GammaUser2014 Spectrum Analysis Exercise

Seppo Klemola

Exercise (rather than intercomparison):

Analysis of radionuclides and their concentrations in (legacy) air filter spectrum

- **Spectrum provided for analysis in two formats** (ORTEC chn + phd ASCII) ICEX1401 at NKS GammaUser2014 GammaWiki web-page: (http://www.gr.is/wiki/GammaWiki/index.php/GammaUser_2014_Intercomparison_exercise)
- Additionally **calibration spectrum** (CalibN4) and **background spectrum** (BGRDN4) were provided
- ***Setup and calibration data in pdf + MS Excel***
  - *Sample data: sampling, geometry, etc.*
  - *Acquisition data: start, live time*
  - *Detector data: type, dimension, absorbing layers*
  - *Calibration source data: geometry, reference activities for 10 nuclides*
  - *Ready-made efficiency calibration as energy – efficiency pairs, 59.5 keV – 1836.1 keV, with uncertainty and TCS-correction coefficients*

Air filter sample

Sampling

- start of sampling: 24.3.1992 16:25
- end of sampling: 24.3.1992 22:15 5 h 50 min
- reference time: 24.3.1992 19:20
- volume: 1020 m^3 ~ 170 m^3/h

Sample Geometry

- Beaker
  - material: polystyrene
  - inner diameter: 21 mm, bottom wall: 1.3 mm, side wall: 2.0 mm
- Sample
  - material: glass-fiber (compressed aerosol filter)
  - sample height: 3.0 mm, sample density: 0.7 g cm^{-3}
  - sample detector distance: 0.3 mm (beaker bottom to detector window)

Measurement

Acquisition

- Start: 27.3.1992 15:16 age of the sample: 4.2 d
- Live time: 3839.41 min

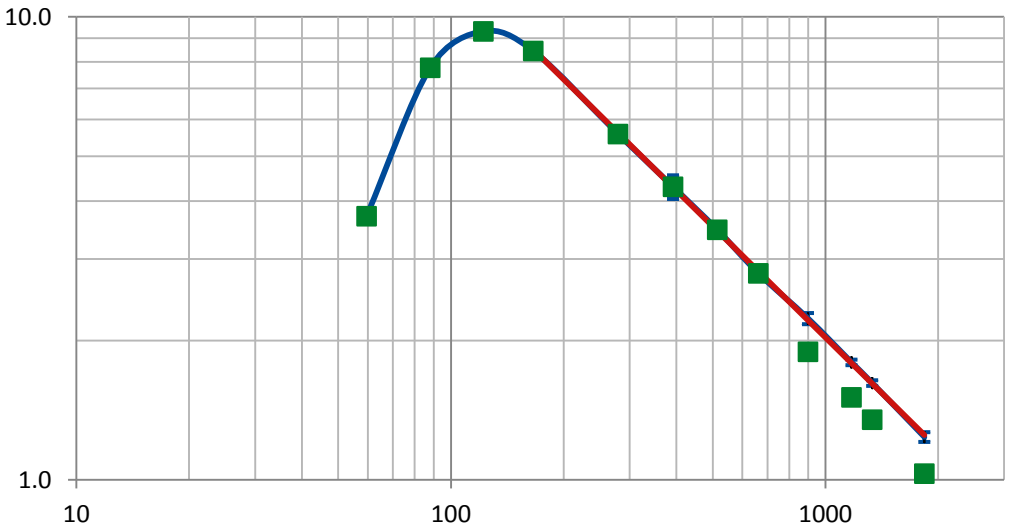
Detector

- HPGe p-type coaxial (ORTEC GEM-40190-P-S, rel. eff.: 39%, FWHM: 1.76 keV)
- crystal diameter: 57.3 mm; length: 73.4 mm
- core diameter: 9.8 mm, length: 60.1 mm
- absorbing layers, mm

	top	side
Ge	0.7	0.7
Al	0.25	0.5
Mylar	0.013	0
vacuum	6.5	7.0
Al	1.2	1.2

Efficiency calibration with multinuclide source

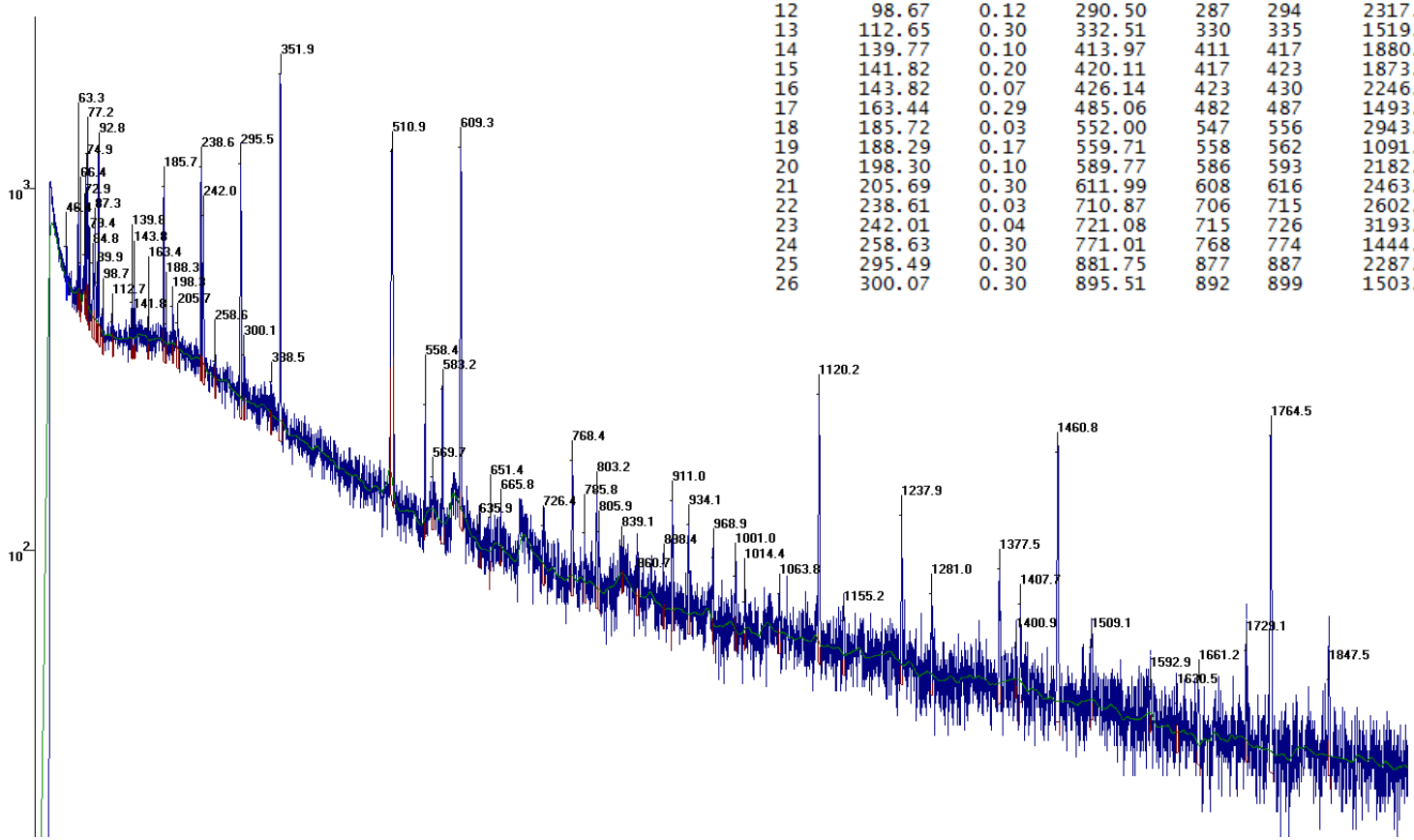
nucl.	keV	cpm	unc.	eff.	unc. %		TSC corr.	corr.eff	unc.
Am-241	59.54	439.8556	0.4 %	3.7105	2.8 %	0.10	1	3.711	0.11
Cd-109	88.03	454.8488	0.3 %	7.7617	3.3 %	0.25	1	7.762	0.25
Co-57	122.06	451.0839	0.3 %	9.3017	2.1 %	0.20	1	9.302	0.20
Ce-139	165.86	360.0701	0.4 %	8.4380	1.9 %	0.16	1	8.438	0.16
Hg-203	279.19	257.6854	0.5 %	5.5829	3.1 %	0.17	1	5.583	0.17
Sn-113	391.70	513.348	0.3 %	4.2951	5.9 %	0.25	1	4.295	0.25
Sr-85	514.00	476.335	0.3 %	3.4682	3.8 %	0.13	1	3.468	0.13
Cs-137	661.66	738.0253	0.2 %	2.7927	3.1 %	0.09	1	2.793	0.09
Y-88	898.04	642.0773	0.3 %	1.8904	2.8 %	0.05	1.18	2.231	0.06
Co-60	1173.23	510.0786	0.3 %	1.5072	1.4 %	0.02	1.19	1.794	0.02
Co-60	1332.49	456.7247	0.3 %	1.3487	1.4 %	0.02	1.20	1.618	0.02
Y-88	1836.05	370.2533	0.3 %	1.0314	2.4 %	0.03	1.20	1.238	0.03



