HIROSAKI UNIVERSITY

Radiation Emergency Medicine 2014 Vol.3, No.1 56–58

REM
Radiation Emergency Medicine

Note

Spectrum Analysis of Gamma Rays Emitted from I-131 Using a Response Matrix for a 3"$\phi \times$ 3" NaI(Tl) Scintillator

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Received 5 June 2013; revised 5 July 2013; accepted 16 July 2013

A 22 × 22 response matrix for a 3"$\phi \times$ 3" NaI(Tl) scintillation spectrometer was derived to unfold pulse height distributions of gamma rays emitted from I-131. The unfolded energy spectra yielded information concerning fluxes and dose rates due to primary and scattered components, respectively.

Key words: response matrix, unfolding, NaI(Tl), I-131

1. Introduction

A 22 × 22 response matrix ranging from 0 to 3 MeV for a NaI(Tl) scintillator has often been used so far in order to unfold natural environmental gamma ray pulse height distributions[1]. The energy bin widths of this matrix, however, were too wide to distinguish between peaks which are quite near to one another when analyzing pulse height distributions due to radionuclides emitting lower energy gamma rays less than 1 MeV.

The purpose of this paper is to construct a new response matrix having narrower energy bin widths in order to analyze pulse height distributions due to gamma rays emitted from I-131. An example of spectrum unfolding will be also described to obtain the fluxes and dose rates due to primary and scattered components.

2. Derivation of the response matrix

The dominant energies of gamma rays emitted from I-131 are 0.2843, 0.3645, 0.6370 and 0.7229 MeV. Therefore, it will be sufficient if we construct the response matrix up to around 1 MeV. Then, we modified a Monte Carlo program SPHERIX[2], whose energy bin width below 1.2 5 MeV is 0.10 MeV, so as to derive a 22 × 22 matrix with an energy bin width of 0.05 MeV (22 × 0.05 = 1.10 MeV). An isotropic gamma ray incidence was assumed and 100,000 histories were traced for each energy bin. Table 1 gives the calculated result.

3. Unfolding

The unfolding technique of converting pulse height distribution into true gamma ray spectrum by means of the response matrix is described in detail[1].

Pulse height distributions measured in a room of a hospital where there is an I-131 therapy facility are used as test samples. Figure 1 shows one of the pulse height distributions. Spectroscopic identification of the energies for the photo-peaks due to I-131 shown in the figure was made in reference to Heath's spectrum catalogue[3]. A natural background distribution is also seen in the figure.

Figure 2 shows the pulse height distribution expressed in energy bin, where we can see the photo-peaks due to natural origin, i.e., K-40 (1.464 MeV), Bi-214 (1.765

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Table 1. Response matrix for a 3"ϕ× 3"NaI(Tl) in an isotropic field

Pulse height (MeV) \ Energy (MeV)	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
0.00	1	68.07																					
0.05	2	0.12	65.44																				
0.10	3	0.00	0.03	63.23	0.03																		
0.15	4	2.24	0.00	0.16	57.95																		
0.20	5	2.08	2.38	0.00	0.40	52.02	0.40																
0.25	6	2.31	2.20	2.03	0.00	0.71	46.44	0.71															
0.30	7	2.54	2.30	2.54	1.67	0.00	1.03	40.79	1.03														
0.35	8	2.57	2.37	2.31	2.56	1.26	0.00	1.33	36.39	1.33													
0.40	9	2.48	2.33	2.25	2.29	2.52	0.97	0.00	1.68	32.45	1.68												
0.45	10	2.33	2.30	2.22	2.21	2.29	2.45	0.78	0.00	1.89	29.01	1.89											
0.50	11	2.21	2.23	2.10	2.08	2.16	2.29	2.34	0.61	0.00	2.13	26.12	2.13										
0.55	12	2.00	2.05	1.98	2.01	1.99	2.07	2.25	2.04	0.52	0.00	2.18	23.93	2.18									
0.60	13	1.94	1.94	1.88	1.87	1.83	1.96	2.05	2.22	1.93	0.48	0.00	2.43	21.42	2.43								
0.65	14	1.73	1.73	1.75	1.72	1.74	1.80	1.91	1.95	2.21	1.80	0.45	0.00	2.51	19.82	2.51							
0.70	15	1.57	1.57	1.60	1.65	1.62	1.62	1.72	1.75	1.92	2.17	1.60	0.43	0.00	2.00	18.40	2.60						
0.75	16	1.54	1.54	1.53	1.49	1.49	1.51	1.53	1.65	1.76	1.94	2.16	1.53	0.39	0.00	2.65	16.79	2.65					
0.80	17	1.41	1.39	1.40	1.39	1.41	1.39	1.44	1.52	1.59	1.74	1.85	2.07	1.44	0.34	0.01	2.75	15.66	2.75	0.01			
0.85	18	1.35	1.26	1.32	1.32	1.34	1.36	1.32	1.33	1.48	1.56	1.63	1.82	1.93	1.34	0.36	0.01	2.85	14.56	2.85	0.01		
0.90	19	1.25	1.22	1.19	1.21	1.26	1.22	1.22	1.30	1.33	1.38	1.48	1.64	1.89	1.89	1.24	0.32	0.01	2.71	13.87	2.71	0.01	
0.95	20	1.08	1.12	1.14	1.12	1.13	1.17	1.13	1.17	1.21	1.30	1.34	1.51	1.67	1.71	1.86	1.18	0.30	0.02	2.82	12.91	2.82	0.02
1.00	21	1.06	1.03	1.10	1.11	1.08	1.11	1.10	1.15	1.15	1.14	1.27	1.33	1.43	1.58	1.71	1.78	1.12	0.30	0.03	2.93	12.01	2.93
1.05	22	0.98	0.98	0.98	0.97	0.97	1.05	1.05	1.03	1.11	1.12	1.16	1.19	1.24	1.38	1.49	1.69	1.74	1.01	0.32	0.03	2.80	11.55
1.10																							

