Langzeituntergründe in der Gammaspektroskopie
Long-term background in gamma-spectroscopy

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Introduction

Gamma spectroscopy is one of the methods used in the Radioactivity Measurements Laboratory at the University of Bremen for purposes of environmental radioactivity surveillance applied to variety of media (water, soil, biota, foodstuff, waste water, sludge, etc.) and for sediment geochronology. Activities of radionuclides in these kinds of samples are often near the limit of detection, therefore a proper estimation of detector background is essential.

Summing up the spectra

As a part of the measurement routine in the laboratory an up-to-date background for each detector has been collected approximately once in a month. In the individual background spectra, which are usually recorded for 3-4 days, only a limited amount of lines is visible. In this study for 3 gamma-ray coaxial HP-Ge detectors the individual spectra were summed up using method based on procedure proposed by Bossew (2005) [1]. In these spectra many additional "exotic" lines, which are not detectable in the individual background spectra, are visible.

Tab. 1:

Description of the detectors used in this study.

Summing up data.

	Det 3	Det 5	Det 6
Description	reverse p-type coaxial Ge detector, Canberra	n-type coaxial Ge detector, Canberra	n-type coaxial Ge detector, Canberra
Size (diameter / length mm)	76 / 60,5	64 / 60	63,5 / 63,5
End- cap	Cu endcap with C epoxy window	Cu endcap with C epoxy window	Cu endcap with C epoxy window
Relative efficiency (%)	51,2	50,8	50,9
FWHM (122 keV / 1332 keV)	0,857 / 1,76	0,931 / 1,87	0,865 / 2,05
Shielding	Pb: 92 mm Cu: 10 mm Cd: 1,3 mm PMMA: 5 mm	Pb: 92 mm Cu: 10 mm Cd: 1,3 mm PMMA: 5 mm	Pb: 100 mm Cu: 10 mm
Number of summed-up spectra	29	43	46
Time period	8/2005-12/2008	8/2004-12/2008	11/2004-12/2008
Total summed-up time (days)	104,5	159,8	171,9
Count rate 20-2040 keV (s^{-1})	1,35	1,28	1,30

Gamma lines detected in summed up spectra

The sources of the common and exotic lines in the background signal were identified [2] in summed-up spectra and can be divided into following groups:

