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Radon study around earthquake affected areas of Nepal

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ABSTRACT

Indoor radon concentrations were measured in dwellings of the earthquake affected areas of Kathmandu valley, Gorkha and Sindhupalchowk districts of Nepal using passive radon dosimeter LR115, a Solid-State Nuclear Track Detector, SSNTD. The radon concentrations in dwellings of Kathmndu valley ranged from 11±6 Bq/m^3 to 135±26 Bq/m^3 with mean of 67.63 Bq/m^3. For Gorkha it ranged from 18±7 Bq/m^3 to 363±65 Bq /m^{3}with an average of 104.64 Bq/m^{3}while minimum, maximum and average radon concentrations for Sindhupalchowk were 14±6 Bq/m^3, 397±71 Bq/m^{3}and 78.46 Bq/m^3 respectively. The average annual effective dose to the inhabitants of Kathmandu valley, Gorkha and Sindhupalchowk districts were calculated as 1.46 mSv/y, 2.26 mSv/y and 1.69 mSv/y respectively. These annual doses were well below the action level of 10 mSv/y recommended by International Commission on Radiological Protection (ICRP) which implies no significant radiological health hazards. Also, Excess Lifetime Cancer Risk and Lungs Cancer Cases per year per million people were determined.

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1. Introduction

Radon Rn-222 is a radioactive gas derived from Uranium-238 decay series. Uranium is a ubiquitous radioactive element present in varying amount in rock, soil and air. Radon has a half-life of 3.8 days that is sufficient for it to migrate through pore space in the soil and rock into dwellings. Despite being a member of noble gases, it spontaneously decays into very high alpha emitters such as Polonium-218 and Polonium-214.

Radon and its progenies represent more than 50% of the total natural radiation of human exposure to ionizing radiation [1]. Radon is considered as carcinogenic to human [2]. It stands second to cause lungs cancer after tobacco smoking in general population [3]. Apart from lungs cancer, radon exposure is also responsible for various non-cancerous diseases like stroke, heart disease and diseases related to respiratory and digestive system [1,4]. Studies on risk assessment of radon, both in mines and dwellings, have shown several health effects [5,6] and the regulatory requirement has been advised to control public exposure due to radon indoors [7].

An earthquake of magnitude 7.6 struck on 25th April 2015 in Nepal and was followed by several aftershocks [8]. Gorkha district, Kathmandu valley and Sindhupalchowk district were the most affected by this earthquake. The cracks and fissures developed on soil due to earthquake or landslides are supposed to enhance radon exhalation from soil [9-12]. As Nepal is prone to earthquake, the assessment of radon concentration has become necessary as a baseline study for future investigation. Therefore, assessment of the indoor radon concentrations has been carried out starting from those most affected areas. In addition, the annual effective dose along with any cancerous risk associated with this radon exposure has been estimated around the earthquake-affected areas of Nepal.

2. Materials and Methods

2.1. Study area

Kathmandu valley, Gorkha and Sindhupalchowk were selected for this study. Kathmandu valley is comprised of three districts Kathmandu, Lalitpur and Bhaktapur and is the capital city of Nepal located at 27° 42' N and 85° 18' E with an average altitude of 1292 m. Gorkha district, the other location is about 80 km northwest of Kathmandu valley with an average altitude of 1900 m from sea level having coordinates 28°12' N and 84°44' E. The epicenter of 2015 earthquake was in Gorkha. Sindhupalchowk, the third location, is 60 km east from Kathmandu with an average elevation of 1450 m located at 27°46' N and 85°43' E.

2.2. Methodology

Solid State Nuclear Track Detector, a passive radon detector (LR-115 type II, Dosirad, France) was employed for radon concentration measurement. Each detector consists of 12 μm thick Cellulose Nitrate film coated on a 100 μm polyester base. The film of the detector can record alpha particles of energy range 0.1 MeV to 4.8 MeV [13].

