Natural Background Radiation Dosimetry in the Highest Altitude Region of Iran

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Background radiation/Dosimetry/Exposure/Altitude.

The natural background radiation has been measured in one of the highest altitude regions (Zagros Mountains), Chaharmahal and Bakhtiari province, in the south west of Iran. The outdoors-environmental monitoring exposure rate of radiation was measured in 200 randomly chosen regions using portable Geiger-Muller and scintillation detectors. Eight measurements were made in each region and an average value was used to calculate the exposure rate from natural background radiation. The average exposure rate was found to be 0.246 $\mu$Gy/h and the annual average effective dose equivalent was found to be 0.49 mSv. An overall population-weighted mean outdoor dose rate was calculated to be 49 nGy/h, which is higher than the worldwide mean value of 44 nGy/h, as reported by UNSCEAR in 1998, and is comparable to the annual effective dose equivalent of 0.38 mSv. A good correlation between the altitude and the exposure rate was observed, as the higher altitude regions have higher natural background radiation levels.

INTRODUCTION

Investigations and measurements of natural environmental radiation (i.e. background radiation) and radioactivity are of great importance and interest in health physics not only for many practical, but also for more fundamental scientific reasons. The main sources of background radiation are cosmic, terrestrial and cosmogenic radiations. Cosmic radiation including secondary highly energetic particles produced by spallation reactions with primary cosmic rays and atmospheric nuclei. Terrestrial radiation originates mostly from radiations of thorium ($^{232}$Th) and uranium ($^{238}$U) series radionuclides and potassium ($^{40}$K). Cosmogenic radionuclides contribute only little to external exposure. The major production of cosmogenic radionuclides results from the interaction of cosmic rays with atmospheric gases. There are many naturally occurring radionuclides that have half-lives of at least the same order of magnitude as the estimated age of the earth, and that have been present since their formation. They include isotopes of potassium, thorium and uranium. Some of these decay to form different radioisotopes which, increases the total radiation on the earth. Natural background radiation varies over a range of concentrations and exposure rates varied due to a variety of causes.

Generally, the background dose rates from cosmic rays depend slightly on the latitude and strongly on the altitude. The latitude effect is due to the charged particle nature of the primary cosmic rays, and the effect of the Earth’s magnetic field, which tends to direct ions away from the equator and toward the poles.

Since natural radiation is the main source of human exposure, studies of the dose from this source and its effects on health are of great value as a reference when standard and regulatory control actions on radiation protection are to be done. Interest in this kind of study has led to many national surveys on natural radiation in the last decade. There are considerable variations of background radiation in different regions. For example, the Indian states Kerala and Madras are among those regions with the highest levels of background radiation in the world. As a result of the underlying rock, they receive an average annual dose of 50–100 mSv, which is much higher than the world-wide average dose.

In developing countries, such as Iran, the main source of human exposure is natural radiation (94%). Thus, the Atomic Energy Agency of Iran organized some survey programs concerning natural radiation. To complete this program, the Department of Medical Physics, Shahrekord University of Medical Sciences carried out a survey of natural background radiation in the highest altitude region of Iran. These regions have less protection from cosmic radiation by the atmosphere. For this reason, the aim of this survey was focused on determining the current background radiation in the highest altitude regions of Chaharmahal and Bakhtiari province (one million populations), in the south west of Iran (Fig. 1). This province is called the roof of Iran.
MATERIALS AND METHODS

The outdoors exposure rate of radiation was measured in 200 randomly selected regions using portable Geiger-Muller (SUM-AD8, Ricken Fine, Japan) and scintillation (Fuji Electric Co. Ltd., Japan) detectors. The detectors were calibrated using standard sources of $^{226}$Ra and $^{60}$Co. Eight measurements were made for each region and an average of those was used to calculate the exposure rate of the natural background radiation.

To estimate the exposure, the regions were divided into two groups: one group was the lower altitude regions (ranging from 1,650 to 2,100 meters above sea level) and the other was the higher altitude region (ranging from 2,100 to 2,600 meters above sea level). A topographic map of the studied regions was obtained from Civic Engineering Organization of the state.

