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New Stochastic Annual Limits on Intake for Selected Radionuclides

EH Carbaugh

August 2009

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Pacific Northwest National Laboratory
Richland, Washington 99352

Contents

1.0 Introduction

Annual limits on intake (ALI) have historically been tabulated by the International Commission on Radiological Protection (e.g., ICRP 1979, 1961) and also by the Environmental Protection Agency (EPA 1988). These compilations have been rendered obsolete by more recent ICRP dosimetry methods, and, rather than provide new ALIs, the ICRP has opted instead to provide committed dose coefficients from which an ALI can be determined by a user for a specific set of conditions. The U.S. Department of Energy historically has referenced compilations of ALIs and has defined their method of calculation in its radiation protection regulation (10 CFR 835), but has never provided a specific compilation. Under June 2007 amendments to 10 CFR 835, ALIs can be calculated by dividing an appropriate dose limit, either 5-rem (0.05 Sv) effective dose or 50 rem (0.5 Sv) equivalent dose to an individual organ or tissue, by an appropriate committed dose coefficient. When based on effective dose, the ALI is often referred to as a stochastic annual limit on intake (SALI), and when based on the individual organ or tissue equivalent limit, it has often been called a deterministic annual limit on intake (DALI).

This report compiles committed effective dose coefficients and SALIs for inhalation of 5-µm activity median aerodynamic diameter (AMAD) particles. These SALIs are compatible with the June 2007 amendments to 10 CFR 835, and were derived using the dose coefficients of the ICRP Database of Dose Coefficients (ICRP 1998), and the 5-rem (0.05 Sv) effective dose limit of 10 CFR 835 according to the following relationship:

$$SALI\ (Bq) \quad = \quad \frac{0.05\ Sv}{e(50)},$$

where e(50) is the committed effective dose coefficient in units of Sv Bq-1.

The entries for H-3 Type F, M, and S metal tritides were based on dose coefficients published in Appendix A of the "DOE Handbook Radiological Control Programs for Special Tritum Compounds (DOE 2004).

The SALI activities were converted from the International System of Units (SI) unit of becquerel (Bq) to the conventional unit of microcurie (µCi) by dividing by 37,000, based on the fundamental relationship of 1 µCi equaling 37,000 Bq.

The SALIs compiled in this report are for radionuclides identified by the Pacific Northwest National Laboratory and Hanford Site contractors as pertinent or potentially pertinent to radiation work permits associated with various waste management and research activities. The SALIs are not necessarily the most limiting of the annual limits on intake, however they are useful for determining if bioassay monitoring may be warranted based on the amount of radioactive material in process. Bioassay monitoring is required by 10 CFR 835.402(c)(1) if a worker is likely to incur an intake resulting in a committed effective dose of 100 mrem, which corresponds to an intake of 2% of a SALI. This compilation of SALIs is intended as a convenient reference for SALI values which might be used for such determinations. There is no intent for this compilation to be a comprehensive list.

Table 1. (contd)

Table 1. Selected Effective Dose Coefficients and Stochastic Annual Limits on Intake

