



HJ 1129- 2020

γ

**Technical Specifications for Determination of γ -emitting Radionuclides
in Soil by In-situ HPGe Spectrometry**

2020- 06- 03

2020- 06- 30

	.....	3
1	.....	4
2	.....	4
3	.....	4
4	.....	6
5	.....	6
6	.....	6
7	.....	7
8	.....	9
9	.....	10
10	.....	11
A	RS	12
B	β	14
C	F	16
D	γ η W	36
E	η	
	W	38
F	η W	41
G	γ	43

γ

A G

2020 06 03

2020 06 30

γ

1

γ

γ

^{137}Cs

100 Bq/m²

2

GB/T 27418

ISO 18589-7

7

γ

Measurement of

radioactivity in the environment - Soil - Part 7: In situ measurement of gamma-emitting radionuclides

3

3.1 relative detection efficiency

25cm

NaI(Tl)

7.62 cm

7.62 cm

^{60}Co

1332.5 keV γ

NaI(Tl)

1332.5 keV γ

1.2×10^{-3}

3.2 energy resolution

γ

keV

3.3 full width at half maximum

keV

FWHM

3.4	field-of-view of a detector				
			90%	γ	
		m			
3.5	lower limit of detection	LLD			
3.6	in-situ measurement				
3.7	detection height				
		m			
3.8	activity concentration				
		Bq·g ⁻¹			
3.9	sedimentation flux				
			Bq·m ⁻²		
3.10	detection efficiency of in-suit HPGe Spectrometry				
	1m		E	γ	
			s ⁻¹ ·(Bq·m ⁻²) ⁻¹	s ⁻¹ ·(Bq·g ⁻¹) ⁻¹	
3.11	effective front area				
			E	γ	
			m ²		
3.12	angle correction factor				
		E	γ		
		γ			
3.13	fluence activity ratio				
			E		
	h	(m ⁻² ·s ⁻¹) · (Bq·g ⁻¹) ⁻¹	(m ⁻² ·s ⁻¹) · (Bq·m ⁻²) ⁻¹		
3.14	relaxation depth				
					e ⁻¹
	37%	cm			

3. 15 relaxation mass per unit area

$$\text{g}\cdot\text{cm}^{-2}$$

3. 16 equivalent surface sedimentation flux

$$0\text{ g}\cdot\text{cm}^{-1}$$

$$\text{Bq}\cdot\text{m}^{-2}$$

4

$$1\text{ m}$$

$$A = \frac{N_f}{\varepsilon} \quad 1$$

A	$\text{Bq}\cdot\text{g}^{-1}$	$\text{Bq}\cdot\text{m}^{-2}$
N_f	s^{-1}	
ε	$\text{s}^{-1}\cdot(\text{Bq}\cdot\text{g}^{-1})^{-1}$	$\text{s}^{-1}\cdot(\text{Bq}\cdot\text{m}^{-2})^{-1}$

5

5. 1

6

5. 2

$$1\text{ m}$$

5. 3

$$1\text{ m}$$

$$1\text{ mm}$$

5. 4

6

6. 1

$$R_s$$

$$R_s$$

$$A$$

6. 2

6.3

6.4

1 m

6.5

10%

6.6 γ

γ

γ

6.7 γ

γ

γ

7

7.1

γ

γ

Beck

$$\varepsilon = F \times W \times \eta \qquad 2$$

$$F \qquad (\text{m}^{-2}\cdot\text{s}^{-1})\cdot(\text{Bq}\cdot\text{g}^{-1})^{-1} \qquad (\text{m}^{-2}\cdot\text{s}^{-1})\cdot(\text{Bq}\cdot\text{m}^{-2})^{-1}$$

$$W \qquad R(\theta) \qquad \gamma \qquad \varphi(\theta)$$

γ

γ

2π

γ

$$\eta \qquad \qquad \text{m}^2$$

7.2

7.2.1

$$\begin{array}{ccccccc} 7.1 & & F & & W & & \eta \\ & & & \varepsilon & & F & W \\ & & \beta & & \beta & & \\ & \beta & & & & 1 & \\ & & F & 2 & & & \\ \eta & 3 & & & \gamma & & \varphi(\theta) \\ & & R(\theta) & & W & \gamma & \varphi(\theta) \end{array}$$

$$7.2.2 \qquad \qquad \beta$$

$$\begin{array}{ccc} & & \beta = 0 \text{ g}\cdot\text{cm}^{-2} \\ & \beta = \infty \text{ g}\cdot\text{cm}^{-2} & \\ & z & 0 \text{ g}\cdot\text{cm}^{-2} < \beta < \infty \text{ g}\cdot\text{cm}^{-2} \\ \beta & \beta = 0 \text{ g}\cdot\text{cm}^{-2} & \\ & \beta & \beta \end{array}$$

B

$$7.2.3 \qquad \qquad F$$

$$\begin{array}{ccccccc} & \beta & & & F & 1 & \\ & 0 \text{ g}\cdot\text{cm}^{-2} & \beta < \infty \text{ g}\cdot\text{cm}^{-2} & & C & C \ 2 & \\ F & \beta = \infty \text{ g}\cdot\text{cm}^{-2} & & C & C \ 3 & & F \ 2 \\ & 0 \text{ g}\cdot\text{cm}^{-2} & \beta < \infty \text{ g}\cdot\text{cm}^{-2} & & & \beta & C \ C \ 2 \\ & \beta & & & F & 3 & C \\ & F & & & & & \end{array}$$

$$7.2.4 \qquad \qquad \eta$$

$$\begin{array}{ccccccc} & & \eta & & 1 & \gamma & \\ & D & 2 & & & & E \\ & & & & & & \\ 3 & & & & & & \\ F & & & & & & \end{array}$$

$$7.2.5 \qquad \qquad W$$

$$\begin{array}{ccc} & W & 1 \ \gamma \\ D & 2 & \end{array}$$

E3

$\beta=0\text{ g.cm}^{-2}$

$\beta=\infty\text{ g.cm}^{-2}$

F

8

8.1

3

$$A=\frac{N_{\text{net}}}{t\cdot\varepsilon}$$

3

A

Bq·m⁻²

Bq·g⁻¹

N_{net}

E

γ

t

s

ε

E

γ

s⁻¹·(Bq·m⁻²)⁻¹

s⁻¹·(Bq·g⁻¹)⁻¹

8.2

GB/T 27418

2

3

3

ε

N_{net}

$$u(A)=A\times\sqrt{\frac{u^2(N_{\text{net}})}{N_{\text{net}}^2}+\frac{u^2(\eta)}{\eta^2}+\frac{u^2(W)}{W^2}+\frac{u^2(F)}{F^2}}$$

4

$u(A)$

A

$u(N_{\text{net}})$

E

γ

N_{net}

$u(\eta)$

E

γ

η

$u(F)$

E

γ

F

$u(W)$

E

γ

W

8.3

95%

γ

LLD

5

$$LLD=\frac{4.65\times\sqrt{N_{\text{g}}}}{t\cdot\varepsilon}$$

5

N_{g}

E

γ

8.4

$$\begin{array}{c} [A \pm u(A)] \\ LLD \end{array}$$

LLD

9

9.1

G

9.2

9.3

9.3.1

9.3.2

9.3.2.1

^{40}K ^{214}Pb ^{214}Bi

^{226}Ra γ

9.3.2.2

1 γ

9.3.2.3

9.4

γ

6

10

10.1

10.2

-

10.3

10.4

:

