Radiopurity studies of the rock samples from the probable sites for an underground laboratory

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Introduction

Efforts are underway in India to setup an underground laboratory for neutrino physics and rare nuclear processes. The radiation from surrounding rocks can have a significant impact on the sensitivity of these experiments and hence it is important to assess the base background. With this motivation, radiopurity measurements have been carried out on rock samples from a few probable sites for the underground laboratory using low background gamma spectroscopy. The rock samples are collected from possible tunnel sites near Jhakri dam and Atal tunnel in Himachal Pradesh, and Zojila pass in Jammu and Kashmir. Measurements have been carried out using TiLES (TIFR Low Background Experimental Setup) [1], employing only passive shielding, to measure the trace elemental concentrations of primordial elements like ^{238}U, ^{232}Th and ^{40}K.

Experimental details

Sample information details are listed in table I. The gamma ray spectra of three rock samples were measured in TiLES [1] at TIFR, Mumbai at sea level. The TiLES consists of a ∼70% relative efficiency high-purity Germanium (HPGe) detector with a passive shielding of 5 cm OFHC copper + 10 cm low activity lead. The rock samples were mounted on a perspex plate, in a close counting geometry to maximise efficiency. Data were recorded using a 14-bit, 100MHz CAEN 6724 series commercial digitizers and analyzed using C++ based ROOT [2] and LAMPS [3] software. The typical energy resolution of the detector is ∼2.7 keV at 1460 keV. Figure 1 shows a comparison of time normalized spectra (t= 1 day) of all three rock samples.

TABLE I: Details of rock samples and counting

Location	Sample tag	m (g)	Approximate shape	t days
Atal tunnel	Atal	6.89	Cuboid	28.90
Jhakri dam	Jkr	10.77	Sector	8.62
Zojila pass	Zojila	130.02	Cuboid	19.77

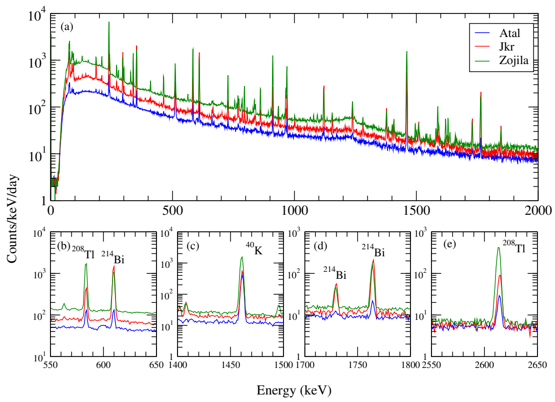

FIG. 1: A comparison of Gamma ray spectra of all three rock samples.

Data Analysis and Results

From the observed gamma rays, the specific activity A_γ of different elements can be esti-

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mated as,

$$A_\gamma = \frac{N_\gamma}{I_\gamma.\varepsilon_\gamma.t.m} \quad (1)$$

Where N_γ is the photopeak counts, I_γ is the branching ratio, ε_γ is the photopeak detection efficiency, t is the counting time and m is the mass of the sample. The photopeak detection efficiency for various gamma rays energies is obtained using the GEANT4 based simulation program [1]. The measured density of the rock and standard rock composition is employed in the simulations and 10^6 events were generated uniformly and isotropically within the sample for each energy of interest. The irregular shape of the rocks is approximated to the closest regular geometry for efficiency calculation and the uncertainties in the efficiency due to variation in rock dimensions about mean values were estimated. It should be mentioned that for in the close counting geometry, the observed photopeak yields need to be corrected for loss due to coincident summing.

From the measured specific activity listed in Table II, assuming the secular equilibrium and standard rock compositions, the trace atomic fraction F_E are estimated as,

$$F_E = \frac{A_E M}{\lambda N_A} \quad (2)$$

where A_E is the specific activity in Bq/g, M is the molar mass in g/mol, λ is the decay constant in s^{-1} and N_A is Avogadro's number. The molar mass was assumed to be that of the BWH rock [4] (21.69 g/mol). The estimated trace concentrations of the primordial nuclides for these rock samples are listed in Table III.

TABLE II: Measured specific activity (in mBq/g).

Nuclide	E_γ(keV)	Atal	Jkr	Zojila
^{214}Pb (^{238}U)	295.2	16.1 (8)	218 (4)	19.2 (4)
^{212}Pb (^{232}Th)	238.6	25 (2)	84 (2)	48 (3)
^{40}K	1460.8	637 (10)	651 (14)	244 (5)

TABLE III: Trace element concentrations (ppm) in rock samples.

Sample tag	^{238}U	^{232}Th	^{40}K
Atal	0.12(1)	0.58(5)	1.30(2)
Jkr	1.60(2)	1.93(5)	1.33(3)
Zojila	0.140(3)	1.11(7)	0.50(1)

All three samples show moderate ^{40}K content (0.5-1.3 ppm). The Atal rock sample has lowest concentrations (less than 1 ppm) of ^{232}Th and ^{238}U, although somewhat higher than the nearby Aut region [5]. The Jhakri sample shows relatively higher levels (~ 2 ppm) of ^{232}Th and ^{238}U. Therefore, from gamma and neutron background considerations Atal tunnel region will be preferable.

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