

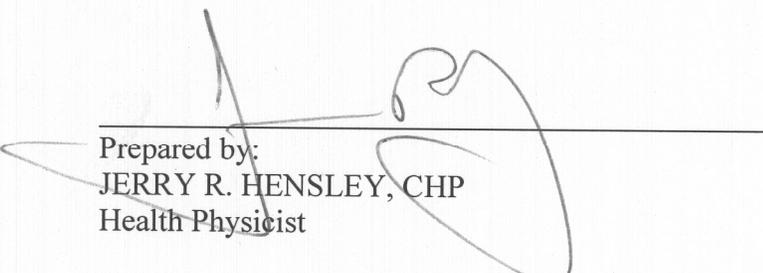
**TECHNICAL BASIS DOCUMENT**  
**CA RADIOLOGIC HEALTH BRANCH**  
**RS-701 RADIATION MAPPING SYSTEM**

**RADIUM 226**

## **NOTICES**

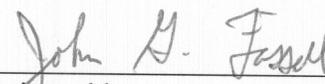
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**TECHNICAL BASIS DOCUMENT FOR THE CA RADIOLOGIC HEALTH  
BRANCH RS-701 RADIATION MAPPING SYSTEM  
RADIUM 226**



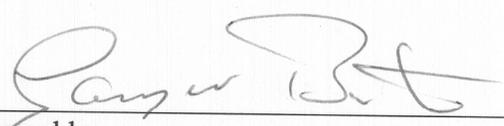
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# **TECHNICAL BASIS DOCUMENT FOR THE CA RADIOLOGIC HEALTH BRANCH RS-701 RADIATION MAPPING SYSTEM RADIUM 226**

## **INTRODUCTION**

The Radiation Solutions Inc., RS-701 Radiation Mapping System (RMS) is used to perform *in situ* radiological surface and matrix (volume) contamination scanning surveys for radionuclides that emit photons during their decay process. These surveys are used to identify areas that are likely to represent anomalies from local background for further investigation based on use of other radiological survey instrumentation. This document addresses instrument operation and use, gamma energy calibration, and detector efficiency and minimum detection calculations.

As with any portable field radiological detection instrumentation, the efficiency and detection limits addressed in this document are specific to the referenced assumptions, particularly regarding spatial activity distribution and shielding conditions. Since actual field conditions are not likely to precisely replicate the referenced assumptions, the efficiency and detection limits are only approximations and should be used with caution. Fixed location measurements and/or samples will need to be obtained and analyzed to more precisely quantify site conditions.

## **DESCRIPTION**

The RMS consists of the RS-701 console, two 10 centimeter (cm) by 10 cm by 40 cm sodium iodide (NaI) detectors, a Trimble Ag global positioning system (GPS), a trailer modified to carry the detectors, and a laptop computer (optional). The detectors are oriented parallel to the ground and each other with their long axis pointed in the direction of travel. The bottom of the detector cases stands 27.5 cm above the ground and the gap between the detectors is 29 cm.

The RMS automatically records the operator's location to within 1 meter (requires OmniStar subscription service) and it records the associated one-second spectral data from each detector to a storage device inside the RS-701 console. Figure 1, RMS, shows the system in its entirety. Data is retrieved from the RS-701 console using associated software (RadAssist). Data can be binned according to a region of interest (ROI) for predetermined radionuclides or retrieved for each of the 1024 channels (gamma energy from 0 to 3 MeV). The RadAssist software is capable of removing Compton continuum from the peaks. Data can be exported to an Excel spreadsheet to facilitate mapping using industry standard software (i.e. ArcView or Surfer).

The RS-701 console contains the multichannel analyzers (MCA) for each detector along with basic operation controls. The system uses primordial radiation to perform the initial energy calibration and to maintain the system energy gain, negating the need for external check sources except for quality assurance a covered in the next paragraph.



**Figure 1, Radiation Monitoring System (RMS)**

### **QUALITY ASSURANCE**

Verification of instrument response shall be performed during each run with a Cs-137 check source prior to start and after completion. Any source trends outside  $\pm 2\sigma$  should be investigated and any values outside  $\pm 3\sigma$  shall be investigated.

### **OPERATION**

The operator connects the cables (Detector 1, Detector 2, GPS, and User if computer connected), applies 12 VDC power, turns the console on (press silver button), exposes the detectors to the Cs-137 check source for QA check, and proceeds to collect data.

The typical scan speed is 1 meter per second. Faster scan speeds will require new minimum detectable calculations.

Upon completion of the survey, the system is turned off and a USB memory device is inserted into the RS-701 console. The data may be captured by a laptop computer during operation. The data is retrieved according to predetermined regions of interest (ROI) or a spectral data file; both with associated GPS coordinates.

Data generated from the ROIs normally should be binned according to the following parameters: background +  $2\sigma$ , greater than  $2\sigma$  but less than  $3\sigma$  above background, and equal to and greater than  $3\sigma$  above background. The specified binning may need to be modified based on the variations in naturally occurring background uranium, thorium, and radium; values as high as  $6\sigma$  may need to be used. Data may also be binned according to Z-Scores.

The GPS will not work indoors due to lack of satellite reception.

### **GAMMA ENERGY CORRELATION**

The system energy calibration is an automated function that uses the gamma energies from primordial radionuclides. Each detector gain is adjusted until the gamma energies are in their respective peak channels. A linear equation is used to convert from a channel number to its keV equivalent. This correlation is 3 keV per 1 channel. The system has 1024 channels.