10.5

10.6

10.7

10.8

A

R_s

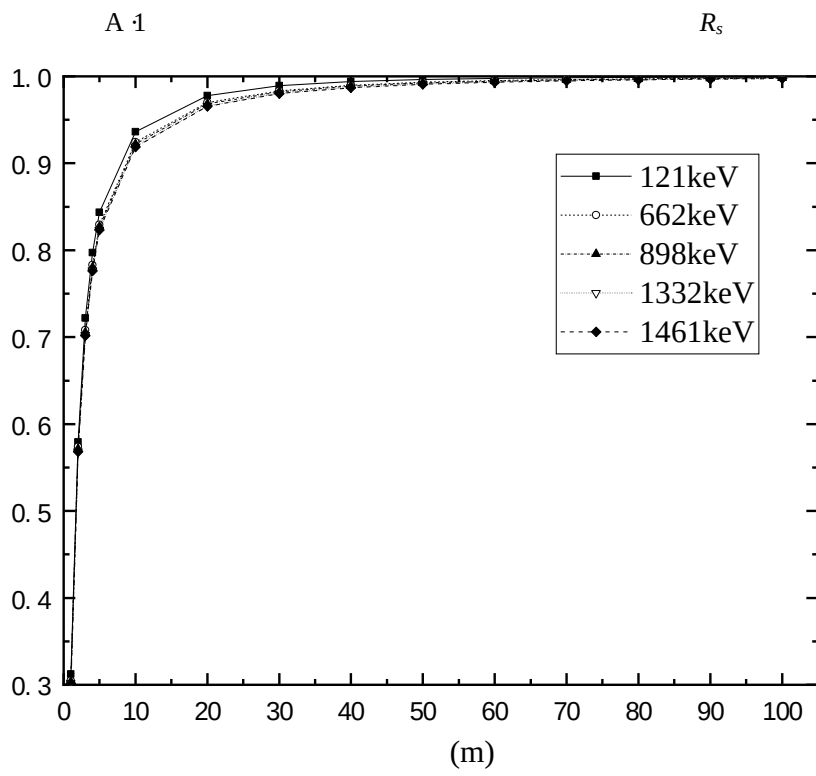
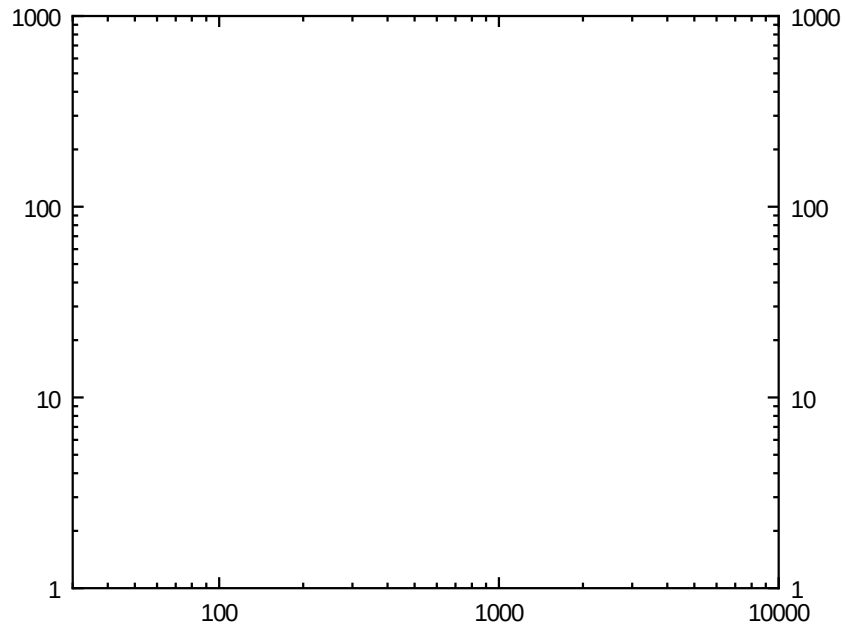
1 m

β γ E

R_s

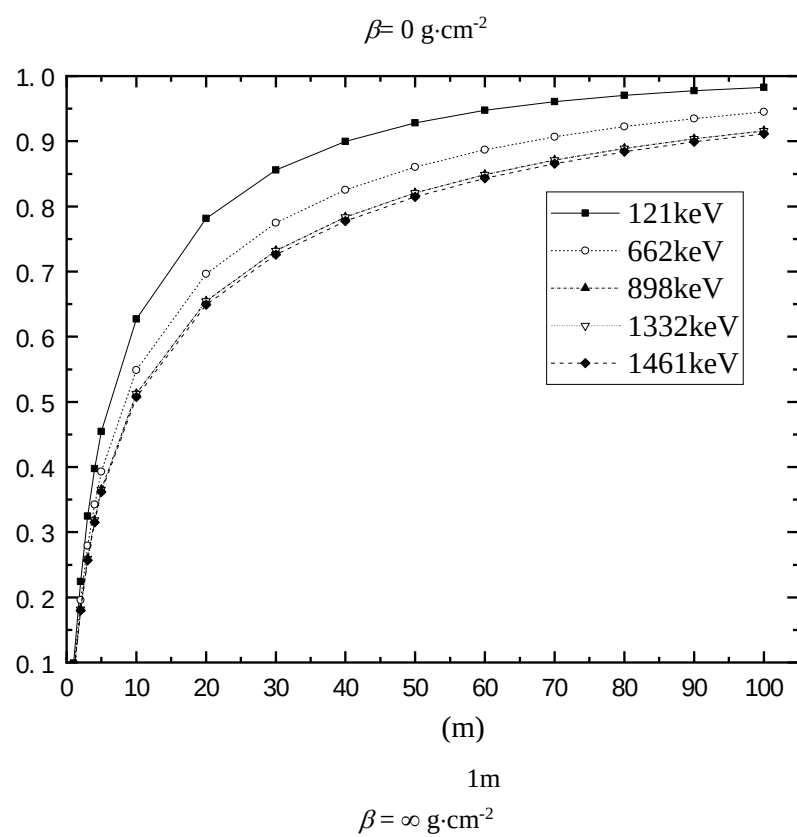
R_s A 1 β

γ E



A 2

1m



A 3

					B	
					β	
B 1					β	
a			R_s			
b						1 cm
c			H_i			
d						$\rho_s \text{ g}\cdot\text{cm}^{-3}$
e			(	i)		A_i
	$\text{Bq}\cdot\text{g}^{-1}$					
f			$H(\text{cm})$			$A_i \text{ Bq}\cdot\text{g}^{-1}$
		$A_{m,0} \text{ Bq}\cdot\text{g}^{-1}$			$\ln(A_i/A_{m,0})$	
	H_i	$\ln(A_i/A_{m,0})$				
g			$\ln(A_i/A_{m,0})$	H_i	$k \text{ cm}^{-1}$	
h			$\beta \text{ g}\cdot\text{cm}^{-2}$	B-1		
					$\beta = -\frac{\rho}{k}$	(B.1)
	β				$\text{g}\cdot\text{cm}^{-2}$	
	ρ	$\text{g}\cdot\text{cm}^{-3}$				
	k	cm^{-1}				
B 2 ^{137}Cs			β			
		B.1	^{137}Cs	β	^a	
					$\beta \text{ g}\cdot\text{cm}$	

C

F

$$\beta = 0 \text{ g.cm}^{-2}$$

$$\beta = \infty \text{ g.cm}^{-2}$$

z

$$0 \text{ g.cm}^{-2} < \beta < \infty \text{ g.cm}^{-2}$$

h

z

C.1

$$A(z) = A_{m,0} \times \exp\left(-\frac{z}{l}\right)$$

C.1

$A_{m,0}$

$\text{Bq} \cdot \text{g}^{-1}$

$A(z)$

z

$\text{Bq} \cdot \text{g}^{-1}$

z

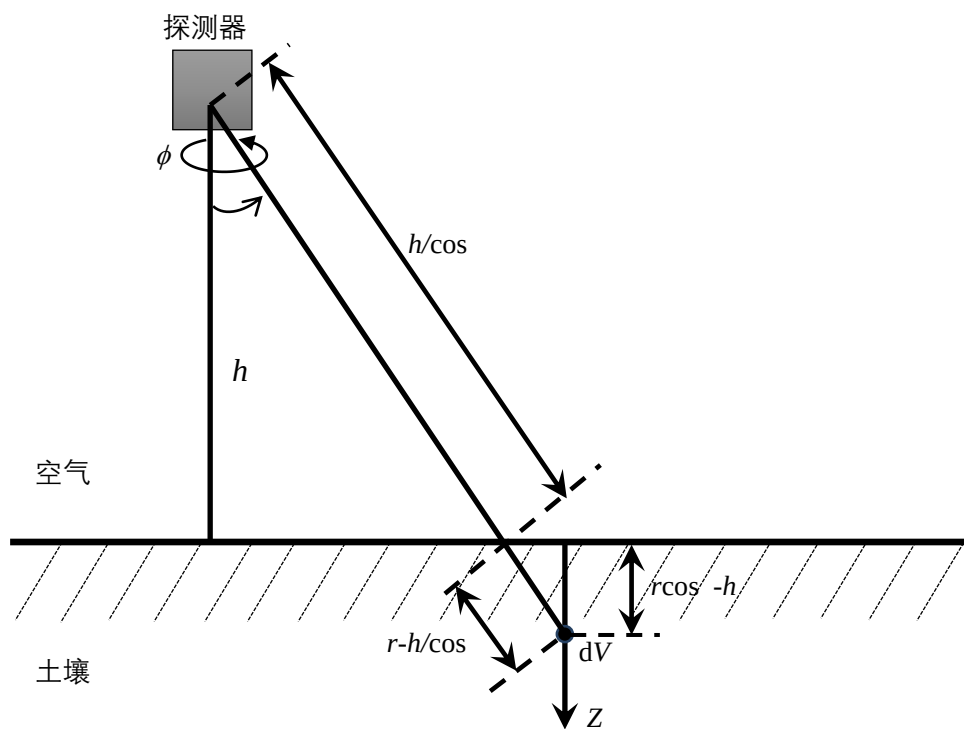
cm

l

cm

HPGe

C.1



C.1

$$\begin{array}{l} h \text{ cm} \\ r \quad \phi \quad \theta \end{array} \quad \begin{array}{l} z \text{ cm} \\ \text{C.2} \end{array}$$

