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INVESTIGATIONS INTO THE LOW ENERGY GAMMA RAY BACKGROUND AND ITS VARIATIONS

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ABSTRACT. The gamma-ray background of Calcutta as determined by scintillation spectrometry using a NaI (thallium activated) crystal consists of two broad energy bands being contributed by the radioactive substances present in the soil, air and building materials and identified as those from the radium and thorium family. The background so determined indicates that there are two possible regions of low level counting which is achieved by choosing an optimum channel level and channel width. The variation in intensity of the background is restricted mostly to lower energy region of the background spectrum and is under further investigation.

INTRODUCTION

In low level counting using scintillation counters the background count is always a limiting factor. On the other hand in certain low level counting, as in bio-medical tracer technique different authorities, (Johnston, 1955; Anderson and Libby, 1957) Medical Research Council (Report 1956) have stressed the need of low doses of radioactive tracers in diagnostic and investigative works. Possibly it is safe to use a dose which is of the order of the natural background in its activity. Furthermore, in *in vivo* measurements during bio-medical tracer works, an effective shielding against the background is often not possible. Thus, in all the above cases an attempt at low level scintillation counting must essentially be preceded by a survey of the nature of the background at the particular place. This means the determining of the energy distribution in the background spectrum, the position of its main peaks, if any, and their relative intensities. As the gamma-emitters usually used in low level counting as in bio-medical work, like I (131), Fe (55), Cr (51), Au (198) etc., have characteristic energies below 700 KeV it is of interest to analyse spectrometrically the region below this.

Recently, many excellent review works on low level counting have been published (Hayes, Anderson and Langham, 1955; Anderson and Hayes, 1956). But hardly any attempt has been made in this country towards a spectrometric study of the background of the place before undertaking such studies. In this laboratory, this spectrometric work has been carried on for the last one year. In the following paper it is desired to report the results of the one-year investigation on the subject, the variations observed and the possible importance of the results obtained in low-level counting, for instance, in bio-medical tracer technique.

METHODS AND MATERIALS

The studies on the radioactive background of Calcutta were carried out with the help of RIDL Scientillation Spectrometer consisting of a Scaler model no. 16D, B-152; Ratemeter/Electronic Sweep Meter type 114-B, serial B-79; and Scintillation counter No. 43A with interchangeable NaI (thallium activated) crystal of ½″ thickness. The gamma energy distribution was determined under the following conditions: crystal used = NaI ½″ thick; counter voltage = 700 volts; period of sweep = ½ hour; ratemeter scale multiplying factor = 0.5; channel width = 2.0; percentage standard deviation = 10%. A full automatic sweep (without any attenuation) was taken in every case in differential position from 100–0 channel volts, the reset level heliopot being kept at '0'. The graphic record was made with the help of a Honeywell Brown Electronik Recorder automatically.

At the above setting of the instrument, graphic records of the background spectrum was taken throughout the whole year. At the same time, keeping the same instrument settings, scans of I (131) and Cr (51) spectrum were made and their peaks, 364 KeV and 330 KeV respectively were used to calibrate the background spectrum so obtained.

In order to eliminate possible influence of circuit oscillations in the discriminator or elsewhere, and also of photomultiplier noise on the background spectrum, the crystal of the counter was removed from the top of photomultiplier tube and the rest of the counter (consisting of photomultiplier tube, cathode follower, etc.) was wrapped light-tight completely in black paper and a full scan from 100–0 channel level volts was taken keeping the settings of the spectrometer as before.

To study the effect of shielding of the counter on the background spectrum, the counter was inserted in a lead castle with walls 1½″ thick and a full scan from 100-0 channel level volts was made under same instrumental settings. Observations were also made on the variation in background spectra with the changes in atmospheric conditions. Thus an attempt was made to note the variation of intensity below 75 KeV at different times of the day at two hours interval.

After calibration, the energies corresponding to the different peaks in the average spectra obtained were found to tally with those of radium and thorium emanations. To examine this fully the spectra of the important naturally occurring isotopes, viz., Ra (226) in the form of needle and Th (230) as crystal sample were recorded in the same graph containing the background spectrum under same instrumental settings. An attempt was made to trace the sources contributing to the background and the following materials were analysed: (1)

sand from Mogra, (usually used for the building materials here), (2) the silt from the banks of the Ganges, (3) soil samples from the northern and southern parts of the city and (4) the soil from around the building housing the spectrometer. To examine these, a lead chamber having 1 cu. ft. (approximately) of internal volume was constructed with walls 3″ thick. A background tracing with only the counter inside was taken initially and then each of the above samples was packed in the space with the counter placed in the middle. Care was taken to preserve the relative geometry of the counter with respect to the surroundings the same in every case.

