Radon concentration in residential areas of Bann Pang Fan, Chiang Mai province, Thailand

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Abstract. This study examined the radon concentration in residential areas of Bann Pang Fan, Chiang Mai Province, Thailand. Measurement was carried out for radon concentration in 59 residences from February to June 2017 using plastic alpha track detectors or CR-39 placed in wooden and cement bedrooms and living rooms. It was found that the radon concentration was 26-322 Bq·m⁻³, with an average at 53.9±29.43 Bq·m⁻³. In the bedroom, the concentration was 28-143 Bq·m⁻³, while in the living room it was 26-322 Bq·m⁻³. When calculating the annual effective dose of the residences, it was found to be at 0.21-1.71 mSv/year. The annual effective dose of 52.54% for the residences was higher than 1 mSv/year, as recommended by UNSCEAR.

1. Introduction
Radon-222 is a radioactive gas in the chain of uranium with a half-life of approximately 3.824 days. It is generally found in soil, rocks, water, and air. It is a radioactive substance that has the potential to cause lung cancer [1-3]. Radon gains access to residences through the leaks and cracks in buildings and pipes. Besides, construction materials containing radium and uranium release radon, which decomposes into radon progeny that can enter the human body through breathing. Therefore, radon and its progeny release alpha rays that affect lung tissues. Residents who inhale radon in high quantities will suffer a negative impact on their respiratory systems. The risk of lung cancer related to inhalation of radon and its progeny also becomes evident, which is more likely in the case of smokers [4-6].

Thailand has previously carried out surveys on radon concentration. However, only few reports are accessible. Titipornpun K et al. [7] measured the radon concentrations in 248 residences in Chaiya and Tha Chana districts of Surat Thani province, southern Thailand using plastic alpha track detectors or CR-39. The results showed that the average radon in Chaiya and Tha Chana was 26±2 and 30±2 Bq·m⁻³, respectively. This was no excess above the action level of US EPA (<148 Bq·m⁻³). Moreover, Titipornpun K et al. [8] investigated radon concentrations in 46 dwelling and 127 workplaces in the Ko Samui district, Surat Thani province with CR-39 for 90 days. The average of radon concentration in the dwellings and workplaces was 46.0±1.55 and 28.8±1.58 Bq·m⁻³, respectively, which was not over the US EPA standard (<148 Bq·m⁻³). In addition, the researcher preliminary surveyed radon concentration in residences surrounding Doi Saket Hot Spring, Chiang Mai in 2015, finding that the radon concentration was 11-272 Bq·m⁻³ with an average of 68±55 Bq·m⁻³. Five residential areas were over the action level of the US EPA. The results were different from that in Nong Kaew, Hang Dong, Chiang
Mai, located in the southern part of Chiang Mai, where radon concentration was quite low at 3 - 17 Bq·m⁻³ and the average was 6±4 Bq·m⁻³.

In this study, the researcher examined radon concentration in residences in Bann Pang Fan, Doi Saket, Chiang Mai. The study area located in the northeastern part of Doi Saket and the eastern part of Chiang Mai. The annual effective dose of the residents received from radon and its decay products was also examined.

2. Materials and Methods

2.1. Study area

Bann Pang Fan is located in the northeastern part of Doi Saket, which is in the eastern part of Chiang Mai, as shown in figure 1. Chiang Mai is a province located in northern Thailand. Most of the geography of Bann Pang Fan is high mountains with some plain areas, 1,025 meters above sea level. It is 18 kilometers from Doi Saket Hot Springs, Chiang Mai and 23 kilometers far from Mae Kha Chan Hot Springs in, Chiang Rai. The last recorded population is 378 males and 332 females (710 people in total) in a total of 238 households.

2.2. Measurement of radon concentration

Plastic alpha track detectors or CR-39 were randomly placed in 59 residences in Bann Pang Fan, Doi Saket, Chiang Mai from 27 February to 24 June 2017 (115 days). The houses involved were both wooden houses and cement houses. CR-39 was positioned in the bedroom and living room from the wall and 2 meters high from the floor. Collected information from installing the devices involved house-story, house description, numbers of windows, and time spent in the room where the devices were positioned. After 115 days, radon concentration was analysed by measuring alpha ray; corroded CR-39 with NaOH, 6.25 N at 60 ºC for 24 hours. Then, CR-39 were cleaned with 80% concentrated ethanol and dried, after which they were tracked a the microscope at magnifying power ×40, as well as rack density, (tracks/mm²) to analyse the radon concentration and annual effective dose of the residents, as the equation of UNSCEAR, 2000 [8]:

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\text{Annual effective dose} = C_R \times F \times T \times DCF
\]

where \( C_R \) is radon concentration (Bq·m⁻³), \( F \) is equilibrium factor for radon and its progeny (0.46), \( T \) is indoor occupancy time (h/y), and \( DCF \) is the dose conversion factor (9 nSv·h⁻¹(Bq·m⁻³)⁻¹) for radon and its progeny (UNSCEAR, 2000)

