

*varskin* V5

EXAMPLES

# Scenario (test case) #1

- Nuclear medicine technician
- 10  $\mu\text{Ci/mL}$  of  $^{186}\text{Re}$  (decays to  $^{186}\text{Os}$  and  $^{186}\text{W}$ )
- Unknown to tech, 5 mL spills on lab coat
- 50  $\text{cm}^2$  circular shape
- 4.5 hr exposure
- Initially,
  - point-source geometry
  - source in contact with the skin
- Then, refine for more realism
  - coat thickness of 0.4 mm, and density of 0.9  $\text{g/cm}^3$

# summary

	Beta Dose	Photon Dose	Total Dose (rad)
Point on Skin	131	0.0673	131
Disk on Skin	26.2	0.0149	26.2
Disk on Coat	9.21	0.0110	9.23
Cylinder in Cloth	16.9	0.0126	16.9

## Scenario (test case) #2

- Radiation worker in reactor containment
- $^{60}\text{Co}$  hot particle (2.5 mCi; 15 min) on gloved hand
- $50\text{ }\mu\text{m}$  @  $8.3\text{ g/cm}^3$  ( $Z=27$ )
- $80 \times 70\text{ }\mu\text{m}$
- Glove characteristics:  $0.3\text{ mm}$  and  $0.6\text{ g/cm}^3$
- Initially, point-source geometry
- Then, refine for more realism ...

# Point source

Varskin 5.0

File Help

**Source Geometry**

☒ Point ☐ Sphere  
☐ Disk ☐ Slab  
☐ Cylinder

**Special Options**

☒ Include Photon Dose  
☐ Perform Volume Averaging  
☐ Offset Particle Model

**Skin Averaging Area**

1.00E+01 cm<sup>2</sup>

**Exposure Time**

1.50E+01 min

**Radionuclide Library**

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]

Activity Units  
mCi

Select  
Add  
Remove

**Point Source Irradiation Geometry**

Skin Thickness or Skin Density Thickness: 7 mg/cm<sup>2</sup>  
Air Gap Thickness 0 mm  
Cover Thickness 3.00E-01 mm  
Cover Density 6.00E-01 g/cm<sup>3</sup>

Multiple Cover Calculator

**Selected Radionuclides**

Co-60 [27]: 2.50E+00 mCi

Edit Remove Clear

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Calculate Doses

# results

Note  $\beta/\gamma$   
contribution

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Co-60 [27]: 2.50E+00 mCi

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	1.30E+02 rad/h	3.25E+01 rad	3.25E+01 rad	Beta	1.30E+02 rad/h	3.25E+01 rad	3.25E+01 rad
Photon	4.22E+01 rad/h	1.05E+01 rad	1.05E+01 rad	Photon	4.22E+01 rad/h	1.05E+01 rad	1.05E+01 rad
Total	1.72E+02 rad/h	4.31E+01 rad	4.31E+01 rad	Total	1.72E+02 rad/h	4.31E+01 rad	4.31E+01 rad

Date/Time 8/6/2013 2:51:08 PM Source Geometry Point Source

Cover Thickness 3.00E-01 mm Cover Density 6.00E-01 g/cm<sup>3</sup>

Air Gap Thickness 0.00E+00 mm Irradiation Time 1.50E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results Close

# Cylindrical equivalent source

$$d = 2 \sqrt{\frac{X \cdot Y}{\pi}} = 2 \sqrt{\frac{80 \mu\text{m} \cdot 70 \mu\text{m}}{\pi}} = 84 \mu\text{m}$$

The screenshot shows the Varskin 5.0 software interface. The 'Source Geometry' section has 'Cylinder' selected. The 'Radionuclide Library' lists Cs-137 [7.42], Co-60 [27], Ba-137m [7.42], and Co-60 [7.42], with 'Co-60 [27]' selected. The 'Activity Units' are set to 'mCi'. The 'Cylinder Source Irradiation Geometry' section shows 'Skin Thickness or Skin Density Thickness' as 7 mg/cm², 'Air Gap Thickness' as 0.00E+00 mm, 'Cover Thickness' as 3.00E-01 mm, and 'Cover Density' as 6.00E-01 g/cm³. The 'Source Diameter' is 8.40E+01 µm, 'Source Thickness' is 5.00E+01 µm, and 'Source Density' is 8.30E+00 g/cm³. A green circle highlights the 'Source Diameter' and 'Source Thickness' fields, with a green arrow pointing from the equation above to the 'Source Diameter' field. The 'Selected Radionuclides' section shows 'Co-60 [27]: 2.50E+00 mCi'. The 'Skin Averaging Area' is 1.00E+01 cm², and the 'Exposure Time' is 1.50E+01 min. The 'Calculate Doses' button is at the bottom right.

Varskin 5.0

File Help

Source Geometry

☐ Point ☐ Sphere

☐ Disk ☐ Slab

☒ Cylinder

Special Options

☒ Include Photon Dose

☐ Perform Volume Averaging

Skin Averaging Area

1.00E+01 cm²

Exposure Time

1.50E+01 min

Radionuclide Library

Cs-137 [7.42]

Co-60 [27]

Ba-137m [7.42]

Co-60 [7.42]

Activity Units

mCi

Select

Add

Remove

Use Distributed Source

Selected Radionuclides

Co-60 [27]: 2.50E+00 mCi

Cylinder Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7 mg/cm²

Air Gap Thickness 0.00E+00 mm

Cover Thickness 3.00E-01 mm

Cover Density 6.00E-01 g/cm³

Multiple Cover Calculator

Source Diameter 8.40E+01 µm

Source Thickness 5.00E+01 µm

Source Density 8.30E+00 g/cm³

varskin V5

Calculate Doses

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Co-60 [27]: 2.50E+00 mCi

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Electron	5.18E+01 rad/h	1.30E+01 rad	1.30E+01 rad	Electron	5.18E+01 rad/h	1.30E+01 rad	1.30E+01 rad
Photon	4.25E+01 rad/h	1.06E+01 rad	1.06E+01 rad	Photon	4.25E+01 rad/h	1.06E+01 rad	1.06E+01 rad
Total	9.44E+01 rad/h	2.36E+01 rad	2.36E+01 rad	Total	9.44E+01 rad/h	2.36E+01 rad	2.36E+01 rad

Date/Time 2/19/2015 10:02:13 AM Source Geometry Cylinder Source

Source Diameter 8.40E+01  $\mu\text{m}$  Source Thickness 5.00E+01  $\mu\text{m}$

Source Density 8.30E+00  $\text{g/cm}^3$

Cover Thickness 3.00E-01 mm Cover Density 6.00E-01  $\text{g/cm}^3$

Air Gap Thickness 0.00E+00 mm Irradiation Time 1.50E+01 min

Skin density thickness 7.00E+00  $\text{mg/cm}^2$  Irradiation Area 1.00E+01  $\text{cm}^2$

Print Results Close



# Deep dose

Varskin 5.0

File Help

Source Geometry

☐ Point ☐ Sphere  
☐ Disk ☐ Slab  
☒ Cylinder

Special Options

☒ Include Photon Dose  
☐ Perform Volume Averaging

Skin Averaging Area

1.00E+01 cm<sup>2</sup>

Exposure Time

1.50E+01 min

Radionuclide Library

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]

Activity Units

mCi

Select  
Add  
Remove

Use Distributed Source

Selected Radionuclides

Co-60 [27]: 2.50E+00 mCi

Edit Remove Clear

Cylinder Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 1.00E+03 mg/cm<sup>2</sup>

Air Gap Thickness 0.00E+00 mm

Cover Thickness 3.00E-01 mm

Cover Density 6.00E-01 g/cm<sup>3</sup>

Multiple Cover Calculator

Source Diameter 8.40E+01 μm

Source Thickness 5.00E+01 μm

Source Density 8.30E+00 g/cm<sup>3</sup>

varskin V5

Calculate Doses

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Co-60 [27]: 2.50E+00 mCi

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Electron	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad	Electron	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad
Photon	1.30E+01 rad/h	3.24E+00 rad	3.24E+00 rad	Photon	1.30E+01 rad/h	3.24E+00 rad	3.24E+00 rad
Total	1.30E+01 rad/h	3.24E+00 rad	3.24E+00 rad	Total	1.30E+01 rad/h	3.24E+00 rad	3.24E+00 rad

Date/Time 2/19/2015 10:04:30 AM Source Geometry Cylinder Source

Source Diameter 8.40E+01  $\mu$ m Source Thickness 5.00E+01  $\mu$ m

Source Density 8.30E+00 g/cm<sup>3</sup>

Cover Thickness 3.00E-01 mm Cover Density 6.00E-01 g/cm<sup>3</sup>

Air Gap Thickness 0.00E+00 mm Irradiation Time 1.50E+01 min

Skin density thickness 1.00E+03 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results Close

# summary

	Beta Dose	Photon Dose	Total Dose (rad)
Point Source	32.5	10.5	43.1
Cylindrical Equivalent	13.0	10.6	23.6
Deep Dose	0	3.24	3.24

## Scenario (test case) #3

- Contaminated aluminum plate
- Known to be  $^{14}\text{C}$ , but activity must be determined
- 6" x 6" (232 cm<sup>2</sup>) uniformly contaminated
- Detector of 50 cm<sup>2</sup> with 3 mg/cm<sup>2</sup> window
  - measured dose rate of 190 mrad/hr on contact
  - 60 mrad/hr at 1 inch
- Using VARSKIN to estimate activity ...

# Reverse calculations

Unit concentration to start

Varskin 5.0

File Help

Source Geometry

- ☐ Point
- ☐ Sphere
- ☒ Disk
- ☐ Slab
- ☐ Cylinder

Special Options

- ☐ Include Photon Dose
- ☐ Perform Volume Averaging
- ☒ Use Distributed Source

Radionuclide Library

Activity Units:  $\mu\text{Ci}/\text{cm}^2$

Select Add Remove

Selected Radionuclides

C-14 [13]:  $1.00\text{E}+00 \mu\text{Ci}/\text{cm}^2$

Edt Remove Clear

Disk Source Irradiation Geometry

Skin Thickness or Skin Density Thickness:  $3.00\text{E}+00 \text{mg}/\text{cm}^2$

Air Gap Thickness: 0 mm

Cover Thickness: 0 mm

Cover Density: 0  $\text{g}/\text{cm}^3$

Multiple Cover Calculator

Source Area:  $2.32\text{E}+02 \text{cm}^2$

Source Diameter:  $1.72\text{E}+01 \text{cm}$

varskin V5

Calculate Doses

Skin Averaging Area:  $5.00\text{E}+01 \text{cm}^2$

Exposure Time:  $6.00\text{E}+01 \text{min}$

# Results

$$1 \frac{\mu\text{Ci}}{\text{cm}^2} \cdot \frac{0.19 \text{ rad/hr}}{4.47 \text{ rad/hr}} = 0.0425 \frac{\mu\text{Ci}}{\text{cm}^2} \cdot 232 \text{ cm}^2 = 9.86 \mu\text{Ci}$$

Non Volume Averaged Results

Help

**Radionuclide: Activity**

C-14 [13]: 1.00E+00  $\mu\text{Ci}/\text{cm}^2$

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	4.47E+00 rad/h	4.47E+00 rad	4.47E+00 rad	Beta	4.47E+00 rad/h	4.47E+00 rad	4.47E+00 rad
Photon				Photon			
Total	4.47E+00 rad/h	4.47E+00 rad	4.47E+00 rad	Total	4.47E+00 rad/h	4.47E+00 rad	4.47E+00 rad

Date/Time 8/6/2013 3:10:34 PM Source Geometry Disk Source

Source Diameter 1.72E+01 cm Source Area 2.32E+02  $\text{cm}^2$

Air Gap Thickness 0.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 3.00E+00  $\text{mg}/\text{cm}^2$  Irradiation Area 5.00E+01  $\text{cm}^2$

Print Results Close

Scales to a source strength of 0.0425  $\mu\text{Ci}/\text{cm}^2$ , and a total activity of 9.86  $\mu\text{Ci}$ .

