CNWRA *A center of excellence in earth sciences and engineering* ™

A Division of Southwest Research Institute®
6220 Culebra Road • San Antonio, Texas, U.S.A. 78228-5166
(210) 522-5160 • Fax (210) 522-5155

June 14, 2005
Contract NRC–02–02–012
Account No. 20.06002.01.352

U.S. Nuclear Regulatory Commission
ATTN: Mrs. Deborah A. DeMarco
Division of High-Level Waste Repository Safety
Office of Nuclear Material Safety and Safeguards
Mail Stop 8A–23
Washington, DC 20555

Subject: Programmatic Review of Presentation Titled "Adding Radionuclides to the Varskin 3 Library Correctly"

Dear Mrs. DeMarco:

The subject presentation is being submitted for programmatic review. This presentation will be given by James Durham at a meeting of the Health Physics Society in Spokane, Washington, July 10–14, 2005. The work discussed in this presentation was originally performed by Dr. Durham prior to his employment at CNWRA; the work was performed on behalf of the NRC Office of Nuclear Regulatory Research. Although this work was not originally performed as part of CNWRA support of the NRC Division of High-Level Waste Repository Safety (HLWRS), we believe the subject matter of the presentation (e.g., approaches for correctly including radionuclides in dose assessment) is directly relevant to the Biosphere Characteristics integrated subissue and the Methodology and Overall System Performance components of the HLWRS program.

Dr. Durham's presentation focuses on the correct method for adding radionuclides to the Varskin 3 radionuclide library. Varskin 3 is a recently-released update to a code that calculates dose from skin contamination. One of the biggest improvements in the code is the ability for the user to create a custom radionuclide library. The library contains only the radionuclides chosen by the user and adding a radionuclide to the library does not require knowledge of basic nuclear physics. For each radionuclide added to the library, the user must choose the cutoff energy and yield (% emitted per disintegration); decay paths for the chosen radionuclide that fail to exceed both criteria will not be included in the library file for that radionuclide. Simply choosing the default values for the minimum photon energy and yield can result in incorrect values because the minimum energy for a dose calculation at one skin depth may not be appropriate at another skin depth.

Washington Office • Twinbrook Metro Plaza #210
12300 Twinbrook Parkway • Rockville, Maryland 20852-1606

Please advise me of the results of your programmatic review. If you have any questions regarding this presentation, please contact me at 210-522-5185. Your cooperation in this matter is appreciated.

Sincerely,

Sitakanta Mohanty

Sitakanta Mohanty
Assistant Director, Engineering and
Systems Assessment

JW/rm
Enclosures: Presentation
NRC Form 390A

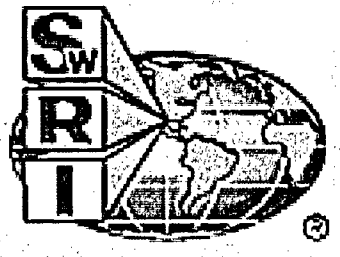
cc: W. Reamer
B. Meehan
E. Whitt
W. Patrick
CNWRA Directors
CNWRA Asst. Directors
CNWRA Element Managers
B. Leslie
Record Copy B

Letter Only
L. Kokajko
E. Collins
T. McCartin
W. Ford
A. Campbell
F. Brown
K. Stablein
M. Bailey
J. Guttmann
J. Rubenstone
T. Kobetz
C. Grossman
R. Codell
K. Compton
M. Waters
C. Ryder
R.K. Johnson
T. Ghosh

Letter Only
L. Gutierrez

Adding Radionuclides to the Varskin 3 Library Correctly

Dr. Jim Durham
Center for Nuclear Waste Regulatory Analyses
Southwest Research Institute
San Antonio, TX



Purpose

- Discuss Recent Changes in Varskin 3
  - Redesign Interface in Version 3.0
  - Correct errors identified in Version 2.2
- Discuss the Correct Method of Adding Radionuclides to the Library
  - New Options in Version 3.0
  - Photon Minimum Energy

Varskin 3

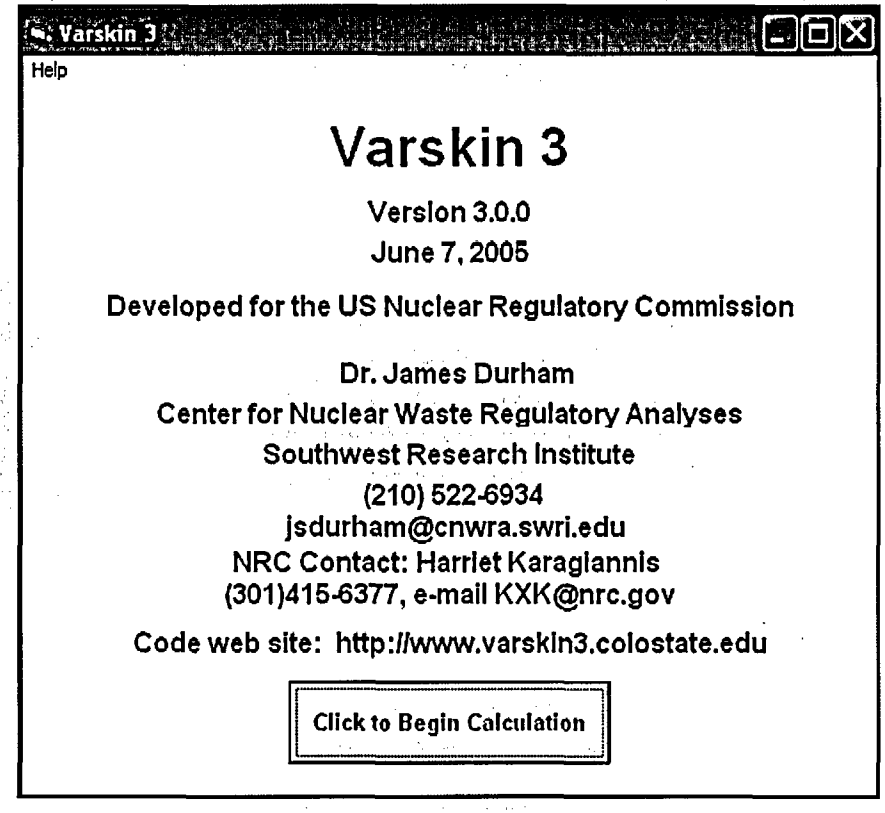
- Calculates dose to skin from contamination on skin or on a cover material
- Uses the Berger Point Kernel:

$$\mathrm{Dose}(x) = \frac{AYkE_{avg}F_{\beta}(x/X_{90})}{4\pi\rho x^{2}X_{90}}$$

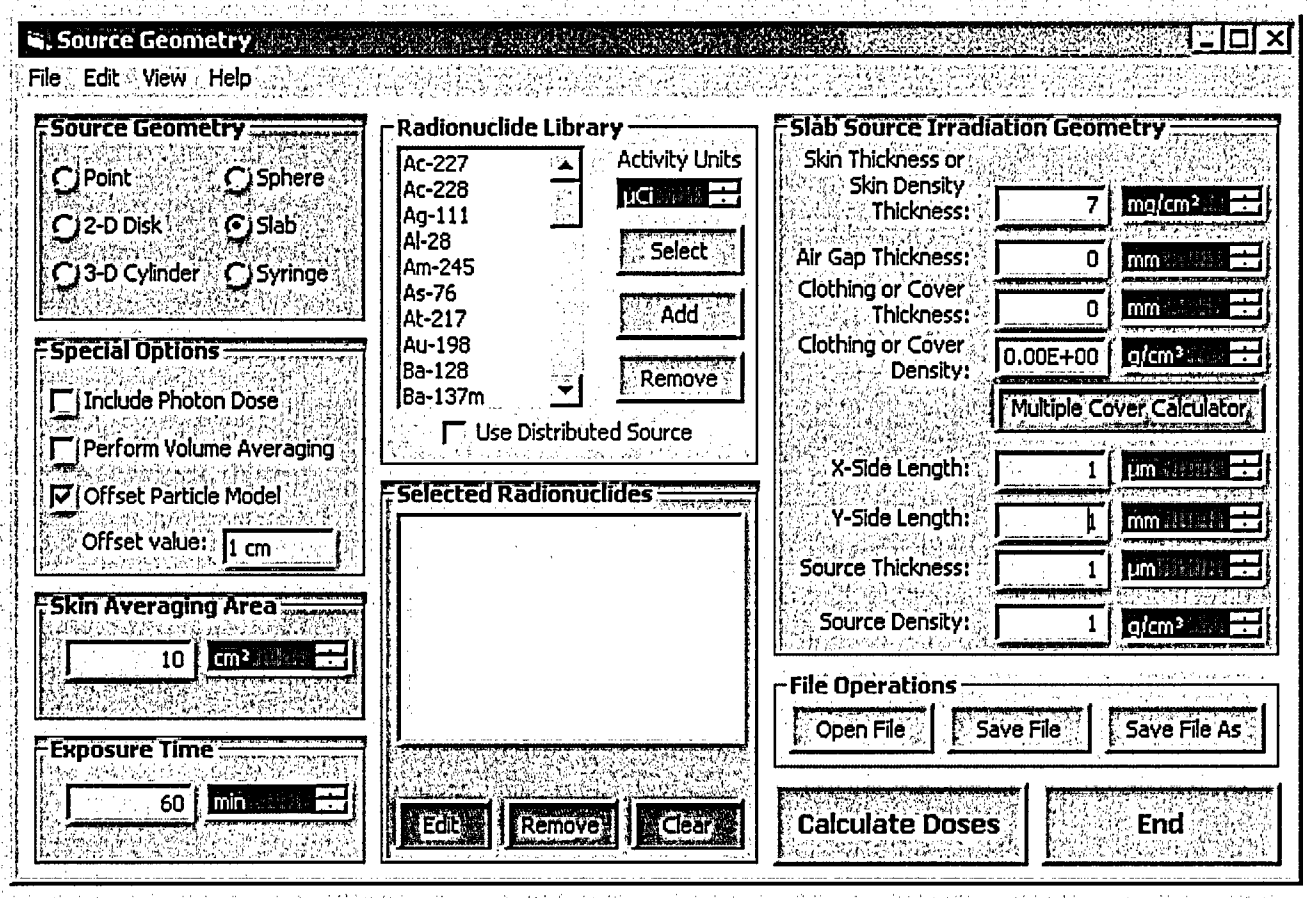
- GUI written in Visual Basic
- Calculation engines written in Fortran