$$\begin{aligned} A\rho_s dV &= A_{m,0} \times \rho_s \times \exp\left(-\frac{z}{l}\right) \times r^2 \sin \theta d\theta d\phi dr \\ &= A_{m,0} \times \rho_s \times \exp\left(-\frac{r \times \cos \theta - h}{l}\right) \times r^2 \sin \theta d\theta d\phi dr \end{aligned} \quad \text{C.2}$$

$$\begin{aligned} dV \\ \text{(C.3)} \end{aligned}$$

$$\begin{aligned} d\varphi &= \frac{A_{m,0} p \rho_s}{4\pi r^2} \times \exp\left(-\frac{r \times \cos \theta - h}{l}\right) \times \exp\left(-\frac{\mu_s}{\rho_s} \times \rho_s \times (r - h / \cos \theta)\right) \\ &\quad \times \exp\left(-\frac{\mu_a}{\rho_a} \times \rho_a \times h / \cos \theta\right) \times r^2 \sin \theta d\theta d\phi dr \end{aligned} \quad \text{C.3}$$

$$\begin{array}{l} p \\ \mu_s \\ \mu_a \\ \rho_s \\ \rho_a \end{array} \quad \begin{array}{l} E \quad \gamma \\ \\ \\ \text{g} \cdot \text{cm}^{-3} \\ \text{g} \cdot \text{cm}^{-3} \end{array} \quad \begin{array}{l} \\ \text{cm}^{-1} \\ \text{cm}^{-1} \\ \\ \end{array}$$

$$\varphi = \int_0^{\pi/2} \int_0^{2\pi} \int_{h/\cos \theta}^{\infty} d\varphi = - \int_0^{\pi/2} \frac{A_{m,0} p \times \exp\left(-\frac{\mu_a}{\rho_a} \times \rho_a \times h / \cos \theta\right)}{2 \left[\frac{1}{\rho_s l} \cos \theta + \frac{\mu_s}{\rho_s} \right]} d \cos \theta \quad \text{(C.4)}$$

$$\begin{array}{l} \omega = \cos \theta \\ \text{C.4} \end{array} \quad \text{C.}$$

$$\varphi = A_a p \int_0^1 \frac{\exp(-\mu_a \times h / \omega)}{2[\omega + \mu_s \cdot l]} d\omega \quad (C.7)$$

h γ

$$\varphi(\omega) = A_a p \frac{\exp(-\mu_a \times h / \omega)}{2[\omega + \mu_s \cdot l]} \quad (C.8)$$

C.7

C.9

$$E_1(X) = \int_x^\infty \frac{\exp(-t)}{t} dt \quad (C.9)$$

$x = \mu_a h / \omega$

C.7

C.10

$$\varphi = \frac{A_a p}{2} [E_1(\mu_a h) - \exp(\frac{\mu_a h}{\mu_s l}) E_1(\mu_a h + \frac{\mu_a h}{\mu_s l})] \quad (C.10)$$

h γ

C.11

$$\frac{\varphi}{A_a} = \frac{p}{2} [E_1(\mu_a h) - \exp(\frac{\mu_a h}{\mu_s l}) E_1(\mu_a h + \frac{\mu_a h}{\mu_s l})] \quad (C.11)$$

$l = 0$ cm

h γ

(C.7)

C.8

C.12

C.13

$$\varphi = A_a p \int_0^1 \frac{\exp(-\mu_a \times h / \omega)}{2\omega} d\omega \quad (C.12)$$

$$\varphi(\omega) = \frac{A_a p \exp(-\mu_a \times h / \omega)}{2\omega} \quad (C.13)$$

$x = \mu_a h / \omega$

C.12

$$\varphi = \frac{A_a p}{2} E_1(\mu_a h) \quad (C.14)$$

h γ

$$\frac{\varphi}{A_a} = \frac{p}{2} E_1(\mu_a h) \quad (C.15)$$

$A_{m,0}$

$l = \infty$ cm

C.5

C.6

h

γ

C.16

C.17

$$\varphi = \int_0^1 \frac{A_{m,0} p \exp(-\mu_a h / \omega)}{2 \mu_s / \rho_s} d\omega \quad (\text{C}\cdot 16)$$

$$\varphi(\omega) = \frac{A_{m,0} p \exp(-\mu_a h / \omega)}{2 \mu_s / \rho_s} \quad (\text{C}\cdot 17)$$

C·16

C·18

$$E_2(X) = \int_x^\infty \frac{\exp(-t)}{t^2} dt \quad (\text{C}\cdot 18)$$

C·16

C·19

$$\varphi = \frac{A_{m,0} p}{2(\mu_s / \rho_s)} E_2(\mu_a h) \quad (\text{C}\cdot 19)$$

γ

C·20

$$\frac{\varphi}{A_{m,0}} = \frac{p}{2(\mu_s / \rho_s)} E_2(\mu_a h) \quad \text{C}\cdot 20$$

C·11

C·15

C·20

$$\beta = \rho_s \cdot l \quad \text{C}\cdot 21$$

C·11

C·15

C·20

C·22

$$\frac{\varphi}{A_x} = \begin{cases} \frac{p E_1(\mu_a h)}{2} & \beta = 0 \\ \frac{p}{2} [E_1(\mu_a h) - \exp(-\frac{(1/\beta) \cdot \mu_a h}{\mu_s / \rho_s}) E_1[(1 + \frac{(1/\beta)}{\mu_s / \rho_s}) \mu_a h]] & 0 < \beta < \infty \\ \frac{p E_2(\mu_a h)}{2(\mu_s / \rho_s)} & \beta = \infty \end{cases} \quad \text{C}\cdot 22$$

(C 1)

C 1

Al₂O₃ Fe₂O₃ SiO₂ CO₂ H₂O

			C 2	(Bq·m ⁻²)				1m	γ		m ⁻² ·s ⁻¹ *					
(keV)			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
11.2	0.255	Pb-210	7.90E-02	3.13E-02	1.86E-02	1.32E-02	8.35E-03	4.34E-03	2.22E							

C 2			(Bq·m ⁻²)				1m		γ		m ⁻² ·s ⁻¹ *		()			
(keV)			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
14.8	0.098	Am-242	6.60E-02	2.98E-02	1.87E-02	1.36E-02	8.91E-03	4.75E-03	2.47E-03	1.66E-03	1.01E-03	5.09E-04	2.55E-04	1.71E-04	1.02E-04	5.12E-05
14.8	0.461	Cm-243	3.10E													

C 2			(Bq·m ⁻²)					1m		γ		m ⁻² ·s ⁻¹ *		()		
(keV)			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
27.8	0.156	Te-129	2.17E-01													



