DEPTH DOSE PROFILES RESULTING FROM BETA EMITTERS ON THE SKIN SURFACE

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INTRODUCTION

Contamination of the skin by beta emitters is a common health physics problem for workers at nuclear facilities. Several different methods are in use for evaluating dose from skin contamination, and the different methods often give conflicting results. The depth dose profile is critical to understanding the stochastic and nonstochastic damage to skin tissues. A computer code called VARSKIN has been developed at PNL for the evaluation of beta skin dose using the specific energy deposition tables of Berger. VARSKIN has been used to evaluate depth dose profiles in the first two millimeters of skin for several different contamination geometries (point source, finite disk source, infinite plane source), and for a number of different radionuclides of interest to the health physics community.

COMPUTER CODE VARSKIN

VARSKIN [1] was developed to evaluate skin doses resulting from beta-emitting contamination on the skin surface. VARSKIN assumes that the beta-emitting radionuclides reside on the skin in one of three configurations: a point, a thin disc, or an infinite plane. The code calculates the beta dose to a thin layer of cells at a user-input depth below the skin surface (typically 0.007 cm, matching standard recommendations for the critical depth). The dose is calculated at a number of points at the chosen depth, and these calculated dose values are smeared into an area-averaged dose. This smeared dose is calculated over a circular area centered below the center of the contamination region, and the area for the smeared dose is chosen by the code user (typically 1 cm^2).

The dose calculation in VARSKIN is based on the tables of specific absorbed energy published by Berger [2]. The specific absorbed fraction accounts for the fraction of emitted energy absorbed in a sphere of water centered about a point source of beta-emitters. The dose to any point is calculated in VARSKIN by performing a point-kernel integration over the source region. Doses are calculated to a number of points at the dose level. The choice of dose points is guided by first finding the maximum range of betas. This range allows the determination of an area under the center of a disc source that is essentially exposed to

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an "infinite plane" of beta emitters. Only one dose point needs to be chosen in this region, since all dose values will be the same. The range also allows the determination of a region beyond the boundary of the source which is exposed to zero dose. The region of varying dose lies between the inner infinite-plane region and the outer zero-dose region. VARSKIN chooses 26 dose points in this boundary region. This scheme of choosing dose points enables an efficient smearing of the dose over the appropriate dose area.

VARSKIN reads specific absorbed energy fractions and other values from a library containing data for about 75 radionuclides. VARSKIN can include from one to five radionuclides in a calculation.

DEPTH DOSE CALCULATIONS

VARSKIN was used to calculate the depth dose profiles for a number of beta emitters residing on the skin in several different contamination configurations. For each radionuclide of interest, a series of VARSKIN calculations was run for a point source. Each of the calculations assumed a different depth, ranging from 0.007 to 0.15 cm. For each VARSKIN run, smeared area doses were ignored; only doses to points on the dose surface were used. The distribution of doses along the points at a given depth were recorded and plotted. A three-dimensional plot was then drawn up with a curve for each of the critical depths.

After the series of depth dose profiles was calculated for the point source, another series of calculations was performed for a disc source with radius 0.1 cm, and a third series of calculations was performed for a disc source with radius 0.5 cm.

The depth dose profiles for point- and disc-source skin contaminations composed of $^{90}Sr/^{90}Y$ are presented in Figures 1 and 2. The vertical axes of these graphs represent dose. There is no numbering on the vertical axis because the actual dose values depend on the source strength of the contamination, and the depth dose profiles will have the same relative shapes no matter what the absolute values. The y-axis corresponds to depth in the skin; a "picture" on the back wall of the graph indicates the approximate depths of the various regions of the skin. The x-axis of the graph corresponds to positions parallel to the surface of the skin.

CONCLUSIONS

An examination of the graphs presented here indicates that beta doses fall off rapidly with depth in the skin. This effect, of course, is a direct result of the limited range of betas in skin. The point source profiles are much more sharply peaked than the disc source profiles, and the dose values fall off much more sharply with depth. This effect reflects a near

$1/r^2$ dependency for a point source. The area-averaged dose to the skin would be far smaller than the maximum point dose value shown on the graph. The peak value falls off rapidly with increasing depth: at 0.050 cm, the maximum dose is only 1.3% of the maximum dose at 0.007 cm; at 0.1 cm, the maximum dose is 0.2% of the 0.007-cm maximum; and at 0.15 cm the maximum value is less than 0.1% of the 0.007-cm maximum.

The disc source profiles fall off much more gradually with depth. For the 0.5-cm disc source, the peak value at a 0.05 cm depth is 34% of the 0.007-cm maximum; at 0.1 cm, the maximum value is 19%; and at 0.15 cm the maximum value is 13% of the 0.007-cm maximum.

