MEASUREMENT OF COSMIC-RAY NEUTRON DOSES IN TAIWAN

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INTRODUCTION

In the natural radiation background, neutron dose is far much lower than gamma-ray dose generally. When one talks about external dose of natural background, only gamma-ray dose is considered or monitored and neutron dose is normally neglected. According to UNSCEAR 1993 Report (1), the average effective dose rate from cosmic-ray neutrons at sea level is estimated to be 3.6 nSv h^{-1} which is equivalent to 30 μSv per year. This value is comparable with the 50 μSv per year dose limit imposed to the site boundary of individual nuclear facility by the regulatory authority in Taiwan. For nuclear power plants, spent fuel interim storage facilities, and high energy accelerator facilities from which both gamma rays and neutrons emanate, the radiation dose at site boundary comes, therefore, not only from skyshine gamma rays but also from stray neutrons scattered from the facility buildings and from the air. The detection of cosmic-ray neutrons has become important and necessary in order to inspect the compliance of nuclear facilities with the dose limit imposed to the site boundary. The composition and intensity of the cosmic radiation change with time and location due to, among others, mainly the following factors (2) : solar-cycle modulation effect, solar flare effect, latitude effect, altitude effect, and temperature effect. Because this change with time and location is more prominent for the neutron component than for the ionized component, the need for long-term monitoring of cosmic-ray neutrons is clear. In this paper a measurement system consisting of large-size BF3 counters with polyethylene enclosure of different radii was set up. The response functions of the BF3 counters were calculated by using the one-dimensional transport code ANISN (3) performed in adjoin mode. A preliminary survey measurement of the cosmic-ray neutron intensity on the plain and on the mountains in Taiwan area was performed.

EXPERIMENTAL SET UP

In this study high sensitivity large-size cylindrical BF3 counters with polyethylene (PE) enclosure of different radii , namely , 5, 8.5, 10 cm and bare BF3 counters were used to measurement of cosmic-ray neutrons. The BF3 counter has a dimensions of 1.5" in diameter and 34" in active length and is filled with BF3 gas in pressure of 45-cm Hg. The enrichment of ^{10}B is 95%. Figure 1 shows the block diagram of the experimental set up. The 4-way fan out was used

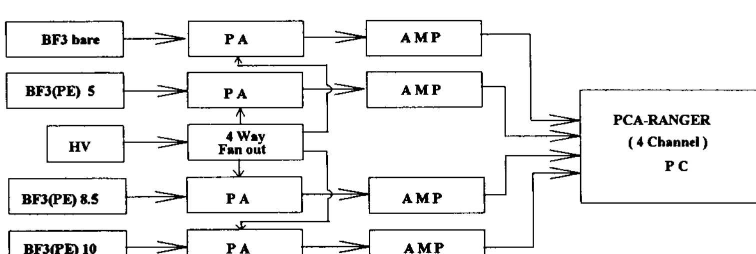

Figure 1. The block diagram of the experimental set up.

to distribute the high voltage to each of the four detectors. The amplifier signals from each detectors were fed into a PCA-Ranger card plugged in a personal computer (PC). The data were acquired every 10 minutes and showed on the hard disk of the PC.

The response functions of the cylindrical BF3 counters with PE enclosures of different radii and bare BF3 counter were calculated by using ANISN code performed in adjoin mode with BUGLE cross section library (4) for energies below 17 MeV and HILO cross section library (5) for energies above 17 MeV. The detector calibration was made in a neutron calibration room with a normal 100 μg californium-252 source.

RESULTS AND DISCUSSION

In order to perform field measurement of cosmic-ray neutrons, a portable diesel generator for power supply and a tent for rain protection were carried with the neutron detection system. First of all, the measurement was made on the plain in National Tsing Hua University and in Synchrotron Radiation Center. Trips were then made to the Ali Mountain and the Hohuan Mountain in summer 1995. Measurements were made on the way at some representative locations with different altitudes. Table 1 shows the altitudes and the measured counting rates for the four BF3 counters at each measurement locations. The measurements at each locations look about one hour in order to make sure the stable operation of the counting system and the counting rates at each locations were the average values over the whole measurement period. Figure 2 shows the plot of measured counting rates of four BF3 counters as a function of altitude. It can be seen from Fig. 2 that the counting rate increases steadily with the altitude and the ratios of counting rates among the four BF3 counters keep more or less constant at each measurement locations, irrespective of the altitude and the BF3 counter with 5-cm polyethylene enclosure has the highest counting rates. Therefore, it seems reasonable to assume that the cosmic-ray neutron spectrum remains the same independent of the altitude. In our previous study (6) , the annual effective dose of cosmic-ray neutrons on the plain was estimated to be 14 μSv by using the BF3 counter with 8.5-cm polyethylene enclosure. When changes to radiation weighting factor for neutrons recommended by the ICRP in 1991 (7) were taken into account, it will lead to an increase of 50 %. of the effective dose rate of cosmic-ray neutrons. therefore, the effective dose rates of cosmic-ray neutrons on the plain was corrected to be 21 μSv /year. If the cosmic-ray neutron spectrum remains the same, as being a reasonable assumption, the effective dose rate will be proportional to the counting rate of the BF3 counter with 8.5-cm polyethylene enclosure. The effective dose rates at other measurement locations could then be estimated accordingly as include in Table 1.