### **Ra-226 SURFACE AREAL EFFICIENCY DETERMINATION**

Measurements were made with a discrete 1.017  $\mu\text{Ci}$  Ra-226 gamma point source that is traceable to the National Institute of Standards and Technology. Data was retrieved using 3 user generated regions of interest (ROI) and is referenced in Table 1, Calibration Data.

The source was placed under the detectors at ground level and moved in increments of 10 centimeters until a field of 1 square meter was measured. The Ra-226 source was placed at each location to allow collection of a minimum of 119 seconds worth of data at each location. The net cps values were used to make efficiency determinations for each ROI, as shown in Table 1, and to determine counts per second (cps) values were modeled to show the detector response patterns, as shown in Figures 3, 4, and 5 while the average net cps values were used for efficiency calculations.

MicroShield modeling was performed for a 1  $\mu\text{Ci}$  Ra-226 source distributed on the surface over one square meter (areal source). The detector height above the source is 27.5 cm above the surface. The calculated fluence values (with buildup) for each ROI were then compared to the average net empirical value for each ROI (all 121 discrete measurements). The detector fluence location is at the center-point between the detectors and level with the bottom of the detector case.

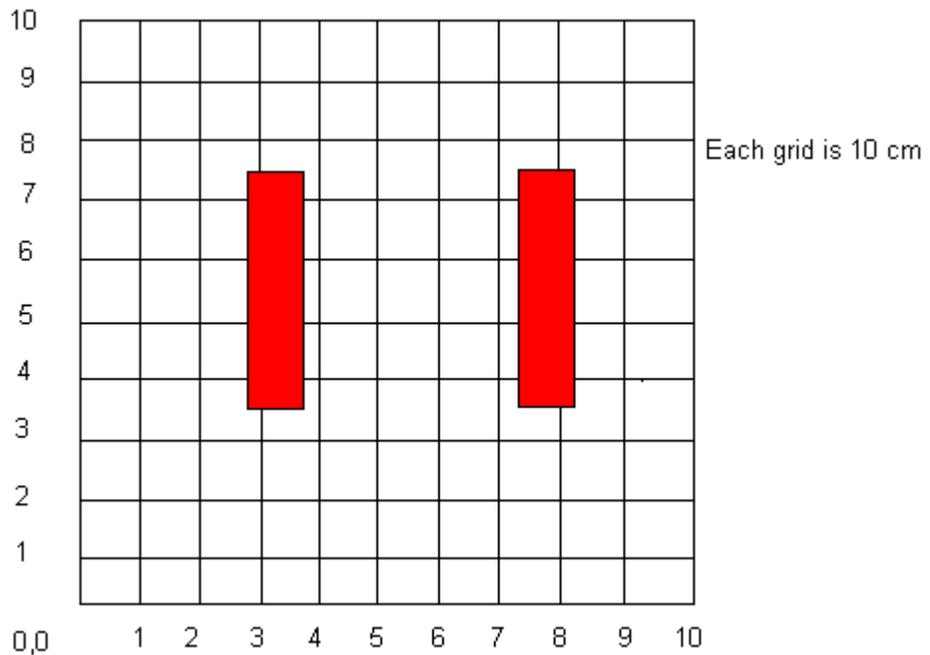
A detector responses for each ROI was calculated by dividing the average net cps values (empirical) by fluence (MicroShield) for each ROI. A net cps per 1 gamma per  $\text{cm}^2$  per second was calculated for each of the ROIs.

**Table 1, Ra-226 Surface Calibration Data (Areal)**

Radionuclide	ROI	Gamma Energy (keV)	Activity ( $\mu\text{Ci}/\text{m}^2$ )	Calculated Fluence (gammas/ $\text{cm}^2/\text{sec}$ )	Detector Response, Net (cps)	Efficiency, (cps per 1 gamma/ $\text{cm}^2/\text{sec}$ )
Ra-226	Gross	45 - 1980	1.02	3.54	2536	716
Ra-226	609 keV	546 - 666	1.02	0.71	242	338
Ra-226	1764 keV	1659 - 1860	1.02	0.28	58.9	210

**Ra-226 SURFACE AREAL EFFICIENCY CALIBRATION DATA**

The layout of the detectors in relation to the source measurements is shown in Figure 2, Detector Calibration Layout. Visual representations of the detectors' response to each source location are shown in Figures 3 to 5 while the detector value in cps is referenced in Tables 2 through 4.



