Original Article

Preliminary study on the measurement of background radiation dose at Antarctica during 32nd expedition

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Abstract

A significant proportion (10%) of the natural background radiation is of cosmic origin. Cosmic ray consists of gamma, protons, electrons, pions, muons, neutrons and low Z nuclei. Due to the geomagnetic effect, cosmic radiation levels at poles are higher. As a consequence, personnel working in Antarctica (or Arctic) are subjected to high level of cosmic radiation. The present study gives the details of the estimation of background radiation (neutrons, gamma and electrons) dose rate around the Indian station at Antartica named "Bharati" measured during 32nd Indian scientific expedition to Antarctica (32nd INSEA). The measurement was carried out by passive dosimeters such as TLDs and CR-39 and active dosimeter such as RadEye G portable gamma survey meter. Gamma and electron components were measured using TLDs and survey meter, whereas CR-39 SSNTDs and neutron sensitive TLDs were used for neutron measurements. These detectors were deployed at few selected locations around Bharati station for about 2½ months during summer expedition. The neutron detectors used in the study were pre-calibrated with ^{241}Am-Be fast/thermal neutron source. The fast neutron dose rate measured based on CR-39 detector was found to about 140-420 nSv/h. The gamma dose rate evaluated by TLDs/survey meter are in the range of 290-400 nSv/h.

Keywords: Cosmic rays, CR-39, thermoluminescence dosimeter

INTRODUCTION

Cosmic radiation accounts for approximately 10% of the total background.[1] Galactic cosmic rays consist of 98% nucleonic component and 2% electrons. The nucleonic component is primarily protons (87% of the flux) and alpha particles (12%), with the remainder heavier nuclei (1%).[2] These primary cosmic particles have an energy spectrum that extends from 10^8 eV to over 10^{20} eV. Another component of cosmic rays is generated near the surface of the sun by magnetic disturbances. These solar particle events are comprised mostly of protons of energies generally below 100 MeV and only rarely above 10 GeV. The galactic cosmic rays produces secondary radiation such as neutrons, gamma and protons, muon etc., due to their interaction with molecules such as N_2 and O_2 present in the air.[2,3] A schematic diagram of such secondary production is given in Figure 1. Many of these secondary particles especially neutron and charged particle have higher biological effectiveness per unit dose than the primary particles. Owing to the orientation of the magnetic lines of force, the charged particles could reach Polar regions without any obstruction. Hence, the abundance of secondary particles produced by these primary charged particles in the environment of Antarctica, could be several times higher than the equatorial region. In view of the above phenomena, the background radiation level due to cosmic rays could be many times higher than the background at equatorial region. Several researchers have earlier carried out dosimetry studies of cosmic rays at Antarctica[4,5] using thermoluminescence dosimeter (TLD). They have studied combined dosimetry which include terrestrial radiation and cosmic rays without separating out the dose due to most important neutron component.

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National Centre for Antarctic and Ocean Research (NCAOR) Goa, has recently established the third permanent research station named Bharati in the Larsmann Hills region of Antarctica and it has been operational since March 18, 2012. The objective of this research station includes multidisciplinary research in the branches of atmosphere, earth and bioscience. The station is located 3000 km away from the Maitri station which is the second permanent Indian station in Antarctica located at a latitude of 70°45′93″S and longitude of 11°44′056′′E. It was eestablished in 1989 on the Schirmacher Oasis and has been conducting experiments in geology, geography and medicine since then.

So far no measurement on the environmental radiation has been carried out in and around Bharati station. In order to estimate the background radiation due to terrestrial and cosmic origin, preliminary study was carried out around Indian station Bharati (69°24′ 50″S, 76° 11′ 24″E) during the 32nd Indian Scientific Expedition (December 12, 2012 to February 19, 2013) to Antarctica by passive as well as active dosimeters. The measurements include neutron, photon and electron components of cosmic ray and gamma of terrestrial origin. No effort was made to measure muon component of cosmic ray during this study.

MATERIALS AND METHODS

All the passive and active dosimeters were handed over to one of the team member of Indian Institute of Geomagnetism, Mumbai who took part in the 32nd Indian Scientific Expedition to Antarctica conducted by NCAOR, Goa. Passive dosimeters such as Poly allyl diglycol carbonate (CR-39) detectors procured from M/s TASL, UK, for fast neutron (>100 keV) and $CaSO_4$:Dy based neutron TL discs for low energy neutrons (<100 keV) and $CaSO_4$:Dy based gamma TL discs[6] for gamma and electrons were deployed to some selected locations around Bharati station as mentioned in Table 1. The height of the dosimeter sets from ground was about 1 m and were fixed on an wooden plank. Distances between the dosimeter sets were few km and the average altitude of the locations is about 50 m from sea level. The dosimeters are packed and sealed in plastic pouch of thickness 50 µ. A representative photograph of deployment of passive dosimeter set at Antarctica is shown in Figure 2.

