minerals

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Supplementary Materials

A Practical Procedure to Determine Natural Radionuclides in Solid Materials from Mining

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Table S1. Experimental efficiency values (ε_c^{exp}) resulting for the calibration matrix of the RGU-1 standard.

E (keV) / *h* (mm)	46	63	93	186	242	295	352
5	0.224(2)	0.233(3)	0.231(3)	0.1675(16)	0.1227(12)	0.1037(6)	0.0869(4)
10	0.173(3)	0.195(3)	0.197(4)	0.141(2)	0.1074(15)	0.0883(8)	0.0741(5)
15	0.1425(19)	0.166(2)	0.177(3)	0.1207(14)	0.0904(10)	0.0755(5)	0.0638(4)
20	0.117(2)	0.134(3)	0.140(4)	0.1022(18)	0.0819(14)	0.0659(7)	0.0577(5)
25	0.0998(19)	0.118(2)	0.124(3)	0.0926(14)	0.0679(10)	0.0587(6)	0.0508(4)
30	0.0889(16)	0.1066(19)	0.112(2)	0.0857(12)	0.0642(9)	0.0541(5)	0.0454(3)
35	0.0778(16)	0.0942(19)	0.097(2)	0.0731(12)	0.0590(9)	0.0485(5)	0.0417(3)
40	0.0708(13)	0.0843(16)	0.099(2)	0.0690(10)	0.0540(7)	0.0447(4)	0.0380(3)
45	0.0634(13)	0.0756(16)	0.088(2)	0.0646(10)	0.0477(7)	0.0405(4)	0.0348(3)
RN	^{210}Pb	^{234}Th	^{234}Th	^{226}Ra+^{235}U	^{214}Pb	^{214}Pb	^{214}Pb
P_γ	0.0425(4)	0.0375(8)	0.0215(19)	0.0614(6)	0.0727(2)	0.1841(4)	0.3560(7)

E (keV) / *h* (mm)	609	768	934	1120	1238	1765
5	0.0433(3)	0.0344(8)	0.0280(10)	0.0246(4)	0.0239(6)	0.0218(3)
10	0.0385(3)	0.031(10)	0.0265(13)	0.0221(5)	0.0202(7)	0.0188(4)
15	0.0332(2)	0.0275(7)	0.0218(9)	0.0196(3)	0.0186(5)	0.0164(3)
20	0.0301(3)	0.0245(9)	0.0192(11)	0.0181(4)	0.0176(7)	0.0145(4)
25	0.0269(2)	0.0217(7)	0.0181(9)	0.0165(3)	0.0157(6)	0.0134(3)
30	0.0247(2)	0.0212(6)	0.0170(8)	0.0151(3)	0.0140(5)	0.0123(3)
35	0.0228(2)	0.0191(6)	0.0149(8)	0.0138(3)	0.0135(5)	0.0112(3)
40	0.02101(17)	0.0179(5)	0.0141(6)	0.0131(2)	0.0121(4)	0.0106(2)
45	0.01933(17)	0.0158(5)	0.0142(7)	0.0116(2)	0.0111(4)	0.0092(2)
RN	^{214}Bi	^{214}Bi	^{214}Bi	^{214}Bi	^{214}Bi	^{214}Bi
P_γ	0.4549(19)	0.04892(16)	0.0310(10)	0.1491(3)	0.05831(14)	0.1531(5)

Table S2. Experimental efficiency values (ε_c^{exp}) resulting for the calibration matrix of the RGTh-1 and RGK-1 standards.