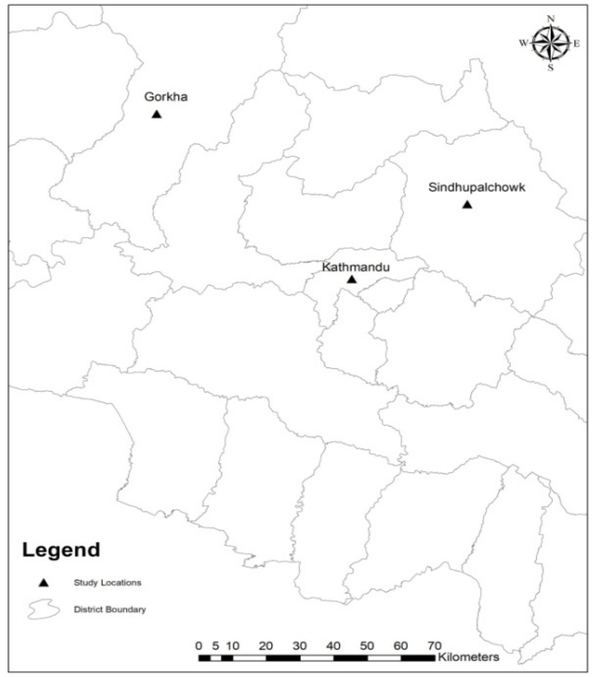

Fig.1: Map of study areas.

A total of 90 dosimeters were fixed in the dwellings of study area out of which 68 detectors were retrieved. The detectors were placed on ground floor approximately 1.5 m above the ground level and were exposed for about 100 days (May to August, 2017). The detectors were read at Dosirad, France. Exposed films were etched on 10 % analytical grade NaOH bath for about 75 to 100 minutes at constant bath temperature of 60°C. After this, films were washed by acidified water (HCl upto pH 3) for 30 minutes and final rinse of around 2 minutes at 20°C by distilled water was done. The etched tracks were counted using a binocular optical research microscope at magnification 400X.

The radon concentrations were used to calculate Annual Effective Dose (AED) using the UNSCEAR, 2000 model [1].

$$\text{AED (mSv/Yr)} = C_{Rn} \times E \times T \times D$$

where, C_{Rn}- Radon Concentration (Bq/m^3).
E-Indoor equilibrium factor (0.4; [1,7])
T-Time in hours per year spent indoor
D-Dose conversion factor (9nSv/Bq.h.m^3; [1])
6000 hours per year was considered to be total time spent indoors by the inhabitants following a questionnaire. Excess Lifetime Cancer Risk (ELCR) was calculated as [14].

$$ELCR = AED \times DL \times RF$$

where, DL- Duration of Life (70.2 years; [15])
RF- Fatal Cancer Risk per Sievert (5.5×10^{-2}; [16])
Lung's cancer cases per year per million people (LCC) were calculated as [17].

$$LCC = AED \times 18 \times 10^{-6}$$

3. Results and Discussions

3.1. Radon concentrations

The indoor radon concentrations were measured in dwellings of different places of Kathmandu valley, Gorkha and Sindhupalchowk districts, which are shown in figure 2, 3 and 4 respectively. As radon concentrations generally follow a log normal distribution [14] the measured radon concentrations also were log-normally distributed (at 0.05 level, Shapiro-Wilk test).

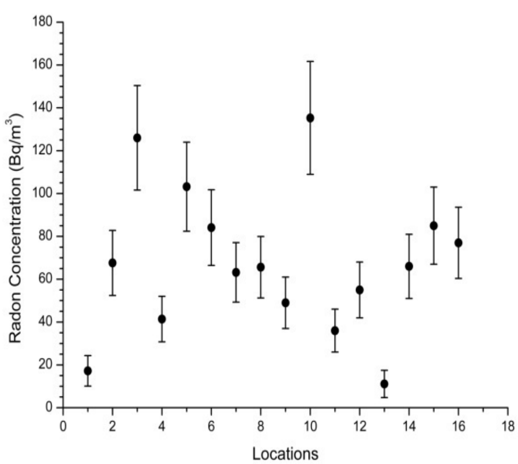

Fig.2: Radon Concentrations in dwellings of Kathmandu Valley.