Radionuclide	Absorption Type	5-µm Inhalation e(50) in Sv Bq-1	Stochastic ALI (Bq)	Stochastic ALI (µCi)	
Ac-225	F	1.0E-06	5.0E+04	1.4E+00	
Ac-225	M	5.7E-06	8.8E+03	2.4E-01	
Ac-225	S	6.5E-06	7.7E+03	2.1E-01	
Ac-227	F	6.3E-04	7.9E+01	2.1E-03	
Ac-227	M	1.5E-04	3.3E+02	9.0E-03	
Ac-227	S	4.7E-05	1.1E+03	2.9E-02	
Ac-228	F	2.9E-08	1.7E+06	4.7E+01	
Ac-228	M & S	1.2E-08	4.2E+06	1.1E+02	
Ag-108m	F	7.3E-09	6.8E+06	1.9E+02	
Ag-110m	S	7.3E-09	6.8E+06	1.9E+02	
Ag-111	S	1.6E-09	3.1E+07	8.4E+02	
Al-26	F	1.4E-08	3.6E+06	9.7E+01	
Am-241	M	2.7E-05	1.9E+03	5.0E-02	
Am-242m	M	2.4E-05	2.1E+03	5.6E-02	
Am-243	M	2.7E-05	1.9E+03	5.0E-02	
Am-244	M	1.5E-09	3.3E+07	9.0E+02	
As-76	M	9.2E-10	5.4E+07	1.5E+03	
Au-195	S	1.2E-09	4.2E+07	1.1E+03	
Au-198	S	1.1E-09	4.5E+07	1.2E+03	
Ba-131	F	3.5E-10	1.4E+08	3.9E+03	
Ba-133	F	1.8E-09	2.8E+07	7.5E+02	
Ba-140	F	1.6E-09	3.1E+07	8.4E+02	
Be-10	S	1.9E-08	2.6E+06	7.1E+01	
Be-7	S	4.6E-11	1.1E+09	2.9E+04	
Bi-207	M	3.2E-09	1.6E+07	4.2E+02	
Bi-210	M	6.0E-08	8.3E+05	2.3E+01	
Bi-212	M	3.9E-08	1.3E+06	3.5E+01	
Bi-214	M	2.1E-08	2.4E+06	6.4E+01	
Bk-249	M	1.0E-07	5.0E+05	1.4E+01	
Br-82	M	8.8E-10	5.7E+07	1.5E+03	
C-14	*	5.8E-10	8.6E+07	2.3E+03	* organic gases and vapors
Ca-45	M	2.3E-09	2.2E+07	5.9E+02	
Cd-109	F	9.6E-09	5.2E+06	1.4E+02	
Cd-113m	F	1.3E-07	3.8E+05	1.0E+01	
Ce-139	S	1.4E-09	3.6E+07	9.7E+02	
Ce-144	S	2.9E-08	1.7E+06	4.7E+01	
Cf-252	M	1.3E-05	3.8E+03	1.0E-01	
Cl-36	M	5.1E-09	9.8E+06	2.6E+02	
Cm-242	M	3.7E-06	1.4E+04	3.7E-01	
Cm-243	M	2.0E-05	2.5E+03	6.8E-02	
Cm-244	M	1.7E-05	2.9E+03	7.9E-02	
Cm-248	M	9.5E-05	5.3E+02	1.4E-02	
Co-57	M	3.9E-10	1.3E+08	3.5E+03	
Co-57	S	6.0E-10	8.3E+07	2.3E+03	

Table 1. (contd)