**Figure 2, Detector Calibration Layout**

Ra-226 Point Source  
 Average = 2537 net CPS  
 Gross ROI

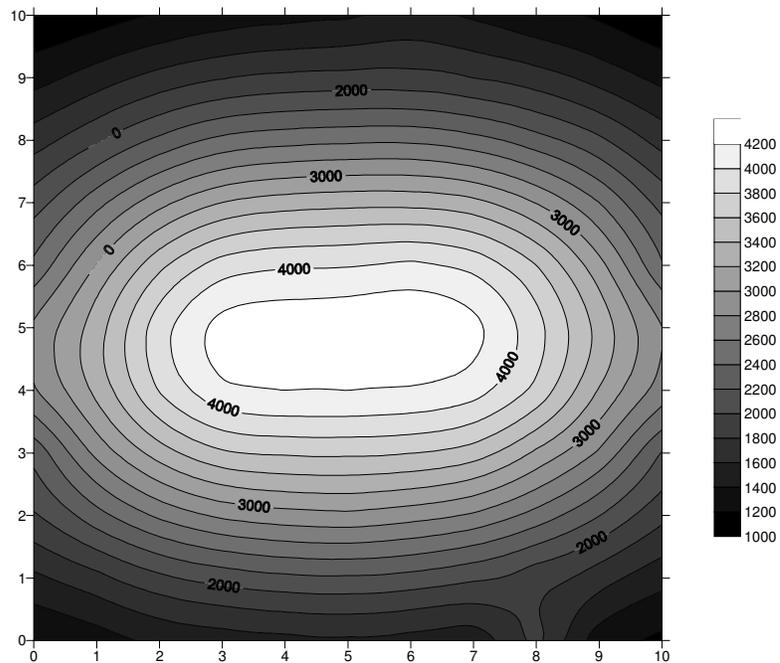


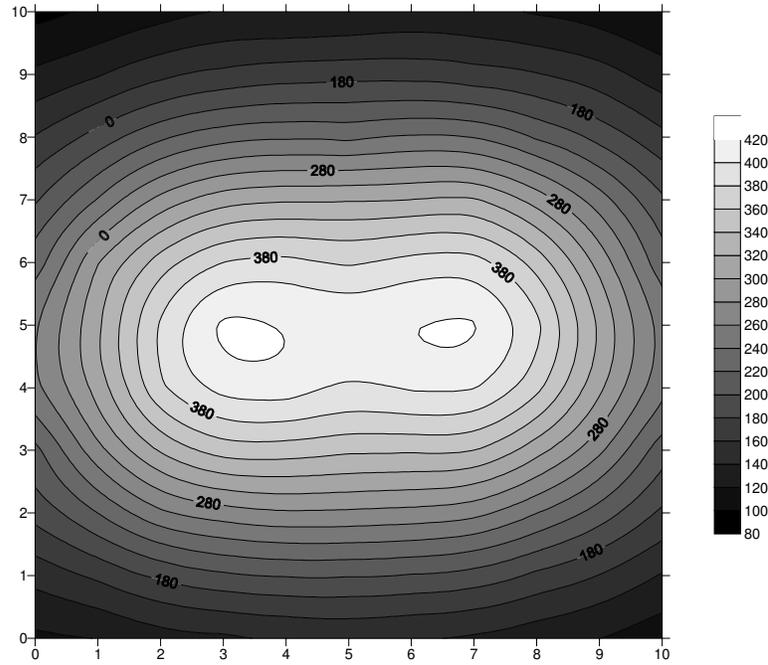
Figure 3, Ra-226, Gross ROI CPS Map

Table 2, Ra-226, Gross ROI Net CPS Calibration Data

10	1021	1112	1208	1295	13 0	13 2	1 65	13 1	125	11 1	1039
9	1323	1500	16 1	1 8	18	1865	1869	1 95	1691	152	13 3
8	1 03	19 1	22 5	2 55	252	255	2565	2 2	2281	20 3	1 18
	2103	2531	2932	3205	3301	3336	333	3261	2993	2602	212
6	2 38	3011	35 8	3892	39 3	398	0 1	3939	360	3068	2 13
5	28 1	3306	3916	2 6	299	318	3 6	25	38 0	3335	2808
	2 82	3256	3815	156	202	203	1 6	08	3 6	3183	2 08
3	2252	2855	329	356	3621	3633	3603	3500	315	2 69	2181
2	19	2326	26 1	2838	2920	2951	2880	2 69	2522	2206	185
1	155	1 35	1951	20	2151	21 1	2129	2030	186	1689	1 0
0	1201	130	1	150	15 3	1569	153	1 65	186	1285	1158
	0	1	2	3		5	6		8	9	10

Average net response is 2537 cps

Ra-226 Poing Source  
 Average = 240 net CPS  
 609 keV ROI



**Figure 4, Ra-226, 609 keV ROI CPS Map**

**Table 3, Ra-226, 609 keV ROI Net CPS Calibration Data**

10	9	103.2	113.2	121.2	120.2	122.2	12 .2	12 .2	118.2	111.2	99.2
9	12	138.2	155.2	165.2	1 1.2	1 3.2	1 3.2	168.2	161.2	1 9.2	129.2
8	161.2	188.2	216.2	232.2	23 .2	235.2	2 2.2	239.2	21 .2	193.2	165.2
	19 .2	2 1.2	286.2	311.2	31 .2	318.2	320.2	322.2	291.2	2 9.2	203.2
6	230.2	299.2	3 9.2	380.2	385.2	3 .2	386.2	38 .2	351.2	292.2	22 .2
5	25 .2	316.2	382.2	23.2	18.2	12.2	19.2	21.2	38 .2	316.2	252.2
	255.2	308.2	3 6.2	06.2	09.2	396.2	02.2	01.2	365.2	30 .2	2 6.2
3	21 .2	2 3.2	322.2	3 8.2	3 9.2	3 3.2	3 2.2	3 0.2	30 .2	26 .2	208.2
2	186	220.2	256.2	2 0.2	2 .2	2 6.2	2 3.2	266.2	2 0.2	211.2	1 6.2
1	1 .2	16 .2	18 .2	196.2	201.2	201.2	198.2	192.2	1 5.2	159.2	138.2
0	116.2	120.2	132.2	136.2	1 1.2	1 .2	1 0.2	13 .2	128.2	120.2	108.2
	0	1	2	3		5	6		8	9	10