Radon concentrations varied in different dwellings in Kathmandu valley with the lowest concentration of 11±6 Bq/ m^3 to highest of 135±26 Bq/ m^3. The arithmetic average, geometric average and median value for the concentrations were 67.63 Bq/m^3, 57.26 Bq/ m^{3}and 66 Bq/ m^3 respectively. Out of studied 16 dwellings of Kathmandu valley 81% of dwellings had radon concentration below 100 Bq/ m^3 and remaining 19% had in between 100-150 Bq/ m^3.

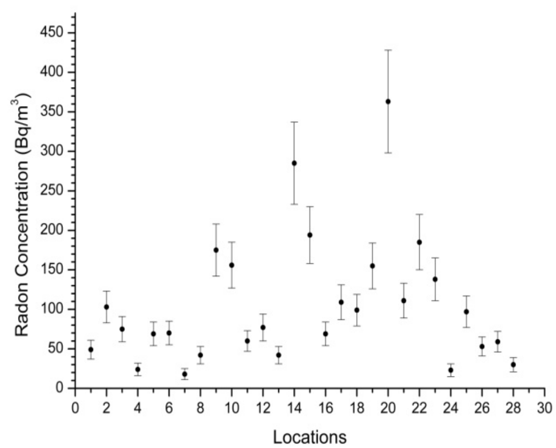

Fig.3: Radon Concentrations in dwellings of Gorkha.

The minimum, maximum and average radon concentrations in Gorkha districts were 18±7 Bq/m^3, 363±65 Bq/m^3 and 104.64 Bq/m^3 respectively with geometric mean of 80.63 Bq/m^3 and median value 76 Bq/m^3. In Gorkha, 61% of the dwellings had concentrations below 100 Bq/m^3, 36% have concentrations in between 100-300 Bq/m^3 and remaining 3% had concentrations above 300 Bq/m^3.

The indoor radon Concentration in Sindhupalchowk ranged from 14±6 Bq/m^3 to 397±71 Bq/m^3 with an arithmetic mean of 78.46 Bq/m^3, geometric mean of 60.78 Bq/m^3 and the median value of 65.5 Bq/m^3. In this district, 79% of dwellings had concentrations below 100 Bq/m^3, 17% were in between 100-300 Bq/m^3 while only 4% were above 300 Bq/m^3.

A comparative representation of radon concentrations in Gorkha, Kathmandu and Sindhupalchowk has been shown in the figure 5. It is observed that radon concentrations in Gorkha and Sindhupalchowk were comparatively higher than those of Kathmandu valley. The variation in radon concentrations might be due to difference in topography of locations, ventilation systems and building materials used in the dwellings [9, 10]. The permissible limit for radon concentration is 300 Bq/m^3[18] and in this study only two of the measurements, 397±71 Bq/m^3 (Sindhupalchowk) and 363±65 Bq/m^3 (Gorkha), were observed above the limit. Both the dwellings were old aged, made from mud with several cracks, fissures and fractures due to devastating earthquake. Furthermore, poor ventilation system was also observed in both cases.

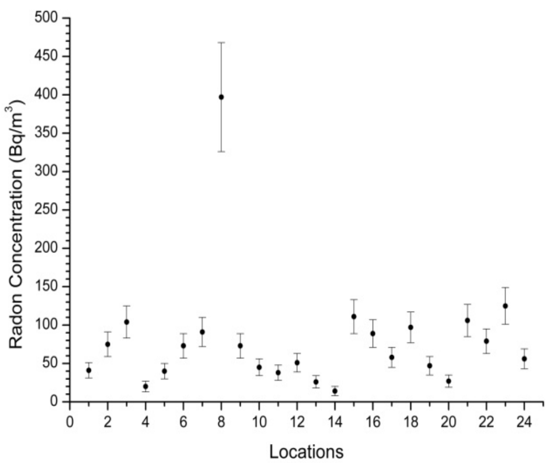

Fig.4: Radon concentrations in dwellings of Sindhupalchowk.