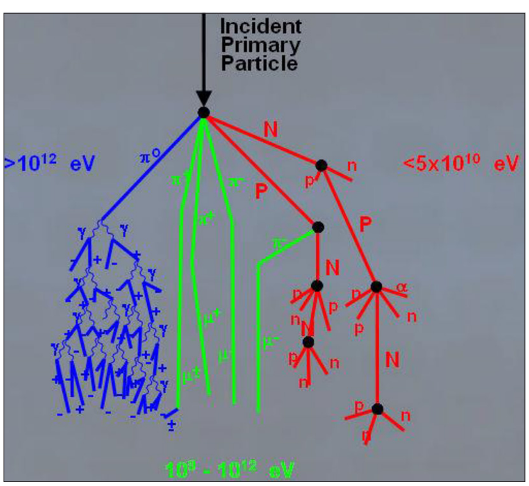

Figure 1: Schematic diagram of secondary particle in the atmosphere due to cosmic rays, where *n* represents neutrons, *p* protons, *µ* represents muon, *π* represents meson and γ represents gamma and N represents Nitrogen atom (Reitz 1993 and Nikolai Kruetzmann 2006)

Energy compensated Geiger Muller counter based gamma survey meter model RadEye G dose rate meter capable of measuring gamma dose rate in the range 50 nGy/h to 100 mGy/h and in the energy range 45 keV-3 MeV was also used along with a global positioning system. The survey meter was always kept at a height of about 1 m from the ground while measuring the dose rate.

Table 1: Neutron and gamma dose equivalents at different locations around Indian station Bharati, measured using CR-39 and TLDs

Locations	Ambient dose equivalent rate (nSv/h)		
	Low energy neutron (<100 keV) (TLD)	Fast neutron (100 keV-14 MeV) CR-39	Gamma (TLD)
69°24′50.3″S 76°11′ 24.4″E	103±8	422±60	290±35
69°24′ 49.0″S 76°11′ 38.7″E	169±14	271±35	402±22
69°24′ 56.8″S 76°12′ 12.1″E	125±9	139±20	371±24
69°24′ 56.8″S 76°12′ 24.5″E	167±7	293±25	378±33

TLD: Thermoluminescence dosimeter

Figure 2: Photograph showing the deployment of passive dosimeters at Antarctica at a height of 1 m from ground on a wooden plank

The passive dosimeters were deployed for a period of about 60-70 days. The TLDs were readout on a Harshaw reader with a heating rate of 5°C/s in the temperature range 30-285°C after a gap of almost one month from the date of recovery from Antarctica. The CR-39 detectors were electrochemically etched with 1 h chemical pre-etching followed by a two step etching conditions viz 3 h at low frequency (100 Hz) followed by 50 min at high frequency (3.5 kHz) at 1360 V in 7N KOH solution maintained at 60°C. After etching, the CR-39 detectors were washed in running water, dried and tracks were counted on an image analyzer system. For the measurement of neutrons, TLDs were calibrated using a thermalised (graphite stag) ^{241}Am-Be source (average energy ≤0.4 eV) and CR-39 detectors were calibrated with a ^{241}Am-Be fast neutron source (average energy 4.4 MeV) in air. The ambient dose equivalent H*(10) delivered during calibration of CR-39 and TLDs was 1 mSv. For calibration of TLDs and CR-39, the neutron fluence n/cm^2 at the distance of irradiation was converted to H*(10) using conversion coefficients 13.5 pSv cm^2 for thermal neutrons and 408 pSv cm^2 for fast neutrons. For calibration of TLD reader to gamma rays, TLDs sandwiched in 3 mm thick perspex plates were irradiated to 3 mSv of ambient dose equivalent (H*(10)) using ^{137}Cs source. The conversion coefficient (Sv/Gy) used to convert air kerma to ambient dose equivalent H*(10) of ^{137}Cs was 1.11. It may be noted that TLDs used to measure lower energy neutrons are not based on albedo technique as albedo technique is generally used for the measurement of personal dose equivalent, whereas the objective of present study is to measure ambient dose equivalent. It is the direct measurement of the neutrons incident on the TLDs. No correction for the neutron spectrum was applied on the TLD based results as it is practically measuring thermal neutrons (although some insignificant contributions of neutrons upto 100 keV) of cosmic ray spectrum which has peaks around thermal energy, few MeV and 100 MeV.[7] Measurement of higher energy neutrons (>100 keV) is taken care of by CR-39 detector. Gamma survey meter was calibrated to a known air kerma rate in the range of 0.1-0.3 mGy/h using a ^{137}Cs gamma source keeping the survey meter at different distances from the source in air.

