DETERMINATION OF RADIONUCLIDE CONCENTRATION IN SAMPLE KEVLAR ROPE

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ABSTRACT

The system used to determine the concentrations of radionuclides in the Kevlar and Vectran sample filaments (SNO-STR-94-023) is now applied to a Kevlar test rope. The concentrations arrived at indicate that the Kevlar rope is suitable for use in suspending the acrylic vessel.

Using the three-crystal, ultra-low background Ge detector ULBT, we have observed the gamma radiation emitted by a 21 liter sample of Kevlar rope. This rope is the proposed material for suspending the acrylic vessel in the SNO detector cavity, and as such it is of critical importance that the concentrations of radionuclides in this rope (particularly Th) are known.

13.450 kg of Kevlar rope were wound onto the spool of a 21 liter Marinelli-geometry sample holder. The rope sample was prepared by P. Jagam of Guelph and shipped to us at Laurentian University by courier. The sample arrived in an intact cardboard box, and was moved underground without breaching the seal. The heavy plastic bag and layers of plastic wrap on the sample were both intact.

Loading the sample involved removing all potentially contaminated outer layers of covering and then lowering the sample into the lead castle around ULBT. This castle is composed of an outer 10" of Pb and an inner 2" of copper. A clean nitrogen purge is maintained into the cavity at a nominal rate of 10 liters per minute. This purge serves to first expel and then exclude radon from the region surrounding the crystals.

ULBT contains three independent Ge crystals. Each has a separate pre-amplifier which is connected to individual amplifiers and, finally, to individual MCA cards, mounted in a PC. Amplifier gains are chosen so that given peak centroids are located at approximately the same channels, regardless of the crystal being examined. For purposes of display only, the spectra accumulated may be scaled using a program written by P. Jagam, RESCAL34. This allows us to display the accumulated data on one graph, including the data for all crystals.

In order to analyze the data effectively and reduce the error bars to the lowest possible level, it is important to maintain stringent knowledge of the energy calibration of the three crystals. Our counting system has experienced problems with drift of the energy calibration before (see SNO-STR-94-023), and it was desired to minimize the harmful effects of such a drift. A hardware calibrator, previously used during double-beta decay studies by the Guelph group, was modified at Laurentian. The control unit was interfaced to the parallel port of a PC and a Windows-based program written to send appropriate commands to the controller. The controller unit sends signals to a stepper motor which moves a Th source down a copper tube into the area directly under the crystals of ULBT.

This combination of hardware and software enables us to contact the underground lab by telephone and remotely place the source inside the detector. A calibration may thus be obtained without travelling underground, which is a rather time-consuming operation if only for the purpose of calibrating the detectors. Originally, we had planned to calibrate ULBT once per day, but owing to problems in contacting the lab (phone connections through the Inco switchboard seem to be prone to disconnecting modems) the actual average was roughly once every two days. To date, our fears of a drift in the ULBT energy calibrations seem, thankfully, to have been groundless. The centroids of the Th calibration peaks have moved less than 0.5 channels per day, and in random directions.

Previously, the background of the detector and an empty castle were measured (SNO-STR-94-

023). During these measurements the counting system was reconfigured. The original system ran for approximately 1.5 Ms and used two separate MCAs, with one gathering information from D1 and D3 of ULBT, the other taking data from D2. The current system uses three MCAs, one for each detector crystal, and has run for about 2.4 Ms. Data taken from the original system was only used if it could be shown that the data from that detector was not being interfered with by the data from another crystal. In the current configuration, all data is used. So, counts for various crystals over various periods were either discarded or accepted, and, if accepted, were used to calculate the counts per Ms in the background. These values were then added to the data for other time periods. The data on background counts at each gamma ray energy is given in Table 1.

Table 1 - Background counts for each useful crystal at each energy of interest. All errors are 2σ. Count rate is given as number of net counts in the region of interest per million seconds of acquired data.