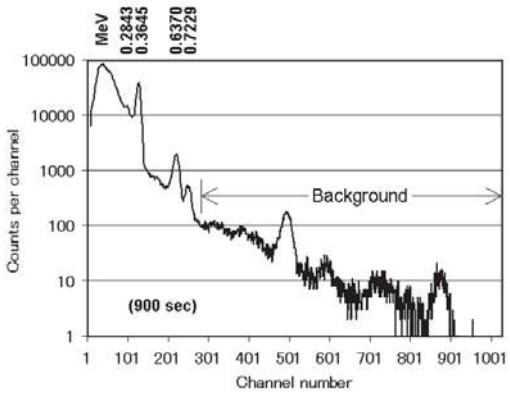

Fig. 1. Example of pulse height distribution.

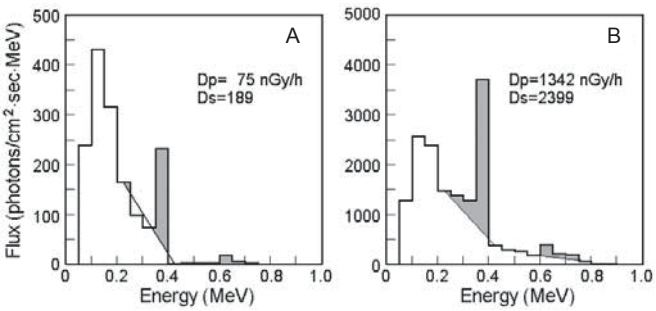

Fig. 3. Examples of energy spectra unfolded for pulse height distributions measured at locations A and B. The terms Dp and Ds represent the dose rates due to primary and scattered components, respectively.

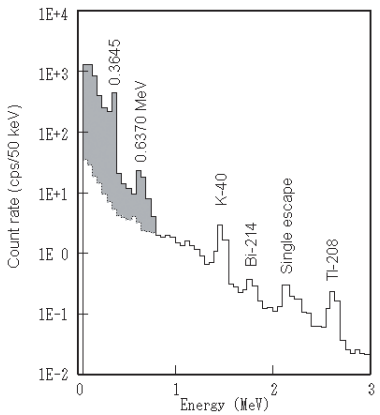

Fig. 2. Pulse height distributions due to natural origin (white part) and I-131 component (grey part).

MeV) and Tl-208 (2.615 MeV). In order to evaluate the component due only to I-131 origin, we have to subtract the natural background pulse height distribution from the total. The natural component shown in Figure 2 was estimated by normalizing an average shape of a number of natural background pulse height distributions at a count rate in bin number 22.

Figure 3 shows the unfolded spectra obtained by operating the 22 × 22 matrix to pulse height distributions measured at two locations in the room. The primary gamma ray fluxes due to I-131 were evaluated by linearly interpolating between the values at nearest bins outside the region occupied by the I-131 primary gamma ray peaks as shown with straight lines in the figure. The dose rates due to the primary component, Dp, and scattered one, Ds, are also given in the figure.

Acknowledgment

I thank Dr. M. Hosoda of Hirosaki University, who provided pulse height distribution data taken in a hospital. This study was approved by the Committee of Medical Ethics of Hirosaki University Graduate School of Medicine (Hirosaki, Japan).

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