of Emergency Response

This work was supported by the U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office, under Contract No. DE-AC08-96NV11718.

FRMAC is an acronym for Federal Radiological Monitoring and Assessment Center.

TABLE OF CONTENTS

Page

This page intentionally left blank.

APPENDIX A. TABLES

Table 1.1. Radiological Data

This table contains radiological decay data for the radionuclides considered in this manual. The data includes half-life (in days and hours), the mean life (in hours), and the radiological decay constant (in days^{-1} and hours^{-1}).

Radionuclide	Half-Life [a] ($T_{1/2}$) (days)	Half-Life [a] ($T_{1/2}$) (hours)	Mean Life [b] (T_m) (days)	Decay Constant [c] (λ) (days^{-1})	Decay Constant [c] (λ) (hours^{-1})
^{3}H	4.51×10^{3}	1.08×10^{5}	6.50×10^{3}	1.54×10^{-4}	6.41×10^{-6}
^{14}C	2.09×10^{6}	5.02×10^{7}	3.02×10^{6}	3.31×10^{-7}	1.38×10^{-8}
^{22}Na	9.50×10^{2}	2.28×10^{4}	1.37×10^{3}	7.30×10^{-4}	3.04×10^{-5}
^{24}Na	6.25×10^{-1}	1.50×10^{1}	9.02×10^{-1}	1.11	4.62×10^{-2}
^{32}P	1.43×10^{1}	3.43×10^{2}	2.06×10^{1}	4.85×10^{-2}	2.02×10^{-3}
^{33}P	2.54×10^{1}	6.10×10^{2}	3.66×10^{1}	2.73×10^{-2}	1.14×10^{-3}
^{35}S	8.74×10^{1}	2.1×10^{3}	1.26×10^{2}	7.93×10^{-3}	3.30×10^{-4}
^{36}Cl	1.10×10^{8}	2.64×10^{9}	1.59×10^{8}	6.31×10^{-9}	2.63×10^{-10}
^{40}K	4.67×10^{11}	1.12×10^{13}	6.74×10^{11}	1.48×10^{-12}	6.18×10^{-14}
^{42}K	5.15×10^{-1}	1.24×10^{1}	7.43×10^{-1}	1.35	5.61×10^{-2}
^{45}Ca	1.63×10^{2}	3.91×10^{3}	2.35×10^{2}	4.25×10^{-3}	1.77×10^{-4}
^{46}Sc	8.38×10^{1}	2.01×10^{3}	1.21×10^{2}	8.27×10^{-3}	3.45×10^{-4}
^{44}Ti	1.73×10^{4}	4.14×10^{5}	2.49×10^{4}	4.01×10^{-5}	1.67×10^{-6}
^{48}V	1.62×10^{1}	3.90×10^{2}	2.34×10^{1}	4.27×10^{-2}	1.78×10^{-3}
^{51}Cr	2.77×10^{1}	6.65×10^{2}	4.00×10^{1}	2.50×10^{-2}	1.04×10^{-3}
^{54}Mn	3.13×10^{2}	7.50×10^{3}	4.51×10^{2}	2.22×10^{-3}	9.24×10^{-5}
^{56}Mn	1.07×10^{-1}	2.58	1.55×10^{-1}	6.45	2.69×10^{-1}
^{55}Fe	9.86×10^{2}	2.37×10^{4}	1.42×10^{3}	7.03×10^{-4}	2.93×10^{-5}
^{58}Co	7.08×10^{1}	1.70×10^{3}	1.02×10^{2}	9.79×10^{-33}	4.08×10^{-4}
^{59}Fe	4.45×10^{1}	1.07×10^{3}	6.42×10^{1}	1.56×10^{-2}	6.49×10^{-4}
^{60}Co	1.92×10^{3}	4.62×10^{4}	2.78×10^{3}	3.60×10^{-4}	1.50×10^{-5}
^{63}Ni	3.50×10^{4}	8.41×10^{5}	5.06×10^{4}	1.98×10^{-5}	8.24×10^{-7}
^{64}Cu	5.29×10^{-1}	1.27×10^{1}	7.63×10^{-1}	1.31	5.46×10^{-2}
^{65}Zn	2.44×10^{2}	5.85×10^{3}	3.52×10^{2}	2.84×10^{-3}	1.18×10^{-4}
^{68}Ga	4.72×10^{-2}	1.13	6.81×10^{-2}	1.47×10^{1}	6.12×10^{-1}
^{68}Ge	2.88×10^{2}	6.91×10^{3}	4.15×10^{2}	2.41×10^{-3}	1.00×10^{-4}
^{75}Se	1.20×10^{2}	2.88×10^{3}	1.73×10^{2}	5.79×10^{-3}	2.41×10^{-4}
^{85}Kr	3.91×10^{3}	9.39×10^{4}	5.64×10^{3}	1.77×10^{-4}	7.38×10^{-6}
^{85m}Kr	1.87×10^{-1}	4.48	2.69×10^{-1}	3.71	1.55×10^{-1}
^{87}Kr	5.30×10^{-2}	1.27	7.64×10^{-2}	1.31×10^{1}	5.45×10^{-1}

Table 1.1. Radiological Data (continued)

Radionuclide	Half-Life [a] ($T_{1/2}$) (days)	Half-Life [a] ($T_{1/2}$) (hours)	Mean Life [b] (T_m) (days)	Decay Constant [c] (λ) (days^{-1})	Decay Constant [c] (λ) (hours^{-1})
^{88}Kr	1.18×10^{-1}	2.84	1.71×10^{-1}	5.86	2.44×10^{-1}
^{86}Rb	1.87×10^{1}	4.48×10^{2}	2.69×10^{1}	3.71×10^{-2}	1.55×10^{-3}
^{87}Rb	1.72×10+13	4.12×10+14	2.47×10+13	$4.04\times10^{-1}4$	$1.68\times10^{-1}5$
^{88}Rb	1.24×10^{-2}	2.97×10^{-1}	1.78×10^{-2}	5.61×10^{1}	2.34
^{89}Sr	5.05×10^{1}	1.21×10^{3}	7.29×10^{1}	1.37×10^{-2}	5.72×10^{-4}
^{90}Sr	1.06×104	2.55×10^{5}	1.53×104	6.52×10^{-5}	2.72×10^{-6}
^{91}Sr	3.96×10^{-1}	9.50	5.71×10^{-1}	1.75	7.30×10^{-2}
^{90}Y	2.67	6.40×10^{1}	3.85	2.60×10^{-1}	1.08×10^{-2}
^{91}Y	5.85×10^{1}	1.40×10^{3}	8.44×10^{1}	1.18×10^{-2}	4.94×10^{-4}
^{91m}Y	3.45×10^{-2}	8.29×10^{-1}	4.98×10^{-2}	2.01×10^{1}	8.37×10^{-1}
^{93}Zr	5.58×10^{8}	1.34×10^{10}	8.06×10^{8}	1.24×10^{-9}	$5.17\times10^{-1}1$
^{95}Zr	6.40×10^{1}	1.54×10^{3}	9.23×10^{1}	1.08×10^{-2}	4.51×10^{-4}
^{97}Zr	7.04×10^{-1}	1.69×10^{1}	1.02	9.84×10^{-1}	4.10×10^{-2}
^{94}Nb	7.41×10^{6}	1.78×10^{8}	1.07×10^{7}	9.35×10^{-8}	3.90×10^{-9}
^{95}Nb	$3.52\times\times10^{1}$	8.44×102	5.07×10^{1}	1.97×10^{-2}	8.22×10^{-4}
^{99}Mo	2.75	6.60×10^{1}	3.97	2.52×10^{-1}	1.05×10^{-2}
^{99}Tc	7.77×10^{7}	1.87×10^{9}	1.12×10^{8}	8.92×10^{-9}	3.71×10^{-10}
^{99m}Tc	2.51×10^{-1}	6.02	3.62×10^{-1}	2.76	1.15×10^{-1}
^{103}Ru	3.93×10^{1}	9.43×10^{2}	5.67×10^{1}	1.76×10^{-2}	7.35×10^{-4}
^{105}Ru	1.85×10^{-1}	4.44	2.67×10^{-1}	3.75	1.56×10^{-1}
^{106}Ru	3.68×10^{2}	8.84×10^{3}	5.31×10^{2}	1.88×10^{-3}	7.84×10^{-5}
^{105}Rh	1.47	3.54×10^{1}	2.13	4.70×10^{-1}	1.96×10^{-2}
^{106}Rh	3.46×10^{-4}	8.31×10^{-3}	4.99×10^{-4}	2.00×10^{3}	8.35×10^{1}
^{110m}Ag	2.50×10^{2}	6.00×10^{3}	3.61×102	2.77×10^{3}	1.16×10^{-4}
^{109}Cd	4.64×10^{2}	1.11×10^{4}	6.69×10^{2}	1.49×10^{3}	6.22×10^{-5}
^{113m}Cd	4.96×10^{3}	1.19×10^{5}	7.16×10^{3}	1.40×10^{-4}	5.82×10^{-6}
^{114m}In	4.95×10^{1}	1.19×10^{3}	7.14×10^{1}	1.40×10^{-2}	5.83×10^{-4}
^{113}Sn	1.15×10^{2}	2.76×10^{3}	1.66×10^{2}	6.02×10^{3}	2.51×10^{-4}
^{123}Sn	1.29×10^{2}	3.10×10^{3}	1.86×10^{2}	5.36×10^{3}	2.24×10^{-4}
^{126}Sn	3.65×10^{7}	8.76×10^{8}	5.27×10^{7}	1.90×10^{-8}	7.91×10^{-10}
^{124}Sb	6.02×10^{1}	1.44×10^{3}	8.69×10^{1}	1.15×10^{-2}	4.80×10^{-4}
^{126}Sb	1.24×10^{1}	2.98×10^{2}	1.79×10^{1}	5.59×10^{-2}	2.33×10^{-3}
^{126m}Sb	1.32×10^{-2}	3.17×10^{-1}	1.90×10^{-2}	5.25×10^{1}	2.19
^{127}Sb	3.85	9.24×10^{1}	5.55	1.80×10^{-1}	7.50×10^{-3}

Table 1.1. Radiological Data (continued)

Radionuclide	Half-Life[a] ($T_{1/2}$) (days)	Half-Life[a] ($T_{1/2}$) (hours)	Mean Life[b] (T_m) (days)	Decay Constant[c] (λ) (days^{-1})	Decay Constant[c] (λ) (hours^{-1})
^{129}Sb	1.80×10^{-1}	4.32	2.60×10^{-1}	3.85	1.60×10^{-1}
^{127}Te	3.90×10^{-1}	9.35	5.62×10^{-1}	1.78	7.41×10^{-2}
^{127m}Te	1.09×10^{2}	2.62×10^{3}	1.57×10^{2}	6.36	2.65×10^{-4}
^{129}Te	4.83×10^{-2}	1.16	6.97×10^{-2}	1.43×10^{1}	5.98×10^{-1}
^{129m}Te	3.36×10^{1}	8.06×10^{2}	4.85×10^{1}	2.06×10^{-2}	8.60×10^{-4}
^{131}Te	1.74×10^{-2}	4.17×10^{-1}	2.50×10^{-2}	3.99×10^{1}	1.66
^{131m}Te	1.25	3.00×10^{1}	1.80	5.55×10^{-1}	2.31×10^{-2}
^{132}Te	3.26	7.82×10^{1}	4.70	2.13×10^{-1}	8.86×10^{-3}
^{125}I	6.01×10^{1}	1.44×10^{3}	8.68×10^{1}	1.15×10^{-2}	4.80×10^{-4}
^{129}I	5.73×10^{9}	1.38×10^{11}	8.27×10^{9}	1.21×10^{-10}	5.04×10^{-12}
^{131}I	8.04	1.93×102	1.16×10^{1}	8.62×10^{-2}	3.59×10^{-3}
^{132}I	9.58×10^{-2}	2.30	1.38×10^{-1}	7.23	3.01×10^{-1}
^{133}I	8.67×10^{-1}	2.08×10^{1}	1.25	8.00×10^{-1}	3.33×10^{-2}
^{134}I	3.65×10^{-2}	8.77×10^{-1}	5.27×10^{-2}	1.90×10^{1}	7.91×10^{-1}
^{135}I	2.75×10^{-1}	6.61	3.97×10^{-1}	2.52	1.05×10^{-1}
^{131m}Xe	1.19×10^{1}	2.86×10^{2}	1.72×10^{1}	5.82×10^{-2}	2.43×10^{-3}
^{133}Xe	5.25	1.26×10^{2}	7.57	1.32×10^{-1}	5.51×10^{-3}
^{133m}Xe	2.19	5.25×10^{1}	3.16	3.17×10^{-1}	1.32×10^{-2}
^{135}Xe	3.79×10^{-1}	9.09	5.46×10^{-1}	1.83	7.63×10^{-2}
^{135m}Xe	1.06×10^{-2}	2.55×10^{-1}	1.53×10^{-2}	6.53×10^{1}	2.72
^{138}Xe	9.84×10^{-3}	2.36×10^{-1}	1.42×10^{-2}	7.04×10^{1}	2.93
^{134}Cs	7.53×10^{2}	1.81×10^{4}	1.09×10^{3}	9.21×10^{-4}	3.84×10^{-5}
^{135}Cs	8.40×10^{8}	2.01×10^{10}	1.21×10^{9}	$8.26\times10^{-}10$	3.44×10^{-11}
^{136}Cs	1.31×10^{1}	3.14×10^{2}	1.89×10^{1}	5.29×10^{-2}	2.20×10^{-3}
^{137}Cs	1.10×10^{4}	2.63×10^{5}	1.58×10^{4}	6.33×10^{-5}	2.64×10^{-6}
^{138}Cs	2.24×10^{-2}	5.37×10^{-1}	3.23×10^{-2}	3.10×10^{1}	1.29
^{133}Ba	3.92×10^{3}	9.41×10^{4}	5.66×10^{3}	1.77×10^{-4}	7.37×10^{-6}
^{137m}Ba	1.77×10^{-3}	4.25×10^{-2}	2.56×10^{-3}	3.91×10^{2}	1.63×10^{1}
^{140}Ba	1.27×10^{1}	3.06×10^{2}	1.84×10^{1}	5.44×10^{-2}	2.27×10^{-3}
^{140}La	1.68	4.03×10^{1}	2.42	4.13×10^{-1}	1.72×10^{-2}
^{141}Ce	3.25×10^{1}	7.80×10^{2}	4.69×10^{1}	2.13×10^{-2}	8.89×10^{-4}
^{143}Ce	1.38	3.30×10^{1}	1.98	5.04×10^{-1}	2.10×10^{-2}
^{144}Ce	2.84×10^{2}	6.82×10^{3}	4.10×10^{2}	2.44×10^{-3}	1.02×10^{-4}
^{143}Pr	1.36×10^{1}	3.25×102	1.96×10^{1}	5.11×10^{-2}	2.13×10^{-3}

Table 1.1. Radiological Data (continued)

Radionuclide	Half-Life [a] ($T_{1/2}$) (days)	Half-Life [a] ($T_{1/2}$) (hours)	Mean Life [b] (T_m) (days)	Decay Constant [c] (λ) ($days^{-1}$)	Decay Constant [c] (λ) ($hours^{-1}$)
^{144}Pr	1.20×10^{-2}	2.88×10^{-1}	1.73×10^{-2}	5.78×10^{1}	2.41
^{144m}Pr	5.00×10^{-3}	1.20×10^{-1}	7.21×10^{-3}	1.39×10^{2}	5.78
^{145}Pm	6.46×10^{3}	1.55×10^{5}	9.32×10^{3}	1.07×10^{-4}	4.47×10^{-6}
^{147}Nd	1.10×10^{1}	2.64×10^{2}	1.58×10^{1}	6.31×10^{-2}	2.63×10^{-3}
^{147}Pm	9.58×10^{2}	2.30×10^{4}	1.38×10^{3}	7.24×10^{-4}	3.02×10^{-5}
^{147}Sm	3.87×10^{13}	9.29×10^{14}	5.58×10^{13}	1.79×10^{-14}	7.46×10^{-16}
^{151}Sm	3.29×10^{4}	7.88×10^{5}	4.74×10^{4}	2.11×10^{-5}	8.79×10^{-7}
^{152}Eu	4.87×10^{3}	1.17×10^{5}	7.02×10^{3}	1.42×10^{-4}	5.94×10^{-6}
^{154}Eu	3.21×10^{3}	7.71×10^{4}	4.63×10^{3}	2.16×10^{-4}	8.99×10^{-6}
^{155}Eu	1.81×10^{3}	4.34×10^{4}	2.61×10^{3}	3.83×10^{-4}	1.60×10^{-5}
^{153}Gd	2.42×10^{2}	5.81×10^{3}	3.49×10^{2}	2.86×10^{-3}	1.19×10^{-4}
^{160}Tb	7.23×10^{1}	1.74×10^{3}	1.04×10^{2}	9.59×10^{-3}	3.99×10^{-4}
^{166m}Ho	4.38×10^{5}	$1.05\times10^{+7}$	6.32×10^{5}	1.58×10^{-6}	6.59×10^{-8}
^{170}Tm	1.29×10^{2}	3.09×10^{3}	1.86×10^{2}	5.39×10^{-3}	2.25×10^{-4}
^{169}Yb	3.20×10^{1}	7.68×10^{2}	4.62×10^{1}	2.17×10^{-2}	9.02×10^{-4}
^{172}Hf	6.83×10^{2}	1.64×10^{4}	9.85×10^{2}	1.02×10^{-3}	4.23×10^{-5}
^{181}Hf	4.24×10^{1}	1.02×10^{3}	6.12×10^{1}	1.63×10^{-2}	6.81×10^{-4}
^{182}Ta	1.15×10^{2}	2.76×10^{3}	1.66×10^{2}	6.03×10^{-3}	2.51×10^{-4}
^{187}W	9.96×10^{-1}	2.39×10^{1}	1.44	6.96×10^{-1}	2.90×10^{-2}
^{192}Ir	7.40×10^{1}	1.78×10^{3}	1.07×10^{2}	9.36×10^{-3}	3.90×10^{-4}
^{198}Au	2.70	6.47×10^{1}	3.89	2.57×10^{-1}	1.07×10^{-2}
^{203}Hg	4.66×10^{1}	1.12×10^{3}	6.72×10^{1}	1.49×10^{-2}	6.20×10^{-4}
^{204}Tl	1.38×10^{3}	3.31×10^{4}	1.99×10^{3}	5.03×10^{-4}	2.09×10^{-5}
^{210}Pb	8.14×10^{3}	1.95×10^{5}	1.17×10^{4}	8.52×10^{-5}	3.55×10^{-6}
^{207}Bi	1.39×10^{4}	3.33×10^{5}	2.00×10^{4}	5.00×10^{-5}	2.08×10^{-6}
^{210}Bi	5.01	1.20×10^{2}	7.23	1.38×10^{-1}	5.76×10^{-3}
^{210}Po	1.38×10^{2}	3.32×10^{3}	2.00×10^{2}	5.01×10^{-3}	2.09×10^{-4}
^{226}Ra	5.84×10^{5}	1.40×10^{7}	8.43×10^{5}	1.19×10^{-6}	4.95×10^{-8}
^{227}Ac	7.95×10^{3}	1.91×10^{5}	1.15×10^{4}	8.72×10^{-5}	3.63×10^{-6}
^{228}Ac	2.55×10^{-1}	6.13	3.68×10^{-1}	2.71	1.13×10^{-1}
^{227}Th	1.87×10^{1}	4.49×10^{2}	2.70×10^{1}	3.70×10^{-2}	1.54×10^{-3}
^{228}Th	6.98×10^{2}	1.68×10^{4}	1.01×10^{3}	9.93×10^{-4}	4.14×10^{-5}
^{230}Th	2.81×10^{7}	6.75×10^{8}	4.05×10^{7}	2.47×10^{-8}	1.03×10^{-9}
^{231}Th	1.06	2.55×10^{1}	1.53	6.52×10^{-1}	2.72×10^{-2}

Table 1.1. Radiological Data (continued)

Radionuclide	Half-Life [a] ($T_{1/2}$) (days)	Half-Life [a] ($T_{1/2}$) (hours)	Mean Life [b] (T_m) (days)	Decay Constant [c] (λ) ($days^{-1}$)	Decay Constant [c] (λ) ($hours^{-1}$)
^{232}Th	5.13×10^{12}	1.23×10^{14}	7.40×10^{12}	1.35×10^{-13}	5.63×10^{-15}
^{234}Th	2.41×10^{1}	5.78×10^{2}	3.48×10^{1}	2.88×10^{-2}	1.20×10^{-3}
^{231}Pa	1.20×10^{7}	2.87×10^{8}	1.73×10^{7}	5.80×10^{-8}	2.42×10^{-9}
^{233}Pa	2.70×10^{1}	6.48×10^{2}	3.90×10^{1}	2.57×10^{-2}	1.07×10^{-3}
^{232}U	2.63×10^{4}	6.31×10^{5}	3.79×10^{4}	2.64×10^{-5}	1.10×10^{-6}
^{233}U	5.79×10^{7}	1.39×10^{9}	8.35×10^{7}	1.20×10^{-8}	4.99×10^{-10}
^{234}U	8.92×10^{7}	2.14×10^{9}	1.29×10^{8}	7.77×10^{-9}	3.24×10^{-10}
^{235}U	2.57×10^{11}	6.17×10^{12}	3.71×10^{11}	2.70×10^{-12}	1.12×10^{-13}
^{236}U	8.55×10^{9}	2.05×10^{11}	1.23×10^{10}	8.11×10^{-11}	3.38×10^{-12}
^{238}U	1.63×10^{12}	3.91×10^{13}	2.35×10^{12}	4.25×10^{-13}	1.77×10^{-14}
^{237}Np	7.81×10^{8}	1.87×10^{10}	1.13×10^{9}	8.87×10^{-10}	3.70×10^{-11}
^{239}Np	2.36	5.65×10^{1}	3.40	2.94×10^{-1}	1.23×10^{-2}
^{236}Pu	1.04×10^{3}	2.50×10^{4}	1.50×10^{3}	6.66×10^{-4}	2.78×10^{-5}
^{238}Pu	3.20×10^{4}	7.69×10^{5}	4.62×10^{4}	2.16×10^{-5}	9.02×10^{-7}
^{239}Pu	8.78×10^{6}	2.11×10^{8}	1.27×10^{7}	7.89×10^{-8}	3.29×10^{-9}
^{240}Pu	2.39×10^{6}	5.73×10^{7}	3.44×10^{6}	2.91×10^{-7}	1.21×10^{-8}
^{241}Pu	5.26×10^{3}	1.26×10^{5}	7.58×10^{3}	1.32×10^{-4}	5.49×10^{-6}
^{242}Pu	1.37×10^{8}	3.30×10^{9}	1.98×10^{8}	5.05×10^{-9}	2.10×10^{-10}
^{241}Am	1.58×10^{5}	3.79×10^{6}	2.28×10^{5}	4.39×10^{-6}	1.83×10^{-7}
^{242m}Am	5.55×10^{4}	1.33×10^{6}	8.00×10^{4}	1.25×10^{-5}	5.21×10^{-7}
^{243}Am	2.69×10^{6}	6.46×10^{7}	3.89×10^{6}	2.57×10^{-7}	1.07×10^{-8}
^{242}Cm	1.63×10^{2}	3.91×10^{3}	2.35×10^{2}	4.26×10^{-3}	1.77×10^{-4}
^{243}Cm	1.04×10^{4}	2.50×10^{5}	1.50×10^{4}	6.66×10^{-5}	2.78×10^{-6}
^{244}Cm	6.61×10^{3}	1.59×10^{5}	9.54×10^{3}	1.05×10^{-4}	4.37×10^{-6}
^{245}Cm	3.10×10^{6}	7.45×10^{7}	4.48×10^{6}	2.23×10^{-7}	9.31×10^{-9}
^{252}Cf	9.63×10^{2}	2.31×10^{4}	1.39×10^{3}	7.20×10^{-4}	3.00×10^{-5}

[a] Source: Based on data from EPA93 Table A.1.

[b] Mean Life (Tm) = 1/λ = $T_{1/2}$ / (ln 2).

[c] Radioactive Decay Constant (λ) = (ln 2) / $T_{1/2}$

Table 2.1. Dose Limits for Workers Performing Emergency Services

TEDE Dose Limit[a] (mrem)	Lens of Eye Dose Limit (mrem)	Other Organ, Thyroid, Skin Dose Limit (mrem)	Activity	Condition
5,000	15,000	50,000	All.	
10,000	30,000	100,000	Protecting valuable property.	Lower dose not practicable.
25,000	75,000	250,000	Life saving or protection of large populations.	Lower dose not practicable.
>25,000	>75,000	>250,000	Life saving or protection of large populations.	Only on a voluntary basis by persons fully aware of the risks involved (see Tables 2.2 and 2.3).

Source: EPA92, Table 2-2

[a] Sum of external EDE and CEDE to nonpregnant adults from exposure and intake during an emergency situation. These limits apply to all doses from an incident, except those received in unrestricted areas as members of the public during the Intermediate Phase of the incident (see Chapters 3 and 4 in Volume 1).

Table 2.2. Health Effects Associated with Whole-Body Absorbed Doses Received Within a Few Hours

Whole-Body Absorbed Dose (rad)	Early Fatalities[a, b] (percent)	Whole-Body Absorbed Dose (rad)	Prodromal Effects[a, c] (percent affected)
140	5	50	2
200	15	100	15
300	50	150	50
400	85	200	85
460	95	250	98

Source: EPA92, Table 2-3

[a] Risks will be lower for protracted exposure periods.

[b] Supportive medical treatment may increase the dose where these frequencies occur by approximately 50 percent.

[c] Forewarning symptoms of more serious health effects associated with large doses of radiation.

Table 2.3. Cancer Risk to Average Individuals from 25 rem Effective Dose Equivalent Delivered Promptly

Age at Exposure (years)	**Approximate Risk of Premature Death (deaths per 1,000 persons exposed)**	**Average Years of Life Lost if Premature Death Occurs (years)**
20 to 30	9.1	24
30 to 40	7.2	19
40 to 50	5.3	15
50 to 60	3.5	11

Source: EPA92, Table 2-4

Table 3.1. Early Health Effects from Exposure to Radiation

Organ	**Dose Threshold**	**Early Health Effects[a]**
Bone Marrow (hematopoietic syndrome)	50 rad (0.5 Gy)	Marrow depression
Small Intestine (gastrointestinal syndrome)	50 rad (0.5 Gy) 100 rad (1 Gy) 800 rad (8 Gy)	Vomiting Diarrhea Lethality
Skin	200 rad (2 Gy)	Transient erythema
Thyroid	300 rad (3 Gy)	Hypothyroidism
Lung	600 rad* (6 Gy*) (includes RBE for alpha radiation)	Pneumonitis
Bone	1000 rad (10Gy)	Osteonecrosis

Source Me95

[a] The lung doses include an RBE of 10 applied to the high LET (alpha) DCFs

Table 3.2. Early Phase PAGs

Protective Action	PAG(P_{EP}) Projected Dose	Comments
Evacuation[a] (or sheltering)	1-5 rem TEDE[b] 5-25 rem thyroid[b] 50-250 rem skin[b]	Evacuation (or for some situations, sheltering[a]) should normally be initiated at 1 rem.
Administration of stable iodine	25 rem[c] (25,000 mrem)	Requires approval of state medical officials.

Source: EPA92, Table 2-1

a Sheltering may be the preferred protective action when it provides protection equal to or greater than evacuation, based on consideration of factors such as source-term characteristics and temporal or other site-specific conditions.

b The sum of the EDE resulting from exposure to external sources and the CEDE incurred from all significant inhalation pathways during the early phase. CDE to the thyroid and to the skin may be 5 and 50 times larger, respectively.

c CDE to the thyroid from radioiodine.

Table 3.3. Inhalation Dose Conversion Factors

Purpose: For simplicity, the DCFs are provided in terms of mrem acquired in 1 hour breathing an air concentration of 1 µCi/m^3. To arrive at these DCFs, the breathing rate of an adult performing light activity (1.2 m^3/hr) was assumed as recommended by EPA88. The thyroid dose is the CDE to the thyroid from radioiodine. The early bone and early lung DCFs are for dose absorbed for 30 days after the nuclide has been inhaled. CEDE ($DCF_{e,50}$) is the committed dose for 50 years. The daughters are included in all the inhalation doses. The lung class giving the highest dose was assumed except for UF_6. Method M.3.10 can be used to calculate DCFs for nuclides not listed or for different assumptions.

	50-Year Dose Equivalents		Early (30-Day) Absorbed Doses			
	$DCF_{e,50i}$	$DCF_{T(thyroid),50i}$	$DCF_{T(GI),Ei}$	$DCF_{T(RBM),Ei}$	$DCF_{T(thyroid),Ei}$	$DCF_{T(lung),Ei}$
	CEDE[a]	Thyroid CDE[b]	Small Intestine[c]	Red Bone Marrow[c]	Thyroid[c]	Lung[d]
Nuclide *i*	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$
^{3e}H	1.15×10^{-1}	1.15×10^{-1}	1.01×10^{-1}	1.01×10^{-1}	1.01×10^{-1}	1.01×10^{-1}
^{14}C	2.50	2.50	1.79×10^{-1}	5.55×10^{-2}	5.55×10^{-2}	3.87×10^{1}
^{22}Na	9.19	7.10	3.82	5.37	3.58	3.40
^{24}Na	1.45	6.79×10^{-1}	4.88×10^{-1}	6.62×10^{-1}	5.37×10^{-1}	5.95×10^{-1}
^{32}P	1.86×10^{1}	1.50	1.05	6.88	6.79×10^{-1}	9.06×10^{1}
^{33}P	2.78	2.25×10^{-1}	1.33×10^{-1}	3.45×10^{-1}	9.15×10^{-2}	4.40×10^{1}
^{35}S	2.97	2.02×10^{-1}	1.31×10^{-1}	9.77×10^{-3}	9.77×10^{-3}	3.45×10^{1}
^{36}Cl	2.63×10^{1}	2.24	7.77×10^{-1}	7.68×10^{-1}	7.68×10^{-1}	1.03×10^{2}
^{40}K	1.48×10^{1}	1.36×10^{1}	3.83	3.74	3.74	3.81
^{42}K	1.63	4.66×10^{-1}	3.46×10^{-1}	3.29×10^{-1}	3.32×10^{-1}	4.88×10^{-1}
^{45}Ca	7.95	1.99×10^{-1}	2.18×10^{-1}	3.70×10^{-1}	2.59×10^{-2}	5.68×10^{1}
^{46}Sc	3.56×10^{1}	8.97	2.53	2.42	1.65	9.86×10^{1}
^{44}Ti	1.22×10^{3}	1.64×10^{2}	3.60	3.14	2.18	2.00×10^{2}
^{48}V	1.23×10^{1}	2.45	3.19	2.54	1.54	4.93×10^{1}
^{51}Cr	4.01×10^{-1}	4.80×10^{-2}	4.93×10^{-2}	3.72×10^{-2}	2.49×10^{-2}	4.71×10^{-1}
^{54}Mn	8.04	3.29	1.14	1.45	8.26×10^{-1}	7.73
^{56}Mn	4.53×10^{-1}	5.33×10^{-2}	4.48×10^{-1}	9.32×10^{-2}	5.42×10^{-2}	1.78×10^{-1}
^{55}Fe	3.22	2.41	3.45×10^{-2}	2.06×10^{-1}	2.80×10^{-2}	2.81×10^{-2}
^{58}Co	1.31×10^{1}	3.87	1.19	1.21	8.08×10^{-1}	2.56×10^{1}
^{59}Fe	1.78×10^{1}	1.31×10^{1}	3.52	6.57	2.32	2.92
^{60}Co	2.62×10^{2}	7.19×10^{1}	3.04	3.19	2.27	1.05×10^{2}
^{63}Ni	7.55	7.55	1.40×10^{-1}	1.40×10^{-1}	1.40×10^{-1}	4.84
^{64}Cu	3.32×10^{-1}	2.21×10^{-2}	1.82×10^{-1}	2.66×10^{-2}	2.09×10^{-2}	2.81

Table 3.3. Inhalation Dose Conversion Factors (Continued)

Nuclide *i*	50-Year Dose Equivalents		Early (30-Day) Absorbed Doses			
	$DCF_{e,50i}$	$DCF_{T(thyroid),50i}$	$DCF_{T(GI),Ei}$	$DCF_{T(RBM),Ei}$	$DCF_{T(thyroid),Ei}$	$DCF_{T(lung),Ei}$
	CEDE[a]	Thyroid CDE[b]	Small Intestine[c]	Red Bone Marrow[c]	Thyroid[c]	Lung[d]
	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$
^{65}Zn	2.45×10^{1}	1.34×10^{1}	6.84×10^{-1}	7.46×10^{-1}	5.19×10^{-1}	7.68
^{68}Ga	1.66×10^{-1}	1.67×10^{-2}	1.79×10^{-1}	2.48×10^{-2}	1.85×10^{-2}	1.19×10^{-1}
^{68}Ge	6.22×10^{1}	3.06	6.70×10^{-1}	1.27	1.01	1.61×10^{2}
^{75}Se	1.02×10^{1}	3.73	6.44×10^{-1}	6.04×10^{-1}	4.18×10^{-1}	1.09×10^{1}
^{85}Kr	NC	NC	NC	NC	NC	NC
^{85m}Kr	NC	NC	NC	NC	NC	NC
^{87}Kr	NC	NC	NC	NC	NC	NC
^{88}Kr	NC	NC	NC	NC	NC	NC
^{86}Rb	7.95	5.91	2.66	5.06	2.63	2.73
^{87}Rb	3.88	3.18	6.57×10^{-1}	1.29	6.57×10^{-1}	7.41×10^{-1}
^{88}Rb	1.00×10^{-1}	6.08×10^{-3}	1.26×10^{-2}	7.73×10^{-3}	7.73×10^{-3}	1.39×10^{-1}
^{89}Sr	4.97×10^{1}	3.53×10^{-2}	1.69	7.95×10^{-2}	6.93×10^{-3}	1.41×10^{2}
^{90}Sr	1.56×10^{3}	1.19	1.00	1.61×10^{-1}	1.27×10^{-2}	3.01×10^{2}
^{91}Sr	1.99	4.28×10^{-2}	1.47	8.61×10^{-2}	4.36×10^{-2}	6.44
^{90}Y	1.01×10^{1}	2.30×10^{-3}	2.36	5.42×10^{-3}	1.87×10^{-4}	3.47×10^{1}
^{91}Y	5.86×10^{1}	3.77×10^{-2}	1.76	3.80×10^{-2}	3.57×10^{-3}	1.47×10^{2}
^{91m}Y	4.36×10^{-2}	2.23×10^{-3}	1.71×10^{-2}	4.02×10^{-3}	3.00×10^{-3}	1.26×10^{-1}
^{93}Zr	3.85×10^{2}	7.73×10^{-2}	4.75×10^{-2}	7.46×10^{-1}	2.36×10^{-2}	2.85×10^{-2}
^{95}Zr	2.84×10^{1}	6.39	1.95	7.41	1.19	1.32
^{97}Zr	5.19	1.03×10^{-1}	2.97	2.07×10^{-1}	1.01×10^{-1}	1.69×10^{1}
^{94}Nb	4.97×10^{2}	9.86×10^{1}	2.34	2.22	1.49	1.21×10^{2}
^{95}Nb	6.97	1.59	9.50×10^{-1}	8.61×10^{-1}	5.68×10^{-1}	3.63×10^{1}
^{99}Mo	4.75	6.75×10^{-2}	1.19	9.15×10^{-2}	4.84×10^{-2}	2.66×10^{1}
^{99}Tc	9.99	4.75	2.71×10^{-1}	1.70×10^{-2}	5.42×10^{-1}	7.28×10^{1}
^{99m}Tc	3.91×10^{-2}	2.22×10^{-1}	1.58×10^{-2}	7.41×10^{-3}	1.74×10^{-1}	2.09×10^{-2}
^{103}Ru	1.07×10^{1}	1.14	8.44×10^{-1}	5.68×10^{-1}	3.70×10^{-1}	6.79×10^{1}
^{105}Ru	5.46×10^{-1}	1.84×10^{-2}	6.48×10^{-1}	3.52×10^{-2}	1.99×10^{-2}	3.54
^{106}Ru	5.73×10^{2}	7.64	4.48	3.42×10^{-1}	2.48×10^{-1}	3.03×10^{2}
^{105}Rh	1.15	1.28×10^{-2}	3.98×10^{-1}	2.06×10^{-2}	1.17×10^{-2}	1.02×10^{1}
^{106}Rh	NC	NC	NC	NC	NC	NC
^{110m}Ag	9.63×10^{1}	2.84×10^{1}	3.40	3.64	2.49	7.06×10^{1}
^{109}Cd	1.37×10^{2}	1.18×10^{1}	4.16×10^{-1}	2.69×10^{-1}	2.88×10^{-1}	4.12×10^{-1}
^{113m}Cd	1.83×10^{3}	1.47×10^{2}	7.28×10^{-1}	5.15×10^{-1}	5.15×10^{-1}	6.08×10^{-1}

Table 3.3. Inhalation Dose Conversion Factors (Continued)