Isotope	Peak Energy (keV)	Rate per Ms
Th	2614	12.4(46)
	911	20.3(108)
	583	31.3(224)
U	1764	24.8(110)
	1001	-
	609	141.2(225)
K	1461	66.1(92)

Calculation of concentrations cannot be accomplished without knowledge of the counting efficiency of the detectors. In this case, we utilized a 21 liter Marinelli holder, filled with vermiculite. The known concentrations of radioactive U, Th and K in the vermiculite are (2σ errors):

Isotope	Concentration
Th	2141 (94) ppb
U	77 (14) ppb
K	4.74 (20) %

The counts produced by the vermiculite standard immediately following the Kevlar rope run are given in Table 2. A vermiculite standard measurement made during June of 1994 yielded essentially identical efficiency values, as have several shorter runs done since October of 1993.

Table 2 - Analysis of vermiculite standard run (637,583 s). All errors are 2σ. All detectors were used in analysis.

Isotope	Peak Energy (keV)	Gross Counts	Net Counts
Th	2614	11257	10955(215)
	911	66962	14802(690)
	583	73852	22261(708)
U	1764	2657	1560(123)
	1001	-	-
	609	44466	7318(571)
K	1461	595661	582036(1561)

Using the above values, we are now able to calculate the concentrations of radionuclides in the Kevlar rope. The data from the Kevlar rope sample is stored in files which are nominally 12 hours (43,200 s) long. Each of these files can be examined for the number of counts in the peaks at 609 keV and 352 keV. These peaks are the most sensitive indicators of radon contamination. For the first 8 runs, for example (1σ errors):

Run No.	Net Counts (352 keV + 609 keV)
1	198 (19)
2	14 (9)
3	0 (9)
4	15 (9)
5	6 (8)
6	22 (9)
7	10 (8)
8	3 (9)

Note that it is NOT expected for there to be no counts in the sum of these two peaks. Even without any U present in the sample, there is still some U in the detector and shield, and there is probably a low level of radon in equilibrium in the gas within the shield. However, these levels indicate that it is safe, in this case, to use the data from all runs following #1.

All runs are examined for anomalous count rates at the 609 keV and 352 keV peak positions. The data for the Kevlar rope sample at the usual peak positions, for all detectors, is given in Table 3.

Table 3 - Final results for the Kevlar rope sample, background corrected. Mass of the sample was 13.450 kg. Counting time was 1,860,202 s. All errors are 2σ. Where a peak was not present above background, a 2σ limit is shown.

Isotope	Peak Energy (keV)	Gross Counts	Net Counts	Concentration
Th	2614	49	20.5(172)	232(209) ppt
	911	405	60.3(570)	506(524) ppt
	583	624	-69.1(1478)	<825 ppt
U	1764	81	16.1(286)	46(94) ppt
	1001	-	-	-
	609	861	29.8(865)	18(57) ppt
K	1461	2218	1991.8(980)	9.4(9) ppm

If we perform a weighted average on the Th values, we determine that the Th concentration is 255(189) ppt (2σ). Similarly, the U concentration determined by the above is 26(49) ppt (2σ).

So we see that the concentration of Th is well below the 1 ppb level, but is likely above 100 ppt. In addition, the U concentration is very low, making it seem unlikely that the Th level is due to contamination by rock dust.

Figure 1 - Full spectrum from Kevlar rope data (1,860,202 s). Mass of sample is 13.450 kg, volume of sample is 21 liters.

