Interferences in gamma spectrometry

γ-SPEKT/INTERF

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ISSN 1865-8725 Version March 2019

Procedures Manual for monitoring of radioactive substances in the environment and of external radiation
(Messanleitungen für die „Überwachung radioaktiver Stoffe in der Umwelt und externer Strahlung")

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1 Introduction

When evaluating complex pulse height spectra, the individual gamma peaks must be clearly attributed to the respective radionuclide based on their position in the pulse height spectrum and in accordance with their respective energy. Other radionuclides – especially members of the natural decay series – with identical or very similar gamma energies (so-called interfering emitters) may make it difficult to clearly attribute fission and activation products.

Some radionuclides emit gamma energies that are so close to each other that their gamma peaks in the pulse height spectrum can no longer be resolved. In such cases, corrections must be applied via other, non-interfering gamma peaks. If this approach cannot be used, then other procedures, such as radiochemical separation, must be applied.

2 Interfering gamma peaks

Table 1 lists gamma peaks that may interfere in the pulse height spectrum when determining the activity of selected radionuclides in environmental sample.

In column 1, radionuclides that usually occur in the radioactive equilibrium in environmental samples (e. g. Mo-99/Tc-99m, Ru-106/Rh-106) are always listed as parent/progeny pair. In the case of radionuclide pairs in which radioactive equilibrium cannot be assumed *a priori* (e. g. Zr-95/Nb-95, Ba-140/La-140), the radionuclides are stated separately.

Radionuclides that may interfere when determining the activity of radionuclides or radionuclide pairs listed in column 1 are listed in column 5. The parent nuclide associated with the respective interfering nuclide is stated in the last column.

Note:
All nuclear data used in this General Chapter is as of June 2018. Up-to-date values can be found in the General Chapter KERNDATEN of this Procedures Manual.

Tab. 1: Gamma peaks likely to interfere in the pulse height spectrum when determining the activity of selected radionuclides in environmental samples

Radionuclide/ radionuclide pair	E_γ in keV	p_γ in keV	t_r in keV	Intefering nuclide	E_γ in keV	p_γ in keV	t_r in keV	Parent nuclide of the interfering nuclide
Be-7	477,60	0,1044	53,22	Eu-154	478,27	0,224	$3{,}14 \cdot 10^3$	
Na-22	1274,58	0,9994	950,67	Eu-154	1274,43	0,349	$3{,}14 \cdot 10^3$	
Cr-51	320,08	0,0989	27,70	Nd-147	319,41	0,0199	10,99	
Mn-54	834,85	0,9998	312,19	Ac-228	835,70	0,017	$5{,}12 \cdot 10^{12}$*	Th-232
Co-57	122,06	0,8549	271,81	Se-75	121,12	0,1686	119,78	
				Eu-152	121,78	0,2841	$4{,}94 \cdot 10^3$	
				Eu-154	123,07	0,404	$3{,}14 \cdot 10^3$	
	136,47	0,1071		Tl-201	135,31	0,026	3,04	
				Se-75	136,00	0,577	119,78	
				Re-186	137,16	0,0942	3,719	
Co-58	810,76	0,9944	70,85	I-132	809,5	0,026	3,23*	Te-132
				Eu-156	811,77	0,097	15,19	
				I-132	812,0	0,055	3,23*	Te-132
Fe-59	1099,25	0,5651	44,49	–	–	–	–	
	1291,59	0,4323		I-132	1290,8	0,0113	0,0956	Te-132
Co-60	1173,23	0,9985	1925,2	I-132	1172,92	0,017	0,0956	Te-132
	1332,49	0,9998						
Se-75	121,12	0,1686	119,78	Eu-152	121,78	0,2841	$4{,}94 \cdot 10^3$	
				Co-57	122,06	0,8549	271,81	
				Eu-154	123,07	0,404	$3{,}14 \cdot 10^3$	
	136,00	0,577		Tl-201	135,31	0,026	3,04	
				Co-57	136,47	0,1071	271,81	
				Re-186	137,16	0,0942	3,719	
	303,92	0,0131		Ba-133	302,85	0,1831	$3{,}85 \cdot 10^3$	
Zr-95	724,19	0,4427	64,03	Eu-156	723,47	0,054	15,19	
	756,73	0,5438		Ac-228	755,31	0,0103	$5{,}12 \cdot 10^{12}$*	Th-232
Zr-97/ Nb-97m	743,36	0,9790	0,6979	Pa-234	742,8	0,0208	$1{,}63 \cdot 10^{12}$*	U-238
				Ag-110m	744,28	0,0471	249,78	
Mo-99/ Tc-99m	777,92	0,0428	2,748	Eu-152	778,90	0,1297	$4{,}94 \cdot 10^3$	
Ru-106/ Rh-106	621,90	0,0987	371,5	Ag-110m	620,36	0,0272	249,78	
				I-132	621,2	0,016	3,23*	Te-132
				Eu-157	622,75	0,097	0,6325	
Ag-110m	620,36	0,0272	249,78	I-132	621,2	0,016	3,23*	Te-132
				Rh-106	621,90	0,0987	371,5*	Ru-106
	744,28	0,0471		Nb-97m	743,36	0,9790	0,6979*	Zr-97
	818,02	0,0733		Cs-136	818,51	0,997	13,16	
				Pa-234	819,20	0,019	$1{,}63 \cdot 10^{12}$*	U-238
	884,68	0,740		Pa-234	883,24	0,097	$1{,}63 \cdot 10^{12}$*	U-238
Sb-124	602,73	0,9778	60,21	Sb-127	603,9	0,0421	3,85	
Sb-125	176,31	0,0682	1007,5	Cs-136	176,60	0,100	13,16	
	427,87	0,2955		Pb-211	427,15	0,0181	$7{,}95 \cdot 10^3$*	Ac-227
	463,37	0,1048		Ac-228	463,00	0,0445	$5{,}12 \cdot 10^{12}$*	Th-232