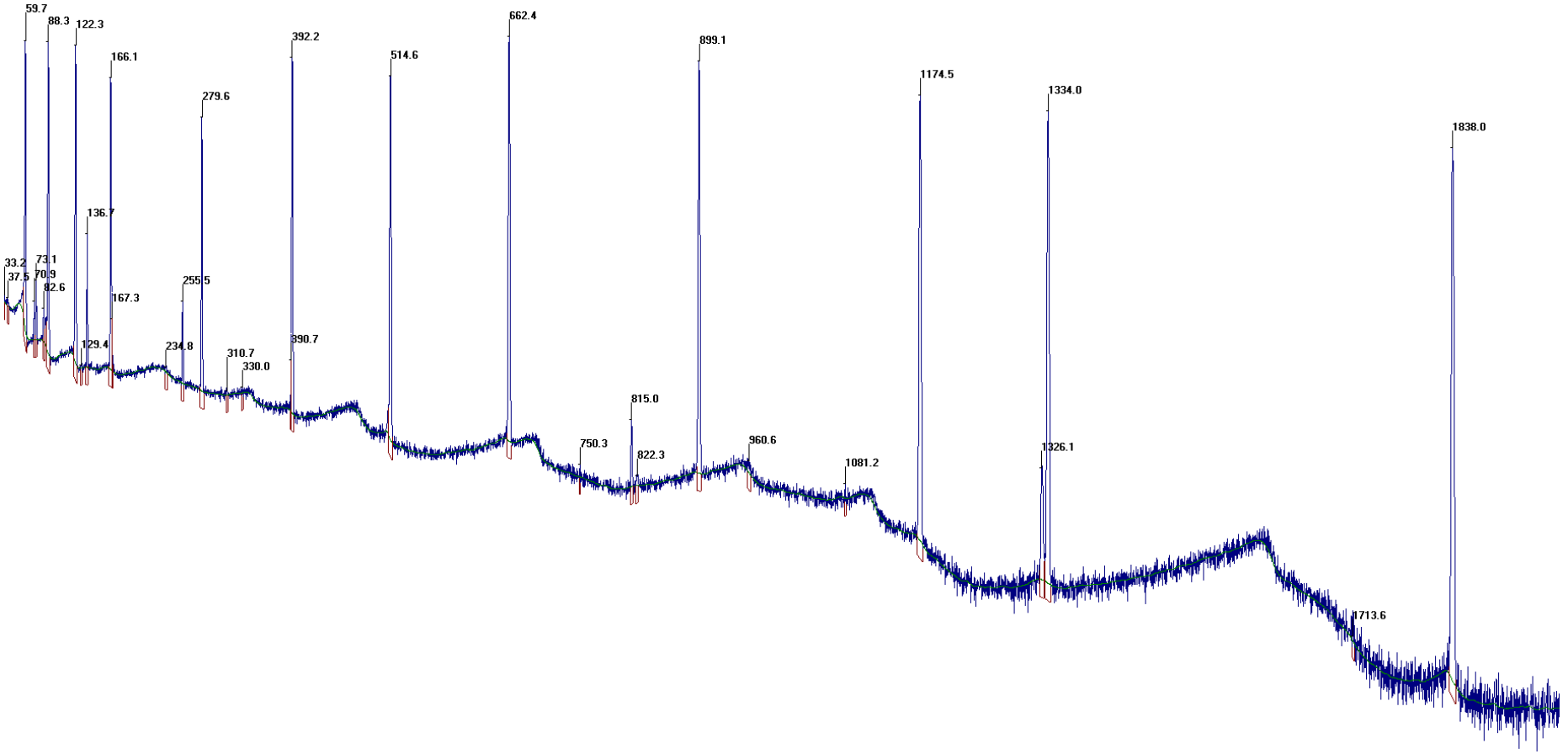
E [keV]	peak.eff.	unc. K=1
59.54	0.0618	4 %
88.03	0.1294	3.3 %
122.06	0.1550	3.0 %
165.86	0.1406	3.0 %
279.19	0.0930	3.1 %
391.70	0.0716	5.9 %
514.00	0.0578	3.8 %
661.66	0.0465	3.1 %
898.04	0.0372	3.0 %
1173.23	0.0299	3.0 %
1332.49	0.0270	3.0 %
1836.05	0.0206	3.0 %

Background spectrum

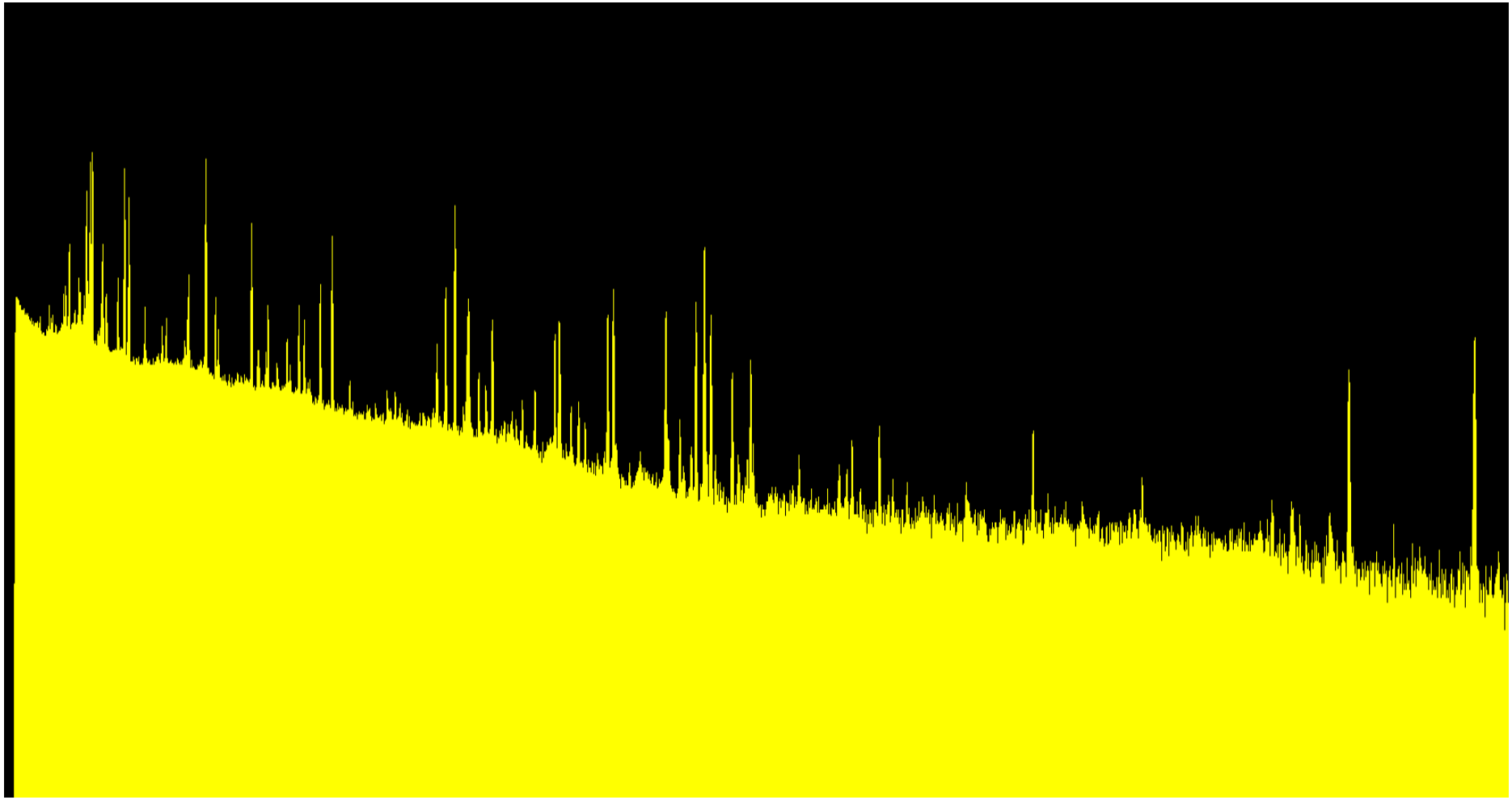
NR	ENERGY KEV	ERROR KEV	PEAK IN CH	LO CH	HI CH	BACKGR	CPM	R.S.D CPM
1	46.40	0.30	133.51	131	136	2209.5	0.0680	12
2	63.30	0.05	184.27	181	188	3078.5	0.1656	6
3	66.37	0.30	193.49	190	197	2976.0	0.0677	14
4	72.87	0.30	212.99	211	215	1503.2	0.0472	14
5	74.85	0.06	218.96	215	223	3412.9	0.2670	4
6	77.18	0.05	225.95	223	230	2803.1	0.3442	3
7	79.37	0.16	232.53	230	235	1814.0	0.0281	25
8	84.84	0.30	248.97	245	253	3014.9	0.1356	7
9	87.32	0.05	256.40	253	261	2971.6	0.1811	5
10	89.94	0.16	264.29	261	268	2514.1	0.0633	14
11	92.81	0.30	272.91	268	278	3699.1	0.4563	2
12	98.67	0.12	290.50	287	294	2317.9	0.0389	21
13	112.65	0.30	332.51	330	335	1519.5	0.0287	23
14	139.77	0.10	413.97	411	417	1880.6	0.0474	16
15	141.82	0.20	420.11	417	423	1873.1	0.0140	51
16	143.82	0.07	426.14	423	430	2246.6	0.0753	11
17	163.44	0.29	485.06	482	487	1493.0	0.0255	25
18	185.72	0.03	552.00	547	556	2943.5	0.3144	3
19	188.29	0.17	559.71	558	562	1091.2	0.0123	43
20	198.30	0.10	589.77	586	593	2182.5	0.0565	14
21	205.69	0.30	611.99	608	616	2463.7	0.0381	22
22	238.61	0.03	710.87	706	715	2602.1	0.3890	2
23	242.01	0.04	721.08	715	726	3193.9	0.2878	4
24	258.63	0.30	771.01	768	774	1444.5	0.0301	21
25	295.49	0.30	881.75	877	887	2287.5	0.5846	2
26	300.07	0.30	895.51	892	899	1503.8	0.0527	13



