A new algorithm for nuclide identification of HYPERGAM

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1. Introduction

HyperGam has been developed to analyze an HPGe γ-ray spectrum by Applied Nuclear Physics Group in Seoul National University [1]. In the previous work, the automatic algorithm of nuclide identification had been developed considering with yield, efficiency, energy and peak area of the γ-ray line from radionuclide to use the HyperGam as a tool of automatic spectrum acquisition and isotopic analysis for ambient radiation monitoring [2]. However, a mismatch in activity determination and a number of misses & false hits were revealed from the performance test [3].

In this study, a new algorithm for nuclide identification was developed. In addition correction routines for detailed identification were incorporated to the HyperGam package. Performance of the new algorithm was tested by using the IAEA 2002 test spectra. And the result of performance test was compared with those of the well-known software packages in γ-ray spectrum analysis.

2. New algorithm for nuclide identification

Fig. 1 summarizes the overall procedure for nuclide identification of the HyperGam. The procedure is divided into two stages. Users can determine the level of the identification considering the processing speed or the condition of measurement. At first stage, the HyperGam identifies nuclides in the spectrum by using the simple library (EML, TOI) which contains main γ-emitters for environmental radiation monitoring. Primary nuclides are determined through three tests (Ratio, Detection and Energy tests) considering a multiple of the emission yield, efficiency, energy and peak area of candidate nuclides [2].

The newly developed algorithm embodied in second stage performs sophisticated identification and quantitative analysis by using the expanded library. The library data was taken from Nudat2.5 (Nuclear Data2.5 : selected data derived from ENSDF and other sources)[4]. The library includes nuclides originated from natural decay chains (the uranium, actinium and thorium series), Pu-241 decay chains, reactor fuel cycle nuclides, fission product, fall out, activation in reactor (reactor inside and surrounding, isotope production and application), activation in accelerator (isotope production & application) and other activation.

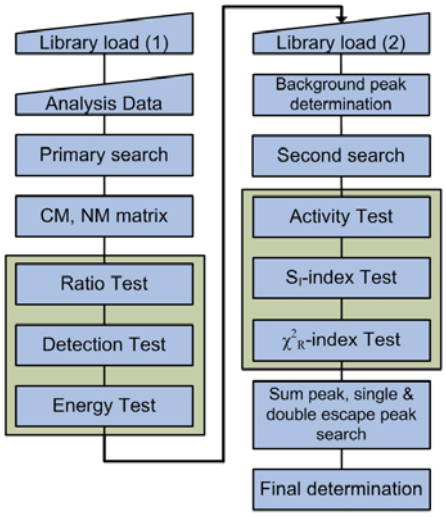

Fig. 1. Flow chart of the nuclide identification.

After loading the library, if the background spectrum exists, the background correction is performed based on the peak energy and count rate. At the second search step, uncertain peaks among matched peaks at the first stage are classified to the unidentified peaks based on the number of peaks of matched radionuclide and activity z-score. And candidate nuclides are re-selected by using the expanded library. The following three tests are conducted for nuclide identification. Firstly, an activity test is performed by comparing activity of radionuclide identified at the first stage with activity of unidentified peak. To verify the identification of a particular radionuclide in a spectrum, the number of detected peaks is compared to the number of possible peaks. This value gives more weight to the more intense peaks. It is expressed as the S_I-index :

$$S_{I,i} = \sum_{j=1}^{n} emission\ rate_{j,i} \Big/ \sum_{k=1}^{m} emission\ rate_{k,i}$$

where j is sum over the detected peaks of nuclide i and k is sum over the possible peaks of nuclide i. S_I-index is between 0 for no peaks detected and 1 for all peaks detected. And the reduced χ^2 test is conducted to identify multiple γ-ray emitters based on the probability of undetected γ-ray peaks.

Nuclides passed all the tests are determined final identified nuclides. And true coincidence sum peaks, single and double escape peaks and interfered peaks are checked for identified nuclides. Finally, weighted average activities of identified nuclides are determined by considering every identified peaks and the identification report is written.

3. Performance test

Performance of the nuclide identification by HyperGam has been tested by using the IAEA 2002 set of test spectra for low-level γ-ray spectrometry [5]. The result of the intercomparison in reference [6] was used in this study to compare to the HyperGam. The performance test was performed in the same manner as the previous test [3].

Fig. 1 shows the numbers of identified radionuclides, the misses and false hits and Table 1 shows the ratio of analyzed and certified activities for the MIX1EQ spectrum. With respect to the number of hits, the best performance tool is Inter Winner which reported 14 hits from 22 unknown nuclides, and the second best tool is the HyperGam which reported 13 hits. As can be seen in Table 1, analyzed activities of the Inter Winner are 10 times higher than certified activities for K-40, Pa-234m and Th-231, however the HyperGam reported reasonably good activities for the hit nuclides.

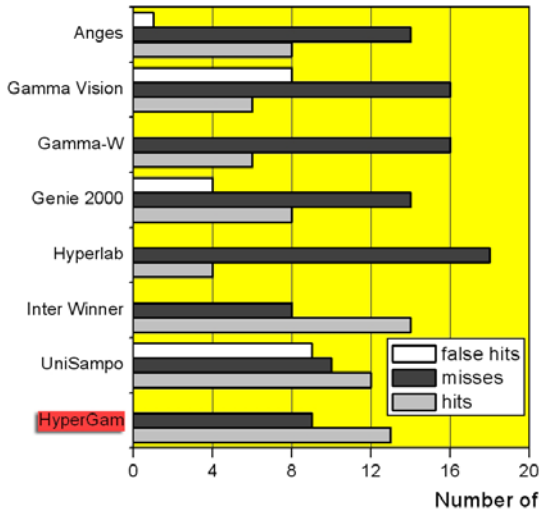

Fig. 1. Number of identified nuclides, misses and false hits in the MIX1EQ spectrum.

Table 1. Ratio of analyzed and certified activities for MIX1EQ spectrum.

Radioisotope	Inter-Winner	Hyper-Gam	Radioisotope	Inter-Winner	Hyper-Gam
K-40	39.13	N.D.	Th-227	0.73	N.D.
U-238	N.D.	N.D.	Rn-219	N.D.	0.94
Th-234	1.42	1.22	Pb-211	N.D.	N.D.
Pa-234m	14.26	1.15	Th-232	N.D.	N.D.
Ra-226	N.D.	0.79	Ac-228	0.98	0.94
Pb-214	1.29	1.01	Th-228	N.D.	N.D.
Bi-214	0.96	1.00	Ra-224	1.02	0.95
Pb-210	0.63	0.62	Rn-220	1.10	N.D.
U-235	1.18	1.33	Pb-212	N.D.	0.97
Th-231	10.48	N.D.	Bi-212	1.00	1.15
Ac-227	N.D.	N.D.	Tl-208	0.97	0.97

N.D. : not detected

4. Conclusion

A new algorithm with expanded library for nuclide identification was developed and implanted to the HyperGam. In addition, correction routines (background peak correction, interfered peak correction) and searching routines for coincidence sum peak, single & double escape peak were added. The automatic nuclide identification function of HyperGam was tested by using the IAEA 2002 test spectra. Comparing to the results of the previous test, false hits and unidentified peaks in the test spectra were reduced considerably. And the analyzed values of activities were close to the certified values.

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