Natural Radiation Survey in Dalat University

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1. Introduction

All living organisms are continually exposed to ionizing radiation, which has always existed naturally. The sources of that exposure include cosmic rays that come from outer space and the surface of the sun as well as terrestrial radionuclides that occur in the Earth's crust, in building materials and in air, water, foods and in the human body itself. The exposures can vary widely depending on location.

Since the establishment of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [1] by the General Assembly on December 3rd, 1955, the Committee thoroughly reviews and evaluates global and regional exposures of natural radiation and the doses that result from them. This issue is also concerned by other organizations such as WHO (World Health Organization), IAEA (International Atomic Energy Agency) and ICRP (International Commission on Radiological Protection), among others. The dose limit for radiation workers averaged over 5 years is 100 mSv, and for members of the general public is 1 mSv per year. There are many high natural radiation areas around the world where the annual dose received by members of the general public is several times higher than the ICRP dose limit for radiation workers. It's very important that any exposure above the natural background radiation should be kept as low as reasonably achievable, but below the individual dose limits.

In the present investigation, an effort has been made to estimate the annual effective dose on Dalat University, based on: (1) measurement of the indoor radon concentration, (2) survey of the terrestrial gamma rays exposure, (3) calculation of the dose rates due to cosmic rays including (a) the photon/directly ionizing component and (b) neutron, taking the variations of altitude and latitude into account, (4) taking the reference value of outdoor radon concentration and the worldwide average annual effective dose contributed by ingestion of contaminated foodstuffs.

2. Survey Equipment and Theories

2.1. Survey Equipment

In this study, external dose rate by terrestrial gamma radiation was measured by the AT6101 Gamma Spectrometer (using NaI(Tl) scintillator). AT6101 was installed on the holder, one meter height from the ground. It takes about 5 minutes until the statistical error is below 5% for recording the result.

The long term measurement can comprise all the factors of weather (rainy, sunny, cloudy, dawn, sunset, etc.), thus the result is more reliable than immediate measurement. It was performed continuously in 6 months of dry season (from December to June) by the Thermo Luminescent Dosimeter (TLD), which was put in the Radiation Monitoring Box (made by Aluminum) in Dalat University campus.

For the indoor radon measurement, the real time Smart Radon Detector Radon Eye+ (using the ion chamber) was kept inside each surveyed place for about one week to record the indoor radon concentration with an interval of 1 hour. As such, about 168 data points were recorded from each place. The Radon Eye+ was installed at least 50 cm apart from the wall, window and floor. The time for the first reliable data display was just within 1 hour, with less than 10% error from the starting time of measurement. The data was updated every hour.

2.2. Cosmic Ray Exposure Calculation

Estimates of the photon/ionizing component dose rates at elevations above sea level are obtained using a procedure published by Bouville and Lowder [2]:

$$E_z = E_0 \times (0.21 \times e^{-1.649z} + 0.79 \times e^{0.4528z}) \qquad (1)$$

Where E_0 is the dose rate at sea level (nSv/h), and z is the altitude (km). The dose rate is about 6.25% lower at the geomagnetic equator than at high latitudes.

The outdoor cosmic ray neutron dose rate D (nSv/h) at vary altitudes is inferred by applying a neutron fluence energy distribution weighting factor of 720 ($nSv.h^{-1}$)/($n.cm^{-2}.s^{-1}$) [2]:

$$D = 720 \times \dot{E} = 720 \times 22.37 \times e^{-0.00721p} \qquad (2)$$

Where $\dot{E}$ ($n.cm^{-2}.s^{-1}$) is the neutron fluence rate; the relation between height above sea level, h_v (km), and atmospheric depth, p ($p > 230$ g/cm^2) is:

$$h_v = 44.34 - 11.86 \times p^{0.19} \qquad (3)$$

The latitude variation is given by 40% with the lower values near the equator [3].