	50-Year Dose Equivalents		Early (30-Day) Absorbed Doses			
	$DCF_{e,50i}$	$DCF_{T(thyroid),50i}$	$DCF_{T(GI),Ei}$	$DCF_{T(RBM),Ei}$	$DCF_{T(thyroid),Ei}$	$DCF_{T(lung),Ei}$
	CEDE[a]	Thyroid CDE[b]	Small Intestine[c]	Red Bone Marrow[c]	Thyroid[c]	Lung[d]
Nuclide *i*	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$
^{114m}In	1.07×10^{2}	1.24×10^{1}	3.48	6.48×10^{1}	2.29	2.49
^{113}Sn	1.28×10^{1}	1.01	6.84×10^{-1}	5.06×10^{-1}	2.42×10^{-1}	4.21×10^{1}
^{123}Sn	3.90×10^{1}	8.04×10^{-1}	1.48	4.66×10^{-1}	7.02×10^{-2}	1.25×10^{2}
^{126}Sn	1.19×10^{2}	2.18×10^{1}	4.28	3.39	1.75	2.59×10^{2}
^{124}Sb	3.02×10^{1}	2.99	3.02	2.62	1.40	1.12×10^{2}
^{126}Sb	1.41×10^{1}	2.13	3.52	2.59	1.41	6.79×10^{1}
^{126m}Sb	4.07×10^{-2}	5.02×10^{-3}	2.55×10^{-2}	7.06×10-3	6.30×10^{-3}	7.81×10^{-2}
^{127}Sb	7.24	2.73×10^{-1}	1.47	5.19×10^{-1}	1.83×10^{-1}	4.71×10^{1}
^{129}Sb	7.73×10^{-1}	4.32×10^{-2}	1.15	7.19×10^{-2}	3.82×10^{-2}	3.85
^{127}Te	3.82×10^{-1}	8.17×10^{-3}	3.57×10^{-1}	7.59×10^{-3}	1.25×10^{-2}	3.33
^{127m}Te	2.58×10^{1}	4.29×10^{-1}	5.06×10^{-1}	1.14	1.68	1.50×10^{2}
^{129}Te	1.07×10^{-1}	7.24×10^{-3}	1.10×10^{-1}	9.10×10^{-3}	1.07×10^{-2}	1.07×10^{-1}
^{129m}Te	2.87×10^{1}	6.93×10^{-1}	1.60	1.95	2.89	1.53×10^{2}
^{131}Te	5.73×10^{-1}	1.17×10^{1}	3.91×10^{-2}	4.97×10^{-3}	1.31	1.07×10^{-1}
^{131m}Te	7.68	1.60×10^{2}	1.49	3.90×10^{-1}	1.07×10^{1}	2.03×10^{1}
^{132}Te	1.13×10^{1}	2.79×10^{2}	2.64	9.81×10^{-1}	1.93×10^{1}	4.48×10^{1}
^{125}I	2.90×10^{1}	9.59×10^{2}	1.51×10^{-2}	2.01×10^{-2}	1.92×10^{2}	2.67×10^{-2}
^{129}I	2.08×10^{2}	6.93×10^{3}	2.65×10^{-2}	3.13×10^{-2}	5.55×10^{2}	7.77×10^{-2}
^{131}I	3.95×10^{1}	1.30×10^{3}	6.62×10^{-2}	1.55×10^{-1}	6.13×10^{2}	2.55×10^{-1}
^{132}I	4.57×10^{-1}	7.73	5.19×10^{-2}	5.15×10^{-2}	6.04	1.62×10^{-1}
^{133}I	7.02	2.16×10^{2}	6.88×10^{-2}	8.21×10^{-2}	1.26×10^{2}	1.88×10^{-1}
^{134}I	1.58×10^{-1}	1.28	2.66×10^{-2}	2.45×10^{-2}	1.15	1.33×10^{-1}
^{135}I	1.47	3.76×10^{1}	6.93×10^{-2}	7.50×10^{-2}	2.56×10^{1}	1.79×10^{-1}
^{131m}Xe	NC	NC	NC	NC	NC	NC
^{133}Xe	NC	NC	NC	NC	NC	NC
^{133m}Xe	NC	NC	NC	NC	NC	NC
^{135}Xe	NC	NC	NC	NC	NC	NC
^{135m}Xe	NC	NC	NC	NC	NC	NC
^{138}Xe	NC	NC	NC	NC	NC	NC
^{134}Cs	5.55×10^{1}	4.93×10^{1}	6.22	5.59	5.59	5.33
^{135}Cs	5.46	5.33	5.06×10^{-1}	5.06×10^{-1}	5.06×10^{-1}	5.64×10^{-1}
^{136}Cs	8.79	7.68	4.15	3.66	3.74	3.60
^{137}Cs	3.83×10^{1}	3.52×10^{1}	3.72	3.49	3.49	3.47
^{138}Cs	1.22×10^{-1}	1.59×10^{-2}	2.16×10^{-2}	1.74×10^{-2}	1.90×10^{-2}	1.38×10^{-1}

Table 3.3. Inhalation Dose Conversion Factors (Continued)

Nuclide *i*	50-Year Dose Equivalents		Early (30-Day) Absorbed Doses			
	$DCF_{e,50i}$	$DCF_{T(thyroid),50i}$	$DCF_{T(GI),Ei}$	$DCF_{T(RBM),Ei}$	$DCF_{T(thyroid),Ei}$	$DCF_{T(lung),Ei}$
	CEDE[a]	Thyroid CDE[b]	Small Intestine[c]	Red Bone Marrow[c]	Thyroid[c]	Lung[d]
	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$
^{133}Ba	9.37	4.44	7.81×10^{-1}	1.10	1.55×10^{-1}	2.02×10^{-1}
^{137m}Ba	NC	NC	NC	NC	NC	NC
^{140}Ba	4.48	1.14	1.97	5.59	4.75×10^{-1}	6.17×10^{-1}
^{140}La	5.82	3.05×10^{-1}	2.47	5.95×10^{-1}	2.92×10^{-1}	1.75×10^{1}
^{141}Ce	1.07×10^{1}	1.13×10^{-1}	5.91×10^{-1}	9.19×10^{-2}	5.64×10^{-2}	9.68×10^{1}
^{143}Ce	4.07	2.77×10^{-2}	1.22	6.39×10^{-2}	2.97×10^{-2}	2.10×10^{1}
^{144}Ce	4.48×10^{2}	1.30	3.87	1.32×10^{-1}	5.02×10^{-2}	3.42×10^{2}
^{143}Pr	9.72	7.46×10^{-9}	8.75×10^{-1}	5.91×10^{-3}	5.28×10^{-5}	7.10×10^{1}
^{144}Pr	5.19×10^{-2}	3.76×10^{-5}	5.15×10^{-2}	7.02×10^{-5}	7.02×10^{-5}	2.51×10^{-1}
^{144m}Pr	NC	NC	NC	NC	NC	NC
^{145}Pm	3.65×10^{1}	7.64×10^{-1}	1.13×10^{-1}	4.31×10^{-2}	1.90×10^{-2}	6.48
^{147}Nd	8.21	8.08×10^{-2}	9.06×10^{-1}	1.17×10^{-1}	6.48×10^{-2}	7.24×10^{1}
^{147}Pm	4.71×10^{1}	8.79×10^{-5}	1.84×10^{-1}	4.44×10^{-3}	1.80×10^{-5}	5.68×10^{1}
^{147}Sm	8.97×10^{4}	0.00	9.15×10^{-2}	9.81	2.89×10^{-2}	4.32×10^{3}
^{151}Sm	3.60×10^{1}	5.86×10^{-5}	5.55×10^{-2}	8.66×10^{-2}	2.48×10^{-4}	6.53
^{152}Eu	2.65×10^{2}	3.66×10^{1}	1.93	2.40	1.02	7.10×10^{1}
^{154}Eu	3.43×10^{2}	3.17×10^{1}	2.45	3.13	1.10	1.47×10^{2}
^{155}Eu	4.97×10^{1}	1.07	2.83×10^{-1}	3.53×10^{-1}	5.68×10^{-2}	4.19×10^{1}
^{153}Gd	2.85×10^{1}	1.26	3.41×10^{-1}	1.88	8.52×10^{-2}	3.10×10^{-1}
^{160}Tb	3.00×10^{1}	2.90	2.10	2.74	8.97×10^{-1}	1.26×10^{2}
^{166m}Ho	9.28×10^{2}	9.50×10^{1}	2.77	3.49	1.59	1.05×10^{2}
^{170}Tm	3.16×10^{1}	6.30×10^{-1}	9.59×10^{-1}	1.96	3.77×10^{-2}	1.12×10^{2}
^{169}Yb	9.68	3.81×10^{-1}	7.95×10^{-1}	3.66×10^{-1}	2.25×10^{-1}	7.46×10^{1}
^{172}Hf	3.82×10^{2}	6.39×10^{1}	2.90	1.32×10^{1}	1.82	2.01
^{181}Hf	1.85×10^{1}	2.60	1.60	7.99	8.44×10^{-1}	1.03
^{182}Ta	5.37×10^{1}	6.79	2.09	1.58	1.10	1.66×10^{2}
^{187}W	7.41×10^{-1}	1.94×10^{-2}	4.66×10^{-1}	1.09×10^{-1}	5.33×10^{-2}	1.67×10^{-1}
^{192}Ir	3.38×10^{1}	2.89	1.60	1.07	7.06×10^{-1}	1.15×10^{2}
^{198}Au	3.94	1.05×10^{-1}	1.04	1.51×10^{-1}	9.01×10^{-2}	2.34×10^{1}
^{203}Hg	8.79	3.59	1.07	9.32×10^{-1}	9.06×10^{-1}	8.61×10^{-1}
^{204}Tl	2.89	1.84	8.84×10^{-1}	8.84×10^{-1}	8.84×10^{-1}	9.72×10^{-1}
^{210}Pb	1.63×10^{4}	1.41×10^{3}	1.58	8.18	1.51	6.80
^{207}Bi	2.40×10^{1}	4.80	2.10	1.88	1.25	3.77×10^{1}

Table 3.3. Inhalation Dose Conversion Factors (Continued)

	50-Year Dose Equivalents		Early (30-Day) Absorbed Doses			
	$DCF_{e,50i}$	$DCF_{T(thyroid),50i}$	$DCF_{T(GI),Ei}$	$DCF_{T(RBM),Ei}$	$DCF_{T(thyroid),Ei}$	$DCF_{T(lung),Ei}$
	CEDE[a]	Thyroid CDE[b]	Small Intestine[c]	Red Bone Marrow[c]	Thyroid[c]	Lung[d]
Nuclide *i*	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrem/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$	$\frac{mrad/hr}{\mu Ci/m^3}$
^{210}Bi	2.35×10^{2}	2.87×10^{-1}	9.33×10^{-1}	1.22×10^{-2}	1.22×10^{-2}	9.54×10^{2}
^{210}Po	1.13×10^{4}	1.79×10^{3}	1.37×10^{1}	1.27×10^{2}	1.36×10^{1}	1.76×10^{2}
^{226}Ra	1.03×10^{4}	4.53×10^{2}	6.84×10^{-1}	4.95	2.14×10^{-1}	3.32×10^{4}
^{227}Ac	8.04×106	1.59×10^{2}	3.80	9.33×10^{1}	3.59	3.51×10^{1}
^{228}Ac	3.70×10^{2}	3.91×10^{-2}	4.86×10^{-1}	2.99×10^{-1}	5.38×10^{-2}	2.78×10^{-1}
^{227}Th	1.94×10^{4}	1.31×10^{1}	6.60×10^{-1}	9.10×10^{-1}	1.83×10^{-1}	1.33×10^{5}
^{228}Th	4.10×10^{5}	1.02×10^{3}	1.03	2.69	9.70×10^{-1}	2.45×10^{5}
^{230}Th	3.91×10^{5}	1.81×10^{3}	1.07	3.07×10^{1}	8.96×10^{-1}	3.18×10^{4}
^{231}Th	1.05	1.37×10^{-3}	3.97×10^{-1}	3.17×10^{-3}	1.07×10^{-3}	9.73
^{232}Th	1.97×10^{6}	3.30×10^{3}	9.17×10^{-1}	2.62×10^{1}	7.70×10^{-1}	2.39×10^{4}
^{234}Th	4.20×10^{1}	5.64×10^{-2}	2.55	8.57×10^{-2}	1.89×10^{-2}	1.82×10^{2}
^{231}Pa	1.54×10^{6}	3.39×10^{1}	1.35	3.31×10^{1}	1.00	3.51×10^{4}
^{233}Pa	1.15×10^{1}	2.50×10^{-1}	7.95×10^{-1}	2.30×10^{-1}	1.39×10^{-1}	1.03×10^{2}
^{234}Pa	9.77×10^{-1}	5.46×10^{-2}	1.16	1.14×10^{-1}	6.22×10^{-2}	8.13
^{232}U **Caution**[h]	7.90×10^{5}	1.08×10^{2}	2.28×10^{-1}	1.18×10^{-1}	1.96×10^{-2}	4.89×10^{4}
^{233}U **Caution**[h]	1.63×10^{5}	1.20×10^{1}	1.71×10^{-1}	8.56×10^{-2}	7.52×10^{-3}	3.93×10^{4}
^{234}U **Caution**[h]	1.59×10^{5}	1.18×10^{1}	1.90×10^{-1}	8.47×10^{-2}	7.25×10^{-3}	3.86×10^{4}
^{235}U **Caution**[h]	1.47×10^{5}	1.82×10^{1}	6.17×10^{-1}	3.20×10^{-1}	1.64×10^{-1}	3.40×10^{4}
^{236}U **Caution**[h]	1.51×10^{5}	1.11×10^{1}	1.77×10^{-1}	8.01×10^{-2}	6.79×10^{-3}	3.54×10^{4}
^{238}U **Caution**[h]	1.42×10^{5}	1.21×10^{1}	2.74×10^{-1}	9.83×10^{-2}	1.42×10^{-2}	3.11×10^{4}
U Dep and Nat[f] **Caution**[h]	1.42×10^{5}	1.21×10^{1}	2.74×10^{-1}	9.83×10^{-2}	1.42×10^{-2}	3.11×10^{4}
U Enrich **Caution**[h]	1.59×10^{5}	1.18×10^{1}	1.90×10^{-1}	8.47×10^{-2}	7.25×10^{-3}	3.86×10^{4}
UF_6[g] Sol ^{234}U **Caution**[h]	3.27×10^{3}	1.11×10^{2}	2.01	2.22×10^{1}	1.93	5.24×10^{1}
^{237}Np	6.48×10^{5}	5.95×10^{1}	1.10	2.33×10^{1}	7.42×10^{-1}	3.29×10^{4}
^{239}Np	3.01	3.38×10^{-2}	7.55×10^{-1}	1.51×10^{-1}	3.47×10^{-2}	2.81×10^{1}
^{236}Pu	1.74×10^{5}	8.26	1.40	3.12×10^{1}	1.20	4.57×10^{4}
^{238}Pu	4.71×10^{5}	4.27	1.34	3.01×10^{1}	1.15	4.17×10^{4}
^{239}Pu	5.15×10^{5}	4.01	1.24	2.82×10^{1}	1.08	3.71×10^{4}
^{240}Pu	5.15×10^{5}	4.02	1.26	2.83×10^{1}	1.08	3.72×10^{4}
^{241}Pu	9.90×10^{3}	5.51×10^{-2}	1.58×10^{-2}	3.16×10^{-2}	1.18×10^{-3}	3.36
^{242}Pu	4.93×10^{5}	3.90	1.19	2.69×10^{1}	1.03	3.42×10^{4}
^{241}Am	5.33×10^{5}	7.10	8.89×10^{-1}	1.66×10^{1}	5.50×10^{-1}	4.16×10^{4}

Table 3.3. Inhalation Dose Conversion Factors (Continued)

	50-Year Dose Equivalents		Early (30-Day) Absorbed Doses			
	$DCF_{e,50i}$	$DCF_{T(thyroid),50i}$	$DCF_{T(GI),Ei}$	$DCF_{T(RBM),Ei}$	$DCF_{T(thyroid),Ei}$	$DCF_{T(lung),Ei}$
	CEDE[a]	Thyroid CDE[b]	Small Intestine[c]	Red Bone Marrow[c]	Thyroid[c]	Lung[d]
Nuclide *i*	$\frac{\text{mrem/hr}}{\mu\text{Ci/m}^3}$	$\frac{\text{mrem/hr}}{\mu\text{Ci/m}^3}$	$\frac{\text{mrad/hr}}{\mu\text{Ci/m}^3}$	$\frac{\text{mrad/hr}}{\mu\text{Ci/m}^3}$	$\frac{\text{mrad/hr}}{\mu\text{Ci/m}^3}$	$\frac{\text{mrad/hr}}{\mu\text{Ci/m}^3}$
^{242m}Am	5.11×10^{5}	2.50	3.46×10^{-1}	1.72	6.43×10^{-2}	2.29×10^{3}
^{243}Am	5.28×10^{5}	3.68×10^{1}	1.07	1.69×10^{1}	7.11×10^{-1}	3.88×10^{4}
^{242}Cm	2.07×10^{4}	4.18	7.49×10^{-1}	1.71×10^{1}	5.52×10^{-1}	4.93×10^{4}
^{243}Cm	3.69×10^{5}	1.70×10^{1}	1.31	1.80×10^{1}	6.88×10^{-1}	4.67×10^{4}
^{244}Cm	2.97×10^{5}	4.48	7.42×10^{-1}	1.74×10^{1}	5.56×10^{-1}	4.66×10^{4}
^{245}Cm	5.46×10^{5}	1.63×10^{1}	9.96×10^{-1}	1.64×10^{1}	6.07×10^{-1}	4.00×10^{4}
^{252}Cf	1.88×10^{5}	1.42×10^{2}	NC	NC	NC	NC

NC=Not calculated.

[a] CEDE Factor ($DCF_{e,50}$) is Committed Effective Dose Equivalent Dose Conversion Factor:

$$DCF_{e,50} = EDCF_{e,50} \times BR \times CF$$

[b] Thyroid Committed Dose Equivalent (CDE) $DCF_{T(Thyroid),50}$ Dose Conversion Factor for an adult:

$$DCF_{T(thyroid),50} = EDCF_{T} \times BR \times CF$$

[c] Early Absorbed Dose Conversion Factor [$DCF_{T(Organ),E}$] for the small intestine, red bone marrow, and the thyroid:

$$DCF_{T(Organ),E} = \left[EAD_{Organ(H)} + EAD_{Organ(L)}\right] \times BR \times CF$$

[d] Early Lung Absorbed Dose Conversion Factor [$DCF_{T(lung),E}$]:

$$DCF_{T(Lung),E} = \left[EAD_{Lung(H)} \times RBE + EAD_{Lung(L)}\right] \times BR \times CF$$

Where (for [a] to [d] above):

$EAD_{Organ(H\ or\ L)}(Gy/Bq)$ = Early Absorbed Dose (High or Low LET) from inhalation for the indicated organ in Gy/Bq from Ec01 (adult 30 day). Most conservative lung clearance class (based on effective DCF from EPA88) is used in this manual.

BR = Breathing Rate for an adult performing light activity from EPA88, page 20 (0.020 m^3/min x 60 min/hr = 1.2 m^3/hr). This BR overestimates the average daily rate (see Table 3.10).

$DCF_{e,50}$ = CEDE adult Inhalation Dose Conversion Factors (50 years committed).

$DCF_{T(thyroid),50}$ = Adult Inhalation Dose Conversion Factors for the specified tissue (i.e., CDE thyroid), 50 years committed.

$DCF_{T(Organ),E}$ = Adult early inhalation Dose Conversion Factors for the specified tissue (i.e., red bone marrow, small intestine, lung, or thyroid), 30 days committed.

$EDCF_{e,50}$ = Exposure to Dose Conversion Factors from EPA-520/1-88-020 (EPA88) "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion:

Federal Guidance Report No 11," Table 2.1, page 121, "Effective" column.

$EDCF_T$ = Exposure to Dose Conversion Factor for the thyroid, from EPA88, Table 2.1, page 121, "Thyroid" column.

RBE = Relative Biological Effectiveness. The early-absorbed dose to the lung was computed using an RBE of 10 for high LET radiation to better represent the early dose to that organ.

CF = Conversion Factor for units.

$$1\frac{Sv}{Bq}\times\frac{1.0E+05\ mrem}{Sv}\times\frac{Bq}{2.7E-05\ \mu Ci}=\frac{3.7E+09\ mrem}{\mu Ci}$$

e Tritium inhalation DCFs were multiplied by 1.5 to account for skin absorption.

f For natural and depleted uranium, it is assumed all the release is ^{238}U and for enriched uranium it is assumed all of the release is ^{234}U. The specific activity of enriched uranium is dominated by the concentration of ^{234}U (because of its high SpA). Releases of natural and enriched uranium will be composed principally of a mixture of ^{234}U, ^{235}U, and ^{238}U. Information for specific uranium mixtures can be found in Volume 3, Section 5 (Nuclear Fuel Accident/Incident).

g Assumed the day lung class (soluble) when estimating inhalation dose because the "U" in UF_6 is in a soluble form. Inhalation Class D was assumed when estimating the inhalation dose for UF_6 because the uranium is expected to be in a very soluble form.

h **Caution** for early health effects involving uranium, the chemical toxicity may be more limiting than the dose. See the discussion in Section 5 of Volume 3.

Table 3.4. Early Phase Deposition and Air Dose Conversion Factors

Purpose: The Exposure Rate Conversion Factor (ECF_{gi}) is the exposure rate at 1 m AGL from 1 µCi/m^2 deposition of nuclide *i*, corrected by a factor of 0.7 for ground roughness. The DCF from ground shine (DCF_{gi}) is EDE for 1 hour of external exposure (again, corrected by a factor of 0.7 for ground roughness). The DCF from air immersion (DCF_{ai}) is the EDE rate for exposure to a semi-infinite cloud of constant concentration. Method M.3.10 can be used to calculate the air submersion, ground shine, and exposure rate conversion factors for nuclides not listed or for different assumptions. The daughters are included in all the inhalation doses and in the external doses where noted (e.g., ^{44}Tiand ^{44}Sc). Ground roughness is considered in all external doses and exposures from ground contamination.

	ECF_{gi}	DCF_{gi}	DCF_{ai}
	Deposition External Exposure Rate[a]	Deposition External EDE Rate[b]	Air Submersion External EDE Rate[c]
Radionuclide *i*	$\frac{mR/hr}{\mu Ci/m^2}$	$\frac{mrem/hr}{\mu Ci/m^2}$	$\frac{mrem/hr}{\mu Ci/m^3}$
^{3}H	0.0	0.0	4.4×10^{-6}
^{14}C	2.1×10^{-7}	1.5×10^{-7}	3.0×10^{-6}
^{22}Na	2.8×10^{-2}	2.0×10^{-2}	1.4
^{24}Na	4.8×10^{-2}	3.4×10^{-2}	2.9
^{32}P	3.9×10^{-5}	2.7×10^{-5}	1.3×10^{-3}
^{33}P	5.9×10^{-7}	4.2×10^{-7}	1.1×10^{-5}
^{35}S	2.2×10^{-7}	1.6×10^{-7}	3.2×10^{-6}
^{36}Cl	9.0×10^{-6}	6.3×10^{-6}	3.0×10^{-4}
^{40}K	1.9×10^{-3}	1.4×10^{-3}	1.1×10^{-1}
^{42}K	3.5×10^{-3}	2.5×10^{-3}	1.9×10^{-1}
^{45}Ca	6.1×10^{-7}	4.3×10^{-7}	1.1×10^{-5}
^{46}Sc	2.6×10^{-2}	1.8×10^{-2}	1.3
^{44}Ti + ^{44}Sc	2.9×10^{-2}	2.1×10^{-2}	1.5
^{48}V	3.7×10^{-2}	2.6×10^{-2}	1.9
^{51}Cr	4.1×10^{-4}	2.9×10^{-4}	2.0×10^{-2}
^{54}Mn	1.1×10^{-2}	7.6×10^{-3}	5.4×10^{-1}
^{56}Mn	2.1×10^{-2}	1.5×10^{-2}	1.1
^{55}Fe	0.0	0.0	0.0
^{58}Co	1.3×10^{-2}	8.9×10^{-3}	6.3×10^{-1}

Table 3.4. Early Phase Deposition and Air Dose Conversion Factors (continued)

Radionuclide *i*	ECF_{gi} Deposition External Exposure Rate[a] $\frac{mR/hr}{\mu Ci/m^2}$	DCF_{gi} Deposition External EDE Rate[b] $\frac{mrem/hr}{\mu Ci/m^2}$	DCF_{ai} Air Submersion External EDE Rate[c] $\frac{mrem/hr}{\mu Ci/m^3}$
^{59}Fe	1.5×10^{-2}	1.0×10^{-2}	8.0×10^{-1}
^{60}Co	3.1×10^{-2}	2.2×10^{-2}	1.7
^{63}Ni	0.0	0.0	0.0
^{64}Cu	2.5×10^{-3}	1.7×10^{-3}	1.2×10^{-1}
^{65}Zn	7.4×10^{-3}	5.2×10^{-3}	3.9×10^{-1}
^{68}Ga	1.3×10^{-2}	8.8×10^{-3}	6.1×10^{-1}
$^{68}Ge + ^{68}Ga$	1.3×10^{-2}	8.8×10^{-3}	6.1×10^{-1}
^{75}Se	5.0×10^{-3}	3.5×10^{-3}	2.5×10^{-1}
^{85}Kr	3.5×10^{-5}	2.5×10^{-5}	1.6×10^{-3}
^{85m}Kr	2.0×10^{-3}	1.4×10^{-3}	1.0×10^{-1}
^{87}Kr	9.8×10^{-3}	6.8×10^{-3}	5.5×10^{-1}
$^{88}Kr + ^{88}Rb$	3.1×10^{-2}	2.2×10^{-2}	1.8
^{86}Rb	1.2×10^{-3}	8.7×10^{-4}	6.4×10^{-2}
^{87}Rb	1.2×10^{-6}	8.2×10^{-7}	2.4×10^{-5}
^{88}Rb	7.9×10^{-3}	5.5×10^{-3}	4.5×10^{-1}
^{89}Sr	3.0×10^{-5}	2.1×10^{-5}	1.0×10^{-3}
^{90}Sr	3.8×10^{-6}	2.6×10^{-6}	1.0×10^{-4}
^{91}Sr	9.0×10^{-3}	6.3×10^{-3}	4.6×10^{-1}
^{90}Y	7.1×10^{-5}	5.0×10^{-5}	2.5×10^{-3}
^{91}Y	7.6×10^{-5}	5.4×10^{-5}	3.5×10^{-3}
^{91m}Y	7.0×10^{-3}	4.9×10^{-3}	3.4×10^{-1}
^{93}Zr	0.0	0.0	0.0
^{95}Zr	9.6×10^{-3}	6.7×10^{-3}	4.8×10^{-1}
^{97}Zr	2.3×10^{-3}	1.6×10^{-3}	1.2×10^{-1}
^{94}Nb	2.0×10^{-2}	1.4×10^{-2}	1.0
^{95}Nb	1.0×10^{-2}	7.0×10^{-3}	5.0×10^{-1}
$^{99}Mo + ^{99m}Tc$	3.4×10^{-3}	2.4×10^{-3}	1.7×10^{-1}
^{99}Tc	1.0×10^{-6}	7.3×10^{-7}	2.2×10^{-5}
^{99m}Tc	1.6×10^{-3}	1.1×10^{-3}	7.8×10^{-2}
^{103}Ru	6.2×10^{-3}	4.3×10^{-3}	3.0×10^{-1}

Table 3.4. Early Phase Deposition and Air Dose Conversion Factors (continued)

Radionuclide *i*	ECF_{gi} Deposition External Exposure Rate[a] $\frac{mR/hr}{\mu Ci/m^2}$	DCF_{gi} Deposition External EDE Rate[b] $\frac{mrem/hr}{\mu Ci/m^2}$	DCF_{ai} Air Submersion External EDE Rate[c] $\frac{mrem/hr}{\mu Ci/m^3}$
^{105}Ru	1.0×10^{-2}	7.2×10^{-3}	5.1×10^{-1}
$^{106}Ru + {}^{106}Rh$	2.8×10^{-3}	2.0×10^{-3}	1.4×10^{-1}
^{105}Rh	1.0×10^{-3}	7.1×10^{-4}	5.0×10^{-2}
^{106}Rh	2.8×10^{-3}	2.0×10^{-3}	1.4×10^{-1}
^{110m}Ag	3.5×10^{-2}	2.5×10^{-2}	1.8
$^{109}Cd + {}^{109m}Ag$	4.3×10^{-4}	3.0×10^{-4}	6.5×10^{-3}
^{113m}Cd	3.5×10^{-6}	2.5×10^{-6}	9.2×10^{-5}
^{114m}In	1.2×10^{-3}	8.5×10^{-4}	5.6×10^{-2}
$^{113}Sn + {}^{113m}In$	3.7×10^{-3}	2.6×10^{-3}	1.7×10^{-1}
^{123}Sn	1.1×10^{-4}	7.8×10^{-5}	5.4×10^{-3}
$^{126}Sn + {}^{126m}Sb$	2.1×10^{-2}	1.5×10^{-2}	1.0
^{124}Sb	2.3×10^{-2}	1.6×10^{-2}	1.2
^{126}Sb	3.7×10^{-2}	2.6×10^{-2}	1.8
^{126m}Sb	2.0×10^{-2}	1.4×10^{-2}	1.0
^{127}Sb	9.0×10^{-3}	6.3×10^{-3}	4.4×10^{-1}
^{129}Sb	1.8×10^{-2}	1.3×10^{-2}	9.5×10^{-1}
^{127}Te	6.9×10^{-5}	4.8×10^{-5}	3.2×10^{-3}
^{127m}Te	1.5×10^{-4}	1.1×10^{-4}	2.0×10^{-3}
^{129}Te	8.0×10^{-4}	5.6×10^{-4}	3.7×10^{-2}
^{129m}Te	5.0×10^{-4}	3.5×10^{-4}	2.1×10^{-2}
^{131}Te	5.5×10^{-3}	3.8×10^{-3}	2.7×10^{-1}
^{131m}Te	1.8×10^{-2}	1.3×10^{-2}	9.3×10^{-1}
^{132}Te	3.0×10^{-3}	2.1×10^{-3}	1.4×10^{-1}
^{125}I	5.7×10^{-4}	4.0×10^{-4}	7.0×10^{-3}
^{129}I	3.4×10^{-4}	2.4×10^{-4}	5.1×10^{-3}
^{131}I	5.0×10^{-3}	3.5×10^{-3}	2.4×10^{-1}
^{132}I	2.9×10^{-2}	2.1×10^{-2}	1.5
^{133}I	8.0×10^{-3}	5.6×10^{-3}	3.9×10^{-1}
^{134}I	3.4×10^{-2}	2.4×10^{-2}	1.7
$^{135}I + {}^{135m}Xe$	2.5×10^{-2}	1.8×10^{-2}	1.3

Table 3.4. Early Phase Deposition and Air Dose Conversion Factors (continued)

Radionuclide *i*	ECF_{gi} Deposition External Exposure Rate[a] $\frac{mR/hr}{\mu Ci/m^2}$	DCF_{gi} Deposition External EDE Rate[b] $\frac{mrem/hr}{\mu Ci/m^2}$	DCF_{ai} Air Submersion External EDE Rate[c] $\frac{mrem/hr}{\mu Ci/m^3}$
^{131m}Xe	2.7×10^{-4}	1.9×10^{-4}	5.2×10^{-3}
^{133}Xe	6.1×10^{-4}	4.3×10^{-4}	2.1×10^{-2}
^{133m}Xe	5.4×10^{-4}	3.8×10^{-4}	1.8×10^{-2}
^{135}Xe	3.2×10^{-3}	2.3×10^{-3}	1.6×10^{-1}
^{135m}Xe	5.6×10^{-3}	4.0×10^{-3}	2.7×10^{-1}
^{138}Xe	1.4×10^{-2}	9.6×10^{-3}	7.7×10^{-1}
^{134}Cs	2.0×10^{-2}	1.4×10^{-2}	1.0
^{135}Cs	4.4×10^{-7}	3.1×10^{-7}	7.5×10^{-6}
^{136}Cs	2.8×10^{-2}	1.9×10^{-2}	1.4
$^{137}Cs + ^{137m}Ba$	7.4×10^{-3}	5.2×10^{-3}	3.6×10^{-1}
^{138}Cs	2.9×10^{-2}	2.0×10^{-2}	1.6
^{133}Ba	5.3×10^{-3}	3.7×10^{-3}	2.4×10^{-1}
^{137m}Ba	7.8×10^{-3}	5.5×10^{-3}	3.8×10^{-1}
^{140}Ba	2.4×10^{-3}	1.7×10^{-3}	1.1×10^{-1}
^{140}La	2.9×10^{-2}	2.0×10^{-2}	1.6
^{141}Ce	9.8×10^{-4}	6.9×10^{-4}	4.6×10^{-2}
^{143}Ce	3.7×10^{-3}	2.6×10^{-3}	1.7×10^{-1}
$^{144}Ce + ^{144m}Pr + ^{144}Pr$	7.8×10^{-4}	5.4×10^{-4}	3.7×10^{-2}
^{143}Pr	9.3×10^{-6}	6.5×10^{-6}	2.8×10^{-4}
^{144}Pr	5.0×10^{-4}	3.5×10^{-4}	2.6×10^{-2}
^{144m}Pr	1.7×10^{-4}	1.2×10^{-4}	3.7×10^{-3}
^{145}Pm	4.3×10^{-4}	3.0×10^{-4}	9.4×10^{-3}
^{147}Nd	1.9×10^{-3}	1.3×10^{-3}	8.2×10^{-2}
^{147}Pm	4.5×10^{-7}	3.2×10^{-7}	9.2×10^{-6}
^{147}Sm	0.0	0.0	0.0
^{151}Sm	6.7×10^{-8}	4.7×10^{-8}	4.8×10^{-7}
^{152}Eu	1.5×10^{-2}	1.0×10^{-2}	7.5×10^{-1}
^{154}Eu	1.6×10^{-2}	1.1×10^{-2}	8.2×10^{-1}
^{155}Eu	7.9×10^{-4}	5.5×10^{-4}	3.3×10^{-2}
^{153}Gd	1.4×10^{-3}	9.9×10^{-4}	4.9×10^{-2}

Table 3.4. Early Phase Deposition and Air Dose Conversion Factors (continued)

Radionuclide *i*	ECF_{gi} Deposition External Exposure Rate[a] $\frac{mR/hr}{\mu Ci/m^2}$	DCF_{gi} Deposition External EDE Rate[b] $\frac{mrem/hr}{\mu Ci/m^2}$	DCF_{ai} Air Submersion External EDE Rate[c] $\frac{mrem/hr}{\mu Ci/m^3}$
^{160}Tb	1.4×10^{-2}	1.0×10^{-2}	7.4×10^{-1}
^{166m}Ho	2.3×10^{-2}	1.6×10^{-2}	1.1
^{170}Tm	7.9×10^{-5}	5.5×10^{-5}	3.0×10^{-3}
^{169}Yb	4.0×10^{-3}	2.8×10^{-3}	1.7×10^{-1}
^{172}Hf	1.5×10^{-3}	1.1×10^{-3}	5.4×10^{-2}
^{181}Hf	7.3×10^{-3}	5.1×10^{-3}	3.5×10^{-1}
^{182}Ta	1.6×10^{-2}	1.1×10^{-2}	8.5×10^{-1}
^{187}W	6.2×10^{-3}	4.4×10^{-3}	3.0×10^{-1}
^{192}Ir	1.1×10^{-2}	7.5×10^{-3}	5.2×10^{-1}
^{198}Au	5.3×10^{-3}	3.7×10^{-3}	2.6×10^{-1}
^{203}Hg	3.1×10^{-3}	2.2×10^{-3}	1.5×10^{-1}
^{204}Tl	2.0×10^{-5}	1.4×10^{-5}	7.4×10^{-4}
^{210}Pb	3.3×10^{-5}	2.3×10^{-5}	7.5×10^{-4}
^{207}Bi	2.0×10^{-2}	1.4×10^{-2}	1.0
^{210}Bi	1.4×10^{-5}	9.8×10^{-6}	4.4×10^{-4}
^{210}Po	1.1×10^{-7}	7.7×10^{-8}	5.5×10^{-6}
^{226}Ra	8.6×10^{-5}	6.0×10^{-5}	4.2×10^{-3}
^{227}Ac	2.1×10^{-6}	1.5×10^{-6}	7.8×10^{-5}
^{228}Ac	1.2×10^{-2}	8.7×10^{-3}	6.4×10^{-1}
^{227}Th	1.4×10^{-3}	9.7×10^{-4}	6.5×10^{-2}
^{228}Th	3.1×10^{-5}	2.2×10^{-5}	1.2×10^{-3}
^{230}Th	1.0×10^{-5}	7.0×10^{-6}	2.3×10^{-4}
^{231}Th	2.5×10^{-4}	1.7×10^{-4}	7.0×10^{-3}
^{232}Th	7.3×10^{-6}	5.1×10^{-6}	1.2×10^{-4}
^{234}Th + ^{234m}Pa	3.6×10^{-4}	2.5×10^{-4}	1.7×10^{-2}
^{231}Pa	5.4×10^{-4}	3.8×10^{-4}	2.3×10^{-2}
^{233}Pa	2.6×10^{-3}	1.8×10^{-3}	1.2×10^{-1}
^{232}U **Caution**[d]	1.3×10^{-5}	9.4×10^{-6}	1.9×10^{-4}
^{233}U **Caution**[d]	9.5×10^{-6}	6.7×10^{-6}	2.2×10^{-4}
^{234}U **Caution**[d]	1.0×10^{-5}	7.0×10^{-6}	1.0×10^{-4}

Table 3.4. Early Phase Deposition and Air Dose Conversion Factors (continued)

	ECF_{gi}	DCF_{gi}	DCF_{ai}
	Deposition External Exposure Rate[a]	**Deposition External EDE Rate**[b]	**Air Submersion External EDE Rate**[c]
Radionuclide *i*	$\frac{mR/hr}{\mu Ci/m^2}$	$\frac{mrem/hr}{\mu Ci/m^2}$	$\frac{mrem/hr}{\mu Ci/m^3}$
^{235}U **Caution**[d]	2.0×10^{-3}	1.4×10^{-3}	9.6×10^{-2}
^{236}U **Caution**[d]	8.7×10^{-6}	6.1×10^{-6}	6.7×10^{-5}
^{238}U **Caution**[d]	7.3×10^{-6}	5.1×10^{-6}	4.5×10^{-5}
U Dep and Nat[e] **Caution**[d]	7.3×10^{-6}	5.1×10^{-6}	4.5×10^{-5}
U Enrich[e] **Caution**[d]	1.0×10^{-5}	7.0×10^{-6}	1.0×10^{-4}
UF_6[f] class D (soluble) ^{234}U **Caution**[d]	1.0×10^{-5}	7.0×10^{-6}	1.0×10^{-4}
^{237}Np	3.8×10^{-4}	2.7×10^{-4}	1.4×10^{-2}
^{239}Np	2.2×10^{-3}	1.5×10^{-3}	1.0×10^{-1}
^{236}Pu	1.3×10^{-5}	9.1×10^{-6}	8.5×10^{-5}
^{238}Pu	1.1×10^{-5}	7.8×10^{-6}	6.5×10^{-5}
^{239}Pu	4.9×10^{-6}	3.4×10^{-6}	5.6×10^{-5}
^{240}Pu	1.1×10^{-5}	7.5×10^{-6}	6.3×10^{-5}
^{241}Pu	2.6×10^{-8}	1.8×10^{-8}	9.7×10^{-7}
^{242}Pu	8.9×10^{-6}	6.2×10^{-6}	5.3×10^{-5}
^{241}Am	3.7×10^{-4}	2.6×10^{-4}	1.1×10^{-2}
^{242m}Am	4.0×10^{-5}	2.8×10^{-5}	4.2×10^{-4}
^{243}Am	7.1×10^{-4}	5.0×10^{-4}	2.9×10^{-2}
^{242}Cm	1.3×10^{-5}	8.9×10^{-6}	7.6×10^{-5}
^{243}Cm	1.7×10^{-3}	1.2×10^{-3}	7.8×10^{-2}
^{244}Cm	1.2×10^{-5}	8.2×10^{-6}	6.5×10^{-5}
^{245}Cm	1.2×10^{-3}	8.1×10^{-4}	5.3×10^{-2}
^{252}Cf	9.6×10^{-6}	6.7×10^{-6}	6.7×10^{-5}

[a] Exposure Rate Conversion Factor ground shine (ECF_g) from deposition at 1 m AGL for 1 hour based on "Dose Conversion for Exposure to Contaminated Ground Surface" (DCECGS) factors from EPA93, Table III.3. The external dose from daughters expected to be in equilibrium is included where noted. (e.g., ^{137}Cs + ^{137m}Ba).

$$ECF_g = \left(DCECGS \times SICF \times GRCF\right) / DEXP$$

Where:

GRCF = Ground roughness correction factor of 0.7 to convert the dose projected for a smooth plane to typical ground surface.