Outdoor radiation measurements were performed by placing the detectors at least six meters away from any building or wall and one meter higher than the ground, to reduce their effects on the radiation field. The values of the outdoor absorbed dose were calculated using an occupancy factor (representing the weighted average for the population of this region) of 20%. The values of the annual effective dose were determined based on the equivalent dose.

RESULTS

Comparison of detector results

The results of measurements of the natural background radiation exposure rate in 200 randomly selected regions using portable Geiger-Muller and scintillation detectors are shown in Table 1. As shown in this table, there was no significant difference among the results by the detectors used. The results reported here are the average of the measured exposure rate and the dose rate using both detectors.

The exposure rate measurements

As previously mentioned, the regions were divided into two groups of lower altitude and higher altitude regions. The t-Student analysis showed no significant difference ($p < 0.05$) between the lower altitude regions and the higher altitude regions. The exposure rate was found to be $0.242 \pm 0.012 \mu\text{Gy/h}$ and $0.251 \pm 0.091 \mu\text{Gy/h}$ for lower and higher altitude regions, respectively. The correlation between the altitude and the exposure rate for different regions is shown in Fig. 2. As can be seen from this figure, there is a correlation between the altitude and the exposure rate.
exposure rate ($r^2 = 0.83$).

The relationship between the absorbed dose rate ($D_{air}$) and the exposure rate ($X$) is given by the following equation:

$$D_{air} = 8.69 \times 10^{-3} \times X \text{ (Gy)}$$

where $8.69 \times 10^{-3}$ is a conversion factor obtained using the 34 eV ionization energy required to produce an ion pair, multiplied by $1.6 \times 10^{12}$ ions produced for one Roentgen exposure.

The overall population weighted mean outdoor dose rate is 49 nGy/h, which is slightly higher than the world-wide mean value of 44 nGy/h reported in UNSCEAR, 1998. Using the dose rate obtained from different studied regions and the conversion occupancy factor of 0.2, as recommended by UNSCEAR in 1988 and 2000, the average of exposure rate was found to be $0.246 \pm 0.014$ µGy/h and the annual effective dose was found to be 0.49 mSv.

**DISCUSSION**

The presence of natural background radiation and environmental radioactivity is due to the distribution of radionuclides in the earth and causes exposure to all living organisms. The contents of natural radionuclides (uranium, potassium, and thorium) as well as the thin layer of atmosphere in the higher altitude regions (mountains) are reasons why they have high levels of human exposure. The highest gamma radiation is associated with areas comprising metamorphic rocks heavily intruded by granites and granitic pegmatites.

Since altitude is one of the important factors relevant to the measured dose rate, the results of this work showed that the altitude of the region had a significant effect on the level of background radiation. Some areas showed low background radiation in spite of their high altitude, as a result of the low concentrations of radionuclides in their soils. But a more detailed analysis of this result from individual measurements shows that there is a correlation between the altitude and exposure rate, as shown in Fig. 2.

The average exposure rate was found to be $0.246 \pm 0.014$ µGy/h, or 49 nGy/h, and the annual effective dose was found to be $0.49 \pm 0.04$ mSv. In relation to altitude, results also showed that higher altitude regions have higher natural background radiation levels, in good agreement with the literature. The dose-rate level of 49 nGy/h and the annual effective dose of 0.49 mSv are comparable with the dose rate of 55 nGy/h reported by Butt et al. and the annual effective dose of 0.38 mSv reported by UNSCEAR in 1998.

It is of interest to note that the average total annual effective dose in the studied region (including the concentration of radionuclides in the earth, aerosols and other factors) from radiation of natural origin is about 2.3 mSv, which is much lower than that of the annual equivalent dose, as reported by NRPB in 1981.

The main goal of this paper was to measure natural background radiation for comparison with worldwide data. The results of measurements of the background radiation in the studied regions have been shown to conform well with observations in various other countries. The results reported here provide a valuable and useful reference for the design and development of specific regional surveys related to the measurement of outdoor natural background radiation in the highest altitude regions of Chaharmahal and Bakhtiari province, in the south west of Iran.

**REFERENCES**