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memorandum

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DATE: August 9, 2002

REPLY TO ATTN OF: Office of Environmental Policy and Guidance: EH-412 Peterson 6-9640

SUBJECT: Radiation Risk Estimation from Total Effective Dose Equivalents (TEDEs)

TO: Distribution

The Interagency Steering Committee on Radiation Standards (ISCORS) recently issued guidance on calculating radiation risk estimates from dose. An EH-41 Information Brief discussing the method and the ISCORS technical report, "A Method for Estimating Radiation Risk from TEDE," are attached. Exposure-to-risk estimates have been tabulated in a 1999 report, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13*. This report was distributed within DOE previously for limited review and comment and it is now available on the EH-41 web site: http://www.eh.doe.gov/oepa. Although the approach used in Federal Guidance Report # 13 is more appropriate for circumstances where a radiation risk assessment is required than the dose-to-risk approach in the attached report, it is applicable only when the intake of an inhaled or ingested radionuclide is known or the radionuclide concentration in air, water or on the ground is known. In many cases, doses (specifically the TEDE) are calculated directly from computer codes and estimates of the intake or radionuclide concentrations are not directly available. The attached document is intended to facilitate the estimation of risk in those situations where dose (TEDE) is calculated directly.

If you have any questions concerning this guidance please contact Hal Peterson (202-586-9640 or harold.peterson@eh.doe.gov).

Andy Lawrence

Andy Lawrence
Director
Office of Environmental Policy & Guidance

Attachments: (2)
1. InfoBrief EH-412-2002-1
2. ISCORS Technical Report No.1

Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE) ISCORS Technical Report No. 1

The Interagency Steering Committee on Radiation Standards (ISCORS), issued a technical report entitled *"A Method for Estimating Radiation Risk from TEDE."* ISCORS technical reports are guidance to Federal agencies to assist them in preparing and reporting the results of analyses and implementing radiation protection standards in a consistent and uniform manner. This report provides dose-to-risk conversion factors where doses are estimated using total effective dose equivalent. Its is recommended for use by Department of Energy personnel and contractors when computing potential radiation risk from calculated radiation dose for comparison purposes. However, for situations in which a radiation risk assessment is required for making risk management decisions, the radionuclide-specific risk coefficients in Federal Guidance Report No. 13 should be used.

Estimation of the potential risk from low levels of ionizing radiation requires application of dose-to-risk conversion factors to an estimate of the dose. The Environmental Protection Agency, in coordination with other Federal agencies involved in radiation protection, has issued Federal Radiation Guidance Report # 13, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (FRG # 13), September 1999. This document is a compilation of risk factors for doses from external gamma radiation and internal intakes of radionuclides. FRG #13 is the basis of the radionuclide risk coefficients used in the EPA Health Effects Assessment Summary Tables (HEAST, EPA 2001) and in computer dose codes such as the DOE-Argonne RESRAD code.

However, the Department and other agencies regularly conduct dose assessments with models and codes that calculate radiation dose from exposure or intake using dose conversion factors (FRG#11 and FRG#12[1]) and do not compute risk directly. In these cases, where it is necessary or desirable to estimate risk for comparative purposes (e.g., comparing the risk associated with alternative actions), it is common practice to simply multiply the calculated total effective dose equivalent (TEDE) by a risk-to-dose factor. DOE previously recommended a TEDE-to-fatal cancer risk factors of 5×10^{-4} rem^{-1} for the public and 4×10^{-4} rem^{-1} for working-age populations. These values were based upon recommendations of the former Committee on Interagency Radiation Research and Policy Coordination (CIRRPC 1992). The ISCORS guidance supercedes the 1992 CIRRPC guidance and recommends that agencies use a conversion factor of 6×10^{-4} fatal cancers per TEDE (rem) for mortality and 8×10^{-4} cancers per rem for morbidity when making qualitative or semi-quantitative estimates of risk from radiation exposure to members of the general public[2].