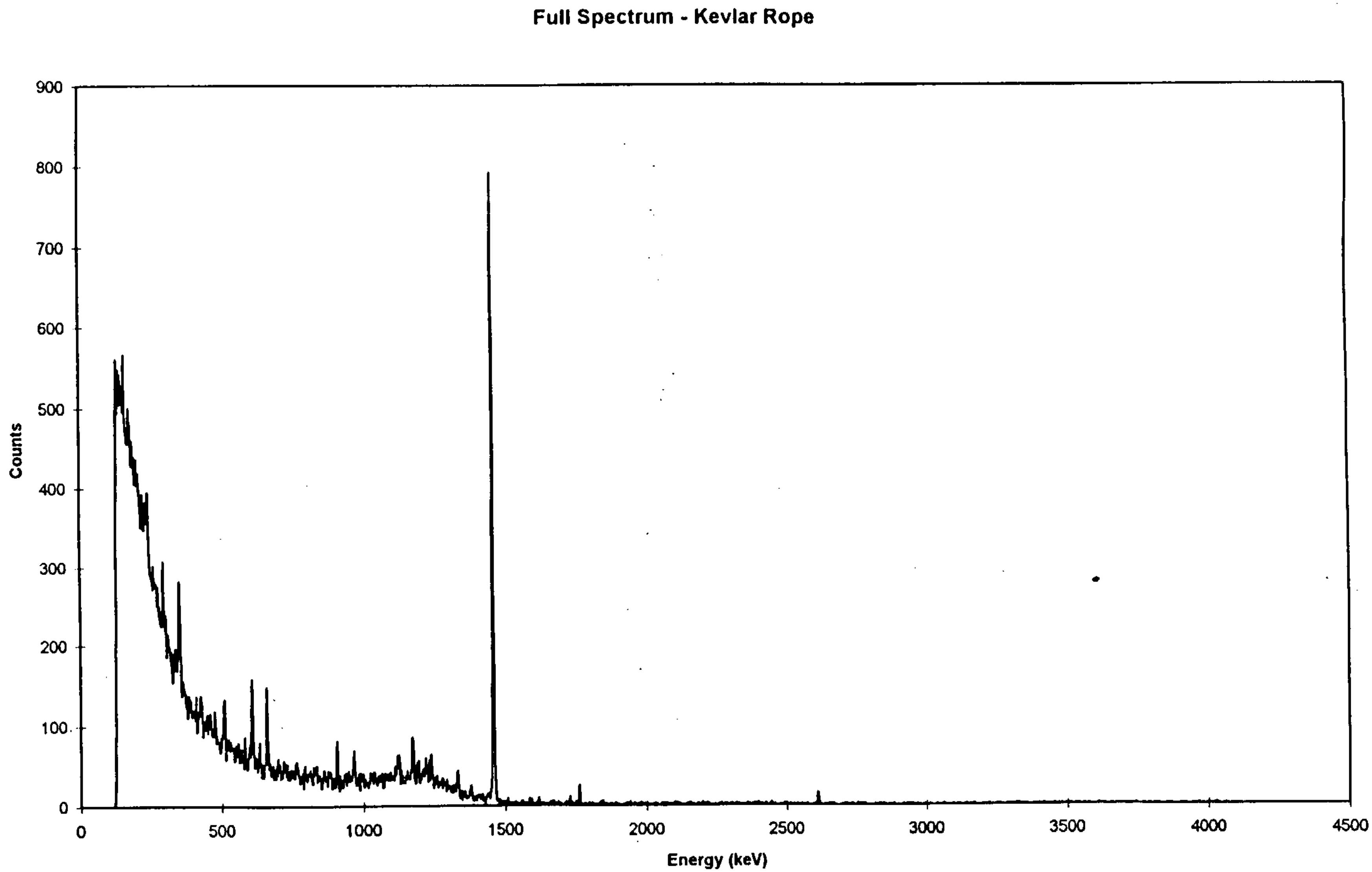

Figure 2 - 1461 keV region of Kevlar rope data. With background subtraction taken into account, the overall concentration of K is calculated to be 9.4 (9) ppm (2σ error).