C 2			(Bq·m ⁻²)				1m		γ		m ⁻² ·s ⁻¹ *		()			
(keV)			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
77.1	0.176	Pb-212	2.99E-01	2.48E-01	2.19E-01	2.00E-01	1.72E-01	1.33E-01	9.49E-02	7.53E-02	5.36E-02	3.16E-02	1.75E-02	1.21E-02	7.49E-03	3.84E-03
84.2	0.067	Th-231	1.15E-01	9.55E-02	8.48E-02	7.74E-02	6.70E-02	5.21E-02	3.76E-02	2.99E-02	2.14E-02	1.27E-02	7.09E-03	4.92E-03	3.06E-03	1.57E-03
86.5	0.123	Np-237	2.10E-01	1.76E-01	1.56E-01	1.42E-01	1.23E-01	9.63E-02	6.96E-02	5.55E-02	3.98E-02	2.37E-02	1.32E-02	9.18E-03	5.71E-03	2.93E-03
86.5	0.309	Eu-155	5.29E-01	4.41E-01	3.92E-01	3.58E-01	3.10E-01	2.42E-01	1.75E-01	1.40E-01	1.00E-01	5.97E-02	3.33E-02	2.31E-02	1.44E-02	7.38E-03
86.9	1.089	Sn-126	1.53E-01	1.27E-01	1.13E-01	1.03E-01	8.96E-02	6.99E-02	5.06E-02	4.04E-02	2.90E-02	1.73E-02	9.63E-03	6.68E-03	4.16E-03	2.14E-03
87.6	0.37	Sn-126	6.33E-01	5.29E-01	4.70E-01	4.30E-01	3.73E-01	2.91E-01	2.11E-01	1.68E-01	1.21E-01	7.20E-02	4.01E-02	2.79E-02	1.73E-02	8.91E-03
91.1	0.279	Nd-147	4.78E-01	4.00E-01	3.57E-01	3.26E-01	2.84E-01	2.22E-01	1.61E-01	1.29E-01	9.30E-02	5.57E-02	3.11E-02	2.16E-02	1.35E-02	6.93E-03
97.1	0.166	U-237	2.85E-01	2.40E-01	2.14E-01	1.96E-01	1.71E-01	1.35E-01	9.86E-02	7.91E-02	5.72E-02	3.45E-02	1.93E-02	1.35E-02	8.41E-03	4.32E-03
98.4	0.157	Pa-233	2.71E-01	2.28E-01	2.04E-01	1.87E-01	1.63E-01	1.29E-01	9.42E-02	7.56E-02	5.47E-02	3.30E-02	1.85E-02	1.29E-02	8.07E-03	4.15E-03
99.6	0.147	Cm-243	2.53E-01	2.13E-01	1.91E-01	1.75E-01	1.53E-01	1.21E-01	8.86E-02	7.11E-02	5.16E-02	3.11E-02	1.75E-02	1.22E-02	7.62E-03	3.92E-03
99.6	0.157	Np-239	2.70E-01	2.27E-01	2.04E-01	1.87E-01	1.63E-01	1.29E-01	9.44E-02	7.58E-02	5.49E-02	3.32E-02	1.86E-02	1.30E-02	8.12E-03	4.18E-03
99.6	0.185	Cm-245	3.17E-01	2.67E-01	2.40E-01	2.19E-01	1.92E-01	1.51E-01	1.11E-01	8.91E-02	6.46E-02	3.90E-02	2.19E-02	1.53E-02	9.55E-03	4.91E-03
101.1	0.266	U-237	4.59E-01	3.87E-01	3.47E-01	3.18E-01	2.78E-01	2.19E-01	1.61E-01	1.29E-01	9.38E-02	5.67E-02	3.18E-02	2.22E-02	1.39E-02	7.15E-03
103.8	0.059	Am-242	1.02E-01	8.60E-02	7.71E-02	7.07E-02	6.18E-02	4.89E-02	3.59E-02	2.89E-02	2.10E-02	1.27E-02	7.13E-03	4.98E-03	3.11E-03	1.60E-03
103.8	0.236	Cm-243	4.06E-01	3.43E-01	3.08E-01	2.82E-01	2.47E-01	1.95E-01	1.43E-01	1.15E-01	8.36E-02	5.06E-02	2.84E-02	1.98E-02	1.24E-02	6.39E-03
103.8	0.251	Np-239	4.33E-01	3.65E-01	3.28E-01	3.00E-01	2.63E-01	2.08E-01	1.53E-01	1.23E-01	8.91E-02	5.39E-02	3.30E-02	2.11E-02	1.32E-02	6.81E-03
103.8	0.295	Cm-245	5.09E-01	4.30E-01	3.85E-01	3.53E-01	3.09E-01	2.44E-01	1.80E-01	1.44E-01	1.05E-01	6.34E-02	3.56E-02	2.49E-02	1.56E-02	8.01E-03
105.3	0.206	Eu-155	3.55E-01	3.00E-01	2.69E-01	2.47E-01	2.16E-01	1.71E-01	1.26E-01	1.01E-01	7.33E-02	4.44E-02	2.50E-02	1.74E-02	1.09E-02	5.62E-03
106.1	0.272	Np-239	4.70E-01	3.97E-01	3.56E-01	3.27E-01	2.86E-01	2.26E-01	1.66E-01	1.34E-01	9.72E-02	5.89E-02	3.31E-02	2.31E-02	1.45E-02	7.45E-03
117.3	0.066	Cm-245	1.14E-01	9.66E-02	8.68E-02	7.98E										

C 2			(Bq·m ⁻²)			1m			γ			m ⁻² ·s ⁻¹ *			()		
(keV)			(g cm ⁻²)														
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100	
127.5	0.141	Cs-134m	2.46E-01	2.09E-01	1.88E-01	1.74E-01	1.53E-01	1.21E-01	8.99E-02	7.27E-02	5.33E-02	3.25E-02	1.84E-02	1.29E-02	8.10E-03	4.19E-03	
133	0.419	Hf-181	7.35E-01	6.27E-01	5.64E-01	5.21E-01	4.58E-01	3.64E-01	2.71E-01	2.19E-01	1.61E-01	9.85E-02	5.59E-02	3.92E-02	2.46E-02	1.27E-02	
133.5	0.111	Ce-144	1.94E-01	1.66E-01	1.49E-01	1.38E-01	1.21E-01	9.65E-02	7.18E-02	5.61E-02	4.13E-02	2.53E-02	1.44E-02	1.01E-02	6.33E-03	3.38E-03	
136	0.59	Se-75	1.04E+00	8.85E-01	7.96E-01	7.36E-01	6.47E-01	5.15E-01	3.84E-01	3.11E-01	2.28E-01	1.40E-01	7.95E-02	5.58E-02	3.50E-02	1.81E-02	
136.5	0.106	Co-57	1.87E-01	1.60E-01	1.44E-01	1.33E-01	1.17E-01	9.31E-02	6.93E-02	5.61E-02	4.13E-02	2.53E-02	1.44E-02	1.01E-02	6.33E-03	3.28E-03	
140.5	0.89	Tc-99m	1.57E+00	1.34E+00	1.21E+00	1.12E+00	9.83E-01	7.83E-01	5.84E-01	4.73E-01	3.48E-01	2.14E-01	1.22E-01	8.54E-02	5.36E-02	2.78E-02	
143.8	0.11	U-235	1.93E-01	1.66E-01	1.49E-01	1.38E-01	1.22E-01	9.70E-02	7.24E-02	5.87E-02	4.33E-02	2.66E-02	1.52E-02	1.06E-02	6.68E-03	3.46E-03	
145.4	0.484	Ce-141	8.55E-01	7.33E-01	6.61E-01	6.12E-01	5.39E-01	4.30E-01	3.21E-01	2.60E-01	1.92E-01	1.18E-01	6.73E-02	4.73E-02	2.93E-02	1.54E-02	
158.6	0.864	Sn-117m	1.54E+00	1.32E+00	1.19E+00	1.10E+00	9.74E-01	7.79E-01	5.84E-01	4.75E-01	3.51E-01	2.17E-01	1.24E-01	8.72E-02	5.48E-02	2.84E-02	
159	0.084	Te-123m	1.50E+00	1.28E+00	1.16E+00	1.07E+00	9.47E-01	7.58E-01	5.68E-01	4.62E-01	3.42E-01	2.11E-01	1.21E-01	8.49E-02	5.33E-02	2.77E-02	
162.6	0.062	Ba-140	1.11E-01	9.52E-02	8.57E-02	7.95E-02	7.02E-02	5.62E-02	4.22E-02	3.43E-02	2.54E-02	1.57E-02	8.98E-03	6.32E-03	3.97E-03	2.06E-03	
165.9	0.238	Ba-139	4.24E-01	3.65E-01	3.28E-01	3.05E-01	2.69E-01	2.16E-01	1.62E-01	1.32E-01	9.77E-02	6.03E-02	3.45E-02	2.44E-02	1.53E-02	7.94E-03	
174.9	0.095	Cm-245	1.71E-01	1.47E-01	1.32E-01	1.23E-01	1.08E-01	8.71E-02	6.55E-02	5.33E-02	3.96E-02	2.45E-02	1.41E-02	9.93E-03	6.24E-03	3.24E-03	
181.1	0.061	Mo-99	1.09E-01	9.40E-02	8.45E-02	7.84E-02	6.94E-02	5.59E-02	4.21E-02	3.43E-02	2.54E-02	1.58E-02	9.07E-03	6.41E-03	4.03E-03	2.09E-03	
185.7	0.572	U-235	1.03E+00	8.90E-02	8.01E-02	7.43E-02	6.57E-02	5.31E-02	4.00E-02	3.26E-01	2.43E-01	1.50E-01	8.64E-02	6.12E-02	3.84E-02	2.00E-02	
186	0.033	Ra-226	5.92E-02	5.10E-02	4.59E-02	4.26E-02	3.77E-02	3.04E-02	2.29E-02	1.87E-02	1.39E-02	8.62E-03	4.96E-03	3.51E-03	2.20E-03	1.14E-03	
202.5	0.985	Y-90m	1.75E+00	1.51E+00	1.35E+00	1.26E+00	1.11E+00	9.02E-02	6.82E-02	5.57E-01	4.16E-01	2.59E-01	1.49E-01	1.06E-01	6.65E-02	3.45E-02	
205.3	0.05	U-235	9.14E-02	7.89E-02	7.09E-02	6.59E-02	5.83E-02	4.73E-02	3.57E-02	2.92E-02	2.18E-02	1.36E-02	7.83E-03	5.55E-03	3.49E-03	1.81E-03	
208	0.216	U-237	3.95E-01	3.41E-01	3.06E-01	2.84E											

