Journal of Environmental Radioactivity 167 (2017) 54–61

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Measurements of background radiation levels around Indian station Bharati, during 33rd Indian Scientific Expedition to Antarctica

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ARTICLE INFO

Article history:
Received 18 May 2016
Received in revised form
22 November 2016
Accepted 24 November 2016
Available online 1 December 2016

Keywords:
Antarctica
Radioactivity
Gamma radiation level
HPGe
TLDs
PADC

ABSTRACT

A comprehensive measurement of radioactivity concentrations of the primordial radionuclides ^{238}U, ^{232}Th and ^{40}K and their decay products in the soil samples collected from the sites of Indian research stations, Bharati and Maitri, at Antarctica was carried out using gamma spectrometric method. The activity concentrations in the soil samples of Bharati site were observed to be few times higher than of Maitri site. The major contributor to radioactivity content in the soil at Bharati site is ^{232}Th radionuclide in higher concentration. The gamma radiation levels based on the measured radioactivity of soil samples were calculated using the equation given in UNSCEAR 2000. The calculated radiation levels were compared with the measured values and found to correlate reasonably well. The study could be useful for the scientists working at Antarctica especially those at Indian station to take decision to avoid areas with higher radioactivity before erecting any facility for long term experiment or use.

1. Introduction

Antarctica and the surrounding ocean are the world's last frontiers and cover an enormous area of around 14 million km^2. Being the coldest, driest and the windiest continent on Earth, it is challenging to work in this region. However, it creates multiple opportunities for scientific research. National Centre for Antarctic and Ocean Research (NCAOR) Goa, has recently established the second research station, namely, Bharati, in the Larsmann Hills region of Antarctica at 69°24.41′S, 76°11.72′ E approximately at 35 m above sea level with an objective to facilitate scientific research activity in the field of atmosphere, earth and bioscience (Bakshi et al., 2013). The station is located 3000 km away from the first station namely, Maitri which is operational since 1990. To maintain the logistics of the station and to carry out research activities, about 25 persons reside at the station throughout the year. During the summer expedition, 20–30 additional personnel stay for a period of about four months.

Cai et al. (1995) measured background radiation levels around the Chinese station Zhongsham, Antarctica (latitude 69°22′23.36″S longitude 76°22′17.14″E) using LiF:Mg,Cu,P based TLDs (Thermo Luminescence Dosimeters). However, to the best of our knowledge, there is no report on the measurement of the radioactivity of soil and rock samples around the Chinese station. It is noted that the Chinese station is located very near to the Indian station Bharati. Earlier, some preliminary measurements on the background radiation levels in and around Bharati station using the passive dosimeters such as TLDs, solid state nuclear track detectors (CR-39) and a gamma survey meter were carried out during the 32nd summer expedition of Indian Scientific Expedition to Antarctica (INSEA) (Bakshi et al., 2013). In this study, it was reported that gamma radiation levels at Bharati site were higher than that at Maitri. Some locations at Bharati showed gamma radiation levels in the range of 600–700 nGy/h which is a few times higher than the gamma levels at Maitri (100–200 nGy/h). In view of the above, the present study was undertaken during 33rd summer expedition of INSEA with the following objectives: (i) measurement of radioactivity of soil samples around Bharati station in order to correlate the higher gamma radiation level with the soil activity, (ii) measurements of neutron and gamma radiation levels using passive dosimeters to estimate the background radiation at and around

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http://dx.doi.org/10.1016/j.jenvrad.2016.11.025
0265-931X/

Bharati Station and (iii) to understand distribution of terrestrial gamma dose rate due natural radionuclide at Bharati site.

2. Materials and methods

2.1. Collection of soil samples

The soil samples were collected from ten different sites of Bharati and three different sites of Maitri and processed as per the procedure described in IAEA TRS-295 (IAEA, 1989). The procedure involved the following steps: (i) selection of the location, (ii) recording of latitude and longitude coordinates of the location, (iii) recording of the GM Survey meter reading after stabilization (iv) demarcating an area of approximately 1 m × 1 m and removing all the pebbles, stones or other debris, if any, (v) scraping the surface adequately, (vi) collection of approximately 1–1.5 kg of soil sample covering the demarcated area from each location and (vii) storing the sample in a plastic bag and sealing the bag in another plastic bag with identification details including global positioning system (GPS) coordinates and gamma survey meter readings. For the comparison of activity, soil samples from three locations around Maitri site were also collected. It is noted that although Antarctica is an extremely cold region, however, it is reported that (Luis, 2013) the vegetation/organic components of Antarctica consists of flowering plants namely Deschampsia antarctica and Colobanthus quitensis, 27 liverworts, 111 species of mosses, 380 species of lichens and more than 300 species of algae and cynobacteria. It was noticed that surface of soil had traces of organic components mentioned above in several sites. Hence scraping was carried out uniformly to avoid those organic components at the time of soil collection. Same procedures were followed while collecting soil samples at Maitri site also.