Calibration spectrum



Air filter spectrum

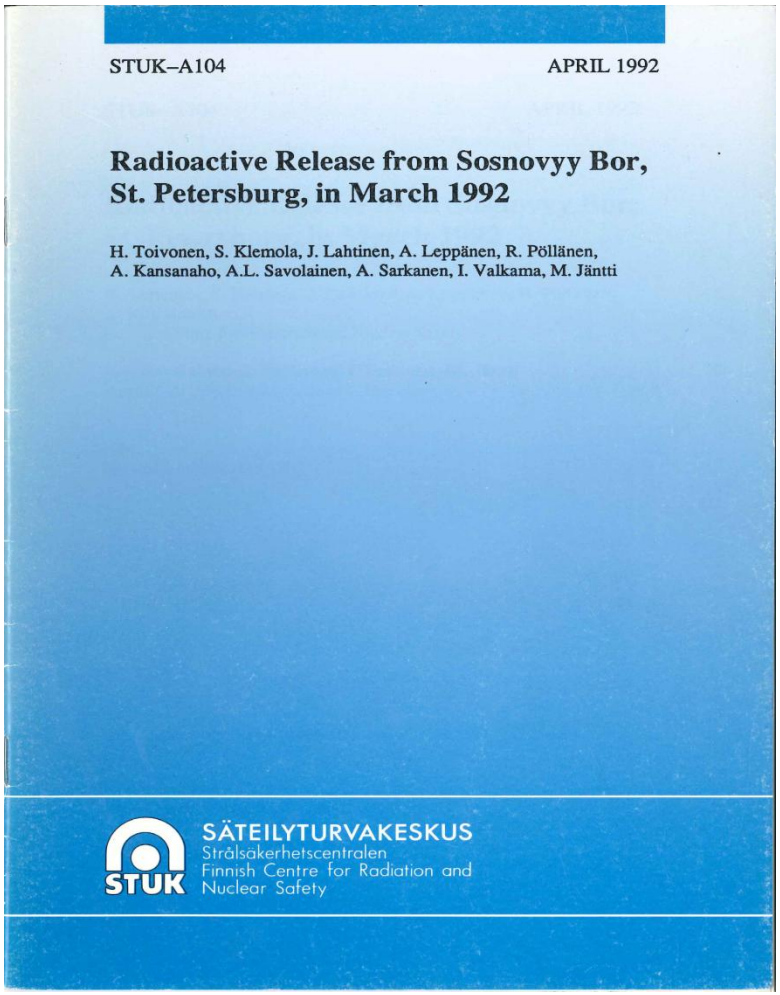


40 – 1600 keV

A Sosnovyy Bor Release in 1992

- On March 24th 1992 01:37 AM EET, a nuclear incident occurred in unit 3 of the RBMK reactor in Sosnovyy Bor NPP , in the course of which radionuclides were released in the environment.
- There had been a breakdown in one of 1700 fuel channels causing a pressure rise in the reactor space and subsequent exceeding of triggering level of the protection system.
- Steam and gases from the damaged fuel channel flowed to the accident localization system.
- The system operated normally, but noble gases, iodine, and other radionuclides were released through the cleaning filters.
- The air masses from the release reached the Finnish coast in about 12 hours.

Publications



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Release from the Nuclear Power Plant in Sosnovyy Bor in March 1992

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Radioactive release / Air sampling / Atmospheric transport

Abstract

Radionuclides released from the Sosnovyy Bor nuclear power plant were detected along the south coast of Finland on 24th of March 1992. The composition of the radioactive material was similar to that found during the Chernobyl accident six years ago. However, the radionuclide concentrations were now about 1 mBq m^{-3}, i.e. five orders of magnitude smaller than the maximum concentration detected in Finland during the Chernobyl fallout.

The consequences of the incident in Finland are only of theoretical interest. No countermeasures or protective means were needed. However, the studies showed that the release contained not only radioactive gases, such as noble gases and iodine, but also other substances that were attached to small uranium fuel particles.

Incident progression

Unit 3 of the RBMK nuclear power plant in Sosnovyy Bor was operating at the nominal power level (1000 MW_e) on 24th of March 1992. At 1.37 Finnish mean time (23.37 UTC, Universal Time Coordinated, 23rd of March) the pressure in the reactor vessel exceeded the triggering level of the protection system. The reactor was transferred to a subcritical state.

The pressure rise occurred after the breakdown of one of the fuel channels. A channel contains cooling water (steam) and about 100 kg of uranium. The total number of channels is about 1700 and, therefore, the maximum theoretical release could be approximately 0.1% of the total inventory. The true release fraction is several orders of magnitude smaller.

Steam, gases and radioactive substances from the damaged fuel channel flowed to the accident localization system. According to the preliminary information from Russia [1], the release of ^{131}I was about 26–93 GBq through the bypass and 6.7 GBq through the cleaning filters. Noble gases were released through the same paths; the total release was 190 TBq.

Meteorological situation

On 24th of March 1992 there was an extensive low-pressure area reaching from Southern and Central Europe up to the Baltic States and southernmost Finland. A ridge of high pressure was extending from Central Scandinavia over the central part of Finland. Due to this ridge there was a weak south-eastern air flow over Sosnovyy Bor area at the reported time of the incident [2].

During the incident light surface winds prevailed (0–3 m s^{-1}) from south or south-east. Throughout the day light rain was reported on the southern side of the Gulf of Finland.

At the time of the incident the wind in the eastern Gulf of Finland, outside Kotka, was from south, about 2–3 m s^{-1}. During the morning the wind turned east with a velocity of 4 m s^{-1}. During the afternoon and the evening the wind turned gradually towards north-east. The wind over the western part of Gulf of Finland, outside Helsinki, was at first from east with a velocity of 2–3 m s^{-1}. During the morning the wind turned to between east and north-east. Wind velocity during the day was 3–5 m s^{-1}.

There was a patchy precipitation area over southern and eastern Finland moving during the day slowly towards south-east. In southern Finland the precipitation fell as rain or sleet and further north as snow.

Estimation of the plume transport

The radioactive plume stayed in a rather shallow layer near the ground. The meteorological situation, the time of the release, the low sea surface temperature of the Gulf of Finland and the vertical cross-sections of computed three dimensional trajectories suggest that the vertical mixing during transport has probably been limited. The Finnish Air Forces checked the air space over the south coast of Finland at an altitude of 1 km. No signs of radioactive releases were detected.

The route of the radioactive plume was estimated using three-dimensional air parcel trajectories [3] computed from numerical forecasts of the European Centre for Medium-Range Weather Forecast (Figs. 1 and 2).