RESULTS

The background spectrum consists of two broad energy bands. One such graph is given in Fig. 1. The whole energy spectrum extends from 50 to 275 KeV (Table I). On removing the crystal, a graph was obtained as shown in Fig. 2. This therefore gives the contribution due to circuit oscillations and photomultiplier noise. Comparing Figs. 1 and 2 one can easily recognise the resultant background intensities in this low energy region. Shielding of the counter with lead $1\frac{1}{2}$″ thick cuts off completely the broader higher energy band and attenuates the lower energy region to about $\frac{1}{3}$ of its unshielded value (Fig. 3). From Fig. 4, where the Ra (226) and Th (230) graphs are superposed on the background. one finds that the energy peaks corresponding to values round about 230—270 KeV and 105—120 Kev could be associated with the gamma-rays of Ra (226) and Th (230). These elements have been traced in the sand of the building materials and the soil of the city (Figs. 5-9; Table II). From these figures the relative contributions of the sand or of the soil may be clearly seen. Scanning for whole day at two hours intervals showed a variation in the intensity under 55 KeV. The maximum increase of the intensity in this region occurred round about afternoon. Attempts have also been made to indicate this variation together with that of atmospheric temperature and humidity as obtained from the Meteorological office, Alipore.

TABLE I

Results of the gamma ray spectrometric analysis of the background of Calcutta

	Energy range in KeV	Peak values in KeV	Maximum intensity range	Natural radio-active isotope with same energy range
Higher energy band	275–105	275, 245, 230, 185, 175, 170, 160, 135, 125, 105.	160–135	Radium and Thorium family

TABLE II

	Samples	Gamma ray energy range in KeV	Maximum intensity range in KeV
1.	Sand (from Mogra)	215–50	130–125
2.	Soil (from the Ganges)	170–50	145–125
3.	Soil (from Lake area)	265–50	140–125
4.	Soil (from Science College compound)	175–50	140–130
5.	Soil (from S.S.K.M. Hospital compound)	220–50	135–126

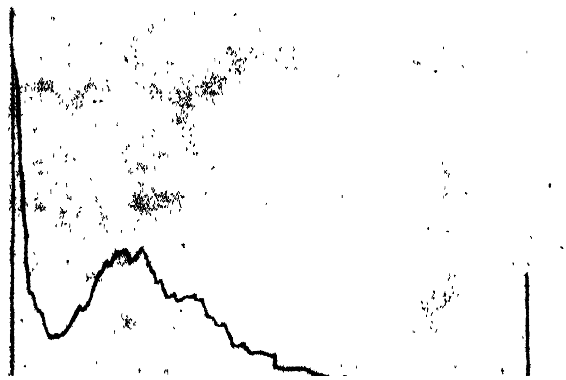

Fig. 1. Shows the radiation background of Calcutta. The scanning was done with the help of RIDL scintillation spectrometer from right to left. The energy of the gamma rays extends from 275–50 KeV.

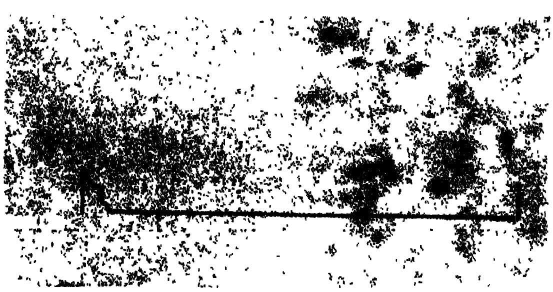

Fig. 2. Shows the contribution due to circuit oscillation and photomultiplier noise. This was taken with the crystal (NaI—thallium activated) removed.

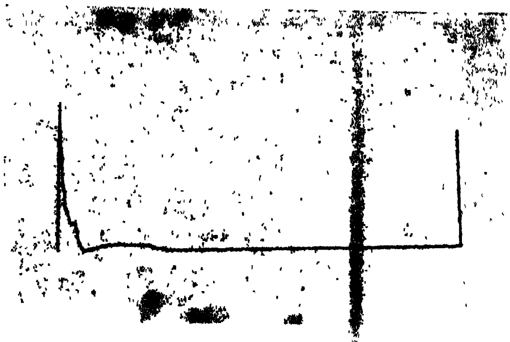

Fig. 3. Indicates the effect of shielding the probe with lead, $1\frac{1}{2}''$ thick. It shows the complete cutting off of the broader higher energy band and attenuation of the lower energy region to about 1/3 of its unshielded value.

Fig. 4. Shows the superimposition of the tracings due to Ra (226) and Th (230) on the background tracing. Note that the energy peaks of the background could be associated with the gamma rays of radium and thorium family.

Fig. 5. Shows the gamma ray contribution of soil, collected from lake area (South Calcutta), to the background of the place. The gamma ray energy range due to this extends from 265–50 KeV.

Fig. 6. Shows the gamma ray contribution of soil, collected from Science College (Calcutta) compound, to the background of the place. The gamma ray energy range due to this extends from 175–50 KeV.

Fig. 7. Shows the gamma ray contribution of sand, collected from Mogra, to the background of the place. The gamma ray energy range due to this extends from 215–50 KeV.