			C 2	(Bq·m ⁻²)					1m	γ	m ² ·s ⁻¹ *		()				
			(keV)	(g cm ⁻²)													
				0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
									6.41E-01	5.25E-01	3.94E-01	2.46E-01	1.42E-01	1.01E-01	6.38E-02	3.32E-02	

C 2			(Bq·m ⁻²)				1m		γ		m ⁻² ·s ⁻¹ *		()			
(keV)			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
342.1	0.067	Ag-111	1.28E-01	1.12E-01	1.01E-01	9.43E-02	8.42E-02	6.87E-02	5.26E-02	4.36E-02	3.31E-02	2.10E-02	1.24E-02	8.80E-03	5.62E-03	2.94E-03
344.3	0.266	Eu-155	5.11E-01	4.44E-02	4.03E-01	3.75E-01	3.35E-01	2.74E-01	2.09E-01	1.74E-01	1.32E-01	8.39E-02	4.94E-02	3.51E-02	2.24E-02	1.17E-02
345.9	0.12	Hf-181	2.31E-01	2.01E-01	1.82E-01	1.70E-01	1.52E-01	1.24E-01	9.46E-02	7.85E-02	5.59E-02	3.79E-02	2.23E-02	1.59E-02		

C 2			(Bq·m ⁻²)				1m		γ		m ² ·s ⁻¹ *		()			
(keV)			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
487	0.459	La-140	9.19E-01	8.00E-01	7.31E-01	6.81E-01	6.12E-01	5.02E-01	3.91E-01	3.26E-02	2.51E-01	1.62E-01	9.67E-02	6.94E-02	4.42E-02	2.34E-02

C 2			(Bq·m ⁻²)			1m			γ			m ⁻² ·s ⁻¹ *			()		
(keV)			(g cm ²)														
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100	
610.3	0.056	Ru-103	1.14E-01	9.99E-02	9.15E-02	8.54E-02	7.69E-02	6.35E-02	4.98E-02	4.17E-02	3.23E-02	2.11E-02	1.27E-02	9.18E-03	5.90E-03	3.12E-03	
618.4	0.073	W-187	1.48E-02	1.30E-01	1.19E-01	1.11E-01	1.00E-01	8.26E-02	6.48E-02	5.43E-02	4.21E-02	2.75E-02	1.66E-02	1.20E-02	7.70E-03	4.07E-03	
621.8	0.098	Rh-106	2.00E-01	1.75E-01	1.61E-01	1.50E-01	1.35E-01	1.12E-01	8.76E-02	7.34E-02	5.69E-02	3.71E-02	2.24E-02	1.62E-02	1.04E-02	5.51E-03	
628.7	0.31	Sb-128	6.33E-01	5.55E-01	5.08E-01	4.74E-01	4.28E-01	3.53E-01	2.77E-01	2.32E-01	1.80E-01	1.18E-01	7.12E-02	5.14E-02	3.31E-02	1.75E-02	
630	0.886	Pm-148m	1.81E+00	1.59E+00	1.45E+00	1.36E+00	1.22E+00	1.01E+00	7.93E-01	6.65E-01	5.15E-01	3.37E-01	2.04E-01	1.47E-01	9.46E-02	5.00E-02	
635.9	0.113	Sb-125	2.31E-01	2.03E-01	1.86E-01	1.73E-01	1.56E-01	1.29E-01	1.01E-01	8.51E-02	6.60E-02	4.31E-02	2.61E-02	1.88E-02	1.21E-02	6.41E-03	
636.2	0.36	Sb-128	7.36E-01	6.45E-01	5.91E-01	5.52E-01	4.98E-01	4.11E-01	3.23E-01	2.71E-01	2.10E-01	1.37E-01	8.30E-02	5.99E-02	3.86E-02	2.04E-02	
637	0.073	I-131	1.49E-01	1.30E-01	1.19E-01	1.11E-01	1.00E-01	8.30E-02	6.52E-02	5.47E-02	4.24E-02	2.77E-02	1.68E-02	1.21E-02	7.79E-03	4.12E-03	
641.3	0.474	La-142	9.69E-01	8.50E-01	7.79E-01	7.27E-01	6.56E-01	5.42E-01	4.26E-01	3.57E-01	2.77E-01	1.81E-01	1.10E-01	7.91E-02	5.10E-02	2.69E-02	
647.5	0.194	Te-133m	3.97E-01	3.48E-01	3.19E-01	2.98E-01	2.69E-01	2.22E-01	1.75E-01	1.46E-01	1.14E-01	7.44E-02	4.50E-02	3.25E-02	2.09E-02	1.11E-02	
657.7	0.947	Ag-110m	1.94E+00	1.70E+00	1.56E+00	1.46E+00	1.32E+00	1.09E+00	8.55E-01	7.18E-01	5.57E-01	3.65E-01	2.21E-01	1.60E-01	1.03E-01	5.44E-02	
657.9	0.983	Nb-97	2.01E+00	1.77E+00	1.62E+00	1.51E+00	1.37E+00	1.13E+00	8.88E-01	7.45E-01	5.78E-01	3.79E-01	2.30E-01	1.66E-01	1.07E-01	5.65E-02	
661.6	0.899	Ba-137m	1.84E+00	1.62E+00	1.48E+00	1.38E+00	1.25E+00	1.03E+00	8.13E-01	6.82E-01	5.30E-01	3.47E-01	2.10E-01	1.52E-01	9.80E-02	5.18E-02	
664.5	0.053	Ce-143	1.08E-01	9.45E-02	8.67E-02	8.09E-02	7.30E-02	6.04E-02	4.75E-02	3.99E-02	3.10E-02	2.03E-02	1.23E-02	8.88E-03	5.73E-03	3.03E-03	
666.3	0.997	Sb-126	2.05E+00	1.80E+00	1.65E+00	1.54E+00	1.39E+00	1.15E+00	9.02E-01	7.58E-01	5.88E-01	3.86E-01	2.34E-01	1.69E-01	1.09E-01	5.76E-02	
667.7	0.987	I-132	2.03E+00	1.78E+00	1.63E+00	1.52E+00	1.37E+00	1.14E+00	8.94E-01	7.50E-01	5.83E-01	3.82E-01	2.32E-01	1.67E-01	1.08E-01	5.71E-02	
668.5	0.961	I-130	1.97E+00	1.73E+00	1.59E+00	1.48E+00	1.34E+00	1.11E+00	8.71E-01	7.31E-01	5.68E-01	3.72E-01	2.26E-01	1.63E-01	1.05E-01	5.56E-02	
676.4	0.157	Ru-105	3.22E-01	2.82E-01	2.59E-01	2.42E-01	2.18E-01	1.81E-01	1.42E-01	1.19E-01	9.27E-02	6.08E-02	3.69E-02	2.67E-02	1.72E-02	9.10E-03	
685.7	0.353	Sb-127	7.26E-01	6.38E-01	5.85E-01	5.46E-01	4.93E-01	4.08E-01	3.21E-01	2.70E-01	2.10E-01	1.38E-01	8.36E-02	6.04E-02	3.90E-02	2.06E-02	
685.8	0.316	W-187	6.50E-01	5.71E-01	5.23E-01	4.89E-01	4.41E-01	3.65E-01	2.88E-01	2.42E-01	1.88E-01	1.23E-01	7.48E-02	5.41E-02	3.49E-02	1.85E-02	
695	0.997	Sb-126	2.05E+00	1.80E+00	1.65E+00	1.55E+00	1.39E+00	1.16E+00	9.10E-01	7.65E-01	5.49E-01	3.90E-01	2.37E-01	1.72E-01	1.11E-01	5.86E-02	
697	0.289	Sb-126	5.96E-01	5.23E-01	4.80E-01	4.48E-01	4.05E-01	3.35E-01	2.64E-01	2.22E-01	1.72E-01	1.13E-01	6.88E-02	4.98E-02	3.21E-02	1.70E-02	

