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Construction of a generic reference material for gamma ray spectrometric analysis

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Abstract

An artificial reference material (RGMIX) has been constructed from three IAEA materials (RGU-1, RGTH-1, RGK-1). The material is analogous of an environmental radioactive material. The material is systematically analysed on a NaI(Tl) detector using the method of spectrum decomposition. The spectrum of the sample is similar to that of a geological material.

Keywords: *Gamma ray spectrometry; NaI(Tl) detector; Reference materials.*

1. Introduction

Human beings are exposed to radiation from naturally occurring radionuclides on the earth's surface. Prolonged exposure to these radiations can pose health challenges to the population. Therefore there is need for continuous monitoring of these radiations. In doing this correct methods and proper equipment should be used. Gamma ray spectrometry is an experimental technique used to determine levels of radionuclides in a variety of matrices. There are different types of gamma ray detectors that are being developed for purposes of radiation detection and measurements. Calibration of such detectors is done using reference radioactive materials. These reference materials are also used in calculation of activity concentration[1)]. Most of the reference materials contain one radionuclide only therefore not analogous of environmental and geological materials. In this work a special sample analogous to an environmental sample is constructed in our laboratory. This sample will be used in radioactivity measurements of geological materials.

2 Materials and Methods

2.1 NaI(Tl) gamma ray spectrometer

The gamma ray spectrometer consists of a shielded 3″×3″ NaI(Tl) detector. The system also includes an Oxford PCA-P Multichannel analyzer (MCA) card and its software for spectral data acquisition and analysis. The PCAP contains a high voltage supply, a charge sensitive pre-amplifier, a shaping amplifier, 80 MHz Wilkinson analogue to digital converter (ADC) with Multichannel Analyzer (MCA).

2.2 Standard samples and calibration

Calibration of NaI(Tl) gamma-ray spectrometer and decomposition of measured spectrum into components were done using three standard materials (RGK-1, RGU-1 and RGTH-1 for potassium, uranium and thorium respectively) which were obtained from International Atomic Energy Agency[2)]. Energy calibration of the spectrometer was performed using the following gamma - lines: ^{214}Pb (352keV), ^{40}K (1460 keV), ^{214}Bi (1765keV), and ^{208}Tl (2615 keV).

2.3 Construction of a secondary standard material

A secondary calibration material was prepared in our laboratory by mixing the three reference samples in appropriate ratios. This sample was named RGMIX. The activity concentrations of the three radionuclides (238U, 232Th and 40K) in this sample were computed from the available isotopic data. The RGMIX is considered analogous to most geological materials. The equivalent activity concentrations in the mixture were calculated. These were to be compared with those obtained after measurements. Table 1 shows the activity concentration of the three radionuclides in the standard samples and in RGMIX.

Table 1. Activity concentration of radionuclides in the IAEA samples and calculated activity concentrations in RGMIX

Material	Activity concentration (BqKg^{-1})		
	^{238}U	^{232}Th	^{40}K
RGU-1	4900±30	<4	< 0.6
RGTH-1	77±5	3280±70	6±3
RGK-1	<0.012	<0.04	13400
RGMIX	1250±20	1150±30	5400±90

2.4 Experimental procedures

The constructed sample (RGMIX) was sealed in a plastic container and kept for three weeks to achieve radioactive equilibrium between parents and daughter radionuclides in the Uranium decay series. The spectrum of this sample was measured on the NaI(Tl) gamma ray spectrometer for 30000s. The spectra for the other standard samples were also counted on the spectrometer. In order to determine the background components in the spectra, an inert

sample comprising of a plastic container filled with distilled water was counted in the same geometry as the samples.

2.5 Spectrum analysis

The spectrum of RGMIX was reduced to spectral components of its constituent radionuclides (^{238}U, ^{232}Th and ^{40}K) using the method of spectrum decomposition. This was performed as follows: a spectrum Y of a natural sample was assumed to comprise of the spectra of the three natural radionuclides and the background spectrum as shown in equation (1).

$$Y = Y_b + Y\left(U\right) + Y(Th) + Y(K) \quad (1)$$

Where Y_b is the background spectra and Y(U), Y(Th) and Y(K) are the spectra of ^{238}U and ^{232}Th decay series, and ^{40}K respectively. By subtracting the background, equation (1) becomes

$$Y = Y\left(U\right) + Y(Th) + Y(K) \quad (2)$$

To obtain the ^{232}Th component in the RGMIX sample, 2615keV gamma-line of ^{208}Tl photo peak which weakly interferes with others was selected. The ratio of its peak intensity in RGMIX to the corresponding intensity in the thorium standard (RGTH-1) was computed by using equation (3)

$$Y_{Th}(RGMIX) = aE(RGTh-1) \quad (3)$$

Where a is a constant and E(RGTh-1) is the spectrum of the thorium standard. This procedure was repeated to obtain the uranium and thorium components in the sample. Net counts (area under photo peaks) were determined by Gaussian fitting of the gamma ray photo peaks in the spectrum using origin software. With this method, errors due to photopeak interference were highly minimised. Figure 1 shows the spectrum of RGMIX.

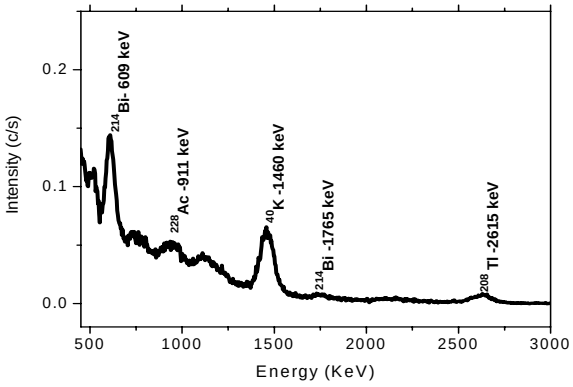

Figure 1. A gamma ray spectrum of RGMIX sample.

2.6 Activity concentration

The activity concentration of the three radionuclides in the constructed sample after spectrum decomposition are calculated using the relation[3)]

$$A = \frac{C_a}{\varepsilon P_r M} \quad (4)$$

where C_a is the net gamma counting rate (counts per second), ε the detector efficiency of the specific gamma-ray, P_r the absolute transition probability of gamma-decay and M the mass of the sample (kg).

These values were compared with those calculated from the isotopic data and concentration values provided in the reference materials preparation certificates[2,4)].

3. Results and Discussions

The spectrum of the constructed sample (RGMIX) is shown in figure1. It is evident that the spectrum is analogous of an environmental radioactive sample.

Table 2. Activity concentration of the three radionuclides after spectrum decomposition

Activity concentration of ^{238}U, ^{232}Th and ^{40}K in RGMIX after spectrum decomposition(BqKg^{-1})		
^{238}U	^{232}Th	^{40}K
1246±20	1139±20	5410±60

The calculated values of activity concentration after spectrum decomposition are shown in Table 2. The calculated activity concentrations after spectrum decomposition are not far from those obtained from the certificates.

4. Conclusions

An artificial sample analogous of an environmental radioactive sample has been successively constructed in our laboratories. This sample was analysed using the method of gamma ray spectrum decomposition. The measured activity concentrations of the three radionuclides, ^{238}U, ^{232}Th and ^{40}K in the constructed sample are not far from those calculated from isotopic data. The constructed sample can now be used as a reference material in measuring geological radioactive materials using gamma ray spectrometers.

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