The overall average radon concentration of study locations was 83.57 Bq/m^3 which is lower than those reported in the dwellings of Hemavathi river basin, Karnatak, India (99.35 Bq/m^3;[9]), Lahore and Islamabad, Pakistan (135.25 Bq/m^3 and 112.5 Bq/m^3 respectively; [19, 20]), Shenyan and Gansu, China (115.7 and 222.9 Bq/m^{3}respectively; [21]), nationwide average of Korea (102 Bq/m^3; [22]), nationwide average of U.K. (101 Bq/m^3; [23]), Fredicton and Halifax of Canada (138 Bq/m^{3}and 259Bq/m^3 respectively; [24]). However, the average of this study was higher than those calculated in the dwellings of Kathmandu valley, Nepal (80 Bq/m^3; [25, 26]), nationwide average of Japan (14.3 Bq/m^3; [27]) and indoor radon of Meghalaya, India (59.9 Bq/m^3; [10]) . In addition this average was slightly more than double the world average indoor radon concentration of 40 Bq/m^3[1]. The higher radon concentrations in some dwellings might be due to following reasons.

- Cracks, fissures and fractures in the basement and wall of the house due to earthquake
- Higher uranium content in the soil
- High permeability and porosity of bedrock
- Some old houses built from mud and wood
- Poor ventilation condition in some houses
- Some houses built on old landslide deposits

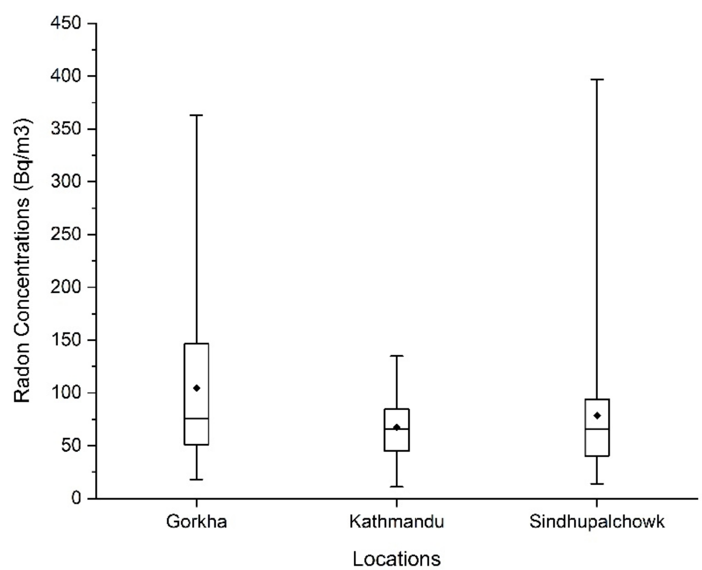

Fig.5: Box plot of radon concentrations.

3.2. Annual Effective Dose

The radon concentrations obtained in the study of Kathmandu valley, Gorkha and Sindhupalchowk districts were used to estimate the annual effective dose (AED) to the inhabitants using UNSCEAR, 2000 model. The AED due to radon received by residents of Kathmandu valley, Gorkha and Sindhupalchowk districts are shown in figure 6, 7 and 8 respectively.

