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AN EXPOSURE TO NATURAL BACKGROUND RADIATION IN EASTERN NEPAL

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ABSTRACT

Monitoring natural background radiation is important to locate the high background area. The objective of the work is to find the average background radiation in the Morang district and to observe the effects of cosmic radiation at high altitudes. In this study, background radiation was measured in 17 different municipalities of Morang with the help of a GM counter of model GMC-300E plus. The result showed that the annual effective dose of Morang was 0.24±0.02mSv/y and was below the recommended value of 1 mSv/y set by ICRP for public health. The radiation level was slightly higher in the hospital area. The frequency distribution indicates that there is a good fit of observed data with a known Gaussian distribution. The variation of background radiation with an altitude from 381 to 2550m showed an increasing trend. The best-fitted line depicted that background radiation increased by 16% with 1000m in altitude and it was slightly higher than the literature's result of 10-12%. The comparative study of the present work showed that the effective dose was the least value in the Morang (0.24mSv/y) and the highest in the Pokhara Valley (0.81mSv/yr).

KEYWORDS: Ionizing radiation, Cosmic radiation, Effective dose, G.M. Counter, Gaussian distribution,

INTRODUCTION

Humans are constantly exposed to ionizing radiation from natural sources on the earth. Ionizing radiation has enough energy to knock out electrons from atoms, breaking chemical bonds and producing harmful effects on organisms. The ionizing radiation originated from cosmogenic and primordial sources (Sannappa et al., 2003; Omeje et al., 2018). Cosmogenic radionuclides are formed after the interaction of atmospheric molecules with cosmic radiation and have a significant contribution to human health in areas at high altitudes. But, at low altitudes, the earth's atmosphere greatly protects us due to its shielding property (Sihver, et al., 2015). They are the dominant sources of ionizing radiation in the atmosphere from an altitude of 1km to 70km and become double for every 1.5km above the earth's surface (Bouville & Lowder, 1988). However, due to the balance between the pace at which they are created and decayed, cosmogenic radionuclides such as ^{32}P, ^{14}C, and ^{3}H are normally found in a consistent amount in the earth's environment (Balonov, 2008). On the other hand, primordial radionuclide, such as ^{238}U, ^{232}Th, ^{40}K, and their daughters naturally exist in the earth from its beginning and they have a long half-life period (Kasumović et al., 2018). They are not uniformly distributed in soils and vary significantly in various geography and geological formations (Osman et al., 2022; Wallova et al., 2010). However, both types of radiation are the main contributors to environmental background radiation. The ^{238}U, ^{232}Th, and ^{235}U decay series are the most prominent sources of ionizing radiation among terrestrial radionuclides, accounting for approximately 83 percent and the ^{40}K accounts for roughly 16 percent of the annual effective dose that the global population experienced (Asaduzzaman et al., 2015). On accounting the natural background radiation, cosmic radiation exposure is around 0.39 mSv/y, terrestrial radiation is 0.48 mSv/y, radiation from water and food is 0.29 mSv/y, radiation from the air is 1.26 mSv/y and artificial radiation is approximately 0.5mSv/year. As a result, the average human receives roughly 2.4mSv/year from natural sources and 0.5mSv/y from man-made sources. The guidelines set a dosage limit of 1 mSv/y for public exposure excluding dose due to natural radiation, which is roughly half of the global average of 2.4mSv/year for natural radiation exposure (Kadum et al., 2013). Different places on the earth have been recognized to have high natural background radiation. For example, Ramsar in Iran, Kerala and Madras states in India, Guarapari in Brazil, and Yangjiang County in China (Ghiassi-Nejad et al., 2002; Hendry, et al., 2009).

During the radiometric survey, when sandstone-type uranium deposition was found in the Siwalik hill of the Himalayan range of Pakistan during the 1970s. Nepali researchers were also inspired to conduct such work in the Siwalik range of Nepal. The first preliminary ground radiometric survey was conducted in 1977/1978 and confirmed the presence of deposition of the mineralized bodies in Tinbhangale, Makawanpur. The baseline data obtained from such a survey became very useful to locate the high background radiation area. It is also a regulatory prerequisite for the installation and operation of a research reactor and nuclear power plant and to test nuclear weapons. Therefore, the comprehensive investigation to assess background radiation levels across the country is the most important and immediate concern to the general population (Bhatt et al., 2012).

In some countries, there are no mountains or small mountain peaks just under 1km. As a result, the effect of altitude on doses from cosmic radiation exposure is disregarded (Colgan et al., 2007). In contrast, Nepal is situated in the Himalayas mountain range in the world and has numerous mountain peaks. There are 1310 mountain peaks over 6000m including the world's highest peak, Mt. Everest of height 8848m. Every year, many people climb the various mountain peaks in Nepal. Dho Tarap is the world's highest human settlement at 4,080 meters that also exists in Nepal. People living in high-altitude regions and mountain climbers are receiving a higher dose of ionizing radiation. Therefore, radiation exposure to people at high altitudes has gained much attention in recent years due to the lack of information about radiation and limited knowledge on this topic. Hence, the main objective of the work is to evaluate the effective dose received by the human population in Morang district of Nepal and to calculate the effect of altitude on the background radiation.

