Study of Radon Exhalation Rate in Soil Samples of Kathmandu Valley Using Passive Detector LR115

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Abstract

Magnitude of indoor radon (^{222}Rn) concentration depends on building materials like bricks, sand, cement etc., outdoor air radon concentration and amount of radon in underlying soil. So, radon exhalation rate of the soil (either underlying soil or soil used to make building materials or soil around the building) is important. To account this, level of radon concentration and its exhalation rate in soil samples of Kathmandu Valley, Nepal has been studied by time integrated method using LR-115, type II plastic track detectors based on Solid State Nuclear Track Detector (SSNTD). It was found, the average Radon concentration lies between (750.00±1165.97) and (4918.00±1165.97)with average (2321.14±1165.97)Bqm^{-3}, Surface exhalation rate lies between (0.4368±0.6265) and (2.7913±0.6265) with average (1.2753±0.6265) Bqm^{-2}hr^{-1} and Mass exhalation rate lies between (0.00219±0.003207) and (0.01403±0.003207)with average (0.006410±0.003207)BqKg^{-1}hr^{-1}. Higher value of radon exhalation rate was found in the soil samples corresponding to the dwellings with high indoor radon concentration.

Keywords: Building materials, Radon exhalation rate, SSNTD, Soil sample

Introduction

Radon, a naturally occurring radioactive inert gas (half-life of 3.8 days) exists in three natural isotopes viz. radon (^{222}Rn), thoron (^{220}Rn), and actinon (^{219}Rn) resulting from the radioactive decay of Uranium, Thorium, and the actinium series [1, 2]. These days, radon and its progeny constitute the most important natural radiation exposure. After smoking, radon represents the second most important cause of developing lungs cancer in general people [3, 4].

Since Radon is a colorless, odorless and tasteless gas it can't be realized until it manifests some biological disorders in the organisms. Unlike radon, the radon decay products are extremely small solid particles that can be easily inhaled and can produce highly ionizing alpha, beta or gamma radiation. Densely ionizing alpha particles emitted by deposited short-lived decay products of radon (^{218}Po and ^{214}Po) can interact with biological tissue in the lungs and disrupt the DNA of these lung cells. The damaged DNA is potential enough to lead to cancer. This DNA damage, associated with radon, can occur at any level of exposure because a single alpha particle can genetically damage a cell [5, 6, 7]. It has been pointed out that indoor radon exposure is also tentatively linked with the risk of leukemia and certain other cancers, such as melanoma and cancers of the kidney and prostate [8].

The magnitude of indoor radon concentration depends primarily on building materials like bricks, sand, cement etc., outdoor radon concentration and amount of radon in underlying soil [9, 10].The concentration of radon in the atmosphere varies depending upon the place, time, height above the ground and meteorological conditions [11]. Generally, all building materials contain certain amount of uranium and radium. It is found that the building materials containing by-product gypsum, concrete containing alum shale, and bricks made with soil and rocks with high levels of natural radioactivity as volcanic tuffs and pozzolana [10]. Radon can escape from this soil or solid by Diffusion or recoiling - radon atom receives a momentum, which enables it to travel a certain distance trough a material [12]. So the exhalation of radon from these materials to the inside of the house can be a source of residential radon. Outdoor air can also play a role for the radon entering inside the dwellings through open doors and windows, cracks and fissures in the buildings, etc. [13].

To understand and minimize the risk of the radon gas, radon exhalation rate of the soil (i.e. either underlying soil or outdoor air soil or soil used to make construction materials) is important. Indoor radon concentration in different dwellings of Kathmandu valley has been studied [2] earlier. So to study the source of the radon in the dwellings, soil exhalation rate (In terms of area in $Bqm^{-2}hr^{-1}$ and in terms of mass in $BqKg^{-1}hr^{-1}$) of the different samples of the soil collected from the different locations of the Kathmandu valley is studied using Solid State Nuclear Track Detector (SSNTD): a fairly reliable, low cost and easily accessible method for the integrated and long term measurement of indoor radon activity [14, 1].

