ASSESSMENT OF SOIL-RADIUM CONTENT, INDOOR RADON ACTIVITY AND THE ASSOCIATED RADIATION RISKS IN KOHIMA TOWN, NAGALAND

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Abstract: Measurements of the radium content in soil samples and adjacent indoor radon activity measurement from sites located in Kohima town of Nagaland is reported. Solid State Nuclear Track Detectors (LR-115 Type2 films) was used and the radium content are found to vary from 14.56 to 27.29 $Bq.kg^{-1}$ with an arithmetic mean value of 18.98 ± 2.89 $Bq.kg^{-1}$ and a geometric mean value of 18.78 ± 1.15 $Bq.kg^{-1}$ in the studied soil samples. The indoor radon activity concentrations measured are found to range between 25.9 to 75.5 $Bq.m^{-3}$ with an arithmetic mean value of 49.2 ± 14.7 $Bq.m^{-3}$ and a geometric mean value of 47.13 ± 1.35 $Bq.m^{-3}$. A weak positive linear correlation is observed between radium content of the soil samples and indoor radon activity concentration at the study sites.

Keywords: SSNTD; radon; exhalation rate; radium; annual effective dose; life time fatality risk

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1. Introduction:

Ambient radiation is an inescapable fact of nature and every constituent of biota on planet earth is subjected to its exposure. Radon and radium are the naturally occurring radioactive elements derived from the radioactive decay of the primordial radionuclide Uranium, primarily found in the lithosphere. The amount of radon found in soils and rocks depends on the radium content and the extent to which radon atoms actually emanate from mineral grains [**1**]. Radon emanated into the soil pores eventually enters houses and buildings through cracks and gaps by means of various transportation processes leading to its accumulation in the structures. According to UNSCEAR, average annual effective dose to an individual from naturally occurring sources of ionizing radiation has been estimated at 2.4 mSv, out of which 52% is due to inhalation exposure and 92% of this fraction is contributed by the radioactive element radon and its progenies [**2**]. Different international health agencies and countries have determined/legislated limits to control the domestic and occupational exposures from radon, which to a certain extent provide a measure of normally acceptable radon levels. The aim of our study is to find the value of radium content of soil samples and indoor radon activity concentration and assess the associated radiation risk in Kohima, the capital town of Nagaland and consequently demographically one of the densest in the state. The study area includes 20 locations in 10 sites that are located in populated areas of Kohima town; these sites are listed in table 1.

2. Materials and Methods:

The SSNTD methodology is used [**1**], with LR-115 type2 as the detectors. It is a red dyed cellulose nitrate plastic film of 12-13 µm in thickness manufactured by Kodak, Pathe, France and marketed by Dosirad, France. Its chemical composition is $C_6H_8O_9N_2$ with refractive index value of 1.51.

(a) Radium content and radon exhalation estimates: Radium content of the soil samples is estimated using the sealed Can-technique. This technique has been used by Abujarad *et al*, (1980) and Somogyi *et al*, (1986) for measurement of radon flux from various construction materials and by M. Shakir Khan *et al*, (2012) to study radium content and radon flux in the soil samples of northern India. We have used this technique to estimate the radon flux of soil samples collected from selected study sites. Soil samples of about 500 grams are collected from a depth of ~50 cm. After soil samples are heated for 24 hours at 100°C, it is crushed with a mortar then sieved through 200 micro-mesh sieves. 250 grams of the sieved sample is then filled into a polylab wide mouth

plastic 1 liter bottle (which serves as our emanation chamber) and is left undisturbed for 30 days. LR-115 Type 2 films of sizes 2.5x2.5 cm^2 are pasted onto the lid such that the sensitive surface is exposed to the surface of soil sample and then sealed for 90 days. After the films are retrieved, the processing is carried out in the laboratory; tracks are counted and the resulting density of the tracks are recorded.

Radium Content of the soil samples is found using the following equation:

$$C_{RA} = \frac{\rho h A}{kT_e M} \quad (1)$$

where, ρ is the track density, h is the distance between the soil surface and detector, A is the area of the bottle, k is the calibration factor and M is the mass of the sample.

The radon flux in terms of area (E_A) in $Bq.m^{-2}\ h^{-1}$ is calculated from equation:

$$E_A = \frac{CV\lambda}{A[T+\frac{1}{\lambda}(e^{-\lambda T}-1)]} \quad (2)$$

where, C is integrated radon exposure ($Bq.m^{-3}h$), V is effective volume of the bottle in cubic meter (m^3), T is exposure time in hours (h), λ is decay constant for radon (h^{-1}) and A is area of the bottle (m^2).