These depth dose profiles illustrate the dramatic difference between disc and point sources for producing doses at different skin depths. In evaluating an actual case of skin contamination, the health physicist must be careful to accurately assess the nature of contamination on the skin surface. The issue of area-averaging doses also plays a crucial role in arriving at a dose: the dose to a small point will be far higher than the dose averaged over a larger area.

REFERENCES

[1] Traub, R. J., W. D. Reece, R. I. Scherpelz and L. A. Sigalla. 1987. Dose Calculation for Contamination of the Skin Using the Computer Code VARSKIN. NUREG/CR-4418, U.S. Nuclear Regulatory Commission, Washington, D.C.

[2] Berger, M. J. 1971. "Distribution of Absorbed Dose Around Point Sources of Electrons and Beta Particles in Water and Other Media." Medical Internal Radiation Dose Committee, Pamphlet No. 7, J. Nucl. Med. 12(5):5.

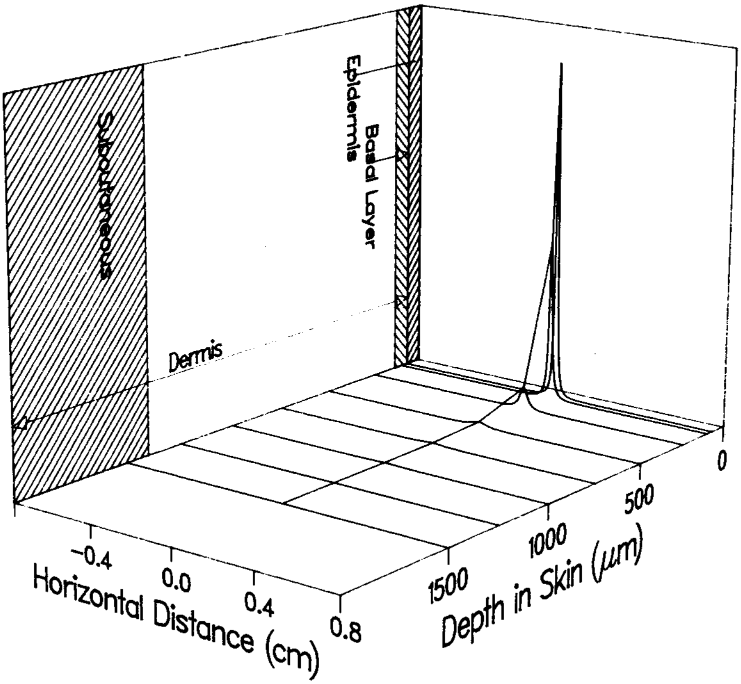

FIGURE 1. Dose Profiles in Skin $^{90}Sr/^{90}Y$ Point Source

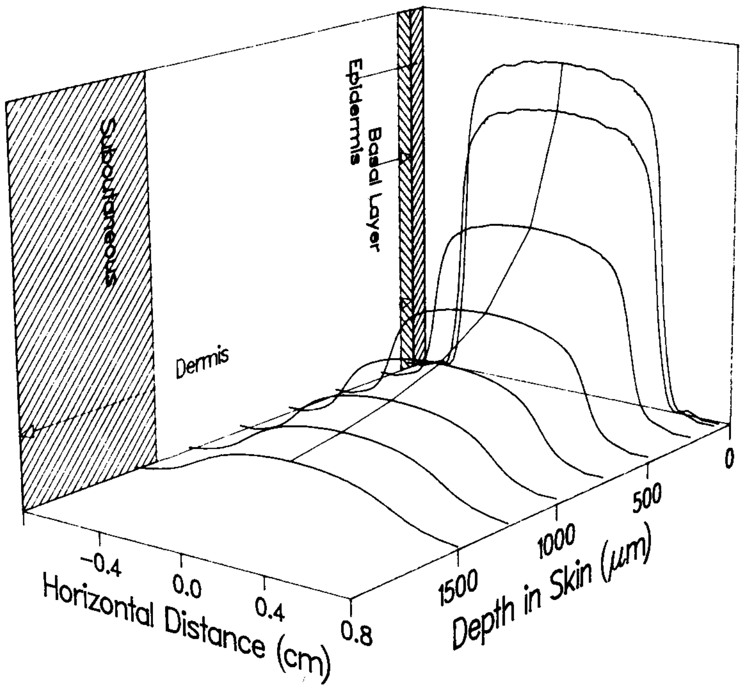

FIGURE 2. Dose Profiles in Skin $^{90}Sr/^{90}Y$ 0.5-cm Disc Source