The TEDE-to-risk factor provided by ISCORS in Technical Report 1 is based upon a static population with characteristics consistent with the U. S. population. There are no separate ISCORS recommendations for workers. For workers (adults), a risk of fatal cancer of 5×10^{-4} rem^{-1} and a morbidity risk of 7×10^{-4} rem^{-1} may be used. However, given the uncertainties in the risk estimates, for most estimates the value for the general population of 6×10^{-4} rem^{-1} could be used for workers.

The Office of Environmental Policy and Guidance (OEPG) recommends use of these values, but we also emphasize that they are principally suited for comparative analyses and where it would be impractical to calculate risk using FRG Report 13. If risk estimates for specific radionuclides are needed, the cancer risk coefficients in FRG#13 should be used.

The ISCORS report notes that the recommended risk

[1] Federal Guidance Reports No. 11 and No.12 or DOE equivalent guidance in DOE/EH-0070 and DOE/EH-0071.

[2] Such estimates should not be stated with more than 1 significant digit.

coefficients used with TEDE dose estimates generally produce conservative radiation risk estimates (i.e., they overestimate risk)[3]. For the ingestion pathway of eleven radionuclides compared, risks would be overestimated compared to the FRG#13 values for about eight radionuclides and significantly overestimated (by up to a factor of six) for four of these. OEPG also compared the TEDE x conversion factor approach to FGR#13 for the inhalation pathway and found a bias toward overestimation of risk, although it was not as severe as for ingestion. For 16 radionuclides/ chemical states evaluated, seven were significantly overestimated (by more than a factor of two) and five were significantly underestimated and the remainder agreed within about a factor of two. Generally, these differences are within the uncertainty of transport and uptake portions of dose or risk modeling and, therefore, the approach recommended is fully acceptable for comparative assessments. That notwithstanding, it is strongly recommended that, wherever possible, the more rigorous approach with FGR#13 cancer risk coefficients, be used.

References:

CIRRPC, 1992. Science Panel Report No. 9, *Use of BEIR V and UNSCEAR 1988 in Radiation Risk Assessment - Lifetime Total Cancer Mortality Risk Estimates at Low Doses and Low Dose Rates for Low-LET Radiation*, Committee on Interagency Radiation Research and Policy Coordination, December 1992.

DOE, 1988a. *External Dose-Rate Conversion Factors for Calculation of Dose to the Public,* DOE Report DOE/EH-0070, July 1988.

DOE, 1988b. *Internal Dose Conversion Factors for Calculation of Dose to the Public*, DOE Report DOE/EH-0071, July 1988.

EPA, 1988. Federal Guidance Report No. 11, "*Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion,*" EPA-520/1-88-020, September 1988. (Available at www.eh.doe.gov/oepa/ in the "focus areas" under "dose and risk assessment" under "Dose and Risk Assessment Databases" or at the web link www.epa.gov/radiation/federal/techdocs.htm).

EPA, 1993. Federal Guidance Report No. 12, "*External Exposure to Radionuclides in Air, Water, and Soil,*" EPA 402-R-93-081, September 1993. (Available at www.eh.doe.gov/oepa/ in the "focus areas" under "dose and risk assessment" under "Dose and Risk Assessment Databases" or the web link www.epa.gov/radiation/federal/techdocs.htm).

EPA, 1999. Federal Guidance Report No. 13, "*Cancer Risk Coefficients for Environmental Exposure to Radionuclides.*" EPA 402-R-99-001, September 1999. (See http:// www.epa.gov/radiation/federal/techdocs.htm).

EPA, 2001. U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, *Health Effects Assessment Summary Tables* (HEAST) - Radionuclides Table (April 16, 2001) (Available from http://www.epa.gov/radiation/ heast).

ISCORS, 2002. ISCORS Technical Report No. 1, *A method for Estimating Radiation Risk from TEDE*, Interagency Steering Committee on Radiation Standards, July 2002. (Available at www.iscors.org or www.eh.doe.gov/oepa/ in the "policy and guidance" area under "radiation protection.")