Radionuclide	Absorption Type	5-µm Inhalation e(50) in Sv Bq-1	Stochastic ALI (Bq)	Stochastic ALI (µCi)	
Co-58	M	1.4E-09	3.6E+07	9.7E+02	
Co-58	S	1.7E-09	2.9E+07	7.9E+02	
Co-60	M	7.1E-09	7.0E+06	1.9E+02	
Co-60	S	1.7E-08	2.9E+06	7.9E+01	
Co-60m	M & S	1.2E-12	4.2E+10	1.1E+06	
Cr-51	S	3.6E-11	1.4E+09	3.8E+04	
Cs-131	F	4.5E-11	1.1E+09	3.0E+04	
Cs-132	F	3.8E-10	1.3E+08	3.6E+03	
Cs-134	F	9.6E-09	5.2E+06	1.4E+02	
Cs-135	F	9.9E-10	5.1E+07	1.4E+03	
Cs-136	F	1.9E-09	2.6E+07	7.1E+02	
Cs-137	F	6.7E-09	7.5E+06	2.0E+02	
Cu-64	M & S	1.5E-10	3.3E+08	9.0E+03	
Es-253	M	2.1E-06	2.4E+04	6.4E-01	
Eu-152	M	2.7E-08	1.9E+06	5.0E+01	
Eu-154	M	3.5E-08	1.4E+06	3.9E+01	
Eu-155	M	4.7E-09	1.1E+07	2.9E+02	
F-18	S	9.3E-11	5.4E+08	1.5E+04	
Fe-55	F	9.2E-10	5.4E+07	1.5E+03	
Fe-59	M	3.2E-09	1.6E+07	4.2E+02	
Ga-72	M	8.4E-10	6.0E+07	1.6E+03	
Ge-71	M	1.1E-11	4.5E+09	1.2E+05	
Gd-153	F	2.5E-09	2.0E+07	5.4E+02	
H-3	HTO*	1.8E-11	2.8E+09	7.5E+04	*tritiated water/vapor
H-3	OBT*	4.1E-11	1.2E+09	3.3E+04	*organically bound tritium
H-3	Type F tritides	5.5E-11	9.1E+08	2.5E+04	Based on DOE (2004 Appendix A
H-3	Type M tritides	8.6E-11	5.8E+08	1.6E+04	Based on DOE (2004 Appendix A
H-3	Type S tritides	2.6E-10	1.9E+08	5.2E+03	Based on DOE (2004 Appendix A
Hg-203	Vapor	7.0E-09	7.1E+06	1.9E+02	
Hg-203	M	1.9E-09	2.6E+07	7.1E+02	
I-125	Vapor	1.4E-08	3.6E+06	9.7E+01	
I-129	Vapor	9.6E-08	5.2E+05	1.4E+01	
I-131	Vapor	2.0E-08	2.5E+06	6.8E+01	
I-132	Vapor	3.1E-10	1.6E+08	4.4E+03	
In-111	M	3.1E-10	1.6E+08	4.4E+03	
In-115m	M	8.7E-11	5.7E+08	1.6E+04	
In-116m	M	8.0E-11	6.3E+08	1.7E+04	
Ir-192	S	4.9E-09	1.0E+07	2.8E+02	
K-40	F	3.0E-09	1.7E+07	4.5E+02	
La-140	M	1.5E-09	3.3E+07	9.0E+02	
Mn-53	F & M	3.6E-11	1.4E+09	3.8E+04	
Mn-54	M	1.2E-09	4.2E+07	1.1E+03	
Mo-93	F	1.4E-09	3.6E+07	9.7E+02	
Mo-99	S	1.1E-09	4.5E+07	1.2E+03	
Na-22	F	2.0E-09	2.5E+07	6.8E+02	

Table 1. (contd)

Radionuclide	Absorption Type	5-µm Inhalation e(50) in Sv Bq-1	Stochastic ALI (Bq)	(µCi)
Na-24	F	5.3E-10	9.4E+07	2.5E+03
Nb-93m	S	8.6E-10	5.8E+07	1.6E+03
Nb-94	S	2.5E-08	2.0E+06	5.4E+01
Nb-95	M & S	1.3E-09	3.8E+07	1.0E+03
Ni-59	Carbonyl	8.3E-10	6.0E+07	1.6E+03
Ni-63	Carbonyl	2.0E-09	2.5E+07	6.8E+02
Np-235	M	2.7E-10	1.9E+08	5.0E+03
Np-236	M	2.0E-06	2.5E+04	6.8E-01
Np-237	M	1.5E-05	3.3E+03	9.0E-02
Np-239	M	1.1E-09	4.5E+07	1.2E+03
P-32	M	2.9E-09	1.7E+07	4.7E+02
P-33	M	1.3E-09	3.8E+07	1.0E+03
Pb-210	F	1.1E-06	4.5E+04	1.2E+00
Pb-211	F	5.6E-09	8.9E+06	2.4E+02
Pb-212	F	3.3E-08	1.5E+06	4.1E+01
Pb-214	F	4.8E-09	1.0E+07	2.8E+02
Pd-103	M	3.0E-10	1.7E+08	4.5E+03
Pd-107	S	2.9E-10	1.7E+08	4.7E+03
Pm-147	M	3.5E-09	1.4E+07	3.9E+02
Po-210	M	2.2E-06	2.3E+04	6.1E-01
Pr-144	S	3.0E-11	1.7E+09	4.5E+04
Pu-236	M	1.3E-05	3.8E+03	1.0E-01
Pu-237	S	3.0E-10	1.7E+08	4.5E+03
Pu-238	M	3.0E-05	1.7E+03	4.5E-02
Pu-238	S	1.1E-05	4.5E+03	1.2E-01
Pu-239	M	3.2E-05	1.6E+03	4.2E-02
Pu239	S	8.3E-06	6.0E+03	1.6E-01
Pu-240	M	3.2E-05	1.6E+03	4.2E-02
Pu-240	S	8.3E-06	6.0E+03	1.6E-01
Pu-241	M	5.8E-07	8.6E+04	2.3E+00
Pu-241	S	8.4E-08	6.0E+05	1.6E+01
Pu-242	M	3.1E-05	1.6E+03	4.4E-02
Pu-242	S	7.7E-06	6.5E+03	1.8E-01
Pu-244	M	3.0E-05	1.7E+03	4.5E-02
Pu-244	S	7.4E-06	6.8E+03	1.8E-01
Ra-223	M	5.7E-06	8.8E+03	2.4E-01
Ra-224	M	2.4E-06	2.1E+04	5.6E-01
Ra-225	M	4.8E-06	1.0E+04	2.8E-01
Ra-226	M	2.2E-06	2.3E+04	6.1E-01
Ra-228	M	1.7E-06	2.9E+04	7.9E-01
Rb-86	F	1.3E-09	3.8E+07	1.0E+03
Rh-103m	S	2.5E-12	2.0E+10	5.4E+05
Rh-106m	S	1.9E-10	2.6E+08	7.1E+03
Ru-103	S	2.2E-09	2.3E+07	6.1E+02
Ru-106	S	3.5E-08	1.4E+06	3.9E+01
S-35	M	1.1E-09	4.5E+07	1.2E+03
Sm-153	M	6.8E-10	7.4E+07	2.0E+03
Sb-125	M	3.3E-09	1.5E+07	4.1E+02