# Confirmation using air gap

Varskin 5.0

File Help

Source Geometry

☐ Point ☐ Sphere

☒ Disk ☐ Slab

☐ Cylinder

Special Options

☐ Include Photon Dose

☐ Perform Volume Averaging

Radionuclide Library

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]

Activity Units

$\mu\text{Ci}$

Select

Add

Remove

Use Distributed Source

Selected Radionuclides

C-14 [13]: 9.86E+00  $\mu\text{Ci}$

Skin Averaging Area

5.00E+01  $\text{cm}^2$

Exposure Time

6.00E+01 min

Disk Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 3.00E+00  $\text{mg}/\text{cm}^2$

Air Gap Thickness: 1.00E+00 in

Cover Thickness 0 mm

Cover Density 0  $\text{g}/\text{cm}^3$

Multiple Cover Calculator

Source Area 2.32E+02  $\text{cm}^2$

Source Diameter 1.72E+01 cm

varskin V5

Calculate Doses

Edit Remove Clear

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

C-14 [13]: 9.86E+00  $\mu$ Ci

**All Radionuclides**

Unit Selection

☒ English Units  
☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	6.04E-02 rad/h	6.04E-02 rad	6.04E-02 rad	Beta	6.04E-02 rad/h	6.04E-02 rad	6.04E-02 rad
Photon				Photon			
Total	6.04E-02 rad/h	6.04E-02 rad	6.04E-02 rad	Total	6.04E-02 rad/h	6.04E-02 rad	6.04E-02 rad

Date/Time 8/6/2013 3:14:58 PM Source Geometry Disk Source

Source Diameter 1.72E+01 cm Source Area 2.32E+02 cm<sup>2</sup>

Air Gap Thickness 1.00E+00 in Irradiation Time 6.00E+01 min

Skin density thickness 3.00E+00 mg/cm<sup>2</sup> Irradiation Area 5.00E+01 cm<sup>2</sup>

Print Results Close

Compares to the measured value of 60 mrad/hr at 1 inch.



## scenario #4

- Contamination found on the outside of a boot
- 160 minute exposure
- Contains 14 nuclides (fission products)
- Conservatively modeled as a point source
- Boot has thickness of 0.44 mm, and density of 1 g/cm<sup>3</sup>

# source term

<u>NUCLIDE</u>	<u>ACTIVITY (uCi)</u>
Co-57	7.41E-4
Co-60	2.86E-4
Sr-89	2.40E-2
Sr-90	2.18E-2
Y-90	2.18E-2
Y-91	4.69E-2
Zr-95	2.81E-3
Te-129m	2.76E-1
Cs-134	9.29E-5
Cs-137	1.96E-3
Ba-137m	1.96E-3
Ba-140	9.05E-5
Ce-141	1.09E-2
Ce-144	2.44E-1

# point source

Varskin 5.0

File Help

Source Geometry

☒ Point ☐ Sphere  
☐ Disk ☐ Slab  
☐ Cylinder

Special Options

☒ Include Photon Dose  
☐ Perform Volume Averaging  
☐ Offset Particle Model

Skin Averaging Area

10 cm<sup>2</sup>

Exposure Time

1.60E+02 min

Radionuclide Library

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
Ce-141 [7.42]  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units

$\mu\text{Ci}$

Select  
Add  
Remove

Selected Radionuclides

Zr-95 [7.42]: 2.81E-03  $\mu\text{Ci}$   
Te-129m [7.42]: 2.76E-01  $\mu\text{Ci}$   
Cs-137 [7.42]: 1.96E-03  $\mu\text{Ci}$   
Ba-137m [7.42]: 1.96E-03  $\mu\text{Ci}$   
Cs-134 [7.42]: 9.29E-05  $\mu\text{Ci}$   
Ba-140 [7.42]: 9.05E-05  $\mu\text{Ci}$   
Ce-141 [7.42]: 1.09E-02  $\mu\text{Ci}$   
Ce-144 [7.42]: 2.44E-01  $\mu\text{Ci}$

Edit Remove Clear

Point Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7 mg/cm<sup>2</sup>

Air Gap Thickness 0 mm

Cover Thickness 4.40E-02 cm

Cover Density 1.00E+00 g/cm<sup>3</sup>

Multiple Cover Calculator

varskin V5

Calculate Doses

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Co-57 [7.42]: 7.41E-04  $\mu$ Ci  
Co-60 [7.42]: 2.86E-04  $\mu$ Ci  
Sr-89 [7.42]: 2.40E-02  $\mu$ Ci  
Sr-90 [7.42]: 2.18E-02  $\mu$ Ci

**All Radionuclides**

Unit Selection  
☒ English Units  
☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad	Beta	5.65E-02 rad/h	1.51E-01 rad	1.50E-01 rad
Photon	9.84E-06 rad/h	2.62E-05 rad	2.62E-05 rad	Photon	4.12E-04 rad/h	1.10E-03 rad	1.07E-03 rad
Total	9.84E-06 rad/h	2.62E-05 rad	2.62E-05 rad	Total	5.69E-02 rad/h	1.52E-01 rad	1.51E-01 rad

Date/Time 1/16/2014 2:42:26 PM Source Geometry Point Source

Cover Thickness 4.40E-01 mm Cover Density 1.00E+00 g/cm<sup>3</sup>

Air Gap Thickness 0.00E+00 mm Irradiation Time 1.60E+02 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results Close

# beta/gamma dose

<u>Nuclide</u>	<u>Activity (uCi)</u>	<u>Beta Dose (mrad)</u>	<u>Photon Dose (mrad)</u>
Co-57	7.41E-4	---	2.62E-2
Co-60	2.86E-4	1.88E-3	1.34E-2
Sr-89	2.40E-2	1.80E+1	---
Sr-90	2.18E-2	4.58E+0	---
Y-90	2.18E-2	2.03E+1	---
Y-91	4.69E-2	3.58E+1	---
Zr-95	2.81E-3	8.75E-2	5.36E-2
Te-129m	2.76E-1	6.93E+1	7.56E-1
Cs-134	9.29E-5	1.75E-2	3.76E-3
Cs-137	1.96E-3	3.53E-1	---
Ba-137m	1.96E-3	2.02E-1	3.19E-2
Ba-140	9.05E-5	3.34E-2	1.06E-3
Ce-141	1.09E-2	1.02E+0	2.74E-2
Ce-144	2.44E-1	<u>9.20E-1</u> 1.50E+2	<u>1.85E-1</u> 1.07E+0

## scenario #5

- Dose rate from general contamination
- $^{141}\text{Ce}$  directly on the skin
  - with concentration ( $0.25 \mu\text{Ci}/\text{cm}^2$ )
- 1" x 1" contamination area
- Exposure to  $1.61 \mu\text{Ci}$  liquid source
- As before, point-source geometry for a bounding estimate
- ... then refine for more realism ...

# Point source

Varskin 5.0

File Help

**Source Geometry**

☒ Point ☐ Sphere  
☐ Disk ☐ Slab  
☐ Cylinder

**Special Options**

☒ Include Photon Dose  
☐ Perform Volume Averaging  
☐ Offset Particle Model

**Radionuclide Library**

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
**Ce-141 [7.42]**  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units  
 $\mu\text{Ci}$   
Select  
Add  
Remove

**Point Source Irradiation Geometry**

Skin Thickness or Skin Density Thickness: 7  $\text{mg}/\text{cm}^2$   
Air Gap Thickness: 0 mm  
Cover Thickness: 0.00E+00 mm  
Cover Density: 0  $\text{g}/\text{cm}^3$   
Multiple Cover Calculator

**Skin Averaging Area**  
10  $\text{cm}^2$

**Exposure Time**  
60 min

**Selected Radionuclides**  
**Ce-141 [7.42]: 1.61E+00  $\mu\text{Ci}$**

Edit Remove Clear

varskin V5

Calculate Doses

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Ce-141 [7.42]: 1.61E+00  $\mu$ Ci

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	9.54E-01 rad/h	9.54E-01 rad	9.53E-01 rad	Beta	9.54E-01 rad/h	9.54E-01 rad	9.53E-01 rad
Photon	2.29E-03 rad/h	2.29E-03 rad	2.29E-03 rad	Photon	2.29E-03 rad/h	2.29E-03 rad	2.29E-03 rad
Total	9.56E-01 rad/h	9.56E-01 rad	9.55E-01 rad	Total	9.56E-01 rad/h	9.56E-01 rad	9.55E-01 rad

Date/Time 9/4/2013 9:23:32 PM Source Geometry Point Source

Air Gap Thickness 0.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results Close



# 2D Disk source

Varskin 5.0

File Help

Source Geometry

☐ Point ☐ Sphere

☒ Disk ☐ Slab

☐ Cylinder

Special Options

☒ Include Photon Dose

☐ Perform Volume Averaging

Radionuclide Library

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
**Ce-141 [7.42]**  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units

$\mu\text{Ci}/\text{cm}^2$

Select

Add

Remove

Use Distributed Source

Selected Radionuclides

**Ce-141 [7.42]: 2.50E-01  $\mu\text{Ci}/\text{cm}^2$**

Skin Averaging Area

10  $\text{cm}^2$

Exposure Time

60 min

Disk Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7  $\text{mg}/\text{cm}^2$

Air Gap Thickness 0 mm

Cover Thickness 0.00E+00 mm

Cover Density 0  $\text{g}/\text{cm}^3$

Multiple Cover Calculator

Source Area 1.00E+00  $\text{in}^2$

Source Diameter 1.13E+00 in

varskin V5

Calculate Doses

Edit Remove Clear

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Ce-141 [7.42]: 2.50E-01  $\mu\text{Ci}/\text{cm}^2$

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Electron	9.65E-01 rad/h	9.65E-01 rad	9.65E-01 rad	Electron	9.65E-01 rad/h	9.65E-01 rad	9.65E-01 rad
Photon	2.15E-03 rad/h	2.15E-03 rad	2.15E-03 rad	Photon	2.15E-03 rad/h	2.15E-03 rad	2.15E-03 rad
Total	9.67E-01 rad/h	9.67E-01 rad	9.67E-01 rad	Total	9.67E-01 rad/h	9.67E-01 rad	9.67E-01 rad

Date/Time 2/19/2015 11:11:59 AM Source Geometry Disk Source

Source Diameter 1.13E+00 in Source Area 1.00E+00 in<sup>2</sup>

Air Gap Thickness 0.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results Close

# Slab source

Varskin 5.0

File Help

Source Geometry

☐ Point ☐ Sphere  
☐ Disk ☒ Slab  
☐ Cylinder

Special Options

☒ Include Photon Dose  
☐ Perform Volume Averaging

Radionuclide Library

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
**Ce-141 [7.42]**  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units  
 $\mu\text{Ci}$

Select  
Add  
Remove

☐ Use Distributed Source

Selected Radionuclides

**Ce-141 [7.42]: 1.61E+00  $\mu\text{Ci}$**

Skin Averaging Area  
10  $\text{cm}^2$

Exposure Time  
60 min

Slab Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7  $\text{mg}/\text{cm}^2$   
Air Gap Thickness 0 mm  
Cover Thickness 0 mm  
Cover Density 0  $\text{g}/\text{cm}^3$   
Multiple Cover Calculator  
X-Side Length 1 in  
Y-Side Length 1 in  
Source Thickness 0.1  $\mu\text{m}$   
Source Density 1  $\text{g}/\text{cm}^3$

varskin V5

Calculate Doses

Edit Remove Clear

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Ce-141 [7.42]: 1.61E+00  $\mu$ Ci