According to the forward trajectories in Figure 1 the plume was transported near the sea level towards the southern and south-eastern coasts of Finland. Due to a high pressure ridge over southern Finland the winds over the Finnish mainland were from east to north-east and the approaching plume was deflected

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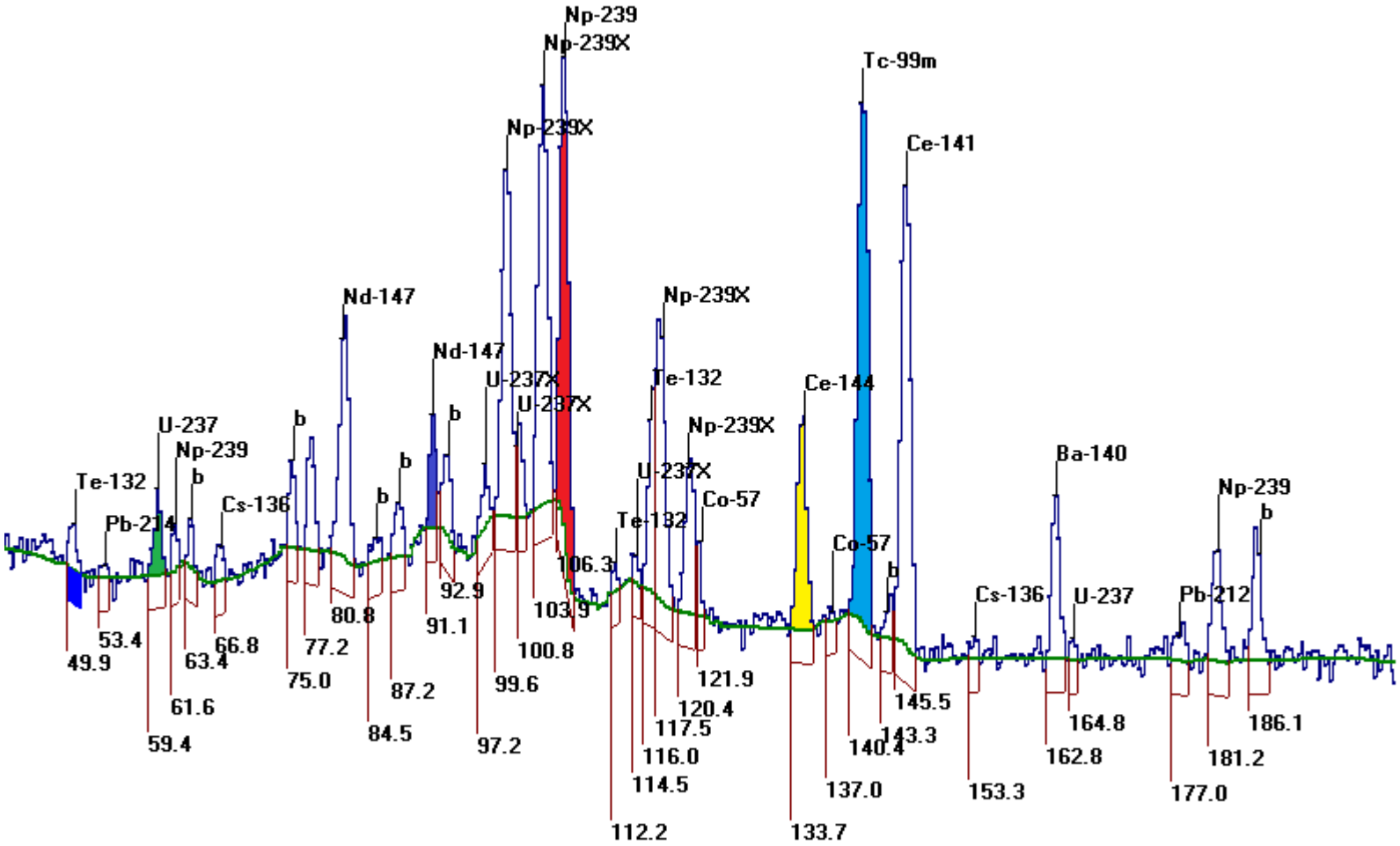
A Sosnovyy Bor Release in 1992

- Following the incident several radionuclides were identified in the surface air in south-eastern coast of Finland.
- STUK conducted sampling of ground level air on three sites in south-eastern coast of Finland.
- The filter collected at Kotka (ca. 130 km east from Helsinki) 24.3.1992, was measured over the next weekend, 3 days later.
- Conclusions
  - The radionuclide concentrations were five orders of magnitude smaller than the concentrations during the Chernobyl accident in 1986.
  - The radiological consequences in Finland were insignificant.
  - Even a minor release, across the sea and more than 100 km away, can be detected and important information, including the time of the incident and the composition of the release and the burn-up of the damaged fuel, can be revealed by the most accurate radioactivity measurements.

STUK results

Nuclide	Bq/m^3	
Be-7	1.10E-03	4
K-40	2.94E-03	5
Zr-95	8.71E-04	4
Nb-95	1.17E-03	4
Zr-97	7.27E-04	16
Nb-97	5.30E-04	19
Tc-99m	1.72E-03	4
Mo-99	1.84E-03	4
Ru-103	1.35E-03	4
Rh-105	9.65E-04	9
Ru-106	6.91E-04	7
Te-132	1.65E-03	4
I-131	8.72E-04	4
I-132	1.66E-03	4
I-133	1.41E-03	9
Cs-134	2.50E-04	4
Cs-136	5.86E-05	9
Cs-137	3.78E-04	4
Ba-140	1.11E-03	4
La-140	4.95E-03	4
Ce-141	8.05E-04	4
Ce-143	6.77E-04	7
Ce-144	8.00E-04	4
Nd-147	1.70E-04	7
U-237	3.80E-04	10
Np-239	9.61E-03	4


Np-239
Np-239X
Np-239X
Tc-99m
Ce-141
Nd-147
Np-239X
Nd-147
U-237X
U-237X
Te-132
Ce-144
U-237
Np-239
Np-239X
Ba-140
Np-239
Te-132
Pb-214
Cs-136
U-237X
Co-57
Co-57
Cs-136
U-237
Pb-212
49.9
53.4
59.4
61.6
63.4
66.8
75.0
77.2
80.8
84.5
87.2
91.1
92.9
97.2
99.6
100.8
103.9
106.3
112.2
114.5
116.0
117.5
120.4
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145.5
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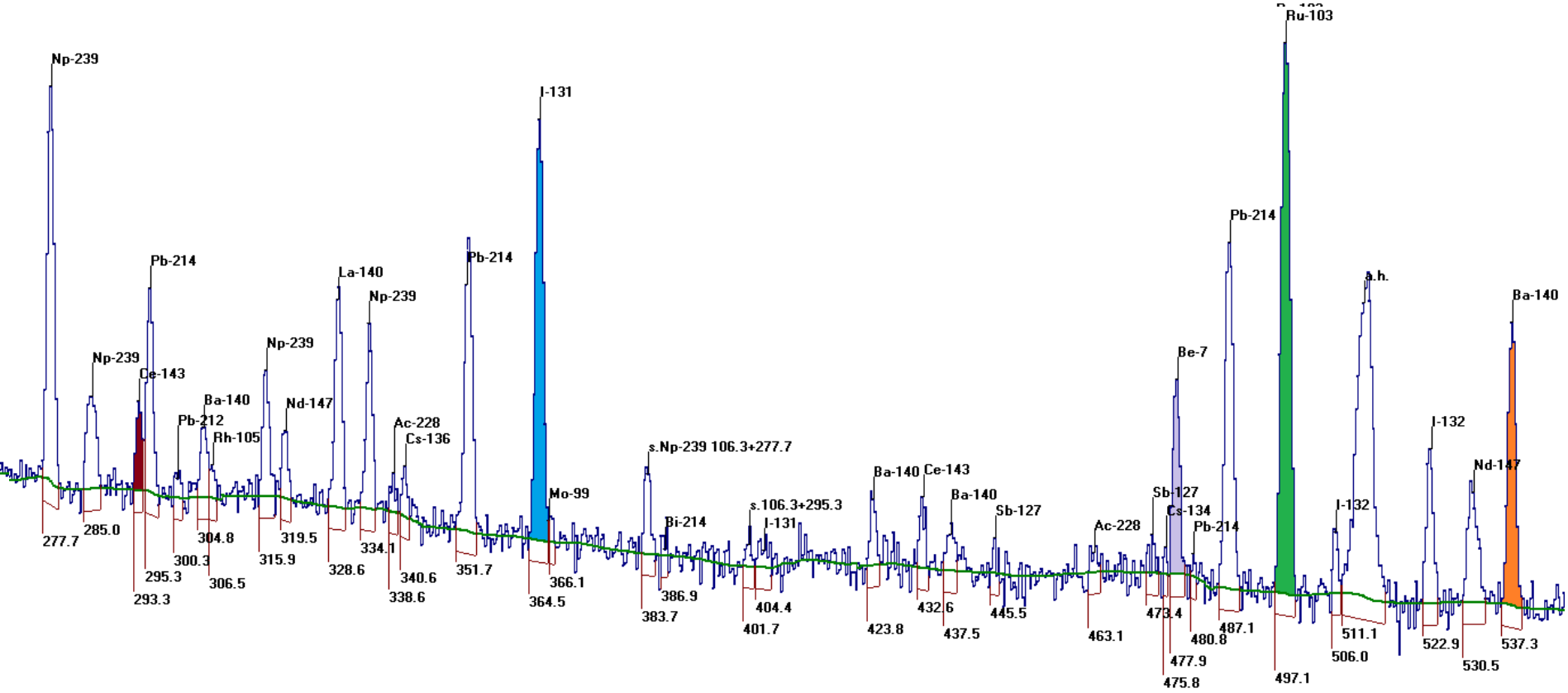
162.8
164.8
177.0
181.2
186.1