MATERIALS AND METHODS

Description of Instrument

The GM counter of model GMC-300E plus is a nuclear radiation monitoring device that generates a pulse of electrical current each time when radiation passes through the tube and causes ionization. Each pulse is electronically detected by the instrument and registers as a count. The GMC-300E plus displays the counts in three different modes: counts per minute (CPM), milliroentgen per hour (mR/h), and microsievert per hour (μSv/h). This fully portable battery-operated instrument counts high-energy alpha particles, beta particles, and gamma rays.

Study area

First of all, the background radiation of Morang district had been measured using GMC-300E detector. Morang district consists of 17 different municipalities. Measurements had been carried out in each municipality for 10 minutes in every 20 seconds interval of time. The number of observations at any municipality depends upon the available fields. Overall, 41measurements had been carried out in Morang district. The detector was allowed to reset for 5 minutes for each measurement. For background measurement in each municipality, different fields such as paddy fields, banana fields, maize fields, forests, rivers, and the hospital area were chosen. In the hospital area, measurement was carried out just outside the hospital. Similarly, to observe the variation of the background radiation with altitude, measurement was conducted from Dharan to the base camp of Temke hill. The annual effective dose rate was calculated by using Eq. (1) (Begum et al., 2018).

$$\text{Dose rate (mSv/y)} = 0.2 \times 8760 \times \text{background radiation } (\mu\text{Sv/hr}) \ldots. (1)$$

The chi-square test was also carried out to check whether observed data fit the Gaussian distribution or not.

RESULTS AND DISCUSSION

The background radiation of Morang district was presented in Fig. 1. The lowest background radiation $(0.1\,0 \pm 0.02)\mu\text{Sv/h}$ was observed in Gramthan and highest radiation $(0.15 \pm 0.04)\mu\text{Sv/h}$ was observed in Jadaha. The average background radiation of Morang district is $0.14 \pm 0.01\,\mu\text{Sv/h}$. The background radiation was converted into equivalent dose rate using Eq. (1) and found to have $0.24 \pm 0.02\,\text{mSv/y}$. It was below the

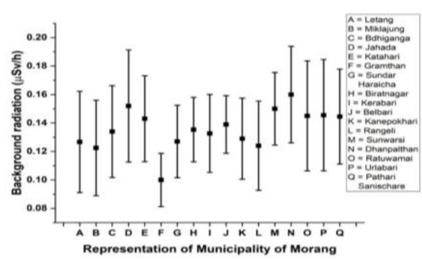

Fig. 1. Natural background radiation at different municipalities of Morang District

recommended value of 1 mSv/y set by International Commission on Radiological Protection (ICRP) for non-radiation workers and the public (Charles, 2001). On observing the error bar, it was found that the fluctuation of background radiation was nearly the same in all places.

The background radiation was also measured in the different fields such as paddy field, banana field, maize field, forest, bank of rivers and hospital area and displayed in Fig. 2. The highest background radiation (0.15±0.01 μSv/h) was observed in the hospital area. It may be due to the radiation emitted during CT scans and X-ray operations. It also showed that the hospital is the area where there is a higher activity of radiation. The second higher background radiation (0.14±0.02 μSv/h) was measured in the banana field. It may be due to the presence of 40K. The banana has a relatively higher amount of 40K radioisotopes and contributes to increasing the background radiation. It is one of the major sources to increase the internal radiation of the human body (Ilori & Chetty, 2020). The least background radiation (0.12±0.02 μSv/h) was observed in the maize field. During the measurement, it was an off-season of maize and obtained only recently planted maize in Kerabari. It may be a result to have the least value of background radiation.

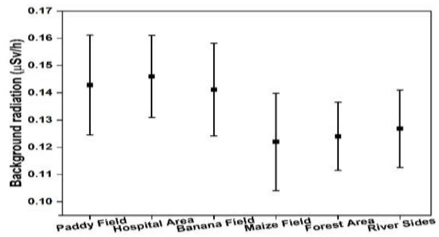

Fig. 2. Natural background radiation in different fields and areas

The frequency distribution of the observed background radiation at Pathari Sanischare was plotted against the observed dose rates and presented in Fig. 3 along with Gaussian fit at 0.05 level of significance. The Gaussian distribution has the mean value of background radiation 0.16μSv/h with a standard deviation of 0.12. The Chi-square test for the set of observed data was carried out and the reduced chi-square test value was found to have 5.82, very close to 1. It indicates that there is a good fit of the observed data with a known Gaussian distribution.

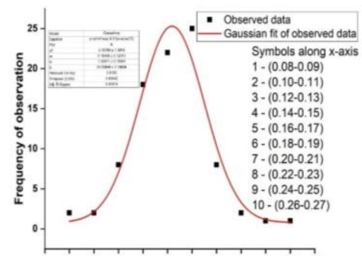

Fig. 3. The frequency distribution of the observed background radiation at Pathari, Sanischare

To observe the variation of background radiation with altitude, the measurement was conducted from Dharan to the base camp of Temke hill, the highest peak in province 01 of Nepal. The observed data set and the best fit line have been presented in Fig. 4. The best-fit line showed that there is an increasing trend of background radiation with altitude. Mulghat was the lowest altitude of 381m and Temke base camp was the highest altitude of 2550m from sea level.