3. Results and Discussions

3.1. Indoor Radon Measurement

Eight places were chosen for indoor radon concentration measurements. Among them, four places inside Dalat University were surveyed: the Library (which has the high external radiation dose rate and contains some gypsum in the building material), A11 basement (located underground, which is thought to have high radon concentration), Administration Building (where many staff work) and A11 1st floor (located in the same building with A11 basement). The indoor radon concentrations were also measured at three schools and one child center with different age categories in Dalat area because children's lung has greater risk of cancer than adults from radon irradiation. These places are Tran Phu High School, ADV Primary School, Nursery No. 9 School and TDV center. All the surveyed places mentioned above were located on the 1st floor, except for the A11 basement. The indoor radon behaviors are different at each site. The average values and peak values of indoor radon concentration are calculated and indicated in Table 1.

Table 1: Radon concentration at eight surveyed places

No.	Place	Average value (Bq/m^3)	Peak value (Bq/m^3)
1	Library	169.70 ± 10%	316.00
2	A11 basement	150.70 ± 10%	340.00
3	A11 1st floor	42.73 ± 10%	97.00
4	Administration building	81.73 ± 10%	180.00
5	Tran Phu High school	25.60 ± 10%	55.00
6	ADV Primary school	26.65 ± 10%	80.00
7	Nursery No. 9 school	25.36 ± 10%	68.00
8	TDV center	55.20 ± 10%	97.00
Average		**72.21**	

The results in Table 1 show that the indoor average concentration of radon in the Library and A11 basement are about 1.5-time higher than the reference level of 100 Bq/m^3 (proposed by WHO). Radon is carried indoors through many access routes, such as cracks in solid floors, construction joints, cracks in walls below ground level, and gaps around pipes; note that the A11 basement is located underground. While the radon concentration of A11 1st floor is just nearly one-third of A11 basement, illustrated by 42.73 Bq/m^3 compared with 150.70 Bq/m^3. The Library contains a lot of gypsum in the building material. The additional radon concentration arises from the established building materials (gypsum contains concentrations of radium). Furthermore, the ventilation conditions are not good because ventilation actions are dependent on the working times of the staff.

The indoor radon behaviors are different at each site, as illustrated in Fig. 1. Generally, during the weekdays, the indoor radon concentration continuously decreases from the peak level in the early morning to the lowest level in the late afternoon, and then increases until the next morning. The behavior of indoor radon is due to ventilation and natural effect (mainly by air inversion phenomena). Ventilation has been demonstrated as a major factor that influences indoor radon concentration. Ventilation actions, such as opening doors and windows, can lead to the mixing of indoor and outdoor air, and thus, the radon concentration quickly decreases at about 7 am in the morning.

On the weekend, no ventilation leads to a higher radon concentration compared with that during the weekday since radon accumulates inside the room.

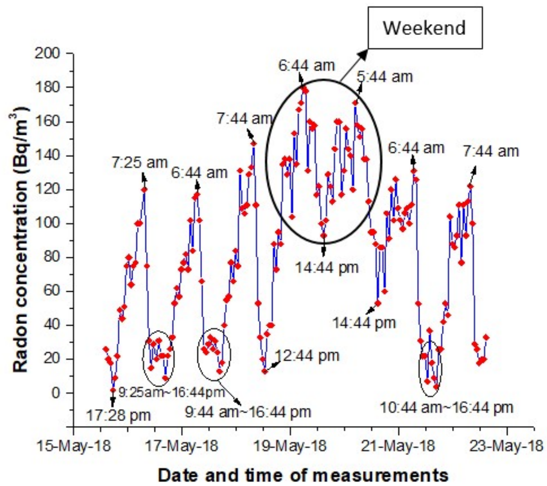

Fig. 1. Daily variations of indoor radon concentration at the Administration building

3.2. External Exposure Survey

The external terrestrial exposure survey contains 31 indoor places and 22 outdoor places in Dalat University, the results are calibrated against TLD data. The average dose rates are also calculated, such values for indoor and outdoor are 0.091 µSv/h and 0.061 µSv/h, respectively. The source geometry changes from half-space to a more surrounding configuration. The building materials act as sources of radiation and also as shields against outdoor radiation. Indoor exposure due to gamma rays, mainly determined by the materials of construction, is greater than outdoor exposure. The outdoor measurements may have been influenced by the presence of buildings nearby, depending on its distance from buildings or construction materials.