Radionuclide/ radionuclide pair	E_γ in keV	p_γ in keV	t_r in keV	Intefering nuclide	E_γ in keV	p_γ in keV	t_r in keV	Parent nuclide of the interfering nuclide
Sb-125	635,95	0,1132		I-131	636,99	0,0712	8,023	
Sb-127	603,9	0,0421	3,85	Sb-124	602,73	0,9778	60,21	
				Ir-192	604,41	0,082	73,827	
				Cs-134	604,72	0,9763	754,0	
Te-129/ Te-129m	695,88	0,031	33,6*	Pr-144	696,51	0,0141	284,89*	Ce-144
I-131	636,99	0,0712	8,023	Sb-125	635,95	0,1132	1007,5	
	722,91	0,0179		Eu-154	723,30	0,2005	$3{,}14 \cdot 10^3$	
Te-132/ I-132	228,33	0,8812	3,23*	Pa-234	227,25	0,058	$1{,}63 \cdot 10^{12}$*	U-238
				Np-239	228,18	0,1132	2,356	
	621,20	0,016		Ag-110m	620,36	0,0272	249,78	
				Rh-106	621,90	0,0987	371,5*	Ru-106
	772,60	0,756		Ac-228	772,29	0,0152	$5{,}12 \cdot 10^{12}$*	Th-232
	809,50	0,026		Co-58	810,76	0,9944	70,85	
	812,00	0,055		Co-58	810,76	0,9944	70,85	
				Eu-156	811,77	0,097	15,19	
I-133	529,87	0,863	0,870	Nd-147	531,02	0,127	10,99	
Ba-133	302,85	0,1831	$3{,}85 \cdot 10^3$	Se-75	303,92	0,0131	119,78	
Cs-134	604,72	0,9763	754,0	Sb-127	603,9	0,0421	3,85	
				Ir-192	604,41	0,082	73,827	
	795,86	0,8547		Ac-228	794,94	0,0431	$5{,}12 \cdot 10^{12}$*	Th-232
				Pa-234	796,10	0,026	$1{,}63 \cdot 10^{12}$*	U-238
Cs-136	163,92	0,0339	13,1	Ba-140	162,66	0,0649	12,753	
				U-235	163,36	0,0508	$2{,}57 \cdot 10^{11}$	
				Pm-151	163,58	0,0155	1,183	
	176,60	0,100		Sb-125	176,31	0,0682	1007,5	
	340,55	0,422		Pm-151	340,08	0,225	1,183	
	818,51	0,997		Ag-110m	818,02	0,0733	249,78	
				Pa-234	819,2	0,019	$1{,}63 \cdot 10^{12}$*	U-238
Ba-140	162,66	0,0649	12,753	U-235	163,36	0,0508	$2{,}57 \cdot 10^{11}$	
				Pm-151	163,58	0,0155	1,183	
				Cs-136	163,92	0,0339	13,16	
Ce-141	145,44	0,4829	32,50	Ra-223	144,27	0,0336	$7{,}95 \cdot 10^3$*	Ac-227
Ce-143	293,27	0,428	1,377	Pa-234	293,79	0,030	$1{,}63 \cdot 10^{12}$*	U-238
Ce-144/ Pr-144	696,51	0,0141	284,89*	Te-129m	695,88	0,031	33,6*	Te-129
Nd-147	319,41	0,0199	10,99	Cr-51	320,08	0,0989	27,70	
	531,02	0,127		I-133	529,87	0,863	0,870	
Pm-151	104,84	0,035	1,183	Eu-155	105,31	0,211	1736	
				Ac-228	105,40	0,015	$5{,}12 \cdot 10^{12}$*	Th-232
				Np-239	106,13	0,0259	2,356	
	163,58	0,0155		Ba-140	162,66	0,0649	12,753	
				U-235	163,36	0,0508	$2{,}57 \cdot 10^{11}$	
				Cs-136	163,92	0,0339	13,16	
	209,00	0,0173		U-237	208,00	0,213	6,749	
				Ac-228	209,25	0,0397	$5{,}12 \cdot 10^{12}$*	Th-232