SICF = SI unit Conversion Factor, see equation below.

$$1\frac{Sv/s}{Bq/m^2}\times\frac{3.6E+03\ s}{hr}\times\frac{1E+05\ mrem}{Sv}\times\frac{Bq}{2.7E-05\ \mu Ci}=\frac{1.33E+13\ mrem/hr}{\mu Ci/m^2}$$

DEXP = Conversion Factor of 0.7 to convert from dose rate (rem per hour) to exposure rate (roentgens per hour).

[b] Dose Conversion Factor ground shine (DCF_{gi}). EDE from external exposure at 1 m AGL from a deposition for 1 hour based on Dose Coefficients for Exposure to Contaminated Ground Surface (DCECGS) from EPA93, Table III.3 (*multiplied by 0.7 to correct for ground roughness*). The external dose from daughters expected to be in equilibrium is included where noted (e.g., ^{137}Cs + ^{137m}Ba).

$$DCF_g = DCECGS \times SICF \times GRCF$$

c Dose Conversion Factor Air (DCF_a). EDE from external exposure to a semi-infinite cloud of uniform concentration. Based on EPA93, Table III.1 – Dose Coefficients for Air Submersion (DCAS).

$$DCF_a = DCAS \times SICF$$

[d] **Caution** for early health effects involving uranium, the chemical toxicity may be more limiting than the dose. See the discussion in Section 5 of Volume 3.

[e] For natural and depleted uranium, it is assumed that all the release is ^{238}U and for enriched uranium it is assumed all of the release is ^{234}U. The activity of enriched uranium is dominated by the concentration of ^{234}U (because of its high Specific Activity). Releases of natural and enriched uranium will be composed principally of a mixture of ^{234}U, ^{235}U, and ^{238}U. Information for specific uranium mixtures can be found in Volume 3, Section 5 (Nuclear Fuel Accident/Incident).

[f] Assumed the D (day) lung class (soluble) when estimating Early Phase inhalation dose, because the “U” in UF_6 is in a soluble form.

Table 3.5. Early Phase Deposition Dose Conversion Factors and Derived Response Levels

Purpose: The Early Phase deposition (ground) DCF (DCF_{EPgi}) estimates the total dose from remaining on deposition for four days. It includes the EDE from ground shine and inhalation CEDE from resuspension. The daughters are included in all the inhalation doses and in the external doses where noted (e.g., ^{44}Ti + ^{44}Sc). Ground roughness is considered in all external doses and exposures from ground contamination. The Early Phase deposition DRL expresses the Early Phase PAG in terms of the level of deposition on the ground that corresponds to a projected dose equal to the PAG. Method M.3.4 can be used to calculate Early Phase deposition DCFs (DCF_{EPgi}) and the associated DRLs for other nuclides or for different assumptions.

	DCF_{EPgi}	**DRL_{EPgi}**
	Deposition Four-Day Dose External and Resuspension[a]	**Early Phase Deposition DRL[b]**
Radionuclide *i*	$\frac{mrem}{\mu Ci/m^2}$	$\mu Ci/m^2$
^{3}H	NC	NC
^{14}C	NC	NC
^{22}Na	1.9	5.3×10^{2}
^{24}Na	7.2×10^{-1}	1.4×10^{3}
^{32}P	3.4×10^{-3}	3.0×10^{5}
^{33}P	1.9×10^{-4}	5.3×10^{6}
^{35}S	$1.8X10^{-4}$	$5.5X10^{6}$
^{36}Cl	2.1×10^{-3}	4.8×10^{5}
^{40}K	1.3×10^{-1}	7.6×10^{3}
^{42}K	4.4×10^{-2}	2.3×10^{4}
^{45}Ca	4.9×10^{-4}	2.0×10^{6}
^{46}Sc	1.7	5.9×10^{2}
^{44}Ti + ^{44}Sc	2.0	4.9×10^{2}
^{48}V	2.3	4.4×10^{2}
^{51}Cr	2.6×10^{-2}	3.8×10^{4}
^{54}Mn	7.2×10^{-1}	1.4×10^{3}
^{56}Mn	5.5×10^{-2}	1.8×10^{4}
^{55}Fe	1.8×10^{-4}	5.5×10^{6}
^{58}Co	8.3×10^{-1}	1.2×10^{3}
^{59}Fe	9.7×10^{-1}	1.0×10^{3}
^{60}Co	2.1	4.7×10^{2}

Table 3.5. Early Phase Deposition Dose Conversion Factors and Derived Response Levels (continued)

Radionuclide *i*	DCF_{EPgi} Deposition Four-Day Dose External and Resuspension[a] $\frac{mrem}{\mu Ci/m^2}$	DRL_{EPgi} Early Phase Deposition DRL[b] $\mu Ci/m^2$
^{63}Ni	4.3×10^{-4}	2.3×10^{6}
^{64}Cu	3.2×10^{-2}	3.1×10^{4}
^{65}Zn	4.9×10^{-1}	2.0×10^{3}
^{68}Ga	1.4×10^{-2}	7.0×10^{4}
^{68}Ge + ^{68}Ga	8.4×10^{-1}	1.2×10^{3}
^{75}Se	3.3×10^{-1}	3.0×10^{3}
^{85}Kr	NC	NC
^{85m}Kr	NC	NC
^{87}Kr	NC	NC
^{88}Kr + ^{88}Rb	NC	NC
^{86}Rb	7.8×10^{-2}	1.3×10^{4}
^{87}Rb	3.0×10^{-4}	3.3×10^{6}
^{88}Rb	2.4×10^{-3}	4.2×10^{5}
^{89}Sr	4.8×10^{-3}	2.1×10^{5}
^{90}Sr	8.9×10^{-2}	1.1×10^{4}
^{91}Sr	8.6×10^{-2}	1.2×10^{4}
^{90}Y	3.4×10^{-3}	3.0×10^{5}
^{91}Y	8.3×10^{-3}	1.2×10^{5}
^{91m}Y	5.8×10^{-3}	1.7×10^{5}
^{93}Zr	2.2×10^{-2}	4.6×10^{4}
^{95}Zr	6.3×10^{-1}	1.6×10^{3}
^{97}Zr	3.9×10^{-2}	2.6×10^{4}
^{94}Nb	1.4	7.2×10^{2}
^{95}Nb	6.4×10^{-1}	1.6×10^{3}
^{99}Mo + ^{99m}Tc	1.4×10^{-1}	7.0×10^{3}
^{99}Tc	6.4×10^{-4}	1.6×10^{6}
^{99m}Tc	9.8×10^{-3}	1.0×10^{5}
^{103}Ru	4.0×10^{-1}	2.5×10^{3}
^{105}Ru	4.6×10^{-2}	2.2×10^{4}
^{106}Ru + ^{106}Rh	2.2×10^{-1}	4.5×10^{3}

Table 3.5. Early Phase Deposition Dose Conversion Factors and Derived Response Levels (continued)

Radionuclide *i*	DCF_{EPgi} Deposition Four-Day Dose External and Resuspension[a] (mrem / µCi/m²)	DRL_{EPgi} Early Phase Deposition DRL[b] (µCi/m²)
^{105}Rh	3.1×10^{-2}	3.3×10^{4}
^{106}Rh	NC	NC
^{110m}Ag	2.4	4.2×10^{2}
^{109}Cd + ^{109m}Ag	3.7×10^{-2}	2.7×10^{4}
^{113m}Cd	1.0×10^{-1}	9.6×10^{3}
^{114m}In	8.6×10^{-2}	1.2×10^{4}
^{113}Sn + ^{113m}In	2.4×10^{-1}	4.1×10^{3}
^{123}Sn	9.6×10^{-3}	1.0×10^{5}
^{126}Sn + ^{126m}Sb	1.4	7.1×10^{2}
^{124}Sb	1.5	6.7×10^{2}
^{126}Sb	2.2	4.5×10^{2}
^{126m}Sb	6.5×10^{-3}	1.5×10^{5}
^{127}Sb	4.3×10^{-1}	2.3×10^{3}
^{129}Sb	8.0×10^{-2}	1.2×10^{4}
^{127}Te	6.6×10^{-4}	1.5×10^{6}
^{127m}Te	1.1×10^{-2}	8.7×10^{4}
^{129}Te	9.4×10^{-4}	1.1×10^{6}
^{129m}Te	3.4×10^{-2}	2.9×10^{4}
^{131}Te	2.3×10^{-3}	4.4×10^{5}
^{131m}Te	4.9×10^{-1}	2.0×10^{3}
^{132}Te	1.4×10^{-1}	7.3×10^{3}
^{125}I	3.9×10^{-2}	2.6×10^{4}
^{129}I	3.5×10^{-2}	2.9×10^{4}
^{131}I	2.9×10^{-1}	3.5×10^{3}
^{132}I	6.8×10^{-2}	1.5×10^{4}
^{133}I	1.6×10^{-1}	6.2×10^{3}
^{134}I	3.0×10^{-2}	3.4×10^{4}
^{135}I + ^{135m}Xe	1.7×10^{-1}	5.9×10^{3}
^{131m}Xe	NC	NC
^{133}Xe	NC	NC

Table 3.5. Early Phase Deposition Dose Conversion Factors and Derived Response Levels (continued)

	DCF_{EPgi}	**DRL_{EPgi}**
	Deposition Four-Day Dose External and Resuspension[a]	**Early Phase Deposition DRL**[b]
Radionuclide *i*	$\frac{\text{mrem}}{\mu\text{Ci/m}^2}$	$\mu\text{Ci/m}^2$
^{133m}Xe	NC	NC
^{135}Xe	NC	NC
^{135m}Xe	NC	NC
^{138}Xe	NC	NC
^{134}Cs	1.4	7.3×10^{2}
^{135}Cs	3.4×10^{-4}	2.9×10^{6}
^{136}Cs	1.7	5.9×10^{2}
^{137}Cs + ^{137m}Ba	5.0×10^{-1}	2.0×10^{3}
^{138}Cs	1.6×10^{-2}	6.3×10^{4}
^{133}Ba	3.6×10^{-1}	2.8×10^{3}
^{137m}Ba	NC	NC
^{140}Ba	1.5×10^{-1}	6.9×10^{3}
^{140}La	9.5×10^{-1}	1.1×10^{3}
^{141}Ce	6.4×10^{-2}	1.6×10^{4}
^{143}Ce	1.1×10^{-1}	9.3×10^{3}
^{144}Ce + ^{144m}Pr + ^{144}Pr	7.7×10^{-2}	1.3×10^{4}
^{143}Pr	1.1×10^{-3}	9.2×10^{5}
^{144}Pr	1.5×10^{-4}	6.8×10^{6}
^{144m}Pr	NC	NC
^{145}Pm	3.1×10^{-2}	3.2×10^{4}
^{147}Nd	1.1×10^{-1}	9.1×10^{3}
^{147}Pm	2.7×10^{-3}	3.7×10^{5}
^{147}Sm	5.1	2.0×10^{2}
^{151}Sm	2.1×10^{-3}	4.9×10^{5}
^{152}Eu	1.0	1.0×10^{3}
^{154}Eu	1.1	9.2×10^{2}
^{155}Eu	5.6×10^{-2}	1.8×10^{4}
^{153}Gd	9.6×10^{-2}	1.0×10^{4}
^{160}Tb	9.5×10^{-1}	1.1×10^{3}
^{166m}Ho	1.6	6.4×10^{2}
^{170}Tm	7.0×10^{-3}	1.4×10^{5}

Table 3.5. Early Phase Deposition Dose Conversion Factors and Derived Response Levels (continued)

Radionuclide *i*	DCF_{EPgi} Deposition Four-Day Dose External and Resuspension[a] $\frac{mrem}{\mu Ci/m^2}$	DRL_{EPgi} Early Phase Deposition DRL[b] $\mu Ci/m^2$
^{169}Yb	2.6×10^{-1}	3.8×10^{3}
^{172}Hf	1.2×10^{-1}	8.2×10^{3}
^{181}Hf	4.7×10^{-1}	2.1×10^{3}
^{182}Ta	1.1	9.2×10^{2}
^{187}W	1.4×10^{-1}	7.1×10^{3}
^{192}Ir	7.1×10^{-1}	1.4×10^{3}
^{198}Au	2.2×10^{-1}	4.5×10^{3}
^{203}Hg	2.0×10^{-1}	4.9×10^{3}
^{204}Tl	1.5×10^{-3}	6.7×10^{5}
^{210}Pb	9.3×10^{-1}	1.1×10^{3}
^{207}Bi	1.3	7.5×10^{2}
^{210}Bi	1.2×10^{-2}	8.5×10^{4}
^{210}Po	6.4×10^{-1}	1.6×10^{3}
^{226}Ra	5.9×10^{-1}	1.7×10^{3}
^{227}Ac	4.6×10^{2}	2.2
^{228}Ac	8.0×10^{-2}	1.3×10^{4}
^{227}Th	1.1	8.8×10^{2}
^{228}Th	2.3×10^{1}	4.3×10^{1}
^{230}Th	2.2×10^{1}	4.5×10^{1}
^{231}Th	5.9×10^{-3}	1.7×10^{5}
^{232}Th	1.1×10^{2}	8.9
^{234}Th + ^{234m}Pa	2.5×10^{-2}	3.9×10^{4}
^{231}Pa	8.8×10^{1}	1.1×10^{1}
^{233}Pa	1.7×10^{-1}	6.0×10^{3}
^{232}U **Caution**[c]	4.5×10^{1}	2.2×10^{1}
^{233}U **Caution**[c]	9.2	1.1×10^{2}
^{234}U **Caution**[c]	9.0	1.1×10^{2}
^{235}U **Caution**[c]	8.5	1.2×10^{2}
^{236}U **Caution**[c]	8.6	1.2×10^{2}
^{238}U **Caution**[c]	8.1	1.2×10^{2}

Table 3.5. Early Phase Deposition Dose Conversion Factors and Derived Response Levels (continued)

	DCF_{EPgi}	DRL_{EPgi}
	Deposition Four-Day Dose External and Resuspension[a]	**Early Phase Deposition DRL**[b]
Radionuclide *i*	$\frac{\text{mrem}}{\mu\text{Ci/m}^2}$	$\mu\text{Ci/m}^2$
U Dep and Nat[d] **Caution**[c]	8.1	1.2×10^{2}
U Enrich[d] **Caution**[c]	9.0	1.1×10^{2}
UF_6[e] class D (soluble) ^{234}U **Caution**[c]	1.9×10^{-1}	5.4×10^{3}
^{237}Np	3.7×10^{1}	2.7×10^{1}
^{239}Np	8.6×10^{-2}	1.2×10^{4}
^{236}Pu	9.9	1.0×10^{2}
^{238}Pu	2.7×10^{1}	3.7×10^{1}
^{239}Pu	2.9×10^{1}	3.4×10^{1}
^{240}Pu	2.9×10^{1}	3.4×10^{1}
^{241}Pu	5.6×10^{-1}	1.8×10^{3}
^{242}Pu	2.8×10^{1}	3.6×10^{1}
^{241}Am	3.0×10^{1}	3.3×10^{1}
^{242m}Am	2.9×10^{1}	3.4×10^{1}
^{243}Am	3.0×10^{1}	3.3×10^{1}
^{242}Cm	1.2	8.5×10^{2}
^{243}Cm	2.1×10^{1}	4.7×10^{1}
^{244}Cm	1.7×10^{1}	5.9×10^{1}
^{245}Cm	3.1×10^{1}	3.2×10^{1}
^{252}Cf	1.1×10^{1}	9.3×10^{1}

NC=Not calculated.

a Dose Conversion Factor Early Phase ground (DCF_{EPgi}) is the dose from the external exposure from deposition and CEDE from resuspension from remaining on contaminated ground for four days. See Method M.3.4 for a full description of how DCF_{EPgi} is calculated. The external dose from daughters expected to be in equilibrium is included where noted (e.g., ^{137}Cs + ^{137m}Ba).

b Derived Response Level (DRL_{EPgi}). The Early Phase deposition DRL is the level of deposition on the ground that corresponds to a projected dose equal to the PAG.

$$DRL_{EPgi} = P_{EP} \div DCF_{EPgi}$$

Where P_{EP} is the Early Phase PAG.

c **Caution** for early health effects involving uranium, the chemical toxicity may be more limiting than the dose. See the discussion in Section 5 of Volume 3.

[d] For natural and depleted uranium, it is assumed that all the release is ^{238}U and for enriched uranium it is assumed all of the release is ^{234}U. The activity of enriched uranium is dominated by the concentration of ^{234}U (because of its high Specific Activity). Releases of natural and enriched uranium will be composed principally of a mixture of ^{234}U, ^{235}U, and ^{238}U. Information for specific uranium mixtures can be found in Volume 3, Section 5 (Nuclear Fuel Accident/Incident).

[e] Assumed the D (day) lung class (soluble) when estimating Early Phase inhalation dose, because the “U” in UF_6 is in a soluble form. "Inhalation Class D was assumed when estimating the inhalation dose for UF_6 because the uranium is expected to be in a very soluble form."

Table 3.6. Stability Class and Dilution Factors

Purpose: Tables 3.6.A and 3.6.B are used to estimate the stability class. Table 3.6.C is used to estimate dilution factor (DF) by stability class.

Table 3.6.A. Stability Class Descriptions and Relationship to Standard Deviation of Wind Direction and Lapse Rate

Class	**Description**	**Standard Deviation of Horizontal Wind Direction (sigma-theta)**	**Lapse Rate (Delta T) Degrees C/100 m**
A	Extremely unstable conditions	25.0°	< -1.9
B	Moderately unstable conditions	20.0°	-1.9 to -1.7
C	Slightly unstable conditions	15.0°	-1.7 to -1.5
D	Neutral conditions	10.0°	-1.5 to -0.5
E	Slightly stable conditions	5.0°	-0.5 to 1.5
F	Moderately stable conditions	2.5°	1.5 to 4.0

Source: DOE84, page 591

Table 3.6.B. Relationship of Stability Class to Weather Conditions

Surface Winds	**Daytime Insolation (Solar Radiation)**			**Nighttime Conditions**		**Day or Night**
Speed (m/s)	Strong	Moderate	Slight	Thin Overcast or More Than Four-Eighths Cloudiness	Less Than Three-Eighths Cloudiness	Heavy Overcast
<2	A	A-B	B	–	–	D
2	A-B	B	C	E	F	D
4	B	B-C	C	D	E	D
6	C	C-D	D	D	D	D
>6	C	D	D	D	D	D

Source: DOE84, page 221

Table 3.6.C. Dilution Factors $\chi\bar{u}/Q$ (m^{-2})

Purpose: This table provides the dilution factors (DFs) for the center line of a ground-level release for the various stability classes. Note that the dilution factor for close to the source (less than 1/4 mile) is constant and independent of the stability class. This is because it is assumed that the DF close to the source will be dominated by the building wake.

Miles	Stability Class A	Stability Class B	Stability Class C	Stability Class D	Stability Class E	Stability Class F
≤ 0.25	1.0×10^{-3} [a]	1.0×10^{-3} [a]	1.0×10^{-3} [a]	1.0×10^{-3} [a]	1.0×10^{-3} [a]	1.0×10^{-3} [a]
1	1.0×10^{-6}	6.0×10^{-6}	1.7×10^{-5}	5.4×10^{-5}	1.1×10^{-4}	2.5×10^{-4}
2	7.0×10^{-7}	1.5×10^{-6}	5.0×10^{-6}	2.0×10^{-5}	4.0×10^{-5}	1.0×10^{-4}
3	4.5×10^{-7}	6.5×10^{-7}	2.2×10^{-6}	1.2×10^{-5}	2.5×10^{-5}	6.0×10^{-5}
4	3.5×10^{-7}	4.5×10^{-7}	1.2×10^{-6}	8.0×10^{-6}	1.6×10^{-5}	4.0×10^{-5}
5	3.0×10^{-7}	4.0×10^{-7}	9.5×10^{-7}	5.0×10^{-6}	1.1×10^{-5}	3.0×10^{-5}
10	1.7×10^{-7}	2.2×10^{-7}	3.0×10^{-7}	2.0×10^{-6}	5.0×10^{-6}	1.2×10^{-5}
15	1.2×10^{-7}	1.5×10^{-7}	2.0×10^{-7}	1.0×10^{-6}	2.6×10^{-6}	7.0×10^{-6}
20	9.5×10^{-8}	1.1×10^{-7}	1.7×10^{-7}	7.0×10^{-7}	2.0×10^{-6}	5.0×10^{-6}
25	8.0×10^{-8}	9.0×10^{-8}	1.3×10^{-7}	4.5×10^{-7}	1.4×10^{-6}	4.0×10^{-6}

Source: EPA70 (Figures 3-5 a through 3-5 f at a vertical dispersion limit of 1,000 meters and a ground level release)

[a] These factors are dominated by building wake. They are based on interpretation of NRC88, Figures 5-7, pages 25-27.

Table 3.7. Shielding Factors from Gamma Cloud Source

Structure or Location	Shielding Factor[a]
Outside	1.0
Vehicles	1.0
Wood frame house[b] (no basement)	0.9
Basement of wood frame house	0.6
Masonry house (no basement)	0.6
Basement of masonry house	0.4
Large office or industrial building	0.2

Source: EGG75

[a] Ratio of the interior dose to the exterior dose.

[b] A wood frame house with brick or stone veneer is approximately equivalent to a masonry house for shielding purposes.

Table 3.8. Shielding Factors for Surface Deposition

Structure or Location	Representative Shielding Factor[a]
Cars on fully contaminated road	0.5
Cars on fully decontaminated 50-feet road	0.25
Trains	0.4
One- and two-story wood-frame house (no basement)	0.4[b]
One- and two-story block and brick house (no basement)	0.2[b]
House basement, one or two walls fully exposed	0.1[b]
One story, less than two feet of basement, wall exposed	0.05[b]
Two stories, less than two feet of basement, wall exposed	0.03[b]
Three- or four-story structures, 5,000 to 10,000 square feet per floor	
First and second floors	0.05[b]
Basement	0.01[b]
Multi-story structures, greater than 10,000 square feet per floor	
Upper floors	0.01[b]
Basement	0.005[b]

Source: EGG75

[a] The ratio of the interior dose to the exterior dose.

[b] Away from doors and windows.

Table 3.9. Early Phase Effective Exposure Period (T_{EPeep})

Purpose: The effective exposure period multiplied by the exposure or dose rate will give the total dose during the exposure period when radioactive decay is considered. For the Early Phase, the deposition exposure is for a period of four days (96 hours).

Nuclide *i*	$T_{1/2}$ Half-Life (Hours)	T_{EPeep} [b] Effective Exposure Period (Hours)
^{3}H	1.1×10^{5}	96
^{14}C	5.0×10^{7}	96
^{22}Na	2.3×10^{4}	96
^{24}Na	1.5×10^{1}	21
^{32}P	3.4×10^{2}	87
^{33}P	6.1×10^{2}	91
^{35}S	2.1×10^{3}	94
^{36}Cl	2.6×10^{9}	96
^{40}K	1.1×10^{13}	96
^{42}K	1.2×10^{1}	18
^{45}Ca	3.9×10^{3}	95
^{46}Sc	2.0×10^{3}	94
^{44}Ti + ^{44}Sc [a]	4.1×10^{5}	96
^{48}V	3.9×10^{2}	88
^{51}Cr	6.6×10^{2}	91
^{54}Mn	7.5×10^{3}	96
^{56}Mn	2.6	3.7
^{55}Fe	2.4×10^{4}	96
^{58}Co	1.7×10^{3}	94
^{59}Fe	1.1×10^{3}	93
^{60}Co	4.6×104	96
^{63}Ni	8.4×10^{5}	96
^{64}Cu	1.3×10^{1}	18
^{65}Zn	5.9×10^{3}	95
^{68}Ga	1.1	1.6
^{68}Ge + ^{68}Ga [a]	6.9×10^{3}	96
^{75}Se	2.9×10^{3}	95

Table 3.9. Early Phase Effective Exposure Period (T_{EPeep}) (Continued)

Nuclide *i*	$T_{1/2}$ Half-Life (Hours)	T_{EPeep}[b] Effective Exposure Period (Hours)
^{85}Kr	9.4×10^{4}	96
^{85m}Kr	4.5	6.5
^{87}Kr	1.3	1.8
^{88}Kr + ^{88}Rb[a]	2.8	4.1
^{86}Rb	4.5×10^{2}	89
^{87}Rb	4.1×10^{14}	96
^{88}Rb	3.0×10^{-1}	0.43
^{89}Sr	1.2×10^{3}	93
^{90}Sr	2.6×10^{5}	96
^{91}Sr	9.5	14
^{90}Y	6.4×10^{1}	60
^{91}Y	1.4×10^{3}	94
^{91m}Y	8.3×10^{-1}	1.2
^{93}Zr	1.3×10^{10}	96
^{95}Zr	1.5×10^{3}	94
^{97}Zr	1.7×10^{1}	24
^{94}Nb	1.8×10^{8}	96
^{95}Nb	8.4×10^{2}	92
^{99}Mo + ^{99m}Tc[a]	6.6×10^{1}	60
^{99}Tc	1.9×10^{9}	96
^{99m}Tc	6.0	8.7
^{103}Ru	9.4×10^{2}	93
^{105}Ru	4.4	6.4
^{106}Ru + ^{106}Rh[a]	8.8×10^{3}	96
^{105}Rh	3.5×10^{1}	43
^{106}Rh	8.3×10^{-3}	0.01
^{110m}Ag	6.0×10^{3}	95
^{109}Cd + ^{109m}Ag[a]	1.1×10^{4}	96
^{113m}Cd	1.2×10^{5}	96
^{114m}In	1.2×10^{3}	93
^{113}Sn + ^{113m}In[a]	2.8×10^{3}	95
^{123}Sn	3.1×10^{3}	95
^{126}Sn + ^{126m}Sb[a]	8.8×10^{8}	96

Table 3.9. Early Phase Effective Exposure Period (T_{EPeep}) (Continued)

Nuclide *i*	$T_{1/2}$ Half-Life (Hours)	T_{EPeep}[b] Effective Exposure Period (Hours)
^{124}Sb	1.4×10^{3}	94
^{126}Sb	3.0×10^{2}	86
^{126m}Sb	3.2×10^{-1}	0.46
^{127}Sb	9.2×10^{1}	68
^{129}Sb	4.3	6.2
^{127}Te	9.4	13
^{127m}Te	2.6×10^{3}	95
^{129}Te	1.2	1.7
^{129m}Te	8.1×10^{2}	92
^{131}Te	4.2×10^{-1}	0.6
^{131m}Te	3.0×10^{1}	39
^{132}Te	7.8×10^{1}	65
^{125}I	1.4×10^{3}	94
^{129}I	1.4×10^{11}	96
^{131}I	1.9×10^{2}	81
^{132}I	2.3	3.3
^{133}I	2.1×10^{1}	29
^{134}I	8.8×10^{-1}	1.3
^{135}I + ^{135m}Xe[a]	6.6	10
^{131m}Xe	2.9×10^{2}	86
^{133}Xe	1.3×10^{2}	75
^{133m}Xe	5.3×10^{1}	54
^{135}Xe	9.1	13
^{135m}Xe	2.5×10^{-1}	0.37
^{138}Xe	2.4×10^{-1}	0.34
^{134}Cs	1.8×10^{4}	96
^{135}Cs	2.0×10^{10}	96
^{136}Cs	3.1×10^{2}	87
^{137}Cs + ^{137m}Ba[a]	2.6×10^{5}	96
^{138}Cs	5.4×10^{-1}	0.77
^{133}Ba	9.4×10^{4}	96
^{137m}Ba	4.3×10^{-2}	0.06
^{140}Ba	3.1×10^{2}	86

Table 3.9. Early Phase Effective Exposure Period (T_{EPeep}) (Continued)

Nuclide *i*	$T_{1/2}$ Half-Life (Hours)	T_{EPeep} [b] Effective Exposure Period (Hours)
^{140}La	4.0×10^{1}	47
^{141}Ce	7.8×10^{2}	92
^{143}Ce	3.3×10^{1}	41
$^{144}Ce + ^{144m}Pr + ^{144}Pr$ [a]	6.8×10^{3}	96
^{143}Pr	3.3×10^{2}	87
^{144}Pr	2.9×10^{-1}	0.42
^{144m}Pr	1.2×10^{-1}	0.17
^{145}Pm	1.6×10^{5}	96
^{147}Nd	2.6×10^{2}	85
^{147}Pm	2.3×10^{4}	96
^{147}Sm	9.3×10^{14}	96
^{151}Sm	7.9×10^{5}	96
^{152}Eu	1.2×10^{5}	96
^{154}Eu	7.7×10^{4}	96
^{155}Eu	4.3×10^{4}	96
^{153}Gd	5.8×10^{3}	95
^{160}Tb	1.7×10^{3}	94
^{166m}Ho	1.1×10^{7}	96
^{170}Tm	3.1×10^{3}	95
^{169}Yb	7.7×10^{2}	92
^{172}Hf	1.6×10^{4}	96
^{181}Hf	1.0×10^{3}	93
^{182}Ta	2.8×10^{3}	95
^{187}W	2.4×10^{1}	32
^{192}Ir	1.8×10^{3}	94
^{198}Au	6.5×10^{1}	60
^{203}Hg	1.1×10^{3}	93
^{204}Tl	3.3×10^{4}	96
^{210}Pb	2.0×10^{5}	96
^{207}Bi	3.3×10^{5}	96
^{210}Bi	1.2×10^{2}	74
^{210}Po	3.3×10^{3}	95

Table 3.9. Early Phase Effective Exposure Period (T_{EPeep}) (Continued)

Nuclide *i*	$T_{1/2}$ Half-Life (Hours)	T_{EPeep}[b] Effective Exposure Period (Hours)
^{226}Ra	1.4×10^{7}	96
^{227}Ac	1.9×10^{5}	96
^{228}Ac	6.1	8.8
^{227}Th	4.5×10^{2}	89
^{228}Th	1.7×10^{4}	96
^{230}Th	6.7×10^{8}	96
^{231}Th	2.6×10^{1}	34
^{232}Th	1.2×10^{14}	96
^{234}Th + ^{234m}Pa[a]	5.8×10^{2}	91
^{231}Pa	2.9×10^{8}	96
^{233}Pa	6.5×10^{2}	91
^{232}U	6.3×10^{5}	96
^{233}U	1.4×10^{9}	96
^{234}U	2.1×10^{9}	96
^{235}U	6.2×10^{12}	96
^{236}U	2.1×10^{11}	96
^{238}U	3.9×10^{13}	96
^{234}U	2.1×10^{9}	96
^{237}Np	1.9×10^{10}	96
^{239}Np	5.7×10^{1}	56
^{236}Pu	2.5×10^{4}	96
^{238}Pu	7.7×10^{5}	96
^{239}Pu	2.1×10^{8}	96
^{240}Pu	5.7×10^{7}	96
^{241}Pu	1.3×10^{5}	96
^{242}Pu	3.3×10^{9}	96
^{241}Am	3.8×10^{6}	96
^{242m}Am	1.3×10^{6}	96
^{243}Am	6.5×10^{7}	96
^{242}Cm	3.9×10^{3}	95
^{243}Cm	2.5×10^{5}	96
^{244}Cm	1.6×10^{5}	96

Table 3.9. Early Phase Effective Exposure Period (T_{EPeep}) (Continued)

Nuclide *i*	$T_{1/2}$ Half-Life (Hours)	T_{EPeep} [b] Effective Exposure Period (Hours)
^{245}Cm	7.4×10^{7}	96
^{252}Cf	2.3×10^{4}	96

[a] For nuclides with short-lived daughters (e.g., ^{137}Cs + ^{137m}Ba) that are expected to be in equilibrium. The effective period is based on the half-life of the parent

[b] Early Phase effective exposure period is calculated as follows:

$$T_{EPeepi} = \int_0^{96} e^{-\lambda t}\,dt$$
$$= \frac{1}{\lambda}\left(1 - e^{-\lambda \times 96}\right),$$

Where

t = time in hours (96 hours is equivalent to 4 days) and

λ = radioactive decay constant ((ln 2)/$T_{1/2}$)

The early phase effective exposure period is the 96-hour early phase time period adjusted for radioactive decay.

Table 3.10. Breathing Rates

Purpose: The manual assumes the breathing rate for an adult performing light activity. However, this slightly overestimates the dose for 24 hours. This table lists the breathing rates for the Reference Man from ICRP-23 (ICRP74). They can be used in Method M.3.10 to calculate inhalation dose factors.

Breathing Rate (m^3/hr) for Reference Man					
	Adult Man	**Adult Woman**	**Child (10 yr)**	**Infant (1 yr)**	**Newborn**
Resting (m^3/hr)	0.45	0.36	0.29	0.09	0.03
Light Activity (m^3/hr)	1.20	1.14	0.78	0.25	0.09
Liters of Air Breathed for Reference Man					
8 hr light activity (L)	9,600	9,100	6,240	2,500 (10 hr)	90 (1 hr)
8 hr resting (L)	3,600	2,900	2,300	1,300 (14 hr)	690 (23 hr)
24 hr (L)[a]	23,000	21,000	15,000	3,800	800

Source: ICRP74 (ICRP-23)

[a] Includes 16 hours light activity and 8 hours resting, except where noted.

Table 4.1. Relocation PAGs and Long-Term Objectives (Deposited Radioactive Material)

PAGs		
Protective Action	**PAG (P_R) (Projected 1st-Year Dose)**	**Comments**
Relocate the general population[a]	≥ 2,000 mrem[b] > 100,000 mrem beta skin dose	
Apply simple dose reduction techniques[c]	< 2,000 mrem[b]	These protective actions should be taken to reduce doses to as low as practicable levels.

Source: EPA92, Table 4-1

[a] Persons previously evacuated from areas outside the relocation zone defined by this PAG may return to occupy their residences. Cases involving relocation of persons at high risk from such action (*e.g.*, patients under intensive care) should be evaluated individually.

[b] The projected sum of effective dose equivalent from external gamma radiation and committed effective dose equivalent from inhalation of resuspended materials from exposure or intake during the first year. Projected dose refers to the dose that would be received in the absence of shielding from structures or the application of dose reduction techniques. These PAGs may not provide adequate protection from some long-lived radionuclides. Therefore, (1) doses in any single year after the first year will not exceed 0.5 rem and (2) the cumulative dose over 50 years (including the first and second years) will not exceed 5 rem.

[c] Simple dose reduction techniques include scrubbing and/or flushing hard surfaces, soaking or plowing soil, minor removal of soil from spots where radioactive materials have concentrated, and spending more time than usual indoors or in other low-exposure-rate areas. See Method M.4.4 to assess the effectiveness of decontamination techniques.

Long-Term Objectives	
Period	Objective
2nd year[a]	500 mrem[b]
50 years	5,000 mrem[b]

Source: EPA92, section 4.2.1

[a] Any single year after the first year.

[b] The projected sum of effective dose equivalent from external gamma radiation and committed effective dose equivalent from inhalation of resuspended materials.

