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Dose Rate Measurement by Analysis of Radioactivity Concentration: A Study of Sedimentary Sample

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Elemental radioactivity assessment is one of the prevalent practice for Gamma spectroscopy. In the current study, dose rate has been assessed in the sedimentary sample taken beneath an old living Banyan tree which is designated as Heritage tree of Chandigarh and an old tree from Fatehabad region. The assessment of Radioactive concentration has been done by using coaxial n- type HPGe detector. For the dose measurement in the sedimentary sample, the energy peaks corresponding to K and progenies of Uranium and Thorium has been analyzed in the Gamma spectrum of the sample.

Keywords: Dose rate, FWHM, Gamma spectrum, HPGe detector, Elemental concentration

1 Introduction

Radioactivity investigation can be done by using Traditional methods which includes alpha spectrometry, mass spectrometry or liquid-scintillation counting, However, these methods can measure only low level natural isotopes. Mineral grains present in the sediments has the potential to trap signal due to long lived radionuclide in the Natural environmental radioactivity. Gamma spectroscopy method can be used to measure the concentration of these ionizing radiations. The concentrations of U, Th, and K present in the sample can be estimated using this technique. However, other standard practise for the valuation of Uranium and Thorium is ICP-MS (Inductively Coupled Plasma Mass Spectrometry) but this needs a many pre-treatments. Gamma ray spectrometry by High Pure Germanium Detector adopts simple preparation methods and analyze the radioactivity concentration using decay products in the sample. HPGe detector identifies the emitted gammas from the sample. The radioactive isotopes usually release γ of intrinsic energy thus assessment of this energy will lead to the type of isotope and hence its activity.

In present study, the sediment sample beneath an old living Banyan tree of Chandigarh region and an old Banyan tree from Fatehabad region in India are analyzed and their dose rate has been estimated using HPGe detector. The sites have been chosen so that the age of these old Banyan trees could be estimated scientifically and as the sediments have potential to store the dose received during burial so sedimentary dose rate estimation is a mandatory part of the investigation. As Chandigarh region has a number of heritage banyan trees whose age has been given by wildlife and forest department which has no scientific authentication. Present study is intended to find the age of old banyan tress using Optical Stimulated Luminescence.

2 Materials and Methods

2.1 Sample Collection

The sediment sample beneath an old living Banyan tree of Chandigarh region region and an old Banyan tree from Fatehabad region in India are extracted by digging a pit near the trunk of tree. The samples have been taken in a pipe from a depth of 1 m below the surface. Any other external contamination has been avoided while extracting the sample. The sedimentary sample was sealed immediately after extraction. Sediments from both the extreme corners of pipe were discarded while working for dose rate. In the laboratory, the homogenized sample is dried in oven at 150 ^{0}C after removing (by sieving) out pebbles and unwanted objects. The sample was stored for twenty days to achieve secular equilibrium.

2.2 Instrumentation

For present experiment, coaxial n type HPGe detector (Canberra, GR-2018) is used. It has relative efficiency 20 % and peak to Compton ratio of 50. The Full Width at Half Maxima (FWHM) Resolution in is

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1.8 keV for 60Co gamma-ray energy of 1.3 MeV. The gamma ray spectrum has been analyzed using Genie -2000 software.

2.3 Decay schemes

Primary natural radionuclides are present in Soil's Geological matrix. It generally includes Single Potassium-40 and decay series of Uranium and Thorium (Fig. 1). The decay produces alpha, beta particles and gamma radiations. Gamma radiations are used for spectroscopy due to their greater penetration power. The idea is that the daughter nuclides of Uranium and Thorium have same activity concentration as that Parent.

Energy peaks of daughter elements in U and Th series were observed in the gamma spectrum which are assessed to estimate elemental concentration.

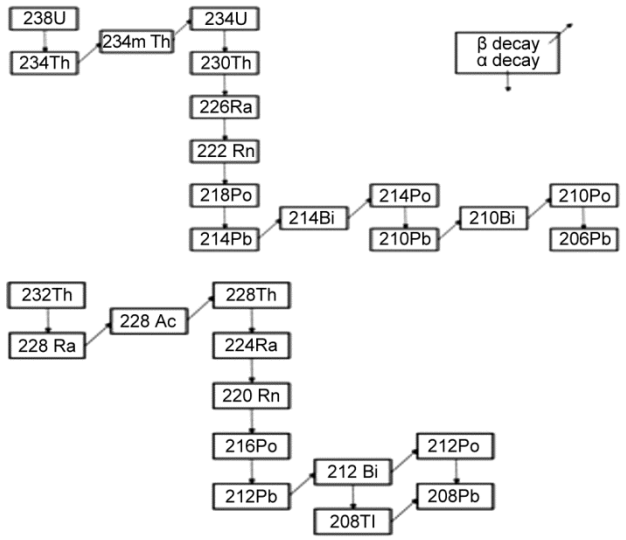

Fig. 1 — Decay series of Uranium and Thorium

3 Results

The sediment sample of 50 gm was observed for 8 hours and a spectrum was obtained by using Genie 2000 software (Fig. 2 (a) and (b)). For assessment of dose rate, the activity of Uranium, activities of Ra-226 (186 keV), Pb-214 (295 keV, 352 keV) and Bi-214 (609 keV, 1120 keV, 1700 keV) were measured. Also for Thorium estimation, the activity of Pb-212 (238keV) and Ac-228 (911 keV) were measured. For Potassium estimation, its own gamma ray energy i.e. 1460 keV was used. The spectrum obtained has shown in the Fig. 3. To measure specific activity of the radionuclides, absolute method given by equation (1) was used.