Table 1 . Measured counting rates (counts / 10 min.) of BF3 counters and effective dose rates (μSv/ year) as a function of altitude.

Altitude (meter)	BF_3 bare	BF_3(PE) 8.5 cm	BF_3(PE) 5 cm	BF_3(PE) 10 cm	Effective dose rate
3275 (Mount Wulin)	120.2 (5.9)*	304.0 (12.9)	395.4 (10.7)	268.6 (9.2)	152
2500 (Mount Ali)	84.5 (5.2)	200.3 (9.0)	268.0 (21.5)	159.8 (7.9)	100
1800	58.0 (5.2)	124.3 (3.5)	157.0 (8.9)	99.0 (11.5)	62
1300	47.3 (8.2)	104.5 (14.2)	133.3 (2.2)	80.8 (9.0)	52
1148	40.7 (5.1)	87.8 (8.7)	123.7 (8.2)	75.3 (7.6)	44
500	29.8 (4.9)	61.3 (7.7)	71.5 (8.6)	45.8 (7.6)	33
0	25.3 (7.4)	42 (3.6)	58.5 (8.0)	35.3 (3.6)	21

* standard deviation

Figure 3 shows the plot of the effective dose rate of cosmic-ray neutrons as a function of altitude. The diamond marks show the data of this work. The smooth curve comes from analytical expressions developed in reference (8) and cited in UNSCEAR 1993 Report (1). It can be seen from Fig. 3 that the increase of cosmic-ray intensity with altitude indicated in our measured data agrees very well that cited in UNSCEAR 1993 Report although our measured effective dose rates are about 50% lower, which is clearly due to the lower latitude of the measurement locations (23.5°N). It is also interested to note from Table 1 and Fig. 3 that the effective dose rates of cosmic-ray neutrons at Mount Ali (2500 m above sea level) and at Mount Wulin (3275 m above sea level)were about five times and 7.2 times higher than that on the plain, respectively.

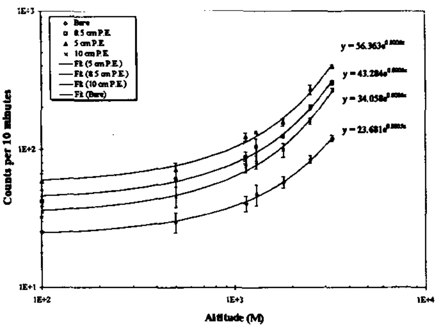

Fig.2 Measured counting rates of BF_3 counters as a function of altitude

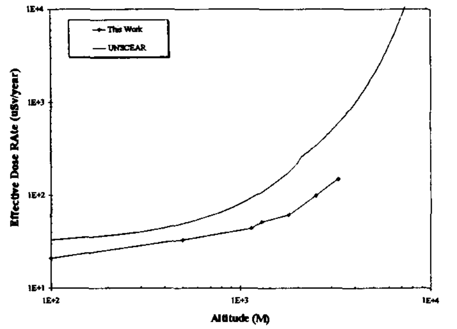

Fig.3 Effective dose rate of cosmic-ray neutrons as a function of altitude

CONCLUSIONS

In this paper a high sensitive neutron detection system has been successfully established. By using this detection system it is the first time the effective dose rates of cosmic-ray neutrons as a function of the altitude in Taiwan area has been measured. On the plain the effective dose rate was estimated to be about 21 μSv /year. On Mount Ali (2500 m above sea level) and Mount Wulin (3275 m above sea level) the effective dose rates were found to be about five times and 7.2 times higher than that on the plain. The measured variation of the effective dose rate as a function of altitude agreed very well with that cited in UNSCEAR 1993 Report. Since cosmic-ray neutron intensity changes with time and space, it is strongly suggested that the extensive survey and long-term monitoring should be taken as soon as possible.

ACKNOWLEDGMENT

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