Average net response is 240 cps

Ra-226 Point Source  
 Average = 58.9 net CPS  
 1764 keV ROI

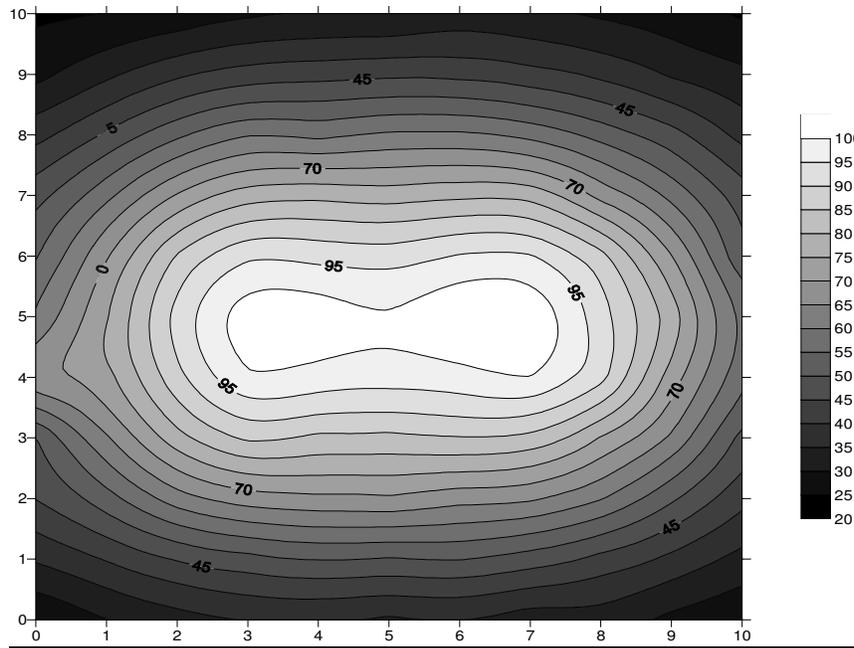


Figure 5, Ra-226, 1764 keV ROI CPS Map

Table 4, Ra-226, 1764 keV ROI Net CPS Calibration Data

10	2 .1	25.1	26.8	29.2	30.2	30.2	32.3	31	29.3	2 .	2 .
9	28.5	33.9	39	2.2	3.2		3.6	1.	38.8	3 .3	31.1
8	38.2	5.8	53.9	59.	58.6	60.8	60.9	58.5	53.1		38.
	8.1	58.5	0.5	.6	8.6	.6	8.8	8.3	68.2	58.5	.
6	5 .5	69.	85.5	9 .1	93.2	92.	95.	95.5	86.6	0.2	51.2
5	60.6	.5	91.6	102.6	102.3	100.3	103.5	103.	91.9	.5	58.6
	69.	3.3	88.3	99.3	9 .	9	9 .8	100	91.6	2.6	56.5
3	9.8	6 .3	8	85.9	83.	83.6	8 .	83.5	.5	6 .1	8.5
2	5.2	52.9	62.	6 .5	68.8	69.3	66.8	65.8	60.	50.9	1.5
1	35.6	0.	5.	8.3	50.2	9.5	50.3	.6	3.	38.	33.
0	25.	29.9	33	35.2	35.6	3 .2	35.1	32.3	32.8	28.8	26
	0	1	2	3		5	6		8	9	10

Average net response is 58.9 cps

## CALIBRATION CALCULATION FOR Ra-226 SOIL MATRIX

Data referenced in this section is only for calculating priori detection limits and should not be used as a conversion tool for converting detector cps to a pCi/g or cps to  $\mu\text{Ci}$  value for Ra-226. Contamination may be in the form of a homogenized mixture or in the form of discrete particles. Because the distribution of the contamination is not known prior to performing the survey or even immediately after the survey, data generated by the instrument should be used as indication only.

Discrete or point source efficiencies were obtained by dividing the activity of the Ra-226 (1  $\mu\text{Ci}$ ) point source by the average net cps for each ROI.

Soil matrix contamination detection limits were calculated by modeling soil contamination using MicroShield. Input assumptions to calculate a fluence value include: 1 pCi/g Ra-226 (decayed 1 year to ensure gamma-emitting progeny are in secular equilibrium, soil density 1.5 grams/cc, detectors are 27.5 cm above the surface, and area of 1 meter by 1 meter with a soil depth of 15 cm. A scan speed of 1 meter per second is assumed. MicroShield calculations are provided in Attachment B. The calculated fluence values are based an average discrete 1  $\text{cm}^2$  area at the center of the detectors and at the corner of one of the detectors. See Table 5, Calibration Data (Soil Matrix) for additional information.

Typical background data referenced in this document were obtained from 300 one-second data collections. These values may or may not represent actual site conditions. Actual background data from the survey site should be used to calculate average and standard deviation values using the methodology noted below.

