First Results from CO.R.A. Project

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Abstract

CO.R.A. (acronym for COsmic Rays in Antarctica) is a new international project carried out in the frame of a collaboration between Argentine and Italian Institutions. The aim of the project is to evaluate the composition and the characteristics of the secondary cosmic radiation in atmosphere at the Marambio Antarctic Base (Argentina; 64°13′ S – 56°43′ W, 196 m a.s.l.), with special attention to the environmental dosimetric data. The acquisition of such kind of data, at present very poor especially in the Southern hemisphere, is relevant for the knowledge of the effects on human health of the exposure to environmental radiation at high latitudes. To this end, several passive and active detectors (both for electromagnetic and charged components and for the neutron component, covering different energy intervals) were selected and used in measurement campaigns. A detailed description of the project and of the used instruments is presented together with the first results obtained from the recorded data during 2013 and 2015.

1 Introduction

Secondary cosmic radiation in atmosphere rapresents a main component of the environmental radiation on Earth. Primary Galactic Cosmic Rays (GCR) interact with nuclei constituting the atmosphere, mainly N_2 ($\approx 78\%$) and O_2 ($\approx 21\%$) and produce a complex secondary shower (e.g. protons, neutrons, electrons, positrons, mesons, etc.). The radiation environment varies with altitude, because of the shielding effect of the atmosphere, with latitude, because of the geomagnetic field shape and with solar activity, because of the shielding effect of solar wind against primary Galactic Cosmic Rays [1] [2] [3].
Sites at high altitude and high latitude are of special interest for assessment of environmental radiation dose due to cosmic rays [4] [5]. In particular the Antarctic region is the site in the planet where the cosmic rays induced radiation is more intense. A wide variety of conditions is encountered, because the Antarctic bases are located at different altitudes (from sea level to 4000 m a.s.l. on the Plateau) and at different distances from the magnetic Pole. Moreover several reasons suggest the opportunity of investigating the environmental radiation in Antarctica: the Earth magnetic field is lowering and changing [6]; the South Atlantic Anomaly (SAA) is growing and deeping [7]; the solar activity is lowering (also in growing cycles) [8]. As a consequence, the exposure to environmental radiation in antarctic region to GCR could be increasing in the next years. The CO.R.A. Project (COsmic Rays in Antarctica), is carried out in the framework of a collaboration between Italian and Argentine Institutions (INFN, IAPS-INAF, UNLP, IAA) at Argentine Antarctic Marambio base (196 m a.s.l., 64°14′ S - 56°37′ W). A campaign has been carried out, from March to September 2015, by using various active and passive detectors, both for electromagnetic and charged component and for neutron component. In particular special attention has been paid to the evaluation of ambient dose equivalent H*(10) for neutrons of low-intermediate energy by using an active detector (the Rem Counter Atomtex, sensitive in the range 25 meV − 14 MeV) and a set of bubbles detectors (BDT and BD-PND, sensitive respectively at thermal neutron energy and in the range 100 keV − 20 MeV).

2 Material and Methods

The active and passive detectors used in the campaign are listed below:

Neutron detectors. The rem counter BDKN-03 used in the campaign (*BDKN-03, ATOMTEX, Minsk, Republic of Belarus*) is based on a ^{3}He proportional counter in a polyethylene moderator. The instrument is sensitive to ambient dose equivalent rate in the interval $0.1\,\mu$Sv/h $-$ 10 Sv/h. In addition, a set of passive bubble dosimeters (BD and BD-PND, Bubble Technology Industries, Ontario, Canada) is used. The bubble detectors, constituted by vials filled by tissue equivalent gel in which superheated freon drops are dispersed, are sensitive to neutrons in the energy range 25 meV $-$ 4 eV (BDT dosimeters) and to neutrons in the energy range 100 keV $-$ 20 MeV (BD-PND dosimeters).

X **and** γ **detector**. The BDKG-04 detector produced by ATOMTEX Instruments and Technologies for Nuclear Measurements and Radiation Monitoring, is constituted by a scintillation plastic detector (30×15) mm and thickness $150\,\mu$m, sensitive to X and γ dose rate in the interval 0.05 mGy/h $-$ 10 Gy/h and to integral dose in the interval 0.05 mGy $-$ 10 Gy, for radiation energy in the range 50 keV $-$ 3 MeV.

MDU-01 Liulin-I LET spectrometer. Liulin-type detector is based on a 256-channel active silicon semiconductor; its dimensions are $(110 \times 100 \times 45)$ mm. The instrument has been developed at Solar-Terrestrial Influence Laboratory of Bulgarian Academy of Sciences and is able to evaluate energy deposition spectra, fluxes, and doses in mixed radiation fields [9].