Radionuclide/ radionuclide pair	E_γ in keV	p_γ in keV	t_r in keV	Intefering nuclide	E_γ in keV	p_γ in keV	t_r in keV	Parent nuclide of the interfering nuclide
Pm-151				Np-239	209,75	0,0342	2,356	
	340,08	0,225		Ra-223	338,28	0,0285	$7{,}95\cdot10^{3}$*	Ac-227
				Ac-228	338,32	0,114	$5{,}12\cdot10^{12}$*	Th-232
				Cs-136	340,55	0,422	13,16	
Eu-152	121,78	0,2841	$4{,}94\cdot10^{3}$	Se-75	121,12	0,1686	119,78	
				Co-57	122,06	0,8549	271,81	
				Eu-154	123,07	0,404	$3{,}14\cdot10^{3}$	
	778,90	0,1297		Mo-99	777,92	0,0428	2,748	
Eu-152	1408,0	0,2085		Bi-214	1407,98	0,02389	$5{,}82\cdot10^{5}$*	Ra-226
Eu-154	123,07	0,404	$3{,}14\cdot10^{3}$	Se-75	121,12	0,1686	119,78	
				Eu-152	121,78	0,2841	$4{,}94\cdot10^{3}$	
				Co-57	122,06	0,8549	271,81	
	723,30	0,2011		I-131	722,91	0,0179	8,023	
	1274,43	0,34		Na-22	1274,54	0,9994	950,69	
Eu-155	105,31	0,211	1736	Pm-151	104,84	0,035	1,183	
				Ac-228	105,55	0,015	$5{,}12\cdot10^{12}$*	Th-232
				Np-239	106,13	0,0259	2,356	
Eu-156	723,47	0,054	15,19	Zr-95	724,19	0,4427	64,03	
	811,77	0,097		Co-58	810,76	0,9944	70,85	
				I-132	812,0	0,055	3,23*	Te-132
Re-186	137,16	0,0942	3,719	Se-75	136,00	0,577	119,78	
				Co-57	136,47	0,1071	271,81	
Ir-192	205,79	0,0334	73,827	U-235	205,32	0,0502	$2{,}57\cdot10^{11}$	
	295,96	0,2872		Pb-214	295,22	0,1841	0,0187	Ra-226
	604,41	0,082		Sb-127	603,9	0,0421	3,85	
				Cs-134	604,72	0,9763	754,0	
Ra-224	240,99	0,0412	3,631	Pb-214	242,00	0,0727	0,0187	Ra-226
Ra-226	186,21	0,0356	$5{,}84\cdot10^{5}$	U-235	185,72	0,570	$2{,}57\cdot10^{11}$	
U-235	143,78	0,1094	$2{,}57\cdot10^{11}$	Ra-223	144,27	0,03336	$7{,}95\cdot10^{3}$*	Ac-227
	163,36	0,0508		Ba-140	162,66	0,0649	12,753	
				Pm-151	163,58	0,0155	1,183	
				Cs-136	163,92	0,0339	13,16	
	185,72	0,570		Ra-226	186,21	0,0356	$5{,}82\cdot10^{5}$	
	205,32	0,0502		Ir-192	205,79	0,0334	73,827	
U-237	208,00	0,213	6,749	Pm-151	209,00	0,0173	1,183	
				Ac-228	209,25	0,0397	$5{,}12\cdot10^{12}$*	Th-232
Np-239	106,12	0,259	2,356	Pm-151	104,84	0,035	1,183	
				Eu-155	105,31	0,211	1736	
				Ac-228	105,55	0,015	$5{,}13\cdot10^{12}$*	Th-232
	209,75	0,0342		Pm-151	209,00	0,0173	1,183	
				Ac-228	209,25	0,0397	$5{,}12\cdot10^{12}$*	Th-232
				Th-227	210,62	0,0122	18,718	Ac-227
	228,18	0,1132		Pa-234	227,25	0,058	$1{,}63\cdot10^{12}$*	U-238
				I-132	228,33*	0,8812*	3,23*	Te-132
	277,60	0,144		Tl-208	277,37	0,066	698,6*	Th-228

* nuclear data of the parent nuclide

3 Backscattering and Compton scattering

Peak-like structures may occur in the pulse height spectrum due to backscattering or Compton scattering.