RESULTS AND DISCUSSION

Results on the measurement of ambient dose equivalent rates for lower energy neutrons, fast neutrons and gamma and electrons using passive dosimeter sets of TLDs and CR-39 detectors are presented in Table 1. For the calculation of dose equivalent rates (nSv/h) using passive dosimeter sets, the transit dose (80 μSv) in the Mumbai-Cape town- Mumbai air route was deducted from the cumulative dose equivalent and the net value of dose equivalent was divided by the duration of deployment in hour. The transit dose was calculated considering 20 h (10 h each for one way) flying time (round trip) in Mumbai-Cape Town route and average cosmic ray dose rate as 4 μSv/h at an altitude of 10.1 km.[2] The team member of Antarctica expedition travelled by ship in the Cape Town-Antarctica route and hence no correction for transit dose was applied for that route. For lower energy neutrons, no correction was applied for transit dose as it is understood that lower energy neutrons at flight altitude will be insignificant, It can be seen [Table 1] that the fast neutron dose rates varies from 139-422 nSv/h, combined gamma and electron dose rate are in the range of 290-378 nSv/h [Table 1]. The energy response of CR-39 detector along with 1 mm radiator and the etching conditions used, in the energy range 100 keV to 6 MeV is about ± 30%.[8,9] No correction was applied on the response of CR-39 detector for evaluating the neutron dose rate. Wide variation in the fast neutron dose rate measured by CR-39 detector could possibly be attributed to the scattering of neutrons from the surrounding materials of the detector sets and to peak solar activity during 2011-12 periods. The study being the preliminary one, we are not in a position to correlate the variation of fast neutron dose rate with variation in latitude, longitude and solar activity. With repeated and more systematic study during future expeditions we may able to confirm the reason for wide variation.

The gamma dose rates measured at different locations by GM survey meter is presented in Figure 3. Survey meter based data indicate that on an average the gamma dose rate are in the range of 350-400 nGy/h except few locations. At some locations the dose rate recorded by survey meter showed much higher level (~600-700 nGy/h) than the average which may possibly be attributed to the presence of higher concentration of radioactive element such as actinide series (Uranium and Thorium) in the rock. Due to practical difficulties, team member of 32nd INSEA could not collect the rock samples during 32nd expedition, for analysis of

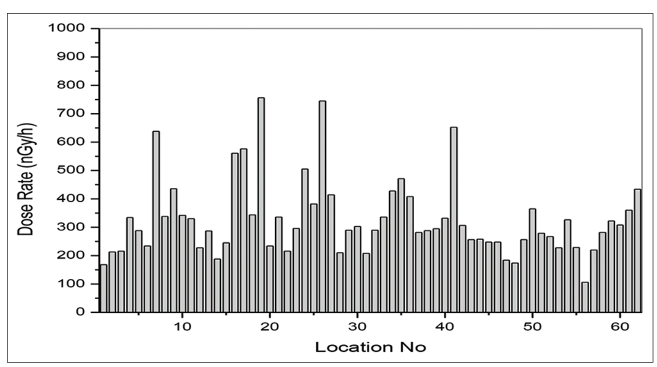

Figure 3: Gamma ray background around Bharati station recorded by GM based survey meter RadEye G

radioactive element and its concentration. In future expeditions, collection of rock/soil samples for radioactivity measurement has been planned.