Revised Opening Screen

- **Reflects new contact information for the author**

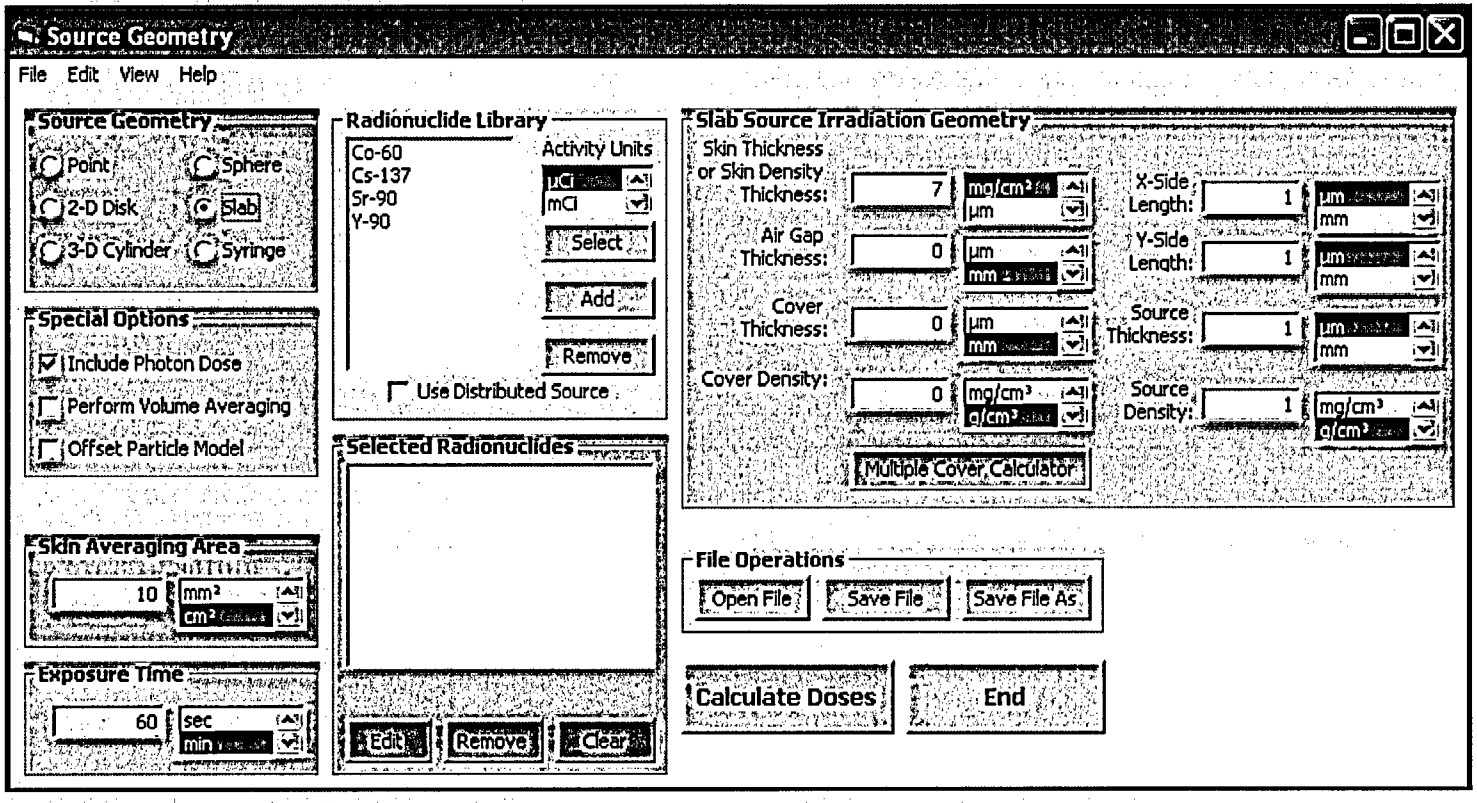


Revised User Interface



- Selected units are more obvious
- Default values and units have not changed

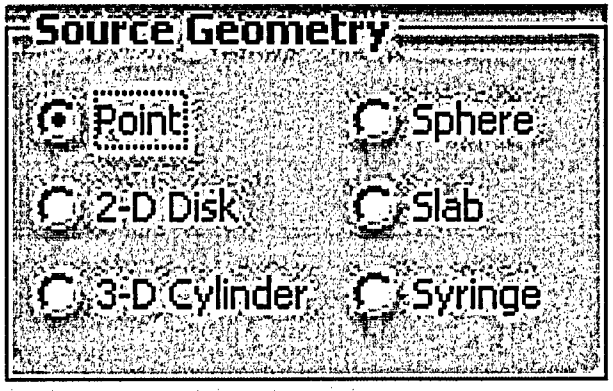
Revised User Interface



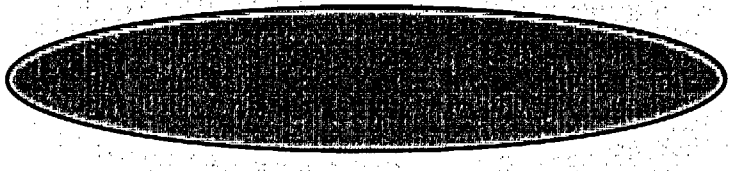
- Selected units are more obvious
- Default values and units have not changed