Experimental Work

Study area Kathmandu Valley

Kathmandu valley, urban center of Nepal lies between the latitudes 27º 32' 13" and 27º 49' 10" north and longitudes 85º 11' 31" and 85º 31' 38" east. It is located at a mean elevation of about 1,300 meters (4, 265 feet) above sea level. The climate of Kathmandu Valley is sub-tropical cool temperate with maximum of 35.6°C in April and minimum of –3°C in January and 75% annual average humidity. The temperature in general is 19 °C to 27 °C in summer and 2 °C to 20°C in winter. Average annual precipitation in the Kathmandu Valley is around 2,000 mm, about 80% of which falls in the monsoon period during June and July. The Kathmandu valley consisting of Kathmandu, Bhaktapur and Lalitpur districts is surrounded by the high rising mountains such as Shivapuri (2,732 m) in the north and Phulchoki (2,762 m) in the south. The soil of the Kathmandu valley is mainly alluvial soil, residual soil, colluvial soil and alluvial fan deposit. This consists of old fluvial and lacustrine sediments, consisting mainly of gravel, sand, silt, clay, peat, lignite and diatomaceous earth, etc., delivered mainly from the mountains with mines and minerals: quartzites, phyllites, dolomite, pegmatite, gneiss, schists, slates, limestones and marbles [15, 1, 16].

Materials and Methods

A passive method using LR-115 type-II plastic track detectors developed by Kodak-pathe, France, based on SSNTD technique, was employed for the assessment of radon concentration. The LR115 type films consist of a 100μm thick polyester base that is coated with a 12μm thin film of red colored cellulose nitrate ($C_6H_8O_9N_2$). This cellulose nitrate is a very useful detector for the direct registration of alpha particles in the energy range of 0.17-4.80 MeV. Such alpha particles penetrate through the thin film of LR115, forming narrow trail of damage called 'latent track' which can be observed through electron microscope after chemical itching [1].

Fig. 1: a) Kodalpha radon Detector b) LR115 Film and c) Alpha tracks in LR115 [2]

Exposure Measurements

Altogether 28 soil samples were collected randomly from Kathmandu, Lalitpur and Bhaktapur districts within Kathmandu Valley including radon vulnerable areas indicated by high indoor radon concentration [2]. All samples were dried so that the moisture is completely removed. All samples were crushed to a fine powder form, the crushed samples were then sieved through a small mesh size to remove the larger grains size and render them more homogenous. About 200 g of sample was placed in a plastic box of size 11 cm in height and 8.0 cm in diameter and the box was then closed for a period of 1 month in order to get equilibrium between radium and radon. A piece of detector of size 2×2 cm was fixed on the top of inner surface of the box, in such a way, that it is sensitive surface always facing the soil sample. The box is sealed air tight with adhesive tape and kept for exposure of 100 days. During exposure period, the sensitive side of the detector always faced the sample and is exposed freely to the emergent radon from the sample in the box so that it could record alpha particles resulting from the decay of radon in the remaining volume of the box [1, 12].

The exposed detectors were collected and sent to Dosirad laboratory, France, for track reading. The detectors were etched in a solution of 2.5mol/l NaOH at 60°C for one and half hour. The counting of alpha tracks was done using a binocular optical research microscope with a magnification of 400×. By using calibration factors (tracks/cm^2—KBq/h) radon exposure was determined.

The average radon concentration (C_{Rn}) in terms of Bq/m3 was determined using equation (1) [17].

$$C_{Rn} = \frac{1000 \times Exposure\,(kBqhm^{-3})}{Time\,(h)} \quad \ldots (1)$$

Radon Exhalation Rate

The rate at which radon escapes or emanates into the surrounding air is known as radon exhalation rate. Surface and Mass radon exhalation rate was calculated in this study.