National Research Council,1990. Committee on the Biological Effects of Ionizing Radiation (BEIR), *Health Effects of Exposure to Low Levels of Ionizing Radiation, (BEIR V),* 1990. (Available for sale from the National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20055 or http://www.nap.edu.)

[3] This statement presumes that FRG#13 is a more accurate measure of potential risk than multiplying the Total Effective Dose Equivalent (TEDE) by a single average risk factor. The numerical estimate of cancer deaths is based upon the linear extrapolation of risk estimates for total cancer mortality derived at radiation doses above 10 rad (0.1 Gy). Other methods of extrapolation would yield higher or lower risk estimates at low doses. Epidemiological studies of human radiation exposure are not sufficiently sensitive to determine the actual level of risk. There is scientific uncertainty about cancer risk in the low-dose region and the possibility of zero risk cannot be excluded (NAS-NRC 1990, CIRRPC 1992).

Interagency Steering Committee on
Radiation Standards

A Method for Estimating Radiation Risk from TEDE

ISCORS Technical
Report No. 1
July 2002

A Method for Estimating Radiation Risk From TEDE

Summary

For external sources of low linear energy transfer (LET) radiation that provide nearly uniform irradiation of the body, the risk of cancer incidence (morbidity) and mortality as a function of external dose can be closely approximated using the conversion factors of 8×10^{-2} risk per sievert and 6×10^{-2} risk per sievert respectively. The documentation for these conversion factors can be found in "Estimating Radiogenic Cancer Risks" and its "Addendum: Uncertainty Analysis."[1] These conversion factors can also provide a generally high-sided, but less accurate, estimation of risk from internal dose. A discussion of the sources and limits of this conservatism is presented in the discussion below. Using these factors to convert internal effective dose equivalent to cancer risk may be appropriate when radionuclide-specific data is missing. The conversion of dose to risk referred to in this document refers primarily to a conversion of total effective dose equivalent (TEDE, as defined by the Department of Energy in 10 CFR 835.2)[2] to lifetime cancer incidence and mortality risks. The conversion of TEDE to cancer risks using these conversion factors will not satisfy the requirements for a comprehensive radiation risk assessment, but may be of use for making less rigorous comparisons of risk. For situations in which a radiation risk assessment is required for making risk management decisions, the radionuclide-specific risk coefficients published in Federal Guidance Report No. 13 should be used.[3] For radiation risk assessments required by EPA's Superfund Program, the risk coefficients in EPA's Health Effects Assessment Summary Tables (HEAST)[4] should be used. Although based on the values in FGR 13, the HEAST risk coefficients (slope factors) are for calculating cancer incidence only; include a risk coefficient for soil ingestion; and use traditional units (i.e., picocuries instead of becquerels for activity).

Discussion

The Environmental Protection Agency has published radionuclide-specific risk coefficients (also called slope factors in the Superfund Program) in Federal Guidance Report No. 13 (FGR 13), "Cancer Risk Coefficients for Environmental Exposure to Radionuclides" (EPA 402-R-99-001, September 1999). This report includes separate coefficients for water and food ingestion, inhalation, and external exposure for over 800 radionuclides. These values, along with an additional soil ingestion coefficient, are also presented in the Health Effects Assessment Summary Tables (HEAST) where they are referred to as slope factors. These risk coefficients are recommended for use whenever a quantitative risk assessment is required. There are also times when it is useful to make a general qualitative statement about the risk associated with dose, which in the United States at present is expressed as effective dose equivalent (H_E).