Source Geometry Options

- Choose from six source geometry models
- Input screen adjusts for data entry

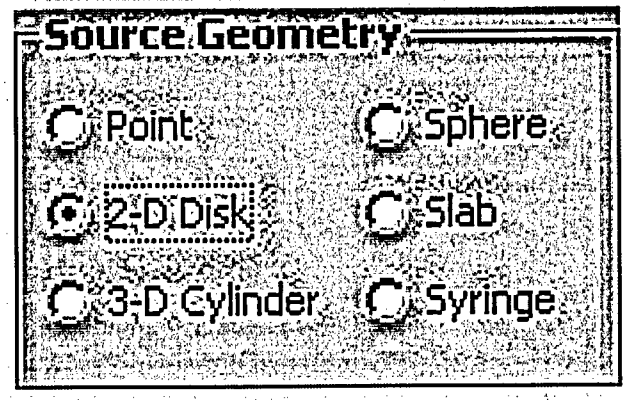


- Point source

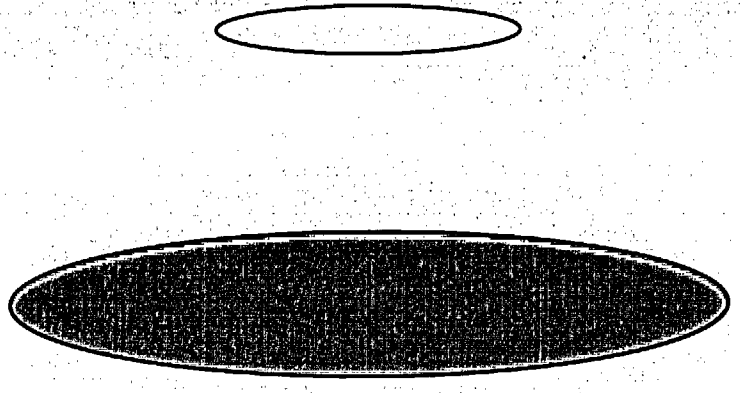


Source Geometry Options

- Choose from six source geometry models
- Input screen adjusts for data entry

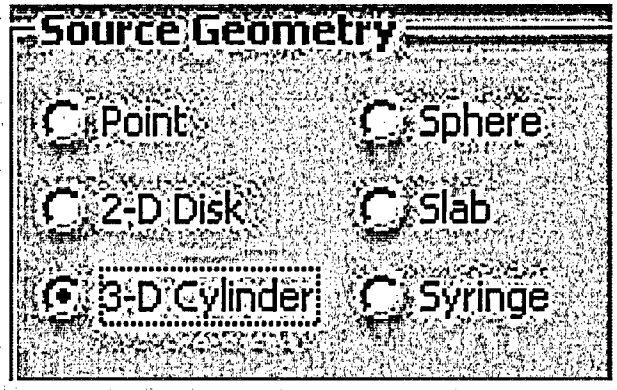


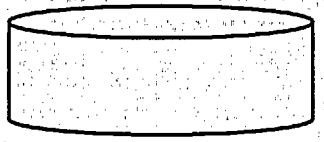
- 2-D disk source



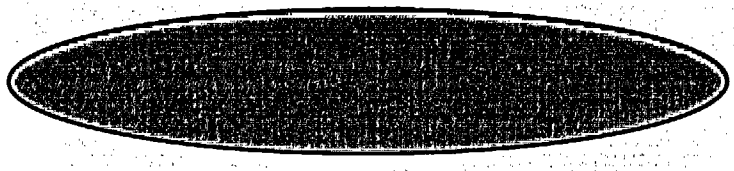
Source Geometry Options