For a sealed cylindrical box fitted with a source of radon and a SSNTD dosimeter fixed at the top of the box (Fig. 2). Radon exhalation rate in terms of area and mass was calculated from Eqns.2 and 3 [1, 12]

$$E_A = \frac{CV\lambda}{AT_{eff}} \quad \ldots (2)$$

$$E_M = \frac{CV\lambda}{MT_{eff}} \ldots (3)$$

Where, T_{eff} is the effective exposure time obtained by using

$$T_{eff} = [t - 1/\lambda\,(1-e^{-\lambda t})] \ldots (4)$$

Where, EA is the radon exhalation rate expressed in $Bqm^{-2}h^{-1}$, EM is the radon exhalation rate in terms of mass ($Bqkg^{-1}hr^{-1}$), C represents the integrated radon exposure ($Bqm^{-3}h$), t(100 days) is the exposure time in hours (h), λ is the decay constant for radon (h^{-1}) , A is cross-sectional area (5.028×10^{-3} m^2) of the box (m^2), V is the effective volume of the box, cross sectional area times height of air column (7.25 cm) and M (200 g) is the mass of sample.

Fig. 2: Plastic box with detectors used during the study

Results and Discussions

The detailed result of the observed radon concentration, radon exhalation rate calculated by using equations 2 and 3 and detailed information about the sample is presented in the Table in Appendix section. According to the result, it is found that the average radon concentration in the sampled soil lies between (750.00±1165.97) and (4918.00±1165.97)Bq/m^3 with average (2321.14±1165.97)Bq/m^3 similarly the surface exhalation rate lies between (0.4368±0.6265) $Bqm^{-2}hr^{-1}$ and (2.7913±0.6265) $Bqm^{-2}hr^{-1}$ with average (1.2753±0.6265) $Bqm^{-2}hr^{-1}$. Also the mass exhalation rate lies between (0.00219±0.003207) $BqKg^{-1}hr^{-1}$ and (0.01403±0.003207) $BqKg^{-1}hr^{-1}$with average (0.006410±0.003207) $BqKg^{-1}hr^{-1}$. This Radon concentration and Exhalation rate (Surface and Mass) within three different districts is presented in the Boxplot in fig. 3.

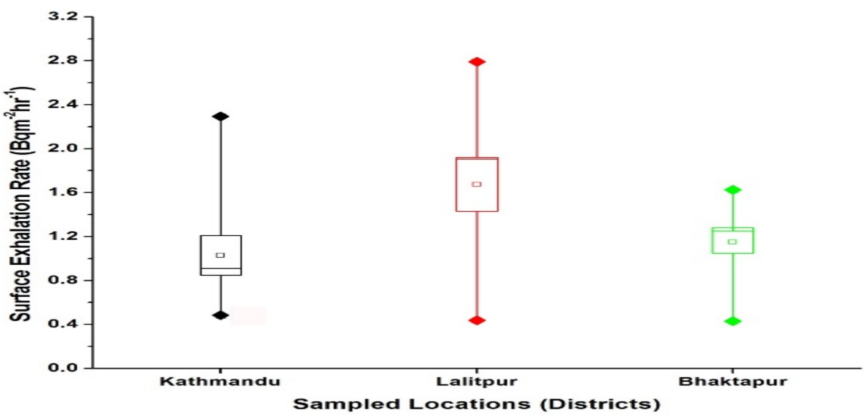

Fig: 3 (a) Boxplot of Radon Surface Exhalation rate, Box represents Mean±S.E. (Standard Error), □ Represents mean value, — Represents median value and ♦ Represents Maximum and Minimum value.

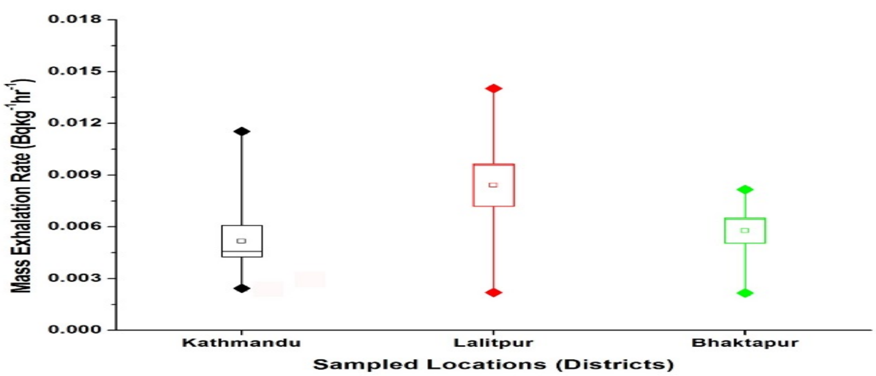

Fig: 3 (a) Boxplot of Radon Surface Exhalation rate, Box represents Mean±S.E. (Standard Error), □ Represents mean value, — Represents median value and ♦ Represents Maximum and Minimum value.