Correlations (1)-(3) were used to calculate the dose rates due to cosmic rays including (a) the photon/directly ionizing component and (b) neutron, respectively. The results are shown in Table 2.

3.3. Annual Effective Dose Estimation

In order to combine indoor and outdoor dose rates to compute total doses, the indoor occupancy factor of 0.8 is use, which implies that people spend 20% of the time outdoors, on average around the world [2]. A mean shielding factor of 0.8 is applied for indoor cosmic rays [2]. The dose conversion factors of 9 nSv (Bq h m^{-3})$^{-1}$, equilibrium factors of 0.4 for indoor and 0.6 for outdoor are applied for inhalation of radon gas [2]. The annual effective dose of Dalat University is calculated and compared with worldwide average value, as shown in Table 2.

Table 2: Calculation of annual effective dose of Dalat University

Source	Worldwide average annual effective dose (mSv/a) [4]	Annual effective dose of Dalat (mSv/a)	Variation factor
External exposure			
Cosmic rays	0.4	0.443*	1.106
Terrestrial gamma rays	0.5	0.745	1.489
Internal exposure			
Inhalation (mainly radon)	1.2	1.911**	1.593
Ingestion	0.3	0.300 [4]	-
Total	2.4	3.398	1.416

*The contribution from (a) the photon/directly ionizing component and (b) neutron are 47.275 nSv/h and 12.862, with the altitude and latitude of Dalat University is about 1500 meters and 12 degrees, respectively.

** The contribution from indoor radon concentrations is 72.21 Bq/m^3. Typical outdoors radon concentrations of 10 Bq/m^3 are used [5].

The results in Table 2 show that the annual effective dose of Dalat varies with worldwide average annual effective dose within a variation factor of 1.416. The cosmic rays dose rate of Dalat University (at 1500 meters altitude) is higher than the worldwide average value (at 900 meters altitude), but the latitude effect (12 degrees latitude compared with 50 degrees latitude of worldwide average) cancels out it, leading to the close value with the worldwide average effective dose. The terrestrial gamma rays effective dose of Dalat University is higher than worldwide average terrestrial gamma rays effective dose since the indoor surveyed places accounted for 60% and the outdoor measurements were influenced by the presence of buildings nearby. The average effective dose causes by inhalation of radon gas in Dalat area is higher than worldwide average value because of the influence of two places which have high concentration of indoor radon concentration (Library and A11 basement).

4. Conclusions

In this study, the natural radiation in Dalat University was surveyed. Through the investigation, we confirm that the terrestrial gamma rays depend strongly on construction materials, the amount of the radionuclides present in the soil and the geographical conditions of different places. The contribution from cosmic rays varies with altitude and latitude. The indoor radon behavior in a day shows the same trend in most surveyed places, which has the peak value in the early morning and the lowest value in the late afternoon. There are also some fluctuations of radon concentration at specific time due to different weather conditions in the day. Indoor radon concentrations exceeding the recommended guidelines were found (150.7-340.0 Bq/m^3) at two of the surveyed areas: the Library and A11 basement, where some corrective actions should be performed to reduce the radon concentration.

The annual effective dose on Dalat University was estimated to be 3.398 mSv per year, higher than worldwide average annual effective dose by a factor of 1.416.

Further study is in progress to analyze radionuclide concentrations in soil and construction materials used in the buildings with high radon concentration and external exposure dose rate measured in Dalat University. The creation of Lam Dong radiation map is also underway.

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