- Choose from six source geometry models
- Input screen adjusts for data entry



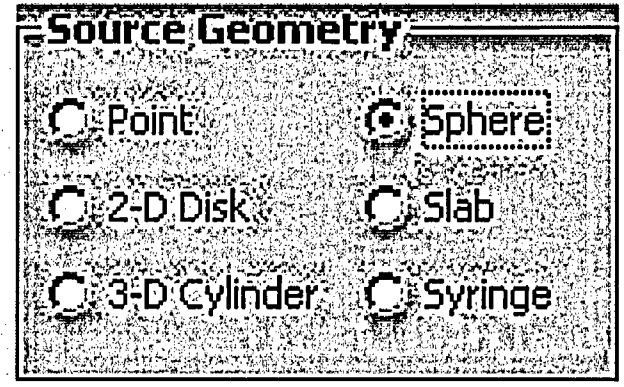


- 3-D cylinder source

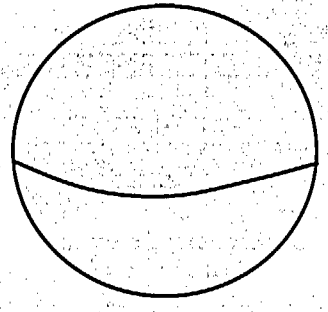


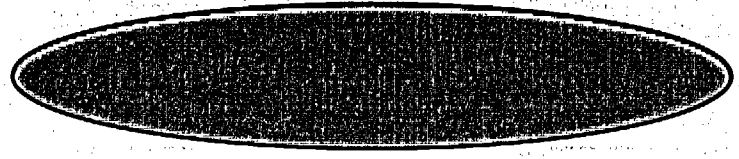
Source Geometry Options

- Choose from six source geometry models
- Input screen adjusts for data entry



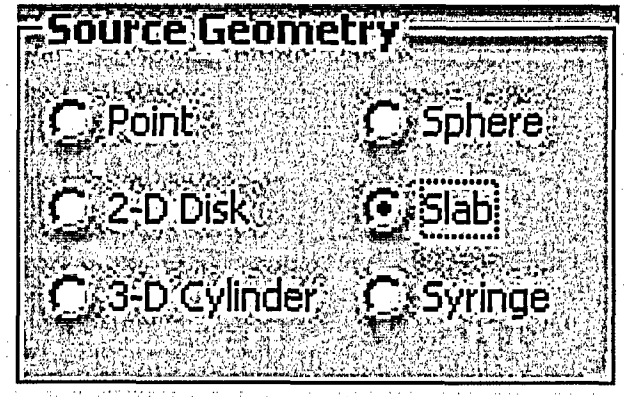
- Sphere source

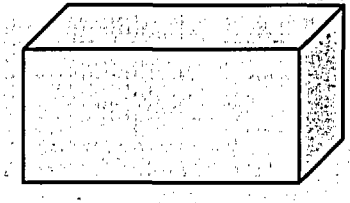




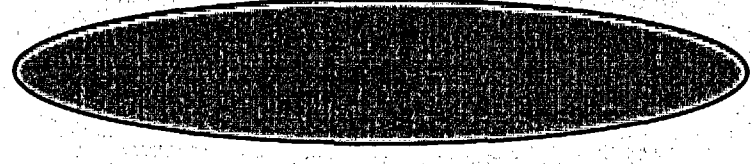
Source Geometry Options