C 2			(Bq·m ⁻²)			1m			γ			m ⁻² ·s ⁻¹ *			()		
(keV)			(g cm ²)														
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100	
720.5	0.538	Sb-126	1.11E+00	9.78E-01	8.79E-01	8.38E-01	7.56E-01	6.28E-01	4.95E-01	4.16E-01	3.24E-01	2.13E-01	1.30E-01	9.39E-02	6.06E-02	3.21E-02	
722	0.051	Ce-143	1.06E-01	9.31E-02	8.54E-02	7.98E-02	7.20E-02	5.97E-02	4.71E-02	3.96E-02	3.08E-02	2.03E-02	1.23E-02	8.94E-03	5.78E-03	3.06E-03	
723.3	0.197	Eu-154	4.07E-01	3.58E-01	3.28E-01	3.07E-01	2.77E-01	2.30E-01	1.81E-01	1.52E-01	1.19E-01	7.81E-02	4.75E-02	3.44E-02	2.22E-02	1.18E-02	
724.2	0.444	Zr-95	9.19E-01	8.08E-01	7.41E-01	6.93E-01	6.25E-01	5.18E-01	4.09E-01	3.44E-01	2.68E-01	1.76E-01	1.07E-01	7.76E-02	5.02E-02	2.66E-02	
724.3	0.473	Ru-105	9.78E-01	8.60E-01	7.88E-01	7.37E-01	6.65E-01	5.52E-01	4.35E-01	3.66E-01	2.85E-01	1.88E-01	1.14E-01	8.26E-02	5.34E-02	2.83E-02	
725.7	0.327	Pm-148m	6.77E-01	5.95E-01	5.45E-01	5.10E-01	4.60E-01	3.82E-01	3.01E-01	2.53E-01	1.97E-01	1.30E-01	7.89E-02	5.72E-02	3.69E-02	1.96E-02	
727.2	0.068	Bi-212	1.40E-01	1.23E-01	1.13E-01	1.05E-01	9.50E-02	7.88E-02	6.21E-02	5.23E-02	4.07E-02	2.68E-02	1.63E-02	1.18E-02	7.63E-02	4.05E-03	
739.5	0.122	Mo-99	2.53E-01	2.22E-01	2.04E-01	1.91E-01	1.72E-01	1.43E-01	1.13E-01	9.48E-02	7.38E-02	4.86E-02	2.96E-02	2.15E-02	1.39E-02	7.36E-03	
739.5	0.823	I-130	1.71E+00	1.50E+00	1.37E+00	1.29E+00	1.16E+00	9.63E-01	7.60E-01	6.40E-01	4.98E-01	3.28E-01	2.00E-01	1.45E-01	9.36E-02	4.97E-02	
742.6	0.151	Te-134	3.13E-01	2.75E-01	2.52E-01	2.36E-01	2.13E-01	1.77E-01	1.39E-01	1.17E-01	9.14E-02	6.03E-02	3.67E-02	2.66E-02	1.72E-02	9.12E-03	
743.3	1	Sb-128	2.07E+00	1.82E+00	1.67E+00	1.56E+00	1.41E+00	1.17E+00	9.24E-01	7.78E-01	6.06E-01	4.00E-01	2.43E-01	1.76E-01	1.14E-01	6.05E-02	
748.3	0.008	Pr-145	1.56E-02	1.37E-02	1.26E-02	1.18E-02	1.06E-02	8.83E-03	6.97E-03	5.87E-03	4.57E-03	3.02E-03	1.84E-03	1.33E-03	8.61E-04	4.57E-04	
754	1	Sb-128	2.08E+00	1.83E+00	1.67E+00	1.57E+00	1.41E+00	1.17E+00	9.27E-01	7.81E-01	6.08E-01	4.02E-01	2.45E-01	1.77E-01	1.15E-01	6.09E-02	
756.7	0.549	Zr-95	1.14E+00	1.00E+00	9.19E-01	8.60E-01	7.76E-01	6.45E-01	5.09E-01	4.29E-01	3.34E-01	2.21E-01	1.34E-01	9.75E-02	6.30E-02	3.35E-02	
763.9	0.224	Ag-110m	4.65E-01	4.09E-01	3.75E-01	3.51E-01	3.17E-01	2.63E-01	2.08E-01	1.75E-01	1.36E-01	9.02E-02	5.50E-02	3.99E-02	2.58E-02	1.37E-02	
765.8	1	Nb-95	2.08E+00	1.83E+00	1.68E+00	1.57E+00	1.42E+00	1.18E+00	9.30E-01	7.84E-01	6.11E-01	4.04E-01	2.46E-01	1.79E-01	1.15E-01	6.13E-02	
767.2	0.29	Te-134	6.04E-01	5.31E-01	4.87E-01	4.56E-01	4.11E-01	3.42E-01	2.70E-01	2.27E-01	1.77E-01	1.17E-01	7.14E-02	5.18E-02	3.35E-02	1.78E-02	
772.6	0.762	I-132	1.59E+00	1.40E+00	1.28E+00	1.20E+00	1.08E+00	8.99E-01	7.10E-01	5.98E-01	4.67E-01	3.08E-01	1.88E-01	1.37E-01	8.83E-02	4.69E-02	
773.7	0.382	Te-131m	7.95E-01	6.99E-01	6.41E-01	6.00E-01	5.42E-01	4.50E-01	3.56E-01	3.00E-01	2.34E-01	1.54E-01	9.42E-02	6.84E-02	4.42E-02	2.35E-02	
778.9	0.13	Eu-152	2.70E-01	2.38E-01	2.18E-01	2.04E-01	1.84E-01	1.53E-01	1.21E-01	1.02E-01	7.95E-02	5.26E-02	3.21E-02	2.33E-02	1.51E-02	8.01E-03	
783.7	0.145	Sb-127	3.03E-01	2.66E-01	2.44E-01	2.29E-01	2.06E-01	1.72E-01	1.36E-01	1.14E-01	8.92E-02	5.90E-02	3.60E-02	2.61E-02	1.69E-02	8.99E-03	
793.4	1	Sb-130	2.09E+00	1.84E+00	1.68E+00	1.58E+00	1.42E+00	1.18E+00	9.37E-01	7.90E-01	6.17E-01	4.08E-01	2.49E-01	1.81E-01	1.17E-01	6.23E-02	