Cai *et al*.[4] has reported the average background dose in the range of 93-580 nGy/h due to gamma and other ionising radiations using LiF: Mg, Cu, *P* based TL dosimeter around Chinese station Zhongshan (latitude 69°22′23.36″S longitude 76°22′17.14″E) on Larsemann Hills, Prydz Bay in East Antarctica. It may be noted that Chinese station (69°22′23.36″S longitude 76°22′17.14″E) is located closed to Bharati station (69°24′ 50″S, 76° 11′ 24″E) where the preset study was conducted. The results reported by Cai *et al*. matches with our results based on the gamma sensitive TLD (290-380 nGy/h) and gamma survey meter (200-600 nGy/h) of the present study, reasonably well. Measurement of cosmic ray background inside ice at a depth of 93 cm around Showa Station located at 69°00′15.6″S and 39°34′48.9″E by Japanese[5] usingi CaF_2(Tm) TLDs reported that the gamma dose rate is about 0.38 mSv/year. This corresponds to about 43 nSv/h of gamma dose rate at a depth inside ice and is expected to be much higher had it been measured at the surface of ice. Results on the measurement of cosmic ray dose at ground level in Japan in the latitude range 24-45 °N[10] showed that the average dose rates due to neutron is about 6.5 nSv/h and that of gamma and ionising component together is 31 nSv/h. The above mentioned Japanese measurements show that dose rates due to the cosmic rays at Antarctica could be much higher than equatorial region. It is also reported by Cai *et al*.[4] that the background dose rates are quite erratic and varies upto a factor of 20.

CONCLUSIONS

After the establishment of the new Indian station Bharati at Antarctica, 1st time the radiation doses due to cosmic rays and terrestrial gamma were measured by different types of passive dosimeters and gamma survey meter. Using neutron sensitive $CaSO_4$:Dy TLDs and CR-39 detectors, we could separately measure the lower energy neutrons (<100 keV) and fast neutrons (>100 keV). The study suggests that neutron and gamma dose equivalent rates at Antarctica around Bharati station are several times higher than the equatorial region of the earth. Further studies using passive and active dosimeters are being continued to ascertain the dose rates measured and influence of terrestrial activity from the rock/soil activity measurement.

Even at certain places around the world (Kerala, India; Guarapari, Brazil; Ramsar, Iran) where the annual background dose is extremely high ranging from 10 mSv to 260 mSv,[11] there is no evidence of increased cancer incidence. Hence there is nothing alarming or unusual about the high dose values reported around Bharati Station, Antarctica based on the present study. Moreover, there are no permanent human inhabitants at Antarctica, except those who go for different research activities, stay for a limited period.

REFERENCES

1. UNSCEAR-2008. Sources and Effects of Ionising Radiation, Vol. 1, United Nations, New York. 2010.
2. Reitz G. Radiation environment in the stratosphere. Radiat Prot Dosim 1993;48:1,5-20.
3. Kruetzmann N. Antarctic Dosimetry, University of Canterbury, Project Report GCAS. 2006.
4. Cai G, Geng K, Wang Q. The environmental monitoring of the Natural radiation background in Antarctica with LiF, Mg, Cu P TLD and X-γ radiations. Radiat Prot Dosim 1995;60:259-62.
5. Nakajima T, Kamiyama T, Fujii Y, Motoyama H, Esumi S. Ice-based altitude distribution of natural radiation annual exposure rate in the Antarctica zone over the latitude range 69 degrees S-77 degrees S using a pair-filter thermoluminescence method. Appl Radiat Isot 1995;46:1363-8.
6. Bakshi AK, Pradhan AS, Kher RK, Srivastava K, Varadharajan G, Chatterjee S, *et al*. Study on the response of indigenously developed CaSO4:Dy phosphor-based neutron dosemeter. Radiat Prot Dosimetry 2009;133:73-80.
7. Rasolonjatovo DA, Suzuki H, Hirabayashi N, Nunomiya T, Nakamura T, Nkao N. Measurement for the dose-rates of the cosmic-ray, components on the ground. Journal Radiat Res 2002;43 Suppl:S27-33.
8. Luigi T. Electrochemical etching processes for the detection of neutrons and Radon-decay products. Nucl Techn Radiat Prot 2004;1:12-9.
9. Cross WG, Arneja A, Ing H. The response of electrochemically-etched CR-39 to protons of 10 keV to 3 MeV, Nucl Tracks Radiat Meas 1986;12:649-53.
10. Nagaoka K, Hiraide, Sato K, Nakamura T. Nationwide measurements of cosmic-ray dose rates throughout Japan. Radi Prot Dosimetry 2009;132:365-74.
11. Ghiassi-nejad M, Mortazavi SM, Cameron JR, Niroomand-rad A, Karam PA. Very high background radiation areas of Ramsar, Iran: Preliminary biological studies. Health Phys 2002;82:87-93.

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