Table 1. (contd)

Radionuclide	Absorption Type	5-µm Inhalation e(50) in Sv Bq-1	Stochastic ALI (Bq)	(µCi)
Sb-126	M	3.2E-09	1.6E+07	4.2E+02
Sb-129	M	3.5E-10	1.4E+08	3.9E+03
Sc-46	S	4.8E-09	1.0E+07	2.8E+02
Se-75	M	1.7E-09	2.9E+07	7.9E+02
Se-79	M	3.1E-09	1.6E+07	4.4E+02
Sm-151	M	2.6E-09	1.9E+07	5.2E+02
Sn-113	M	1.9E-09	2.6E+07	7.1E+02
Sn-121m	M	3.3E-09	1.5E+07	4.1E+02
Sn-125	M	2.8E-09	1.8E+07	4.8E+02
Sn-126	M	1.8E-08	2.8E+06	7.5E+01
Sr-85	F	5.6E-10	8.9E+07	2.4E+03
Sr-85	S	6.4E-10	7.8E+07	2.1E+03
Sr-89	F	1.4E-09	3.6E+07	9.7E+02
Sr-89	S	5.6E-09	8.9E+06	2.4E+02
Sr-90	F	3.0E-08	1.7E+06	4.5E+01
Sr-90	S	7.7E-08	6.5E+05	1.8E+01
Sr-91	F	2.9E-10	1.7E+08	4.7E+03
Sr-91	S	5.7E-10	8.8E+07	2.4E+03
Ta-182	S	7.4E-09	6.8E+06	1.8E+02
Tb-160	M	5.4E-09	9.3E+06	2.5E+02
Tc-95m	M	8.6E-10	5.8E+07	1.6E+03
Tc-97	M	1.6E-10	3.1E+08	8.4E+03
Tc-97m	M	2.7E-09	1.9E+07	5.0E+02
Tc-99	M	3.2E-09	1.6E+07	4.2E+02
Tc-99m	M	2.9E-11	1.7E+09	4.7E+04
Te-123m	M	3.4E-09	1.5E+07	4.0E+02
Te-125m	M	2.9E-09	1.7E+07	4.7E+02
Te-132	Vapor	5.1E-09	9.8E+06	2.6E+02
Th-227	M	6.2E-06	8.1E+03	2.2E-01
Th-227	S	7.6E-06	6.6E+03	1.8E-01
Th-228	M	2.2E-05	2.3E+03	6.1E-02
Th-228	S	2.5E-05	2.0E+03	5.4E-02
Th-229	M	6.9E-05	7.2E+02	2.0E-02
Th-229	S	4.8E-05	1.0E+03	2.8E-02
Th-230	M	2.8E-05	1.8E+03	4.8E-02
Th-230	S	7.2E-06	6.9E+03	1.9E-01
Th-232	M	2.9E-05	1.7E+03	4.7E-02
Th-232	S	1.2E-05	4.2E+03	1.1E-01
Th-234	M	5.3E-09	9.4E+06	2.5E+02
Th-234	S	5.8E-09	8.6E+06	2.3E+02
Tl-204	F	6.2E-10	8.1E+07	2.2E+03
Tm-171	M	9.1E-10	5.5E+07	1.5E+03
U-232	M	4.8E-06	1.0E+04	2.8E-01
U-232	S	2.6E-05	1.9E+03	5.2E-02
U-233	M	2.2E-06	2.3E+04	6.1E-01
U-233	S	6.9E-06	7.2E+03	2.0E-01
U-234	M	2.1E-06	2.4E+04	6.4E-01
U-234	S	6.8E-06	7.4E+03	2.0E-01