The dose quantity H_E is a risk-weighted mean of the dose equivalent for selected groups of organs and tissues. The values of the weighting factors are defined in International Commission on Radiological Protection (ICRP) Publication 26 which considered nominal estimates of both genetic and cancer mortality risks due to ionizing radiation. The dose coefficients in FGR 11 are consistent with the methodology of ICRP Publication 30 which used age-invariant dose models considered appropriate at the time of its publication and the ICRP Publication 26 weighting factors in its calculations of annual

limits on intake and derived air concentrations for over 700 radionuclides. The cancer risk coefficients in FGR 13/HEAST are calculated using the more recent age-specific dose models developed for ICRP Publication 72 and its supporting publications with the age-specific radiation carcinogenesis models adopted by EPA. (In ICRP 60, the dose quantity, E, is called effective dose to distinguish it from the older quantity, H_E .) Thus the differences in dose models and the prescribed method for the calculation of H_E mean that there can be no unique relationship between the dose coefficients provided by FGR 11 and the risk coefficients provided by FGR 13/HEAST. Further differences arise due to the use of committed dose equivalent for calculating H_E and the use of age-specific high- and low-LET absorbed dose rates for calculating FGR 13/HEAST risks. Another complication for alpha particle emitting radionuclides arises from the use of site-specific relative biological effectiveness values (RBEs) in FGR 13/HEAST as opposed to using ICRP-specified quality factors, which by definition are independent of site, in determining H_E. There are additional factors that make a simple dose to risk conversion unsatisfactory, including the overestimation of H_E for bone-seeking transuranics, the use of a site-specific dose and dose rate effectiveness factor (DDREF), and a life table analysis to account for competing causes of death in FGR 13/HEAST. In short, it is not possible to convert a dose assessment made using FGR 11 dose coefficients into a risk assessment that will be consistent with FGR 13/HEAST.

For external sources of beta and gamma radiation (low LET) that provide nearly uniform irradiation of the body, these problems are greatly mitigated. For cancer incidence (morbidity) and mortality, factors of 8×10^{-2} risk per sievert and 6×10^{-2} risk per sievert may be used, respectively, to estimate cancer risk per H_E. Using these factors to convert internal effective dose equivalent, H_E, to cancer risk must include appropriate caveats as noted above.

An EPA internal document from March 1996[5] examined the degree to which the risk per unit dose for individual radionuclides agreed with a lifetime cancer incidence risk of 3×10^{-4} from receiving 15 millirem/year over 30 years. This relationship corresponded to the estimate at that time of about 7×10^{-2} risk per sievert (or 7×10^{-7} risk per millirem). For the reasons just described, a constant linear relationship between risk and dose is not expected. However, the analysis showed that almost all radionuclides were within a factor of ten of this relationship and most were within a factor of 3. The relationship between risk and dose for some of the bone-seeking transuranics represents the extreme, with the nominal conversion factors overestimating the risk by about a factor of ten. The radionuclides whose risks are underestimated by the given conversion factor do not exceed the predicted risk by more than a factor of 3. The important radionuclides in this category include Cs-137 (factor of 1.7 higher), Pu-244+D (includes all nuclides in secular equilibrium) and Tc-99 (both about a factor of 3 higher). From this analysis, it is reasonable to assume that the current risk to dose relationships are predictive to within about the same degree of uncertainty.

When radionuclide-specific data is missing, it is common to have dose recorded as the TEDE. This quantity is defined by DOE as the sum of the effective dose equivalent (external exposure) and the committed effective dose equivalent (internal exposure). TEDE can be estimated using the conversion factors for uniform low LET external radiation provided the caveats mentioned above are acknowledged. In general, using these coefficients to convert TEDE to risk for a mixture of

radionuclides will usually provide a high-sided estimate of risk.

These factors are recommended for comparison and qualitative presentations only. Only one significant digit should be presented in a calculated risk to avoid implying more certainty than is warranted. Table 1 (below) provides some comparisons between cancer risk coefficients calculated using FGR 11 dose coefficients with these approximations and those in FGR13.

Table 1. Nominal cancer risk coefficients for ingestion of a few radionuclides calculated from FGR 11 dose coefficients and a comparison between them and those in FGR 13.