Table 4.2. Relocation Dose Conversion Factors for Deposition (DCF_{Rgi})

Purpose: This table contains the DCFs for the 1st-year, 2nd-year, and 50-year periods of exposure to deposition. Decay and weathering (as far as it is included in the resuspension function) have been considered. The DCFs were calculated using the methods described in Volume 1. The DCF includes dose from external exposure and resuspension. The CEDE from inhalation has been estimated assuming resuspension factors as described in NCRP99. Chart 4.1 presents comparison plots of various resuspension models. Method M.4.2 can be used to calculate DCFs for nuclides not in this table or for different resuspension factors.

	DCF_{Rgi} [a]		
	1st-Year	**2nd-Year**	**50-Years**
Radionuclide *i*	$\frac{mrem}{\mu Ci/m^2}$		
^{3}H	NC	NC	NC
^{14}C	NC	NC	NC
^{22}Na	1.5×10^{2}	1.2×10^{2}	6.4×10^{2}
^{24}Na	7.3×10^{-1}	0.0	7.3×10^{-1}
^{32}P	1.5×10^{-2}	2.8×10^{-10}	1.5×10^{-2}
^{33}P	5.8×10^{-4}	1.8×10^{-8}	5.8×10^{-4}
^{35}S	7.6×10^{-4}	2.6×10^{-5}	7.9×10^{-4}
^{36}Cl	5.9×10^{-2}	5.5×10^{-2}	2.8
^{40}K	1.2×10^{1}	1.2×10^{1}	6.0×10^{2}
^{42}K	4.4×10^{-2}	0.0	4.4×10^{-2}
^{45}Ca	2.9×10^{-3}	4.2×10^{-4}	3.4×10^{-3}
^{46}Sc	5.0×10^{1}	2.4	5.2×10^{1}
^{44}Ti + ^{44}Sc	1.8×10^{2}	1.8×10^{2}	6.4×10^{3}
^{48}V	1.5×10^{1}	2.5×10^{-6}	1.5×10^{1}
^{51}Cr	2.8×10^{-1}	3.0×10^{-5}	2.8×10^{-1}
^{54}Mn	4.5×10^{1}	2.0×10^{1}	8.2×10^{1}
^{56}Mn	5.5×10^{-2}	0.0	5.5×10^{-2}
^{55}Fe	4.5×10^{-4}	3.8×10^{-5}	5.6×10^{-4}
^{58}Co	2.1×10^{1}	5.9×10^{-1}	2.2×10^{1}
^{59}Fe	1.6×10^{1}	5.5×10^{-2}	1.6×10^{1}
^{60}Co	1.8×10^{2}	1.6×10^{2}	1.5×10^{3}
^{63}Ni	1.1×10^{-3}	1.3×10^{-4}	3.9×10^{-3}
^{64}Cu	3.2×10^{-2}	0.0	3.2×10^{-2}
^{65}Zn	2.8×10^{1}	1.0×10^{1}	4.4×10^{1}

Table 4.2. Relocation Dose Conversion Factors for Deposition (DCF_{Rgi}) (continued)

Radionuclide *i*	DCF_{Rgi} [a]		
	1st-Year	2nd-Year	50-Years
	$\frac{mrem}{\mu Ci/m^2}$		
^{68}Ga	1.4×10^{-2}	0.0	1.4×10^{-2}
$^{68}Ge + ^{68}Ga$	5.1×10^{1}	2.1×10^{1}	8.8×10^{1}
^{75}Se	1.3×10^{1}	1.6	1.5×10^{1}
^{85}Kr	NC	NC	NC
^{85m}Kr	NC	NC	NC
^{87}Kr	NC	NC	NC
$^{88}Kr + ^{88}Rb$	NC	NC	NC
^{86}Rb	5.6×10^{-1}	7.3×10^{-7}	5.6×10^{-1}
^{87}Rb	7.8×10^{-3}	7.3×10^{-3}	3.6×10^{-1}
^{88}Rb	2.4×10^{-3}	0.0	2.4×10^{-3}
^{89}Sr[b]	4.1×10^{-2}	2.5×10^{-4}	4.2×10^{-2}
^{90}Sr[b]	2.5×10^{-1}	4.8×10^{-2}	1.3
^{91}Sr	8.7×10^{-2}	0.0	8.7×10^{-2}
^{90}Y[b]	4.8×10^{-3}	0.0	4.8×10^{-3}
^{91}Y[b]	1.1×10^{-1}	1.4×10^{-3}	1.1×10^{-1}
^{91m}Y	5.8×10^{-3}	0.0	5.8×10^{-3}
^{93}Zr	5.6×10^{-2}	6.6×10^{-3}	2.2×10^{-1}
^{95}Zr	1.5×10^{1}	2.8×10^{-1}	1.5×10^{1}
^{97}Zr	4.0×10^{-2}	0.0	4.0×10^{-2}
^{94}Nb	1.3×10^{2}	1.2×10^{2}	6.2×10^{3}
^{95}Nb	8.5	6.3×10^{-3}	8.5
$^{99}Mo + ^{99m}Tc$	2.2×10^{-1}	0.0	2.2×10^{-1}
^{99}Tc	7.8×10^{-3}	6.5×10^{-3}	3.2×10^{-1}
^{99m}Tc	9.8×10^{-3}	0.0	9.8×10^{-3}
^{103}Ru	5.9	9.3×10^{-3}	5.9
^{105}Ru	4.6×10^{-2}	0.0	4.6×10^{-2}
$^{106}Ru + ^{106}Rh$	1.3×10^{1}	6.3	2.5×10^{1}
^{105}Rh	3.6×10^{-2}	0.0	3.6×10^{-2}
^{106}Rh	NC	NC	NC
^{110m}Ag	1.4×10^{2}	4.9×10^{1}	2.1×10^{2}
$^{109}Cd + ^{109m}Ag$	2.0	1.2	4.8
^{113m}Cd	2.9×10^{-1}	4.9×10^{-2}	9.4×10^{-1}

Table 4.2. Relocation Dose Conversion Factors for Deposition (DCF_{Rgi}) (continued)

Radionuclide *i*	DCF_{Rgi}[a] 1st-Year	2nd-Year	50-Years
	$\frac{mrem}{\mu Ci/m^2}$		
^{114m}In	1.5	8.8×10^{-3}	1.5
^{113}Sn + ^{113m}In	9.1	1.0	1.0×10^{1}
^{123}Sn	3.0×10^{-1}	4.2×10^{-2}	3.5×10^{-1}
^{126}Sn + ^{126m}Sb	1.3×10^{2}	1.3×10^{2}	6.4×10^{3}
^{124}Sb	3.3×10^{1}	4.9×10^{-1}	3.3×10^{1}
^{126}Sb	1.1×10^{1}	1.5×10^{-8}	1.1×10^{1}
^{126m}Sb	6.5×10^{-3}	0.0	6.5×10^{-3}
^{127}Sb	8.4×10^{-1}	0.0	8.4×10^{-1}
^{129}Sb	8.0×10^{-2}	0.0	8.0×10^{-2}
^{127}Te	6.5×10^{-4}	0.0	6.5×10^{-4}
^{127m}Te	3.6×10^{-1}	3.5×10^{-2}	4.0×10^{-1}
^{129}Te	9.4×10^{-4}	0.0	9.4×10^{-4}
^{129m}Te	4.1×10^{-1}	2.2×10^{-4}	4.1×10^{-1}
^{131}Te	2.3×10^{-3}	0.0	2.3×10^{-3}
^{131m}Te	5.5×10^{-1}	0.0	5.5×10^{-1}
^{132}Te	2.4×10^{-1}	0.0	2.4×10^{-1}
^{125}I	8.2×10^{-1}	1.2×10^{-2}	8.3×10^{-1}
^{129}I	2.1	2.1	1.1×10^{2}
^{131}I	9.8×10^{-1}	2.1×10^{-14}	9.8×10^{-1}
^{132}I	6.8×10^{-2}	0.0	6.8×10^{-2}
^{133}I	1.7×10^{-1}	0.0	1.7×10^{-1}
^{134}I	3.0×10^{-2}	0.0	3.0×10^{-2}
^{135}I + ^{135m}Xe	1.7×10^{-1}	0.0	1.7×10^{-1}
^{131m}Xe	NC	NC	NC
^{133}Xe	NC	NC	NC
^{133m}Xe	NC	NC	NC
^{135}Xe	NC	NC	NC
^{135m}Xe	NC	NC	NC
^{138}Xe	NC	NC	NC
^{134}Cs	1.1×10^{2}	7.5×10^{1}	3.7×10^{2}
^{135}Cs	3.5×10^{-3}	2.8×10^{-3}	1.4×10^{-1}
^{136}Cs	8.8	3.6×10^{-8}	8.8

Table 4.2. Relocation Dose Conversion Factors for Deposition (DCF_{Rgi}) (continued)

Radionuclide *i*	DCF_{Rgi} [a] 1st-Year	2nd-Year	50-Years
	$\frac{mrem}{\mu Ci/m^2}$		
^{137}Cs + ^{137m}Ba	4.5×10^{1}	4.4×10^{1}	1.3×10^{3}
^{138}Cs	1.6×10^{-2}	0.0	1.6×10^{-2}
^{133}Ba	3.1×10^{1}	2.9×10^{1}	4.8×10^{2}
^{137m}Ba	NC	NC	NC
^{140}Ba	7.4×10^{-1}	1.8×10^{-9}	7.4×10^{-1}
^{140}La	1.2	0.0	1.2
^{141}Ce	7.7×10^{-1}	3.2×10^{-4}	7.8×10^{-1}
^{143}Ce	1.2×10^{-1}	0.0	1.2×10^{-1}
^{144}Ce + ^{144m}Pr + ^{144}Pr	3.2	1.3	5.4
^{143}Pr	3.7×10^{-3}	2.4×10^{-11}	3.7×10^{-3}
^{144}Pr	1.5×10^{-4}	0.0	1.5×10^{-4}
^{144m}Pr	NC	NC	NC
^{145}Pm	2.6	2.5	5.8×10^{1}
^{147}Nd	4.9×10^{-1}	4.8×10^{-11}	4.9×10^{-1}
^{147}Pm	9.0×10^{-3}	2.4×10^{-3}	1.9×10^{-2}
^{147}Sm	1.3×10^{1}	1.5	5.2×10^{1}
^{151}Sm	5.6×10^{-3}	1.0×10^{-3}	3.5×10^{-2}
^{152}Eu	8.8×10^{1}	8.3×10^{1}	1.6×10^{3}
^{154}Eu	9.4×10^{1}	8.6×10^{1}	1.2×10^{3}
^{155}Eu	4.5	3.9	3.4×10^{1}
^{153}Gd	5.4	1.9	8.3
^{160}Tb	2.4×10^{1}	7.4×10^{-1}	2.5×10^{1}
^{166m}Ho	1.4×10^{2}	1.4×10^{2}	6.8×10^{3}
^{170}Tm	2.1×10^{-1}	3.0×10^{-2}	2.5×10^{-1}
^{169}Yb	3.1	1.2×10^{-3}	3.1
^{172}Hf	7.8	5.3	2.5×10^{1}
^{181}Hf	7.5	1.9×10^{-2}	7.5
^{182}Ta	4.1×10^{1}	4.5	4.6×10^{1}
^{187}W	1.5×10^{-1}	0.0	1.5×10^{-1}
^{192}Ir	1.9×10^{1}	6.1×10^{-1}	1.9×10^{1}
^{198}Au	3.5×10^{-1}	0.0	3.5×10^{-1}
^{203}Hg	3.5	1.5×10^{-2}	3.5
^{204}Tl	1.1×10^{-1}	9.2×10^{-2}	6.6×10^{-1}

Table 4.2. Relocation Dose Conversion Factors for Deposition (DCF_{Rgi}) (continued)

Radionuclide *i*	DCF_{Rgi} [a] 1st-Year	2nd-Year	50-Years
	$\frac{mrem}{\mu Ci/m^2}$		
^{210}Pb	2.6	4.6×10^{-1}	1.1×10^{1}
^{207}Bi	1.2×10^{2}	1.2×10^{2}	4.0×10^{3}
^{210}Bi	1.1×10^{-2}	0.0	1.1×10^{-2}
^{210}Po	1.3	1.6×10^{-2}	1.3
^{226}Ra	2.0	7.0×10^{-1}	3.2×10^{1}
^{227}Ac	1.2×10^{3}	1.3×10^{2}	2.9×10^{3}
^{228}Ac	7.7×10^{-2}	0.0	7.7×10^{-2}
^{227}Th	1.9	9.0×10^{-7}	1.9
^{228}Th	5.6×10^{1}	4.3	6.6×10^{1}
^{230}Th	5.7×10^{1}	6.8	2.3×10^{2}
^{231}Th	6.4×10^{-3}	0.0	6.4×10^{-3}
^{232}Th	2.9×10^{2}	3.4×10^{1}	1.2×10^{3}
^{234}Th + ^{234m}Pa	2.2×10^{-1}	5.9×10^{-6}	2.2×10^{-1}
^{231}Pa	2.3×10^{2}	3.0×10^{1}	1.1×10^{3}
^{233}Pa	1.7	1.4×10^{-4}	1.7
^{232}U	1.1×10^{2}	1.3×10^{1}	3.9×10^{2}
^{233}U	2.4×10^{1}	2.8	9.8×10^{1}
^{234}U	2.3×10^{1}	2.8	9.6×10^{1}
^{235}U	3.4×10^{1}	1.5×10^{1}	6.9×10^{2}
^{236}U	2.2×10^{1}	2.6	9.1×10^{1}
^{238}U	2.1×10^{1}	2.5	8.5×10^{1}
^{234}U class D	2.3×10^{1}	2.8	9.6×10^{1}
U Depleted and Natural [c]	2.1×10^{1}	2.5	8.5×10^{1}
U Enriched [c]	2.3×10^{1}	2.8	9.6×10^{1}
^{237}Np	9.7×10^{1}	1.3×10^{1}	5.0×10^{2}
^{239}Np	1.2×10^{-1}	0.0	1.2×10^{-1}
^{236}Pu	2.4×10^{1}	2.2	3.1×10^{1}
^{238}Pu	6.8×10^{1}	8.0	2.4×10^{2}
^{239}Pu	7.5×10^{1}	8.9	3.0×10^{2}
^{240}Pu	7.5×10^{1}	8.9	3.0×10^{2}
^{241}Pu	1.4	1.6×10^{-1}	3.1
^{242}Pu	7.2×10^{1}	8.5	2.9×10^{2}

Table 4.2. Relocation Dose Conversion Factors for Deposition (DCF_{Rgi}) (continued)

Radionuclide *i*	DCF_{Rgi} [a]		
	1st-Year	**2nd-Year**	**50-Years**
	$\frac{mrem}{\mu Ci/m^2}$		
^{241}Am	8.0×10^{1}	1.1×10^{1}	4.1×10^{2}
^{242m}Am	7.4×10^{1}	8.9	2.9×10^{2}
^{243}Am	8.1×10^{1}	1.3×10^{1}	5.3×10^{2}
^{242}Cm	2.5	5.0×10^{-2}	2.5
^{243}Cm	6.3×10^{1}	1.6×10^{1}	4.4×10^{2}
^{244}Cm	4.3×10^{1}	4.9	1.0×10^{2}
^{245}Cm	8.6×10^{1}	1.6×10^{1}	6.7×10^{2}
^{252}Cf	2.6×10^{1}	2.3	3.3×10^{1}

NC=Not calculated.

[a] Dose includes external dose from ground shine and CEDE from resuspension. Ground shine dose factors are from EPA93 and are corrected for ground roughness. CEDE dose factors are from Federal Guidance Report No.11 (EPA88). Doses are calculated using Method M.4.2. Initial resuspension rate (1×10^{-6}) and the entire resuspension function are from NCRP99. The effects of weathering are included in the resuspension factors since they were derived from data measured following the Chernobyl incident. The resuspension function is presented in Chart 4.1.

[b] For strontium and yttrium, beta dose to the skin from resuspension may be critical. See Table 4.5.

[c] For natural and depleted uranium, it is assumed that all of the release is ^{238}U, and for enriched uranium, it is assumed that all of the release is ^{234}U. The activity of enriched uranium is dominated by the concentration of ^{234}U (because of its high SpA). Releases of natural and enriched uranium will be composed of a mixture of ^{234}U, ^{235}U, and ^{238}U. Information for specific uranium mixtures can be found in Volume 3, Section 5 (Nuclear Fuel Accident/Incident).

Table 4.3. Relocation Derived Response Levels for Deposition (DRL_{Rgi})

Purpose: This table contains the Relocation deposition DRLs (DRL_{Rgi}) for the 1st-year, 2nd-year, and 50-year periods of exposure to deposition. The Relocation deposition DRL expresses the Relocation PAG in terms of the level of deposition on the ground that corresponds to a projected dose equal to the PAG. Method M.4.2 can be used to calculate DRLs for other nuclides or for different assumptions.

Radionuclide *i*	**DRL_{Rgi}[a]** 1st-Year (μCi/m²)	2nd-Year	50-Years
	1st-Year	**2nd-Year**	**50-Years**
	μCi/m²		
^{3}H	NC	NC	NC
^{14}C	NC	NC	NC
^{22}Na	1.3×10^{1}	4.3	7.8
^{24}Na	2.7×10^{3}	None*	6.9×10^{3}
^{32}P	1.4×10^{5}	1.8×10^{12}	3.4×10^{5}
^{33}P	3.5×10^{6}	2.8×10^{10}	8.7×10^{6}
^{35}S	2.6×10^{6}	1.9×10^{7}	6.4×10^{6}
^{36}Cl	3.4×10^{4}	9.0×10^{3}	1.8×10^{3}
^{40}K	1.7×10^{2}	4.2×10^{1}	8.4
^{42}K	4.5×10^{4}	None	1.1×10^{5}
^{45}Ca	7.0×10^{5}	1.2×10^{6}	1.5×10^{6}
^{46}Sc	4.0×10^{1}	2.1×10^{2}	9.6×10^{1}
$^{44}Ti + ^{44}Sc$	1.1×10^{1}	2.8	7.8×10^{-1}
^{48}V	1.4×10^{2}	2.0×10^{8}	3.4×10^{2}
^{51}Cr	7.3×10^{3}	1.7×10^{7}	1.8×10^{4}
^{54}Mn	4.4×10^{1}	2.5×10^{1}	6.1×10^{1}
^{56}Mn	3.6×10^{4}	None	9.1×10^{4}
^{55}Fe	4.5×10^{6}	1.3×10^{7}	9.0×10^{6}
^{58}Co	9.5×10^{1}	8.4×10^{2}	2.3×10^{2}
^{59}Fe	1.2×10^{2}	9.1×10^{3}	3.1×10^{2}
^{60}Co	1.1×10^{1}	3.2	3.4
^{63}Ni	1.8×10^{6}	3.9×10^{6}	1.3×10^{6}
^{64}Cu	6.3×10^{4}	None	1.6×10^{5}
^{65}Zn	7.1×10^{1}	5.0×10^{1}	1.1×10^{2}
^{68}Ga	1.4×10^{5}	None	3.5×10^{5}
$^{68}Ge + ^{68}Ga$	3.9×10^{1}	2.4×10^{1}	5.7×10^{1}

*The DCF for the second year was zero, so there is no second-year DRL.

Table 4.3. Relocation Derived Response Levels for Deposition (DRL_{Rgi}) (continued)

Radionuclide *i*	DRL_{Rgi} [a]		
	1st-Year	2nd-Year	50-Years
	μCi/m²		
^{75}Se	1.6×10^{2}	3.2×10^{2}	3.4×10^{2}
^{85}Kr	NC	NC	NC
^{85m}Kr	NC	NC	NC
^{87}Kr	NC	NC	NC
^{88}Kr + ^{88}Rb	NC	NC	NC
^{86}Rb	3.6×10^{3}	6.9×10^{8}	8.9×10^{3}
^{87}Rb	2.6×10^{5}	6.9×10^{4}	1.4×10^{4}
^{88}Rb	8.4×10^{5}	None	2.1×10^{6}
^{89b}Sr	4.8×10^{4}	2.0×10^{6}	1.2×10^{5}
^{90b}Sr	8.1×10^{3}	1.0×10^{4}	3.8×10^{3}
^{91}Sr	2.3×10^{4}	None	5.8×10^{4}
^{90}Y[b]	4.1×10^{5}	None	1.0×10^{6}
^{91}Y [b]	1.8×10^{4}	3.5×10^{5}	4.4×10^{4}
^{91m}Y	3.4×10^{5}	None	8.6×10^{5}
^{93}Zr	3.6×10^{4}	7.6×10^{4}	2.2×10^{4}
^{95}Zr	1.4×10^{2}	1.8×10^{3}	3.3×10^{2}
^{97}Zr	5.1×10^{4}	None	1.3×10^{5}
^{94}Nb	1.6×10^{1}	4.0	8.0×10^{-1}
^{95}Nb	2.4×10^{2}	7.9×10^{4}	5.9×10^{2}
^{99}Mo + ^{99m}Tc	8.9×10^{3}	None	2.2×10^{4}
^{99}Tc	2.6×10^{5}	7.6×10^{4}	1.5×10^{4}
^{99m}Tc	2.0×10^{5}	None	5.1×10^{5}
^{103}Ru	3.4×10^{2}	5.3×10^{4}	8.5×10^{2}
^{105}Ru	4.4×10^{4}	None	1.1×10^{5}
^{106}Ru + ^{106}Rh	1.6×10^{2}	7.9×10^{1}	2.0×10^{2}
^{105}Rh	5.5×10^{4}	None	1.4×10^{5}
^{106}Rh	NC	NC	NC
^{110m}Ag	1.5×10^{1}	1.0×10^{1}	2.3×10^{1}
^{109}Cd + ^{109m}Ag	9.8×10^{2}	4.2×10^{2}	1.0×10^{3}
^{113m}Cd	7.0×10^{3}	1.0×10^{4}	5.3×10^{3}
^{114m}In	1.4×10^{3}	5.7×10^{4}	3.4×10^{3}
^{113}Sn + ^{113m}In	2.2×10^{2}	5.0×10^{2}	4.9×10^{2}
^{123}Sn	6.6×10^{3}	1.2×10^{4}	1.4×10^{4}
^{126}Sn + ^{126m}Sb	1.6×10^{1}	3.9	7.8×10^{-1}

Table 4.3. Relocation Derived Response Levels for Deposition (DRL_{Rgi}) (continued)

Radionuclide *i*	DRL_{Rgi} [a]		
	1st-Year	2nd-Year	50-Years
	μCi/m²		
^{124}Sb	6.1×10^{1}	1.0×10^{3}	1.5×10^{2}
^{126}Sb	1.8×10^{2}	3.3×10^{10}	4.5×10^{2}
^{126m}Sb	3.1×10^{5}	None	7.7×10^{5}
^{127}Sb	2.4×10^{3}	None	5.9×10^{3}
^{129}Sb	2.5×10^{4}	None	6.2×10^{4}
^{127}Te	3.1×10^{6}	None	7.7×10^{6}
^{127m}Te	5.5×10^{3}	1.4×10^{4}	1.2×10^{4}
^{129}Te	2.1×10^{6}	None	5.3×10^{6}
^{129m}Te	4.9×10^{3}	2.3×10^{6}	1.2×10^{4}
^{131}Te	8.7×10^{5}	None	2.2×10^{6}
^{131m}Te	3.6×10^{3}	None	9.0×10^{3}
^{132}Te	8.3×10^{3}	None	2.1×10^{4}
^{125}I	2.4×10^{3}	4.1×10^{4}	6.0×10^{3}
^{129}I	9.4×10^{2}	2.4×10^{2}	4.7×10^{1}
^{131}I	2.0×10^{3}	2.4×10^{16}	5.1×10^{3}
^{132}I	2.9×10^{4}	None	7.3×10^{4}
^{133}I	1.2×10^{4}	None	3.0×10^{4}
^{134}I	6.7×10^{4}	None	1.7×10^{5}
^{135}I + ^{135m}Xe	1.2×10^{4}	None	3.0×10^{4}
^{131m}Xe	NC	NC	NC
^{133}Xe	NC	NC	NC
^{133m}Xe	NC	NC	NC
^{135}Xe	NC	NC	NC
^{135m}Xe	NC	NC	NC
^{138}Xe	NC	NC	NC
^{134}Cs	1.9×10^{1}	6.6	1.4×10^{1}
^{135}Cs	5.7×10^{5}	1.8×10^{5}	3.6×10^{4}
^{136}Cs	2.3×10^{2}	1.4×10^{10}	5.7×10^{2}
^{137}Cs + ^{137m}Ba	4.5×10^{1}	1.1×10^{1}	3.7
^{138}Cs	1.3×10^{5}	None	3.2×10^{5}
^{133}Ba	6.4×10^{1}	1.7×10^{1}	1.0×10^{1}
^{137m}Ba	NC	NC	NC
^{140}Ba	2.7×10^{3}	2.8×10^{11}	6.8×10^{3}
^{140}La	1.7×10^{3}	None	4.3×10^{3}

Table 4.3. Relocation Derived Response Levels for Deposition (DRL_{Rgi}) (continued)

Radionuclide *i*	DRL_{Rgi} [a]		
	1st-Year	2nd-Year	50-Years
	μCi/m²		
^{141}Ce	2.6×10^{3}	1.6×10^{6}	6.4×10^{3}
^{143}Ce	1.6×10^{4}	None	4.0×10^{4}
$^{144}Ce + ^{144m}Pr + ^{144}Pr$	6.2×10^{2}	3.9×10^{2}	9.2×10^{2}
^{143}Pr	5.5×10^{5}	2.1×10^{13}	1.4×10^{6}
^{144}Pr	1.4×10^{7}	None	3.4×10^{7}
^{144m}Pr	NC	NC	NC
^{145}Pm	7.6×10^{2}	2.0×10^{2}	8.6×10^{1}
^{147}Nd	4.1×10^{3}	1.0×10^{13}	1.0×10^{4}
^{147}Pm	2.2×10^{5}	2.1×10^{5}	2.7×10^{5}
^{147}Sm	1.5×10^{2}	3.3×10^{2}	9.5×10^{1}
^{151}Sm	3.6×10^{5}	4.9×10^{5}	1.4×10^{5}
^{152}Eu	2.3×10^{1}	6.0	3.1
^{154}Eu	2.1×10^{1}	5.8	4.1
^{155}Eu	4.4×10^{2}	1.3×10^{2}	1.5×10^{2}
^{153}Gd	3.7×10^{2}	2.6×10^{2}	6.0×10^{2}
^{160}Tb	8.2×10^{1}	6.8×10^{2}	2.0×10^{2}
^{166m}Ho	1.4×10^{1}	3.6	7.3×10^{-1}
^{170}Tm	9.3×10^{3}	1.7×10^{4}	2.0×10^{4}
^{169}Yb	6.4×10^{2}	4.3×10^{5}	1.6×10^{3}
^{172}Hf	2.6×10^{2}	9.4×10^{1}	2.0×10^{2}
^{181}Hf	2.7×10^{2}	2.6×10^{4}	6.7×10^{2}
^{182}Ta	4.9×10^{1}	1.1×10^{2}	1.1×10^{2}
^{187}W	1.3×10^{4}	None	3.3×10^{4}
^{192}Ir	1.1×10^{2}	8.2×10^{2}	2.6×10^{2}
^{198}Au	5.7×10^{3}	None	1.4×10^{4}
^{203}Hg	5.8×10^{2}	3.3×10^{4}	1.4×10^{3}
^{204}Tl	1.8×10^{4}	5.4×10^{3}	7.6×10^{3}
^{210}Pb	7.8×10^{2}	1.1×10^{3}	4.5×10^{2}
^{207}Bi	1.7×10^{1}	4.3	1.3
^{210}Bi	1.9×10^{5}	None	4.7×10^{5}
^{210}Po	1.5×10^{3}	3.1×10^{4}	3.8×10^{3}
^{226}Ra	9.9×10^{2}	7.1×10^{2}	1.6×10^{2}
^{227}Ac	1.7	3.8	1.7

Table 4.3. Relocation Derived Response Levels for Deposition (DRL_{Rgi}) (continued)

Radionuclide *i*	DRL_{Rgi}[a]		
	1st-Year	2nd-Year	50-Years
	μCi/m²		
^{228}Ac	2.6×10^{4}	None	6.5×10^{4}
^{227}Th	1.0×10^{3}	5.6×10^{8}	2.6×10^{3}
^{228}Th	3.5×10^{1}	1.2×10^{2}	7.6×10^{1}
^{230}Th	3.5×10^{1}	7.4×10^{1}	2.2×10^{1}
^{231}Th	3.1×10^{5}	None	7.9×10^{5}
^{232}Th	7.0	1.5×10^{1}	4.3
^{234}Th + ^{234m}Pa	9.3×10^{3}	8.5×10^{7}	2.3×10^{4}
^{231}Pa	8.8	1.7×10^{1}	4.7
^{233}Pa	1.2×10^{3}	3.5×10^{6}	2.9×10^{3}
^{232}U	1.7×10^{1}	3.7×10^{1}	1.3×10^{1}
^{233}U	8.5×10^{1}	1.8×10^{2}	5.1×10^{1}
^{234}U	8.6×10^{1}	1.8×10^{2}	5.2×10^{1}
^{235}U	6.0×10^{1}	3.4×10^{1}	7.2
^{236}U	9.1×10^{1}	1.9×10^{2}	5.5×10^{1}
^{238}U	9.7×10^{1}	2.0×10^{2}	5.9×10^{1}
^{234}U class D	8.6×10^{1}	1.8×10^{2}	5.2×10^{1}
U Depleted and Natural[c]	9.7×10^{1}	2.0×10^{2}	5.9×10^{1}
U Enriched[c]	8.6×10^{1}	1.8×10^{2}	5.2×10^{1}
^{237}Np	2.1×10^{1}	3.7×10^{1}	1.0×10^{1}
^{239}Np	1.6×10^{4}	None	4.0×10^{4}
^{236}Pu	8.2×10^{1}	2.3×10^{2}	1.6×10^{2}
^{238}Pu	2.9×10^{1}	6.2×10^{1}	2.1×10^{1}
^{239}Pu	2.7×10^{1}	5.6×10^{1}	1.7×10^{1}
^{240}Pu	2.7×10^{1}	5.6×10^{1}	1.6×10^{1}
^{241}Pu	1.4×10^{3}	3.2×10^{3}	1.6×10^{3}
^{242}Pu	2.8×10^{1}	5.9×10^{1}	1.7×10^{1}
^{241}Am	2.5×10^{1}	4.4×10^{1}	1.2×10^{1}
^{242m}Am	2.7×10^{1}	5.6×10^{1}	1.8×10^{1}
^{243}Am	2.5×10^{1}	3.7×10^{1}	9.5
^{242}Cm	8.0×10^{2}	1.0×10^{4}	2.0×10^{3}
^{243}Cm	3.2×10^{1}	3.1×10^{1}	1.1×10^{1}
^{244}Cm	4.7×10^{1}	1.0×10^{2}	4.9×10^{1}
^{245}Cm	2.3×10^{1}	3.0×10^{1}	7.4

Table 4.3. Relocation Derived Response Levels for Deposition (DRL_{Rgi}) (continued)

Radionuclide *i*	**DRL_{Rgi} [a]** 1st-Year	2nd-Year	50-Years
	μCi/m²		
^{252}Cf	7.6×10^{1}	2.2×10^{2}	1.5×10^{2}

NC=Not calculated.

[a] DRLs are based on the DCFs in the previous table and are calculated using Method M.4.2.

[b] For strontium and yttrium, beta dose to the skin from resuspension may be critical. See Table 4.5.

[c] For natural and depleted uranium, it is assumed that all of the release is ^{238}U, and for enriched uranium, it is assumed that all of the release is ^{234}U. The activity of enriched uranium is dominated by the concentration of ^{234}U (because of its high SpA). While releases from natural and enriched uranium will be composed of a mixture of ^{234}U, ^{235}U, and ^{238}U, the dose factors of all these nuclides are all within 10 percent. Therefore, it is reasonable to use a single DRL. Information for specific uranium mixtures can be found in Volume 3, Section 5 (Nuclear Fuel Accident/Incident).

Table 4.4. Relocation Dose Conversion Factor for Inhalation of Resuspended Material

Purpose: This table provides committed effective dose equivalent for one year per unit air concentration. It is assumed that the air concentration is maintained by resuspension, and only decay is assumed to reduce the air concentration with time. This should be conservative after an accident because no reduction is assumed for weathering.

Nuclide *i*	**DCF_{Rai}[a]** (mrem)/(μCi/m³)
^{3}H (HTO)	9.8×10^{2}
^{14}C (Organic)	2.2×10^{4}
^{22}Na	7.1×10^{4}
^{24}Na	3.1×10^{1}
^{32}P	9.2×10^{3}
^{33}P	2.4×10^{3}
^{35}S	8.5×10^{3}
^{36}Cl	2.3×10^{5}
^{40}K	1.3×10^{5}
^{42}K	2.9×10^{1}
^{45}Ca	3.5×10^{4}
^{46}Sc	9.8×10^{4}
$^{44}Ti + ^{44}Sc$	1.1×10^{7}
^{48}V	6.9×10^{3}
^{51}Cr	3.8×10^{2}
^{54}Mn	4.8×10^{4}
^{56}Mn	1.7
^{55}Fe	2.5×10^{4}
^{58}Co	3.1×10^{4}
^{59}Fe	2.7×10^{4}
^{60}Co	2.2×10^{6}
^{63}Ni	6.6×10^{4}
^{64}Cu	6.1
^{65}Zn	1.3×10^{5}
^{68}Ga	2.7×10^{-1}
$^{68}Ge + ^{68}Ga$	3.6×10^{5}
^{75}Se	3.7×10^{4}
^{85}Kr	NC
^{85m}Kr	NC

Table 4.4. Relocation Dose Conversion Factor for Inhalation of Resuspended Material (continued)

Nuclide *I*	DCF_{Rai} [a] (mrem)/(μCi/m^3)
^{87}Kr	NC
^{88}Kr + ^{88}Rb	NC
^{86}Rb	5.1×10^{3}
^{87}Rb	3.4×10^{4}
^{88}Rb	4.3×10^{-2}
^{89}Sr	8.6×10^{4}
^{90}Sr	1.3×10^{7}
^{91}Sr	2.7×10^{1}
^{90}Y	9.3×10^{2}
^{91}Y	1.2×10^{5}
^{91m}Y	5.2×10^{-2}
^{93}Zr	3.4×10^{6}
^{95}Zr	6.2×10^{4}
^{97}Zr	1.3×10^{2}
^{94}Nb	4.4×10^{6}
^{95}Nb	8.5×10^{3}
^{99}Mo + ^{99m}Tc	4.5×10^{2}
^{99}Tc	8.8×10^{4}
^{99m}Tc	3.4×10^{-1}
^{103}Ru	1.5×10^{4}
^{105}Ru	3.5
^{106}Ru + ^{106}Rh	3.6×10^{6}
^{105}Rh	5.8×10^{1}
^{106}Rh	NC
^{110m}Ag	5.3×10^{5}
^{109}Cd + ^{109m}Ag	9.3×10^{5}
^{113m}Cd	1.6×10^{7}
^{114m}In	1.8×10^{5}
^{113}Sn + ^{113m}In	4.5×10^{4}
^{123}Sn	1.5×10^{5}
^{126}Sn + ^{126m}Sb	1.0×10^{6}
^{124}Sb	6.2×10^{4}
^{126}Sb	6.0×10^{3}
^{126m}Sb	1.9×10^{-2}
^{127}Sb	9.6×10^{2}

Table 4.4. Relocation Dose Conversion Factor for Inhalation of Resuspended Material (continued)

Nuclide *I*	DCF_{Rai} [a] (mrem)/(μCi/m^3)
^{129}Sb	4.8
^{127}Te	5.2
^{127m}Te	8.8×10^{4}
^{129}Te	1.8×10^{-1}
^{129m}Te	3.3×10^{4}
^{131}Te	3.4×10^{-1}
^{131m}Te	3.3×10^{2}
^{132}Te	1.3×10^{3}
^{125}I	5.9×10^{4}
^{129}I	1.8×10^{6}
^{131}I	1.1×10^{4}
^{132}I	1.5
^{133}I	2.1×10^{2}
^{134}I	2.0×10^{-1}
^{135}I + ^{135m}Xe	1.4×10^{1}
^{131m}Xe	NC
^{133}Xe	NC
^{133m}Xe	NC
^{135}Xe	NC
^{135m}Xe	NC
^{138}Xe	NC
^{134}Cs	4.1×10^{5}
^{135}Cs	4.8×10^{4}
^{136}Cs	4.0×10^{3}
^{137}Cs + ^{137m}Ba	3.3×10^{5}
^{138}Cs	9.4×10^{-2}
^{133}Ba	7.9×10^{4}
^{137m}Ba	NC
^{140}Ba	2.0×10^{3}
^{140}La	3.4×10^{2}
^{141}Ce	1.2×10^{4}
^{143}Ce	1.9×10^{2}
^{144}Ce + ^{144m}Pr + ^{144}Pr	2.6×10^{6}
^{143}Pr	4.6×10^{3}
^{144}Pr	2.2×10^{-2}
^{144m}Pr	NC

Table 4.4. Relocation Dose Conversion Factor for Inhalation of Resuspended Material (continued)

Nuclide *I*	DCF_{Rai}[a] (mrem)/(μCi/m^3)
^{145}Pm	3.1×10^{5}
^{147}Nd	3.1×10^{3}
^{147}Pm	3.6×10^{5}
^{147}Sm	7.9×10^{8}
^{151}Sm	3.1×10^{5}
^{152}Eu	2.3×10^{6}
^{154}Eu	2.9×10^{6}
^{155}Eu	4.1×10^{5}
^{153}Gd	1.6×10^{5}
^{160}Tb	7.3×10^{4}
^{166m}Ho	8.1×10^{6}
^{170}Tm	1.2×10^{5}
^{169}Yb	1.1×10^{4}
^{172}Hf	2.8×10^{6}
^{181}Hf	2.7×10^{4}
^{182}Ta	1.9×10^{5}
^{187}W	2.6×10^{1}
^{192}Ir	8.4×10^{4}
^{198}Au	3.7×10^{2}
^{203}Hg	1.4×10^{4}
^{204}Tl	2.3×10^{4}
^{210}Pb	1.4×10^{8}
^{207}Bi	2.1×10^{5}
^{210}Bi	4.1×10^{4}
^{210}Po	4.5×10^{7}
^{226}Ra	9.0×10^{7}
^{227}Ac	6.9×10^{10}
^{228}Ac	3.3×10^{3}
^{227}Th	1.3×10^{7}
^{228}Th	3.0×10^{9}
^{230}Th	3.4×10^{9}
^{231}Th	3.9×10^{1}
^{232}Th	1.7×10^{10}
^{234}Th + ^{234m}Pa	3.5×10^{4}
^{231}Pa	1.3×10^{10}

Table 4.4. Relocation Dose Conversion Factor for Inhalation of Resuspended Material (continued)

Nuclide *I*	DCF_{Rai}[a] (mrem)/(μCi/m³)
^{233}Pa	1.1×10^{4}
^{232}U	6.9×10^{9}
^{233}U	1.4×10^{9}
^{234}U	1.4×10^{9}
^{235}U	1.3×10^{9}
^{236}U	1.3×10^{9}
^{238}U	1.2×10^{9}
U Depleted	1.2×10^{9}
U Natural	1.2×10^{9}
U Enriched	1.4×10^{9}
^{234}U class D	2.9×10^{7}
^{237}Np	5.7×10^{9}
^{239}Np	2.5×10^{2}
^{236}Pu	1.4×10^{9}
^{238}Pu	4.1×10^{9}
^{239}Pu	4.5×10^{9}
^{240}Pu	4.5×10^{9}
^{241}Pu	8.5×10^{7}
^{242}Pu	4.3×10^{9}
^{241}Am	4.7×10^{9}
^{242m}Am	4.5×10^{9}
^{243}Am	4.6×10^{9}
^{242}Cm	9.2×10^{7}
^{243}Cm	3.2×10^{9}
^{244}Cm	2.6×10^{9}
^{245}Cm	4.8×10^{9}
^{252}Cf	1.5×10^{9}

NC=Not calculated.