**Table 5, Calibration Correlation (Soil Matrix)**

<b>Radionuclide</b>	<b>ROI</b>	<b>Gamma Energy (keV)</b>	<b>Activity (pCi/g)</b>	<b>Calculated Fluence gammas/<math>\text{cm}^2</math>/sec (middle/detector corner)</b>	<b>Efficiency – (net cps per 1 gamma/<math>\text{cm}^2</math>/sec) (Table 1)</b>	<b>Calculated net cps Response (1pCi/g)</b>
Ra-226	Gross	45 - 1980	1	0.51 (0.64/0.37)	716	361.6
Ra-226	609 keV	546 - 666	1	0.10 (0.13/0.1)	338	34.9
Ra-226	1764 keV	1659 - 1860	1	0.04 (0.05/0.03)	210	8.4

## DETECTION CALCULATIONS FOR RA-226 POINT SOURCES AND SOIL MATRIX

### 609 keV Bi-214 ROI – Soil Matrix

For the purposes of calculating a typical detection limit, an average background value for 609 keV ROI from the Bi-214 (Ra-226 progeny) peak was 161.1 cps with a standard deviation of 12 cps. Background ambient radiation levels were 6  $\mu\text{R/hr}$ . This equates to the following detection limits:

Background + $2\sigma$ (24 net cps)	=	0.70 pCi/g
Background + $3\sigma$ (36 net cps)	=	1.03 pCi/g
Background + $6\sigma$ (72 net cps)	=	2.10 pCi/g

### 609 keV Bi-214 ROI – Point Source on Surface

For the purposes of calculating a typical detection limit, an average background value for 609 keV ROI from the Bi-214 (Ra-226 progeny) peak was 161.1 cps with a standard deviation of 12 cps. Background ambient radiation levels were 6  $\mu\text{R/hr}$ . This equates to the following detection limits:

Background + $2\sigma$ (24 net cps)	=	0.10 $\mu\text{Ci}$
Background + $3\sigma$ (36 net cps)	=	0.15 $\mu\text{Ci}$
Background + $6\sigma$ (72 net cps)	=	0.30 $\mu\text{Ci}$

### 1764 keV Bi-214 ROI– Soil Matrix

For the purposes of calculating a typical detection limit, an average background value for 1764 keV ROI from the Bi-214 (Ra-226 progeny) peak was 23.4 cps with a standard deviation of 5 cps. Background ambient radiation levels were 6  $\mu\text{R/hr}$ . This equates to the following detection limits:

Background + $2\sigma$ (10 net cps)	=	1.19 pCi/g
Background + $3\sigma$ (15 net cps)	=	1.80 pCi/g
Background + $6\sigma$ (30 net cps)	=	3.57 pCi/g

### 1764 keV Bi-214 ROI– Point Source on Surface

For the purposes of calculating a typical detection limit, an average background value for 1764 keV ROI from the Bi-214 (Ra-226 progeny) peak was 23.4 cps with a standard deviation of 5 cps. Background ambient radiation levels were 6  $\mu\text{R/hr}$ . This equates to the following detection limits:

Background + $2\sigma$ (10 net cps)	=	0.17 $\mu\text{Ci}$
Background + $3\sigma$ (15 net cps)	=	0.25 $\mu\text{Ci}$
Background + $6\sigma$ (30 net cps)	=	0.51 $\mu\text{Ci}$

### Gross ROI– Soil Matrix

For the purposes of calculating a typical detection limit, an average background value for Gross ROI was 3349 cps with a standard deviation of 57.9 cps. Background ambient radiation levels were 6  $\mu\text{R/hr}$ . Care should be taken due to the easily-attenuated low energy photons used to calculate the fluence conversion factors. This equates to the following detection limits:

Background + $2\sigma$ (116 net cps)	=	0.32 pCi/g
Background + $3\sigma$ (174 net cps)	=	0.48 pCi/g
Background + $6\sigma$ (347 net cps)	=	0.96 pCi/g

### Gross ROI– Point Source on Surface

For the purposes of calculating a typical detection limit, an average background value for Gross ROI was 3349 cps with a standard deviation of 57.9 cps. Background ambient radiation levels were 6  $\mu\text{R/hr}$ . Care should be taken due to the easily-attenuated low energy photons used to calculate the fluence conversion factors.. This equates to the following detection limits:

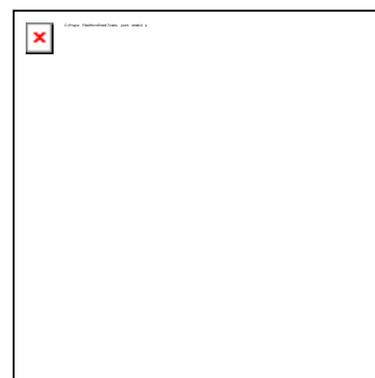
Background + $2\sigma$ (116 net cps)	=	0.05 $\mu\text{Ci}$
Background + $3\sigma$ (174 net cps)	=	0.07 $\mu\text{Ci}$
Background + $6\sigma$ (347 net cps)	=	0.14 $\mu\text{Ci}$

**Appendix A**  
**Radium 226 MicroShield Modeling**

**MicroShield 7.00**  
**Dept. of Health Services (06-msd-7.00-1126)**

<b>Date</b>	<b>By</b>	<b>Checked</b>	
<b>Filename</b>	<b>Run Date</b>	<b>Run Time</b>	<b>Duration</b>
radium point mshield.ms6	November 29, 2009	8:40:47 AM	00:00:00
<b>Project Info</b>			
Case Title	Ra-226 1 $\mu$ Ci Pt		
Description	1 $\mu$ Ci Ra-226 point source over 1m by 1m		
Geometry	13 - Rectangular Volume		