- Choose from six source geometry models
- Input screen adjusts for data entry





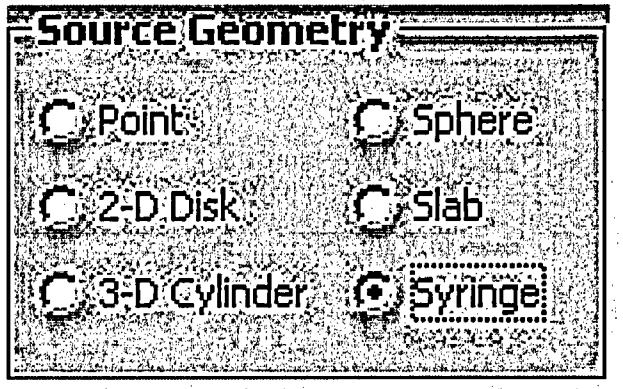
- Slab source

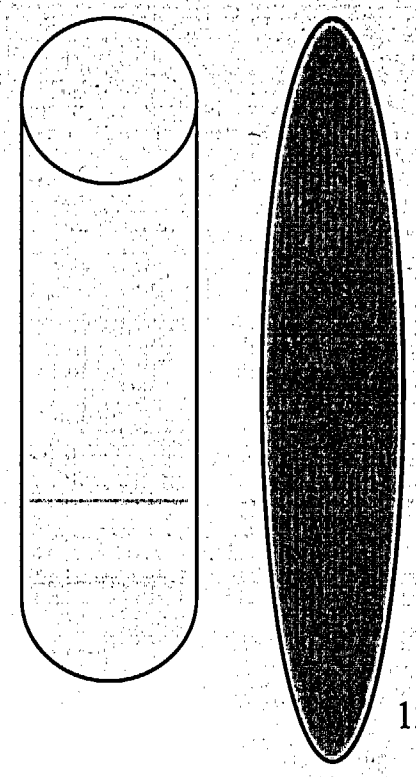


Source Geometry Options

- Choose from six source geometry models
- Input screen adjusts for data entry

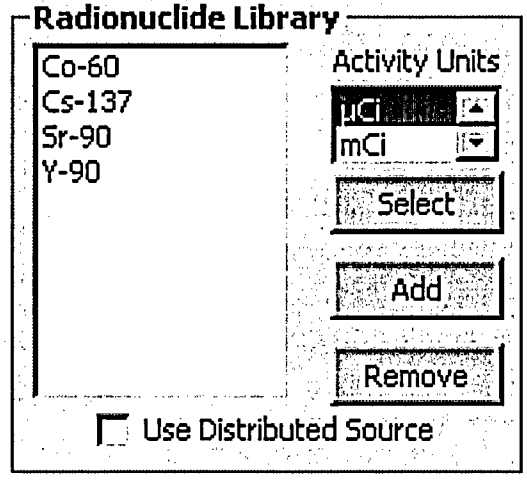
- Syringe source



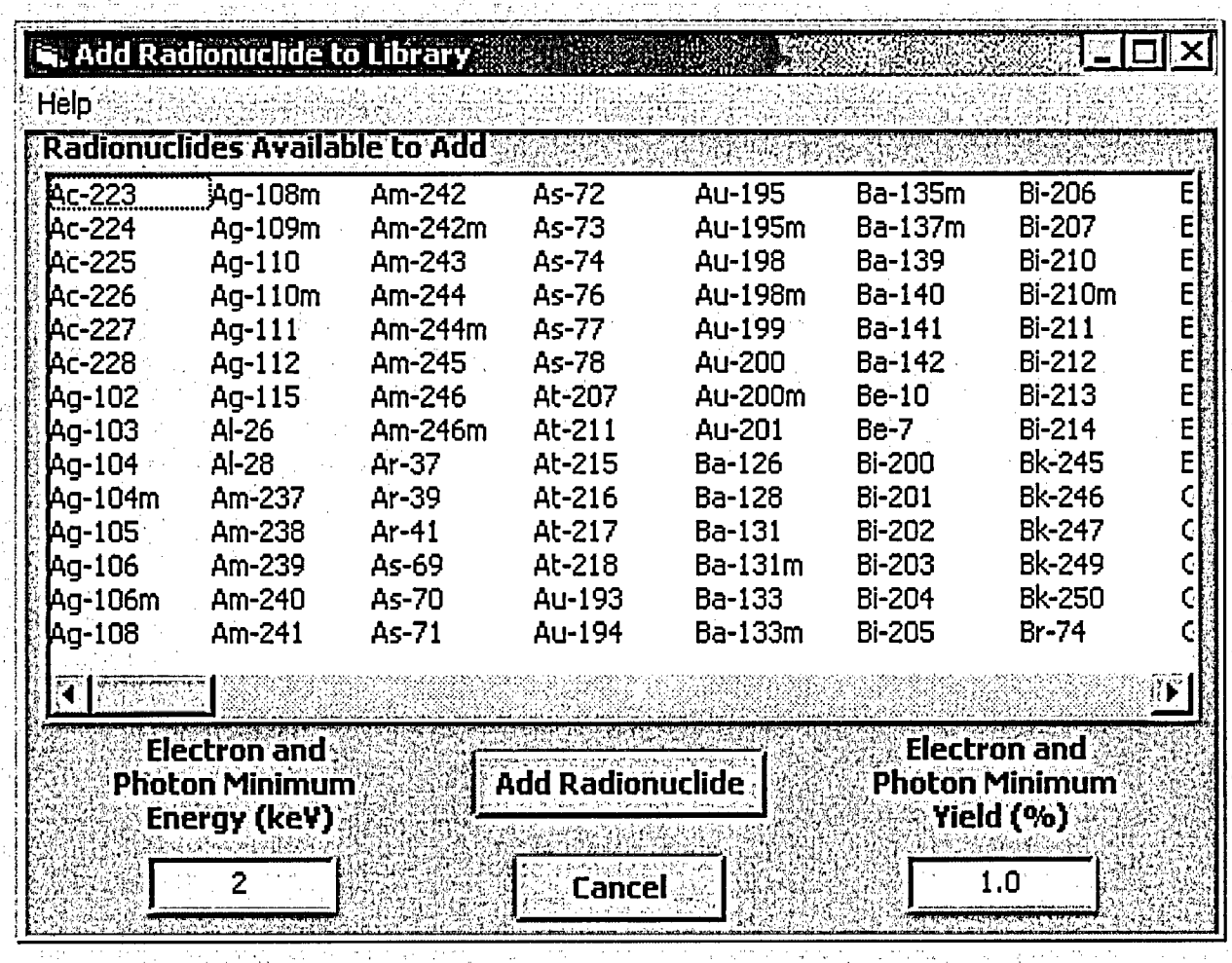


Radionuclide Library

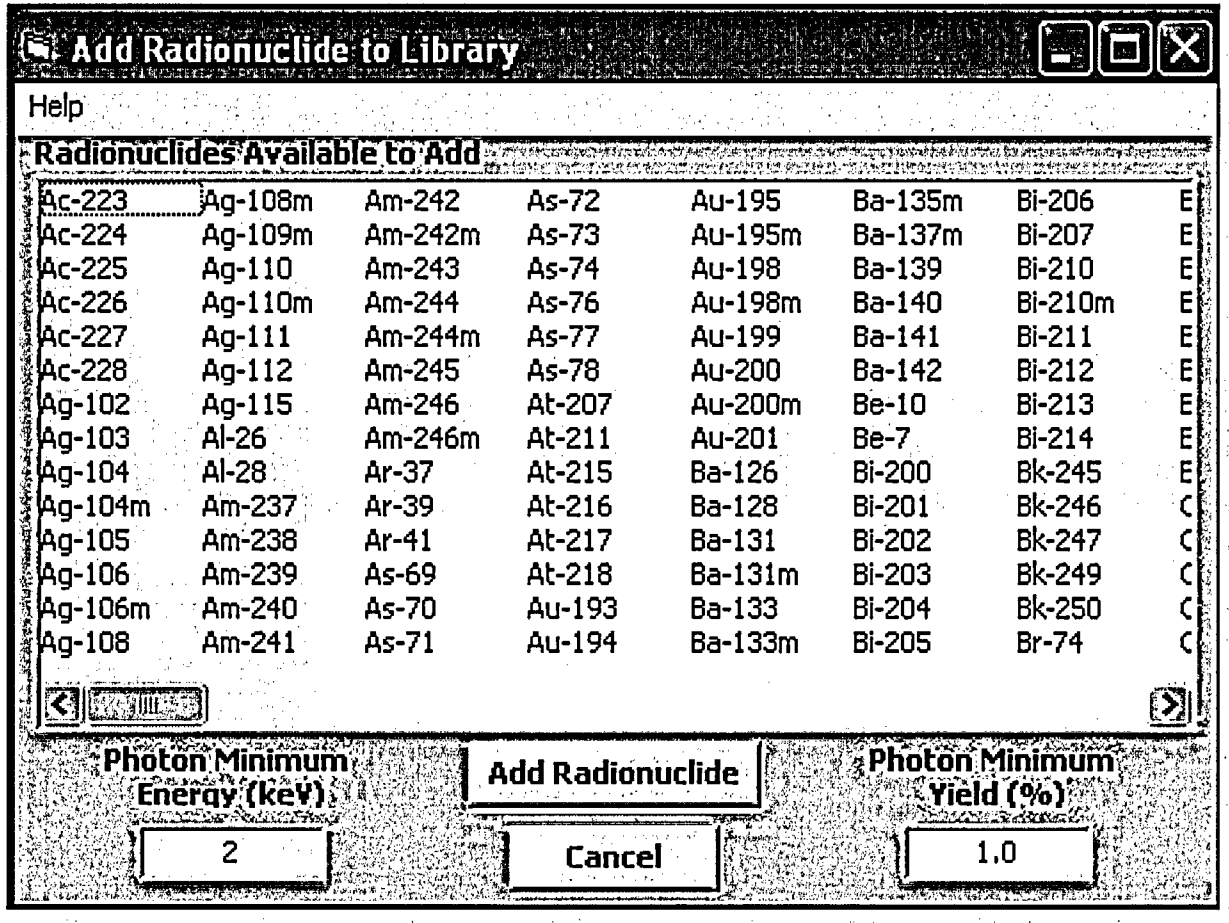
- **Library is built using "Add" button**