[a] Calculated using the dose factors in Table 3.3 times the Intermediate Phase effective exposure period (see Table 4.6).

Table 4.5. Intermediate Phase Dose Conversion Factors for Skin Dose from Deposition

Purpose: This table provides the total dose to the skin from one-year exposure to deposition. This includes dose equivalent integrated for a one-year exposure at 1-meter height plus the estimated dose to the skin from material deposited on the skin as a result of resuspension (EPA92). These factors consider decay and weathering and should be conservative. The skin dose from resuspension is not considered critical for a reactor accident. Skin dose is projected based on deposition due to the difficulty in estimating skin dose based on other methods.

Nuclide *I*	**DCF_{skin} (1st yr) (mrem)/(μCi/m^2)**
^{58}Co	1.20×10^{-1}
^{60}Co	4.20×10^{-1}
^{86}Rb	6.30×10^{1}
^{89}Sr	1.50×10^{2}
^{90}Sr	1.20×10^{1}
^{90}Y	2.20×10^{2}
^{91}Y	1.60×10^{2}
^{95}Zr	7.20×10^{-1}
^{95}Nb	6.10×10^{-1}
^{99}Mo	4.40
^{99m}Tc	7.70×10^{-3}
^{103}Ru	6.80×10^{-1}
^{106}Ru + ^{106}Rh	6.40×10^{-1}
^{105}Rh	6.50×10^{-2}
^{127}Sb	3.40
^{127}Te	1.00
^{127m}Te	7.80×10^{-1}
^{129}Te	5.00×10^{-1}
^{129m}Te	3.40×10^{1}
^{131m}Te	2.90×10^{-1}
^{132}Te	5.40×10^{-3}
^{131}I	8.50×10^{-1}
^{132}I	5.00×10^{1}
^{134}Cs	2.60×10^{1}
^{136}Cs + ^{136}Ba	1.40×10^{-1}
^{137}Cs + ^{137m}Ba	2.10×10^{1}

Table 4.5. Intermediate Phase Dose Conversion Factors for Skin Dose from Deposition (continued)

Nuclide *i*	**DCF_{skin} (1st yr) (mrem)/(μCi/m^2)**
^{140}Ba	9.10
^{140}La	1.20×10^{1}
^{141}Ce	6.60×10^{-1}
^{143}Ce	2.30
^{144}Ce + ^{144}Pr	8.70×10^{-1}
^{143}Pr	1.30×10^{1}
^{147}Nd	4.30
^{239}Np	3.40×10^{-2}
^{238}Pu[a]	0.00
^{239}Pu[a]	0.00
^{240}Pu[a]	0.00
^{241}Pu[a]	0.00
^{241}Am	4.60×10^{-2}
^{242}Cm[a]	0.00
^{244}Cm[a]	0.00

Source: EPA92 (Table 7-5) multiplied by 1×10^6 to convert to mrem/μCi except where noted by "a." DCFs for the nuclides indicated by "a" are from EPA89 Table A.1.

Table 4.6. Intermediate Phase Effective Exposure Period (T_{IPeep})

Purpose: The effective exposure period multiplied by the exposure or dose rate will give the total dose during the exposure period when radioactive decay is considered. For the Intermediate Phase, the external exposure is for a period of 8,760 hours (1 year).

Radionuclide *I*	$T_{1/2}$ Half-Life (hr)	T_{IPeep} 1st Year Effective Exposure Period (Eff. hr) [b]	2nd Year Effective Exposure Period (Eff. hr) [c]	50-Year Effective Exposure Period (Eff. hr) [c]
^{3}H	1.1×10^{5}	8519	8054	146647
^{14}C	5.0×10^{7}	8759	8758	436678
^{22}Na	2.3×10^{4}	7690	5892	32884
^{24}Na	1.5×10^{1}	22	0	22
^{32}P	3.4×10^{2}	495	0	495
^{33}P	6.1×10^{2}	879	0	879
^{35}S	2.1×10^{3}	2860	158	3028
^{36}Cl	2.6×10^{9}	8760	8760	437975
^{40}K	1.1×10^{13}	8760	8760	438000
^{42}K	1.2×10^{1}	18	0	18
^{45}Ca	3.9×10^{3}	4448	942	5644
^{46}Sc	2.0×10^{3}	2761	135	2903
^{44}Ti + ^{44}Sc[a]	4.1×10^{5}	8696	8570	310484
^{48}V	3.9×10^{2}	562	0	562
^{51}Cr	6.6×10^{2}	959	0	959
^{54}Mn	7.5×10^{3}	6005	2672	10820
^{56}Mn	2.6	4	0	4
^{55}Fe	2.4×10^{4}	7726	5977	34123
^{58}Co	1.7×10^{3}	2383	67	2451
^{59}Fe	1.1×10^{3}	1537	5	1542
^{60}Co	4.6×10^{4}	8208	7197	66522
^{63}Ni	8.4×10^{5}	8728	8666	367652
^{64}Cu	1.3×10^{1}	18	0	18
^{65}Zn	5.9×10^{3}	5452	1932	8445
^{68}Ga	1.1	2	0	2
^{68}Ge + ^{68}Ga[a]	6.9×10^{3}	5829	2422	9972
^{75}Se	2.9×10^{3}	3646	441	4148

Table 4.6. Intermediate Phase Effective Exposure Period (T_{IPeep}) (continued)

	$T_{1/2}$	T_{IPeep} [b]	[c]	[c]
Radionuclide *i*	**Half-Life (hr)**	**1st Year Effective Exposure Period (Eff. hr)**	**2nd Year Effective Exposure Period (Eff. hr)**	**50-Year Effective Exposure Period (Eff. hr)**
^{85}Kr	9.4×10^{4}	8483	7952	130136
^{85m}Kr	4.5	6	0	6
^{87}Kr	1.3	2	0	2
$^{88}Kr + ^{88}Rb$[a]	2.8	4	0	4
^{86}Rb	4.5×10^{2}	646	0	646
^{87}Rb	4.1×10^{14}	8760	8760	438000
^{88}Rb	3.0×10^{-1}	0.4	0	0
^{89}Sr	1.2×10^{3}	1737	12	1749
^{90}Sr	2.6×10^{5}	8657	8453	256077
^{91}Sr	9.5	14	0	14
^{90}Y	6.4×10^{1}	92	0	92
^{91}Y	1.4×10^{3}	1999	26	2026
^{91m}Y	8.3×10^{-1}	1.2	0	1.2
^{93}Zr	1.3×10^{10}	8760	8760	437995
^{95}Zr	1.5×10^{3}	2173	42	2215
^{97}Zr	1.7×10^{1}	24	0	24
^{94}Nb	1.8×10^{8}	8760	8760	437626
^{95}Nb	8.4×10^{2}	1216	1	1217
$^{99}Mo + ^{99m}Tc$[a]	6.6×10^{1}	95	0	95
^{99}Tc	1.9×10^{9}	8760	8760	437964
^{99m}Tc	6.0	9	0	9
^{103}Ru	9.4×10^{2}	1358	2	1360
^{105}Ru	4.4	6	0	6
$^{106}Ru + ^{106}Rh$[a]	8.8×10^{3}	6336	3187	12749
^{105}Rh	3.5×10^{1}	51	0	51
^{106}Rh	8.3×10^{-3}	0.01	0	0.01
^{110m}Ag	6.0×10^{3}	5509	2002	8653
$^{109}Cd + ^{109m}Ag$[a]	1.1×10^{4}	6753	3914	16066
^{113m}Cd	1.2×10^{5}	8541	8116	158434
^{114m}In	1.2×10^{3}	1704	10	1714
$^{113}Sn + ^{113m}In$[a]	2.8×10^{3}	3543	393	3985
^{123}Sn	3.1×10^{3}	3842	542	4474

Table 4.6. Intermediate Phase Effective Exposure Period (T_{IPeep}) (continued)

	$T_{1/2}$	T_{IPeep} [b]	[c]	[c]
Radionuclide *i*	**Half-Life (hr)**	**1st Year Effective Exposure Period (Eff. hr)**	**2nd Year Effective Exposure Period (Eff. hr)**	**50-Year Effective Exposure Period (Eff. hr)**
$^{126}Sn + ^{126m}Sb$ [a]	8.8×10^{8}	8760	8760	437924
^{124}Sb	1.4×10^{3}	2053	31	2084
^{126}Sb	3.0×10^{2}	429	0	429
^{126m}Sb	3.2×10^{-1}	0.5	0	0.5
^{127}Sb	9.2×10^{1}	133	0	133
^{129}Sb	4.3	6	0	6
^{127}Te	9.4	13	0	13
^{127m}Te	2.6×10^{3}	3404	334	3774
^{129}Te	1.2	2	0	2
^{129m}Te	8.1×10^{2}	1163	0.6	1163
^{131}Te	4.2×10^{-1}	0.6	0	0.6
^{131m}Te	3.0×10^{1}	43	0	43
^{132}Te	7.8×10^{1}	113	0	113
^{125}I	1.4×10^{3}	2051	31	2082
^{129}I	1.4×10^{11}	8760	8760	438000
^{131}I	1.9×10^{2}	278	0	278
^{132}I	2.3	3	0	3
^{133}I	2.1×10^{1}	30	0	30
^{134}I	8.8×10^{-1}	1.3	0	1.3
$^{135}I + ^{135m}Xe$ [a]	6.6	10	0	10
^{131m}Xe	2.9×10^{2}	412	0	412
^{133}Xe	1.3×10^{2}	182	0	182
^{133m}Xe	5.3×10^{1}	76	0	76
^{135}Xe	9.1	13	0	13
^{135m}Xe	2.5×10^{-1}	0.4	0	0.4
^{138}Xe	2.4×10^{-1}	0.3	0	0.3
^{134}Cs	1.8×10^{4}	7440	5316	26060
^{135}Cs	2.0×10^{10}	8760	8760	437997
^{136}Cs	3.1×10^{2}	454	0	454
$^{137}Cs + ^{137m}Ba$ [a]	2.6×10^{5}	8660	8462	259719
^{138}Cs	5.4×10^{-1}	0.8	0	0.8
^{133}Ba	9.4×10^{4}	8483	7953	130347

Table 4.6. Intermediate Phase Effective Exposure Period (T_{IPeep}) (continued)

	$T_{1/2}$	T_{IPeep} [b]	[c]	[c]
Radionuclide *i*	**Half-Life (hr)**	**1st Year Effective Exposure Period (Eff. hr)**	**2nd Year Effective Exposure Period (Eff. hr)**	**50-Year Effective Exposure Period (Eff. hr)**
^{137m}Ba	4.3×10^{-2}	0.1	0	0.1
^{140}Ba	3.1×10^{2}	441	0	441
^{140}La	4.0×10^{1}	58	0	58
^{141}Ce	7.8×10^{2}	1125	0.5	1125
^{143}Ce	3.3×10^{1}	48	0	48
^{144}Ce + ^{144m}Pr + ^{144}Pr [a]	6.8×10^{3}	5801	2382	9844
^{143}Pr	3.3×10^{2}	470	0	470
^{144}Pr	2.9×10^{-1}	0.4	0	0.4
^{144m}Pr	1.2×10^{-1}	0.2	0	0.2
^{145}Pm	1.6×10^{5}	8591	8261	192122
^{147}Nd	2.6×10^{2}	380	0	380
^{147}Pm	2.3×10^{4}	7698	5911	33154
^{147}Sm	9.3×10^{14}	8760	8760	438000
^{151}Sm	7.9×10^{5}	8726	8659	363525
^{152}Eu	1.2×10^{5}	8536	8104	155952
^{154}Eu	7.7×10^{4}	8424	7786	109048
^{155}Eu	4.3×10^{4}	8175	7109	62627
^{153}Gd	5.8×10^{3}	5434	1910	8379
^{160}Tb	1.7×10^{3}	2428	73	2503
^{166m}Ho	1.1×10^{7}	8757	8752	431735
^{170}Tm	3.1×10^{3}	3830	536	4453
^{169}Yb	7.7×10^{2}	1108	0.4	1108
^{172}Hf	1.6×10^{4}	7320	5053	23633
^{181}Hf	1.0×10^{3}	1464	4	1468
^{182}Ta	2.8×10^{3}	3541	392	3982
^{187}W	2.4×10^{1}	34	0	34
^{192}Ir	1.8×10^{3}	2479	81	2563
^{198}Au	6.5×10^{1}	93	0	93
^{203}Hg	1.1×10^{3}	1606	7	1614
^{204}Tl	3.3×10^{4}	8004	6662	47754
^{210}Pb	2.0×10^{5}	8625	8361	222257
^{207}Bi	3.3×10^{5}	8681	8524	287327

Table 4.6. Intermediate Phase Effective Exposure Period (T_{IPeep}) (continued)

	$T_{1/2}$	T_{IPeep} [b]	[c]	[c]
Radionuclide *i*	**Half-Life (hr)**	**1st Year Effective Exposure Period (Eff. hr)**	**2nd Year Effective Exposure Period (Eff. hr)**	**50-Year Effective Exposure Period (Eff. hr)**
^{210}Bi	1.2×10^{2}	174	0	174
^{210}Po	3.3×10^{3}	4021	646	4791
^{226}Ra	1.4×10^{7}	8758	8754	433290
^{227}Ac	1.9×10^{5}	8622	8352	219152
^{228}Ac	6.1	9	0	9
^{227}Th	4.5×10^{2}	648	0.001	648
^{228}Th	1.7×10^{4}	7349	5115	24178
^{230}Th	6.7×10^{8}	8760	8760	437901
^{231}Th	2.6×10^{1}	37	0	37
^{232}Th	1.2×10^{14}	8760	8760	438000
^{231}Pa	2.9×10^{8}	8760	8760	437768
^{233}Pa	6.5×10^{2}	935	0.1	935
^{232}U	6.3×10^{5}	8718	8634	347644
^{233}U	1.4×10^{9}	8760	8760	437952
^{234}U	2.1×10^{9}	8760	8760	437969
^{235}U	6.2×10^{12}	8760	8760	438000
^{236}U	2.1×10^{11}	8760	8760	438000
^{238}U	3.9×10^{13}	8760	8760	438000
^{237}Np	1.9×10^{10}	8760	8760	437996
^{239}Np	5.7×10^{1}	82	0	82
^{236}Pu	2.5×10^{4}	7776	6098	36031
^{238}Pu	7.7×10^{5}	8725	8657	361843
^{239}Pu	2.1×10^{8}	8760	8760	437685
^{240}Pu	5.7×10^{7}	8760	8759	436841
^{241}Pu	1.3×10^{5}	8553	8151	165589
^{242}Pu	3.3×10^{9}	8760	8760	437980
^{241}Am	3.8×10^{6}	8753	8739	420899
^{242m}Am	1.3×10^{6}	8740	8700	391654
^{243}Am	6.5×10^{7}	8760	8759	436973
^{242}Cm	3.9×10^{3}	4445	940	5637
^{243}Cm	2.5×10^{5}	8654	8446	253425
^{244}Cm	1.6×10^{5}	8594	8272	195108

Table 4.6. Intermediate Phase Effective Exposure Period (T_{IPeep}) (continued)

	$T_{1/2}$	T_{IPeep} [b]	[c]	[c]
Radionuclide *i*	**Half-Life (hr)**	**1st Year Effective Exposure Period (Eff. hr)**	**2nd Year Effective Exposure Period (Eff. hr)**	**50-Year Effective Exposure Period (Eff. hr)**
^{245}Cm	7.4×10^7	8760	8759	437108
^{252}Cf	2.3×10^4	7704	5924	33339

[a] For nuclides with short-lived daughters (e.g., ^{137}Cs and ^{137m}Ba) that are expected to be in equilibrium, the effective period is based on the half-life of their parent.

[b] Intermediate Phase Effective exposure period is calculated as follows for the first year:

$$T_{IPeepi} = \int_0^{8760} e^{-\lambda t}\, dt$$
$$= \frac{1}{\lambda}\left(1 - e^{-\lambda \times 8760}\right),$$

Where

t = time in hours (8760 is the number of hours in one year) and

λ = radioactive decay constant ((ln 2)/$T_{1/2}$)

The first-year intermediate phase effective exposure period is 1 year (8760-hours) adjusted for radioactive decay.

[c] Calculations for the second year and for 50 years are similar, with the integration limits being changed to fit the calculation.

Table 5.1. Ingestion PAG

The ingestion PAG is expressed in terms of committed dose (to age 70) due to ingestion of contaminated food for one year.

PAG (rem)	Dose Quantity	Qualifier
0.5	CEDE	Whichever is more limiting
5	CDE to an individual tissue or organ	

Source: FDA98

Table 5.2. Ingestion DILs

Radionuclide Group	FDA DIL [a] (Bq/kg)	FDA DIL [a] (pCi/kg)
Principal Nuclides		
^{90}Sr	160	4300
^{131}I	170	4600
^{134}Cs + ^{137}Cs	1200	32000
^{238}Pu + ^{239}Pu + ^{241}Am	2	54
^{103}Ru + ^{106}Ru	(^{103}Ru/6800) + (^{106}Ru/450)<1	(^{103}Ru/180,000) + (^{106}Ru/12,000)<1
Secondary Nuclides		
^{89}Sr	1400	38000
^{91}Y	1200	32000
^{95}Zr	4000	110000
^{95}Nb	12000	320000
^{132}Te	4400	120000
^{129}I	56	1500
^{133}I	7000	190000
^{140}Ba	6900	190000
^{141}Ce	7200	190000
^{144}Ce	500	14000
^{237}Np	4	110
^{239}Np	28000	760000
^{241}Pu	120	3200
^{242}Cm	19	510
^{244}Cm	2	54

[a] A food sample is considered to exceed the DIL if it meets or exceeds the DIL for any individual nuclide. Analysis results are not summed across nuclides except for the combinations specifically stated (i.e., ^{134}Cs + ^{137}Cs, ^{238}Pu + ^{239}Pu + ^{241}Am, and ^{103}Ru + ^{106}Ru).

Table 5.3. Ingestion Protective Actions

Purpose: HHS has developed guidance (FDA98) on the protective actions that should be considered if the ingestion of contaminated food may result in doses that meet or exceed the PAG. This guidance is summarized below.

Simple Precautionary Actions Actions prior to declaration of Site Area Emergency or General Emergency	
All foods	Modest adjustment of normal operations prior to arrival of contamination (e.g., cover exposed products).
Animals	Move to shelter, corral livestock, provide protected feed and water.
Precautionary Action with Potential for Substantial Impact May be taken at declaration of General Emergency	
All foods	Apply a temporary embargo on products if prediction of off-site contamination is persuasive.
Actions to Salvage Contaminated Products Actions to eliminate contamination or reduce to acceptable levels.	
All foods	Isolate by temporary embargo until survey and initial sampling is completed. Determine whether condemnation or other disposition is appropriate.
Milk	Hold for decay or divert to other products involving adequate decay during processing (e.g., cheese, butter, dry milk solids, evaporated milk).
Fruits and Vegetables	Wash, brush, scrub or peel to remove surface contamination. Preserve by canning, freezing, dehydration, or storage to permit decay.
Grains	Process by milling and polishing to remove surface contamination.
Packaged food	Wash or vacuum to remove surface contamination.

Note: No actions are to be implemented that place personnel in jeopardy from an imminent release, or that may interfere with them taking shelter, or cause them to leave shelter during a release.

Table 5.4. Ingestion Deposition Derived Response Level

Purpose: The DRLs in this table represent the deposition level of a single radionuclide that would indicate that fresh produce or milk (from cows consuming contaminated fresh forage) produced in an area with this level of deposition may result in radioactivity concentrations in food equal to or greater than the FDA DILs. They were calculated using the method presented in the notes following the table. Method M.5.8 can be used to calculate DRLs for nuclides not listed or for different assumptions.

Radionuclide *i*	DRL_{Ingg} [a] Fresh Produce Deposition $\mu Ci/m^2$	DRL_{Ingg} [b] Grazing Cow Deposition Grass-Cow-Infant $\mu Ci/m^2$
Principal Nuclides		
^{90}Sr	4.3×10^{-2}	4.3×10^{-2}
^{131}I	9.2×10^{-3}	1.5×10^{-2}
^{134}Cs	3.2×10^{-1}	1.1×10^{-1}
^{137}Cs	3.2×10^{-1}	1.1×10^{-1}
^{238}Pu	5.4×10^{-4}	1.4
^{239}Pu	5.4×10^{-4}	1.4
^{241}Am	5.4×10^{-4}	1.0
^{103}Ru	1.8	1.6×10^{3}
^{106}Ru	1.2×10^{-1}	1.0×10^{2}
$^{134}Cs + ^{137}Cs$	3.2×10^{-1}	1.1×10^{-1}
$^{238}Pu + ^{239}Pu + ^{241}Am$	5.4×10^{-4}	1.4
$^{103}Ru + ^{106}Ru$	NC*	NC
Secondary Nuclides		
^{89}Sr	3.8×10^{-1}	3.9×10^{-1}
^{91}Y	3.2×10^{-1}	1.5×10^{1}
^{95}Zr	1.1	5.6×10^{3}
^{95}Nb	3.2	2.3×10^{4}
^{132}Te	1.2	1.1×10^{1}
^{129}I	1.5×10^{-2}	4.2×10^{-3}
^{133}I	1.9	2.6
^{140}Ba	1.9	1.2×10^{1}
^{141}Ce	2.0	1.9×10^{2}
^{144}Ce	1.4×10^{-1}	1.3×10^{1}
^{237}Np	1.1×10^{-3}	6.2×10^{-1}

NC = Not calculated.

Table 5.4. Ingestion Deposition Derived Response Level (Continued)

	DRL_{Ingg} [a]	DRL_{Ingg} [b]
Radionuclide *i*	**Fresh Produce Deposition µCi/m^2**	**Grazing Cow Deposition Grass-Cow-Infant µCi/m^2**
^{239}Np	7.6	7.6×10^{3}
^{241}Pu	3.2×10^{-2}	8.1×10^{1}
^{242}Cm	5.1×10^{-3}	7.2
^{244}Cm	5.4×10^{-4}	7.6×10^{-1}

[a] Produce.

$$DRL_{Ingg}\left(\mu Ci/m^2\right) = \frac{DIL\left(pCi/kg\right)\times Y\left(kg/m^2\right)\times CF}{r}$$

[b] DRL for the forage for grass-cow-infant pathway is calculated as described below. See Method M.5.8 for a further discussion of the calculation of deposition DRLS.

$$DRL_{Milk}\left(\mu Ci/m^2\right) = \frac{DIL\left(pCi/kg\right)\times Y\left(kg/m^2\right)\times \rho_{milk}\times CF}{U_{cow}\left(kg/d\right)\times r\times f_F\times f_m\left(d/L\right)}$$

Where

DIL (pCi/kg) = DIL for milk or food concentrations from Table 5.2.

Y(kg/m^2) = Productivity (2 kg/m^2 for produce; 0.7 kg/m^2 for pasture) (See Table 5.9).

r = Retention factor. This manual assumed 0.5 for pasture and 0.2 for produce (except for radioiodines, for which 1 was used) (see Table 5.9).

U_{COW} = Cow consumption (50 kg/day fresh) (See Table 5.9).

f_f = Fraction of cow's diet that is contaminated. This manual used one.

f_m*(d/L)* = Transfer factor for each radionuclide from Table 5.6.

CF = Conversion factor for units (as needed).

ρ_{milk} = Density of milk (1 kg/liter).

Table 5.5. Fresh-To-Dry-Weight Ratios for Various Food Crops and Forage (adapted from NRC83 Table 5.16)

Purpose: These fresh-to-dry weight ratios may be needed to adjust DRLs to fit the situation being assessed. For example, the DRLs in Tables 5.4 and 5.10 were calculated using fresh forage weight. If dry weights are provided then these ratios would be used to modify the DRLs.

Forage (fresh)

Alfalfa	4.4
Clover	5
Grass	5.5
Silage	4.2
Class	4.5

Forage (dry)

Alfalfa	1.1
Barley	1.1
Oat	1.1
Soybean	1.1
Wheat	1.1
Class	1.1

Grains

Barley	1.08
Rice	1.14
Wheat	1.15
Corn	3.8
Class	1.1

Root vegetables (+ tubers)

A	
Potato	4.5
Sweet potato	3.4
Yam	3.8
Class	4

B	
Beets	7.9
Carrots	8.5
Onions	8.6
Class	8.2

C	
Radishes	18
Turnips	11.8
Class	13

Leafy vegetables

A	
Asparagus	12
Cabbage	13
Cauliflower	12
Celery	16
Lettuce	20
Rhubarb	19
Spinach	12
Class	12.6

B	
Broccoli	9.1
Brussels sprouts	6.8
Kale	8
Spinach	10.8
Turnip greens	10
Class	8.5

Legumes

A (dry)	
Lima beans	3.1
Peas	5.9
Class	3.5

B (fresh)	
Green beans	10
Class	10

Table 5.5. Fresh-to-dry-weight ratios for various food crops and forage (adapted from NRC83 Table 5.16) (continued)

Nuts

Chestnuts	2.1
Peanuts	1.06
Class	1

Fruits

A	
Apples	6.7
Apricots	6.8
Bananas	4.1
Blackberries	6.4
Blueberries	6
Cherries	5.1
Figs	4.4
Pears	6
Pineapple	6.8
Plums	5.3
Raspberries	5.7
Class	5.7

B	
Cucumbers	20
Eggplant	13
Peppers	15
Pumpkin	11.9
Squash	16.7
Tomatoes	15
Class	NP

NP = Not provided

C	
Grapefruit	8.6
Oranges	7.1
Peaches	9.2
Strawberries	9.9
Class	8.3

Table 5.6. Cow-Transfer Factors (Milk Pathway)

Purpose: This table lists the transfer factor (f_m) for the milk pathway.

Radionuclide	Transfer Factor, f_m (μCi/L)/(μCi/d)	Radionuclide	Transfer Factor, f_m (μCi/L)/(μCi/d)	Radionuclide	Transfer Factor, f_m (μCi/L)/(μCi/d)
^{3}H	1.4×10^{-2}	^{86}Rb	1.2×10^{-2}	^{126m}Sb	2.5×10^{-5}
^{14}C	1.5×10^{-2}	^{87}Rb	1.2×10^{-2}	^{127}Sb	2.5×10^{-5}
^{22}Na	1.6×10^{-2}	^{88}Rb	1.2×10^{-2}	^{129}Sb	2.5×10^{-5}
^{24}Na	1.6×10^{-2}	^{89}Sr	2.8×10^{-3}	^{127}Te	4.5×10^{-4}
^{32}P	1.6×10^{-2}	^{90}Sr	2.8×10^{-3}	^{127m}Te	4.5×10^{-4}
^{33}P	1.6×10^{-2}	^{91}Sr	2.8×10^{-3}	^{129}Te	4.5×10^{-4}
^{35}S	1.6×10^{-2}	^{90}Y	6.0×10^{-5}	^{129m}Te	4.5×10^{-4}
^{36}Cl	1.7×10^{-2}	^{91}Y	6.0×10^{-5}	^{131}Te	4.5×10^{-4}
^{40}K	7.2×10^{-3}	^{91m}Y	6.0×10^{-5}	^{131m}Te	4.5×10^{-4}
^{42}K	7.2×10^{-3}	^{93}Zr	5.5×10^{-7}	^{132}Te	4.5×10^{-4}
^{45}Ca	3.0×10^{-3}	^{95}Zr	5.5×10^{-7}	^{125}I	1.0×10^{-2}
^{46}Sc	6.0×10^{-5}	^{97}Zr	5.5×10^{-7}	^{129}I	1.0×10^{-2}
^{44}Ti	1.0×10^{-2}	^{94}Nb	4.1×10^{-7}	^{131}I	1.0×10^{-2}
^{48}V	5.0×10-4	^{95}Nb	4.1×10^{-7}	^{132}I	1.0×10^{-2}
^{51}Cr	1.0×10^{-5}	^{99}Mo	1.7×10^{-3}	^{133}I	1.0×10^{-2}
^{54}Mn	3.0×10^{-5}	^{99}Tc	2.3×10^{-5}	^{134}I	1.0×10^{-2}
^{56}Mn	3.0×10^{-5}	^{99m}Tc	2.3×10^{-5}	^{135}I	1.0×10^{-2}
^{55}Fe	3.0×10^{-5}	^{103}Ru	3.3×10^{-6}	^{131m}Xe	0.0
^{58}Co	2.0×10^{-3}	^{105}Ru	3.3×10^{-6}	^{133}Xe	0.0
^{59}Fe	3.0×10^{-5}	^{106}Ru	3.3×10^{-6}	^{133m}Xe	0.0
^{60}Co	2.0×10^{-3}	^{105}Rh	5.0×10^{-4}	^{135}Xe	0.0
^{63}Ni	1.6×10^{-2}	^{106}Rh	5.0×10^{-4}	^{135m}Xe	0.0
^{64}Cu	2.0×10^{-3}	^{110m}Ag	5.0×10^{-5}	^{138}Xe	0.0
^{65}Zn	1.0×10^{-2}	^{109}Cd	2.0×10^{-3}	^{134}Cs	7.9×10^{-3}
^{68}Ga	1.0×10^{-5}	^{113m}Cd	2.0×10^{-3}	^{135}Cs	7.9×10^{-3}
^{68}Ge	1.0×10^{-2}	^{114m}In	2.0×10^{-4}	^{136}Cs	7.9×10^{-3}
^{75}Se	1.0×10^{-2}	^{113}Sn	1.0×10^{-3}	^{137}Cs	7.9×10^{-3}
^{85}Kr	0.0	^{123}Sn	1.0×10^{-3}	^{138}Cs	7.9×10^{-3}
^{85m}Kr	0.0	^{126}Sn	1.0×10^{-3}		
^{87}Kr	0.0	^{124}Sb	2.5×10^{-5}		
^{88}Kr	0.0	^{126}Sb	2.5×10^{-5}		

Table 5.6. Cow-Transfer Factors (Milk Pathway) (continued)

Radionuclide	Transfer Factor, f_m (µCi/L)/(µCi/d)
^{133}Ba	4.8×10^{-4}
^{137m}Ba	4.8×10^{-4}
^{140}Ba	4.8×10^{-4}
^{140}La	6.0×10^{-5}
^{141}Ce	3.0×10^{-5}
^{143}Ce	3.0×10^{-5}
^{144}Ce	3.0×10^{-5}
^{143}Pr	6.0×10^{-5}
^{144}Pr	6.0×10^{-5}
^{144m}Pr	6.0×10^{-5}
^{145}Pm	6.0×10^{-5}
^{147}Nd	6.0×10^{-5}
^{147}Pm	6.0×10^{-5}
^{147}Sm	6.0×10^{-5}
^{151}Sm	6.0×10^{-5}
^{152}Eu	6.0×10^{-5}
^{154}Eu	6.0×10^{-5}
^{155}Eu	6.0×10^{-5}
^{153}Gd	6.0×10^{-5}
^{160}Tb	6.0×10^{-5}
^{166m}Ho	6.0×10^{-5}
^{170}Tm	6.0×10^{-5}
^{169}Yb	6.0×10^{-5}

Radionuclide	Transfer Factor, f_m (µCi/L)/(µCi/d)
^{172}Hf	2.0×10^{-5}
^{181}Hf	2.0×10^{-5}
^{182}Ta	5.0×10^{-6}
^{187}W	3.0×10^{-4}
^{192}Ir	2.0×10^{-6}
^{198}Au	1.0×10^{-5}
^{203}Hg	4.7×10^{-4}
^{204}Tl	3.0×10^{-3}
^{210}Pb	3.0×10^{-4}
^{207}Bi	1.0×10^{-3}
^{210}Bi	1.0×10^{-3}
^{210}Po	3.4×10^{-4}
^{226}Ra	1.3×10^{-3}
^{227}Ac	2.0×10^{-6}
^{228}Ac	2.0×10^{-6}
^{227}Th	5.0×10^{-6}
^{228}Th	5.0×10^{-6}
^{230}Th	5.0×10^{-6}
^{231}Th	5.0×10^{-6}
^{232}Th	5.0×10^{-6}
^{231}Pa	5.0×10^{-6}
^{233}Pa	5.0×10^{-6}
^{232}U	4.0×10^{-4}

Radionuclide	Transfer Factor, f_m (µCi/L)/(µCi/d)
^{233}U	4.0×10^{-4}
^{234}U	4.0×10^{-4}
^{235}U	4.0×10^{-4}
^{236}U	4.0×10^{-4}
^{238}U	4.0×10^{-4}
^{237}Np	5.0×10^{-6}
^{239}Np	5.0×10^{-6}
^{236}Pu	1.1×10^{-6}
^{238}Pu	1.1×10^{-6}
^{239}Pu	1.1×10^{-6}
^{240}Pu	1.1×10^{-6}
^{241}Pu	1.1×10^{-6}
^{242}Pu	1.1×10^{-6}
^{241}Am	1.5×10^{-6}
^{242m}Am	1.5×10^{-6}
^{243}Am	1.5×10^{-6}
^{242}Cm	2.0×10^{-6}
^{243}Cm	2.0×10^{-6}
^{244}Cm	2.0×10^{-6}
^{245}Cm	2.0×10^{-6}
^{252}Cf	2.0×10^{-6}

Sources: IAEA94 Table XII
NCRP96 Table 5.2
NRC83 Table 5.36

Table 5.7. Human Consumption Rates (U_f)

Purpose: This table lists the average human consumption rates for populations of various ages in the United States. All values except the total annual intake are given in grams per day. The annual intake is given in kilograms per year.

Food Category	Daily Consumption (g/day)					
	3 months	1 year	5 years	10 years	15 years	Adult
Total Dairy	568.7	493.5	455.9	501.7	483.8	290.2
Fresh Cow's Milk	272.0	324.7	411.8	451.4	430.7	238.5
Other	296.7	168.9	44.2	50.3	53.1	51.7
Fresh Eggs	4.9	12.4	18.4	18.2	22.1	28.5
Total Meat	45.2	68.8	110.5	144.4	174.9	188.7
Beef	18.4	30.3	52.8	72.7	90.7	97.7
Pork	5.8	9.7	15.9	20.2	25.9	30.8
Poultry	18.4	18.7	21.9	27.4	31.5	33.2
Other	2.6	10.1	20.0	24.2	26.9	27.0
Total Fish	0.9	3.8	8.8	12.1	14.9	19.0
Fin Fish	0.6	3.5	8.2	11.0	13.2	16.0
Shellfish	0.3	0.3	0.6	1.1	1.7	3.0
Total Produce	155.0	159.7	194.9	244.2	264.5	285.5
Leafy	3.2	6.2	14.6	23.1	28.8	41.5
Exposed	75.5	65.6	62.4	73.0	74.4	82.8
Protected	50.8	72.7	111.7	140.3	154.2	154.7
Other	25.5	15.3	6.2	7.8	7.2	6.5
Total Grains	55.9	106.9	187.2	232.4	246.7	208.3
Breads	16.2	60.4	129.5	170.3	187.4	158.1
Cereals	37.9	38.2	39.0	38.0	32.6	25.5
Other	1.8	8.3	18.8	24.2	26.7	24.7
Total Beverages	305.3	524.1	802.3	944.4	1135.1	1530.6
Tap Water	170.7	302.7	477.8	570.6	642.5	679.2
Water-Based Drinks	8.3	53.1	107.2	128.3	170.8	472.5
Soups	10.1	27.0	40.2	36.0	35.1	44.4
Other	116.2	141.4	177.1	209.5	286.8	334.5
Miscellaneous	5.5	15.5	31.0	38.6	39.3	34.4
Total Daily Intake (g)	1141.4	1384.5	1808.9	2135.7	2381.1	2585.3
Total Annual Intake (kg)	418	506	660	779	869	943

Sources: EPA84
FDA98

Table 5.8. Ingestion Dose Conversion Factors (DCF_{Ing})

Purpose: Ingestion doses are calculated for a specific food using the food consumption data in Table 5.7 (unless locality-specific data are available) and the dose conversion factors in this table. Doses are calculated for the critical tissue and population (those receiving the highest dose) for each radionuclide being considered. For milk ingestion, the infant is generally used as the critical segment of the population. For other foods and water, the child (10 years old) is used. Considering ingestion rates and dose factors, the child was considered to be representative of the general population but conservative. This table lists the ingestion DCFs used in this manual, which are from ICRP-56 (ICRP89) where available, and NRPB-GS7 (NRPB87) for the other nuclides. The DCFs in the EPA Federal Report No. 11 (EPA88) were not used because they did not provide values for the needed populations. Method M.5.12 can be used to calculate DCFs for radionuclides not listed or to use different sources or assumptions.

