Evolving Adjustments to External (Gamma) Slope Factors for CERCLA Risk and Dose Assessments - 12290

Stuart Walker
U.S. Environmental Protection Agency

ABSTRACT

To model the external exposure pathway in risk and dose assessments of radioactive contamination at Superfund sites, the U.S. Environmental Protection Agency (EPA) uses slope factors (SFs), also known as risk coefficients, and dose conversion factors (DCFs). Without any adjustment these external radiation exposure pathways effectively assumes that an individual is exposed to a source geometry that is effectively an infinite slab. The concept of an “infinite slab” means that the thickness of the contaminated zone and its aerial extent are so large that it behaves as if it were infinite in its physical dimensions. EPA has been making increasingly complex adjustments to account for the extent of the contamination and its corresponding radiation field to provide more accurate risk and dose assessment modeling when using its calculators.

INTRODUCTION

Prior to 2000, EPA assumed for purposes of estimating the external pathway for risk and dose assessment of radioactive contamination at Superfund sites, the contamination existed over an infinite distance and depth. In more recent years, EPA has issued new guidance to more accurately reflect the gamma radiation fields posed by contamination at Superfund sites.

METHOD AND RESULTS

Initial area correction factors (ACFs) for soil

In Part 5 of the “Soil Screening Guidance for Radionuclides: Technical Background Document” [1], EPA developed Area Correction Factors (ACFs) for adjusting slope factors for eight site sizes. In this guidance EPA provided recommended ACFs for radionuclides as a function of source area calculated using MicroShield V5.01.1. Since the default source size is 0.5-acre (i.e., 2,000 m^2), the default ACF for default soil screening level risk assessment equations were set at 0.9. The calculations assumed a uniform layer of contamination 15 cm deep with a soil density of 1.6 g/cm^3. A single recommended value was considered suitable for all radionuclides over the range of source areas since EPA’s analysis shows that ACFs vary little from one radionuclide to another.

EPA has also provided examples of ACFs for seven radionuclides as a function of source area calculated using MicroShield V5.01. The calculations again assumed a uniform layer of contamination 15 cm deep with a soil density of 1.6 g/cm^3. The guidance recommended that users that have one of the radionuclides from the analysis as a contaminant at their site may use the radionuclide specific ACF that is appropriate for their source area rather than the general value otherwise used for all radionuclides.

Adjustments for buildings

For the Preliminary Remediation Goals for Radionuclides in Buildings (BPRG) electronic calculator issued on August 29, 2007 [2], EPA made two sets of further enhancements. First, EPA issued external ground plane SFs for 800 radionuclides for assessing contamination that existed only on the surface of walls, floors, or ceiling. This was in addition to the traditional external SFs that assumed an infinite depth. These ground plane slope factors were developed by converting the ground plane external DCFs in Federal Guidance 13. [3]

Second, EPA issued surfaces factors (FSURF) to account for the varying radiation fields inside a contaminated room within a structure. The surfaces factor, in the recommended default and site-specific equations, is based on exposure to 4 walls, the floor and the ceiling in a room. This calculator uses the relationship between the dose rate coefficients for exposures in a contaminated room and dose rate coefficients for an infinite source to calculate a surfaces factor (FSURF). The dose quantity evaluated is the air kerma rate one meter above the floor. The floor, walls and ceiling of the rooms are assumed to be contaminated to the same level. 81 locations in 5 room sizes, ranging from 10 by 10 by 10 feet to 400 by 400 by 40 feet, were modeled to account for the dose contribution from multiple surfaces. The FSURF for the default option is set to the most protective value across the 5 room sizes and 4 receptor positions. In the site-specifc option the user can select from the 5 room sizes and 4 receptor positions: average, center, center wall and corner for each of 800 radionuclides. Further, photon energies of each radioisotope were incorporated into the modeling. The methodology for developing isotope-specific dose rates and the results are discussed in the report "Dose Rates in Contaminated Rooms of Various Sizes" [4]. The results show that only at very low photon energies, is the position of the receptor in the room likely to be relevant. Also shown is that only at very low photon levels is the size of the room likely to be relevant as shown in Figures 1 and 2. The report contains a table of the 16,000 FSURF values used in the BPRG calculator for each radioisotope, room size and receptor position.