3 Experimental

The dosimetric instruments were exposed inside the LAMBI Laboratory (Laboratorio Antartico Multidisciplinario Marambio) shielded against electromagnetic disturbs with a Faraday cage shielding. The data from active detectors were mailed every week from the base personnel. The reading of bubble detectors was performed once per week. All the bubble dosimeters were zeroed and restarded after 24h to preserve the characteristics of the tissue equivalent gel. In the period July 8 - September 8, the bubble detectors were substituted by new ones. This fact corresponds to a lack of data in the same period.

4 Results and Discussion

In Figure 1 the results obtained in 2015 campaign are shown (mean value over 8 days) for all dosimetric instrments. For bubble detectors , the sum of data recorded by BDT and BD-PND dosimeter is considered. In Table 1 the mean values over the entire measurament period (1 March – 20 September 2015) are summarized.

TABLE **1:** Mean value over the measurament period 1 March – 20 September 2015.

Atomtex BDKN-03 ($0.025\,\text{eV} < E_n < 14\,\text{MeV}$)	H*/h [μSv/h] 0.024 ± 0.002
Bubble (BDT + BD-PND) (BDT: $0.025\,\text{eV} < E_n < 4\,\text{eV}$; BD-PND: $100\,\text{keV} < E_n < 20\,\text{MeV}$)	H*/h [μSv/h] 0.017 ± 0.005
Atomtex BDKG-04 ($50\,\text{keV} < E_n < 3\,\text{MeV}$)	D/h [μGy/h] 0.042 ± 0.003
MDU-01 Liulin-I ($0.135 - 69.4\,\text{keV}/\mu\text{m}$)	D/h [μGy/h] 0.08 ± 0.01

The results obtained in the 2015 campaign (1 March - 20 September 2015) were compared with those obtained in the faisibility study performed in the period 4 January - 20 May 2013, by using bubble detectors and Liulin LET spectrometer (Figure 2). The comparison is performed on the data recorded by Bubble detectors (BDT + BD-PND) and Liulin-I MDU-01 spectrometer, used in both campaigns.

The dosimetric data in the two campaigns are consistent, considering the difference in solar activity and meteorological conditions during the two measurement periods. In Figure 3 and Table 2 the dosimetric results obtained in 2013 and 2015 campaigns are summarized.

TABLE **2:** Comparison 2013 and 2015 campaigns (mean values over the entire measurement period).

Year 2013	
BDT+ BD-PND [H*/h]	$(0.023 \pm 0.007)\,\mu$Sv/h
BDKN-03 [H*/h]	/
BDKG-04 [D/h]	/
Liulin-I MDU-01 [D/h]	$(0.07 \pm 0.01)\,\mu$Gy/h
Year 2015	
BDT+ BD-PND [H*/h]	$(0.017 \pm 0.005)\,\mu$Sv/h
BDKN-03 [H*/h]	$(0.024 \pm 0.002)\,\mu$Sv/h
BDKG-04 [D/h]	$(0.042 \pm 0.003)\,\mu$Gy/h
Liulin-I MDU-01 [D/h]	$(0.08 \pm 0.01)\,\mu$Gy/h

5 Conclusions

The first systematic campaign for the assessment of environmental dosimetry in Antarctic region has been carried out at Argentine Antarctic Marambio base, in the period March-September (Antarctic winter) 2015, by using a set of active and passive instruments for the separate evaluation of the different components of environmental radiation. The mean value (on the March - September 2015 measuring period) for X and γ rays dose rate is $(0.042 \pm 0.003)\,\mu$Gy/h; the H*rate mean value for neutrons (0.025 eV $-$ 14 MeV)

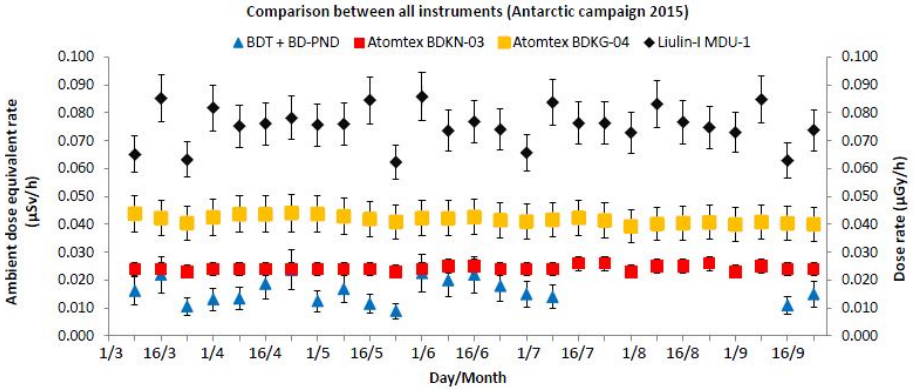

FIG. **1:** Comparison between all instruments data measured in the period 1 March – 20 September 2015 (8 days mean data) at Argentine Antarctic Marambio Base. The blue triangles represent the sum of data recorded by BDT and BD-PND dosimeters.