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Electron	1.05E+00 rad/h	1.05E+00 rad	1.05E+00 rad	Electron	1.05E+00 rad/h	1.05E+00 rad	1.05E+00 rad
Photon	1.95E-03 rad/h	1.95E-03 rad	1.95E-03 rad	Photon	1.95E-03 rad/h	1.95E-03 rad	1.95E-03 rad
Total	1.05E+00 rad/h	1.05E+00 rad	1.05E+00 rad	Total	1.05E+00 rad/h	1.05E+00 rad	1.05E+00 rad

Date/Time 2/19/2015 10:31:15 AM

Source Geometry Slab Source

X side Length 1.00E+00 in

Y side Length 1.00E+00 in

Source Thickness 1.00E-01  $\mu$ m

Source Density 1.00E+00 g/cm<sup>3</sup>

Air Gap Thickness 0.00E+00 mm

Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup>

Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results

Close

# Slab source (low density)

Varskin 5.0

File Help

**Source Geometry**

☐ Point ☐ Sphere  
☐ Disk ☒ Slab  
☐ Cylinder

**Special Options**

☒ Include Photon Dose  
☐ Perform Volume Averaging

**Radionuclide Library**

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
**Ce-141 [7.42]**  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units  
 $\mu\text{Ci}$

Select  
Add  
Remove

☐ Use Distributed Source

**Selected Radionuclides**

**Ce-141 [7.42]: 1.61E+00  $\mu\text{Ci}$**

Edit Remove Clear

**Slab Source Irradiation Geometry**

Skin Thickness or Skin Density Thickness: 7  $\text{mg}/\text{cm}^2$   
Air Gap Thickness 0 mm  
Cover Thickness 0 mm  
Cover Density 0  $\text{g}/\text{cm}^3$   
Multiple Cover Calculator  
X-Side Length 1.00E+00 in  
Y-Side Length 1.00E+00 in  
Source Thickness 1.00E-01  $\mu\text{m}$   
Source Density 1.29E-03  $\text{g}/\text{cm}^3$

varskin V5

Calculate Doses

Skin Averaging Area  
10  $\text{cm}^2$

Exposure Time  
60 min

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Ce-141 [7.42]: 1.61E+00  $\mu$ Ci

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Electron	9.52E-01 rad/h	9.52E-01 rad	9.52E-01 rad	Electron	9.52E-01 rad/h	9.52E-01 rad	9.52E-01 rad
Photon	1.95E-03 rad/h	1.95E-03 rad	1.95E-03 rad	Photon	1.95E-03 rad/h	1.95E-03 rad	1.95E-03 rad
Total	9.54E-01 rad/h	9.54E-01 rad	9.54E-01 rad	Total	9.54E-01 rad/h	9.54E-01 rad	9.54E-01 rad

Date/Time 2/19/2015 10:48:08 AM Source Geometry Slab Source

X side Length 1.00E+00 in Y side Length 1.00E+00 in

Source Thickness 1.00E-01  $\mu$ m Source Density 1.29E-03 g/cm<sup>3</sup>

Air Gap Thickness 0.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results Close

# Slab source (1 cm<sup>2</sup>)

Varskin 5.0

File Help

**Source Geometry**

☐ Point ☐ Sphere  
☐ Disk ☒ Slab  
☐ Cylinder

**Special Options**

☒ Include Photon Dose  
☐ Perform Volume Averaging

**Radionuclide Library**

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
**Ce-141 [7.42]**  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units

☐ Use Distributed Source

**Selected Radionuclides**

**Ce-141 [7.42]: 1.61E+00 μCi**

**Slab Source Irradiation Geometry**

Skin Thickness or Skin Density Thickness:    
Air Gap Thickness    
Cover Thickness    
Cover Density

X-Side Length    
Y-Side Length    
Source Thickness    
Source Density

**varskin V5**

**Skin Averaging Area**

**Exposure Time**

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Ce-141 [7.42]: 1.61E+00  $\mu$ Ci

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Electron	1.61E+00 rad/h	1.61E+00 rad	1.61E+00 rad	Electron	1.61E+00 rad/h	1.61E+00 rad	1.61E+00 rad
Photon	1.13E-02 rad/h	1.13E-02 rad	1.13E-02 rad	Photon	1.13E-02 rad/h	1.13E-02 rad	1.13E-02 rad
Total	1.62E+00 rad/h	1.62E+00 rad	1.62E+00 rad	Total	1.62E+00 rad/h	1.62E+00 rad	1.62E+00 rad

Date/Time 2/19/2015 11:01:45 AM Source Geometry Slab Source

X side Length 1.00E+00 in Y side Length 1.00E+00 in

Source Thickness 1.00E-01  $\mu$ m Source Density 1.00E+00 g/cm<sup>3</sup>

Air Gap Thickness 0.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+00 cm<sup>2</sup>

Print Results Close



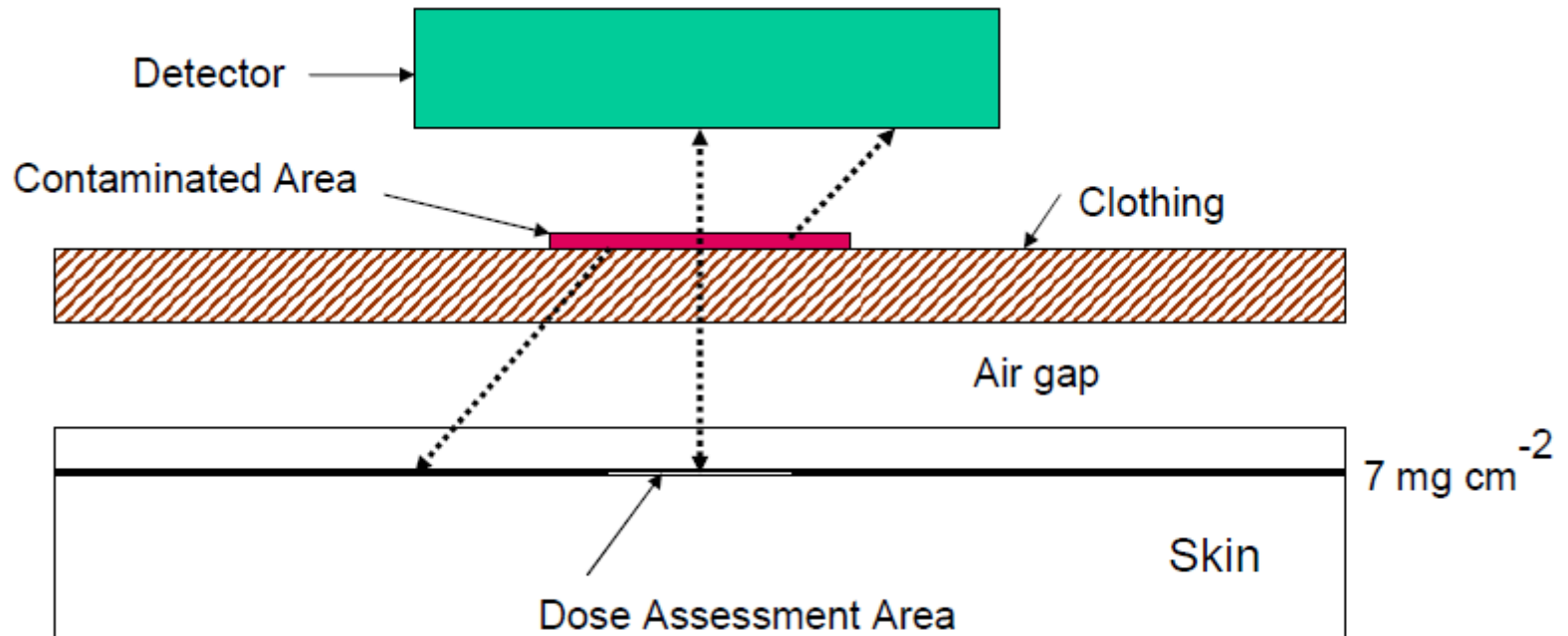
# summary

1" x 1"	Beta Dose Rate	Photon Dose Rate	Total Dose Rate (rad/hr)
Point Source	0.954	0.00229	0.956
2D Disk Source	0.965	0.00215	0.967
Water Slab Source	1.05	0.00195	1.05
Air Slab Source	0.952	0.00195	0.954
Water Slab (1 cm <sup>2</sup> )	1.61	0.0113	1.62

## scenario #6

- Particle (not captured) on plastic lab coat
  - will assume 3 mm air gap (very arbitrary)
  - coat thickness of 0.20 mm, and density of 0.36 g/cm<sup>3</sup>
- Source measurements indicate:
  - 0.0036  $\mu$ Ci of Co-57
  - 0.1920  $\mu$ Ci of Ru-106 (Rh-106)
  - 0.0028  $\mu$ Ci of Cs-134
  - 0.0036  $\mu$ Ci of Cs-137 (Ba-137m)
- Modeled as a point source
- Interested in a beta and gamma depth-dose profile

# Beta activity determination



# Varskin input

Varskin 5.0

File Help

Source Geometry

☒ Point ☐ Sphere  
☐ Disk ☐ Slab  
☐ Cylinder

Special Options

☒ Include Photon Dose  
☐ Perform Volume Averaging  
☐ Offset Particle Model

Skin Averaging Area

10 cm<sup>2</sup>

Exposure Time

60 min

Radionuclide Library

Ce-144 [7.42]  
Ce-141 [7.42]  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]  
Sr-90 [7.42]  
Te-129m [7.42]  
Y-90 [7.42]  
Y-91 [7.42]  
Zr-95 [7.42]  
Ru-106 [7.42]  
Rh-106 [7.42]

Activity Units

$\mu\text{Ci}$

Select  
Add  
Remove

Selected Radionuclides

Co-57 [7.42]: 3.60E-03  $\mu\text{Ci}$   
Cs-134 [7.42]: 2.80E-03  $\mu\text{Ci}$   
Cs-137 [7.42]: 3.60E-03  $\mu\text{Ci}$   
Ba-137m [7.42]: 3.60E-03  $\mu\text{Ci}$   
Ru-106 [7.42]: 1.92E-01  $\mu\text{Ci}$   
Rh-106 [7.42]: 1.92E-01  $\mu\text{Ci}$

Edit Remove Clear

Point Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7.00E+00 mg/cm<sup>2</sup>  
Air Gap Thickness: 3.00E+00 mm  
Cover Thickness: 2.00E-01 mm  
Cover Density: 3.60E-01 g/cm<sup>3</sup>

Multiple Cover Calculator

varskin V5

Calculate Doses

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Co-57 [7.42]: 3.60E-03  $\mu\text{Ci}$   
Cs-134 [7.42]: 2.80E-03  $\mu\text{Ci}$   
Cs-137 [7.42]: 3.60E-03  $\mu\text{Ci}$   
Ba-137m [7.42]: 3.60E-03  $\mu\text{Ci}$

**All Radionuclides**

Unit Selection  
☒ English Units  
☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Electron	2.02E-05 rad/h	2.02E-05 rad	2.02E-05 rad	Electron	4.83E-02 rad/h	4.83E-02 rad	2.34E-03 rad
Photon	3.53E-05 rad/h	3.53E-05 rad	3.53E-05 rad	Photon	1.58E-04 rad/h	1.58E-04 rad	4.97E-05 rad
Total	5.54E-05 rad/h	5.54E-05 rad	5.54E-05 rad	Total	4.85E-02 rad/h	4.85E-02 rad	2.39E-03 rad