Np-239
Pb-214
Np-239
Ce-143
Pb-212
Ba-140
Rh-105
Np-239
Nd-147
La-140
Np-239
Ac-228
Cs-136
Pb-214
I-131
Mo-99
s.Np-239 106.3+277.7
Bi-214
s.106.3+295.3
I-131
Ba-140
Ce-143
Ba-140
Sb-127
Ac-228
Sb-127
Cs-134
Be-7
Pb-214
Ru-103
Pb-214
a.h.
I-132
I-132
Nd-147
Ba-140
277.7
285.0
293.3
295.3
300.3
304.8
306.5
315.9
319.5
328.6
334.1
338.6
340.6
351.7
364.5
366.1
383.7
386.9
401.7
404.4
423.8
432.6
437.5
445.5
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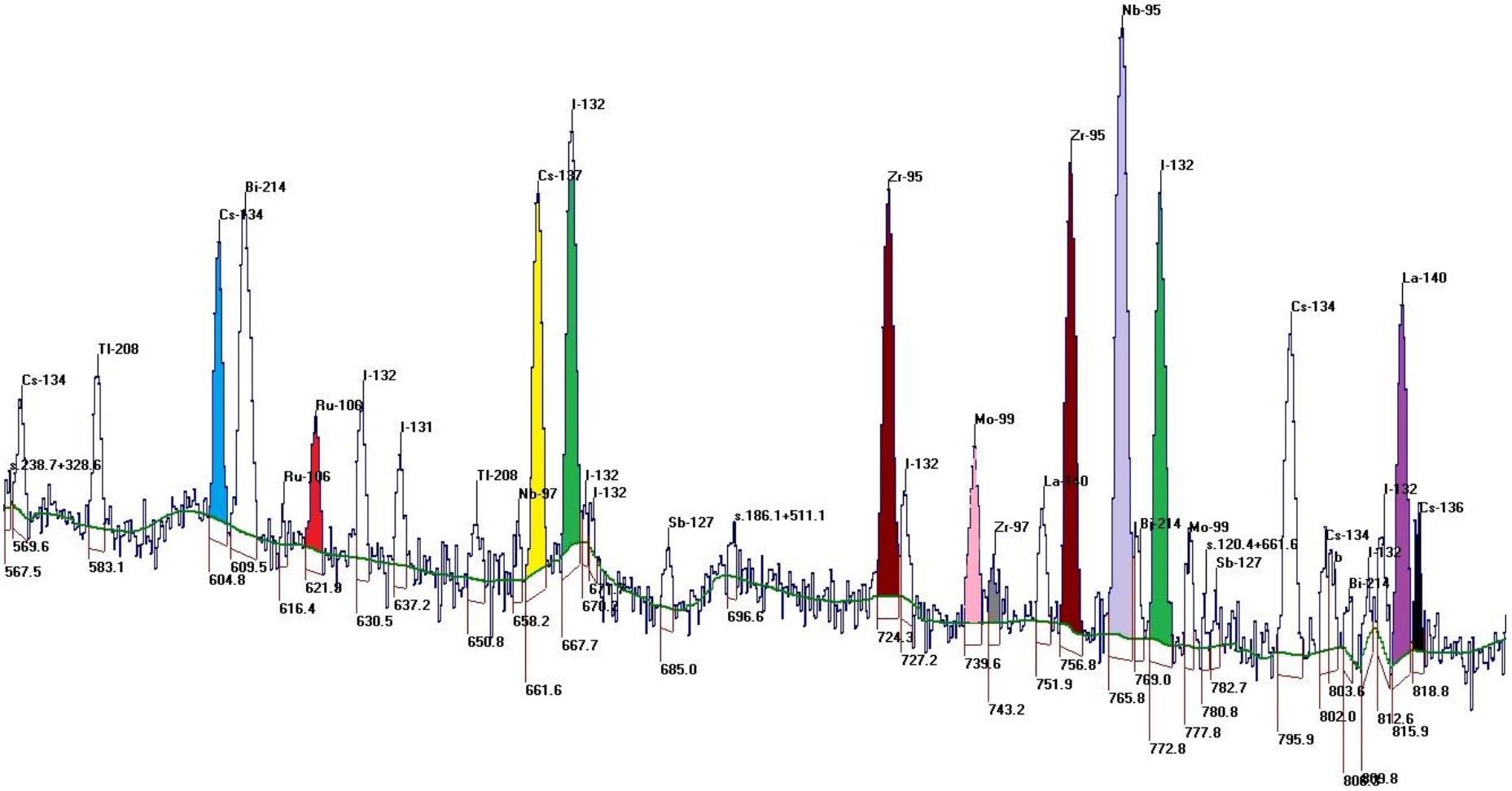
522.9
530.5
537.3


Nb-95
I-132
Zr-95
Cs-137
Zr-95
I-132
Bi-214
Cs-134
Cs-134
La-140
Tl-208
Cs-134
I-132
Mo-99
Ru-106
I-131
La-140
I-132
Cs-136
s.238.7+328.6
Ru-106
Tl-208
Nb-97
I-132
I-132
Sb-127
s.186.1+511.1
Zr-97
Bi-214
Mo-99
Cs-134
s.120.4+661.6
Sb-127
I-132
Bi-214
569.6
567.5
583.1
604.8
609.5
616.4
621.9
630.5
637.2
650.8
658.2
661.6
667.7
670.5
685.0
696.6
724.3
727.2
739.6
743.2
751.9
756.8
765.8
769.0
772.8
777.8
780.8
782.7
795.9
802.0
803.6
812.6
815.9
818.8

07492N4.CHN ICEX

MEAS. STARTED	REFERENCE DATE	MEAS.TIME(MIN)	AGE(DAYS)	CALIB	QUANTITY	UNIT	RHO	HEIGHT
1992 03 27 15 16	1992 03 24 19 20	3839.41	4.16	GAMMA\CALIB n4ic.DAT	1020.0000		0.7	3.0

WPS	TRESH	WIN	BSTF	ETOL	LOCH	ICA
5.9	2.8	6.0	2.0	1.2	0.0	ON

NUCLIDE LIBRARY: ICEX.DAT, 51 NUCLIDES, 489 GAMMA LINES, ALL PEAKS CHECKED.
THE FOLLOWING PEAKS ARE ATTRIBUTED TO ISOTOPES

NUCLIDE	NR	ENERGY	ERR	PEAK	LO	HI	BACKGR	CPM	RSD	ACT.CONC	RSD	FIT	MDC AT	COINS
		KEV	KEV	IN	CH	CH	CH		CPM	AT REF.D.	ACT	NR	REF.D	CORR.
Be-7	69	477,9	0,0	1429,4	1425	1434	1558,3	0,4169	3	1,10E-03	4	1	8,10E-05	1,00
K-40	152	1460,8	0,1	4382,2	4374	4390	343,3	0,6331	2	2,94E-03	5	1	1,40E-04	1,00
Co-57	24	121,9	0,3	360,5	359	362	1122,5	0,0775	13	9,09E-06	13	1	3,10E-06	1,00
Co-57	26	137,0	0,0	405,5	403	408	2187,3	0,0189	69	1,80E-05	69	2	3,50E-05	1,00
Co-57	82	569,6	0,1	1704,8	1700	1709	1138,3	0,144	7	3,55E-01	10	3	7,70E-02	1,41
Cs-134	42	241,7	0,0	720,1	716	724	2576,8	0,3379	5	4,69E-02	41	4	4,40E-02	1,53
Cs-134	80	563,1	0,1	1685,5	1683	1688	600,6	0,0447	16	2,41E-04	17	5	1,00E-04	1,52
Cs-134	82	569,6	0,1	1704,8	1700	1709	1138,3	0,144	7	3,72E-04	10	6	8,10E-05	1,52
Cs-134	84	604,8	0,0	1810,6	1805	1816	1355,8	0,6035	2	2,50E-04	4	7	1,20E-05	1,29
Cs-134	110	795,9	0,0	2384,8	2378	2392	746,9	0,4563	2	2,70E-04	4	8	1,30E-05	1,29
Cs-134	111	802,0	0,0	2403	2400	2406	293,2	0,056	10	3,75E-04	11	9	9,00E-05	1,48
Cs-134	143	1364,9	0,1	4094	4090	4098	237,9	0,017	28	2,60E-04	28	10	1,80E-04	0,76
Sb-127	4	61,6	0,0	179	177	181	2119,6	0,1129	12	6,24E-03	13	11	2,00E-03	1,32
Sb-127	43	253,7	0,0	756	753	759	1717,9	0,0321	37	1,49E-04	38	12	1,50E-04	1,19
Sb-127	47	293,3	0,0	875	872	878	1607,9	0,199	6	5,59E-02	7	13	8,80E-03	2,16
Sb-127	68	472,9	0,3	1415	1412	1418	981,8	0,0368	25	8,34E-05	25	14	5,60E-05	1,04
Sb-127	83	583,1	0,0	1745,5	1741	1750	1030,9	0,2271	5	2,11E-02	12	15	5,70E-03	0,94
Sb-127	84	604,8	0,0	1810,6	1805	1816	1355,8	0,6035	2	1,20E-02	4	16	5,70E-04	1,28
Sb-127	89	637,2	0,0	1908	1904	1912	715,8	0,1061	8	2,74E-02	9	17	5,40E-03	1,32
Sb-127	93	667,7	0,1	1999,7	1994	2005	938,6	1,4399	1	2,46E-01	3	18	4,10E-03	1,28
Sb-127	96	685,0	0,1	2051,5	2047	2055	546,5	0,0402	18	8,30E-05	18	19	3,80E-05	1,01
Sb-127	109	782,7	0,0	2345	2342	2348	302,4	0,0158	33	8,64E-05	33	20	7,40E-05	1
Sb-127	116	815,9	0,0	2444,9	2439	2450	571,9	0,5063	2	2,00E-01	4	21	7,40E-03	1,28
Sb-127	123	925,2	0,1	2773	2768	2778	473	0,1219	6	2,24E-02	8	22	3,10E-03	0,91