<b>Source Dimensions</b>			
Length	1.0 cm (0.4 in)		
Width	100.0 cm (3 ft 3.4 in)		
Height	100.0 cm (3 ft 3.4 in)		
<b>Dose Points</b>			
<b>A</b>	<b>X</b>	<b>Y</b>	<b>Z</b>
#1	28.5 cm (11.2 in)	50.0 cm (1 ft 7.7 in)	50.0 cm (1 ft 7.7 in)
<b>Shields</b>			
<b>Shield N</b>	<b>Dimension</b>	<b>Material</b>	<b>Density</b>
Source	1.00e+04 cm <sup>3</sup>	Air	0.00122
Air Gap		Air	0.00122



**Source Input: Grouping Method - Linear Energy**  
**Number of Groups: 25**  
**Lower Energy Cutoff: 0.015**  
**Photons < 0.015: Included**  
**Library: Grove**

<b>Nuclide</b>	<b>Curies</b>	<b>Becquerels</b>	<b><math>\mu</math>Ci/cm<sup>3</sup></b>	<b>Bq/cm<sup>3</sup></b>
Bi-210	2.9582e-008	1.0945e+003	2.9582e-006	1.0945e-001
Bi-214	9.9937e-007	3.6977e+004	9.9937e-005	3.6977e+000
Pb-210	3.0180e-008	1.1167e+003	3.0180e-006	1.1167e-001
Pb-214	9.9937e-007	3.6977e+004	9.9937e-005	3.6977e+000
Po-210	1.5755e-008	5.8295e+002	1.5755e-006	5.8295e-002
Po-214	9.9916e-007	3.6969e+004	9.9916e-005	3.6969e+000
Po-218	9.9957e-007	3.6984e+004	9.9957e-005	3.6984e+000
Ra-226	9.9957e-007	3.6984e+004	9.9957e-005	3.6984e+000
Rn-222	9.9957e-007	3.6984e+004	9.9957e-005	3.6984e+000

<b>Buildup: The material reference is Source Integration Parameters</b>					
X Direction					10
Y Direction					20
Z Direction					20
<b>Results</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.0516	1.478e+04	3.037e-02	3.095e-02	7.614e-05	7.757e-05
0.1862	1.213e+03	9.018e-03	9.098e-03	1.566e-05	1.580e-05
0.2798	1.040e+04	1.162e-01	1.170e-01	2.184e-04	2.198e-04
0.3527	1.405e+04	1.981e-01	1.992e-01	3.823e-04	3.845e-04
0.4644	6.642e+02	1.234e-02	1.239e-02	2.419e-05	2.430e-05
0.5579	2.336e+02	5.214e-03	5.235e-03	1.021e-05	1.025e-05
0.6112	1.769e+04	4.327e-01	4.343e-01	8.437e-04	8.469e-04
0.7646	2.760e+03	8.450e-02	8.477e-02	1.616e-04	1.621e-04
0.817	7.337e+02	2.400e-02	2.407e-02	4.554e-05	4.567e-05
0.9363	1.367e+03	5.127e-02	5.141e-02	9.551e-05	9.576e-05
1.0605	2.229e+02	9.471e-03	9.495e-03	1.727e-05	1.732e-05
1.1298	7.620e+03	3.449e-01	3.457e-01	6.212e-04	6.227e-04
1.2359	2.367e+03	1.172e-01	1.175e-01	2.071e-04	2.075e-04
1.2827	5.922e+02	3.044e-02	3.050e-02	5.330e-05	5.341e-05
1.3908	3.240e+03	1.806e-01	1.809e-01	3.099e-04	3.106e-04
1.5173	1.106e+03	6.723e-02	6.736e-02	1.128e-04	1.130e-04
1.623	9.158e+02	5.958e-02	5.969e-02	9.807e-05	9.825e-05
1.7581	7.042e+03	4.963e-01	4.971e-01	7.982e-04	7.996e-04
1.846	9.159e+02	6.778e-02	6.789e-02	1.074e-04	1.076e-04
1.8833	1.496e+02	1.130e-02	1.131e-02	1.779e-05	1.782e-05
2.1186	4.342e+02	3.689e-02	3.694e-02	5.601e-05	5.609e-05
2.2042	1.843e+03	1.629e-01	1.631e-01	2.442e-04	2.445e-04
2.2934	1.204e+02	1.107e-02	1.109e-02	1.639e-05	1.641e-05
2.4479	5.765e+02	5.659e-02	5.667e-02	8.201e-05	8.212e-05
<b>Totals</b>	<b>9.104e+04</b>	<b>2.616e+00</b>	<b>2.624e+00</b>	<b>4.615e-03</b>	<b>4.629e-03</b>