Date/Time 2/19/2015 11:26:29 AM Source Geometry Point Source

Cover Thickness 2.00E-01 mm Cover Density 3.60E-01 g/cm<sup>3</sup>

Air Gap Thickness 3.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

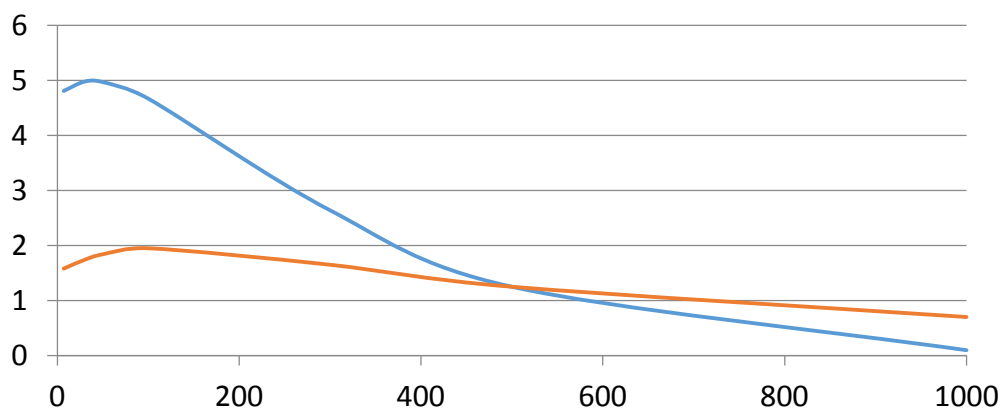
Print Results Close

# Results by nuclide

@ 7 mg/cm <sup>2</sup>	Beta Dose Rate	Photon Dose Rate	Total Dose Rate (rad/hr)
Co-57	2.02E-5	3.53E-5	5.54E-5
Ru-106	0	0	0
Rh-106	4.65E-2	1.04E-4	4.66E-2
Cs-134	6.41E-4	1.27E-5	6.54E-4
Cs-137	1.06E-3	0	1.06E-3
Ba-137m	1.02E-4	6.49E-6	1.09E-4
<b>TOTAL</b>	<b>4.83E-2</b>	<b>1.58E-4</b>	<b>4.85E-2</b>

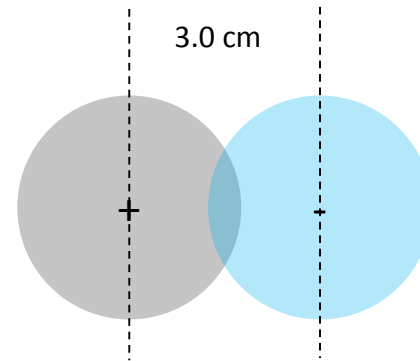
# Results by depth

	Beta Dose Rate	Photon Dose Rate	Total Dose Rate (rad/hr)
7 mg/cm <sup>2</sup>	4.83E-2	1.58E-4	4.85E-2
30	5.00E-2	1.74E-4	5.01E-2
50	4.98E-2	1.84E-4	5.00E-2
100	4.67E-2	1.95E-4	4.69E-2
300	2.64E-2	1.65E-4	2.66E-2
500	1.25E-2	1.25E-4	1.27E-2
1000	9.68E-4	7.00E-5	1.04E-3



## scenario #7 (offset model)

- Two particles on skin
  - separated by 3.0 cm
- Particle #1:
  - 1.38  $\mu\text{Ci}$  of Mn-54 ( $Z=25$ )
- Particle #2:
  - 0.471  $\mu\text{Ci}$  of Co-60 ( $Z=27$ )
- Modeled as two offset point sources
- Offset model only works for photon dosimetry
- Need maximum dose rate to 10 cm<sup>2</sup> disk @ 7 mg/cm<sup>2</sup>





# Point source input

Varskin 5.0

File Help

**Source Geometry**

☒ Point ☐ Sphere  
☐ Disk ☐ Slab  
☐ Cylinder

**Special Options**

☒ Include Photon Dose  
☐ Perform Volume Averaging  
☒ Offset Particle Model  
Offset Value: 0 cm

**Radionuclide Library**

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
Ce-141 [7.42]  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units:  $\mu\text{Ci}$

Select  
Add  
Remove

**Point Source Irradiation Geometry**

Skin Thickness or Skin Density Thickness: 7  $\text{mg}/\text{cm}^2$   
Air Gap Thickness: 0 mm  
Cover Thickness: 0 mm  
Cover Density: 0  $\text{g}/\text{cm}^3$   
Multiple Cover Calculator

**Selected Radionuclides**

Mn-54 [25]:  $1.38\text{E}+00 \mu\text{Ci}$   
Co-60 [27]:  $4.71\text{E}-01 \mu\text{Ci}$

Edit Remove Clear

Skin Averaging Area: 10  $\text{cm}^2$

Exposure Time: 60 min

varskin V5

Calculate Doses

# results

**Non Volume Averaged Results**

Help

**Radionuclide: Activity**

Mn-54 [25]: 1.38E+00 µCi  
Co-60 [27]: 4.71E-01 µCi

**All Radionuclides**

Unit Selection  
☒ English Units  
☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad	Beta	1.68E-01 rad/h	1.68E-01 rad	1.68E-01 rad
Photon	1.55E-02 rad/h	1.55E-02 rad	1.55E-02 rad	Photon	2.15E-02 rad/h	2.15E-02 rad	2.15E-02 rad
Total	1.55E-02 rad/h	1.55E-02 rad	1.55E-02 rad	Total	1.89E-01 rad/h	1.89E-01 rad	1.89E-01 rad

Date/Time 8/9/2013 10:09:00 AM Source Geometry Point Source

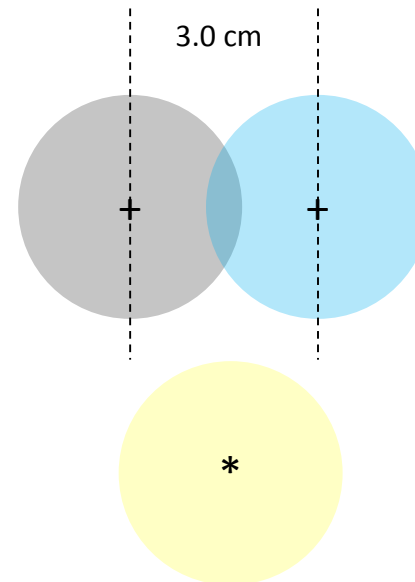
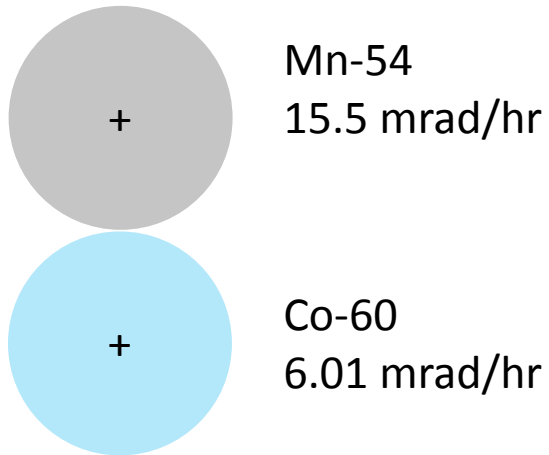
Air Gap Thickness 0.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm² Irradiation Area 1.00E+01 cm²

Offset 0.00E+00 cm

Print Results Close

# Photon dose rate from each source



Where do we place a single averaging disk in order to maximize dose?

# Offset particle model input

The screenshot displays the Varskin 5.0 software interface. The 'Offset Particle Model' checkbox is checked and highlighted with a green circle. The 'Offset Value' is set to 1.50E+00 cm. The 'Radionuclide Library' lists various isotopes, with Co-60 [27] selected. The 'Selected Radionuclides' section shows Mn-54 [25] with an activity of 1.38E+00 µCi and Co-60 [27] with an activity of 4.71E-01 µCi. The 'Point Source Irradiation Geometry' section includes fields for Skin Thickness or Skin Density Thickness (7 mg/cm²), Air Gap Thickness (0 mm), Cover Thickness (0 mm), and Cover Density (0 g/cm³). The 'Calculate Doses' button is visible at the bottom right.

Varskin 5.0

File Help

Source Geometry

☒ Point ☐ Sphere

☐ Disk ☐ Slab

☐ Cylinder

Special Options

☒ Include Photon Dose

☐ Perform Volume Averaging

☒ Offset Particle Model

Offset Value:

1.50E+00 cm

Skin Averaging Area

10 cm²

Exposure Time

60 min

Radionuclide Library

Cs-137 [7.42]

Co-60 [27]

Ba-137m [7.42]

Co-60 [7.42]

Re-186 [7.42]

C-14 [13]

Co-57 [7.42]

Ce-144 [7.42]

Ce-141 [7.42]

Ba-140 [7.42]

Cs-134 [7.42]

Sr-89 [7.42]

Activity Units

µCi

Select

Add

Remove

Point Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7 mg/cm²

Air Gap Thickness 0 mm

Cover Thickness 0 mm

Cover Density 0 g/cm³

Multiple Cover Calculator

Selected Radionuclides

Mn-54 [25]: 1.38E+00 µCi

Co-60 [27]: 4.71E-01 µCi

Edit Remove Clear

varskin V5

Calculate Doses

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Mn-54 [25]: 1.38E+00  $\mu$ Ci  
Co-60 [27]: 4.71E-01  $\mu$ Ci

**All Radionuclides**

Unit Selection  
☒ English Units  
☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad	Beta	1.68E-01 rad/h	1.68E-01 rad	1.68E-01 rad
Photon	1.41E-02 rad/h	1.41E-02 rad	1.41E-02 rad	Photon	1.91E-02 rad/h	1.91E-02 rad	1.91E-02 rad
Total	1.41E-02 rad/h	1.41E-02 rad	1.41E-02 rad	Total	1.87E-01 rad/h	1.87E-01 rad	1.87E-01 rad

Date/Time 8/9/2013 10:10:40 AM Source Geometry Point Source

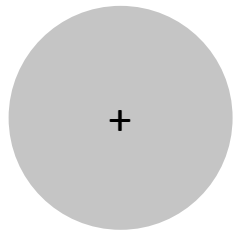
Air Gap Thickness 0.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

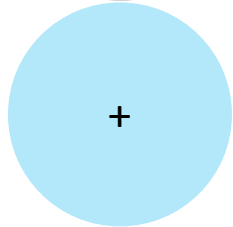
Offset 1.50E+00 cm

Print Results Close

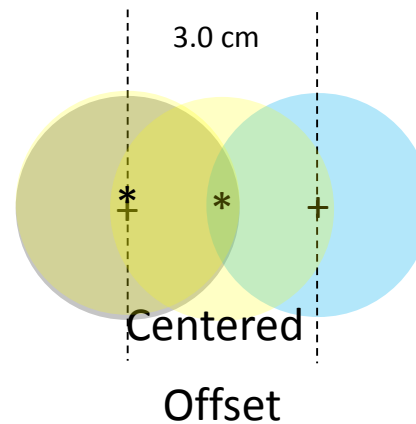
# Dose to single averaging disk



Mn-54  
15.5 mrad/hr

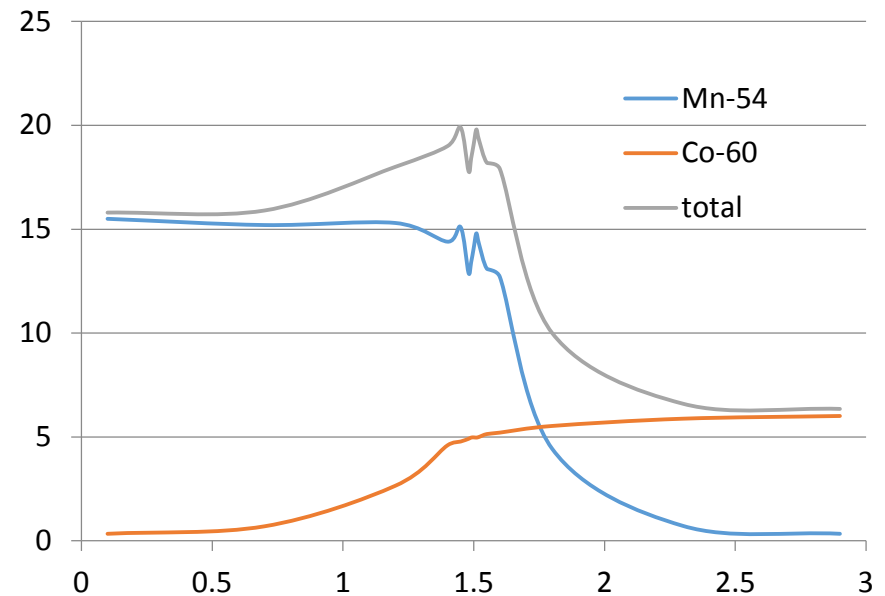


Co-60  
6.01 mrad/hr



# Placement to maximize photon dose

Dose Rate (mrad/hr)	Mn-54	Co-60	Total
Each on-axis (stacked)	15.5	6.01	21.5
0.1 cm from Mn-54	15.5	0.34	15.8
0.7 cm	15.2	0.70	15.9
1.2 cm	15.3	2.65	18.0
1.4 cm	14.4	4.60	19.0
1.45 cm	15.1	4.78	19.9
1.48 cm	12.9	4.91	17.8
1.49 cm	13.4	4.97	18.4
1.5 cm (centered)	14.1	4.98	19.1
1.51 cm	14.8	4.97	19.8
1.52 cm	14.3	5.00	19.3
1.55 cm	13.1	5.14	18.2
1.6 cm	12.7	5.21	17.9
1.8 cm	4.43	5.53	10.0
2.3 cm	0.72	5.88	6.60
2.9 cm (0.1 cm from Co-60)	0.34	6.01	6.35