2.2. Processing of soil samples

From the collected soil samples, soil of grain size up to 500 μm was separated using a sieve and dried. It is noted that, calibration standards used in the study such as IAEA RGU – I,RGTh-I and RGK-I. RGU-I has a 58% of its particles with a size lower than 37 μm and, in total, 100% lower than 104 μm. RGTH-I has a 78% of its particles with a size lower than 38 μm and, in total, 97.7% lower than 74 μm whereas RGK-I has a grain size a little bit higher, with an 8% between 200 and 160 μm and the rest, smaller. The average grain size of the soil samples collected from Antarctica is about 200 μm. The processed samples were filled in the cylindrical plastic containers (Ø 7 cm × 6.5 cm), sealed the plastic container with Araldite gum followed by few layers of electrical insulation tape so that it is air tight and kept for about one month so as to ensure secular equilibrium between radium and radon progenies of both uranium and thorium series.

2.3. Measurement of radioactivity

The samples were analysed using high resolution gamma spectrometry system consists of coaxial p-type High Purity Germanium (HPGe) detector having 50% relative efficiency with respect to 7.62 cm × 7.62 cm NaI (Tl), its energy resolution measured in terms of full width at half maximum (FWHM) is 1.9 keV at 1332.5 keV of ^{60}Co gamma energy at 25 cm from the top of the detector. Integrated digital gamma ray spectrometer with up to 64 K channel multi channe analyser (MCA) coupled with the HPGe detector was used for spectrometry. The detector is shielded with 10 cm lead along with graded shielding to reduce the background contribution of the surrounding.

The certified reference materials IAEA RGU-I, RGTh-I and RGK-I have been used for the energy and efficiency calibration of the system in the energy range of 46.53–2614.53 keV. The spectra were acquired for 100,000 s and the photo peaks were evaluated by using the MCA emulation software. Background spectrum was obtained with silica blank matrix for 100,000 s. The experimental efficiencies were fitted using least square 4th order polynomial as shown in the equation below and in Fig. 1.

$$\log \varepsilon = \sum_{i=0}^{4} a_i (\log E)^i \quad (1)$$

Where ε is the absolute efficiency of the detector and E (keV) is the energy of gamma line. The minimum detectable activity (MDA) of the system has been estimated with 95% confidence level using the following formula (ISO 11929 (E), 2010):

$$\mathrm{MDA}_{\mathrm{ISO11929}} = \mathrm{w}\frac{\mathrm{k}^2 + 2\mathrm{k}\sqrt{\mathrm{B} + \mathrm{B}\frac{\mathrm{n}}{2\mathrm{m}}}}{1 - \mathrm{k}^2\mathrm{var}(\mathrm{w})} \quad (2)$$

where

B – Background counts
n – Number of channels of the ROI
w – Weighting factor, $\mathrm{w} = \frac{1}{(\mathrm{T}\times\gamma\times\varepsilon)}$
T – Counting time (s)
γ – Gamma emission probability
ε – Absolute efficiency of the detector at particular gamma energy
k – coverage factor for the confidence level = 1.645 (95% probability)
m – the number of channels to the left and to the right of the ROI, used for background subtraction

The MDA values for the prominent gamma emitters are shown in Table 1.

Activity of the soil sample and combined uncertainty are calculated using the following formulae (IAEA, 2004).

$$\mathrm{Activity}\left(\mathrm{Bq\ kg^{-1}}\right) = \frac{(\mathrm{N} - \mathrm{B})}{(\mathrm{T}\times\gamma\times\varepsilon\times\mathrm{M}\times\mathrm{K1}\times\mathrm{K2}\times\mathrm{K3}\times\mathrm{K4}\times\mathrm{K5})} \quad (3)$$

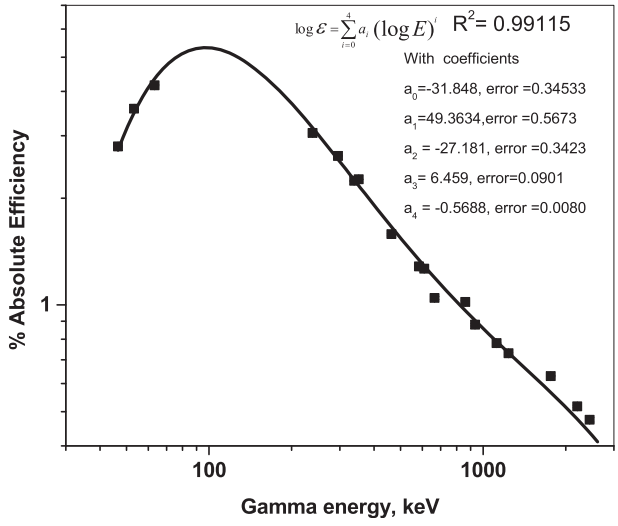

Fig. 1. Calibration of HPGe (p-type, 50%) absolute efficiency for IAEA RGU-I & RGTh-I in 250 cc plastic container.