MicroShieW 7.00 (06-ms -7.00-1126) W

Dept. of Health Services W

Results With BuiWup W

FILE: C:\ra mapping\ra mapping rs701\Ra-226 (Eric)\ra ium point mshieW.ms6 W

Case Title: Ra-226 1  $\mu$ Ci Pt W

This case was run on Sunday, November 29, 2009 at 8:40:47 AM W

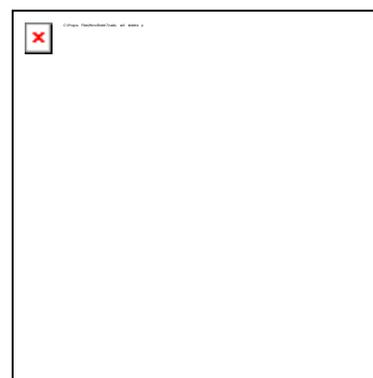
Dose Point # 1 - (28.5,50,50) cm W

Group # W	Energy W (MeV) W	Activity W photons/sec W	Fluence Rate W photons/cm <sup>2</sup> / W sec W	Energy Fluence W MeV/cm <sup>2</sup> /sec W	Exposure Rate W mR/hr W
1	0.0516	1.47 +004	5.992 -001	3.095 -002	7.757 -005
2	0.1 62	1.213 +003	4. 6 -002	9.09 -003	1.5 0 -005
3	0.279	1.040 +004	4.1 2 -001	1.170 -001	2.19 -004
4	0.3527	1.405 +004	5.64 -001	1.992 -001	3. 45 -004
5	0.4644	6.642 +002	2.669 -002	1.239 -002	2.430 -005
6	0.5579	2.336 +002	9.3 3 -003	5.235 -003	1.025 -005
7	0.6112	1.769 +004	7.107 -001	4.343 -001	.469 -004
	0.7646	2.760 +003	1.109 -001	.477 -002	1.621 -004
9	0. 17	7.337 +002	2.946 -002	2.407 -002	4.567 -005
10	0.9363	1.367 +003	5.490 -002	5.141 -002	9.576 -005
11	1.0605	2.229 +002	.953 -003	9.495 -003	1.732 -005
12	1.129	7.620 +003	3.060 -001	3.457 -001	6.227 -004
13	1.2359	2.367 +003	9.506 -002	1.175 -001	2.075 -004
14	1.2 27	5.922 +002	2.37 -002	3.050 -002	5.341 -005
15	1.390	3.240 +003	1.301 -001	1. 09 -001	3.106 -004
16	1.5173	1.106 +003	4.439 -002	6.736 -002	1.130 -004
17	1.623	9.15 +002	3.677 -002	5.969 -002	9. 25 -005
1	1.75 1	7.042 +003	2. 2 -001	4.971 -001	7.996 -004
19	1. 46	9.159 +002	3.67 -002	6.7 9 -002	1.076 -004
20	1. 33	1.496 +002	6.007 -003	1.131 -002	1.7 2 -005
22	2.11 6	4.342 +002	1.744 -002	3.694 -002	5.609 -005
23	2.2042	1. 43 +003	7.399 -002	1.631 -001	2.445 -004
24	2.2934	1.204 +002	4. 35 -003	1.109 -002	1.641 -005
25	2.4479	5.765 +002	2.315 -002	5.667 -002	.212 -005
W	TOTALS: W	9.104e+004 W	3.663e+000 W	2.624e+000 W	4.629e-003 W
W	W	W	W	W	W
W	W	W	W	W	W

**MicroShield 7.00**  
**Dept. of Health Services (06-msd-7.00-1126)**

<b>Date</b>	<b>By</b>	<b>Checked</b>	
<b>Filename</b>	<b>Run Date</b>	<b>Run Time</b>	<b>Duration</b>
radium soil mshield.ms6	November 29, 2009	8:26:43 AM	00:00:02
<b>Project Info</b>			
Case Title	Ra-226 Soil		
Description	Ra-226 1 pCi/g - 1 g/cc 1m by 1m by 15 cm		
Geometry	13 - Rectangular Volume		

<b>Source Dimensions</b>			
Length	15.0 cm (5.9 in)		
Width	100.0 cm (3 ft 3.4 in)		
Height	100.0 cm (3 ft 3.4 in)		
<b>Dose Points</b>			
<b>A</b>	<b>X</b>	<b>Y</b>	<b>Z</b>
#1	42.5 cm (1 ft 4.7 in)	50.0 cm (1 ft 7.7 in)	50.0 cm (1 ft 7.7 in)
<b>Shields</b>			
<b>Shield N</b>	<b>Dimension</b>	<b>Material</b>	<b>Density</b>
Source	1.50e+05 cm <sup>3</sup>	Igneous	1.5
Air Gap		Air	0.00122



**Source Input: Grouping Method - Linear Energy**  
**Number of Groups: 25**  
**Lower Energy Cutoff: 0.015**  
**Photons < 0.015: Included**  
**Library: Grove**

<b>Nuclide</b>	<b>Curies</b>	<b>Becquerels</b>	<b>μCi/cm<sup>3</sup></b>	<b>Bq/cm<sup>3</sup></b>
Bi-210	6.6560e-009	2.4627e+002	4.4373e-008	1.6418e-003
Bi-214	2.2486e-007	8.3198e+003	1.4991e-006	5.5465e-002
Pb-210	6.7905e-009	2.5125e+002	4.5270e-008	1.6750e-003
Pb-214	2.2486e-007	8.3198e+003	1.4991e-006	5.5465e-002
Po-210	3.5449e-009	1.3116e+002	2.3633e-008	8.7442e-004
Po-214	2.2481e-007	8.3180e+003	1.4987e-006	5.5454e-002
Po-218	2.2490e-007	8.3214e+003	1.4994e-006	5.5476e-002
Ra-226	2.2490e-007	8.3214e+003	1.4994e-006	5.5476e-002
Rn-222	2.2490e-007	8.3214e+003	1.4994e-006	5.5476e-002