Cont'd

NUCLIDE	NR	ENERGY	ERR	PEAK	LO	HI	BACKGR	CPM	RSD	ACT.CONC	RSD	FIT	MDC AT	COINS
		KEV	KEV	IN	CH	CH	CH		CPM	AT REF.D.	ACT	NR	REF.D	CORR.
I-131	9	80,8	0,1	236,6	232	241	6042,8	1,4563	2	1,31E-02	5	23	5,50E-04	1,30
I-131	33	177	0,0	525,5	522	529	2686,5	0,0897	17	6,84E-03	17	24	3,10E-03	1,29
I-131	46	285	0,0	850	845	855	2919,8	0,3613	5	1,68E-03	6	25	2,00E-04	1,18
I-131	48	295,3	0,0	880,9	878	886	2215,4	0,6245	2	1,14E+00	55	26	1,50E+00	1,37
I-131	59	364,5	0,0	1088,9	1083	1094	2384,1	2,4009	1	8,78E-04	3	27	1,40E-05	1,00
I-131	64	404,4	0,0	1208,5	1204	1213	1620,6	0,0545	22	4,04E-02	22	28	2,30E-02	1,26
I-131	89	637,2	0,0	1908	1904	1912	715,8	0,1061	8	6,96E-04	9	29	1,40E-04	1,00
I-132	44	262,8	0,2	783,3	781	786	1387	0,0393	27	2,32E-03	27	30	1,70E-03	2,00
I-132	46	285	0,0	850	845	855	2919,8	0,3613	5	3,76E-02	6	31	4,40E-03	1,80
I-132	72	506	0,2	1513,7	1511	1517	867,2	0,0651	14	1,62E-03	14	32	5,70E-04	1,88
I-132	74	522,9	0,0	1564,5	1560	1569	1301,6	0,2595	5	1,74E-03	6	33	1,90E-04	1,59
I-132	87	621,9	0,0	1862,1	1857	1867	1015,1	0,1685	6	1,12E-02	7	34	1,70E-03	1,72
I-132	88	630,5	0,0	1887,9	1884	1892	745,2	0,1823	5	1,77E-03	6	35	2,10E-04	1,65
I-132	90	650,8	0,2	1948,8	1944	1954	840,1	0,0581	16	2,49E-03	23	36	1,30E-03	1,85
I-132	93	667,7	0,1	1999,7	1994	2005	938,6	1,4399	1	1,75E-03	3	37	2,90E-05	1,47
I-132	94	670,2	0,0	2007	2005	2009	269,2	0,0408	13	1,13E-03	13	38	3,50E-04	1,55
I-132	95	671,7	0,0	2011,5	2009	2014	356,4	0,0447	13	1,96E-03	14	39	6,50E-04	1,87
I-132	99	727,2	0,1	2178,3	2176	2183	493,8	0,0798	9	1,13E-03	19	40	4,60E-04	1,88
I-132	106	772,8	0,0	2315,3	2309	2322	747,1	1,0092	1	1,81E-03	3	41	3,80E-05	1,47
I-132	108	780,8	0,0	2339,5	2337	2342	239,6	0,0131	35	1,77E-03	35	42	1,60E-03	1,72
I-132	114	809,8	0,0	2426,5	2423	2430	336,4	0,0343	17	2,08E-03	17	43	8,70E-04	1,66
I-132	115	812,6	0,0	2434,9	2431	2439	391,5	0,0843	8	2,26E-03	9	44	4,10E-04	1,54
I-132	121	911	0,0	2730,5	2726	2735	440,6	0,0647	11	2,72E-03	64	45	4,00E-03	1,81
I-132	125	954,6	0,0	2861,5	2857	2866	394,7	0,1723	5	1,62E-03	6	46	1,50E-04	1,52
I-132	136	1136,1	0,1	3406,9	3403	3411	284,9	0,0349	16	1,96E-03	16	47	7,40E-04	1,34
I-132	137	1173,8	0,1	3520	3514	3526	469,4	0,0377	18	5,36E-03	19	48	2,40E-03	1,20
I-132	141	1295,6	0,0	3886	3884	3888	107,1	0,0093	34	5,14E-04	34	49	4,40E-04	0,74
I-132	142	1298,3	0,1	3894	3891	3897	178,6	0,0136	30	1,25E-03	30	50	9,60E-04	0,59
I-132	144	1372,5	0,1	4117	4114	4120	162,7	0,0095	41	8,46E-04	42	51	8,90E-04	1,51
I-132	146	1398,2	0,1	4194,1	4190	4198	191,3	0,046	11	1,37E-03	12	52	3,20E-04	1,40
I-132	151	1443,1	0,1	4329	4326	4332	121,8	0,0152	23	1,34E-03	24	53	7,60E-04	0,81
Ru-106	86	616,4	0,0	1845,5	1843	1848	464,2	0,0125	49	6,85E-04	49	54	9,30E-04	1,26
Ru-106	87	621,9	0,0	1862,1	1857	1867	1015,1	0,1685	6	6,91E-04	7	55	1,00E-04	1,26
Ru-106	133	1050,8	0,0	3150,5	3147	3154	281,7	0,0183	29	5,14E-04	29	56	3,70E-04	0,85

Cont'd

NUCLIDE	NR	ENERGY	ERR	PEAK	LO	HI	BACKGR	CPM	RSD	ACT.CONC	RSD	FIT	MDC AT	COINS
		KEV	KEV	IN	CH	CH	CH		CPM	AT REF.D.	ACT	NR	REF.D	CORR.
I-133	44	262,8	0,2	783,3	781	786	1387	0,0393	27	5,81E-02	27	57	4,30E-02	1,44
I-133	65	423,8	0,1	1266,9	1263	1271	1437,1	0,1005	11	2,17E-01	12	58	6,40E-02	1,23
I-133	75	530,5	0,1	1587,5	1581	1594	1964,8	0,247	6	1,88E-03	7	59	2,60E-04	1,01
I-133	78	556,8	0,2	1666,4	1662	1668	759,5	0,0288	28	1,28E+00	28	60	9,60E-01	1,31
I-133	105	769	0,0	2303,9	2301	2307	318,3	0,052	11	-2,53E-02	74	61	4,40E-02	1,24
I-133	142	1298,3	0,1	3894	3891	3897	178,6	0,0136	30	7,48E-03	30	62	5,70E-03	0,95
Cs-136	6	66,8	0,1	194,6	192	197	2681,3	0,1059	14	3,71E-04	47	63	4,10E-04	2
Cs-136	11	87,2	0,0	256	253	259	3778,3	0,2174	8	1,63E-04	60	64	2,30E-04	1,6
Cs-136	30	153,3	0,0	454,5	452	457	1807,2	0,0414	29	1,36E-04	29	65	1,10E-04	1,45
Cs-136	32	164,8	0,2	488,9	487	491	1347,9	0,0326	32	1,93E-04	32	66	1,70E-04	1,48
Cs-136	33	177	0,0	525,5	522	529	2686,5	0,0897	17	1,28E-04	17	67	5,80E-05	1
Cs-136	35	186,1	0,0	552,9	549	557	3138,2	0,3185	5	3,05E-04	555	68	3,90E-03	1,84
Cs-136	52	315,9	0,0	942,9	939	948	2480,3	0,3424	5	6,61E-01	6	69	7,50E-02	1,68
Cs-136	53	319,5	0,0	953,5	950	957	1837,9	0,1519	9	9,65E-02	9	70	2,10E-02	1,37
Cs-136	57	340,6	0,0	1017	1014	1020	1374,1	0,0763	14	6,51E-05	15	71	2,50E-05	1,47
Cs-136	117	818,8	0,0	2453,5	2450	2457	351	0,0787	8	5,88E-05	9	72	1,10E-05	1,5
Cs-136	132	1048,1	0,0	3142,5	3138	3147	375,8	0,0454	14	5,24E-05	14	73	1,70E-05	1,52
Rh-105	51	306,5	0,0	914,5	912	917	1229,1	0,0539	19	1,27E-03	19	74	6,40E-04	1
Rh-105	53	319,5	0,0	953,5	950	957	1837,9	0,1519	9	9,88E-04	9	75	2,20E-04	1
Ba-140	20	114,5	0,0	338	336	340	1984,9	0,0646	19	6,77E-02	20	76	3,60E-02	1,44
Ba-140	25	133,7	0,0	395,5	391	400	4185,4	0,8756	2	6,31E-02	3	77	3,60E-03	1,15
Ba-140	31	162,8	0,0	482,9	479	487	3172,9	0,4525	4	1,05E-03	5	78	1,10E-04	1,14
Ba-140	50	304,8	0,0	909,5	906	913	1854,1	0,1695	8	1,16E-03	8	79	2,30E-04	1,3
Ba-140	65	423,8	0,1	1266,9	1263	1271	1437,1	0,1005	11	9,65E-04	12	80	2,80E-04	1,01
Ba-140	67	437,5	0,0	1308	1304	1312	1391,7	0,073	15	1,15E-03	16	81	4,60E-04	1
Ba-140	76	537,3	0,0	1607,9	1602	1614	1767,8	0,745	2	1,11E-03	4	82	4,90E-05	1,01
Ba-140	77	550,5	0,1	1647,6	1645	1651	778,6	0,0467	18	3,01E-01	18	83	1,40E-01	0,86