Adjustments for Outside Hard Surfaces

For the Preliminary Remediation Goals for Radionuclides in Outdoor Surfaces (SPRG) electronic calculator issued on January 16, 2009[5], EPA made three sets of further enhancements, each of which were made for 800 radionuclides. First, EPA issued external 1 centimetre, 5 centimetre, and 15 centimetre SFs for contamination that had was only as thick as each of those respective amounts. These external SFs were in addition to the ground plane SF first used in the BPRG calculator and the traditional infinite depth SF. These differing centimetre slope factors were developed by converting the centimetre DCFs in Federal Guidance 13.[3].

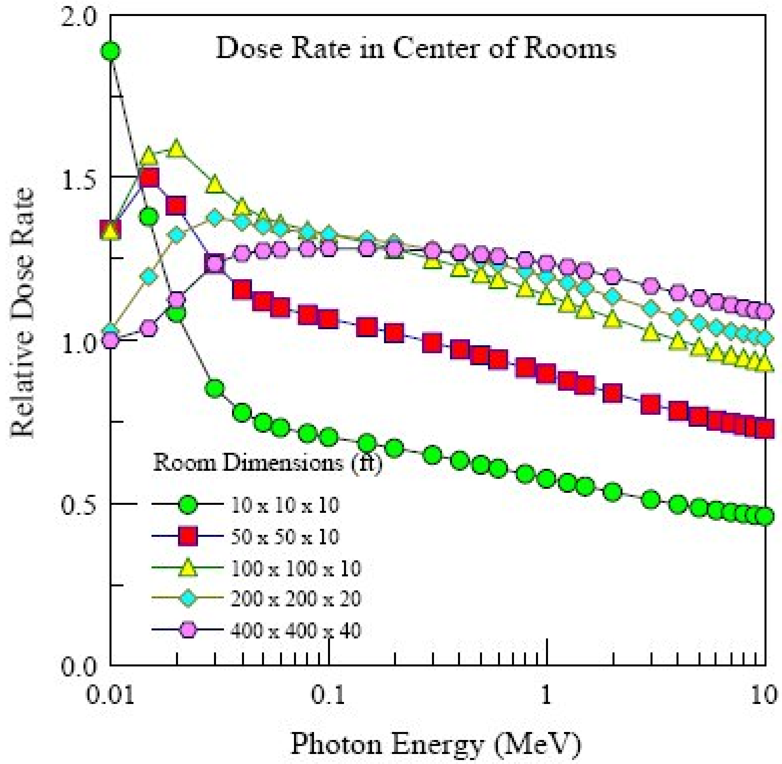

Fig. 1. Relative dose rate in center of rooms of various sizes.

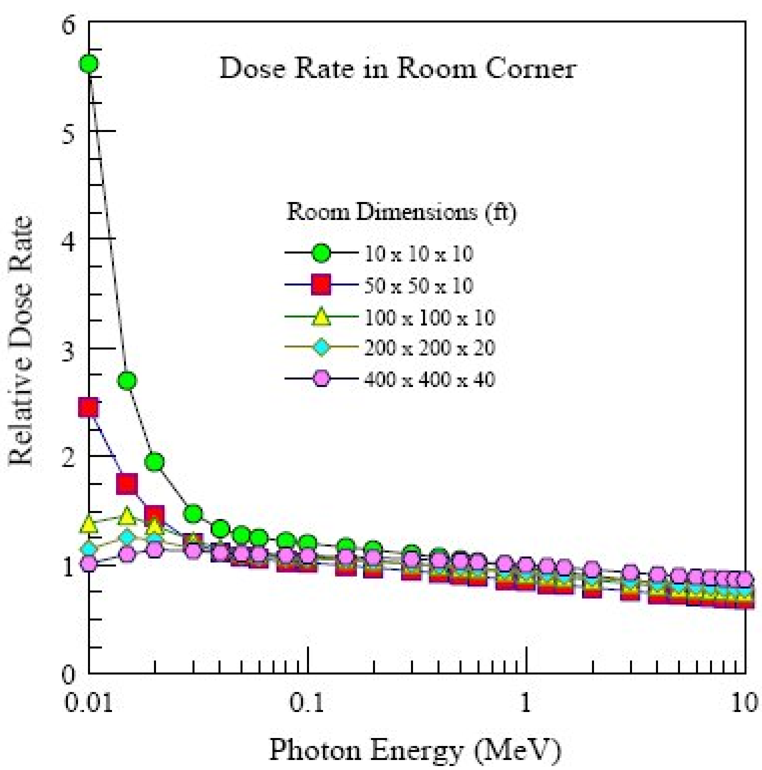

Fig. 2. Relative dose rate in the corner of rooms of various sizes.