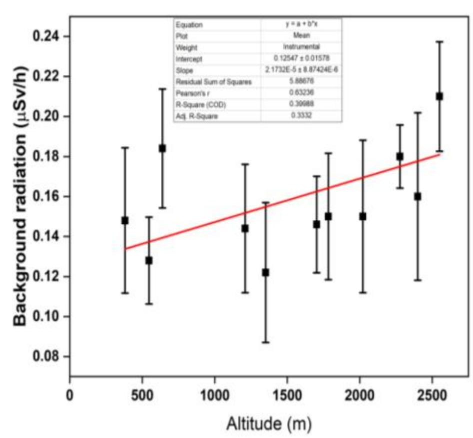

Fig. 4. The variation of natural background radiation with altitude .

The background radiation in Mulghat was 0.15±0.04μSv/h, whereas, in Temke base camp, it was 0.21±0.03 μSv/h. Similarly, the best-fit line depicted that the percentage change in background radiation with 1000m altitude was 16%. It was slightly higher than the literature's result of 10-12% (Mishev & Hristova, 2012; Pooya et al., 2015) It also showed that the background radiation increased by 0.03μSv/h with the rise in 1.5km altitude. However, in literature, it has been mentioned that cosmic radiation becomes double for every 1.5km altitude above the earth's surface. In our case, we measured the ground base data and there is an influence of terrestrial radiation along with cosmic radiation. Assuming, that terrestrial radiation is the same everywhere in our study area and the terrestrial radiation should be reduced from the background radiation to obtain cosmic radiation. The background radiation at the lowest altitude given by the best-fit line is considered to be terrestrial radiation and it is 0.13μSv/h. Hence, the cosmic radiation at an altitude of 381m became zero and at the peak of Temke base camp at an altitude of 2550m became 0.04μSv/h. Calculation showed that the cosmic radiation increased by 2.5 times for every 1.5km altitude. It is in good agreement with literature data. Due to the geographical location of Nepal, it is difficult to measure the background radiation at higher altitudes. However, it is possible to predict the background radiation by extrapolating the best fit line even at a higher altitude.

Table 1. Three different modes of background radiation level

CPM	Background radiation (μSv/h)	Background radiation (mR/h)	Action
5-50	0.03-0.33	0.003-0.033	Normal background. No action needed.
51-99	0.33-0.65	0.033-0.065	Medium level, check the level regularly.
More than 100	More than 0.65	More than 0.065	High level, closely watch reading find out why.
More than 1000	More than 6.50	More than 0.650	Very high, leave the area ASAP and find out why.
More than 2000	More than 13	More than 1.30	Extremely high. Evacuate immediately, report to the government.

Three different modes of background radiation such as count per minute, μSv/h, and mR/h have been shown in Table 1 with the level of radiation. In our cases, all the background radiation was below 0.33μSv/h. It means it is normal background radiation and no action is needed. However, if the background radiation is greater than 13μSv/h, it is considered to have extremely high and should report to the government immediately to take necessary action.

Table 2. Comparative study of annual effective dose measured in a different part of Nepal

SN	City/Country	Effective dose (mSv/y)	Authors
1	Morang, Nepal	0.24	Present study
2	Kathmandu, Nepal	0.47	(Pantha et al., 2018)
3	Pokhara Valley, Nepal	0.81	(Gautam et al., 2020)
4	Kanchanpur, Nepal	0.27	(Dhami et al., 2020)

The comparative study of the present work with other works conducted in Nepal was carried out and presented in Table 2. It showed the effective dose measured in Morang, Kathmandu, Pokhara, and Kanchanpur. The lowest effective dose (0.24mSv/y) was recorded in Morang and the highest dose (0.81mSv/yr) in Pokhara. Morang and Kanchanpur are the two districts that are situated in the plain region and have nearly the same dose rate. However, Kathmandu and Pokhara are situated in the mountain region and have relatively higher dose rates. It may be due to the effect of terrestrial as well as cosmic radiation.

CONCLUSION

In this study, the natural background radiation in Morang district had been monitored and the result showed that the annual effective dose was 0.24±0.02mSv/y. It was below the recommended value of 1 mSv/y set by ICRP for public health. Similarly, the variation of background radiation with an altitude from 381 to 2550m showed an increasing trend. The best-fitted line depicted that background radiation increased by 16% with 1000m and it was slightly higher than the literature's result of 10-12%. The comparative study of the present work was carried out with other works conducted in Nepal and the result showed that the effective dose (0.24mSv/y) in the study area was relatively low as compared to other places and the highest dose (0.81mSv/yr) was monitored in Pokhara Valley.

Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this paper.

Data Availability: These data used to support the findings of this study are available from the corresponding author upon request.

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