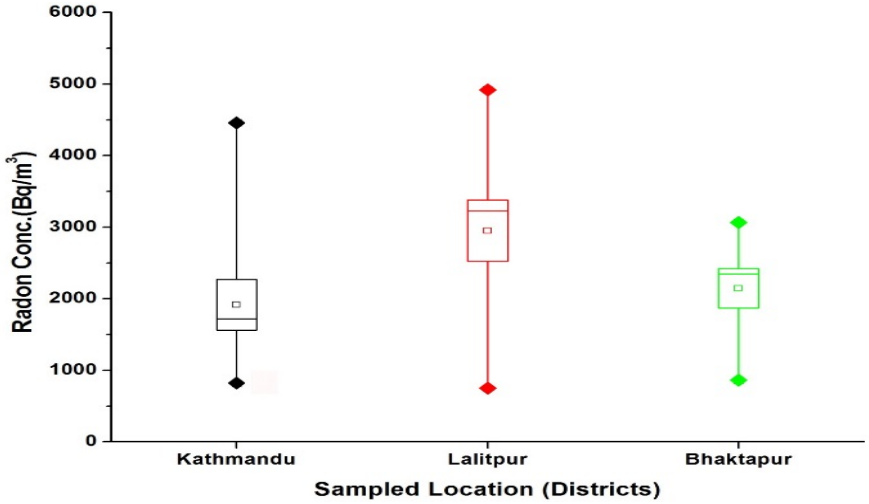

Fig: 3 (c) Boxplot of Radon Concentration, Box represents Mean±S.E. (Standard Error), □ Represents mean value,— Represents median value and ♦ Represents Maximum and Minimum value.

The radon exhalation rate and radon concentration varies appreciably in various samples. It is due to the fact that the soil samples collected from various sites may have appreciably large uranium contents which results in higher radon emanation rates. Different studies show linear relationship between Radon concentration and uranium content [13]. Hence, the place corresponding to the samples with high radon exhalation rate should have high content of uranium inside it. In similar studies [18, 19, 1, 12, 5, 14] radon activity and exhalation rates for different India and other countries samples have been calculated. For different samples, they reported the radon concentration from 246Bqm^{-3} to 905Bqm^{-3} and to 4891.4Bqm^{-3} in mining area [18].

Conclusion

This study shows that the samples have some higher levels compared with those studies, even greater than the level of mining area of India, which indicates the presence of higher uranium contents in this area. Also the higher radon concentration in Lalitpur district (GodamChour, Sanepa etc.) is probably due to the presence of the minerals like granite, gneiss, shale, schist, limestone (marble), dolomite, sand, etc. [20] found in deep earth's crust around these areas, which have high abundances of Uranium [13]. In the study many soil samples are collected from the residential areas in which radon level was measured in the dwellings. This present result is in good agreement to the result of the previous study [2] in terms of the high value of the radon concentration in the dwellings and radon exhalation of the soil sample of the area. Some of the samples were collected from the areas where building materials like bricks are made so, the vulnerable areas must be checked frequently and suitable preventive measures must be disseminated for the public.