1. Radon and thoron progeny in the measurement chamber (Tab.2)

Tab. 2

Nuclide	Energy (keV)	$t_{1/2}$ (%)	Det 3 Energy (keV)	Det 3 Count rate (s^{-1})	Det 3 Rel. error 1 σ (%)	Det 5 Energy (keV)	Det 5 Count rate (s^{-1})	Det 5 Rel. error 1 σ (%)	Det 6 Energy (keV)	Det 6 Count rate (s^{-1})	Det 6 Rel. error 1 σ (%)
^{214}Bi	609,3	46,1	609,2	0,9335	4,2	609,2	0,7718	2,6	609,1	1,3934	1,1
	665,5	1,46	664,8	0,0590	22,3	-	-	-	665,3	0,0564	18,1
	768,4	4,94	768,1	0,1118	12,0	768,6	0,0840	12,8	768,3	0,1657	6,4
	934,1	3,03	934,0	0,0423	37,8	934,1	0,0156	68,1	934,0	0,0873	20,5
	1120,3	15,1	1120,2	0,2402	5,2	1120,2	0,2212	4,6	1120,2	0,4527	2,3
	1155,2	1,63	1155,0	0,0318	47,4	-	-	-	1155,0	0,0422	41,0
	1238,1	5,79	1238,0	0,1422	25,7	1238,0	0,0872	25,7	1238,1	0,1809	0,9
	1281,0	1,43	1280,4	0,0202	80,2	-	-	-	1280,9	0,0400	35,5
	1377,7	4	1377,8	0,0986	22,2	1378,0	0,0764	10,1	1377,6	0,1362	11,3
	1385,3	0,757	-	-	-	1385,3	0,0242	28,8	-	-	-
	1401,5	1,27	1401,0	0,0405	23,5	-	-	-	1401,4	0,0430	16,6
	1408,0	2,95	1408,2	0,0462	20,1	1407,6	0,0481	14,9	1407,8	0,0679	10,9
	1509,2	2,11	1508,7	0,0233	78,1	1508,4	0,0557	13,4	1509,0	0,1045	8,2
	1538,5	0,376	-	-	-	-	-	-	1538,6	0,0322	22,6
	1661,3	1,15	1661,3	0,0460	39,8	1660,6	0,0154	66,2	1661,0	0,0218	25,1
	1739,6	2,92	1729,6	0,0637	20,9	1729,3	0,0502	12,6	1729,7	0,1047	11,5
	1764,5	15,4	1764,6	0,4210	4,6	1764,4	0,3439	5,4	1764,4	0,4807	12,4
	1847,4	2,11	1847,5	0,0484	29,3	1847,0	0,0263	22,7	1847,4	0,0896	19,1
^{210}Pb	53,5*	1,2	53,5	0,3764	13,4	-	-	-	53,4	0,2827	13,1
	242,0	7,43	242,0	0,2280	10,1	242,0	0,2772	8,6	242,0	0,5411	4,7
	295,2	19,3	295,3	0,6464	9,0	295,3	0,6230	8,5	295,2	1,3315	3,3
	351,9	37,6	351,9	1,1721	4,1	351,9	0,8964	2,5	351,9	2,3322	1,7
	786,0	1,07	-	-	-	-	-	-	786,0	0,0760	30,4
^{214}Pb	238,6	43,3	238,7	0,1385	17,0	238,6	0,7236	3,9	238,7	0,2429	9,1
^{208}Tl	583,3	84,5	583,1	0,0844	36,3	583,3	0,2957	5,2	583,3	0,1190	12,2
	1592,5	**	1592,6	0,1007	9,5	1592,5	0,0929	8,3	1592,6	0,0628	10,9

* Interference with ^{214}Ge (53,5 keV), ** ^{208}Tl double escape peak

Summed-up spectra

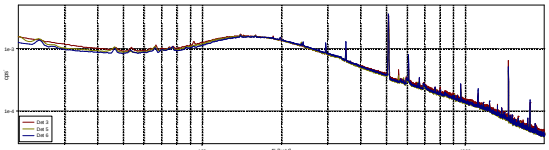

Fig. 1: *Comparison of summed up spectra for all 3 detectors (energy region 20-2000 keV, log/log scale).*

Summed up spectra (Fig.1) together with differential spectra of the 3 detectors (Fig. 2) and the tables of values (Tab. 2-5) show **main differences between the 3 detectors**:

- **The continuum**: 20-170 keV Det3>Det5>Det6; 170-350 keV Det6>Det3 ≅ Det5; 350-400 keV Det6=Det3>Det5; 400-1500 keV Det3>Det6>Det5 keV and 1500-2000 keV Det3>Det6=Det5 (due to different efficiencies of the detectors for different energies)
- **Rn** daughters (^{214}Pb, ^{214}Bi): Det6>>Det3>Det5 (Det6 Pb housing has the highest inner volume)
- **^{210}Pb**: Det5>Det6>Det3 (due to construction material of the detector, therefore Det3 can be used for sediment ^{210}Pb chronology)
- **^{226}Ra, ^{234}Th, ^{238m}Pa, ^{235}U**: Det3>Det5≅Det6; Th series (^{228}Ac): Det5>Det6>Det3
- **^{40}K**:Det3>Det3>Det5
- **Artificial isotopes** (^{137}Cs,^{60}Co): Det5≥Det6>Det3
- **X-rays** (Pb): Det6>Det3>Det5 (housing of the Det6 does not have Cd and PMMA inner layers)
- **^{114m}Cd**: Det3>Det5>Det6 (housing of the Det6 does not contain Cd inner layer)