h (mm) \ E (keV)	129	238	338	583	727	860	911
5	0.139(4)	0.1343(12)	0.0920(10)	0.0431(4)	0.0474(11)	0.0377(12)	0.0356(4)
10	0.119(3)	0.1107(11)	0.0767(12)	0.0380(3)	0.0408(7)	0.0318(7)	0.0311(2)
15	0.094(2)	0.091(4)	0.064(2)	0.0329(2)	0.0348(5)	0.0274(6)	0.02695(19)
20	0.093(3)	0.085(2)	0.0591(7)	0.0305(2)	0.0327(6)	0.0250(7)	0.0249(2)
25	0.077(4)	0.0755(16)	0.0506(8)	0.0279(3)	0.0284(8)	0.0226(8)	0.0222(3)
30	0.074(3)	0.0673(12)	0.0470(6)	0.0253(3)	0.0271(7)	0.0210(7)	0.0206(2)
35	0.068(3)	0.0617(11)	0.0429(7)	0.0238(3)	0.0251(7)	0.0188(7)	0.0183(2)
40	0.058(3)	0.0555(8)	0.0377(6)	0.0215(2)	0.0216(6)	0.0190(6)	0.0169(2)
45	0.055(2)	0.0506(8)	0.0348(5)	0.0199(2)	0.0200(5)	0.0165(5)	0.01584(18)
50	0.0516(17)	0.0478(9)	0.0336(4)	0.01831(16)	0.0187(4)	0.0152(4)	0.01491(14)
RN	^{228}Ac	^{212}Pb	^{228}Ac	^{208}Tl	^{212}Bi	^{208}Tl	^{228}Ac
P_γ	0.0250(7)	0.436(5)	0.114(4)	0.3058(11)	0.0665(4)	0.0446(4)	0.262(8)
h (mm) \ E (keV)	968	1460	1588				
5	0.0343(5)	0.0252(2)	0.0231(8)				
10	0.0297(3)	0.0218(4)	0.0186(5)				
15	0.0277(2)	0.0188(3)	0.0169(4)				
20	0.0239(3)	0.0170(3)	0.0160(3)				
25	0.0215(4)	0.0156(3)	0.0142(4)				
30	0.0203(3)	0.0140(2)	0.0130(4)				
35	0.0175(3)	0.01255(18)	0.0118(5)				
40	0.0164(3)	0.01151(17)	0.0107(3)				
45	0.0152(2)	0.01094(17)	0.0096(4)				
50	0.01442(18)	0.01048(18)	0.0091(4)				
RN	^{228}Ac	^{40}K	^{228}Ac				
P_γ	0.159(5)	0.1055(11)	0.0306(12)				

Table S3. ar_1, ar_2 and ar_3, the reduced chi-square values, χ_R^2 (where the and relative average residuals, <*Res*>, were obtained for each energy after fitting efficiencies in the RGU-1 calibration matrix.

E_γ (keV)	ar_1	$-ar_2(mm^{-1})$	ar_3	χ_R^2	<*Res*> (%)
46.539	0.235(6)	0.064(4)	0.052(3)	0.78	1.62
63.288	0.234(5)	0.049(3)	0.052(3)	0.90	1.57
92.56	0.217(6)	0.049(3)	0.063(4)	3.01	3.49
185.96	0.152(3)	0.051(3)	0.049(2)	1.55	1.83
241.979	0.112(2)	0.043(3)	0.033(3)	2.74	2.44
295.224	0.0926(12)	0.047(2)	0.0303(11)	1.88	1.25
351.932	0.0775(6)	0.043(2)	0.0238(9)	2.15	0.83
609.312	0.0368(4)	0.039(2)	0.0133(6)	1.25	0.90
768.356	0.0292(15)	0.033(2)	0.0097(6)	0.53	2.31
934.06	0.0224(6)	0.040(3)	0.0110(7)	0.49	1.91
1120.285	0.0215(4)	0.028(2)	0.0059(3)	0.70	1.41
1238.11	0.0197(7)	0.032(2)	0.0067(4)	0.50	2.44
1764.494	0.0182(5)	0.041(3)	0.0068(3)	1.15	2.30

Table S4. ar_1, ar_2 and ar_3, the reduced chi-square values, χ_R^2 (where the critical χ_R^2 is 2.01 at 0.05 of significance level and 7 degrees of freedom) and relative average residuals, <*Res*>, were obtained for each energy after fitting efficiencies in the RGTh-1 and RGK-1 calibration matrices.

E_γ (keV)	ar_1	$-ar_2(mm^{-1})$	ar_3	χ_R^2	<*Res*> (%)
129.03	0.122(5)	0.047(3)	0.041(3)	1.73	3.89
238.63	0.1195(7)	0.0505(19)	0.0396(18)	1.68	2.82
338.42	0.0857(7)	0.0442(17)	0.0237(12)	1.88	2.62
583.19	0.0364(7)	0.034(2)	0.0121(6)	2.05	1.58
727.30	0.0412(18)	0.037(2)	0.0125(8)	0.25	1.16
860.00	0.0305(12)	0.048(3)	0.0132(7)	1.23	3.23
911.16	0.0303(6)	0.0374(18)	0.0102(4)	2.02	1.11
968.97	0.0306(8)	0.033(2)	0.0082(5)	2.08	1.97
1460.83	0.0214(4)	0.0419(16)	0.0077(3)	0.93	1.18
1588.23	0.0194(8)	0.0279(18)	0.0049(3)	2.05	2.84