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Appendix

Table No. 1: Details of the Radon concentration and Exhalation Rate (Height of the can is 11 cm and diameter 8 cm)

Sampled Location	Latitude, Longitude and elevation	Height of air column (cm)	Exposure $kBqh/m^3$	Avg. radon conc. Bq/m^3	Exhalation Rate	
					Surface(EA) $(Bqm^{-2}hr^{-1})$	Mass (EM) (BqKg-1hr^{-1})
Hattiban	N 27°38’50.3’’ E085°20’15.7’’ 1328m	7.8	7744	3226.66	1.9053	0.00957
Jadibuti	N27°40’43.3’’ E085°21’58.4’’ 1299m	6.6	2065	860.41	0.4298	0.00216
Gwarko	N 27°40’09.2’’ E085°20’06.9’’ 1297m	7.4	8625	3593.75	2.0127	0.01012
Chabahil	N 27°43’25.7’’ E085°20’41.2’’ 1305m	7.8	1958	815.83	0.4816	0.00242
Sanepa height	N 27°40’51.4’’ E085°18’07.6’’ 1288m	7.5	11802	4917.50	2.7913	0.01403
Sankhadar	N 27°40’27.7’’ E085°23’46.3’’ 1305m	6.8	5977	2490.41	1.2817	0.00644
Godamchou r	N 27°38’60.3’’ E085°20’25.7’’ 1318m	7.5	8793	3663.75	2.0796	0.01045
Samakhusi	N 27°43’46.2’’ E085°19’14.0’’ 1343m	7.0	2619	1091.25	0.5781	0.00290
Khumaltar	N 27°39’25.2’’ E085°19’40.3’’ 1335m	7.5	9626	4010.83	2.2767	0.01144
Lainchour	N 27°43’12.8’’ E085°18’50.7’’ 1390m	7.5	2163	901.25	0.5116	0.00257
Sanothimi	N 27°40’56.1’’ E085°22’39.6’’ 1329m	7.4	5632	2346.66	1.3143	0.00661
Dhapakhel	N 27°38’42.8’’ E085°19’39.2’’ 1338m	7.3	5339	2224.58	1.2290	0.00618
Tinkune	N 27°41’12.7’’ E085°20’56.1’’ 1293m	7.4	3102	1292.50	0.7239	0.00364
Mandikhatar	N 27°43’53.1’’ E085°20’40.5’’ 1340m	7.0	4127	1719.58	0.9110	0.00458
Dhobighat	N 27°40’32.3’’ E085°18’06.5’’ 1285m	7.2	3993	1663.75	0.9066	0.00456
Basundhara	N 27°44’32.1’’	7.1	3619	1507.91	0.8103	0.00407

	E085°19'14.0'' 1345m					
Dudhpati	N 27°40'15.6'' E085°25'13.0'' 1306m	7.4	5188	2161.66	1.2106	0.00609
Duwakot	N27°42'07.0'' E 085°24'37.7'' 1387m	7.0	3136	1306.66	0.6922	0.00348
Pepsicola	N 27°41'39.3'' E085°21'58.4'' 1308m	7.5	2906	1210.83	0.6873	0.00345
Ekantakuna	N 27°39'58.1'' E085°18'35'' 1301m	7.6	6000	2500.00	1.4380	0.00722
Sallaghari	N 27°40'19.3'' E085°24'49.7'' 1330m	7.0	7360	3066.66	1.6247	0.00817
Banasthali	N 27°43'43.9'' E085°17'30.5'' 1310m	7.0	4576	1906.66	1.0101	0.00508
Suryabinaya k	N 27°39'46.8'' E085°25'33.9'' 1309m	7.0	7082	2950.83	1.5633	0.00786
Kirtipur	N 27°40'43.2'' E085°17'13.9'' 1316m	6.8	10696	4456.66	2.2936	0.01153
Ghattaghar	N 27°40'26.1'' E085°21'49.5'' 1316m	7.0	6983	2909.58	1.5414	0.00775
Airport	N 27°41'59.8'' E085°21'51.8'' 1309m	7.1	6393	2663.75	1.4314	0.00719
Kalanki	N 27°41'46.4'' E085°16'47.7'' 1317m	7.3	6670	2779.16	1.5354	0.00772
Mahalaxmis than	N 27°39'33.9'' E085°19'13.5'' 1324m	7.7	1799	749.58	0.4368	0.00219
Arithmetic Mean and Standard Error		7.25, 0.31	5570.46, 2750.64	2321.02, 1146.10	1.2753, 0.6265	0.006410, 0.003207