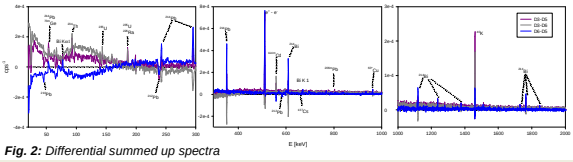

Fig. 2: *Differential summed up spectra*

2. Radionuclides contained in the detector, its accessories and the shielding (Tab. 3)

Tab. 3

Nuclide	Energy (keV)	$t_{1/2}$ (%)	Det 3 Energy (keV)	Det 3 Count rate (s^{-1})	Det 3 Rel. error 1 σ (%)	Det 5 Energy (keV)	Det 5 Count rate (s^{-1})	Det 5 Rel. error 1 σ (%)	Det 6 Energy (keV)	Det 6 Count rate (s^{-1})	Det 6 Rel. error 1 σ (%)
primordial											
^{40}K	1460,8	11	1460,8	2,6333	1,1	1460,7	2,0103	1,1	1460,7	2,0292	1,0
^{238}U series											
^{210}Pb	46,5	4,25	46,4	0,2947	29,5	46,3	0,5852	5,6	46,6	0,4803	12,6
^{234}Th	186,2*	3,59	185,9	0,3963	16,6	186,0	0,1924	15,5	-	-	-
^{234}Th	63,3	4,8	63,5	0,1685	14,6	-	-	-	-	-	-
	92,4 / 92,8	2,81 / 2,77	92,7	0,3492	35,2	-	-	-	93,0	0,1012	45,8
^{238m}Pa	1001	0,837	1001,2	0,0395	64,1	-	-	-	-	-	-
^{235}U series											
^{235}U	143,8	10,96	143,5	0,0839	35,8	-	-	-	-	-	-
	185,7*	57,2	185,9	0,3963	16,6	186,0	0,1924	15,5	-	-	-
^{232}Th series											
^{228}Ac	338,3	11,27	337,5	0,1330	37,1	-	-	-	-	-	-
	911,2	25,8	911,3	0,0450	53,7	911,2	0,1638	7,0	911,5	0,1043	20,7
	969	15,8	969,6	0,0410	27,3	968,9	0,0928	4,3	968,6	0,0474	18,2
	1588,2	3,22	1588,1	0,0552	25,5	1588,2	0,0396	26,0	1588,2	0,0209	28,1
artificial											
^{60}Co	1173,2	100	1172,9	0,0535	40,6	1173,1	0,0897	10,3	1172,9	0,1373	13,9
	1332,5	100	1331,9	0,0223	36,8	1332,4	0,0458	16,2	1332,0	0,0428	16,7
^{137}Cs	661,7	85,1	661,7	0,1355	13,2	661,6	0,2559	4,9	661,7	0,1382	7,9

* Interfering lines of ^{226}Ra and ^{235}U

3. Short-lived activation products formed by reaction of cosmic radiation induced neutrons with material of the detector itself, its accessories and the shielding (Tab. 4)