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NUCLIDE	NR	ENERGY KEV	ERR KEV	PEAK IN	LO CH	HI CH	BACKGR CH	CPM	RSD CPM	ACT.CONC AT REF.D.	RSD ACT	FIT NR	MDC AT REF.D	COINS CORR.
La-140	54	328,6	0,0	981,1	976	986	2616	0,7327	2	5,35E-03	4	84	2,90E-04	1,49
La-140	66	432,6	0,0	1293,5	1290	1297	1212,3	0,0924	11	5,87E-03	12	85	1,70E-03	1,49
La-140	70	487,1	0,0	1457	1451	1463	1957,9	1,2419	1	5,09E-03	3	86	1,40E-04	1,35
La-140	102	751,9	0,0	2252,5	2248	2257	570,1	0,0833	9	4,46E-03	10	87	1,00E-03	1,19
La-140	116	815,9	0,0	2444,9	2439	2450	571,9	0,5063	2	4,82E-03	4	88	1,80E-04	1,07
La-140	119	867,4	0,2	2599,4	2595	2606	578,6	0,0848	9	4,01E-03	10	89	8,90E-04	1,19
La-140	122	919,8	0,1	2757	2752	2762	490,4	0,0556	13	5,02E-03	13	90	1,60E-03	1,06
La-140	123	925,2	0,1	2773	2768	2778	473	0,1219	6	4,81E-03	8	91	6,70E-04	1,19
La-140	154	1596,3	0,1	4789,2	4779	4799	344,2	1,0163	1	4,95E-03	4	92	7,10E-05	1,28
La-140	167	2521,5	0,1	7567,9	7562	7574	52	0,0339	10	4,63E-03	11	93	7,70E-04	0,90
Ce-143	27	140,4	0,0	415,9	411	420	4354,6	5,6434	0,8	1,01E+01	2	94	9,50E-02	1,82
Ce-143	47	293,3	0,0	875	872	878	1607,9	0,199	6	6,77E-04	7	95	1,10E-04	1,11
Ce-143	58	351,7	0,1	1050,2	1044	1056	2767,8	1,1502	2	5,51E-03	19	96	2,70E-03	0,89
Ce-143	66	432,6	0,0	1293,5	1290	1297	1212,3	0,0924	11	1,36E-01	12	97	4,00E-02	1,29
Mo-99	27	140,4	0,0	415,9	411	420	4354,6	5,6434	0,8	4,53E-02	2	98	4,30E-04	1,28
Mo-99	34	181,2	0,1	538,3	535	543	3122,1	0,318	5	2,12E-03	6	99	2,90E-04	1,23
Mo-99	60	366,1	0,3	1093,6	1094	1098	707,4	0,0197	38	9,68E-04	38	100	1,00E-03	1,00
Mo-99	100	739,6	0,1	2215,5	2210	2220	636,9	0,1727	5	1,99E-03	6	101	2,30E-04	1,35
Mo-99	107	777,8	0,1	2330,4	2328	2334	302,5	0,0613	10	1,54E-03	10	102	3,40E-04	1,00
Tc-99m	27	140,4	0,0	415,9	411	420	4354,6	5,6434	0,8	1,79E-03	2	103	1,70E-05	1,00
Ce-144	9	80,8	0,1	236,6	232	241	6042,8	1,4563	2	1,37E-02	5	104	5,70E-04	1,00
Ce-144	25	133,7	0,0	395,5	391	400	4185,4	0,8756	2	8,00E-04	3	105	4,60E-05	1,00
Nd-147	9	80,8	0,1	236,6	232	241	6042,8	1,4563	2	3,75E+01	5	106	1,60E+00	1,35
Nd-147	12	91,1	0,0	267,5	265	270	3498,6	0,39	4	1,70E-04	7	107	2,50E-05	1,01
Nd-147	22	117,5	0,3	347,3	344	351	3602,6	1,5858	1	1,73E+00	3	108	5,10E-02	1,29
Nd-147	23	120,4	0,0	355,6	352	359	3421,3	0,5836	3	3,14E-02	4	109	2,50E-03	1,51
Nd-147	53	319,5	0,0	953,5	950	957	1837,9	0,1519	9	2,57E-03	9	110	5,70E-04	1,39
Nd-147	75	530,5	0,1	1587,5	1581	1594	1964,8	0,247	6	7,10E-04	7	111	1,00E-04	0,99
Nd-147	96	685	0,1	2051,5	2047	2055	546,5	0,0402	18	2,09E-03	18	112	9,50E-04	0,96

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NUCLIDE	NR	ENERGY KEV	ERR KEV	PEAK IN	LO CH	HI CH	BACKGR CH	CPM	RSD CPM	ACT.CONC AT REF.D.	RSD ACT	FIT NR	MDC AT REF.D	COINS CORR.
Tl-208	45	277,7	0,0	828	823	833	3035,5	2,624	1	2,69E-02	3	113	4,40E-04	1,46
Tl-208	83	583,1	0,0	1745,5	1741	1750	1030,9	0,2271	5	1,44E-04	12	114	3,80E-05	1,28
Tl-208	90	650,8	0,2	1948,8	1944	1954	840,1	0,0581	16	1,27E-01	23	115	6,90E-02	1,60
Tl-208	118	860,6	0,3	2579,1	2576	2583	348	0,0268	21	4,20E-05	170	116	1,70E-04	1,09
Tl-208	168	2614,5	0,1	7847,2	7837	7857	83	0,1479	4	8,87E-05	36	117	7,00E-05	1,36
Pb-212	20	114,5	0,0	338	336	340	1984,9	0,0646	19	1,33E-03	20	118	7,20E-04	1,29
Pb-212	33	177	0,0	525,5	522	529	2686,5	0,0897	17	2,60E-02	17	119	1,20E-02	1,31
Pb-212	41	238,7	0,0	711	707	715	2597,8	0,6475	3	8,68E-05	9	120	1,70E-05	1,00
Pb-212	49	300,3	0,2	895,9	893	899	1537,1	0,0528	22	1,22E-06	999	121	2,40E-04	1,31
Pb-214	2	53,4	0,0	154,5	152	157	2717,2	0,0422	35	1,80E-03	36	122	1,70E-03	1,30
Pb-214	36	205,8	0,0	612	609	615	2190,4	0,1965	7	2,33E-01	11	123	5,60E-02	1,30
Pb-214	42	241,7	0,0	720,1	716	724	2576,8	0,3379	5	1,03E-04	41	124	9,80E-05	1,01
Pb-214	48	295,3	0,0	880,9	878	886	2215,4	0,6245	2	3,78E-05	55	125	4,90E-05	1,00
Pb-214	50	304,8	0,0	909,5	906	913	1854,1	0,1695	8	1,38E-01	8	126	2,70E-02	1,43
Pb-214	58	351,7	0,1	1050,2	1044	1056	2767,8	1,1502	2	7,44E-05	19	127	3,60E-05	1,00
Pb-214	70	487,1	0,0	1457	1451	1463	1957,9	1,2419	1	9,77E-02	3	128	2,70E-03	1,29
Pb-214	76	537,3	0,0	1607,9	1602	1614	1767,8	0,745	2	1,42E+00	4	129	6,30E-02	1,31
Ac-228	15	99,6	0,0	293,3	289	297	6503,6	3,4152	1	4,37E-02	3	130	8,20E-04	1,57
Ac-228	30	153,3	0,0	454,5	452	457	1807,2	0,0414	29	7,02E-04	29	131	5,60E-04	1,22
Ac-228	38	209,9	0,0	624,4	621	628	2571,9	1,0283	2	3,87E-03	3	132	1,50E-04	1,14
Ac-228	54	328,6	0,0	981,1	976	986	2616	0,7327	2	5,53E-03	4	133	3,00E-04	1,20
Ac-228	56	338,6	0,0	1011	1008	1014	1412	0,056	20	5,18E-05	43	134	5,40E-05	1,03
Ac-228	57	340,6	0,0	1017	1014	1020	1374,1	0,0763	14	5,37E-03	15	135	2,00E-03	1,44
Ac-228	80	563,1	0,1	1685,5	1683	1688	600,6	0,0447	16	1,57E-03	17	136	6,80E-04	1,06
Ac-228	99	727,2	0,1	2178,3	2176	2183	493,8	0,0798	9	3,43E-03	19	137	1,40E-03	1,34
Ac-228	106	772,8	0,0	2315,3	2309	2322	747,1	1,0092	1	3,40E-02	3	138	7,20E-04	1,34
Ac-228	109	782,7	0,0	2345	2342	2348	302,4	0,0158	33	1,40E-03	33	139	1,20E-03	1,15
Ac-228	110	795,9	0,0	2384,8	2378	2392	746,9	0,4563	2	5,43E-03	4	140	2,50E-04	1,31
Ac-228	121	911	0,0	2730,5	2726	2735	440,6	0,0647	11	2,35E-05	64	141	3,50E-05	1,06
Ac-228	126	964,7	0,0	2892	2889	2895	244,7	0,0199	24	2,04E-04	24	142	1,30E-04	1,12