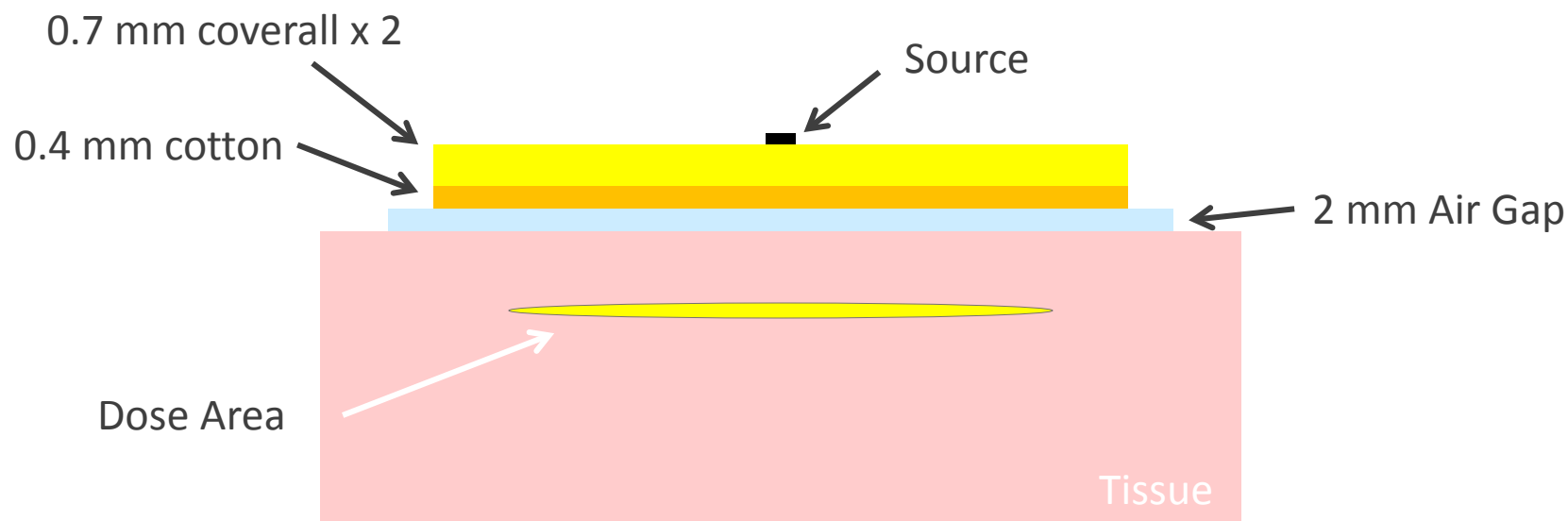


## scenario #8 (multiple cover)

- Using the Multiple Cover Calculator
- Hot particle imbedded in two layers of coveralls (0.7 mm; 0.4 g/cm<sup>3</sup>), and one heavy cotton shirt (assumed similar to cloth lab coat; 0.4 mm; 0.9 g/cm<sup>3</sup>)
- Assume air gap of 1.5 mm + 0.5 mm between coveralls and cotton shirt
- Sr-90 in equilibrium with daughter
- 1.3 µCi in iron (Z=26; 7.87 g/cm<sup>3</sup>), cylindrical source, 20 µm diameter x 40 µm length
- Depth-dose profile to 100 mg/cm<sup>2</sup>



# Cover model



# Multiple cover input

Varskin 5.0

File Help

Source Geometry

- ☐ Point
- ☐ Disk
- ☒ Cylinder

Special Options

- ☐ Include Photo
- ☐ Perform Volume

Skin Averaging

10

Exposure Time

60 min

Multiple Cover Calculator

Help

	Density	Thickness	Density Thickness
Cover 1	4.00E-01 g/cm <sup>3</sup>	7.00E-02 cm	2.80E+01 mg/cm <sup>2</sup>
Cover 2	4.00E-01 g/cm <sup>3</sup>	7.00E-02 cm	2.80E+01 mg/cm <sup>2</sup>
Cover 3	9.00E-01 g/cm <sup>3</sup>	4.00E-02 cm	3.60E+01 mg/cm <sup>2</sup>
Cover 4	g/cm <sup>3</sup>	mm	mg/cm <sup>2</sup>
Cover 5	g/cm <sup>3</sup>	mm	mg/cm <sup>2</sup>
Total	5.11E-01 g/cm <sup>3</sup>	1.80E-01 cm	9.20E-02 g/cm <sup>2</sup>

Cancel Calculate

Edit Remove Clear Calculate Doses

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Sr-90 [26]: 1.30E+00  $\mu$ Ci  
Y-90 [26]: 1.30E+00  $\mu$ Ci

**All Radionuclides**

Unit Selection  
☒ English Units  
☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	8.28E-03 rad/h	8.28E-03 rad	8.28E-03 rad	Beta	3.04E-01 rad/h	3.04E-01 rad	3.02E-01 rad
Photon				Photon			
Total	8.28E-03 rad/h	8.28E-03 rad	8.28E-03 rad	Total	3.04E-01 rad/h	3.04E-01 rad	3.02E-01 rad

Date/Time 1/16/2014 2:57:31 PM Source Geometry Cylinder Source

Source Diameter 2.00E+01  $\mu$ m Source Thickness 4.00E+01  $\mu$ m

Source Density 7.87E+00 g/cm<sup>3</sup>

Cover Thickness 1.80E-01 cm Cover Density 5.11E-01 g/cm<sup>3</sup>

Air Gap Thickness 2.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results Close

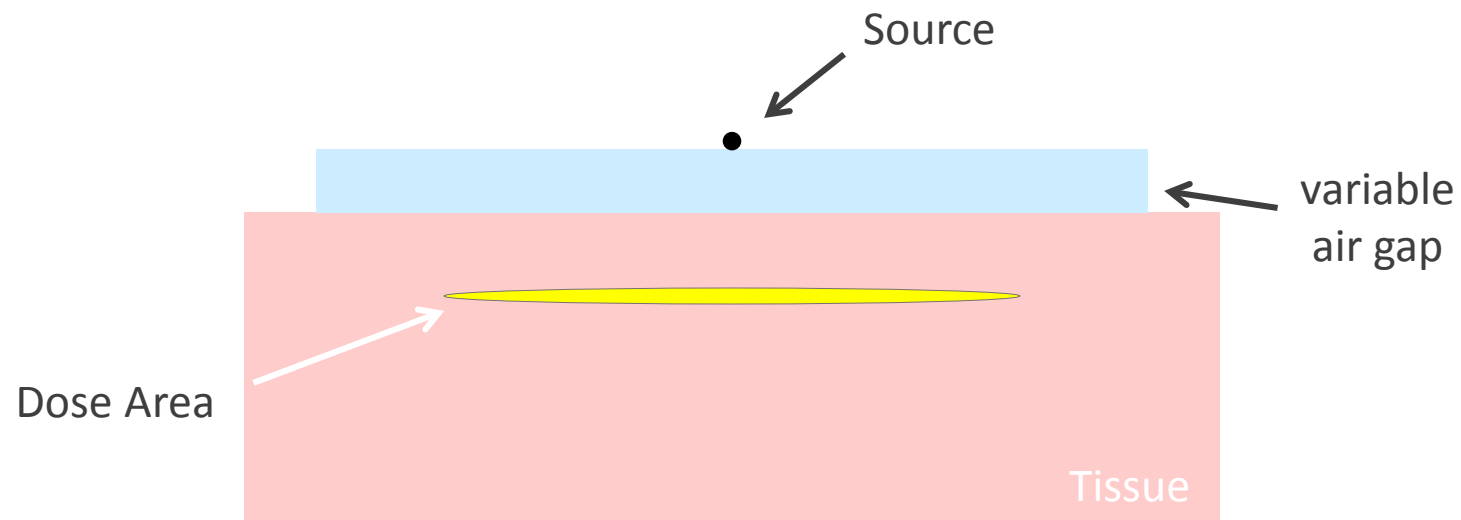
# Depth-dose summary

	Sr-90 Beta	Y-90 Beta	Total Dose (mrad/hr)
7 mg/cm <sup>2</sup>	8.28	296	304
10	6.91	292	298
20	3.67	279	282
30	1.86	267	269
50	0.413	242	242
100	0.185	187	187

## scenario #9 (air gap)

- Using the Air Gap Model
- Co-60 point source (1  $\mu\text{Ci}$ )
- 10  $\text{cm}^2$  averaging area
- Tissue depth of 7  $\text{mg}/\text{cm}^2$
- How does dose vary with an air gap of zero to 5 cm?