Revised "Add Radionuclide" Screen



Revised "Add Radionuclide" Screen



- **Minimum energy and yield is chosen for photon dose only**

How Varskin 3 Calculates Photon Dose

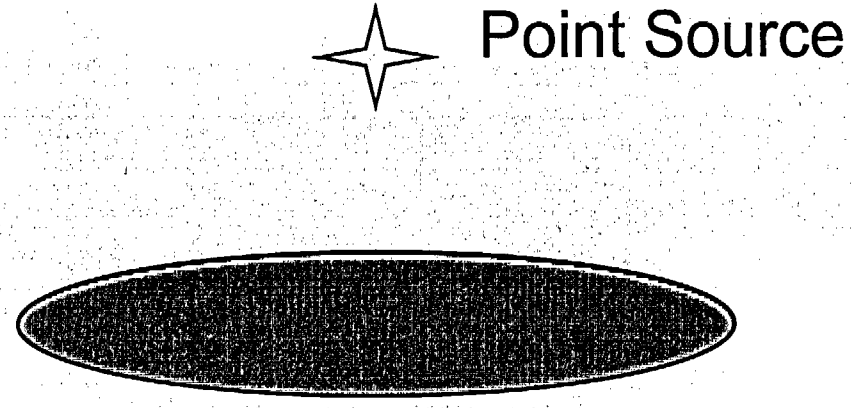
- **Specific Photon Dose Constant (rad-cm^2-mCi^{-1}-h^{-1})**

$$\Gamma = 1938 \left[\sum_{i=1}^{n} P_i \, E_i \left(\frac{\mu_{en}}{\rho} \right)_{E_{i,tissue}} \right]$$

  - **P_i is the probability of emission of a photon having an energy E_i (MeV)**
  - **$(\mu_{en}/\rho)_{Ei,tissue}$ is the mass energy absorption coefficient in tissue (m^2/kg)**
  - **n is the number of photons emitted**

Specific Photon Dose Constant

- Assumes the photon source is a point source



How Varskin 3 Calculates Photon Dose

- **Average Energy (MeV)**

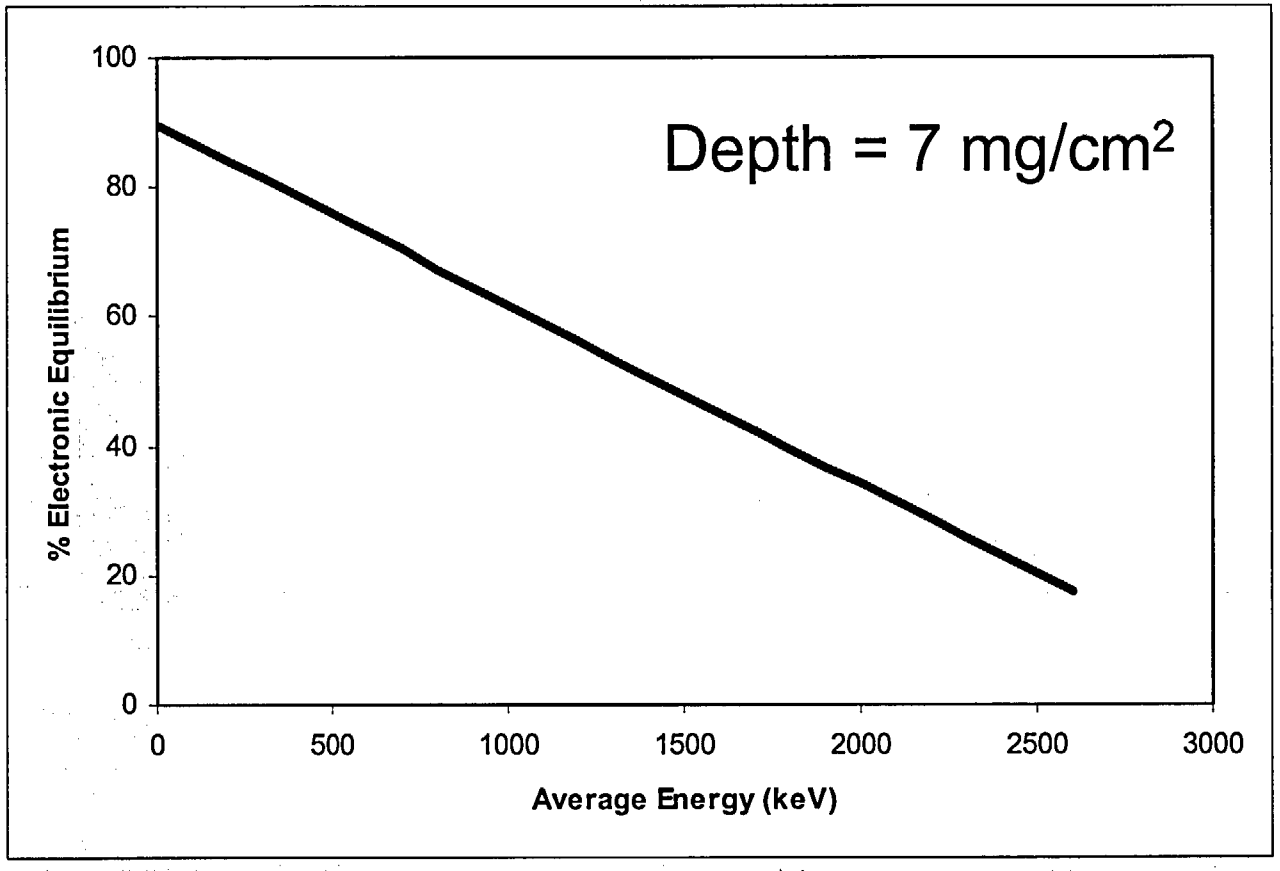
$$E_{avg} = \frac{\sum_i P_i \, E_i}{\sum_i P_i}.$$