2.3. Statistical analysis

The comparison between pairs of groups was performed by means of Student’s t-test.
3. Results and Discussions
From the survey of 59 residences in the village in Bann Pang Fan, Chiang Mai, it was discovered that radon concentration was 26-322 Bq·m⁻³, and the mean was 53.94±29.43 Bq·m⁻³. Radon concentration distribution in the residential area is shown in figure 2, which showed that most residences had radon concentration at 26-50 Bq·m⁻³, 52.54% of the entire residences. Radon concentration in the bedroom was 28-143 Bq·m⁻³ and that in the living room was 26-322 Bq·m⁻³ as shown in table 1. Radon concentration in the residences did not exceed the action level of the WHO and US EPA. There were only two residences, accounting for 3.38%, in which radon concentration was greater than 100 Bq·m⁻³, over the WHO level [9], while one residence, accounting for 1.69%, had a concentration higher than action level of 148 Bq·m⁻³, which recommended by the US EPA [10]. The main reason for the high radon concentration in some residences was inefficient ventilation. The residents in closed the windows 24 hours per day or rarely opened the windows, preferring to turn on the air conditioner and preventing dust from getting into the residence. It have been reported that radon concentrations will be high if ventilation is insufficient or the doors and windows are closed most of the time [11]. It was also found that radon concentration in Pa Miang, Chiang Mai was similar to that in Ko Samui, Chiya and Chana, in Surat Thani province, southern Thailand.

![Figure 2](image-url)  
**Figure 2.** Frequency distribution of radon concentrations in dwellings.

| Room   | No. of room | Radon concentration (Bq·m⁻³) | Min. | Max. | Average ± SD |
|--------|-------------|------------------------------|------|------|---------------|
| Bedroom| 59          | 28-143                       | 28   | 143  | 53.41±19.23  |
| Living room | 58         | 26-322                      | 26   | 322  | 53.56±37.59  |

Table 2 shows radon concentration classified by house-story. It was found that the average radon concentration downstairs was higher than that upstairs. This was in line with many previous researches reporting that radon concentration had a negative correlation with house-story [12]. Moreover, soil and rocks were the main causes for taking radon into the house as it got through soil and rock layers [13]. If there was a crack in the floor, radon could possibly disperse into the house. Therefore, a room attached to the earth was found to have more radon than rooms on upper stories. In this research, the average radon concentration was in a wooden room at 48.84±11.47 Bq·m⁻³, while the average concentration was in a cement room at 58.95±39.40 Bq·m⁻³. The average radon concentration in the cement room was higher than that in the wooden room with statistical significance (p<0.05), as shown in table 2.
Additionally, it was reported that construction materials such as sand, concrete, block and cement are one of the major sources of indoor radon concentration in residence. They would present a higher indoor radon concentration if were used these construction materials together for construction. This was because construction materials contained uranium or radium that could breakdown to radon [14-15].

**Table 2.** Radon concentration according to number of floor and material used for the building.

| No. of Floor/material | No. of room | Radon concentration (Bq·m⁻³) |
|-----------------------|-------------|------------------------------|
|                       |             | Min. | Max. | Average ± SD |
| No. of Floor          |             |      |      |               |
| 1st                   | 83          | 26   | 322  | 56.61±34.19   |
| 2nd                   | 34          | 28   | 64   | 47.41±8.86    |
| Building material     |             |      |      |               |
| wood                  | 58          | 26   | 91   | 48.84±11.47   |
| Cement block          | 59          | 28   | 322  | 58.95±39.40   |

Annual effective dose of the residents who inhaled radon in the residences was 0.21-1.71 mSv/year, the average was 1.05±0.29 mSv/year, as shown in figure 3. The highest annual effective dose of the residents was 1.71 mSv/year, which was lower than 3-10 mSv/y as recommended by ICRP (1993) [16]. 31 residences, accounting for 52.54%, had a value over 1 mSv/y as recommend by UNSCEAR (2000) [17]. From a discussion with the residents having high effective dose, it was found that they spent long periods in the bedroom and living room, not working outside. Moreover, annual effective dose had a direct relationship with the time spent in the bedroom and living room. If the resident stayed in a room with a high rate of radon for a long time, it affected their health. Therefore, efficient and sufficient ventilation are required for the room to minimize the dose.

![Figure 3. Annual effective dose due to radon inhalation.](image)

A limitation of this research was that it conducted examination in only one season, while effective dose involves a yearly calculation. Thus, the results of this study comprise only the estimation of radon studied in the summer season. Further study during other seasons is required to investigate the change of radon.
4. Conclusion
The measure of radon concentration in 59 residences in Bann Pang Fan, Doi Saket, Chiang Mai showed that the concentration was 26-322 Bq·m$^{-3}$, with an average of 53.94±29.43 Bq·m$^{-3}$. Most residences had a lower concentration than action level of 100 Bq·m$^{-3}$ and 148 Bq·m$^{-3}$, which was recommended by WHO and US EPA, respectively. Only 1.69% had a higher concentration than 148 Bq·m$^{-3}$. Furthermore, it was found that the annual effective dose of 52.54% for the residences was higher than 1 mSv/year, as recommended by UNSCEAR. However, the residential areas with a higher radon concentration than the action level should attempt to reduce it as much as possible or lower it to meet the standard in order to reduce the risk of lung cancer.

5. References
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Acknowledgement
This study was supported by the National Research Council of Thailand.