# Air gap model



# Air gap model input

Varskin 5.0

File Help

Source Geometry

☒ Point ☐ Sphere  
☐ Disk ☐ Slab  
☐ Cylinder

Special Options

☒ Include Photon Dose  
☐ Perform Volume Averaging  
☐ Offset Particle Model

Skin Averaging Area

10 cm<sup>2</sup>

Exposure Time

60 min

Radionuclide Library

Activity Units  
μCi

Select  
Add  
Remove

Selected Radionuclides

Co-60 [7.42]: 1.00E+00 μCi

Edit Remove Clear

Point Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7 mg/cm<sup>2</sup>

Air Gap Thickness: 2.50E-01 cm

Cover Thickness 0 mm

Cover Density 0 g/cm<sup>3</sup>

Multiple Cover Calculator

varskin V5

Calculate Doses

# results

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Co-60 [7.42]: 1.00E+00  $\mu$ Ci

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	3.40E-01 rad/h	3.40E-01 rad	3.40E-01 rad	Beta	3.40E-01 rad/h	3.40E-01 rad	3.40E-01 rad
Photon	7.03E-03 rad/h	7.03E-03 rad	7.03E-03 rad	Photon	7.03E-03 rad/h	7.03E-03 rad	7.03E-03 rad
Total	3.47E-01 rad/h	3.47E-01 rad	3.47E-01 rad	Total	3.47E-01 rad/h	3.47E-01 rad	3.47E-01 rad

Date/Time 8/9/2013 10:43:43 AM Source Geometry Point Source

Air Gap Thickness 2.50E-01 cm Irradiation Time 6.00E+01 min

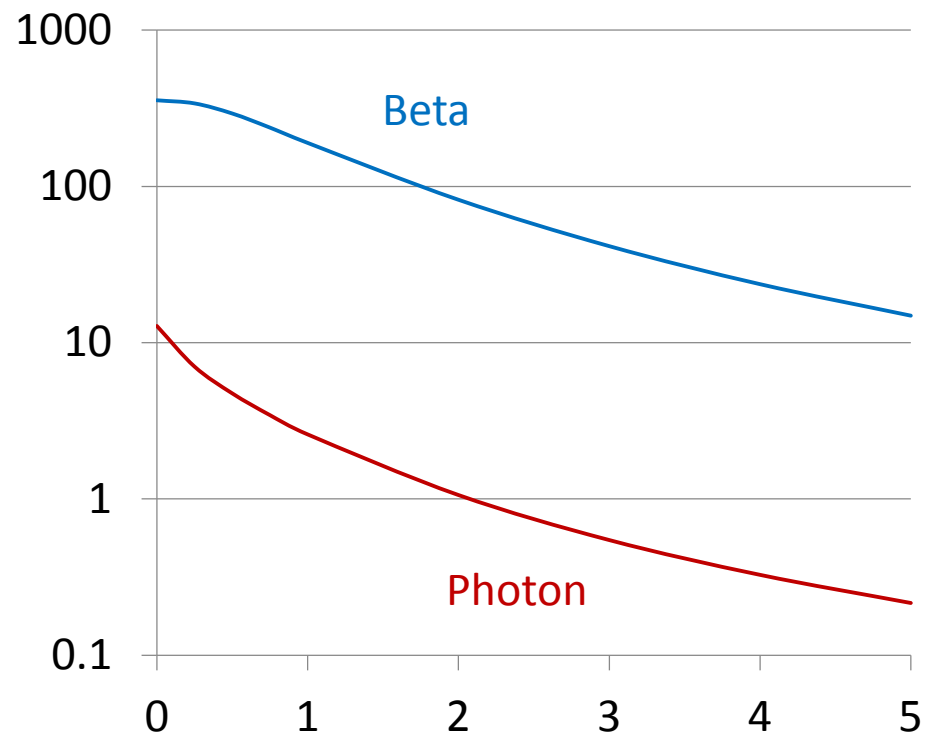
Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

Print Results Close



# Air gap impact on dose

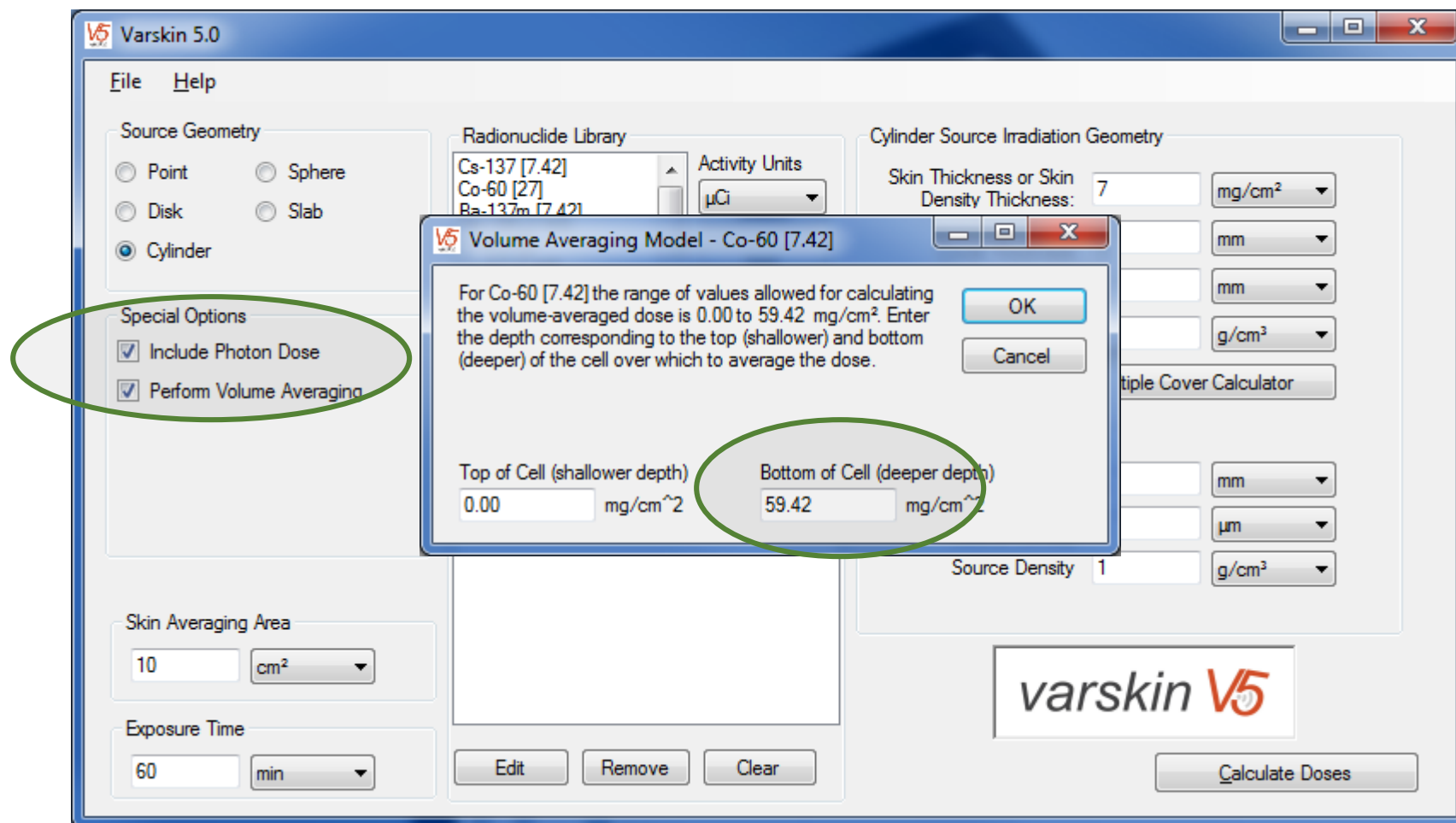
Air Gap (cm)	Beta	Photon	Total
0	356	12.8	369
0.25	340	7.03	347
0.50	293	4.74	298
0.75	238	3.44	241
1	190	2.59	192
2	82.2	1.06	83.3
3	41.5	0.546	42.0
4	23.7	0.327	24.1
5	14.9	0.216	15.1



## scenario #10

- 1  $\mu\text{Ci}$  of Co-60 on skin
- 3D source
- With photon dose calculations
- With volume averaging (beta and gamma)
- For the purpose of examining run times

# 3D source and Volume averaging



# Maximum volume averaging depth

	Max Beta Energy (keV)	Max Depth (mg/cm <sup>2</sup> )
Co-60	318	59.42
Cs-137	514	163.8
Cs-134	658	186.2
Ba-140	1020	295.3
Y-91	1540	604.4

# Calculating beta dose

Varskin 5.0

File Help

Source Geometry

☐ Point ☐ Sphere  
☐ Disk ☐ Slab  
☒ Cylinder

Special Options

☒ Include Photon Dose  
☒ Perform Volume Averaging

Skin Averaging Area

10 cm<sup>2</sup>

Exposure Time

60 min

Radionuclide Library

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
Ce-141 [7.42]  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units

$\mu\text{Ci}$

Select  
Add  
Remove

☐ Use Distributed Source

Selected Radionuclides

Co-60 [7.42]: 1.00E+00  $\mu\text{Ci}$

Edit Remove Clear

Cylinder Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7 mg/cm<sup>2</sup>

Air Gap Thickness 0 mm

Cover Thickness 0 mm

Cover Density 0 g/cm<sup>3</sup>

Multiple Cover Calculator

Source Diameter 1 mm

Source Thickness 1  $\mu\text{m}$

Source Density 1 g/cm<sup>3</sup>

varskin V5

Cancel Calculating beta dose...

# Calculating gamma dose

Varskin 5.0

File Help

**Source Geometry**

☐ Point ☐ Sphere  
☐ Disk ☐ Slab  
☒ Cylinder

**Special Options**

☒ Include Photon Dose  
☒ Perform Volume Averaging

**Radionuclide Library**

Cs-137 [7.42]  
Co-60 [27]  
Ba-137m [7.42]  
Co-60 [7.42]  
Re-186 [7.42]  
C-14 [13]  
Co-57 [7.42]  
Ce-144 [7.42]  
Ce-141 [7.42]  
Ba-140 [7.42]  
Cs-134 [7.42]  
Sr-89 [7.42]

Activity Units  
 $\mu\text{Ci}$

Select  
Add  
Remove

☐ Use Distributed Source

**Selected Radionuclides**

Co-60 [7.42]: 1.00E+00  $\mu\text{Ci}$

Edit Remove Clear

**Cylinder Source Irradiation Geometry**

Skin Thickness or Skin Density Thickness: 7  $\text{mg}/\text{cm}^2$   
Air Gap Thickness 0 mm  
Cover Thickness 0 mm  
Cover Density 0  $\text{g}/\text{cm}^3$   
Multiple Cover Calculator

Source Diameter 1 mm  
Source Thickness 1  $\mu\text{m}$   
Source Density 1  $\text{g}/\text{cm}^3$

Skin Averaging Area  
10  $\text{cm}^2$

Exposure Time  
60 min

varskin V5

Cancel Calculating gamma dose...

# Time (sec) to calculate dose

	Beta	Gamma	Volume Avg Beta	Volume Avg Gamma
Co-60	---	6	6	59
Cs-134	---	28	4	288
Ba-137m	---	10	4	87
Cs-137	---	---	4	---
Ba-140	---	38	4	368
Y-91	---	---	3	---

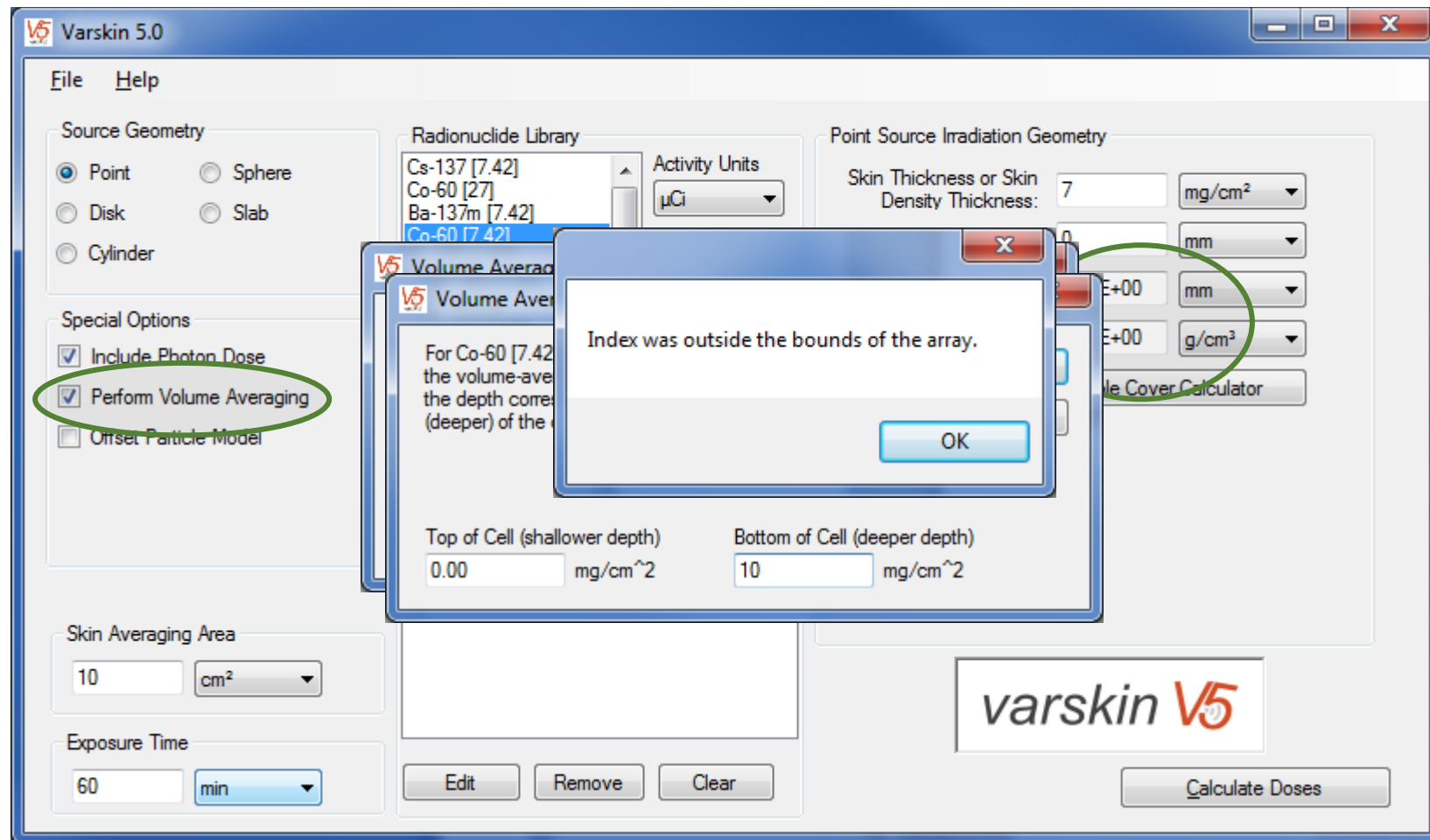
\*Using cylindrical source geometry ( --- indicates <1 second).