Table 2 lists the energies (corresponding to the gamma energies selected) that occur in the presence of backscattering or Compton scattering

3.1 Backscattering

In the case of wide-angle scattering of gamma rays of the energy E_γ into the material surrounding the detector (e.g. in the shielding), the gamma quanta that are backscattered at an angle of approx. 180° hit the detector and generate a wide peak-like structure in the pulse height spectrum. The energy E_R of these so-called backscatter peak can be calculated according to Equation (1).

$$E_\mathrm{R} = \frac{E^2}{511 + 2 \cdot E} \qquad (1)$$

where

E Energy of the gamma rays, in keV;

E_R Energy of the backscatter peak, in keV.

3.2 Compton scattering

The Compton effect occurs when photon radiation interacts with matter. Hereby, a photon is scattered elastically at a free or quasi-free electron in the electron shell of an atom. If Compton scattering occurs at an angle of 180°, it generates a peak-like structure in the pulse height spectrum. This wide and strongly asymmetrical peak is generically called Compton edge. The energy of the Compton edge E_C is calculated according to Equation (2):

$$E_\mathrm{C} = \frac{E}{1 + \frac{2 \cdot E}{511}} \qquad (2)$$

In Equation (2) are:

E Energy of the gamma rays, in keV;

E_C Energy of the Compton edge, in keV.

Tab. 2: Energies of the backscatter peak and Compton edge at selected energies of the gamma rays

Energy of the gamma rays, E in keV		**Energy of the backscatter peak, E_R in keV**	**Energy of the Compton edge, E_C in keV**
a) Examples calculated in the entire energy region of interest (to illustrate the energy dependence)			
10		9,62	0,38
100		71,87	28,13
300		137,98	162,02
1000		203,50	796,50
2000		226,56	1773,44
3000		235,45	2764,55
b) Peaks of common radionuclides occurring in practice			
21,99	(Cd-109)	20,25	1,74
24,70	(X-ray, Sn)	22,52	2,18
46,54	(Pb-210)	39,34	7,17
59,54	(Am-241)	48,29	11,25
80,99	(Ba-133)	61,50	19,49
88,03	(Cd-109)	65,47	22,56
122,06	(Co-57)	82,80	39,46
136,47	(Co-57)	88,96	47,51
165,86	(Ce-139)	100,57	65,29
276,40	(Ba-133)	132,77	143,63
302,85	(Ba-133)	138,58	164,27
356,01	(Ba-133)	148,75	207,26
604,72	(Cs-134)	179,61	425,11
661,66	(Cs-137)	184,32	477,34
795,68	(Cs-134)	193,40	602,28
834,85	(Mn-54)	195,63	639,17
898,04	(Y-88)	198,91	699,09
1115,54	(Zn-65)	207,89	907,65
1173,23	(Co-60)	209,81	963,42
1332,49	(Co-60)	214,39	1118,10

The distance between the backscatter peak and the gamma peak decreases when the energy of the gamma rays decreases, so that the evaluation of gamma peaks is more difficult especially below 100 keV.

3.3 Examples

Backscatter peaks and Compton edges may make the evaluation of pulse height spectra more difficult in particular if the gamma peaks of the nuclides causing them are present with a sufficiently high number of counts in the pulse height spectrum. Examples:

a) Caesium-137:

- The backscatter peak of Cs-137 is located at an energy of 184,32 keV. This peak therefore interferes with the evaluation of the gamma peak of Ra-226 at an energy of 186,21 keV and of the gamma peak of U-235 at an energy of 185,72 keV.
- The Compton edge of Cs-137, which is located at an energy of 477,34 keV, interferes with the evaluation of the gamma peak of Be-7 at an energy of 477,60 keV.

b) Americium-241:

- Due to the backscatter peak of Am-241 at an energy of 48,29 keV, evaluating the gamma peak of Pb-210 may be impeded at an energy of 46,54 keV.

c) Cobalt-57:

- With an energy of 88,97 keV, its backscatter peak may be mistaken for the gamma peak of Cd-109 (E_γ = 88,00 keV).
- If the energy resolution of the gammaspectrometric measurement system is not sufficient, the associated Compton edge at 47,51 keV may also impede the evaluation of the gamma peak of Pb-210 at an energy of 46,54 keV.

Note:

If the deconvolution of a pulse height spectrum is affected via an automatic evaluation routine, backscatter peaks and Compton edges may be identified as gamma peaks of various radionuclides. The preset full width at half maximum (energy resolution) should therefore be adjusted so as not to be smaller than the backscatter peak or the Compton edge.