Table 1. (contd)

Radionuclide	Absorption Type	5-µm Inhalation e(50) in Sv Bq-1	Stochastic ALI (Bq)	Stochastic ALI (µCi)
U-235	M	1.8E-06	2.8E+04	7.5E-01
U-235	S	6.1E-06	8.2E+03	2.2E-01
U-236	M	1.9E-06	2.6E+04	7.1E-01
U-236	S	6.3E-06	7.9E+03	2.1E-01
U-238	M	1.6E-06	3.1E+04	8.4E-01
U-238	S	5.7E-06	8.8E+03	2.4E-01
U-239	M	3.3E-11	1.5E+09	4.1E+04
U-239	S	3.5E-11	1.4E+09	3.9E+04
V-49	F	2.6E-11	1.9E+09	5.2E+04
W-185	F	2.2E-10	2.3E+08	6.1E+03
W-187	F	3.3E-10	1.5E+08	4.1E+03
Y-88	M	3.3E-09	1.5E+07	4.1E+02
Y-88	S	3.0E-09	1.7E+07	4.5E+02
Y-90	M	1.6E-09	3.1E+07	8.4E+02
Y-90	S	1.7E-09	2.9E+07	7.9E+02
Zn-65	S	2.8E-09	1.8E+07	4.8E+02
Zr-93	F	2.9E-08	1.7E+06	4.7E+01
Zr-95	S	4.2E-09	1.2E+07	3.2E+02

2.0 References

10 CFR 835. 2009. U.S. Department of Energy, Occupational Radiation Protection. U.S. Code of Federal Regulations. Accessed on 7/28/2009 at http://www.gpoaccess.gov/cfr.

International Commission on Radiological Protection (ICRP). 1979. Limits for Intakes of Radionuclides by Workers. ICRP Publication 30 Part 1. Annals of the ICRP, Volume 2 No. 3/4. Pergamon Press.

International Commission on Radiological Protection (ICRP). 1991. Annual Limits on Intake of Radionuclides by Workers Based on the 1990 Recommendations. Annals of the ICRP, Volume 21 No 4. Pergamon Press.

International Commission on Radiological Protection (ICRP). 1998. The ICRP Database of Dose Coefficients: Workers and Members of the Public. Version 2.01, update 2001. Pergamon. Distributed by Elsevier Science Ltd., Tarrytown, NY.

U.S. Environmental Protection Agency. 1988. Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. Federal Guidance Report No. 11. U.S. Environmental Protection Agency. Washington, D.C.

U.S. Department of Energy. 2004. DOE Handbook – Radiological Control Programs for Special Tritium Compounds. DOE-HBK-1184-2004. U.S. Department of Energy. Washington, D.C.