C 2

C 2			(Bq·m ⁻²)				1m		γ		m ⁻² ·s ⁻¹ *		()			
(keV)			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
912.7	0.55	Te-133m	1.17E+00	1.03E+00	9.44E-01	8.88E-01	8.01E-01	6.69E-01	5.32E-01	4.50E-01	3.53E-01	2.36E-01	1.45E-01	1.06E-01	6.85E-02	3.67E-02
914.6	0.2	Sb-129	4.26E-01	3.76E-01	3.44E-01	3.24E-01	2.92E-01	2.44E-01	1.94E-01	1.64E-01	1.29E-01	8.59E-02	5.27E-02	3.85E-02	2.50E-02	1.34E-02
914.8	0.109	Te-133m	2.32E-01	2.04E-01	1.87E-01	1.76E-01	1.59E-01	1.33E-01	1.05E-01	8.93E-02	7.00E-02	4.67E-02	2.87E-02	2.09E-02	1.36E-02	7.27E-03
914.8	0.115	Pm-148	2.43E-01	2.15E-01	1.97E-01	1.85E-01	1.67E-01	1.39E-01	1.11E-01	9.38E-02	7.36E-02	4.91E-02	3.01E-02	2.20E-02	1.43E-02	7.64E-03
914.8	0.171	Pm-148m	3.63E-01	3.21E-01	2.94E-01	2.76E-01	2.49E-01	2.08E-01	1.65E-01	1.40E-01	1.10E-01	7.33E-02	4.50E-02	3.29E-02	2.13E-02	1.14E-02
914.8	0.139	Y-92	2.96E-01	2.61E-01	2.39E-01	2.25E-01	2.03E-01	1.70E-01	1.35E-01	1.14E-01	8.98E-02	6.00E-02	3.69E-02	2.70E-02	1.75E-02	9.37E-02
914.8	0.19	Sb-130	4.05E-01	3.57E-01	3.27E-01	3.08E-01	2.78E-01	2.32E-01	1.85E-01	1.56E-01	1.23E-01	8.21E-02	5.04E-02	3.69E-02	2.39E-02	1.28E-02
914.8	0.343	Ag-110m	7.32E-01	6.46E-01	5.91E-01	5.57E-01	5.02E-01	4.20E-01	3.34E-01	2.83E-01	2.22E-01	1.48E-01	9.12E-02	6.67E-02	4.33E-02	2.32E-02
914.8	0.181	I-132	3.86E-01	3.41E-01	3.12E-01	2.94E-01	2.65E-01	2.22E-01	1.77E-01	1.50E-01	1.17E-01	7.86E-02	4.84E-02	3.54E-02	2.30E-02	1.23E-02
914.8	0.12	Eu-152m	2.57E-01	2.27E-01	2.08E-01	1.96E-01	1.77E-01	1.48E-01	1.18E-01	9.97E-02	7.83E-02	5.25E-02	3.23E-02	2.36E-02	1.53E-02	8.22E-03
914.8	0.145	Eu-152	3.10E-01	2.74E-01	2.51E-01	2.36E-01	2.13E-01	1.78E-01	1.42E-01	1.20E-01	9.45E-02	6.33E-02	3.90E-02	2.85E-02	1.85E-02	9.93E-03
914.8	0.055	Ac-228	1.17E-01	1.03E-01	9.44E-02	8.88E-02	8.02E-02	6.71E-02	5.34E-02	4.53E-02	3.56E-02	2.38E-02	1.47E-02	1.07E-02	6.97E-03	3.74E-03
914.8	0.077	Sb-129	1.65E-01	1.45E-01	1.33E-01	1.25E-01	1.13E-01	9.48E-02	7.55E-02	6.40E-02	5.03E-02	3.37E-02	1.07E-02	1.52E-02	9.85E-03	5.28E-03
914.8	0.175	Ac-228	3.74E-01	3.30E-01	3.02E-01	2.85E-01	2.57E-01	2.15E-01	1.71E-01	1.45E-01	1.14E-01	7.64E-02	4.70E-02	3.44E-02	2.24E-02	1.20E-02
914.8	0.278	Np-238	5.96E-01	5.27E-01	4.83E-01	4.55E-01	4.10E-01	3.44E-01	2.74E-01	2.32E-01	1.83E-01	1.22E-01	7.54E-02	5.52E-02	3.59E-02	1.92E-02
914.8	0.103	Eu-154	2.21E-01	1.96E-01	1.79E-01	1.69E-01	1.52E-01	1.28E-01	1.02E-01	8.63E-02	6.79E-02	4.56E-02	2.81E-02	2.06E-02	1.34E-02	7.18E-03
914.8	0.174	Eu-154	3.74E-01	3.31E-01	3.03E-01	2.86E-01	2.58E-01	2.16E-01	1.72E-01	1.46E-01	1.15E-01	7.27E-02	4.76E-02	3.49E-02	2.27E-02	1.22E-02
914.8	0.298	Cs-138	6.42E-01	5.67E-01	5.20E-01	4.90E-01										

C 2			(Bq·m ⁻²)				1m		γ		m ² ·s ⁻¹ *		()			
(keV)			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
1038.8	0.08	I-135	1.73E-01	1.53E-01	1.40E-01	1.32E-01	1.19E-01	1.00E-01	7.98E-02	6.78E-02	5.34E-02	3.59E-02	2.22E-02	1.63E-02	1.06E-02	5.69E-03

C 2			(Bq·m ⁻²)			1m			γ			m ⁻² ·s ⁻¹ *			()		
(keV)			(g cm ⁻²)														
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100	
1235.4	0.2	Cs-136	4.40E-01	3.89E-01	3.58E-01	3.38E-01	3.06E-01	2.58E-01	2.06E-01	1.76E-01	1.39E-01	9.46E-02	5.93E-02	4.35E-02	2.85E-02	1.54E-02	

C 2			(Bq·m ⁻²)													
(keV)			1m													
			γ m ⁻² ·s ⁻¹ * ()													
			(g cm ⁻²)													
			0.0	0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0	10	20	30	50	100
1691	0.488	Sb-124	1.11E+00	9.82E-01	9.09E-01	8.60E-01	7.82E-01	6.65E-01	5.36E-01	4.61E-01	3.69E-01	2.55E-01	1.63E-01	1.20E-01	7.99E-02	4.35E-02
1736.5	0.06	Sb-129	1.36E-01	1.21E-01	1.12E-01	1.06E-01	9.63E-02	8.19E-02	6.61E-02	5.69E-02	4.56E-02	3.16E-02	2.02E-02	1.49E-02	9.91E-03	5.40E-03
1736.5	0.06	Sb-129	1.36E-01	1.21E-01	1.12E-01	1.06E-01	9.63E-02	8.19E-02	6.61E-02	5.69E-02	4.56E-02	3.16E				

C 3

*

		keV		(m ⁻² s ⁻¹ Bq ⁻¹ g)
U-238	Pb-214	295	0.192	8.28E+03
		352	0.369	1.71E+04
	Bi-214	609	0.469	2.75E+04
		665	0.0158	9.65E+02
		768	0.0497	3.25E+03
		934	0.0319	2.29E+03
	Pa-234m	1001	0.00845	6.29E+02
	Bi-214	1120	0.155	1.22E+04
		1238	0.061	5.07E+03
		1378	0.041	3.61E+03
		1408	0.025	2.23E+03
		1509	0.022	2.03E+03
		1730	0.03	2.98E+03
		1765	0.162	1.62E+04
		1847	0.0216	2.22E+03
		2119	0.0125	1.38E+03
		2204	0.0525	5.92E+03
		2448	0.0162	1.93E+03
Th-232	Pb-212	239	0.434	1.73E+04
	Ra-224	241	0.0397	1.58E+03
	Ac-228	338	0.12	5.47E+03
		463	0.0464	2.41E+03
	Tl-208	511	0.0809	4.38E+03
		583	0.306	1.76E+04
	Bi-212	727	0.0675	4.30E+03
	Ac-228	795	0.0484	3.22E+03
	Tl-208	861	0.0453	3.14E+03
	Ac-228	911	0.29	2.06E+04
		965	0.0545	3.98E+03
		969	0.175	1.28E+04
		1588	0.0371	3.52E+03
	Bi-212	1621	0.0149	1.43E+03
	Ac-228	1630	0.0195	1.87E+03
	Tl-208	2615	0.359	4.42E+04
K-40	K-40	1461	0.107	9.71E+04

*

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Gamma-Ray Spectrometry in the Environment

D

γ

η

$\mathcal{W}$

D 1 γ

γ
 ^{241}Am ^{133}Ba ^{137}Cs ^{60}Co ^{152}Eu

a γ 10

5

$$\varphi=\frac{Ap}{4\pi^2}e^{-\mu_a x}e^{-\mu_h y}\qquad\text{D.1}$$

φ $\text{s}^{-1}\cdot\text{cm}^{-2}$

A Bq

p E

μ_a E cm^{-1}

x cm

μ_h E cm^{-1}

y cm

r cm

1 $E>1\text{MeV}$

2 $E<0.1\text{MeV}$

3

$$r\!=\!\frac{1}{\mu}\!\cdot\!\frac{1\!-\!e^{-\mu d}\,(1\!+\!\mu d)}{1\!-\!e^{-\mu d}}\!+\!d_0\!+\!x\qquad\text{D.2}$$

E cm^{-1}

d cm

d_0 cm

b γ n_g

c n_b

d $(n_g\!-\!n_b)$ φ η

$$\eta\!=\!\frac{n_g-n_b}{\varphi}\qquad\text{D.3}$$

e a $\sim$ d η

D 2 γ

D 2. 1 γ $R(\theta)$

^{137}Cs ^{60}Co ^{152}Eu $R(\theta)$ γ D.1 ^{241}Am ^{133}Ba

a 10 = 0 ° $N_f(\)$

b = 0 ° N_0 $N_f(\)$ $N_f(\)/$

N_0

$$R(\theta) = \sum_{i=0}^n k_i \times \cos \theta^i$$
 D-4

n $n = 4$

k_i

D 2. 2 W

E γ W D-5

$$W = \int_0^{\pi/2} \frac{\varphi(\theta)}{\varphi} \cdot R(\theta) d\theta$$
 D-5

$\varphi(\theta)$ γ

C

rad

D.2.1 D.2.2 W

E

η

W

E.1

E.1.1

a

1 5.1.1
2 γ γ γ
3 ^{241}Am ^{152}Eu 0° 45° 90°

b

1 γ 0° 45° 90°
 γ 10 000
1%
2 90° 120° 240°
 γ
3 90° 5%
4 γ

E.1.2

a

X

(CT)