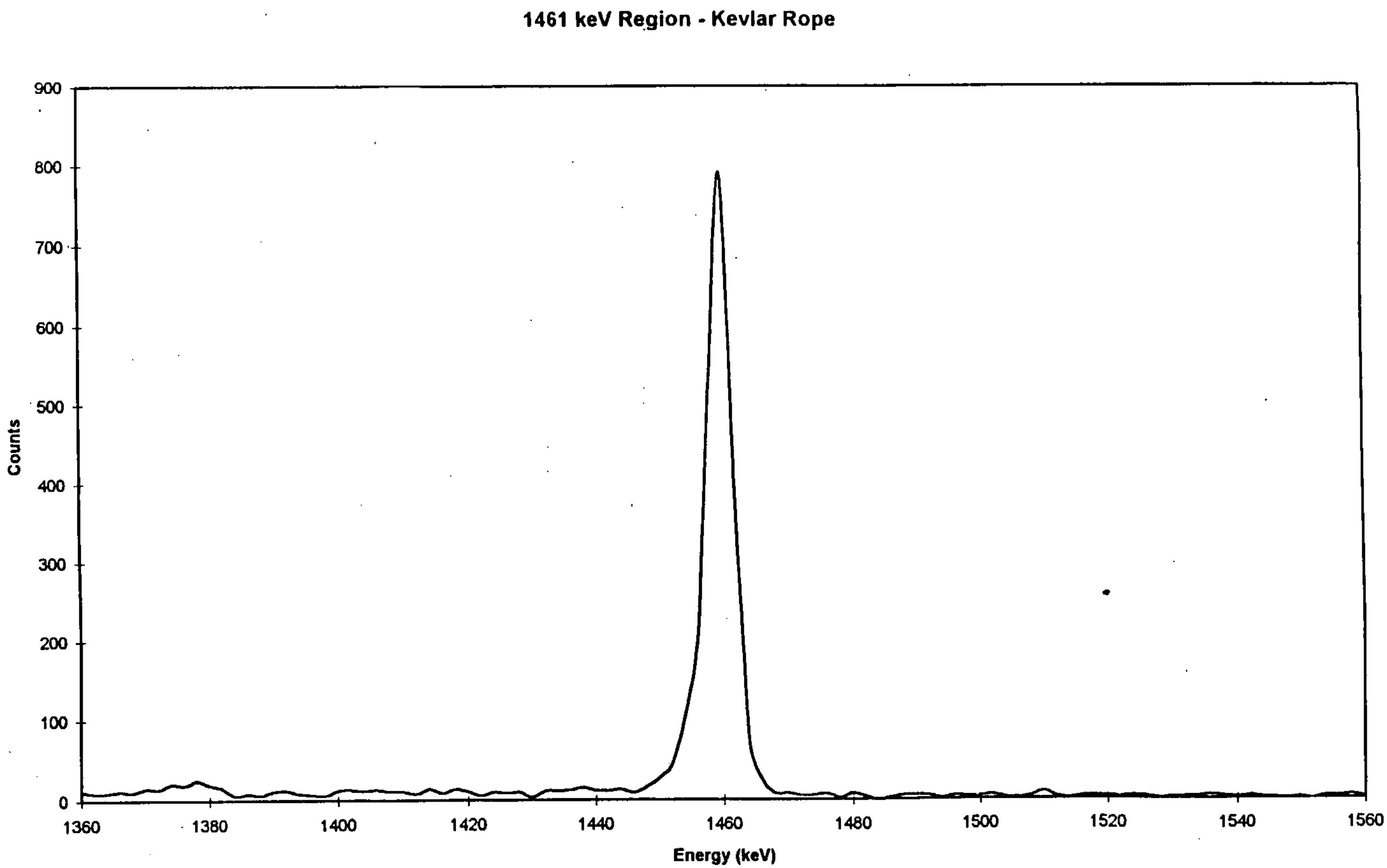

Figure 3 - 1764 keV region of Kevlar rope data. With background subtraction taken into account, the concentration of radioisotopes of U is calculated to be 26 (49) ppt (2σ error), including other peaks in a weighted average.