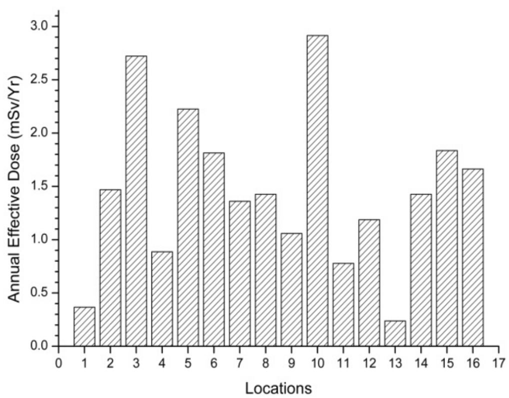

Fig.6: Annual effective dose for Kathmandu valley.

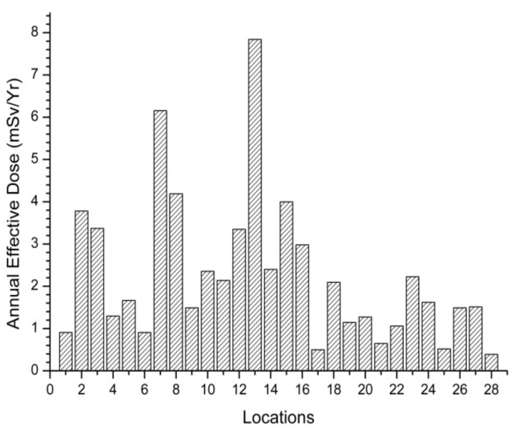

Fig.7: Annual effective dose for Gorkha.

The dose in dwellings of Kathmandu valley varied from 0.24 mSv/y to 2.92 mSv/y with an arithmetic average of 1.46 mSv/y. For Gorkha dose were reported to lie between 0.39 mSv/y and 7.84 mSv/y with an average of 2.26 mSv/y. Similarly, for Sindhupalchowk, the dose ranged from 0.30 mSv/y to 8.58 mSv/y with an average of 1.69 mSv/y. Relatively higher doses were observed in Gorkha which might be attributed to geological variations and nearness to the epicenter of 2015 earthquake. The average doses of all three study locations were higher than the world mean dose from environmental radon of 1.15 mSv/y [1]. However the average doses were below the action level of 3 to 10 mSv/y [7,16].

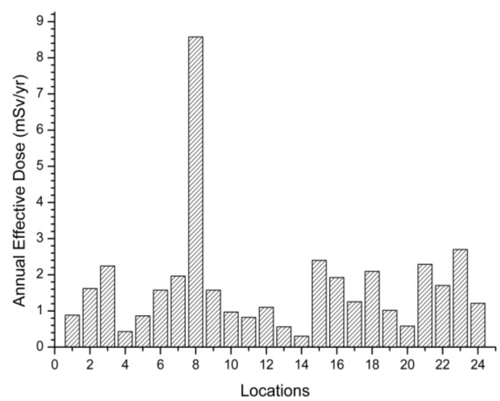

Fig.8: Annual effective dose for Sindhupalchowk.

The average AED was used to determine Excess Lifetime Cancer Risk (ELCR), which was calculated as 0.56%, 0.87% and 0.65% for Kathmandu valley, Gorkha and Sindhupalchowk respectively. The conversion factor of 18×10^{-6} /mSv [17] was used to determine indoor radon induced lungs cancer risk. The lungs cancer cases per year per million persons were 26.28, 40.68 and 30.51 for Kathmandu valley, Gorkha and Sindhupalchowk respectively.

4. Conclusion

The radon concentrations in Kathmandu valley, Gorkha and Sindhupalchowk districts were measured and AED of the study areas were calculated. Relatively higher dose were observed in Gorkha. The annual doses due to radon were below ICRP recommended action level of 10 mSv/y. Thus, there are no significant radiological health hazards to the population and the immediate counter measures are not necessary. However increased ventilation system of houses can be suggested to further reduce the radon concentrations in the dwellings.

All the study areas lie in mid hilly region of Nepal where it is very cold during November to March. As the present study was carried out during summer, it is recommended to have indoor radon measurements in winter season when poor ventilation system is expected which might attribute to higher radon concentrations.

Acknowledgments

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