Second, in the SPRG calculator EPA issued new FSURF values based on exposure to 2 vertical surfaces (outside building surfaces on either side of a street) and a horizontal surface (road and sidewalk). The SPRG calculator uses the relationship between the dose rate coefficients for exposures in a contaminated outdoor setting and dose rate coefficients for an infinite source to calculate a surfaces factor (FSURF). The dose quantity evaluated is the air kerma rate one meter above the sidewalk. The outdoor surfaces are assumed to be contaminated to the same level. Locations in the midpoint of the sidewalk, next to the buildings and in the middle of the street for building heights of 12.5, 30, 59 and 150 and 200 feet, were modeled to account for the dose contribution from multiple surfaces. Further, photon energies of each radioisotope were incorporated into the modeling. The report “Dose Rate in Contaminated Street” [6] contains a detailed explanation of the process. Side Walk Dose Rate shows that building height doesn't affect the dose rate significantly after 150 feet, as shown in Figure 3. The report also shows a table of the FSURF values used in this calculator for each radioisotope. FSURF values were calculated for each position-specific and building-height specific combination.

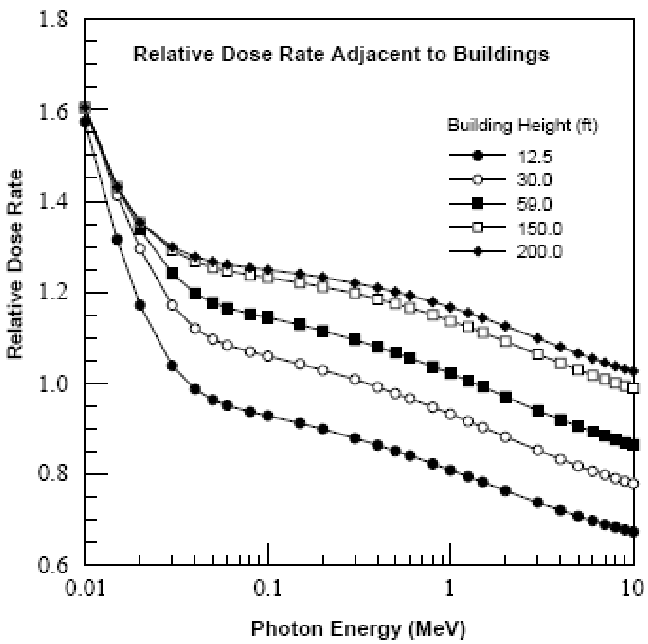

Fig. 3. Relative photon dose rate adjacent to buildings of various heights as a function of photon energy.

Third, for the 2-D exposure models addressing building slabs, a new ACF was developed which is made variable by isotope and area for site-specific analysis. The SPRG calculator allows the user to select from 8 different slab area sizes. If no size is selected for the finite slab analysis, the ACF from the most protective slab size is selected. For further information on the derivation of the isotope-specific/area-specific ACF values for 2-D slabs see the report “Ratios of Dose Rates for Contaminated Slab” [7]. This report indicates that the slab size makes a small difference in comparison to photon energy, which is shown in Figure 4. This report also includes a table of each of these new isotope-specific ACFs for each radionuclide and eight slab sizes.