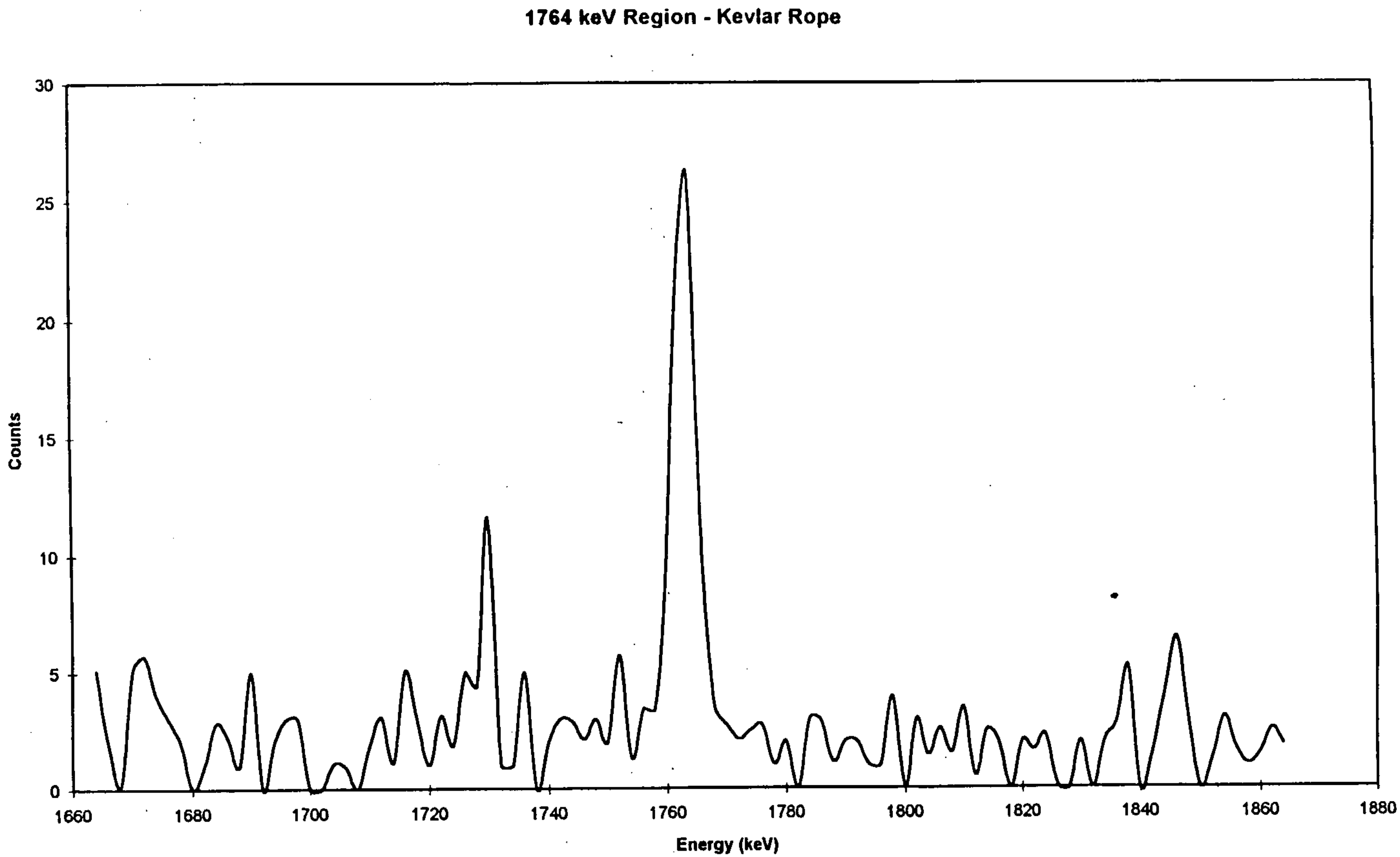

Figure 4 - 2614 keV region of Kevlar rope data. With background subtraction taken into account, the concentration of radioisotopes of Th is calculated to be 255 (189) ppt (2σ error), including other peaks in a weighted average.