## scenario #11

- Using the volume-averaging option w/ the cover model
- If the cover is too thick/dense for the selected beta emitter, the maximum beta range is shown as NEGATIVE
- The code will not run, even if the maximum depth is changed to a non-negative value, because the cover material is preventing any beta dose (glitch in beta dosimetry)



# Volume averaging option



w/o volume averaging

Varskin 5.0

File Help

Source Geometry

☒ Point ☐ Sphere  
☐ Disk ☐ Slab  
☐ Cylinder

Special Options

☒ Include Photon Dose  
☐ Perform Volume Averaging  
☐ Offset Particle Model

Skin Averaging Area

10 cm<sup>2</sup>

Exposure Time

60 min

Radionuclide Library

Activity Units  
μCi

Select  
Add  
Remove

Point Source Irradiation Geometry

Skin Thickness or Skin Density Thickness: 7 mg/cm<sup>2</sup>  
Air Gap Thickness 0 mm  
Cover Thickness 1.00E+00 mm  
Cover Density 1.00E+00 g/cm<sup>3</sup>  
Multiple Cover Calculator

Selected Radionuclides

Co-60 [7.42]: 1.00E+00 μCi

Edit Remove Clear

Calculate Doses

varskin V5

# Zero beta dose

Non Volume Averaged Results

Help

**Radionuclide: Activity**

Co-60 [7.42]: 1.00E+00  $\mu$ Ci

**All Radionuclides**

Unit Selection

☒ English Units

☐ SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose		Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad	Beta	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad
Photon	1.78E-02 rad/h	1.78E-02 rad	1.78E-02 rad	Photon	1.78E-02 rad/h	1.78E-02 rad	1.78E-02 rad
Total	1.78E-02 rad/h	1.78E-02 rad	1.78E-02 rad	Total	1.78E-02 rad/h	1.78E-02 rad	1.78E-02 rad

Date/Time 8/9/2013 11:47:48 AM Source Geometry Point Source

Cover Thickness 1.00E+00 mm Cover Density 1.00E+00 g/cm<sup>3</sup>

Air Gap Thickness 0.00E+00 mm Irradiation Time 6.00E+01 min

Skin density thickness 7.00E+00 mg/cm<sup>2</sup> Irradiation Area 1.00E+01 cm<sup>2</sup>

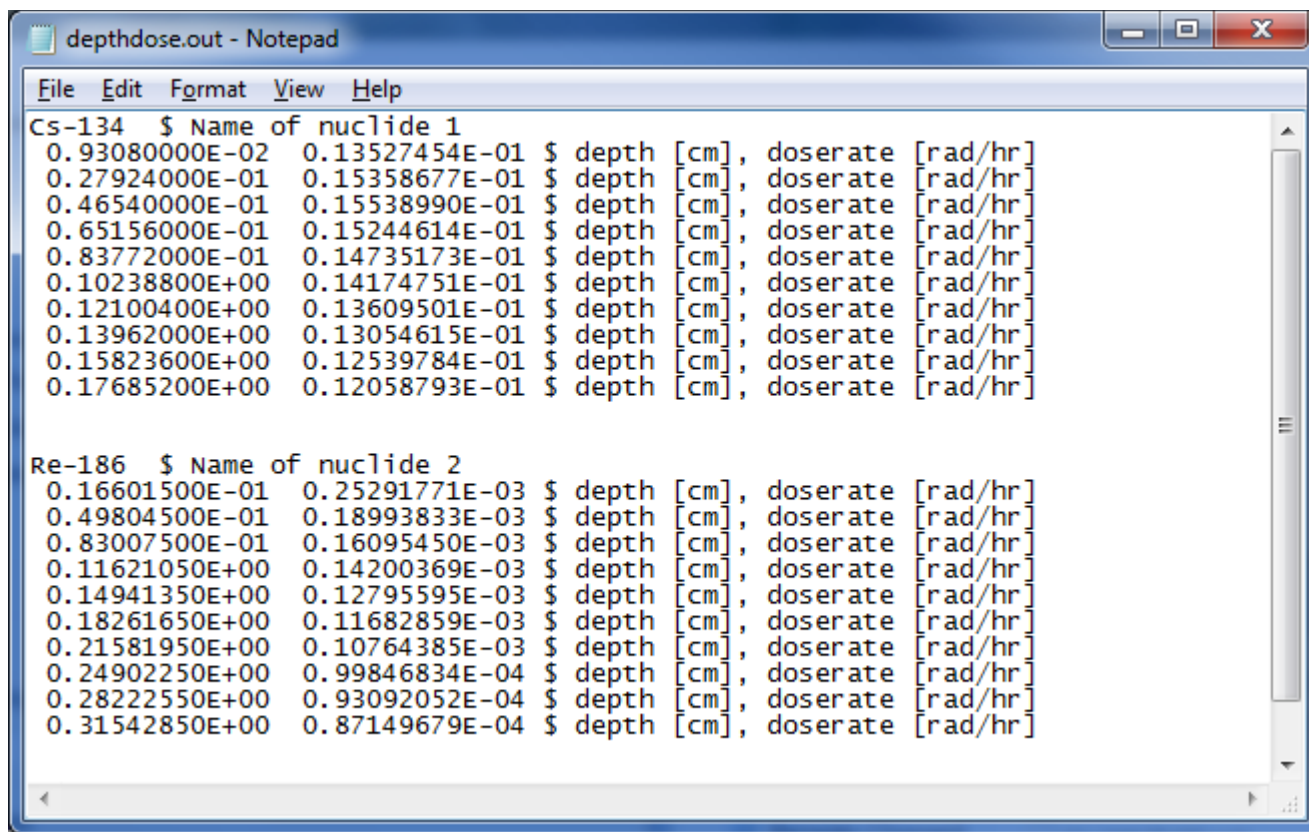
Print Results Close

# “Hidden” output files

- These files could be helpful to you ...
  - depthdose
  - detailed
  - gamdose
  - gaminput
- Developed for photon-model debugging
- They’re found in the “dat” folder

# File “Depthdose”

- Provides gamma dose rate at 10 depths (to max beta depth) when “perform volume averaging” is selected

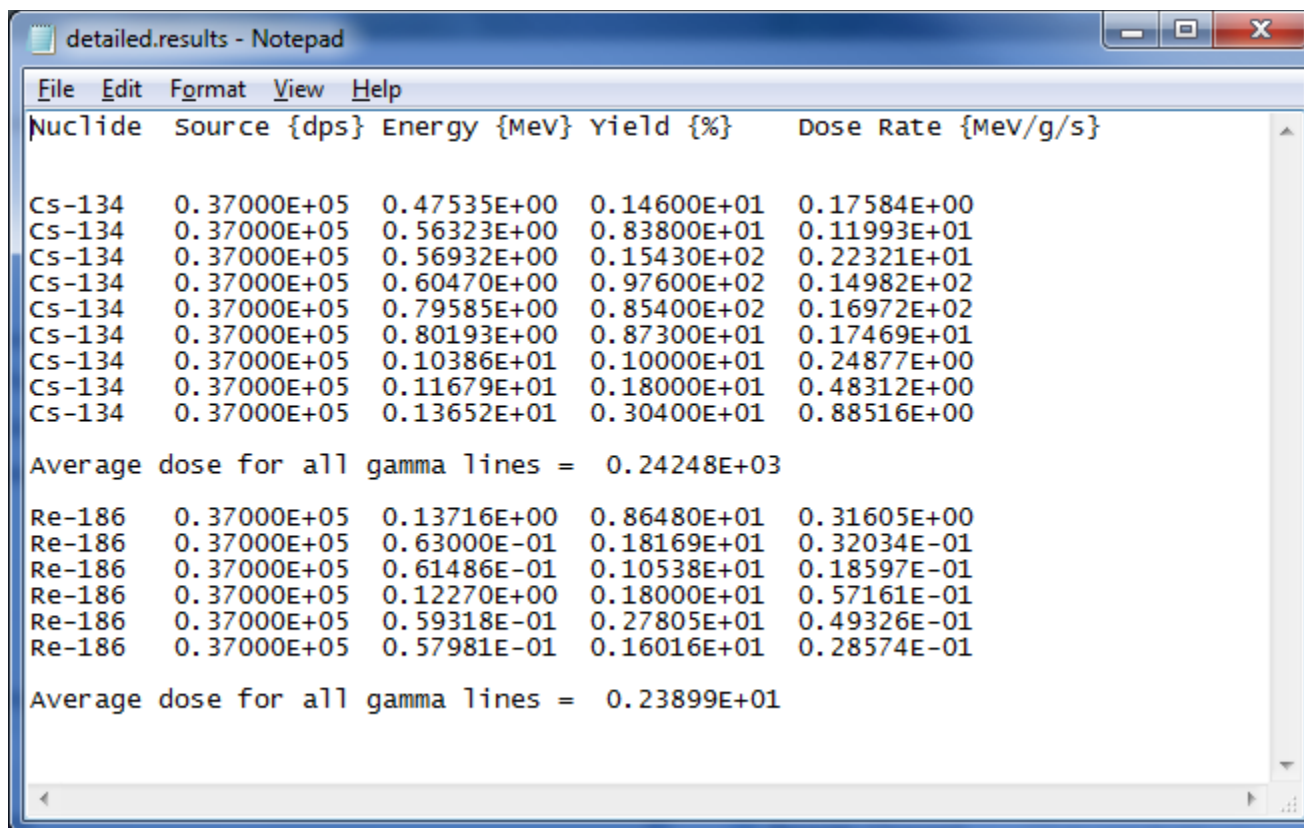


```
depthdose.out - Notepad
File Edit Format View Help
Cs-134 $ Name of nuclide 1
0.93080000E-02 0.13527454E-01 $ depth [cm], doserate [rad/hr]
0.27924000E-01 0.15358677E-01 $ depth [cm], doserate [rad/hr]
0.46540000E-01 0.15538990E-01 $ depth [cm], doserate [rad/hr]
0.65156000E-01 0.15244614E-01 $ depth [cm], doserate [rad/hr]
0.83772000E-01 0.14735173E-01 $ depth [cm], doserate [rad/hr]
0.10238800E+00 0.14174751E-01 $ depth [cm], doserate [rad/hr]
0.12100400E+00 0.13609501E-01 $ depth [cm], doserate [rad/hr]
0.13962000E+00 0.13054615E-01 $ depth [cm], doserate [rad/hr]
0.15823600E+00 0.12539784E-01 $ depth [cm], doserate [rad/hr]
0.17685200E+00 0.12058793E-01 $ depth [cm], doserate [rad/hr]

Re-186 $ Name of nuclide 2
0.16601500E-01 0.25291771E-03 $ depth [cm], doserate [rad/hr]
0.49804500E-01 0.18993833E-03 $ depth [cm], doserate [rad/hr]
0.83007500E-01 0.16095450E-03 $ depth [cm], doserate [rad/hr]
0.11621050E+00 0.14200369E-03 $ depth [cm], doserate [rad/hr]
0.14941350E+00 0.12795595E-03 $ depth [cm], doserate [rad/hr]
0.18261650E+00 0.11682859E-03 $ depth [cm], doserate [rad/hr]
0.21581950E+00 0.10764385E-03 $ depth [cm], doserate [rad/hr]
0.24902250E+00 0.99846834E-04 $ depth [cm], doserate [rad/hr]
0.28222550E+00 0.93092052E-04 $ depth [cm], doserate [rad/hr]
0.31542850E+00 0.87149679E-04 $ depth [cm], doserate [rad/hr]
```