$$\text{Specific Activity } \left(\frac{\text{Bq}}{\text{kg}}\right) = \frac{(\text{CPSs} - \text{CPSb})}{\text{e.I.m}} \quad \ldots (1)$$

where CPS_s is count rate (counts per second) of sample and CPS_b is count rate of background, e is the efficiency with respect to energy as shown in Fig. 2, I

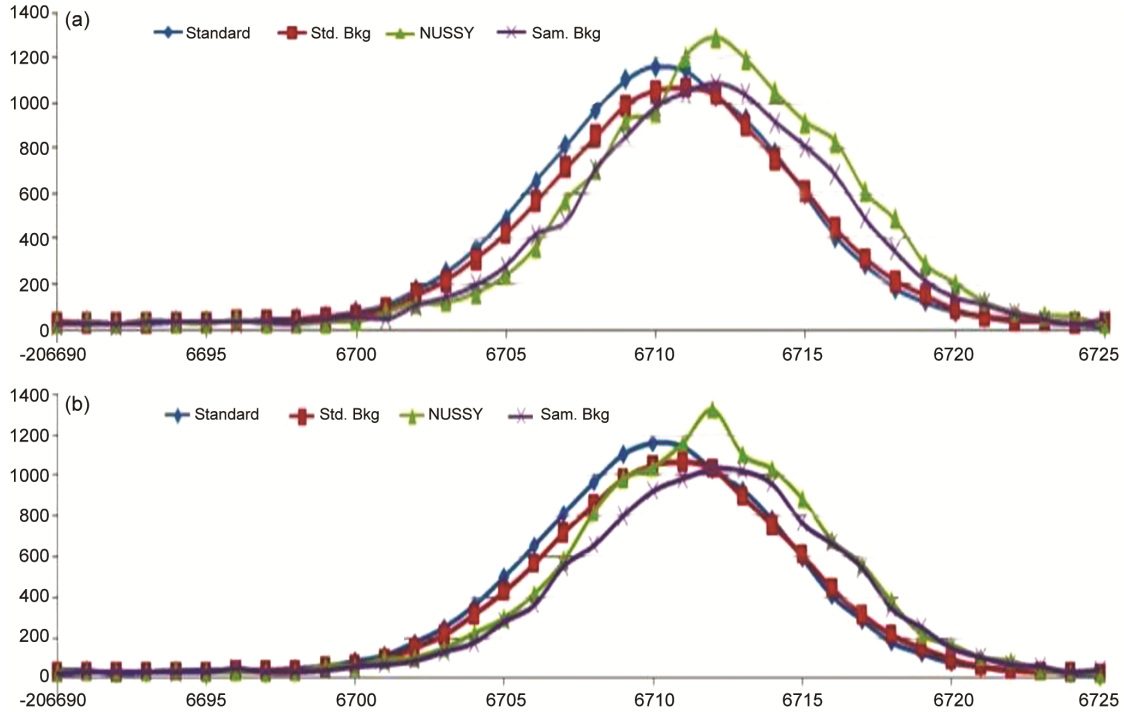

Fig. 2 — (a) Comparison of counts FTB-01; and (b) for sample CHD-03

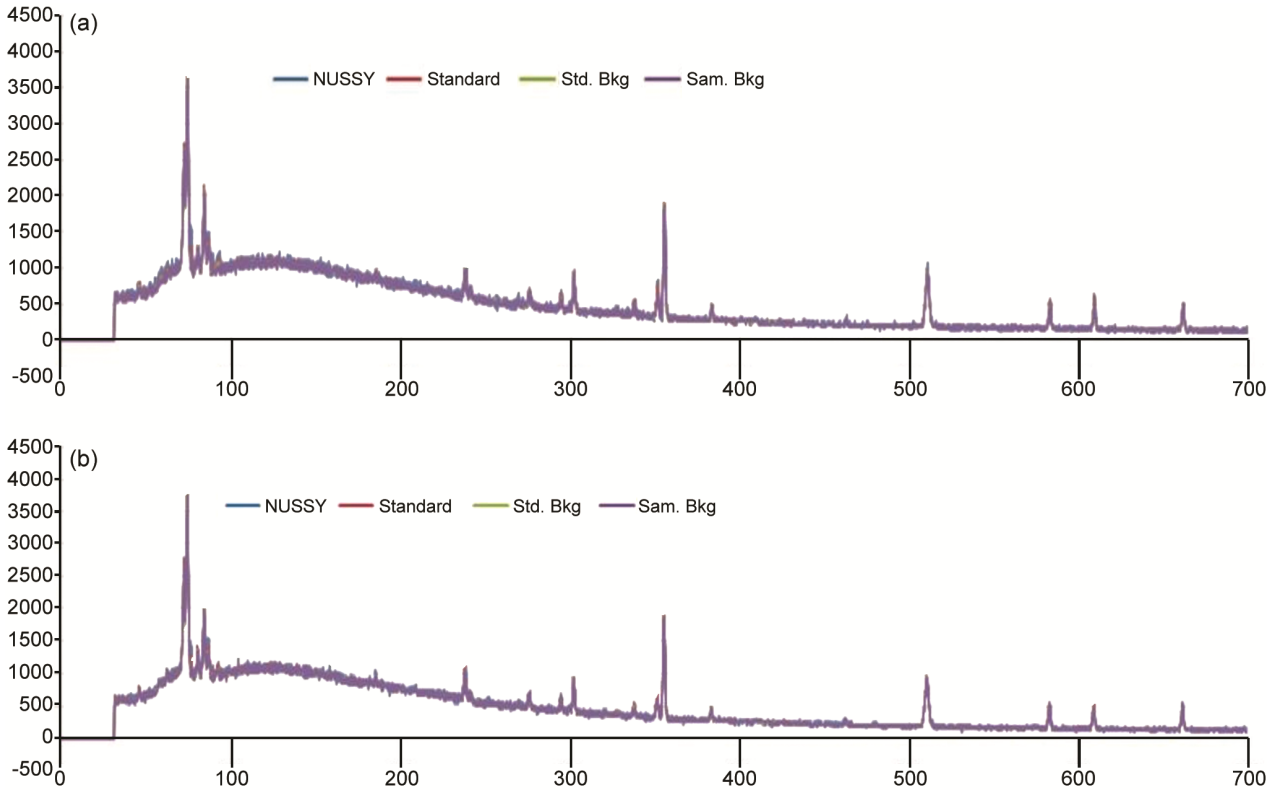

Fig. 3 — (a) depicts sample and background Gamma spectrum of FTB-01; and (b) for sample CHD-03

Table 1 — Concentration of nuclides present in the sample CHD-03 and FTB-01

Radioactive Nuclei	Nuclides	Energy (keV)	Elemental Concentration FTB-01	Elemental Concentration CHD-03
K	K- 40	1460	1.514014	1.867946
U	Ra-226	186	3.846136	2.282182
	Pb-214	295.2	2.182807	2.408044
	Bi-214	352	3.606642	2.172919
		609.3	4.206351	3.392596
		1120.3	1.139394	3.305967
		1700	3.246029	0.69442
Th	Pb-210	46.6	7.013484	5.009066
	Pb-212	238.6	19.9827	11.84031
	Ac-228	911.1	17.22319	5.101462
	Tl-208	2614.5	44.33944	49.89991
		583	11.61677	9.187434

is the photon yield and m is the mass of sample in kilogram. Photon yield and energy values are used by referring International Atomic Energy Agency database.

The elemental concentrations for Thorium and Uranium are measured in units of parts per million (ppm) and of percent (%) for potassium (Table 1). Conversion factor (Table 2) has been used as nuclide's activity has to be converted from Bq/kg to ppm for Uranium and Thorium.