Tab. 4

Nuclide	Energy (keV)	Reaction	Det 3 Energy (keV)	Det 3 Count rate (s^{-1})	Det 3 Rel. error 1 σ (%)	Det 5 Energy (keV)	Det 5 Count rate (s^{-1})	Det 5 Rel. error 1 σ (%)	Det 6 Energy (keV)	Det 6 Count rate (s^{-1})	Det 6 Rel. error 1 σ (%)
Ge											
^{71m}Ge	23,4	^{70}Ge(n, γ)^{71m}Ge	-	-	-	23,9	0,3615	20,6	24,1	0,6038	5,9
	198,3 *	^{72}Ge(n, 2n)^{71m}Ge	198,3	0,5518	6,5	198,1	0,6248	5,3	198,3	0,4549	5,6
^{77}Ge	691+ **	^{76}Ge(n,γ)^{77}Ge	694,0	1,1978	4,8	694	1,1913	3,7	694	1,4401	3,0
^{77}Ge	68,7+ **	^{76}Ge(n,γ)^{77}Ge	70,0	0,0898	24,8	-	-	-	-	-	-
^{75m}Ge	53,5 ***	^{72}Ge(n, γ)^{73m}Ge	53,5	0,3764	13,4	-	-	-	53,4	0,2877	13,1
	66,8 ****	^{74}Ge(n,2n)^{73m}Ge	66,3	0,4531	6,4	66,3	0,4708	7,1	66,3	0,2869	14,9
^{74}Ge	595,9+ **	^{73}Ge(n,γ)^{74}Ge	594,5	1,7370	5,2	594,5	1,7324	4,0	594,5	1,9599	3,5
^{75m}Ge	139,5	^{74}Ge(n, γ)^{75m}Ge, ^{76}Ge(n,2n)^{75m}Ge	139,8	0,3527	10,1	139,7	0,4574	18,1	139,8	0,3127	19,3
^{75m}Ge	159,5	^{76}Ge(n, γ)^{77m}Ge	159,3	0,2803	27,9	159,2	0,2245	18,7	159,5	0,1315	42,1
Cd											
^{111m}Cd	651		651,5	0,0945	29,9	-	-	-	-	-	-
	805,7	^{110}Cd(n, γ)^{111m}Cd	-	-	-	806	0,0374	28,2	806,2	0,0354	26,9
	558,3		558,4	0,5761	7,1	558,4	0,3292	6,3	-	-	-
Pb											
^{199}Pb	803,1	^{200}Pb(n,n')^{199}Pb	803,0	0,1740	16,0	803	0,0982	13,0	803	0,1287	8,8
^{201}Pb	569,7	^{200}Pb(n,γ)^{201}Pb	569,6	0,0493	27,9	-	-	-	569,7	0,1057	27,3
Cu											
^{61}Cu	669,6		669,8	0,3110	5,3	669,8	0,3189	4,1	669,8	0,3505	3,4
	962,1		962,1	0,4353	3,5	962,2	0,4559	1,3	962,2	0,5529	2,1
	1327	^{63}Cu(n,α)^{60}Co	1326,9	0,1034	9,8	1327	0,1463	6,2	1326,9	0,1544	5,7
	1412,1		1412,2	0,0692	14,6	1412,2	0,0705	10,8	1412,3	0,0786	9,8
	1547		-	-	-	-	-	-	1546,9	0,0626	13,2
^{62}Cu	278,3	^{63}Cu(n, 2n)^{62}Cu, ^{65}Cu(n, 4n)^{62}Cu, ^{63}Cu(n,2n)^{62}Cu	278,3	0,1751	29,5	278,1	0,3123	17,0	278,1	0,2770	16,8
^{62}Cu	770,8	^{63}Cu(n,n')^{62}Cu, ^{65}Cu(n,α)^{62}Cu	770,6	0,1154	11,8	770,7	0,1182	10,1	770,8	0,1162	8,5
^{62}Cu, ^{66}Zn	1115,5	^{63}Cu(n,γ)^{64}Cu, ^{65}Cu(n,n')^{64}Cu, ^{66}Zn(n,2n)^{65}Zn	1115,6	0,1569	7,3	1115,6	0,1515	6,2	1115,5	0,1980	4,4
^{60}Cu	1481,7	^{63}Cu(n,α)^{60}Co	1481,8	0,0456	35,2	1481,8	0,0403	29,0	1482	0,0450	25,3

* Summing peak 174,6+23,6 keV, ** Degraded peaks by Doppler-effect (nucleus recoil), *** Interference with ^{207m}Pb (53,5 keV), **** Summing peak 13,3+53,5keV

4. Other: annihilation peak, X-rays and non-identified lines (Tab. 5)

Tab. 5

Line	Energy (keV)	Det 3 Energy (keV)	Det 3 Count rate (s^{-1})	Det 3 Rel. error 1 σ (%)	Det 5 Energy (keV)	Det 5 Count rate (s^{-1})	Det 5 Rel. error 1 σ (%)	Det 6 Energy (keV)	Det 6 Count rate (s^{-1})	Det 6 Rel. error 1 σ (%)
e+ e-	511	511,0	26,1171	0,3	511	18,0024	0,3	510,9	21,3373	0,2
X-rays										
Bi Kα1	77,1	77,2	0,2489	10,6	-	-	-	77,1	0,3981	5,5
Bi Kα2	74,8	74,7	0,1843	13,6	-	-	-	74,9	0,2058	9,3
Bi Kβ2	89,8	-	-	-	-	-	-	87,0	0,0841	47,9
unidentified										
?	203	203,0	0,2128	14,4	203,1	0,2110	13,5	203	0,1024	18,8
?	725,7	725,7	0,0551	25,2	-	-	-	-	-	-
?	899	899,2	0,0760	34,1	898,8	0,0693	14,3	898,8	0,0925	23,0
?	979	-	-	-	979,7	0,0174	21,9	-	-	-
?	1163	1163,0	0,0895	24,0	1163,5	0,0203	37,0	-	-	-
?	1345	-	-	-	1345,3	0,0168	19,9	-	-	-
?	1514	-	-	-	1514	0,0490	14,8	1514	0,0651	11,9
?	1861,1	1860,6	0,0391	35,7	1861,1	0,0251	23,3	1861,1	0,0381	40,6