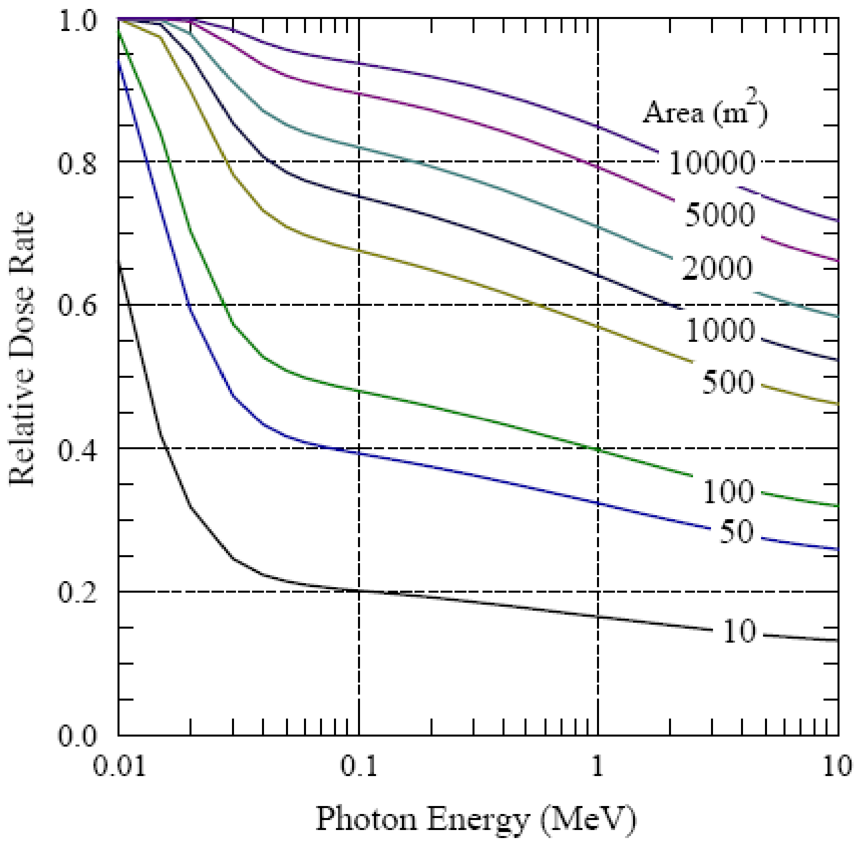

Fig.4. Relative photon dose rate at the center of slabs of various sizes.

RESULTS

In most instances, the more accurate modeling results derived from these gamma adjustments are less conservative. The notable exception are for some radionuclides in rooms with contaminated walls, ceiling, and floors, and the receptor is in location of the room with the highest amount of radiation exposure, usually the corner of small rooms and the center of large conference rooms.

REFERENCES

1. U.S. EPA, "Soil Screening Guidance for Radionuclides: Technical Background Document", Office of Emergency and Remedial Response and the Office of Radiation and Indoor Air, (2000) http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/sstbd.pdf

2. US EPA, "Preliminary Remediation Goals for Radionuclides in Buildings (BPRG) electronic calculator" Includes transmittal memo entitled: "Distribution of Superfund Preliminary Remediation Goals for Radionuclides in Buildings (BPRG) Electronic Calculator" Office of Superfund Remediation and Technology Innovation, (2007) http://epa-bprg.ornl.gov/ http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/memo_buildingcover_fin_clean_6sw.pdf

3. US EPA, "Federal Guidance Report No. 13. Cancer Risk Coefficients for Environmental Exposure to Radionuclides", Office of Radiation and Indoor Air, (1999) http://www.epa.gov/rpdweb00/docs/federal/402-r-99-001.pdf

4. K. F. ECKERMAN, "Dose Rates in Contaminated Rooms of Various Sizes", Oak Ridge National Laboratory, (2005) http://epa-bprg.ornl.gov/documents/Contaminated_Room_Dose_Rate_03_01_07.pdf

5. U.S EPA, "Preliminary Remediation Goals for Radionuclides in Outside Surfaces (SPRG)" electronic calculator. Includes transmittal memo entitled "Distribution of "Preliminary Remediation Goals for Radionuclides in Outside Surfaces (SPRG) Electronic Calculator" Office of Superfund Remediation and Technology Innovation, (2009) http://epa-sprg.ornl.gov/ http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/memo_sprg_elec_calc.pdf

6. K. F. ECKERMAN, "Dose Rate in Contaminated Street", Oak Ridge National Laboratory, (2007) http://epa-sprg.ornl.gov/pdfs/ContaminatedStreet.pdf

7. K. F. ECKERMAN, "Ratios of Dose Rates for Contaminated Slabs", Oak Ridge National Laboratory, (2007) http://epa-sprg.ornl.gov/pdfs/ContaminatedSlabs.pdf