<b>Buildup: The material reference is Source Integration Parameters</b>					
X Direction					10
Y Direction					20
Z Direction					20
<b>Results</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.0516	3.326e+03	5.446e-04	5.525e-03	1.365e-06	1.385e-05
0.1862	2.729e+02	4.517e-04	1.635e-03	7.844e-07	2.838e-06
0.2798	2.340e+03	6.641e-03	2.105e-02	1.248e-05	3.955e-05
0.3527	3.161e+03	1.217e-02	3.585e-02	2.349e-05	6.921e-05
0.4644	1.494e+02	8.262e-04	2.232e-03	1.620e-06	4.377e-06
0.5579	5.256e+01	3.699e-04	9.431e-04	7.244e-07	1.847e-06
0.6112	3.981e+03	3.158e-02	7.825e-02	6.157e-05	1.526e-04
0.7646	6.211e+02	6.610e-03	1.527e-02	1.264e-05	2.920e-05
0.817	1.651e+02	1.916e-03	4.338e-03	3.635e-06	8.230e-06
0.9363	3.076e+02	4.267e-03	9.264e-03	7.950e-06	1.726e-05
1.0605	5.016e+01	8.187e-04	1.711e-03	1.493e-06	3.121e-06
1.1298	1.714e+03	3.038e-02	6.229e-02	5.473e-05	1.122e-04
1.2359	5.327e+02	1.061e-02	2.117e-02	1.873e-05	3.740e-05
1.2827	1.332e+02	2.784e-03	5.497e-03	4.875e-06	9.626e-06
1.3908	7.290e+02	1.691e-02	3.261e-02	2.902e-05	5.597e-05
1.5173	2.488e+02	6.450e-03	1.214e-02	1.082e-05	2.036e-05
1.623	2.061e+02	5.822e-03	1.076e-02	9.584e-06	1.771e-05
1.7581	1.585e+03	4.954e-02	8.959e-02	7.969e-05	1.441e-04
1.846	2.061e+02	6.852e-03	1.223e-02	1.086e-05	1.939e-05
1.8833	3.366e+01	1.148e-03	2.039e-03	1.808e-06	3.212e-06
2.1186	9.770e+01	3.860e-03	6.657e-03	5.861e-06	1.011e-05
2.2042	4.146e+02	1.721e-02	2.939e-02	2.580e-05	4.407e-05
2.2934	2.709e+01	1.181e-03	1.998e-03	1.748e-06	2.958e-06
2.4479	1.297e+02	6.127e-03	1.021e-02	8.879e-06	1.480e-05
<b>Totals</b>	<b>2.048e+04</b>	<b>2.251e-01</b>	<b>4.727e-01</b>	<b>3.901e-04</b>	<b>8.339e-04</b>

MicroShieW 7.00 (06-ms -7.00-1126) W

Dept. of Health Services W

Results With BuiWup W

FILE: C:\ra mapping\ra mapping rsi rs701\Ra-226 (Eric)\ra ium soi mshieW.ms6 W

Case Title: Ra-226 Soi W

This case was run on Sunday, November 29, 2009 at 8:26:43 AM W

Dose Point # 1 - (42.5,50,50) cm W

Group # W	Energy W (MeV) W	Activity W photons/sec W	Fluence Rate W photons/cm <sup>2</sup> / W sec W	Energy Fluence W MeV/cm <sup>2</sup> /sec W	Exposure Rate W mR/hr W
1	0.0516	3.326 +003	1.070 -001	5.525 -003	1.35 -005
2	0.162	2.729 +002	.77 -003	1.635 -003	2.3 -006
3	0.279	2.340 +003	7.524 -002	2.105 -002	3.955 -005
4	0.3527	3.161 +003	1.017 -001	3.55 -002	6.921 -005
5	0.4644	1.494 +002	4.06 -003	2.232 -003	4.377 -006
6	0.5579	5.256 +001	1.690 -003	9.431 -004	1.47 -006
7	0.6112	3.91 +003	1.20 -001	7.25 -002	1.526 -004
	0.7646	6.211 +002	1.99 -002	1.527 -002	2.920 -005
9	0.17	1.651 +002	5.309 -003	4.33 -003	.230 -006
10	0.9363	3.076 +002	9.94 -003	9.264 -003	1.726 -005
11	1.0605	5.016 +001	1.613 -003	1.711 -003	3.121 -006
12	1.129	1.714 +003	5.514 -002	6.229 -002	1.122 -004
13	1.2359	5.327 +002	1.713 -002	2.117 -002	3.740 -005
14	1.227	1.332 +002	4.25 -003	5.497 -003	9.626 -006
15	1.390	7.290 +002	2.345 -002	3.261 -002	5.597 -005
16	1.5173	2.4 +002	.000 -003	1.214 -002	2.036 -005
17	1.623	2.061 +002	6.627 -003	1.076 -002	1.771 -005
1	1.751	1.55 +003	5.096 -002	.959 -002	1.441 -004
19	1.46	2.061 +002	6.627 -003	1.223 -002	1.939 -005
20	1.33	3.366 +001	1.03 -003	2.039 -003	3.212 -006
22	2.116	9.770 +001	3.142 -003	6.657 -003	1.011 -005
23	2.2042	4.146 +002	1.333 -002	2.939 -002	4.407 -005
24	2.2934	2.709 +001	.713 -004	1.99 -003	2.95 -006
25	2.4479	1.297 +002	4.172 -003	1.021 -002	1.40 -005
W	TOTALS: W	2.048e+004 W	6.588e-001 W	4.727e-001 W	8.339e-004 W
W	W	W	W	W	W
W	W	W	W	W	W