Radionuclide *i*	Critical Organ[b]	Source[a]	DCF_{Ing} Child[c] (mrem/μCi)	Infant[d] (mrem/μCi)
^{3}H	All	1	7.04×10^{-2}	1.52×10-1
^{14}C	All	1	2.85	5.56
^{22}Na	Bone Surfaces	2	4.07×10^{1}	1.00×10^{2}
^{24}Na	Stomach	2	9.26	2.44×10^{1}
^{32}P	RBM	2	7.04×10^{1}	2.11×10^{2}
^{33}P			NC	NC
^{35}S	LLI	2	4.81	1.48×10^{1}
^{36}Cl	Stomach	2	9.63	2.89×10^{1}
^{40}K			NC	NC
^{42}K	Stomach	2	1.56×10^{1}	4.44×10^{1}
^{45}Ca	Bone Surfaces	2	4.44×10^{1}	1.26×10^{2}
^{46}Sc	LLI	2	8.15×10^{1}	2.11×10^{2}
^{44}Ti	LLI	2	3.11×10^{2}	8.89×10^{2}
^{48}V	LLI	2	1.04×10^{2}	2.67×10^{2}
^{51}Cr	LLI	2	2.56	7.04
^{54}Mn	LLI	2	1.48×10^{1}	3.19×10^{1}
^{56}Mn	ULI	2	1.15×10^{1}	3.30×10^{1}
^{55}Fe	Spleen	2	3.70	1.11×10^{1}
^{58}Co	LLI	2	5.19×10^{2}	1.19×10^{3}
^{59}Fe	LLI	2	6.67×10^{1}	3.11×10^{1}
^{60}Co	LLI	2	9.26×10^{1}	2.19×10^{2}
^{63}Ni	LLI	2	7.78	2.30×10^{1}

Table 5.8. Ingestion Dose Conversion Factors (DCF_{Ing}) (Continued)

Nuclide *i*	Critical Organ [b]	Source[a]	DCF_{Ing} Child [c] (mrem/μCi)	Infant (mrem/μCi)
^{64}Cu	LLI	2	6.30	1.85×10^{1}
^{65}Zn	LLI	2	3.19×10^{1}	6.67×10^{1}
^{68}Ga	Stomach	2	5.19	1.44×10^{1}
^{68}Ge	Kidney	2	5.93	1.74×10^{1}
^{75}Se	Kidney	2	5.19×10^{1}	1.22×10^{2}
^{85}Kr			NC	NC
^{85m}Kr			NC	NC
^{87}Kr			NC	NC
^{88}Kr			NC	NC
^{86}Rb	Bone Surfaces	2	5.93×10^{1}	1.74×10^{2}
^{87}Rb	Bone Surfaces	2	3.22×10^{1}	9.63×10^{1}
^{88}Rb	Stomach	2	6.30	1.89×10^{1}
^{89}Sr	LLI	2	2.52×10^{2}	7.41×10^{2}
^{90}Sr	Bone Surfaces	1	2.04×10^{3}	2.74×10^{3}
^{91}Sr	LLI	2	4.44×10^{1}	8.89×10^{1}
^{90}Y	LLI	2	2.74×10^{2}	8.15×10^{2}
^{91}Y	LLI	2	2.63×10^{2}	7.78×10^{2}
^{91m}Y	Stomach	2	3.59×10^{-1}	8.89×10^{-1}
^{93}Zr	Bone Surfaces	2	4.07×10^{1}	6.67×10^{1}
^{95}Zr	LLI Walls	1	5.93×10^{1}	1.93×10^{2}
^{94}Nb	Bone Surfaces	2	2.78×10^{2}	7.41×10^{2}
^{95}Nb	LLI Walls	1	3.00×10^{1}	8.89×10^{1}
^{99}Mo	LLI	2	1.19×10^{2}	3.48×10^{2}
^{99}Tc	Stomach	2	2.96×10^{1}	8.89×10^{1}
^{99m}Tc	Thyroid	2	7.04×10^{-1}	2.00
^{103}Ru	LLI Walls	1	5.19×10^{1}	1.67×10^{2}
^{105}Ru	ULI	2	1.33×10^{1}	3.70×10^{1}
^{106}Rh	LLI Walls	1	5.56×10^{2}	1.93×10^{3}
^{106}Ru	LLI	2	6.30×10^{2}	1.81×10^{3}
^{110m}Ag	LLI	2	7.78×10^{1}	1.96×10^{2}
^{109}Cd	Kidney	2	2.89×10^{2}	8.52×10^{2}
^{113m}Cd	Kidney	2	2.67×10^{3}	6.30×10^{3}
^{114m}In	LLI	2	3.70×10^{2}	1.11×10^{3}
^{113}Sn	LLI	2	6.67×10^{1}	1.96×10^{2}

Table 5.8. Ingestion Dose Conversion Factors (DCF_{Ing}) (Continued)

Nuclide *i*	Critical Organ [b]	Source[a]	DCF_{Ing} Child [c] (mrem/μCi)	Infant (mrem/μCi)
^{123}Sn	LLI	2	2.26×10^{2}	6.67×10^{2}
^{126}Sn	LLI	2	3.67×10^{2}	1.07×10^{3}
^{124}Sb	LLI	2	1.93×10^{2}	5.56×10^{2}
^{126}Sb			NC	NC
^{126m}Sb			NC	NC
^{127}Sb	LLI	2	1.67×10^{2}	4.81×10^{2}
^{129}Sb	ULI	2	2.78×10^{1}	7.41×10^{1}
^{127}Te	LLI	2	1.07×10^{1}	3.22×10^{1}
^{127m}Te	Bone Surfaces	2	1.74×10^{2}	5.19×10^{2}
^{129}Te	Stomach	2	3.44	1.04×10^{1}
^{129m}Te	LLI	2	2.15×10^{2}	6.30×10^{2}
^{131}Te	Thyroid	2	9.26	2.81×10^{1}
^{131m}Te	Thyroid	2	1.48×10^{2}	4.44×10^{2}
^{132}Te	Thyroid	2	2.22×10^{2}	8.15×10^{2}
^{125}I	Thyroid	2	2.81×10^{3}	4.81×10^{3}
^{129}I	Thyroid	1	1.41×10^{4}	1.59×10^{4}
^{131}I	Thyroid	1	4.07×10^{3}	1.33×10^{4}
^{132}I	Thyroid	1	3.15×10^{1}	1.33×10^{2}
^{133}I	Thyroid	2	8.52×10^{2}	3.19×10^{3}
^{134}I	Thyroid	2	5.56	2.07×10^{1}
^{135}I	Thyroid	2	1.63×10^{2}	5.93×10^{2}
^{131m}Xe			NC	NC
^{133}Xe			NC	NC
^{133m}Xe			NC	NC
^{135}Xe			NC	NC
^{135m}Xe			NC	NC
^{138}Xe			NC	NC
^{134}Cs	Pancreas	1	5.93×10^{1}	6.30×10^{1}
^{135}Cs	Stomach	2	7.78	1.11×10^{1}
^{136}Cs	Uterus	2	2.15×10^{1}	3.70×10^{1}
^{137}Cs	Stomach Wall	1	3.70×10^{1}	4.44×10^{1}
^{138}Cs	Stomach	2	5.93	1.70×10^{1}
^{133}Ba	LLI	2	3.04×10^{1}	8.15×10^{1}
^{137m}Ba			NC	NC

Table 5.8. Ingestion Dose Conversion Factors (DCF_{Ing}) (Continued)

Nuclide *i*	Critical Organ [b]	Source[a]	DCF_{Ing} Child [c] (mrem/μCi)	Infant (mrem/μCi)
^{140}Ba	LLI	2	2.22×10^{2}	6.67×10^{2}
^{140}La	LLI	2	1.44×10^{2}	4.07×10^{2}
^{141}Ce	LLI	2	7.41×10^{1}	5.93×10^{1}
^{144}Ce	LLI Walls	1	5.56×10^{2}	1.84×10^{3}
^{144}Pr	Stomach	2	3.56	1.07×10^{1}
^{144m}Pr			NC	NC
^{145}Pm			NC	NC
^{147}Pm			NC	NC
^{147}Sm	Bone Surfaces	2	4.07×10^{3}	9.26×10^{3}
^{151}Sm	LLI	2	8.89	2.63×10^{1}
^{152}Eu	LLI	2	8.15×10^{1}	2.22×10^{2}
^{154}Eu	LLI	2	1.48×10^{2}	4.44×10^{2}
^{155}Eu	LLI	2	2.96×10^{1}	8.52×10^{1}
^{153}Gd	LLI	2	2.22×10^{1}	6.30×10^{1}
^{160}Tb			NC	NC
^{166m}Ho			NC	NC
^{170}Tm	LLI	2	1.44×10^{2}	4.44×10^{2}
^{169}Yb	LLI	2	5.93×10^{1}	1.74×10^{2}
^{172}Hf			NC	NC
^{181}Hf	LLI	2	9.63×10^{1}	2.81×10^{2}
^{182}Ta	LLI	2	1.15×10^{2}	3.26×10^{2}
^{187}W	LLI	2	5.56×10^{1}	1.59×10^{2}
^{192}Ir	LLI	2	1.07×10^{2}	3.11×10^{2}
^{198}Au	LLI	2	9.26×10^{1}	2.67×10^{2}
^{203}Hg	Kidney	2	1.52×10^{2}	4.44×10^{2}
^{204}Tl	Kidney	2	4.07×10^{1}	1.19×10^{2}
^{210}Pb	Bone Surfaces	2	1.00×10^{5}	2.07×10^{5}
^{207}Bi	LLI	2	7.41×10^{1}	1.96×10^{2}
^{210}Bi	LLI	2	1.33×10^{2}	4.07×10^{2}
^{210}Po	Spleen	2	3.67×10^{4}	1.11×10^{5}
^{226}Ra	Bone Surfaces	2	3.33×10^{4}	7.41×10^{4}
^{227}Ac	Bone Surfaces	2	3.04×10^{5}	5.93×10^{5}
^{228}Ac	ULI	2	2.04×10^{1}	5.93×10^{1}
^{227}Th	LLI	2	7.78×10^{2}	2.33×10^{3}

Table 5.8. Ingestion Dose Conversion Factors (DCF_{Ing}) (Continued)

Nuclide *i*	Critical Organ [b]	Source[a]	DCF_{Ing} Child [c] (mrem/μCi)	DCF_{Ing} Infant (mrem/μCi)
^{228}Th	Bone Surfaces	2	1.59×10^{4}	4.81×10^{4}
^{230}Th	Bone Surfaces	2	1.63×10^{4}	3.00×10^{4}
^{231}Th	LLI	2	2.93×10^{1}	8.89×10^{1}
^{232}Th	Bone Surfaces	2	7.78×10^{4}	1.15×10^{5}
^{234}Th	LLI	2	3.70×10^{2}	1.11×10^{3}
^{231}Pa	Bone Surfaces	2	3.44×10^{5}	4.81×10^{5}
^{233}Pa	LLI	2	8.89×10^{1}	2.59×10^{2}
U Depleted	Bone Surfaces	2	4.81×10^{3}	1.00×10^{4}
U Natural	Bone Surfaces	2	4.81×10^{3}	1.00×10^{4}
U Enriched (4%)	Bone Surfaces	2	5.19×10^{3}	1.15×10^{4}
^{232}U	Bone Surfaces	2	2.89×10^{4}	5.56×10^{4}
^{233}U	Bone Surfaces	2	5.56×10^{3}	1.15×10^{4}
^{234}U	Bone Surfaces	2	5.19×10^{3}	1.15×10^{4}
^{235}U	Bone Surfaces	2	4.81×10^{3}	1.04×10^{4}
^{236}U	Bone Surfaces	2	5.19×10^{3}	1.07×10^{4}
^{238}U	Bone Surfaces	2	4.81×10^{3}	1.00×10^{4}
^{237}Np	Bone Surfaces	1	3.67×10^{4}	3.30×10^{4}
^{239}Np	LLI Wall	1	7.04×10^{1}	2.37×10^{2}
^{236}Pu	Bone Surfaces	2	1.74×10^{4}	4.44×10^{4}
^{238}Pu	Bone Surfaces	2	7.04×10^{4}	1.26×10^{5}
^{239}Pu	Bone Surfaces	2	8.15×10^{4}	1.37×10^{5}
^{240}Pu	Bone Surfaces	2	8.15×10^{4}	1.37×10^{5}
^{241}Pu	Bone Surfaces	1	1.37×10^{3}	1.26×10^{3}
^{242}Pu	Bone Surfaces	2	7.78×10^{4}	1.30×10^{5}
^{241}Am	Bone Surfaces	1	7.04×10^{4}	7.04×10^{4}
^{242m}Am	Bone Surfaces	2	7.78×10^{4}	1.30×10^{5}
^{243}Am	Bone Surfaces	2	8.15×10^{4}	1.41×10^{5}
^{242}Cm	Bone Surfaces	2	3.30×10^{3}	9.63×10^{3}
^{243}Cm	Bone Surfaces	2	5.56×10^{4}	1.07×10^{5}
^{244}Cm	Bone Surfaces	2	4.44×10^{4}	9.26×10^{4}
^{245}Cm	Bone Surfaces	2	8.52×10^{4}	1.44×10^{5}
^{252}Cf	Bone Surfaces	2	1.81×10^{4}	5.19×10^{4}

NC=Not calculated.

Table 5.8. Ingestion Dose Conversion Factors (DCF_{Ing}) (Continued)

			DCF_{Ing}	
Nuclide *i*	**Critical Organ** [b]	**Source**[a]	**Child** [c] **(mrem/μCi)**	**Infant (mrem/μCi)**

[a] Source: (1) ICRP89
(2) NRPB87

[b] Organ with highest dose from ingestion.
Gastrointestinal (GI) Tract
LLI: Lower Large Intestine
ULI: Upper Large Intestine

[c] The child was used because it was representative of the population considering the range of consumption rates and dose factors.

To convert from Sv/Bq to mrem/μCi, use the following equation:

$$1\frac{Sv}{Bq} \times \frac{1.0E+05\ mrem}{Sv} \times \frac{Bq}{2.7E-05\ \mu Ci} = \frac{3.75+09\ mrem}{\mu Ci}$$

Table 5.9. Retention, Productivity, Cow Consumption Factors

Parameter	Description	Value
U_{cow}	Cow fresh forage consumption (milk cow)	50 kg/d [a]
	Cow fresh forage consumption (beef cattle)	50 kg/d [a]
	Cow water consumption (milk cow)	60 L/d [a,b]
	Cow water consumption (beef cattle)	50 L/d [a]
U_{goat}	Goat fresh forage consumption	6 kg/d [a]
	Goat water consumption	8 L/d [a]
R	Pasture retention factor	0.5 [c,d]
	Fresh produce retention factor, particulates	0.20 [a]
	Fresh produce retention factor, iodines	1.0 [a]
Y	Growth productivity (produce or leafy vegetables)	2.0 kg/m^2 [a]
	Growth productivity (pasture grass)	0.7 kg/m^2 [a]
UAF	Utilized Area Factor (area effectively foraged by a cow)	45 m^2/day [d,e]

[a] NRC77 (Tables E-3 and E-15) and USNRC Regulatory Guide 1.109

[b] NCRP84 (Table 2-12)

[c] Ng77 (Appendix B, page 113)

[d] FEMA87 (Appendix D)

[e] NRC83 (Table 5.35)

Table 5.10. Fresh Cow Forage and Water Concentration Derived Response Levels

Purpose: This table shows the concentration of a single radionuclide in cow's fresh forage or drinking water that could result in concentrations in milk that meet or exceed the FDA DIL. The calculation of these values assumes that 100 percent of the cow's food or water is contaminated. This is for fresh weight. To estimate fresh weight, multiply dry weight by the appropriate factor from Table 5.5. Method M.5.7 can be used to calculate DRLs for nuclides not listed or for different assumptions.

Radionuclide *i*	**$DRL_{Ing,Cow}$ [a] Cow Forage Concentration (µCi/kg)**	**$DRL_{Ing,Cow}$ [b] Cow Water Concentration (µCi/L)**
^{90}Sr	3.1×10^{-2}	2.6×10^{-2}
^{131}I	9.2×10^{-3}	7.7×10^{-3}
^{134}Cs	8.1×10^{-2}	6.8×10^{-2}
^{137}Cs	8.1×10^{-2}	6.8×10^{-2}
^{238}Pu	9.8×10^{-1}	8.2×10^{-1}
^{239}Pu	9.8×10^{-1}	8.2×10^{-1}
^{241}Am	7.2×10^{-1}	6.0×10^{-1}
^{103}Ru	1.1×10^{3}	9.1×10^{2}
^{106}Ru	7.3×10^{1}	6.1×10^{1}
FDA predefined groups	[c]	[c]
^{89}Sr	2.7×10^{-1}	2.3×10^{-1}
^{91}Y	1.1×10^{1}	8.9
^{95}Zr	3.9×10^{3}	3.3×10^{3}
^{95}Nb	1.6×10^{4}	1.3×10^{4}
^{132}Te	5.3	4.4
^{129}I	3.0×10^{-3}	2.5×10^{-3}
^{133}I	3.8×10^{-1}	3.2×10^{-1}
^{140}Ba	7.8	6.5
^{141}Ce	1.3×10^{2}	1.1×10^{2}
^{144}Ce	9.3	7.8
^{237}Np	4.4×10^{-1}	3.7×10^{-1}
^{239}Np	3.0×10^{3}	2.5×10^{3}
^{241}Pu	5.8×10^{1}	4.8×10^{1}
^{242}Cm	5.1	4.3
^{244}Cm	5.4×10^{-1}	4.5×10^{-1}

a, b $$DRL = \frac{DIL\ (Table\ 5.2)}{f_m\,(Table\ 5.6)\times U_{Cow}\ (Table\ 5.9)}$$

See Method M.5.7 for a full discussion on calculating these DRLs.

c No values are given for the predefined groups since this is for individual nuclides

This page intentionally left blank.

APPENDIX B. CHARTS

This page intentionally left blank.

Chart 4.1. Resuspension Factors as a Function of Time

The default resuspension factors used by this Manual are those recommended in NCRP 129 (NCRP99), unless otherwise noted. These time-dependent values are represented by the solid squares (red line) in the chart below. This chart shows wind-driven resuspension factors as a function of time assuming cautious weathering factors.

For comparison purposes, resuspension factors for arid conditions (initial Rest= 1.04×10^{-4}) used at the Nevada Test Site (from Anspaugh, AN75) and the models presented by Garland and Pomeroy (Ga94), and IAEA Safety Series No.81 (IAEA 86) are also presented on this chart. The enclosed box indicates the area covered by curves to fit the resuspension data measured in Europe following the Chernobyl accident (GA94). The resuspension factors used in this Manual are consistent with the other recommendation and actual data.

Prior to using such default resuspension factors, the analyst must judge how appropriate those default factors are for the specific incident site. On arriving at the site, the analyst should consider whether the default resuspension factors should be revised upward to reflect arid or windy conditions. As soon as possible the recommended default resuspension factors should be confirmed (or revised as necessary) based on site-specific measurements.

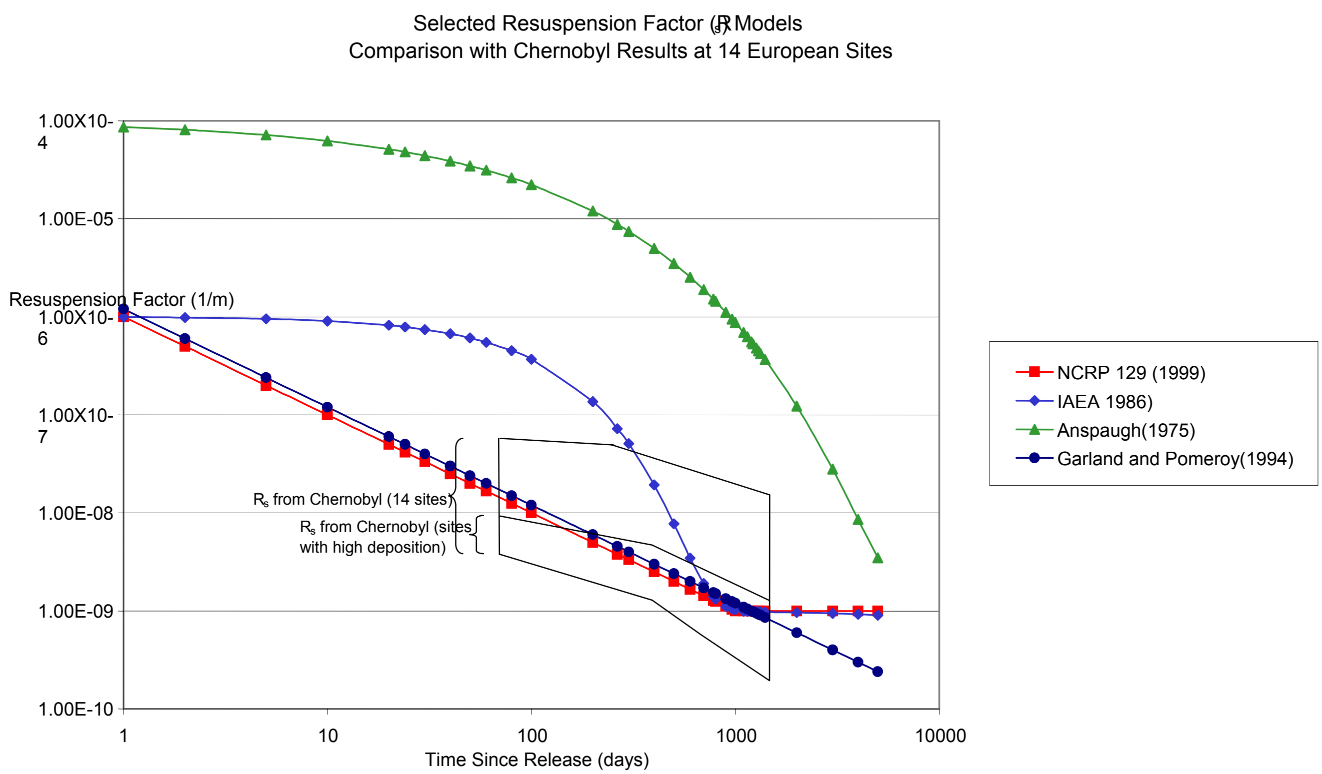
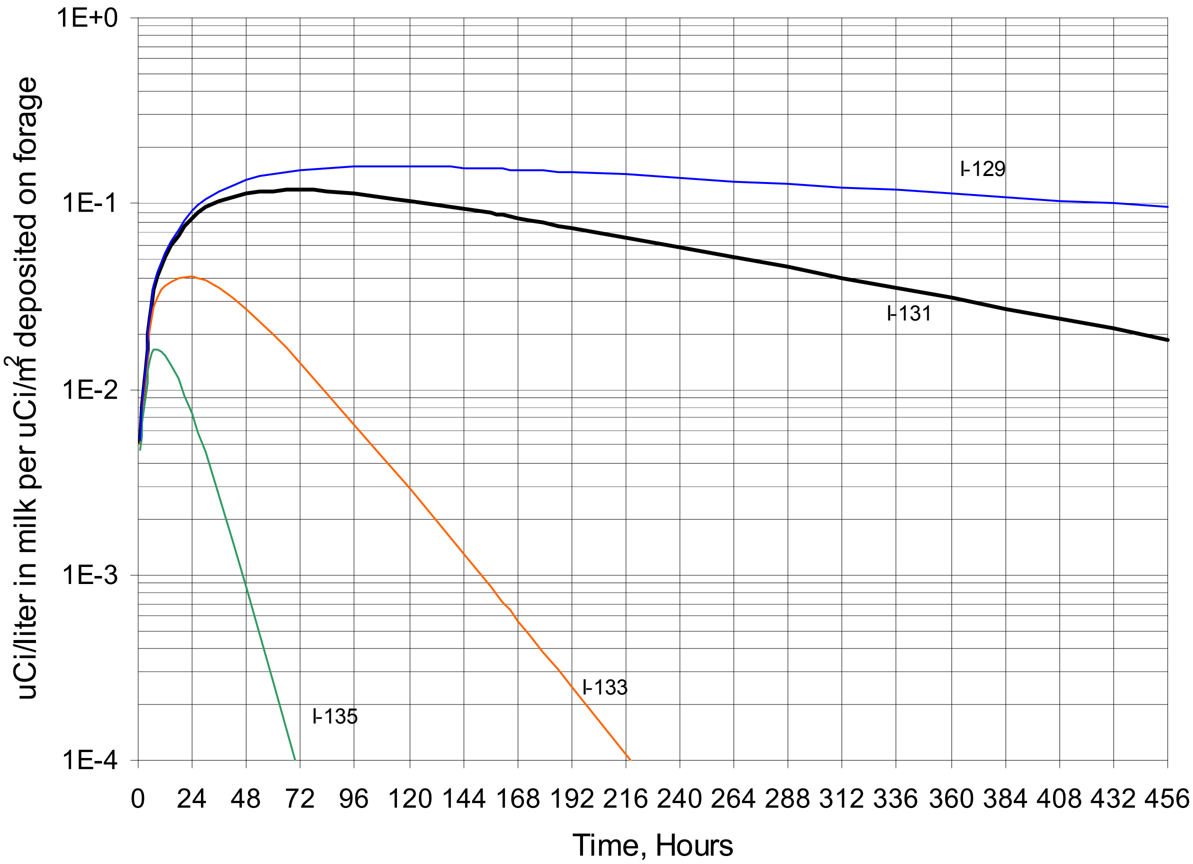


Chart 5.1. Cow-Iodine-Milk Concentrations—Time after Deposition
(^{129}I, ^{131}I, ^{133}I, and ^{135}I)

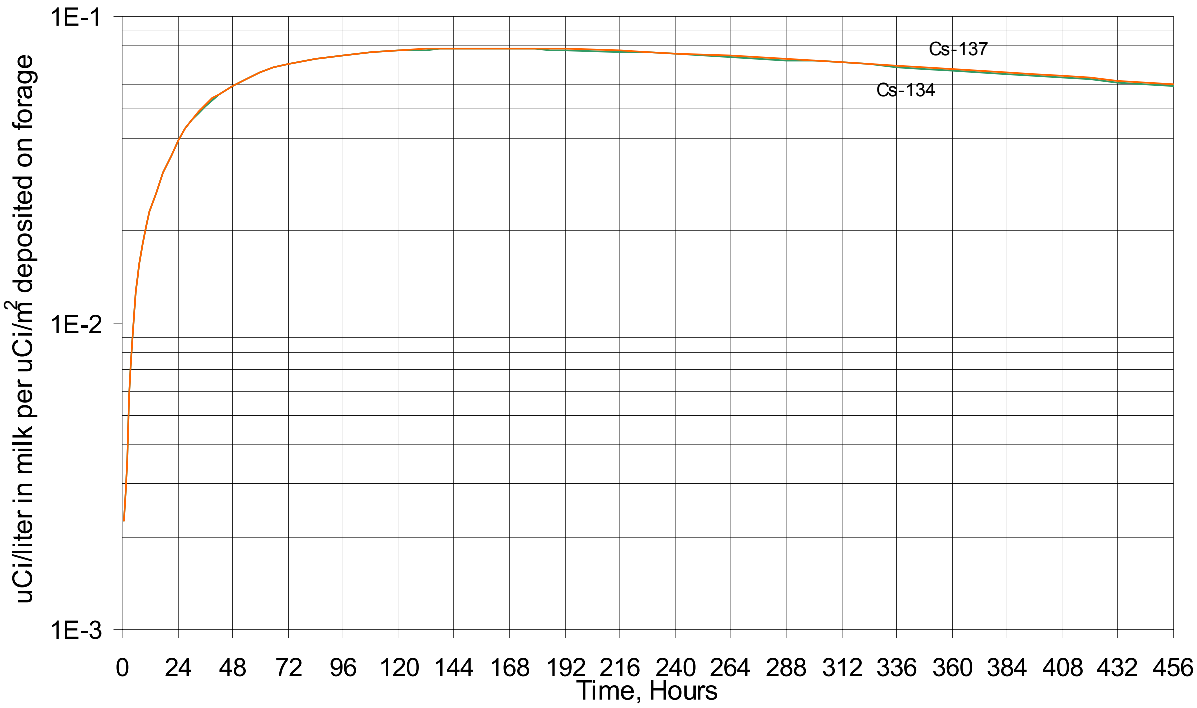
This chart shows the buildup in milk following a single contaminating event. It assumes continuous ingestion and includes decay and weathering.



Source: FEMA87 (page D-1) and Ng77

Chart 5.2. Cow-Cesium-Milk Concentrations—Time after Deposition
(^{134}Cs and ^{137}Cs)

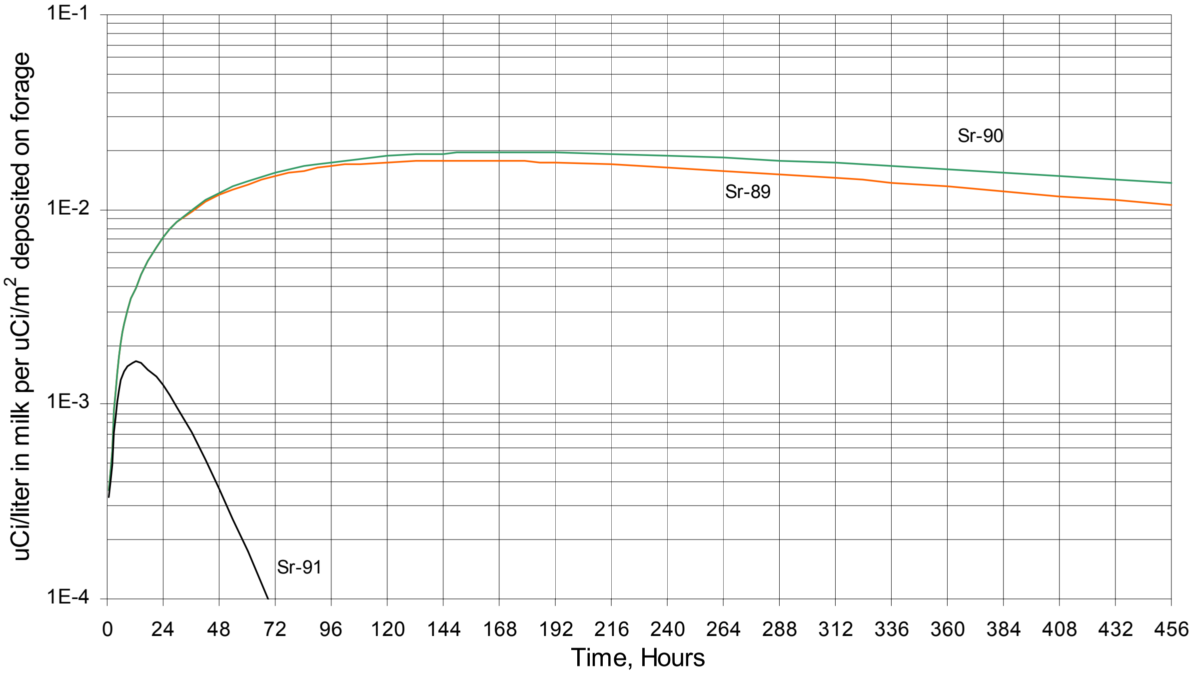
This chart shows the buildup in milk following a single contaminating event. It assumes continuous ingestion and includes decay and weathering.



Source: FEMA87 (page D-1) and Ng77

Chart 5.3. Cow-Strontium-Milk Concentrations—Time after Deposition
(^{89}Sr, ^{90}Sr, and ^{91}Sr)

This chart shows the buildup in milk following a single contaminating event. It assumes continuous ingestion and includes decay and weathering.



Source: FEMA87 (page D-1) and Ng77

APPENDIX C. WORKSHEETS

This page intentionally left blank.

Worksheet 2.1. Emergency Worker Turn-Back Exposure Levels

(Method M.2.1)

Analyst_______________					Date_______________ Time_______________
Emergency Activity	Column A EPA Emergency Worker Limit		Column B External Exposure to Inhalation Conversion Factor		Column C Turn-Back Limit **DO NOT EXCEED**
	(L_{EW}) TEDE Table 2.1 mrem		*(ECF_{ext})* Method M.2.1 mrem/mR		L_{EW}/ECF_{ext} mR
All	5,000	÷	( )$ECF_{ext,\ TEDE}$	=	
Protecting valuable property	10,000	÷	( )$ECF_{ext,\ TEDE}$	=	
Life saving or protecting large populations	25,000	÷	( )$ECF_{ext,\ TEDE}$	=	
Life saving or protecting large populations Voluntary	>25,000	÷	( )$ECF_{ext,\ TEDE}$	=	

Worksheet 3.1. Calculate Plume Dose Contributors

(Method M.3.2)

Analyst ______________________________ Date/Time ______________________

Step 1. Record the dose from each of the contributors to dose.

Dose Contributor					Dose (mrem or mrad)
H_a	=				
H_g	=				
$D_{T(thyroid),50}$	=				
	Plume	+	Resuspension	=	
$D_{T(GI),E}$[a]		+		=	
$D_{T(RBM),E}$[b]		+		=	
$D_{T(lung),E}$		+		=	
$D_{T(thyroid),E}$		+		=	
$H_{e,50}$		+		=	

a GI indicates small intestine dose – which is a predictor for gastrointestinal syndrome

b RBM indicates red bone marrow dose– which is a predictor for hematopoietic syndrome

Worksheet 3.2. Calculate Early Phase DRL from Deposition

(Method M.3.3.B Step B.2)

Sample Number______________		Date_____________		Time_____________	
Sample Location_____________			Analyst____________________________		
Steps B.2.1 through B.2.5					
	Column A	Column B	Column C	Column D	Column E
Nuclide *i*	C_{gi}[a] µCi/m^2	ECF_{gi} Table 3.4 mR/hr/(µCi/m^2)	DCF_{EPgi} Table 3.5 mrem/(µCi/m^2)	A × B mR/hr	A × C mrem
			Σ		

Step B.2.6

$$DRL_{EPg} = P_{EP} \times \frac{\sum Column\ D}{\sum Column\ E} = (\qquad mrem)\left[\frac{(\qquad mR/hr)}{(\qquad mrem)}\right] = (\qquad mR/hr)$$

The DRL$_{Epg}$ is the exposure rate that indicates that Early Phase PAGs may be exceeded from external exposure and resuspension.

[a] The nuclide concentration can be shown in any units because only the relative amount is important (the units will cancel out).

Worksheet 3.3. Calculate Decay Correction Factors

(Method M.3.11.A & Method M.3.11.B)

Date ____________________________ Time ________________

Reference Location ______________________ Analyst ______________________

Last Value – corrections valid until this date/time

E_g *(last)* = _______________ mR/h Current Time ______________________

(Last measured or calculated) (24-hr format, add 24 hr for each day after first)

Start Shift Date/Time	End Shift Date/Time	Shift Midpoint Time (24-hr format)	Decay Period Time since first measurement/shift (24-hr format)	Column A Estimated Exposure Rate at Midpoint Time mR/hr	Column B E_g *(last)* ÷ A Decay Correction Factor *DF(t)*

Worksheet 4.1. Calculate Relocation Exposure Rate DRL for a Deposition Sample

(Method M.4.1)

Sample Number________________ Date ______________ Time ____________

Sample Location ________________________ Analyst__________________________

Steps 2.A.1 through 2.A.5

Nuclide i	Column A C_{gi}[a] µCi/m^2	Column B ECF_{gi} Table 3.4 mR/hr/(µCi/m^2)	Column C DCF_{Rgi} Table 4.2 mrem/(µCi/m^2)	Column D A × B mR/hr	Column E A × C mrem
Notes: [a] The nuclide concentration can be shown in any units because only the relative amount is important (the units will cancel out).			Σ		

Step 2.A.6

$$DRL_{Rg} = P_R \times \frac{\sum Column\ D}{\sum Column\ E} = (\qquad mrem)\left[\frac{(\qquad mR/hr)}{(\qquad mrem)}\right] = (\qquad mR/hr)$$

DRL_{Rg} is the exposure rate indicating that remaining in an area contaminated with this mix for the period of concern may result in doses from direct exposure and inhalation of resuspension in excess of the relocation PAGs or Long-Term Objectives.