Table 2 — Conversion factor for U,Th and K

Nuclie	Bq/kg	ppm
U	1	0.081
Th	1	0.246
K	1	32.3

For K, conversion factor is 313 Bq/kg equals to 1 % of K.

Total dose rate calculation has been done by considering the average dose rates corresponding to different peaks of Uranium and Thorium series. Assessed dose rate for Potassium, Uranium and Thorium is depicted in Table 3.

Table 3 — Results of Uranium, Thorium, potassium concentration and dose rate of sample

Sample name	U(ppm)	Th(ppm)	K %	Dose rate ($Gy.ka^{-1}$)
CHD 3	2.7± 0.3	22.3±1 3.9	1.9± 0.1	3.8±0.7
FTB-1	3.0±0.7	27.2±8.6	1.5±0.1	3.8±0.4

4 Conclusion

The Dose rate in the sediment sample of old Banyan trees has been assessed using HPGe detector. Dose rate has been found to be 3.8±0.7Gy ka^{-1} for CHD-3 and 3.8±0.4 for FTB-1. Requirement of less pre-treatments of sample lead the author to use Gamma spectroscopy for the Estimation of elemental radioactivity in sedimentary sample. Thorium concentration appears to be higher as compared to the Uranium because of less mobility of thorium due to its insolubility. As study areas receives sediments mainly from Shivalik foothills and Uranium gets away due to higher mobility as compared to that of Thorium.

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