Nuclide	FGR 11			Ratio($r_{FGR\,11} : r_{FGR\,13}$)			
	h_E	$r_{mt} = 0.06 \times h_E$	$r_{mb} = 0.08 \times h_E$	Tap Water		Dietary	
	(Sv/Bq)	(/Bq)	(/Bq)	mortality	morbidity	mortality	morbidity
H-3 (HTO)	1.73e-11	1.0e-12	1.4e-12	1.10	1.01	0.87	0.79
H-3 (org)	n/a			0.50	0.46	0.39	0.36
C-14	5.64e-10	3.4e-11	4.5e-11	1.17	1.07	0.92	0.84
Co-60	7.28e-09	4.4e-10	5.8e-10	1.59	1.37	1.13	0.97
Sr-90	3.85e-08	2.3e-09	3.1e-09	1.72	2.04	1.43	1.66
I-131	1.44e-08	8.6e-10	1.2e-09	6.60	0.94	4.67	0.66
Cs-137	1.35e-08	8.1e-10	1.1e-09	1.43	1.31	1.18	1.07
Po-210 (inorg)	5.14e-07	3.1e-08	4.1e-08	4.17	4.03	3.29	3.14
Po-210 (org)	n/a			0.87	0.86	0.69	0.68
U-238	6.88e-08	4.1e-09	5.5e-09	3.65	3.18	2.73	2.35
Pu-239	9.96e-08	6.0e-09	8.0e-09	2.10	2.19	1.65	1.70

Note that separate dose coefficients for organically bound forms of tritium (H-3) and Po were not calculated for FGR 11. Usually, Po would be considered organic in food but inorganic in water. The FGR 11 dose coefficient normally used as a default is used when dose coefficients for multiple values of f_1 are tabulated.

1. The values of 6×10^{-2} risk per sievert for cancer mortality and 8×10^{-2} risk per sievert for cancer incidence from low LET radiation are rounded values that are documented in the EPA publications, "Estimating Radiogenic Cancer Risk" and its "Addendum: Uncertainty Analysis." In particular, the increase in the incidence risk from about 7×10^{-2} to about 8×10^{-2} risk per sievert is documented on page 1 of the Uncertainty Analysis. These documents can be downloaded from EPA's web site at

http://www.epa.gov/radiation/assessment/pubs.html

2. The term total effective dose equivalent or TEDE, was first introduced by the Nuclear Regulatory Commission (NRC) where it is defined as the sum of the committed effective dose equivalent and the deep dose equivalent. The definition used by DOE is consistent with the ICRP definition of effective dose equivalent.

3. Federal Guidance Report No. 13, "Cancer Risk Coefficients for Environmental Exposure to Radionuclides" (EPA 402-R-99-001), is available on the internet at http://www.epa.gov/radiation/assessment/pubs.html.

4.The HEAST slope factors are used in risk assessments conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). To see how HEAST slope factors have been incorporated into EPA risk assessment guidance for CERCLA, please see "Soil Screening Guidance for Radionuclides: User's Guide" (OSWER No. 9355.4-16A, October 2000). An electronic version of the risk assessment equations in this guidance can be found on the Internet at: http://risk.lsd.ornl.gov/rad_start.shtml. HEAST may be found on the internet at http://www.epa.gov/radiation/heast/download.htm.

5. An EPA contractor report, "Comparison of Regulatory Methods for Expressing Radiation Dose Limits and EPA's Methods for Estimating Risks: Implications Concerning the Radiation Site Cleanup Standard" (March, 1996), examined the relationship between risk and dose using risk coefficients in place at the time (pre-FGR 13). It is reasonable to assume that the ratios calculated at that time are still reasonably indicative of the relationships that would be calculated using the current risk coefficients. That is, more radionuclide risks will be overestimated than underestimated and the extremes will likely not exceed about an order of magnitude. This assumption is based on the generally small changes in magnitude between FGR 13 and the risk coefficients it replaced.