Worksheet 4.2. Calculate Intermediate Phase Dose Based on Deposition Levels

(Method M.4.5.A)

Sample Number________________ Date _______________ Time _________

Sample Location _______________________ Analyst_______________________

Steps A.1 through A.3

Nuclide i	Column A C_{gi} μCi/m^2		Column B DCF_{Rgi} Table 4.2 mrem[a]/(μCi/m^2)		Column C A × B $TEDE_{IPi}$ mrem
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
Notes: [a] For 1st, 2nd, or 50 years [b] The sum in Column C is the $TEDE_{IP}$ for the selected period. It includes external exposure and inhalation from resuspension.			Sum of Column C[b]	=	

Worksheet 4.3. Calculate Intermediate Phase Dose Based on Exposure Rates from Deposition

(Method M.4.5.B)

Sample Number________________ Date _______________ Time ____________

Sample Location ________________________ Analyst___________________________

Steps B.1 through B.5

	Column A	Column B	Column C	Column D	Column E
	C_{gi}[a]	DCF_{Rgi} Table 4.2	ECF_{gi} Table 3.4	A × B	A × C
Nuclide *i*	µCi/m^2	mrem[b]/(µCi/m^2)	mR/hr/(µCi/m^2)	mrem[b]	mR/hr
Notes:			Σ		

Notes:

[a] The nuclide concentration can be shown in any units because only the relative amount is important (the units will cancel out).

[b] For 1st, 2nd, or 50 years.

Step B.6

$$EDCF_{IP}\left(\qquad \frac{mrem}{mR/hr}\right) = \frac{\sum Column\ D \quad (\qquad mrem)}{\sum Column\ D \quad (\qquad mR/hr)}$$

Note: EDCF$_{IP}$, when multiplied by the exposure rate, will give the TEDE $_{IP}$ dose for the period for all areas with this mix.

Step B.7

$$TEDE_{IP}\ (\qquad mrem) = I\ (\qquad mR/hr) \times EDCF_{IP}$$

Note: Multiply EDCF$_{IP}$ by the exposure rate (I) to estimate the TEDE$_{IP}$ for the period.

Worksheet 4.4. Calculate Intermediate Dose Based on Marker Nuclide Level

(Method M.4.5.C)

Sample Number ________________ Date________________ Time__________

Sample Location ______________________ Analyst ______________________

Steps C.1 through C.3

	Column A		Column B		Column C
	C_{gi}		DCF_{Rgi} Table 4.2		A × B $TEDE_{IPi}$
Nuclide *i*	μCi/m²		mrem[a]/(μCi/m²)		mrem[a]
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
Notes: a For 1st, 2nd, or 50 year. b The sum in Column C is the $TEDE_{IP}$ for the selected period. It includes external exposure and inhalation from resuspension.			Sum of Column C[b]	=	

Step C.4

$$LDCF_{IP}\left(\qquad \frac{mrem}{\mu Ci/m^2}\right) = \frac{\sum Column\ C\ (\qquad)}{C_{gk-rep}\ (\qquad)}$$

Note: $LDCF_{IP}$ when multiplied by the *marker nuclide* level will give the $TEDE_{IP}$ for the period for all areas with this mix.

Step C.5

$$TEDE_{IP}\ (\qquad mrem) = C_{gk-sample}\ (\qquad \mu Ci/m^2) \times CDCF_{IP}$$

Note: Multiply the $LDCF_{IP}$ by the level of nuclide *k* to estimate the $TEDE_{IP}$ for the period.

Worksheet 4.5. Calculate Intermediate Phase Dose from Air Sample

(Method M.4.5.D)

Sample Number _________________ Date________________ Time__________

Sample Location _______________________ Analyst _______________________

Steps D.1 through D.3

Nuclide i	Column A C_{ai} μCi/m^3		Column B DCF_{Rai} Table 4.4 mrem/(μCi/m^3)		Column C A × B mrem
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
		×		=	
Notes: [a] The sum in Column C is the inhalation dose from remaining in this area for one year.			Sum of Column C[a]	=	

Worksheet 5.1. Deposition Concentration Ingestion Analysis

(Method M.5.2)

Sample Control #	Location:	Analyst:
Soil ☐ Field γ Spect. ☐ Other ☐	Latitude:	Date:
Description:	Longitude:	Time:

If any one contamination test fails, then the sample fails to meet the 1998 FDA PAGs.

^{90}Sr & ^{131}I Tests

Ratio concentration to corresponding DRL.

Fail, if ratio ≥ 1.0

†Bq/m², pCi/m² or µCi/m²

	Column A	Column B			Column C	Column D
Nuclide	Deposition Concentration (unit†/m²)	DRL‡ (Bq/m²)	DRL‡ (pCi/m²)	DRL‡ (µCi/m²)	A ÷ B Match units of A with B	Mark with **X**, if Column C ≥ 1.0
^{90}Sr		1,600	43,000	4.3×10^{-2}		
^{131}I		340	9,200	9.2×10^{-3}		

^{134}Cs & ^{137}Cs Test

Ratio sum of both concentrations to corresponding DRL.

Fail, if ratio ≥ 1.0

†Bq/m², pCi/m² or µCi/m²

	Column A	Column B			Column C	Column D
Nuclide	Deposition Concentration (unit†/m²)	DRL‡ (Bq/m²)	DRL‡ (pCi/m²)	DRL‡ (µCi/m²)	ΣA ÷ B Match units of A with B	Mark with **X**, if Column C ≥ 1.0
^{134}Cs						
^{137}Cs						
Sum ΣA		12,000	320,000	0.32		

$^{238, 239}$Pu & ^{241}Am Test

Ratio sum of all 3 concentrations to corresponding DRL.

Fail, if ratio ≥ 1.0

†Bq/m², pCi/m² or µCi/m²

	Column A	Column B			Column C	Column D
Nuclide	Deposition Concentration (unit†/m²)	DRL‡ (Bq/m²)	DRL‡ (pCi/m²)	DRL‡ (µCi/m²)	ΣA ÷ B Match units of A with B	Mark with **X**, if Column C ≥ 1.0
^{238}Pu						
^{239}Pu						
^{241}Am						
Sum ΣA		20	540	5.4×10^{-4}		

^{103}Ru & ^{106}Ru Test

Ratio concentrations to corresponding DRLs, then sum.

Fail, if ratio ≥ 1.0

†Bq/m², pCi/m² or µCi/m²

	Column A	Column B			Column C	Column D
Nuclide	Deposition Concentration (unit†/m²)	DRL‡ (Bq/m²)	DRL‡ (pCi/m²)	DRL‡ (µCi/m²)	A ÷ B Match units of A with B	Mark with **X**, if Column C ≥ 1.0
^{103}Ru		68,000	1.8×10^{6}	1.8		
^{106}Ru		4,500	120,000	0.12		
				Sum ΣC		

If any one test fails, then the sample exceeds PAG.

This Sample is OK ☐	**This Sample Exceeds PAG ☐**

‡Food concentration DILs converted to deposition DRLs assuming 2 kg/m² productivity and retention=0.2, except iodine =1.0

Worksheet 5.2. Food Contamination Analysis – Principal Radionuclides

(Method M.5.3)

Sample Control #	Location:	Analyst:
Food☐ Milk☐ Water ☐ Other ☐	Latitude:	Date:
Description:	Longitude:	Time:

If any one contamination test fails, then the sample fails to meet the 1998 FDA PAGs.

^{90}Sr & ^{131}I Tests

Ratio concentration to corresponding DIL.

Fail, if ratio ≥ 1.0

†Bq/kg, pCi/kg or µCi/kg

	Column A	Column B			Column C	Column D
Nuclide	Food Concentration (unit†/kg)	DIL (Bq/kg)	DIL (pCi/kg)	DIL (µCi/kg)	A ÷ B Match units of A with B	Mark with **X**, if Column C ≥ 1.0
^{90}Sr		160	4,300	4.3×10^{-3}		
^{131}I		170	4,600	4.6×10^{-3}		

^{134}Cs & ^{137}Cs Test

Ratio sum of both concentrations to corresponding DIL.

Fail, if ratio ≥ 1.0

†Bq/kg, pCi/kg or µCi/kg

	Column A	Column B			Column C	Column D
Nuclide	Food Concentration (unit†/kg)	DIL (Bq/kg)	DIL (pCi/kg)	DIL (µCi/kg)	ΣA ÷ B Match units of A with B	Mark with **X**, if Column C ≥ 1.0
^{134}Cs						
^{137}Cs						
Sum ΣA		1,200	32,000	3.2×10^{-2}		

$^{238,\,239}$Pu & ^{241}Am Test

Ratio sum of all 3 concentrations to corresponding DIL.

Fail, if ratio ≥ 1.0

†Bq/kg, pCi/kg or µCi/kg

	Column A	Column B			Column C	Column D
Nuclide	Food Concentration (unit†/kg)	DIL (Bq/kg)	DIL (pCi/kg)	DIL (µCi/kg)	ΣA ÷ B Match units of A with B	Mark with **X**, if Column C ≥ 1.0
^{238}Pu						
^{239}Pu						
^{241}Am						
Sum ΣA		2	54	5.4×10^{-5}		

^{103}Ru & ^{106}Ru Test

Ratio concentrations to corresponding DILs, then sum.

Fail, if ratio ≥ 1.0

†Bq/kg, pCi/kg or µCi/kg

	Column A	Column B			Column C	Column D
Nuclide	Food Concentration (unit†/kg)	DIL (Bq/kg)	DIL (pCi/kg)	DIL (µCi/kg)	A ÷ B Match units of A with B	Mark with **X**, if Column C ≥ 1.0
^{103}Ru		6,800	180,000	1.8×10^{-1}		
^{106}Ru		450	12,000	1.2×10^{-2}		
				Sum ΣC		

If any one test fails, then the sample exceeds PAG.

No Principal Radionuclide ≥ DIL ☐	**This Sample Exceeds PAG ☐**

Worksheet 5.3. Food Contamination Analysis – Other Radionuclides

(Method M.5.3)

Sample Control #	Location:	Analyst:
Food☐ Milk☐ Water ☐ Other ☐	Latitude:	Date:
Description:	Longitude:	Time:

If any one contamination test fails, then the sample fails to meet the 1998 FDA PAGs.

Part 1 Other Radionuclides

Ratio concentration to corresponding DIL.

Fail, if ratio ≥ 1.0 in any row

	Column A	Column B			Column C	Column D	Column E
Nuclide	Food Concentration (unit†/kg)	DIL (Bq/kg)	DIL (pCi/kg)	DIL (µCi/kg)	**A ÷ B** Match units of A with B	Rank Order	Mark, if dominant
^{89}Sr		1,400	38,000	3.8×10^{-2}			
^{91}Y		1,200	32,000	3.2×10^{-2}			
^{95}Zr		4,000	110,000	1.1×10^{-1}			
^{95}Nb		12,000	320,000	3.2×10^{-1}			
^{132}Te		4,400	120,000	1.2×10^{-1}			
^{129}I		56	1,500	1.5×10^{-3}			
^{133}I		7,000	190,000	1.9×10^{-1}			
^{140}Ba		6,900	190,000	1.9×10^{-1}			
^{141}Ce		7,200	200,000	2.0×10^{-1}			
^{144}Ce		500	14,000	1.4×10^{-2}			
^{237}Np		4	110	1.1×10^{-4}			
^{239}Np		28,000	760,000	7.6×10^{-1}			
^{241}Pu		120	3,200	3.2×10^{-3}			
^{242}Cm		19	510	5.1×10^{-4}			
^{244}Cm		2	54	5.4×10^{-5}			

† Bq/kg, pCi/kg or µCi/kg

If any one test fails, then the sample exceeds PAG.

This Sample is OK ☐	**This Sample Exceeds PAG G**

Part 2 Principal Radionuclides

Results from Worksheet 5.2
Enter ratio from Column C of Worksheet 5.2.

Rank Order 1 to n with above. Greatest ratio is most dominant. Mark Column E in both Part 1 and Part 2 with **X**, if ratio>1/5 of most dominant radionuclide or if ratio ≥ 1.0.

Nuclide	Column C Ratio from Worksheet 5.2	Column D Rank Order	Column E Mark, if dominant
^{90}Sr			
^{131}I			
$^{134}Cs + ^{137}Cs$			
$^{238}Pu + ^{239}Pu + ^{241}Am$			
$^{103}Ru + ^{106}Ru$			

Worksheet 5.4. Cow and Goat Forage and Water Contamination Analysis

(Method M.5.4)

Sample Number: ______________ Analyst: ______________________________

Date: ____ ❑ Forage ❑ Water

Sample Location:______________________________ Time:_____________________

Nuclide *i*	Column A $C_{cow,i}$[a] (μCi/kg) or (μCi/L)		Column B $DRL_{Ing,cow,i}$ Table 5.10 (μCi/kg) or (μCi/L)		Column C[b] A ÷ B
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	

Notes:

[a] Fresh weight

[b] If any value in Column C is greater than or equal to one, consumption of milk produced by cows consuming contaminated forage or water may result in doses that exceed the Ingestion PAGs.

Worksheet 6.1. Assessment Product QA Cover Sheet

(Method M.6.1)

Product:		
Date:		**Time:**
Preparer(s):		
Origin:	❑ Scheduled Assessment Product ❑ Action Request for ______________________	
Distribution:	❑ Internal Use Only ❑ **Approved for Release by** ______________________	
Description: (What is this?)		
Methodology: (How was it made?)		
Inputs: (What data was used? Any deviation from those in the Manual?)		
Assumptions: (What were the assumptions? Any deviation from those in the Manual?)		
Cautions & Limitations: (Are there any restrictions on the interpretation or applicability?)		
Quality / Confidence: (What is the level of quality or confidence? Why?)		

Worksheet 6.2. Response Deposition DRLs

(Method M.6.1)

Analyst ______________________				Date __________
Location ______________________				Time __________
	Exposure Rate (mR/h) at 1 Meter AGL			
Time of Field Measurement[a]				
Early Health Effects[b]				
Early Phase PAG[b]				
Intermediate (Relocation) Phase PAG[c]				
Ingestion DIL[d] for __________				
Ingestion DIL[d] for __________				
	Marker Nuclide Concentration (μCi/m^2) for Nuclide __________			
Time of Field Measurement[a]				
Early Health Effects[b]				
Early Phase PAG[b]				
Intermediate (Relocation) Phase PAG[c]				
Ingestion DIL[d] for __________				
Ingestion DIL[d] for __________				

[a] Time and date when DRLs are applicable. DRLs may change as a function of time if the deposition contains many short-lived nuclides.

[b] Volume 1, Section 3.

[c] Volume 1, Section 4.

[d] Volume 1, Section 5. List the food and nuclide or nuclide group

This page intentionally left blank.

APPENDIX D. PARAMETERS

This list contains the principal parameters used in the manual and the table or method used to derive the parameters.

Parameter	Unit	Description	Manual Reference
Λ	time^{-1}	Radioactive decay constant. It is equal to $(\ln 2)/T_{1/2}$	
ρ_{milk}	g/cm^3 or kg/liter	Density of milk (assumed to be equal to the density of water).	
χ_i	µCi/m^3	Air concentration of nuclide *i*.	
A_i	µCi	Activity of nuclide *i*.	
BR	m^3/hr	Breathing rate. Use 1.2 m^3/hr (adult light activity).	Table 3.10
C_{ai}	µCi/m^3	Air concentration of nuclide *i*.	
$C_{chart\ t}$	µCi/L	Milk concentration from Chart 5.1, Chart 5.2 or Chart 5.3 for time *t* after cow consumes contaminated forage.	Chart 5.1, Chart 5.2, and Chart 5.3
C_{fi}	µCi/kg or µCi/L	Food concentration of nuclide *i*.	
$C_{cow,i}$	µCi/kg or µCi/L	Concentration in cow forage or water	
C_{gi}	µCi/m^2	Deposition level of nuclide *i*.	
$C_{m,t}$	µCi/L	Measured activity concentrations in milk at time *t* after consumption of contamination.	Method M.5.9
$C_{p,t}$	µCi/L	Projected activity concentrations in milk at time *t* after consumption of contamination.	Method M.5.9
$D_{T(Organ),E\ or\ 50}$	mrad or mrem	Organ (early red bone marrow, early small intestine, early lung, early thyroid, and thyroid CDE) dose from inhalation for nuclide *i*. Early doses in mrad and CDE in mrem.	Method M.3.2
DCF_{ai}	(mrem/hr)/(µCi/m^3)	EDE external air submersion Dose Conversion Factor for a semi-infinite cloud for nuclide *i*.	Table 3.4, Method M.3.10
$DCF_{e,50\ i}$	(mrem/hr)/(µCi/m^3)	Dose Conversion Factor for CEDE from inhalation of air containing one µCi/m^3 of nuclide *i* by an adult performing light activity for one hour.	Table 3.3, Method M.3.10.
DCF_{EPgi}	(mrem)/(µCi/m^2)	Early Phase Dose Conversion Factor for deposition of nuclide *i*. This includes external exposure and CEDE (inhalation) from resuspension for remaining on contaminated ground for 96 hours (four days).	Table 3.5, Method M.3.4
DCF_{gi}	(mrem/hr)/(µCi/m^2)	EDE external ground shine Dose Conversion Factor for nuclide *i* considering ground roughness.	Table 3.4, Method M.3.10

Parameter	Unit	Description	Manual Reference
DCF_{Ingi}	mrem/μCi	Ingestion Dose Conversion Factors for the dose equivalent to the tissue and population receiving the highest dose. (EPA92)	Table 5.8, Method M.5.12
DCF_{Rai}	(mrem)/(μCi/m^3)	Intermediate Phase Relocation Dose Conversion Factor for air concentrations for nuclide *i*. Includes CEDE from inhalation resulting from resuspension for one year.	Table 4.4
DCF_{Rgi}	(mrem)/(μCi/m^2)	Intermediate Phase Relocation Dose Conversion Factor for ground contamination for nuclide *i*. Includes external dose and CEDE from inhalation resulting from remaining on contaminated ground for the period of concern (1st, 2nd, or 50 years).	Table 4.2, Method M.4.2
$DCF_{T(Organ),E \text{ or } 50,i}$	(mrad/hr)/(μCi/m^3) or (mrem/hr)/(μCi/m^3)	Dose Conversion Factor for an organ (early red bone marrow, early small intestine, early lung, early thyroid, and thyroid CDE) dose from inhalation of air containing 1 μCi/m^3 of nuclide *i* by an adult performing light activity for one hour.	Table 3.3, Method M.3.10
DEXP	rem/R	Ratio of dose to exposure (0.7 rem/R, based on EPA92 and UNSCEAR82). This is an approximation and does not take into consideration the energy dependence of this quantity.	Table 3.4
DF	m^{-2}	Dilution factor at a distance from the source of a release.	Table 3.6
DI_i	days	Days of Intake. The number of days it is assumed that a food is consumed. Mean life (T_m) is used in this manual. Effective mean life (T_{me}) or another period can be used for days of intake.	Method M.5.10
D_{Ing}	mrem	Dose from ingestion.	Methods M.5.10 and M.5.11
DIL		Derived Intervention Level	Table 5.2
Dis_m	miles, km	Distance from the source of the release that a measurement was taken.	
Dis_p	miles, km	Distance from the source of a release that a projection is being made.	
$DRL_{Ing,cow}$	μCi/kg or L	Derived Response Level for concentrations in cows forage or water	Table 5.10, Method M.5.7
DRL_{EPg}	μCi/m^2 – deposition level; or mR/hr exposure rate from deposition	Derived Response Level for a particular mix indicating that the Early Phase PAGs may be exceeded from exposure to deposition. This considered external exposure and resuspension from remaining on ground contamination for 96 hours (four days).	Method M.3.3
DRL_{Ingi}	μCi/kg or μCi/L	Concentration of nuclide *i* that will produce dose that exceeds the HHS Ingestion PAGs.	

Parameter	Unit	Description	Manual Reference
$DRL_{Ingg,i}$	μCi/m^2	Deposition level of nuclide *i*. Derived Response Level for ingestion indicating that concentration in food, water, or milk will meet or exceed the FDA DIL.	Table 5.4, Method M.5.8
DRL_{Rg}	μCi/m^2 – deposition level of a nuclide or mR/hr exposure rate from deposition.	Derived Response Level for a particular deposition mix indicating that the Intermediate Phase Relocation PAG or Long-Term Objectives may be exceeded. This considers external exposure and resuspension from remaining on deposition for the 1st year, 2nd year, or 50 years.	Method M.4.1
E_a	mR/hr	Exposure rate from air (plume) contamination.	
E_g	mR/hr	Exposure rate at 1m AGL from ground surface contamination	
$ECF_{ext,CEDE}$	mR/mrem	Exposure-to-Dose Conversion Factor for CEDE. The exposure rate (mR/hr) that corresponds to an inhalation dose rate (mrem/hr).	Method M.2.1
$ECF_{ext, thy}$	mR/mrem	Exposure-to-Dose Conversion Factor for thyroid CDE. The exposure rate (mR/hr) that corresponds to an inhalation dose rate (mrem/hr).	Method M.2.1
ECF_{gi}	(mR/hr)(μCi/m^2)	Deposition exposure conversion factor. The exposure rate at 1m AGL from 1 μCi/m^2 deposition of nuclide *i*.	Table 3.4
$EDCF_{IP}$	mrem/(mR/hr)	Intermediate Phase Exposure-to-Dose Conversion Factor. The ratio of the dose during the Intermediate Phase from deposition to the exposure rate at 1 m AGL.	Method M.4.5.B
f_F		Fraction of the cow's diet that is contaminated. HHS (EPA92) and this manual assumed one.	
f_{mi}	(μCi/L)/(μCi/day)	Transfer factors for nuclide *i* for cow's milk.	Table 5.6
FRF_i		Fire release fraction nuclide *i*.	
GCF		Ground Concentration Factor.	
GRCF		Ground Roughness Correction Factor (0.7) – corrects an external exposure or dose rate projected for deposition on a plane surface to actual ground surface.	Table 3.4
H_{ai}	mrem	EDE external dose from air submersion for nuclide *i*.	Method M.3.2
$H_{e,50i}$	mrem	CEDE from inhalation for nuclide *i*.	Method M.3.2
H_{gi}	mrem	EDE external dose from ground shine for nuclide *i*.	Method M.3.2
ht	ft	Height.	
I	mR/hr or mrem/hr	Intensity (exposure or external dose rate).	Method M.3.5

Parameter	Unit	Description	Manual Reference
L	ft	Length.	
L_{EW}	mrem	Emergency Worker Dose Limits.	Table 2.1
$LDCF_{IP}$	(mrem)/(μCi/m^2)	Intermediate Phase Deposition-Level-to-Dose Conversion Factor for the period of interest	Method 4.5.C
MC	m^3/ft^3	Metric Conversion.	
OF		Occupancy Fraction. Fraction of time in the area with the shielding factor (SF)	
P_{EP}	mrem	The dose threshold used by the state for the Early Phase PAG. A state may use the EPA PAG or set its own. The EPA PAGs are 1,000 mrem TEDE and 25,000 mrem CDE to the thyroid from the plume and 96 hours (four days) of ground contamination.	Table 3.2
P_{Ing}	mrem	Ingestion PAGs. HHS recommends two different Ingestion PAGs. One for the CEDE and another for individual organs. They are listed in Table 5.1.	Table 5.1
P_R	mrem	The dose threshold used by the state for the Intermediate Phase Relocation PAG or Long-Term Objectives. The EPA recommendations are shown below. **Period** | **P_R(EPA)** | **Definition** 1st year | 2,000 mrem | PAG 2nd year | 500 mrem | Long-Term Obj. 50 year | 5,000 mrem | Long-Term Obj.	Table 4.1
Q_i	μCi/s	Release rate (source term) of nuclide *i*.	
R		Retention factor is the fraction of deposition that is retained on the crop.	Table 5.9
RF		Reduction Factor is the fraction of the contamination remaining after decay or some process used to reduce the contamination before food is released for consumption. No credit is given in this manual for any process used to reduce the amount of contamination in food.	Methods M.5.6 and M.5.10
R_S	m^{-1}	Resuspension factor used is from NCRP99 and is described as follows: 10^{-6} m^{-1} for the first day; then declining as $10^{-6}/t$, where t is time in days, for times from 1 day to 1000 days; and is constant at 10^{-9} for times greater than 1000 days or use methods M.3.8 or M.4.7 to calculate based on samples.	Chart 4.1, Methods M.3.8, and M.4.7
SF		Shielding Factors.	Tables 3.7 and 3.8
SICF		SI units Conversion Factor	Tables 3.3 and 3.4
SpA_i	μCi/g	Specific Activity of nuclide *i*.	

Parameter	Unit	Description	Manual Reference
T_d	hr, days	Time food is held up before consumption.	
T_{ed}	hr	Exposure duration in hours not corrected for decay. For plume exposure, use the estimated release duration or four hours (average wind persistence in United States) and for ground exposure or resuspension use 96 hours.	
t_f	days	Time to market. The period of time from when a radionuclide is in an animal's feed or forage to when the milk is available for consumption.	
T_{EPeepi}	Eff. hours	Early Phase Effective Exposure Period. Effective exposure hours for nuclide *i* in four days considering decay. See Table 3.9 notes for derivation.	Table 3.9
T_{IPeepi}	Eff. hours	Intermediate Phase Effective Exposure Period. Effective exposure hours for nuclide *i* in one year considering decay. See Table 4.6 notes for derivation.	Table 4.6
T_m	hr	Mean life is the reciprocal of the radioactive decay constant (λ). For ingestion, it is the time that multiplied by the initial dose rate gives the total dose received assuming the food is consumed forever and no other process (e.g., weathering) other than decay is considered $$T_m = 1/\lambda \approx T_{1/2} \times 1.44$$	Table 1.1
T_{me}	hr	Mean effective half-life assumes both radiological decay and weathering are acting to reduce the radioactivity on a crop. (T_{me}) is $$T_{me} = T_E \times 1.44$$ where $$T_E = \frac{T_{1/2} \times T_w}{T_{1/2} + T_w}$$	
T_w	hr	Weathering half-life. T_w of 14 days may be assumed for foods harvested on a daily basis (EPA92).	
$T_{1/2}$	hr	Nuclide *i* radiological half-life.	Table 3.9, Table 4.6, and Table 1.1
$TEDE_{EP}$	mrem	TEDE for the Early Phase. It includes external and inhalation dose from the plume, four days of ground shine, and CEDE for inhalation of four days of resuspension.	Method M.3.2
$TEDE_{IP}$	mrem	TEDE for the Intermediate Phase. It includes external dose from ground shine and CEDE for inhalation from resuspension during the 1st-, 2nd-, or 50-year periods.	Method M.4.5

Parameter	Unit	Description	Manual Reference
$TEOD_{Organ}$	mrad	Total Early Organ Dose for projecting the potential of early health effects. The organs considered here are: red bone marrow (RBM), small intestine – for gastrointestinal tract (GI), lung, and thyroid	Method M.3.2
$\overline{U}$	m/s	Average wind speed.	
U_{COW}	kg/d or L/d	Ingestion rate of fresh forage or water by cows.	Table 5.9
U_{Dirt}	m^2/d	Human ingestion rate for surface contamination in m^2/d, assume $6E^{-4}$ m^2/d.	Method M.5.11
U_f	kg/d or L/d	Consumption rate. It is the amount of a food f consumed by the population of interest.	Table 5.7
UAF	m^2	Effective area grazed by a cow in a day.	Table 5.9
Wt	g	Weight.	
Y	kg/m^2	Productivity. Fresh weight of the food produced per square meter of land. Two kilograms per square meter is assumed.	Table 5.9

APPENDIX E. DATA DICTIONARY

Adm_Flag.db

Field Name	Definition	Data Type	Data Size
Flag	Abbreviated flag descriptions: Ass, Ques, Raw, and Ver	Alpha	6
Description	Flag description	Alpha	30

Cf-Type.db

Field Name	Definition	Data Type	Data Size
CF-Type	Surface type such as grass, gravel, asphalt, etc.	Alpha	25

Loc-data.db

Field Name	Definition	Data Type	Data Size
Location_Description	Location description	Alpha	64
Latitude_Decimal_Degrees	The team specifies the location's latitude in decimal degrees for each measurement and sample taken	Number	
Longitude_Decimal_Degrees	The team specifies the location's longitude in decimal degrees for each measurement and sample taken	Number	
Lat_Decimal_Minutes	The team specifies the location's latitude in decimal minutes for each measurement and sample taken	Alpha	24
Long_Decimal_Minutes	The team specifies the location's latitude in decimal minutes for each measurement and sample taken	Alpha	24

Teamtype.db

Field Name	Definition	Data Type	Data Size
TeamType	Hand Held or Mobile unit	Alpha	32

Team_ins.db

Field Name	Definition	Data Type	Data Size
Team_Name	The name of the team	Alpha	15
Teamdate	The date the team when out to the field	Date	
Instrument	The instrument the team used	Alpha	12

Team.db

Field Name	Definition	Data Type	Data Size
Team_Name	The name of the team	Alpha	15
Teamdate	The date the teams were formed	Date	
Team_Leader	The person in charge of the team	Alpha	40
Start_Date	The team's start date for reading DataPts	Date	
Start_Time	The team's start time on the actual DataPt	Time	
End_Date	The end date on the Data point readings	Date	
Teamtype	Could be a Hand Held or Mobile unit	Alpha	32

Surf_typ.db

Field Name	Definition	Data Type	Data Size
Surface Type	Surface types such as gravel, asphalt, etc.	Alpha	15

Samples.db

Field Name	Definition	Data Type	Data Size
Event	The name of the exercise or real world event	Alpha	64
Location_Description	The name of the location from where the sample was taken	Alpha	64
Latitude_Decimal_Degrees	The team specifies the location's latitude in decimal degrees for each measurement and sample taken	Number	
Longitude_Decimal_Degrees	The team specifies the location's longitude in decimal degrees for each measurement and sample taken	Number	
Key_Team	The name of the team that took the samples	Alpha	15
Teamdate	The date the sample was taken		

Samp_typ.db

Field Name	Definition	Data Type	Data Size
Sample_type	Air filter types: 2, 4, and 8x10 inches	Alpha	20

Msmt_un.db

Field Name	Definition	Data Type	Data Size
Msmt Unit	Measurment units: mR/Hr, uR/Hr, etc	Alpha	15

Inst_typ.db

Field Name	Definition	Data Type	Data Size
Instrument type	The name of the instrument used to take the measurement value of a specific area	Alpha	20
Sample type	Sample types such as depostion, in-situ, exposure,and tissue equivalent	Alpha	20
Types of detection	Types of detections: beta, gamma alpha, neutron, kinetic impactor, etc.	Alpha	20
Description	The instrument description	Alpha	35

Inst.db

Field Name	Definition	Data Type	Data Size
Key_Instrument	The instrument number	Alpha	12
Instrument type	The name of the instrument used to take the measurement value of a specific area	Alpha	20

Filters.db

Field Name	Definition	Data Type	Data Size
FilterSize	Filter size: 2" air flat, 8"x10", or 4 cm	Alpha	32
StartTime	Start time of the measurement	Timestamp	
EndTime	End time of the measurement	Timestamp	
StartRate	The start rate	Number	
EndRate	The end rate	Number	
TotalVolume	Displays the total volume	Number	

Msmt.db

Field Name	Definition	Data Type	Data Size
Meas_Type	Sample types: deposition, in-situ, exposure, and tissue equivalent	Alpha	20
Log_Number	The number found on each of the data acquisition form	Alpha	16

Meas_CF	Surface types: asphalt, grass, gravel, dirt, soil/brush, etc.	Alpha	25
Event	The name of the exercise or real world event	Alpha	64
DataCenterFlag	States whether a record was imported	Logical	
ReleaseFlag	States whether the record has been released to the FRMAC director	Alpha	6
CrossCheck	States whether the record has been cross checked with the field log	Alpha	1
DataEntry	The data entry clerk's name	Alpha	40
Key_Team	The team's name	Alpha	15
Teamdate	The date the team took the readings	Date	
Location_Desc	The location from where the team took the measurements	Alpha	64
Latitude_Decimal_Degrees	The team specifies the location's latitude in decimal degrees for each measurement and sample taken	Number	
Longitude_Decimal_Degrees	The team specifies the location's latitude in decimal degrees for each measurement and sample taken	Number	
Lat_Decimal_Minutes	The team specifies the location's latitude in decimal degrees for each measurement and sample taken	Alpha	24
Long_Decimal_Minutes	The team specifies the location's latitude in decimal degrees for each measurement and sample taken	Alpha	24
Key_Instrument	The instrument number	Alpha	12
Instrument_Type	The name of the instrument used to take the measurement value of a specific area	Alpha	20
Meas_Date	The date the measurement was taken	Date	
Meas_Time	The time the measurement was taken	Time	
Meas_Value	The exposure/count rate obtained from a specific location	Number	
Meas_Value_Units	The measurement units such as $\mu Ci/m^2$, µR/Hr, mR/Hr, etc.	Alpha	15
Normalized_Value	The measurements value converted to normalized value	Number	
Normalized_Value_Units	The measurement value units normalized to another unit of measurement	Alpha	15
Samples	States if a sample taken	Alpha	3

APPENDIX F. EARLY HEALTH EFFECTS AND DOSE GUIDANCE

REAC/TS Input to FRMAC Assessment Manual

1. How should we best define early effects? The intent is to capture deterministic morbidity effects, not just prompt acute effects.

There is no universally agreed time period for "acute" effects. The REAC/TS Registry uses 60 days for death as an endpoint; Guskova et al. (2001) classify "acute radiation sickness" as that occurring within 3 days of exposure; Mettler and Guskova (2001) state that all forms of acute radiation syndrome manifest themselves within 30 days after exposure. For deterministic effects on tissues, Rubin and Casarett (1968) identified acute effects as those occurring within the first 6 months after exposure. Based on the fact that almost all effects, including those arising from local skin irradiation, will manifest to at least some degree, within 30 days after exposure, we recommend that "early effects" be defined as those occurring within 30 days of exposure. It should be noted however, that some deterministic effects, even to the point of lethality, might not manifest within this time period. One such example is radiation pneumonitis, which typically develops 3 to 6 months after absorbed doses of at least 4 Gy to the lung.

2. What is the proper dose commitment period? Is there more than a single period?

This question refers to the calculation on internal dose following intake of a radionuclide. The standard period for occupational radiation protection is 50 years. Although this could be used (and would in most cases be extremely conservative) it has the potential to create much confusion. The occupational dose quantities computed for fifty years are called the committed organ dose equivalent (CODE) and the committed effective dose equivalent (CEDE). Neither quantity should be used in the context of acute, early, deterministic health effects, because both include the quality factor, which is specific for stochastic effects, and the latter includes the tissue weighting factors, which are also specific for stochastic effects. (In addition, because the quantity total effective dose equivalent, TEDE, includes the CEDE, it should not be used in this context either.) Because internal doses are prolonged following an intake, however, it seems reasonable to use 30 days as the integration period for consistency with the time frame for defining early effects. There does not seem to be any significant advantage to including integration times of 1 or 4 days in any table, but a 50-year committed organ dose (not dose equivalent) could be included for reference.

3. What are the relevant end points in terms of dose type and commitment periods?

We propose the following end points and associated dose quantities:

a) acute radiation syndrome (hematopoietic effects), i.e., suppression of bone marrow function. The dose to be computed is the absorbed dose to red marrow, which will comprise the external dose from penetrating radiation, and the 30-day "committed" organ dose to red marrow from intakes of radionuclides.

b) acute radiation syndrome (gastrointestinal effects). The dose to be computed is the absorbed dose to the small intestine, which will comprise the external dose from penetrating radiation, and the 30-day "committed" organ dose to the small intestine from intakes of radionuclides.

c) "cutaneous syndrome" (radiation burns to skin). The dose to be computed is the "shallow" dose (i.e., the absorbed dose at a depth of 7 mg/cm^2 [70 μm] in tissue) from external penetrating radiation and radioactive contamination on the skin.

d) thyroid damage. The dose to be computed is the absorbed dose to the thyroid, which will comprise the external dose from penetrating radiation, and the 30-day "committed" organ dose to the thyroid from intakes of radionuclides (radioiodines).

e) lung damage. The dose to be computed is the absorbed dose to the lung, which will comprise the external dose from penetrating radiation, and the 30-day "committed" organ dose to the lung from intakes of radionuclides. (However, it is difficult to imagine a reactor scenario in which a lung dose capable of causing severe health effects could be received without significant thyroid and whole-body doses also being incurred. If the manual is intended to apply also to atmospheric releases of alpha emitters, e.g., a plutonium fire, then in that case, lung dose may predominate. Also, if such scenarios are to be included, then for completeness the dose to bone surfaces should also be calculated, but severe effects on bone are highly unlikely, and may be neglected, since lung effects following inhalation will occur first and be more severe.)

For the case of the lung, if inhalation of alpha emitters occurs, an RBE factor of ten should be applied to the absorbed dose to the lung (Peterson, 2001; Smith and Stather, 1976). However, the units to be used remain rads or Gy, although an asterisk or other indicator may be used to identify the fact that the absorbed dose has been multiplied by an RBE. Because there are no human data from which to determine the appropriate RBE, we must rely on animal models. There does not appear to be any need for an RBE to be applied to the red marrow, small intestine, skin, or thyroid absorbed doses, since the dose contributions of alpha emitters to these organs are negligible. There is no agreement on an RBE for bone surfaces, and the data from radium in humans and animals, and transuranics in animals, are based on absorbed dose (rads, Gy) to bone surfaces.

4. What are the thresholds for the doses corresponding to the above end points?

a) hematopoietic syndrome: 50 rad (0.5 Gy) for marrow depression

b) gastrointestinal syndrome: 50 rad (0.5 Gy) for vomiting, 100 rad (1 Gy) for diarrhea, 800 rad (8 Gy) for lethality

c) skin: 200 rad (2 Gy) for transient erythema

d) thyroid: 300 rad (3 Gy) for hypothyroidism

e) lung: 600 rad (6 Gy) for pneumonitis (including RBE for alphas)

f) bone: 1000 rad (10 Gy) for osteonecrosis

These values are taken from Mettler and Upton (1995).