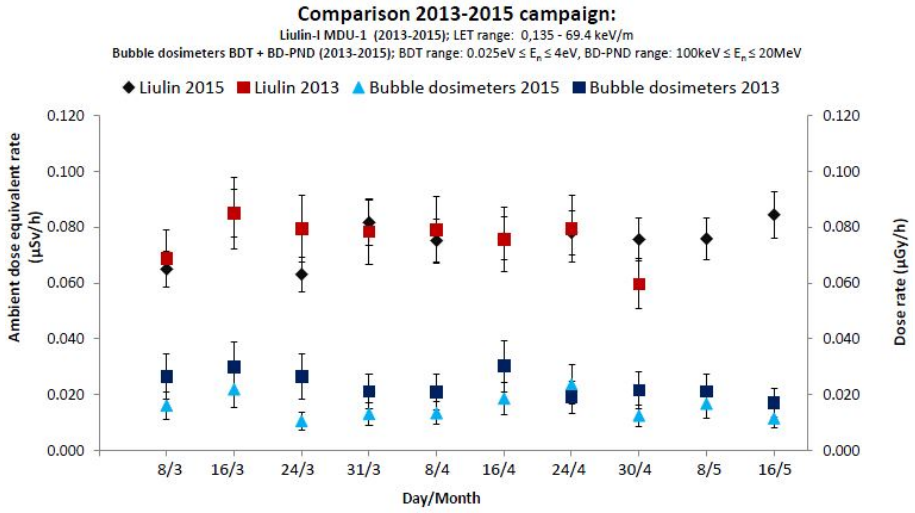

FIG. **2:** Comparison between MDU-01 Liulin-I and bubble detector data obtained in the 2015 campaign and in the 2013 faisibility study. For the bubble detectors, the sum of data recorded by BDT and BD-PND dosimeters is considered.

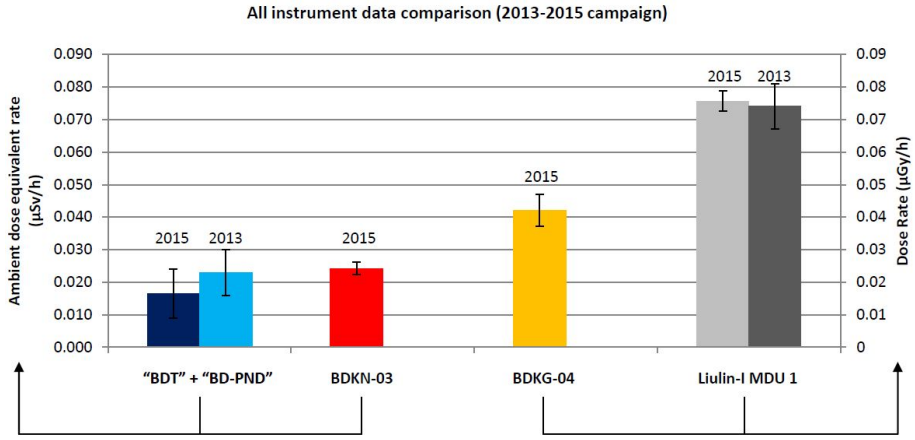

FIG. **3:** Comparison of dosimetric average values obtained in 2013 and 2015 by all instruments. The mean of 2015 campaign is calculated over a period of 204 days (01/03 – 20/09). The mean of 2013 campaign is calculated over a period of 136 days (04/01 – 20/05).

is $(0.024 \pm 0.002)\,\mu$Sv/h. In the last case, considering the location of Marambio base, at sea level and far from South magnetic Pole, it is evident that, for the Antarctic bases at higher altitude and closer to the South magnetic Pole, this value could significantly increase. In the future, a campaign at different locations is planned [Marambio (64°13′ S – 56°43′ W, 196 m a.s.l.), Belgrano (77°52′ 00″ S, 34°37′ 00″ W, 37 m a.s.l.), Dom C (75°6.12′ S 123°23.72′ E, 3220 m a.s.l.)], to better understand the dependence of the environmental dose induced by cosmic rays from latitude and altitude in Antarctic region and to evaluate the exposure of people living in the scientific Antarctic bases.

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