  - **Determines to what extent electronic equilibrium is established**

Problems with the Minimum Energy

- Choosing a low value of the cutoff energy may include the dose contribution from photons that do not contribute to dose at that depth
- Including photons that do not contribute to dose at a chosen depth has two effects
  - The average energy is decreased
  - The specific photon dose constant is overestimated

Electronic Equilibrium



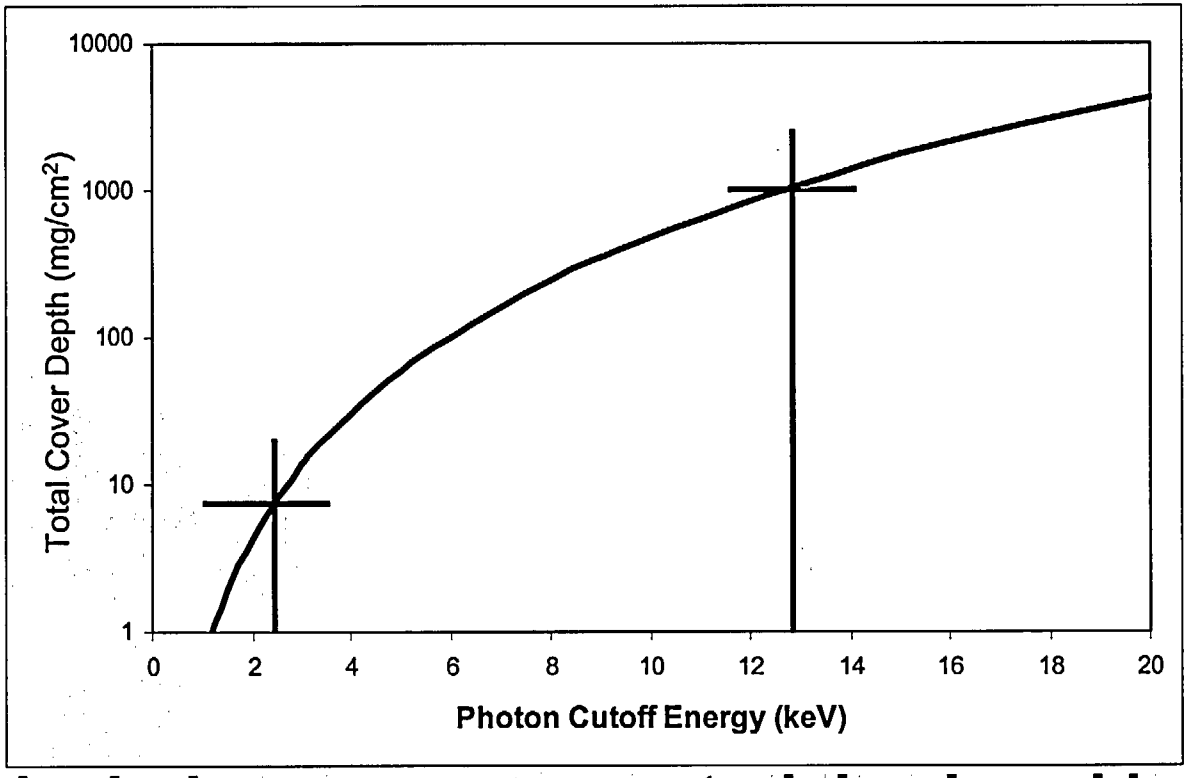
- **Calculated dose is multiplied by the fraction that electronic equilibrium is established**

Example: Photon Minimum Energy

Specific Photon Dose Constant, Γ, as a Function of Minimum Energy for ^{57}Co	
Minimum Energy (keV)	Γ (rad-cm^2-mCi^{-1}-h^{-1})
2	14.98
10	1.00
20	0.556
100	0.556
Published Value	0.9

- **Published value from Radiological Health Handbook**

Minimum Energy vs. Depth



- Depth includes any cover materials plus skin density thickness
- Includes any photon that contributes 10% to dose
- Shallow dose minimum energy: 2 keV
- Deep dose minimum energy: 13 keV

Limitations Imposed on Photon Dose Model

- Maximum source dimension: 1 mm
- Maximum air gap: 5 cm
- No photon dose for syringe model

Additional Changes to Varskin 3

- Printout error corrected
- Offset particle model activated
- Average β energy no longer includes IC and Auger electrons
- NUREG document and Help file updated

Acknowledgements

- Harriet Karagiannis, Office of Nuclear Regulatory Research, US Nuclear Regulatory Commission
- Sami Sherbini, Office of Nuclear Regulatory Research, US Nuclear Regulatory Commission
- Mike Lantz, Arizona Public Service

Disclaimer

The activities presented here were performed on behalf of the U.S. Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research. The work was pursued while the staff author was at Colorado State University. This presentation does not necessarily reflect the view or regulatory position of the NRC.