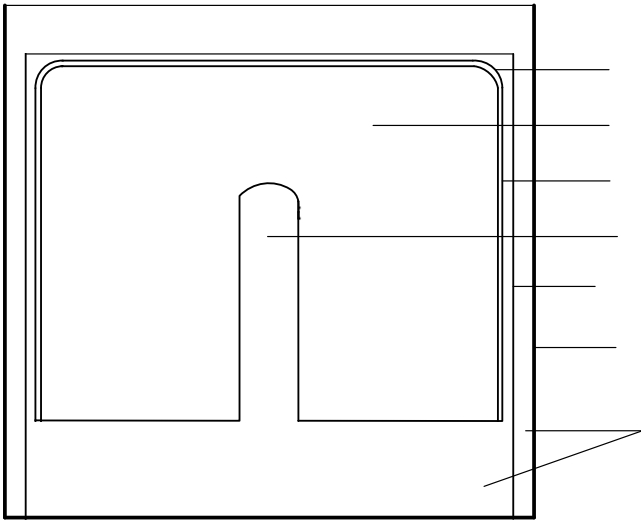
b

c

d

1%

5%



E.1 HPGe

E.2

η

E.1

a

γ

b

γ

c

η

E.3

$R(\theta)$ E.1

a

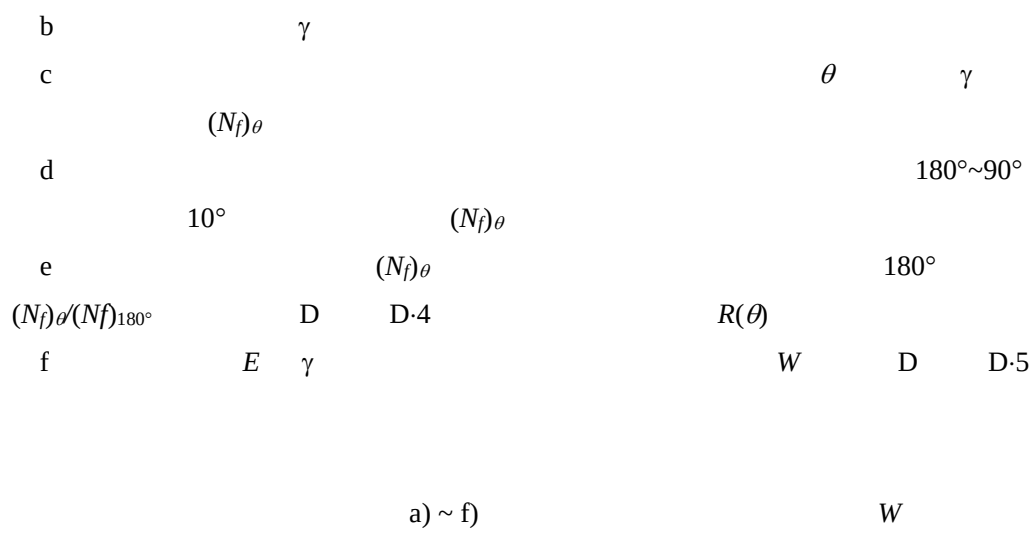
θ

θ

$180^{\circ}\sim90^{\circ}$

θ

$\sqrt{r^2+h^2}$
 γ



F.1

$$\ln(\eta) = a - b \times \ln(E) \quad (\text{F.1})$$

η cm^2

E MeV

a, b

F.2 F.3

$$a = 2.689 + 0.4996 \times \ln \varepsilon + 0.0969 \times (\ln \varepsilon)^2 \quad (\text{F.2})$$

$$b = 1.315 - 0.02044 \times \varepsilon + 0.00012 \times \varepsilon^2 \quad (\text{F.3})$$

ε

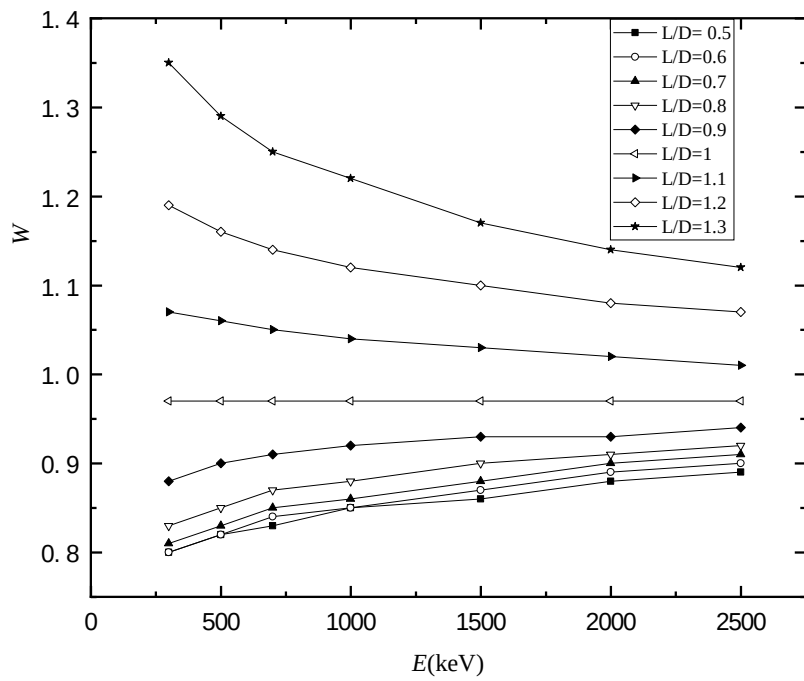
F.2

W

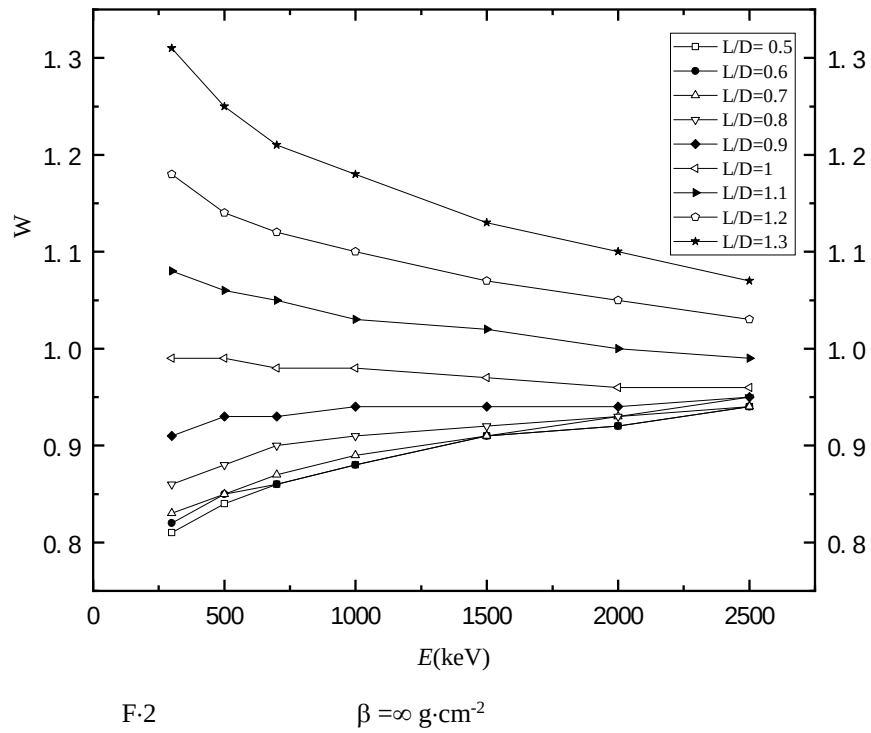
L cm D cm L/D

F.1

F.2 P W



F.1 $\beta=0 \text{ g}\cdot\text{cm}^{-2}$ **W**



Irene K. Herlfer, Kevin M. Miller. Calibration for Ge Detectors Used for Field Spectrometry [J]. Health Physics, 1988, 55(1):15-29

G

γ

G.1

a

b

c

d

1

2

3

G.2

0.3 g

$\cdot \text{cm}^{-2}$

$0 \text{ g} \cdot \text{cm}^{-2}$

γ

$= 0 \text{ g} \cdot \text{cm}^{-2}$

G.3

γ

G.4

γ

^{222}Rn

^{214}Bi

^{214}Pb

^{226}Ra

γ

G.5

G.6

	$E < 100 \text{ keV}$	$> 3 \text{ g}\cdot\text{cm}^{-2}$
	C	$\text{Al}_2\text{O}_3 \text{ 13.5 \%}$ $\text{Fe}_2\text{O}_3 \text{ 4.5 \%}$ SiO_2
67.5 %	$\text{CO}_2 \text{ 4.5 \%}$ $\text{H}_2\text{O} \text{ 10 \%}$	$1.6 \text{ g}\cdot\text{cm}^{-3}$

G.7

G.8

1 m

5cm