5. How should the doses be computed? Because time is critical, detailed computations may be a liability.

The dose calculation algorithms in the current manual should serve as models. All the penetrating (external) radiation doses can be calculated from measured (or calculated) dose rates from the plume, air submersion, and ground deposition times exposure time; all the internal doses can be computed from measured (or calculated) atmospheric concentrations, breathing rate, and exposure time. Skin dose can be calculated from measured external dose rate and skin contamination level times exposure time. Note however, that EDE and TEDE should not be used for early health effects, as in Methods M 3.0 and M 3.0 A [Note: these method numbers refer to the 1996 version of the Assessment Manual. In this manual the corresponding methods are M.3.0 and M.3.1]. For actions to prevent delayed health effects, then EDE and TEDE are appropriate.

6. What is (are) the references that can be cited?

See below.

REFERENCES

Guskova, A. K., Baranov, A. E. and Gusev, I. A. (2001). “Acute radiation sickness: underlying principles and assessment,” pages 33-51 in: Gusev, I. A., Guskova, A. K. and Mettler, F. A., Eds. *Medical Management of Radiation Accidents, 2nd ed*. (CRC Press, Boca Raton, Florida).

Mettler, F. A. and Guskova, A. K. (2001). “Treatment of acute radiation sickness,” pages 53-67 in: Gusev, I. A., Guskova, A. K. and Mettler, F. A., Eds. *Medical Management of Radiation Accidents, 2nd ed.* (CRC Press, Boca Raton, Florida).

Mettler, F. A. and Upton, A. C. (1995). *Medical Effects of Ionizing Radiation, 2nd ed.* (W. B. Saunders & Co., Philadelphia).

Peterson, V. L. (2001). “Deterministic health effects from plutonium inhalation,” EFCOG01 Paper_Final.doc.

Rubin, P. and Casarett, G. W. (1968). *Clinical Radiation Pathology* (W. B. Saunders, Philadelphia).

Smith, W. and Stather, J. R. (1976) NRPB R52.

This page intentionally left blank.

APPENDIX G. DOSE COEFFICIENTS FOR ACUTE HEALTH EFFECTS

The absorbed dose (Gy) following the inhalation intake of a unit activity (1 Bq) of various radionuclides has been tabulated for the reference adult. Values of the absorbed dose per unit intake (a dose coefficient) are given for time periods of 1, 4, and 30 days for both low and high LET (linear energy transfer) radiations emitted by the inhaled radionuclide and any radioactive decay products that form *in vivo*. Coefficients were tabulated for the lung, active (red) marrow, small intestine, thyroid, and skin, which are the tissues of concern for acute (or early) health effects.

The absorbed dose coefficients were derived from the absorbed dose rate file archived on the CD supplement to Federal Guidance Report 13 (EPA 2000). That archive contains files of the age-dependent absorbed dose rate (low and high LET) for each organ/tissue as a function of time post an acute intake by individuals of age 3-months, 1-, 5-, 10-, 15 year, and the adult. We briefly discuss here the basis for these values and refer the reader to Federal Guidance Report 13 for a detailed discussion.

In FGR 13 age-specific biokinetic models are used to calculate the time-dependent inventories of activity in various regions of the body following an acute intake of a unit activity of a radionuclide. The biokinetic models used in the calculations, with a few exceptions, are the same as those applied by the International Commission on Radiological Protection (ICRP) in its development of age-specific dose coefficients for inhalation or ingestion of radionuclides by members of the public (ICRP 1989, 1993, 1995a, 1995b, 1996). Age-specific dosimetric models were used to convert the calculated time-dependent regional activities to absorbed dose rates in the tissues of the body as a function of time post intake. The dosimetric models used in this calculation are the models used in the ICRP's series of documents on age-specific dose noted above. The absorbed dose rate for LET component *j* at time *t*, $\dot{D}_{T,j}(t)$, is given by

$$\dot{D}_{T,j}(t) = \sum_{S} q_S(t) \cdot SE(T \longleftarrow S)_j$$

Where $q_S(t)$ is the time dependent activity present in region *S* and $SE(T \longleftarrow S)_j$ is the absorbed dose rate in target *T* for LET component *j* per unit activity in *S*.

The respiratory tract model of ICRP Publication 66 (ICRP 1994) was used in the calculations. Particulate matter was characterized by an activity median aerodynamic diameter (AMAD) of 1 μm. Calculations were performed for all three default absorption types (Type F, M, and S denoting fast, moderate, and slow rates of absorption from the lung) and also vapor or gaseous forms when indicated.

The model of the gastrointestinal tract applied in FGR 13 was that originally formulated for occupational intakes (ICRP 1979) but also applied to environmental intakes of radionuclide by members of the public (ICRP 1989, 1993, 1995a, 1995b, 1996). The absorption of nuclides from the tract was based on guidance specifically for members of the public as described in the ICRP reports.

With the two exceptions noted below, the systemic biokinetic models are those applied in ICRP Publication 72 (1996). For 31 of the elements, the systemic biokinetic models were developed specifically for members of the public and age-dependence was not reflected in the models for the remaining elements. The age-dependent models frequently included a more detailed treatment of the behavior of decay products formed within in the body. The two exceptions from ICRP Publication 72 noted above were actinium and protactinium, which in FGR 13 were taken to follow the biokinetics of americium and thorium, respectively.

Data on the absorbed dose rate (low and high LET) for each organ/tissue as a function of time post an acute intake by the adult were obtained from the archived file on the Federal Guidance Report 13 CD (EPA 2000). The data resides in the compressed file INHALE.ZIP in the folder DOSE on the CD. The dose rate data for the lung, active (red) marrow, small intestine, thyroid, and skin were then integrated over the time periods of interest. Absorbed dose values for both the low and high LET components were tabulated. A smoothly varying spline function was fitted to the integrand (the absorbed dose rate) and the straightforward integration of the spline function was preformed (Fritsch and Carlson 1980).

References

EPA (1999). U.S. Environmental Protection Agency, Federal Guidance Report 13 Cancer Risk Coefficients for Environmental Exposure to Radionuclides: EPA 402-R-99-001 (Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

EPA (2000). U.S. Environmental Protection Agency, Federal Guidance Report 13 Cancer Risk Coefficients for Environmental Exposure to Radionuclides: CD Supplement, EPA 402-C-99-001 (Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

F. N. Fritsch and R. E. Carlson (1980). "Monotone Piecewise Cubic Interpolation", *SIAM J. Numer. Anal.* 17, 238-246.

ICRP (1979). International Commission on Radiological Protection, "Limits for Intakes by Workers", ICRP Publication 30, Part 1 (Pergamon Press, Oxford).

ICRP (1989). International Commission on Radiological Protection, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides, Part 1", ICRP Publication 56 (Pergamon Press, Oxford).

ICRP (1993). International Commission on Radiological Protection, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides, Part 2", ICRP Publication 67 (Pergamon Press, Oxford).

ICRP (1994). International Commission on Radiological Protection, "Human Respiratory Tract Model for Radiological Protection", ICRP Publication 66 (Pergamon Press, Oxford).

ICRP (1995a). International Commission on Radiological Protection, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides, Part 3", ICRP Publication 69 (Pergamon Press, Oxford).

ICRP (1995b). International Commission on Radiological Protection, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides, Part 4", ICRP Publication 71 (Pergamon Press, Oxford).

ICRP (1996). International Commission on Radiological Protection, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides, Part 5. Compilation of Ingestion and Inhalation Dose Coefficients", ICRP Publication 72 (Pergamon Press, Oxford).

This page intentionally left blank.

APPENDIX H. UNIT CONVERSION TABLE

RADIATION

Absorbed Dose:	100 rad	=	1 Gy
Dose Equivalent:	100 rem	=	1 Sv
Activity:	1 Ci	=	3.7×10^{10} dps = 37 GBq
	1 Bq	=	1 dps = 27 pCi

$$1\frac{Sv}{Bq} = 3.7\times10^{12}\ \frac{rem}{Ci}$$

$$1\frac{\mu Ci}{kg} = 1000\frac{pCi}{g}$$

$$1\frac{(mrem/yr)}{(\mu Ci/m^2)} = 0.114\ \frac{(rem/hr)}{(Ci/m^2)}$$

$$1\frac{Ci}{m^3} = 1\frac{\mu Ci}{cm^3} = 1\frac{mCi}{\ell}$$

$$1\frac{\mu Ci}{m^2} = 1\frac{Ci}{km^2} = 100\frac{pCi}{cm^2}$$

Dose Equivalent

rem	sievert
0.1 mrem	1 μSv
1 mrem	10 μSv
10 mrem	100 μSv (0.1 mSv)
100 mrem	1 mSv
500 mrem	5 mSv
1 rem	10 mSv
5 rem	50 mSv
10 rem	100 mSv
25 rem	250 mSv
50 rem	500 mSv
100 rem	1 Sv

Activity

curie	becquerel
1 pCi	37 mBq
27 pCi	1 Bq
1 nCi	37 Bq
27 nCi	1 kBq
1 μCi	37 kBq
27 μCi	1 MBq
1 mCi	37 MBq
27 mCi	1 GBq
1 Ci	37 GBq
27 Ci	1 TBq
1 kCi	37 TBq
27 kCi	1 PBq
1MCi	37 PBq

Absorbed Dose

100 rad = 1 Gy (gray)

SI Units Prefixes

E	exa	10^{18}	M	mega	10^{6}	μ	micro	10^{-6}
P	peta	10^{15}	k	kilo	10^{3}	n	nano	10^{-9}
T	tera	10^{12}	c	centi	10^{-2}	p	pico	10^{-12}
G	giga	10^{9}	m	milli	10^{-3}			

TIME

1 wk = 168 hr = 10,080 min = 604,800 sec
1 yr = 8,760 hr = 525,600 min = 31,536,000 sec

LENGTH

1 in = 2.540 cm
1 ft = 30.48 cm
1 yd = 0.9144 m
1 nautical mi = 1.151 statute mi
1 m = 39.37 in = 3.281 ft = 1,094 yd
1 km = 3,281 ft = 0.6214 statute mi = 0.5399 nautical mi
1 statute mi = 5,280 ft = 1,760 yd = 1.609 km
1 nautical mi = 6,076 ft = 2,025 yd = 1.852 km

VELOCITY

1 m/s = 3.281 ft/sec = 2.237 mph = 1.943 knots
1 mph = 1.609 km/h = 0.8688 knots
1 mph = 1.467 ft/sec = 0.4469 m/sec
1 km/h = 0.6214 mph = 0.5399 knots
1 km/h = 0.2778 m/sec = 0.9114 ft/sec
1 knot = 1.151 mph = 1.689 ft/sec = 0.5144 m/sec

AREA

1 in^2 = 6.452 cm^2 = 0.006944 ft^2
1 cm^2 = 0.1550 in^2 = 0.001076 ft^2
1 ft^2 = 929.0 cm^2 = 0.1111 yd^2
1 m^2 = 1,550 in^2 = 1.196 yd^2
1 yd^2 = 1,296 in^2 = 0.836 m^2
1 acre = 43,560 ft^2 = 4,047 m^2 = 4,840 yd^2
1 statute mi = 2.590 km^2 = 640 acres
1 km^2 = 0.3861 mi^2 = 247.1 acres
= 10^6 m^2 = 100 ha
1 ha = 100^2 m^2 = 10^4 m^2 = 2.471 acres

VOLUME

1 ℓ = 1,000 cm^3 = 0.001 m^3
1 ℓ = 1.057 qt = 0.2642 gal = 0.2642 fl oz
1 ℓ = 61.02 in^3 = 0.03532 ft^3
1 gal = 4 qt = 8 pt = 128 fl oz
1 gal = 3.785 ℓ = 0.003785 m^3 = 3,785 cm^3
1 gal = 231.0 in^3 = 0.1337 ft^3
1 gal (liquid) = 0.8594 gal (dry)
1 ft^3 = 7.481 gal = 1,728 in^3 = 28.32 ℓ
1 m^3 = 264.2 gal = 35.32 ft^3 = 61,020 in^3
1 acre_ft = 43,560 ft^3 = 325,853 gal = 1,233 m^3
1 bu = 1.244 ft^3 = 8 gal (dry) = 35.24 ℓ
1 bbl = 5.615 ft^3 = 42 gal = 1590.0 ℓ

FLOW RATE

1 cfm = 0.4720 ℓ/sec = 448.9 gal/hr
1 ℓ/sec = 2.119 cfm = 15.85 gal/min
1 m^3/hr = 0.2778 ℓ/sec = 0.5887 cfm
1 gal/min = 0.2271 m^3/hr = 8.022 cfm

WEIGHT

1 lb = 0.4536 kg
1 kg = 2.205 lb = 35.37 oz
1 oz = 28.35 g
1 ton (US) = 2,000 lb
1 ton (US) = 0.9072 tons (metric)
1 metric ton = 1.1023 tons (US) = 2,205 lb

TEMPERATURE

1°C = 1.8°F = 1°K (size)
0°C = 32°F = 273°K (value)
100°C = 212°F = 373°K (value)
°K = °C + 273
°F = (1.8 × °C) + 32
°C = $\frac{(°F - 32)}{1.8}$

DENSITY

$1\ \frac{g}{cm^3} = 1000\ \frac{\text{kg}}{\text{m}^3} = 0.03613\ \frac{\text{lb}}{\text{in}^3} = 62.43\ \frac{\text{lb}}{\text{ft}^3}$

$1\ \frac{\text{lb}}{\text{ft}^3} = 0.0005787\ \frac{\text{lb}}{\text{in}^3} = 16.018\ \frac{\text{kg}}{\text{m}^3} = 0.01618\ \frac{\text{g}}{\text{m}^3}$

1 kg/ℓ = 1 g/cm^3

PRESSURE

1 atm = $14.696\ \frac{\text{lb}}{\text{in}^2}$ = 101.33 kPa = 1.0133 bar
= 760 mm (Hg) = 29.92 in (Hg) = 33.903 ft (H_20)

1 psi = 6.8947 kPa = 68,947 $\frac{\text{dyne}}{\text{cm}^2}$

1 kPa = 0.14503 psi = $10^4\ \frac{\text{dyne}}{\text{cm}^2}$

Pa ≡ N/m^2 = kg/m sec^2

FORCE

1 lb (wt) = 4.4482 N = 453.59 g (wt) = 32.174 poundal

1 poundal ≡ force that would give a free mass of one pound an acceleration of one foot per second per second
= 0.03108 lb (wt)

1 N ≡ $\frac{\text{kg m}}{\text{sec}^2}$ = 0.22481 lb (wt) = 10^5 dyne

1 dyne ≡ $\frac{\text{g cm}}{\text{sec}^2}$ = 0.0010797 g (wt)

ENERGY

1 J = 1 N m = 10^7 ergs = 1 W-sec = 1 V C
= 73,756 ft-lb = 0.2389 cal = 9.481×10^{-4} Btu
= 2.778×10^{-7} kW-hr = 3.725×10^{-7} hp hr
1 cal = 4.1868 J = 3.968×10^{-3} Btu
1 kW-hr = 3,413 Btu = 1.3410 hp hr = 2.655×10^6 ft-lb
1 ℓ atm = 101.3 J = 3.775×10^{-5} hp hr = 24.21 cal
1 Btu = 1,056 J = 252 cal = 0.2933 W-hr
1 amu = 931.16 MeV = 1.492×10^{-10} J = 1.650 g (mass equiv.)
1 eV = 1.60207×10^{-19} J
1 kt ≡ 1×10^{12} cal = 4.186×10^{12} J = 3.968×10^9 Btu
1 MWYE = 8.76×10^6 kW-hr = 3.153×10^{13} J = 0.35 g (mass equiv.)
(all calories are gram calories)

POWER

1 kW = 1.341 hp (mech.) = 1.340 hp (elec.)
1 W = 3.414 Btu/hr = 859.2 cal/hr
1 hp (mech.) = 745.7 W
1 hp (elec.) = 746.0 W
1 Btu/min = 17.58 W
(all calories are gram calories)

FACTOIDS

Water Density = (1 g/cm^3 at 4°C)
1 ft^3 = 7.48 gal = 62.4 lb
1 gal = 8.33 lb

Air Density (0.001293 g/cm^3 at STP)
1 ft^3 = 0.0807 lb
1 m^3 = 1.293 kg

Avogadro's Number
6.02252×10^{23} per g-mole

Molar Volume
22.414 ℓ/g-mole

This page intentionally left blank.

APPENDIX I. GLOSSARY

The glossary contains definitions for terms and acronyms used in the manual.

Acute Health Effects	See Early Health Effects.
AGL	Above ground level.
ALI	Annual Limit of Intake
AMAD	Activity Median Aerodynamic Diameter
AMS	Aerial Measuring System
ARAC	Atmospheric Release Advisory Capability.
ARF	Airborne release fraction
ARG	Accident Response Group
ASHG	Accident Site Health Group
BN	Bechtel Nevada
BWR	Boiling-Water Reactor
CDC	Centers for Disease Control and Prevention
Child	A 10-year-old person.
Cloud Shine	Gamma radiation from radioactive materials in the air (plume).
CMRT	Consequence Management Response Team
Committed Dose Equivalent (CDE)	The dose equivalent to a specific organ for 50 years following intake (inhalation or ingestion). It does not include contributions from external dose.
Committed Effective Dose Equivalent (CEDE)	The sum of the dose equivalent for 50 years following intake (inhalation or ingestion) of a radionuclide to each organ multiplied by a weighting factor. CEDE is used to estimate the risk from delayed health effects.
Concentration	The amount of activity per unit of measure (volume, mass, area, sample, etc.) considered for a sample.

Critical	Most important source of dose, the most important organ, or the most important group of (potentially) exposed population. That is, effects will be dominated by this source of dose or effects (*e.g.*, deaths) will occur first as a result of exposure to this organ or population (*e.g.*, infants) when exposed to radiation through a certain pathway.
Critical Most important source of dose, the most important organ, or the most important group of (potentially) exposed population. That is, effects will be dominated by this source of dose or effects (*e.g.*, deaths) will occur first as a result of exposure to this organ or population (*e.g.*, infants) when exposed to radiation through a certain pathway.	
DAC	Derived Air Concentration
DCENT	Computer database maintained by the FRMAC Data Center
Delayed Health Effects	A wide range of cancers and hereditary effects that usually occur many years after exposure. In contrast to early health effects, it is assumed there are no dose thresholds below which these effects do not occur.
Deposition	The contamination found on the surface of the ground.
Derived Intervention Level (DIL)	The concentration of a radionuclide in food derived from the protective action guide and at which introduction of protective measures should be considered.
Derived Response Level (DRL)	A calculated value (*e.g.*, exposure rate or radionuclide concentration) that corresponds to an early health effect threshold, a PAG, or a DIL. DRLs can be used to relate environmental measurements or laboratory analysis to the potential for early health effects or need for protective actions. Used to facilitate prompt assessments.
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy.
Dose Conversion Factor (DCF)	The dose equivalent per unit intake of a radionuclide (mrem/µCi).
DOT	U.S. Department of Transportation

DQO	Data Quality Objective
DRL	Derived Response Level
Early Health Effects	Health effects that are likely to occur shortly after exposure (hours, weeks) resulting from high doses over a short period (acute doses) to specific organs and involve thresholds below which these health effects are not expected to occur.
Early Phase	The period of time that extends from the time the threat of a major release is identified (before the release) until the release or threat of major release has ended, and areas of major deposition have been identified.
Effective Dose Equivalent (EDE)	The sum of the dose equivalent from external exposure to each organ multiplied by a weighting factor. EDE is used to estimate the risk from delayed health effects. EDE rate from air submersion and ground shine is assumed to equal the exposure rate.
Emergency Worker Guidance	Guidance on the external dose and CEDE incurred by workers (other than a pregnant woman) while performing emergency services.
EPA	U.S. Environmental Protection Agency.
ESRI	Environmental Systems Research Institute, Inc.
External Dose	The dose of radiation received by an individual from a source of ionizing radiation outside the body.
Facility Operator	The organization that operates the facility.
FDA	U.S. Food and Drug Administration.
FRMAC	Federal Radiological Monitoring and Assessment Center.
GIS	Geographic Information System
GM	Geiger-Mueller
Groundshine	Gamma radiation from radioactive materials deposited on the ground.
H&S	Health and Safety
HHS	U.S. Department of Health and Human Services.

Immersion	To be surrounded or engulfed by the radioactive cloud.
Infant	A child one year of age or less.
Intermediate Phase	The period beginning after the release and potential for further major release is over and reliable environmental data are available for use as a basis for relocation and ingestion protective actions. Usually one year of deposition and 30 days of ingestion calculation.
IR	Radionuclide Ratio
LANL	Los Alamos National Laboratory
LET	Linear Energy Transfer
LFA	Lead Federal Agency.
Light-Water Reactor (LWR)	A nuclear reactor that uses natural water as a coolant and moderator. All U.S. commercial power reactors in the United States are LWRs, as are the Russian-constructed VVERs.
LLNL	Lawrence Livermore National Laboratory
Marker Nuclide	A nuclide contained in deposition or samples that is easily identified in the field or laboratory. It is used to determine areas of concern before performing a comprehensive nuclide analysis.
MDA	Minimum Detectable Activity
Mix	The nuclide ratio (relative abundance) of the radionuclides in a sample or deposition.
NARAC	National Atmospheric Release Advisory Center
NDA	National Defense Area
NNSA	National Nuclear Security Administration
NRC	U.S. Nuclear Regulatory Commission.
NSA	National Security Area
Pathways	The paths radionuclides follow from the source through the environment, including vegetation and animals, to reach an individual or a population.

Protective Action Guide (PAG)	The projected dose, from an accidental release of radioactive material, where specific actions to reduce or avoid dose are warranted.
PPE	Personal Protective Equipment
PWR	Pressurized-Water Reactor
Quality Factor (QF)	The principal modifying factor that represents the biological effectiveness of different radiation types with respect to induction of stochastic effects. It is used to calculate the dose equivalent from the absorbed dose. The absorbed dose, expressed in rad or Gy, is multiplied by the appropriate quality factor to obtain the dose equivalent
RAP	Radiological Assistance Program
Relative Biological Effectiveness (RBE)	The RBE of a given type of ionizing radiation is a factor used to compare the biological effectiveness of absorbed radiation doses (i.e., rads) due to one type of ionizing radiation with that of other types of ionizing radiation; more specifically, it is the experimentally determined ratio of an absorbed dose of a radiation in question to the absorbed dose of a reference radiation required to produce an identical biological effect in a particular experimental organism or tissue.
Resuspension	Reintroduction to the atmosphere of material originally deposited onto surfaces.
RF	Respirable fraction
RHU	Radioisotope Heater Unit
RTG	Radioisotope Thermoelectric Generator
RTM	Response Technical Manual.
SCA	Single Channel Analyzer
SCBA	Self-Contained Breathing Apparatus
SI	International System of Units
SNL	Sandia National Laboratories
SNM	Special Nuclear Material

Stability Class	A class that describes conditions of atmospheric turbulence. Classes are generally grouped into six classes ranging from class A, very unstable, through class F, very stable.
TNT	Trinitrotoluene
Total Early Organ Dose ($TEOD_{Organ}$)	Dose estimates used to determine if early health effects are possible from dose to the indicated organ. The organs considered in this manual are the small intestine, red bone marrow, thyroid, and lung. Bone marrow is a critical organ when considering deaths from LWR accidents. TEOD projections in the manual include (1) EDE from air submersion, (2) four days of EDE from ground deposition, (3) early inhalation dose from the plume (dose to the organ for 30 days after inhalation of the radioactive material), and (4) early inhalation from four days of resuspension.
Total Effective Dose Equivalent (TEDE)	The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). Dose projections used for comparison with the EPA Early Phase PAG (EPA92), which is expressed in terms of TEDE, include: (1) the EDE from air submersion, (2) four days of EDE from ground deposition, (3) the inhalation CEDE dose from the plume, and (4) CEDE from inhalation of four days of resuspension.
Total Effective Exposure Period	The time span, considering decay, that will approximate the integrated dose over a period of time when multiplied by the dose rate at the beginning.
Turn-Back Guidance	Guidance given to emergency workers indicating when they should seek areas of lower exposure rate or potential. This guidance is usually implemented via a DRL expressed as an integrated dose reading on a self-reading dosimeter, an exposure rate, or a deposition concentration indicating that the emergency worker should leave the area where further exposure is possible.
USDA	U.S. Department of Agriculture
Weathering	Reduction of dose from deposited radionuclides (external and resuspension) over time due to movement of contamination below the surface or binding on surface materials.

Weighting Factors

An estimate of the mortality risk from delayed health effects arising from irradiation of a particular organ and used to calculate CEDE and EDE.

Organ	**Weighting Factor**[a]
Gonads	0.25
Breasts	0.15
Red Bone Marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone Surface	0.03
Remainder	0.30

[a]Source: EPA88 (page 6)

WGPu

Weapons-Grade Plutonium

This page intentionally left blank.

APPENDIX J. REFERENCES

Reference Title

10 CFR 20 .... *Code of Federal Regulations, Title 10, Part 20 —* S*tandards for protection against radiation*.

An75...................... Anspaugh, L.R., et al. "Resuspension and Redistribution of Plutonium on Soils," *Health Phys*. 29:571-582, 1975.

Be91 .... Beres, D.A. and Hull, A.P. *DEPDOSE: An Interactive Microcomputer Based Program to Calculate Doses from Exposure to Radionuclides Deposited on the Ground, No. 1, Users Manual*. Report No. BNL-47069, Brookhaven National Laboratory; 1991.

Bo92...................... Boughton, B.A. and DeLaurentis, J.M. *Description and Validation of Erad: An Atmospheric Dispersion Model for High Explosive Detonations*, SAND92-2069, Sandia National Laboratories, Albuquerque, NM, October 1992.

DNA72................. Defense Nuclear Agency EM-1 (Effects Manual 1), Capabilities of Nuclear Weapons, 1972.

DNA93................. Defense Nuclear Agency EM-1 (Effects Manual 1), Capabilities of Nuclear Weapons, 1993.

DOE84 .... *Atmospheric Science and Power Production*. Document No. DOE/TIC-27601, U.S. Department of Energy, Washington, DC, 1984.

Du94...................... Durham, J.S. "VARSKIN Mod 2 and SADDE Mod 2: Computer Codes for Assessing Skin Dose from Skin Contamination," NUREG/CR-5873, PNL-5610, Pacific Northwest Laboratory (Nov. 1992; revised Oct./Dec. 1994).

EC01 .... Eckerman, K. "Dose Coefficients for Acute Health Effects" (descriptive text is included as Appendix G), Oak Ridge National Laboratory, September 2001.

EGG75 .... Burson, Z.G., *Structures Shielding from Cloud and Fallout Gamma-Ray Sources for Assessing the Consequence of Reactor Accidents*. Report No. EGG-1183-1670, EG&G, 1975.

EPA70................... Turner. *Workbook of Atmospheric Dispersion Estimates*. U.S. Environmental Protection Agency; 1970.

EPA84................... *An Estimation of the Daily Average Food Intake by Age and Sex for Use in Assessing the Radionuclide Intake of Individuals in the General Population*.

Document No. EPA 520/1-84-021, U.S. Environmental Protection Agency, 1984.

EPA88 .... *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*. Federal Guidance Report No. 11, Document No. EPA 520/1-88-020, U.S. Environmental Protection Agency, 1988.

EPA89 .... *Evaluation of Skin and Ingestion Exposure Pathways*. Document No. EPA 520/1-89-016, U.S. Environmental Protection Agency, 1989.

EPA92 .... *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*. Document No. EPA 400-R-92-001, U.S. Environmental Protection Agency, 1992.

EPA93 .... *External Exposure to Radionuclides in Air, Water, and Soil*. Federal Guidance, Report No. 12, Document No. EPA-402-R-93-081, U.S. Environmental Protection Agency, 1993.

EPA94a .... *PAG Subcommittee Report on Implementation of EPA's Dose Limits for Emergency Workers*. U.S. Environmental Protection Agency, 1994.

EPA94b .... *Guidance for the Data Quality Objectives Process*. EPA QA/G-4, U.S. Environmental Protection Agency, September 1994.

EPA97a .... *Exposure Factors Handbook*. Document No. EPA/600/P-95-002Fa, U.S. Environmental Protection Agency, August 1997.

EPA97b .... *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, EPA 402-R-97-016, U.S. Environmental Protection Agency, December 1997.

FDA98.................. *Accidental Radioactive Contamination of Human Foods and Animal Feeds: Recommendations for State and Local Agencies*. Food and Drug Administration, August 13, 1998.

FEMA87 .... *Guidance on Offsite Emergency Radiation Measurement Systems Phase 2 —The Milk Pathway*. Document No. FEMA REP-12, Federal Emergency Management Agency, 1987.

Ga94...................... Garland, J.A. and Pomeroy, I.R. *Resuspension of Fall-Out Material Following the Chernobyl Accident*. Journal of Aerosol Science, Vol. 25, No. 5, 1994.

Gl77...................... Glasstone, S. and Dolan, P.J. *The Effects of Nuclear Weapons*. U.S. Department of Defense and U.S. Department of Energy, 1977 (3rd edition).

Ho94...................... Homann, S.G. *HOTSPOT Health Physics Codes for the PC*. Report No. UCRL-MA-106315, Version 6.5, Lawrence Livermore National Laboratory, 1994. [Available from NTIS.]

IAEA74................. *Evaluation of Radiation Emergency and Accidents, Selected Criteria and Data*. Technical Reports Series No. 152, International Atomic Energy Agency, Vienna, Austria, 1974.

IAEA86................. *Derived Intervention Levels for Application in Controlling Radiation Doses to the Public in the Event of a Nuclear Accident or Radiological Emergency*. Safety Series No. 81, International Atomic Energy Agency, Vienna, Austria, 1986.

IAEA93................. *Modeling of Weathering Decontamination and Activity Movement in Sewage System*. [Working Draft], International Atomic Energy Agency, Vienna, Austria, 1993.

IAEA94................. *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments*. Technical Reports Series No. 364, International Atomic Energy Agency, Vienna, Austria, 1994.

ICRP74.................. *Report of the Task Group on Reference Man*. ICRP Publication 23, International Commission on Radiological Protection, 1974.

ICRP89.................. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 1*. ICRP Publication 56, International Commission on Radiological Protection, 1989.

ICRP93.................. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 2 Ingestion Dose Coefficients*. ICRP Publication 67, International Commission on Radiological Protection, 1993.

ICRP96.................. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients*. ICRP Publication 72, International Commission on Radiological Protection, 1996.

Me95..................... Mettler, F.A. and Upton, A.C. *Medical Effects of Ionizing Radiation*, 2nd ed.; W. B. Saunders & Co., Philadelphia, 1995.

NCRP84................ *Radiological Assessment: Predicting the Transport, Bioaccumulation and Uptake of Radionuclides Released to the Environment*. NCRP Report No. 76, National Council on Radiation Protection and Measurements, 1984.

NCRP96................ *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground*. NCRP Report No.123 I, National Council on Radiation Protection and Measurements, Bethesda, MD, 1996.

NCRP99 .... *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies*. NCRP Report No. 129, National Council on Radiation Protection and Measurements, 1999.

Ng77...................... Ng, Y.C., Colsher, C.S., Quinn, D.J., and Thompson, S.E. *Transfer Coefficients for the Prediction of the Dose to Man via the Forage-Cow-Milk Pathway from Radionuclides Released to the Biosphere*. Report No. UCRL-51939, Lawrence Livermore National Laboratory, Livermore, California, 1977.

NRC77 .... *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I.* Regulatory Guide 1.109, U.S. Nuclear Regulatory Commission, 1977.

NRC82 .... McGuire, S. *Working Safely in Gamma Radiography, A Training Manual for Industrial Radiographer*. Document No. NUREG/BR-0024, U.S. Nuclear Regulatory Commission, 1982.

NRC83 .... Till, J.E. and Meyer, H.R. *Radiological Assessment: A Textbook on Environmental Dose Analysis*. Document No. NUREG/CR-3332, U.S. Nuclear Regulatory Commission, 1983.

NRC88 .... Ramsdell, J.V. *Atmospheric Diffusion for Control Room Habitability Assessments*. Document No. NUREG/CR-5005, U.S. Nuclear Regulatory Commission, 1988.

NRC88a................. McGuire, S.A. *A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radiological Materials Licensees*. Document No. NUREG-1140, U.S. Nuclear Regulatory Commission, 1988.

NRC89 .... *Health Effects Models for Nuclear Power Plants Accident Consequence Analysis*. Document No. NUREG/CR-4214, Rev. 1, U.S. Nuclear Regulatory Commission, 1989.

NRC93 .... *Response Technical Manual*. RTM93, Document No. NUREG/BR-0150, Vol. 1, Rev. 2, U.S. Nuclear Regulatory Commission, 1993.

NRC94 .... *RASCAL 2.1, Users Manual*. Document No. NUREG/CR-5247, Rev. 2, U.S. Nuclear Regulatory Commission, 1994.

NRC95 .... Soffer, L., et al. *Accident Source Terms for Light-Water Nuclear Power Plants*. Document No. NUREG-1465, U.S. Nuclear Regulatory Commission, 1995.

NRC96 .... *Response Technical Manual*. RTM96, Document No. NUREG/BR-0150, Vol. 1, Rev. 4, U.S. Nuclear Regulatory Commission, 1996.

NRC01 .... Sjoreen, A. L., et al., "*RASCAL 3.0: Description of Models and Methods*," NUREG-1741, U.S. Nuclear Regulatory Commission, 2001.

NRPB85 .... *Doses from Intakes of Radionuclides by Adult and Young People*. Document No. NRPB-R162, National Radiological Protection Board, 1985.

NRPB87 .... *Committed Doses to Selected Organs and Committed Effective Dose for Intake of Radionuclides*. Document No. NRPB-GS7, National Radiological Protection Board, 1987.

PHS70 .... *Radiological Health Handbook*. Document No. PB-230 846, U.S. Public Health Service, 1970.

Su93 .... Sullivan, T.S., Ellis, J.S., et al. *Atmospheric Release Advisory Capability: Real-Time Modeling of Airborne Hazardous Materials*. Bull. Amer. Meteor. Soc. 74:2343-2361, 1993.

Th00 .... Thompson, J.M. and Thompson, E.A. *Savannah River Site Ingestion Pathway Methodology Manual for Airborne Radioactive Releases*, Aiken, SC; Westinghouse Savannah River Company; WSRC-TR-2000-00348, Rev. 0; September 2000.

To01 .... Toohey, R.E., Goans, R.E., and Sugarman, S. "REAC/TS Inputs to FRMAC Assessment Manual." Included as an attachment to an e-mail message from Robert C. Ricks (REAC/TS) to Harvey W Clark (Bechtel Nevada), dated September 6, 2001. (Reproduced in Appendix F.)

UNSCEAR82 .... *Ionizing Radiation: Sources and Biological Effects*. United Nations Scientific Committee on the Effects of Atomic Radiation 1982 Report to the General Assembly, with annexes, United Nations, New York, 1982.

WASH1400........... *Reactor Safety Study*. U.S. Nuclear Regulatory Commission, 1975.

Wa89..................... Wasmer, F.L. 1989. Airrad Fallout Prediction System: Technical Report. Report to Bruce Boughton at Sandia National Laboratories.

This page intentionally left blank.

APPENDIX K. REQUIRED DEPLOYMENT REFERENCES AND CODES

The following list contains the required references and codes used in the manual.

Reference/Code **Title**

Be91 .... Beres, D.A. and Hull, A.P. *DEPDOSE: An Interactive Microcomputer Based Program to Calculate Doses from Exposure to Radionuclides Deposited on the Ground, No. 1, Users Manual*. Report No. BNL-47069, Brookhaven National Laboratory; 1991.

EPA88 .... *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*. Federal Guidance Report No. 11, Document No. EPA 520/1-88-020, U.S. Environmental Protection Agency, 1988.

EPA92 .... *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*. Document No. EPA 400-R-92-001, U.S. Environmental Protection Agency, 1992.

EPA93 .... *External Exposure to Radionuclides in Air, Water, and Soil*. Federal Guidance Report No. 12, Document No. EPA-402-R-93-081, U.S. Environmental Protection Agency, 1993.

FDA98.................. *Accidental Radioactive Contamination of Human Foods and Animal Feeds: Recommendations for State and Local Agencies*. Food and Drug Administration, August 13, 1998.

Ho94 (Code).......... Homann, S.G. *HOTSPOT Health Physics Codes for the PC*. Report No. UCRL-MA-106315, Ver. 6.5, Lawrence Livermore National Laboratory, 1994. [Available from NTIS.]

IAEA94 .... *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments*. Technical Reports Series No. 364, International Atomic Energy Agency, Vienna, Austria, 1994.

ICRP89................. *Age Dependent Doses to Members of the Public from Intake of Radionuclides: Part 1*. Document No. ICRP-56, International Commission on Radiological Protection, 1989.

NRC77 .... *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I*. Regulatory Guide 1.109, U.S. Nuclear Regulatory Commission, 1977.

NRC83 .... Till, J.E. and Meyer, H.R. *Radiological Assessment: A Textbook on Environmental Dose Analysis*. Document No. NUREG/CR-3332, Nuclear Regulatory Commission, 1983.

NRC93 .... *Response Technical Manual*. RTM93, Document No. NUREG/BR-0150, Vol. 1, U.S. Nuclear Regulatory Commission, 1993.

NRC96 .... *Response Technical Manual*. RTM96, Document No. NUREG/BR-0150, Vol. 1, Rev. 4, U.S. Nuclear Regulatory Commission, 1996 (or later version).

NRC94 (Code) ...... *RASCAL 2.1, Users Manual*. Document No. NUREG/CR-5247, Rev.2, U.S. Nuclear Regulatory Commission, 1994.

NRPB85 .... *Doses from Intakes of Radionuclides by Adult and Young People*. Document No. NRPB-R162, National Radiological Protection Board, 1985.

NRPB87 .... *Committed Doses to Selected Organs and Committed Effective Dose for Intake of Radionuclides*. Document No. NRPB-GS7, National Radiological Protection Board, 1987.

Sh92 .... Shleien, B. *Health Physics and Radiological Health Handbook*. Revised Edition, 1992.