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NUCLIDE	NR	ENERGY KEV	ERR KEV	PEAK IN	LO CH	HI CH	BACKGR CH	CPM	RSD CPM	ACT.CONC AT REF.D.	RSD ACT	FIT NR	MDC AT REF.D	COINS CORR.
U-237	1	49,9	0,1	144	141	147	3540,3	0,145	12	4,13E-02	17	144	1,30E-02	1,43
U-237	3	59,4	0,1	172,5	169	176	4133,5	0,2653	7	3,80E-04	10	145	7,20E-05	1,30
U-237	17	103,9	0,0	306	302	310	6842,9	5,4102	0,8	1,48E+01	2	146	1,80E-01	1,13
U-237	32	164,8	0,2	488,9	487	491	1347,9	0,0326	32	3,21E-04	32	147	2,80E-04	1,10
U-237	37	208,2	0,1	619,3	615	621	2183	0,323	4	3,33E-04	5	148	3,80E-05	1,09
Te-132	1	49,9	0,1	144	141	147	3540,3	0,145	12	1,35E-03	17	149	4,30E-04	1,32
Te-132	19	112,2	0,0	331	329	333	1910,9	0,0513	24	3,98E-04	62	150	6,20E-04	1,36
Te-132	21	116	0,3	342,6	340	345	2560,5	0,6489	2	1,06E-02	4	151	6,40E-04	1,34
Te-132	40	228,1	0,1	679	672	685	4958,9	6,7904	0,7	2,81E-03	3	152	2,30E-05	1,07
U-237X	14	97,2	0,0	286	283	289	4390	0,2071	9	2,26E-04	10	153	5,70E-05	1,00
U-237X	16	100,8	0,1	296,7	297	301	2759,2	0,2401	6	1,61E-04	7	154	2,80E-05	1,00
U-237X	20	114,5	0,0	338	336	340	1984,9	0,0646	19	1,14E-04	20	155	6,20E-05	1,00
U-237X	22	117,5	0,3	347,3	344	351	3602,6	1,5858	1	8,12E-03	3	156	2,40E-04	1,00
Np-239	1	49,9	0,1	144	141	147	3540,3	0,145	12	2,27E-01	17	157	7,30E-02	1,39
Np-239	4	61,6	0,0	179	177	181	2119,6	0,1129	12	8,56E-03	13	158	2,70E-03	1,30
Np-239	6	66,8	0,1	194,6	192	197	2681,3	0,1059	14	3,54E-02	47	159	3,90E-02	1,37
Np-239	18	106,3	0,0	313,3	310	317	4909,6	6,0451	0,7	9,61E-03	2	160	8,70E-05	1,29
Np-239	34	181,2	0,1	538,3	535	543	3122,1	0,318	5	1,97E-01	6	161	2,70E-02	1,30
Np-239	38	209,9	0,0	624,4	621	628	2571,9	1,0283	2	1,45E-02	3	162	5,60E-04	1,11
Np-239	40	228,1	0,1	679	672	685	4958,9	6,7904	0,7	3,26E-02	3	163	2,60E-04	1,11
Np-239	43	253,7	0,0	756	753	759	1717,9	0,0321	37	1,54E-02	38	164	1,60E-02	1,03
Np-239	45	277,7	0,0	828	823	833	3035,5	2,624	1	1,11E-02	3	165	1,80E-04	1,11
Np-239	46	285	0,0	850	845	855	2919,8	0,3613	5	2,84E-02	6	166	3,30E-03	1,10
Np-239	52	315,9	0,0	942,9	939	948	2480,3	0,3424	5	1,15E-02	6	167	1,30E-03	0,88
Np-239	55	334,1	0,0	997,6	993	1002	2306,4	0,4864	3	1,13E-02	4	168	8,70E-04	0,75
Np-239X	15	99,6	0,0	293,3	289	297	6503,6	3,4152	1	8,62E-03	3	169	1,60E-04	1,00
Np-239X	17	103,9	0,0	306	302	310	6842,9	5,4102	0,8	8,52E-03	2	170	1,00E-04	1,00
Np-239X	22	117,5	0,3	347,3	344	351	3602,6	1,5858	1	6,63E-03	3	171	2,00E-04	1,00
Np-239X	23	120,4	0,0	355,6	352	359	3421,3	0,5836	3	7,03E-03	4	172	5,50E-04	1,00
Zr-95	98	724,3	0,1	2169,5	2163	2176	1006,4	1,0459	1	8,95E-04	3	1	2,10E-05	1,00
Zr-95	103	756,8	0,0	2267,4	2261	2274	815,5	1,1756	1	8,49E-04	3	2	1,60E-05	1,00
Zr-97	101	743,2	0,0	2226,5	2223	2230	423,6	0,0399	16	7,27E-04	16	1	2,90E-04	1,00
Nb-95	104	765,8	0,1	2294,4	2287	2301	842,6	2,8281	1	1,17E-03	3	1	9,30E-06	1,00
Nb-97	91	658,2	0,1	1971,2	1968	1974	464,8	0,0339	19	5,30E-04	19	1	2,60E-04	1,00
Ru-103	71	497,1	0,0	1487,2	1481	1493	1897,4	4,2451	0,8	1,35E-03	3	1	1,10E-05	1,00
Ru-103	85	609,5	0,1	1824,6	1817	1832	1754	0,9973	2	1,39E-03	11	2	3,20E-04	1,00
Cs-137	92	661,6	0,1	1981,3	1975	1987	1042	0,9543	1	3,78E-04	3	1	1,00E-05	1,00
Ce-141	29	145,5	0,0	431,2	427	435	3378,7	3,4634	1	8,05E-04	3	1	1,10E-05	1,00

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THE FOLLOWING ISOTOPES WERE IDENTIFIED										
NR	NUCLIDE	CONF.VAL	ACT. CONC.	R.S.D.		NR	NUCLIDE	CONF.VAL	ACT. CONC.	R.S.D.
1	Be-7	0.9929	1.0952E-03	4		18	Cs-134	0.8687	2.6381E-04	3
2	K-40	0.9999	2.9418E-03	5		19	Cs-136	0.5634	6.0420E-05	6
3	Co-57	0.9611	9.1670E-06	13		20	Cs-137	0.9997	3.7832E-04	3
4	Zr-95	0.9982	8.7082E-04	3		21	Ba-140	0.8225	1.0856E-03	3
5	Zr-97	0.5857	7.2706E-04	16		22	La-140	0.9118	4.9500E-03	3
6	Nb-95	0.9998	1.1657E-03	3		23	Ce-141	0.9989	8.0486E-04	3
7	Nb-97	0.7144	5.3035E-04	19		24	Ce-143	0.2652	6.7688E-04	7
8	Mo-99	0.9677	1.8400E-03	4		25	Ce-144	0.9634	8.1010E-04	3
9	Tc-99m	0.9793	1.7179E-03	3		26	Nd-147	0.7743	1.6985E-04	7
10	Ru-103	0.9370	1.3494E-03	3		27	Tl-208	0.9272	1.2573E-04	12
11	Ru-106	0.8670	5.8308E-04	8		28	Pb-212	0.9442	5.9969E-05	11
12	Rh-105	0.8960	9.6588E-04	9		29	Pb-214	0.7970	6.0052E-05	19
13	Sb-127	0.2895	7.7400E-05	14		30	Ac-228	0.3578	3.7206E-05	28
14	Te-132	0.9548	1.9638E-03	4		31	U-237	0.7567	3.3896E-04	5
15	I-131	0.8378	8.7197E-04	3		32	U-237X	0.9614	1.6106E-04	5
16	I-132	0.6099	1.6599E-03	3		33	Np-239	0.7704	1.0739E-02	3
17	I-133	0.5471	1.4145E-03	9		34	Np-239X	0.9239	7.5921E-03	3