Time series

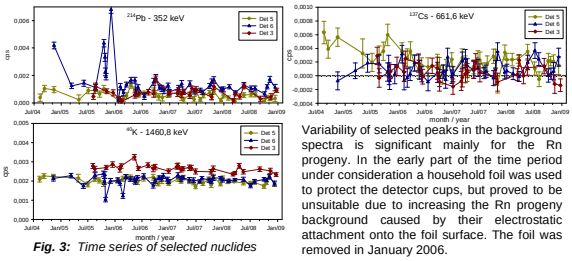

Fig. 3: *Time series of selected nuclides*

Variability of selected peaks in the background spectra is significant mainly for the Rn progeny. In the early part of the time period under consideration a household foil was used to protect the detector cups, but proved to be unsuitable due to increasing the Rn progeny background caused by their electrostatic attachment onto the foil surface. The foil was removed in January 2006.

The descriptive statistics of the time series (selected lines, after January 2006) is given in the Tab. 6. Rn progeny show high variation, as well as ^{210}Pb and ^{137}Cs (with low count rates).

Tab. 6:

		n	Median (cps *10^3)	Minimum (cps *10^3)	Maximum (cps *10^3)	Arit. mean (cps *10^3)	Std. deviation (cps *10^3)	Coef. of variation (%)
^{210}Pb 46,5 keV	Det 3	29	0,424	-0,148	0,753	0,35	0,207	59,2
	Det 5	35	0,663	-0,669	1,25	0,533	0,455	85,5
	Det 6	37	0,454	-0,099	1,036	0,481	0,229	47,6
^{214}Pb 352 keV	Det 3	29	0,532	0,532	2,825	1,24	0,537	43,3
	Det 5	35	0,953	0,135	2,097	0,909	0,399	43,9
	Det 6	37	1,818	0,235	3,184	1,921	0,641	33,4
Annihilation 511 keV	Det 3	29	19,5	19,2	20,9	20,1	0,5	2,4
	Det 5	35	17,9	15,2	18,8	17,7	1,0	5,8
	Det 6	37	21,3	18,2	22,7	21,3	0,8	3,6
^{40}K 460,8 keV	Det 3	29	2,78	2,33	3,24	2,649	0,182	6,9
	Det 5	35	1,964	1,713	2,262	1,988	0,146	7,3
	Det 6	37	2,067	1,218	2,049	2,045	0,185	9,0
^{137}Cs 662 keV	Det 3	29	0,29	-0,158	0,29	0,052	0,121	232,5
	Det 5	35	0,179	-0,123	0,359	0,177	0,112	63,4
	Det 6	37	0,065	-0,088	0,367	0,098	0,122	124,8
^{214}Bi 1763 keV	Det 3	29	0,493	0,271	0,648	0,415	0,095	23
	Det 5	35	0,311	0,117	0,545	0,311	0,085	27,4
	Det 6	37	0,424	0,124	0,711	0,434	0,120	27,7

At the moment the authors consider implementation of the results obtained by this study to day to day laboratory practice to improve the quality management.

REFERENCES:

[1] Bossew P. (2005): A very long-term HPGe-background gamma spectrum. Appl. Radiat. Isot., 62(4):635-44.

[2] Chu S.Y.F., Ekström L.P. and Firestone R.B., *WWW Table of Radioactive Isotopes*, database version 2/28/1999, *http://nucleardata.nuclear.lu.se/nucleardata/toi (accessed Jan. - Feb. 2009)*

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