# File “Detailed”

- Provides gamma dose-rate (note units!) by gamma energy and average dose by nuclide

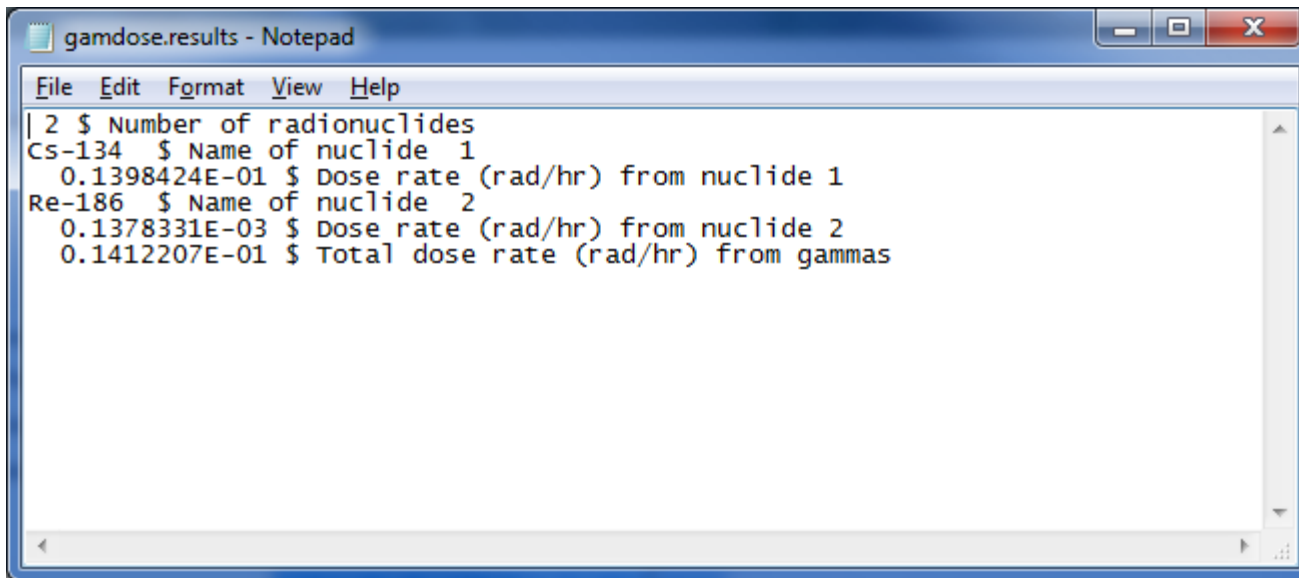


The screenshot shows a Notepad window with the title 'detailed.results - Notepad'. The window contains a table of data with the following columns: Nuclide, Source {dps}, Energy {Mev}, Yield {%, and Dose Rate {Mev/g/s}. The data is organized into two sections, one for Cs-134 and one for Re-186, each with a summary line for the average dose for all gamma lines.

Nuclide	Source {dps}	Energy {Mev}	Yield {%	Dose Rate {Mev/g/s}
Cs-134	0.37000E+05	0.47535E+00	0.14600E+01	0.17584E+00
Cs-134	0.37000E+05	0.56323E+00	0.83800E+01	0.11993E+01
Cs-134	0.37000E+05	0.56932E+00	0.15430E+02	0.22321E+01
Cs-134	0.37000E+05	0.60470E+00	0.97600E+02	0.14982E+02
Cs-134	0.37000E+05	0.79585E+00	0.85400E+02	0.16972E+02
Cs-134	0.37000E+05	0.80193E+00	0.87300E+01	0.17469E+01
Cs-134	0.37000E+05	0.10386E+01	0.10000E+01	0.24877E+00
Cs-134	0.37000E+05	0.11679E+01	0.18000E+01	0.48312E+00
Cs-134	0.37000E+05	0.13652E+01	0.30400E+01	0.88516E+00
Average dose for all gamma lines =				0.24248E+03
Re-186	0.37000E+05	0.13716E+00	0.86480E+01	0.31605E+00
Re-186	0.37000E+05	0.63000E-01	0.18169E+01	0.32034E-01
Re-186	0.37000E+05	0.61486E-01	0.10538E+01	0.18597E-01
Re-186	0.37000E+05	0.12270E+00	0.18000E+01	0.57161E-01
Re-186	0.37000E+05	0.59318E-01	0.27805E+01	0.49326E-01
Re-186	0.37000E+05	0.57981E-01	0.16016E+01	0.28574E-01
Average dose for all gamma lines =				0.23899E+01

# File “gamdose”

- Provides gamma dose-rate contribution by nuclide and total gamma dose rate



```
gamdose.results - Notepad
File Edit Format View Help
| 2 $ Number of radionuclides
Cs-134 $ Name of nuclide 1
0.1398424E-01 $ Dose rate (rad/hr) from nuclide 1
Re-186 $ Name of nuclide 2
0.1378331E-03 $ Dose rate (rad/hr) from nuclide 2
0.1412207E-01 $ Total dose rate (rad/hr) from gammas
```

# File “gaminput”

- Provides data for each gamma emission of selected nuclides

```
GamInput - Notepad
File Edit Format View Help
Co-60          $ nuclide name
2             $ number of photon lines
1             $ 000 Co-60 integer radiation type
99.9          $ 000 Co-60 yield (%)
1.17321       $ 000 Co-60 energy (MeV)
1             $ 001 Co-60 integer radiation type
99.9824       $ 001 Co-60 yield (%)
1.33247       $ 001 Co-60 energy (MeV)
Cs-137        $ nuclide name
0             $ number of photon lines
Ba-137m       $ nuclide name
3             $ number of photon lines
1             $ 000 Ba-137m integer radiation type
89.7759       $ 000 Ba-137m yield (%)
0.661645      $ 000 Ba-137m energy (MeV)
2             $ 001 Ba-137m integer radiation type
3.92427       $ 001 Ba-137m yield (%)
0.0321936     $ 001 Ba-137m energy (MeV)
2             $ 002 Ba-137m integer radiation type
2.13088       $ 002 Ba-137m yield (%)
0.031817      $ 002 Ba-137m energy (MeV)
```



# Varskin Limitations

# Input limits

- Skin averaging area: 0.01 – 100 cm<sup>2</sup>
- Air gap thickness: 5 cm
- Covers: Up to 5
- Volume averaging: non-negative
  - and “deeper” must be greater than “shallower” depth
- Large source dimensions results in a warning, but code is still executed
  - possible error w/ small-area dose averaging

# Modeling limitations

- Radionuclide selection
- Source dimensions
- Air gap model
- Cover model
- Multiple sources

# Modeling limitations

- Source/geometry
  - Calculates dose to skin from skin contamination
    - uses should be restricted to this application
  - Radioactive progeny are not included in parent nuclides
    - must be selected explicitly ( $^{137\text{m}}\text{Ba}$  for example)
    - but, be careful of decay-corrected dose!
  - Reliable for particulate sources with dimensions up to 8x nuclide beta range in tissue
  - Not tested extensively for dose areas  $> 10 \text{ cm}^2$ 
    - but, our quick study indicates that linearity exists for photons with averaging areas between  $10^{-3} \text{ cm}^2$  and  $10^3 \text{ cm}^2$

# Modeling limitations

- Infinite sources (e.g., enveloping cloud)
  - Choosing very large source dimensions will result in inaccurate or zero doses because integration routine becomes unstable
  - Correct approach is to determine maximum penetration distance ( $X_{99}$ ) and set source dimensions accordingly
  - Essentially use dimensions to allow betas to expose the skin, while considering self absorption and backscatter
  - Again, this scenario may mean that the code is being applied outside its intended use

# Modeling limitations

- Photon model limited to an air gap  $< 5$  cm
  - A large air gap means that skin contamination isn't the proper scenario; not proper code usage
    - (however, as requested, v 5.3 will allow air gap up to 20 cm)
  - Large air gap will likely result in errors due to multiple scattering events in air
  - Code will not allow calculations for air gap  $> 5$  cm, and a warning is displayed
  - Results indicate that a disruption in electronic equilibrium with air gaps could make deterministic modeling quite difficult

# Modeling limitations

- Cover model allows 5 layers of covering
  - User enters up to 5 cover thickness/density combinations
  - Code will calculate “equivalent” (single) cover
  - Source assumed to sit on top of cover
  - If air is present, it is assumed to be between skin and cover
  - Current model does not consider alterations in charged-particle buildup caused by cover

# Modeling limitations

- Multiple Contamination Source Locations
  - Determining the maximum dose to a given dose-averaging area for multiple contaminations requires multiple calculations
  - The calculations require elements that are not available in VARSKIN 4, but that can be accomplished manually
  - Based on the orientation of particles on the skin, sketch dose-averaging areas (e.g., 10 cm<sup>2</sup> circles) centered on each radioactive particle
  - Determine average dose to a common averaging area for each source particle
  - Use the offset particle model to perform dose calculation
    - VARSKIN 4/5 only allows off-axis dose calculations for a point source



## A few tips

- Set exposure time to 1 second and use an activity of 1 Bq; resulting dose will be a “dose conversion factor” with units of dose per decay.
- Calculate dose for point source first, then refine in several steps changing geometry in each step. This provides an indication of the sensitivity of your geometry choice and a boundary of possible dose values.
- Use the “Save/Load Default State” option to run common scenarios.

User input to date

# Users would like to see ...

- Calculation for a particle trapped under the skin
- Increase the 5 cm limit on air gap **CHANGED < 20 cm**
- Clothing and air gap cause issues with electronic buildup
- Include daughter products (Ga-68 was point out)
- Include ICRP 107 data
- Web-based operation
- Smart phone app
- Inclusion of obscure nuclides: V-52, Re-183, Ga-68
- Uncertainty/Sensitivity analysis capability
- IEEE certification

# Where will VARSKIN fail?

- If, in dose volume averaging, the user enters a value greater than the  $X_{99}$  distance, the dose average is less than the maximum because now the code is averaging zeroes and negative dose values may be calculated
- In the photon model, if the dose averaging area is small relative to the source cross section on the skin, errors will occur in the calculation of lens volume **REPAIRED**
- Photon dosimetry with point and disk geometries is excellent, but the air and cover models currently are not reliable
- Users have found electron dose from Be-7, Y-90, Ho-166m, to be very high (short-lived nuclides) **REPAIRED**