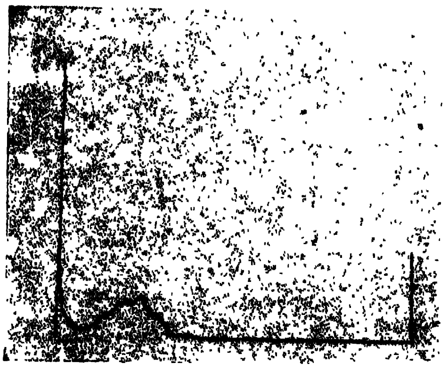

Fig. 8. Shows the gamma ray contribution of soil, collected from the Ganges, to the background of the place. The gamma ray energy range due to this extends from 170–50 KeV.

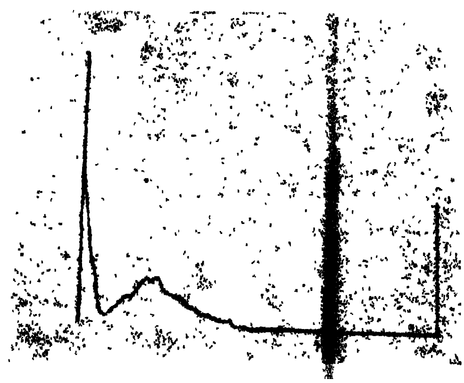

Fig. 9. Shows the gamma ray contribution of soil collected from the S.S.K.M Hospital compound, to the background of the place. The gamma ray energy range due to this extends from 220–50 KeV.

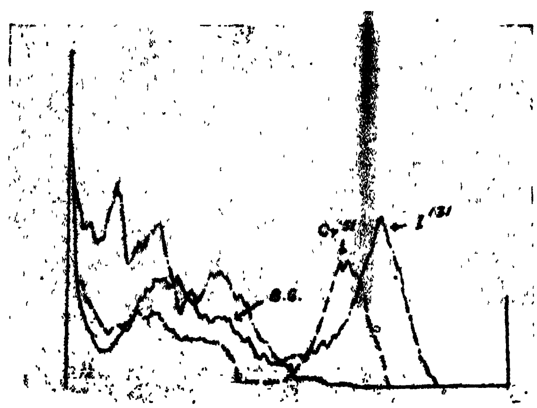

Fig. 10. Shows the superimposition of the three gamma ray spectra due to the background (——), radio-iodine (I–131, —.—) and radio-chromium (Cr-51, — — —). It shows that 50% of the count due to the two isotopes for a particular sample lie above the highest energy limits of the background.

Fig. 11. Shows the background scan carried out at Eindhoven, Holland, with the help of Philips Scintillation Spectrometer. Note the important peaks round about 90 and 220 KeV with possible peaks at 50 and 28 KeV.

Scanning with samples of I (131) and Cr (51) showed that nearly 50% of the counts resulting from particular sample were above the highest energy limits of the background (Fig. 10). This, more or less, was experienced with the other isotopes mentioned above except Fe (55) in which case the radiations were found to be concentrated in the region 90–105 KeV.

A similar background scan was carried out at Eindhoven, Holland, by one of the authors with the help of Philips scintillation spectrometer. The graph thus obtained has important peaks round about 90 and 220 KeV with possible peaks at 28 and 50 KeV, and is similar to the ones obtained here. The intensity of the energy round about 80 to 90 KeV was greatest. The energies in the spectrum would correspond to those found in the members of the uranium and radium family (Fig. 11).

DISCUSSION

The background of Calcutta consists of 2 broad energy bands being contributed by the radioactive substances present in the soil, air and the building materials. The radioactive elements present are those of the Radium and Thorium family.

From the background spectra obtained it is evident that most of the background counts are concentrated in 2 regions—the first between 260 to 135 KeV after which on both sides the counts fall off rapidly and the second region is found to be below 65 KeV. Therefore, in low level counting as with the isotopes for bio-medical tracer work it is necessary only to adjust the channel level of the pulse-height analyser in such a way as to eliminate these regions. The background counts automatically will then fall off without going into the problem of shielding. The best procedure would be to set the channel level potentiometer to a value which corresponds to energies higher than 270 KeV and then expanding the channel window to include the characteristic peak of the isotope being used within the channel window which lies above 275 KeV. The window width preferably should be greater than 2W where 'W' is the recorded half width of the photopeak of the isotope used. In the case of Fe (55) the window should be adjusted near about the trough found between the higher and lower energy bands, i.e., between 65 and 105 KeV. Hence there are 2 regions of low level counting—one above 270 KeV and the other in trough between the higher and lower energy band, i.e. between 60—105 KeV. Thyroid uptake measurements with low doses using the above procedure yielded more reproducible results.

The effect of shielding on the 2 energy bands of the background may at first sight seem to be anomalous as because the lower energy region is expected to be cut off more easily than the higher energy rays on shielding. Possibly, low energy secondary radiations produced by cosmic rays in the material of the shield is responsible for this.

The reason for the variation in the intensity of the low energy region as obtained during certain period of the day cannot be explained satisfactorily right now without further investigation. According to Wait (1937) there is some fluctuation in the gamma-ray content of the atmosphere with a maximum at about noon. This is in agreement with our observation. Further, others (Wilkening, 1952) have reported the variation in the radon and thoron content of the atmosphere with the time of the day. The present investigation points out that this variation in background is restricted mostly to low energy region of the background spectrum. This is a subject matter of further investigation.

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