The radon flux in terms of mass (E_M) is calculated from the equation:

$$E_M = \frac{CV\lambda}{M[T+\frac{1}{\lambda}(e^{-\lambda T}-1)]} \quad (3)$$

where, M is the mass of soil sample (250 gms). A calibration constant of 0.0245 $tracks.cm^{-2}d^{-1}$ per $Bq.m^{-3}$ [**6**] is used to convert the track density ($tracks.cm^{-2}$) into radon activity concentration ($Bq.m^{-3}$).

(b) Indoor radon activity measurements: LR-115 type2 films are cut into small sizes of about 2.5 x 2.5 cm^2 and pasted onto a cardboard of dimension 6 x 9 cm^2. These are then hung in a corner of the room such that the detectors are at least 10 cm away from the nearest wall and about 2 meters from the ground. After an exposure period of about 60 days, the detectors are retrieved. The exposed films are then chemically etched in 2.5N NaOH solution at 60ºC for 90 minutes. The perforated holes or tracks that appear as bright spot in reddish background are counted using an optical microscope at 150x magnification. The areal track density obtained is then converted into radon activity concentration using the following equation:

$$C_{RN} = \frac{\rho}{kT} \quad (4)$$

where, ρ is the density of the tracks (number of tracks per square cm of the film), k is the calibration factor used 0.0312 $tracks.cm^{-2}\ d^{-1}\ (Bq.m^{-3})^{-1}$ **[7]** and T is the duration in days for which the detectors were exposed.

3. Results and Discussions:

The radium content estimated from the soil samples and the radon exhalation rates calculated using equations (1), (2) and (3) respectively are summarized in table 2. The radium content is found to vary from 14.56 (at a site in Midland) to 27.29 $Bq.kg^{-1}$ (at a site in Billy Graham Road) with the arithmetic mean value of 18.98 ± 2.89 $Bq.kg^{-1}$ and geometric mean value of 18.78 ± 1.15 $Bq.kg^{-1}$. Alpha index value that quantifies excess alpha radiation due to radon inhalation originating from the soil samples when used as a building material **[8]** has also been calculated and is found to range from 0.08 to 0.1.

Table 1: Location of the study sites

Location	Latitude			Longitude		
Peraciezie	25	42	17.4	94	5	47.7
	25	42	17.4	94	5	48
Periezie	25	41	45.3	94	5	49.2
	25	41	46.1	94	5	47.3
Gashie	25	41	31.2	94	5	24.1
	25	41	31.3	94	5	24.3
Jotsoma	25	40	3.4	94	4	26.1
	25	40	3.3	94	4	25.9
Lerie	25	39	15.4	94	7	3
	25	39	15	94	7	3
Minister's Hill	25	38	54.7	94	6	4.9
	25	38	55.1	94	6	5
Sepfuzuo	25	40	49.5	94	6	11.5

	25	40	50.2	94	6	11.6
Billy Graham Road.	25	41	10.7	94	6	41.4
	25	41	10.7	94	6	40.8
Midland	25	39	51	94	6	51
	25	39	51.1	94	6	14.8
Agri	25	39	41.4	94	5	32.6
	25	39	40.9	94	5	32.9

Table 2: List of sites (from where the soil samples were collected) with the measured radium content values, radon Exhalation Rates in terms of Mass and Area and the Alpha Index value.

Name of the Site	Radium Content in Bq.kg^{-1}				Radon Exhalation Rates				Alpha Index value
					Mass (Bq.kg^{-1}h^{-1})		Area (Bq.m^{-2} h^{-1})		
	AM*	SD*	GM*	GSD*	AM*	SD*	AM*	SD*	
Peraciezie	18.79	1.15	18.77	1.04	0.18	0.012	2.97	0.20	0.09
Periezie	19.74	2.83	19.64	1.11	0.19	0.027	3.11	0.45	0.10
Gashie	15.37	0.32	15.36	1.01	0.15	0.002	2.51	0.04	0.08
Jotsoma	18.11	0.30	18.11	1.01	0.17	0.003	2.91	0.05	0.09
Lerie	17.31	1.41	17.28	1.06	0.17	0.014	2.80	0.23	0.09
Minister's Hill	19.02	1.19	19.00	1.05	0.18	0.012	3.03	0.20	0.10
Sepfuzou	21.87	1.57	21.84	1.05	0.21	0.014	3.50	0.24	0.11
Billy Graham Road	23.53	5.33	23.23	1.18	0.05	0.048	3.77	0.80	0.12
Midland	16.74	3.08	16.60	1.14	0.16	0.029	2.69	0.50	0.08
Agri	19.32	1.73	19.28	1.07	0.18	0.019	3.08	0.32	0.10

* (AM =arithmetic mean: SD= standard deviation: GM=geometric mean: GSD= Geometric Standard Deviation)

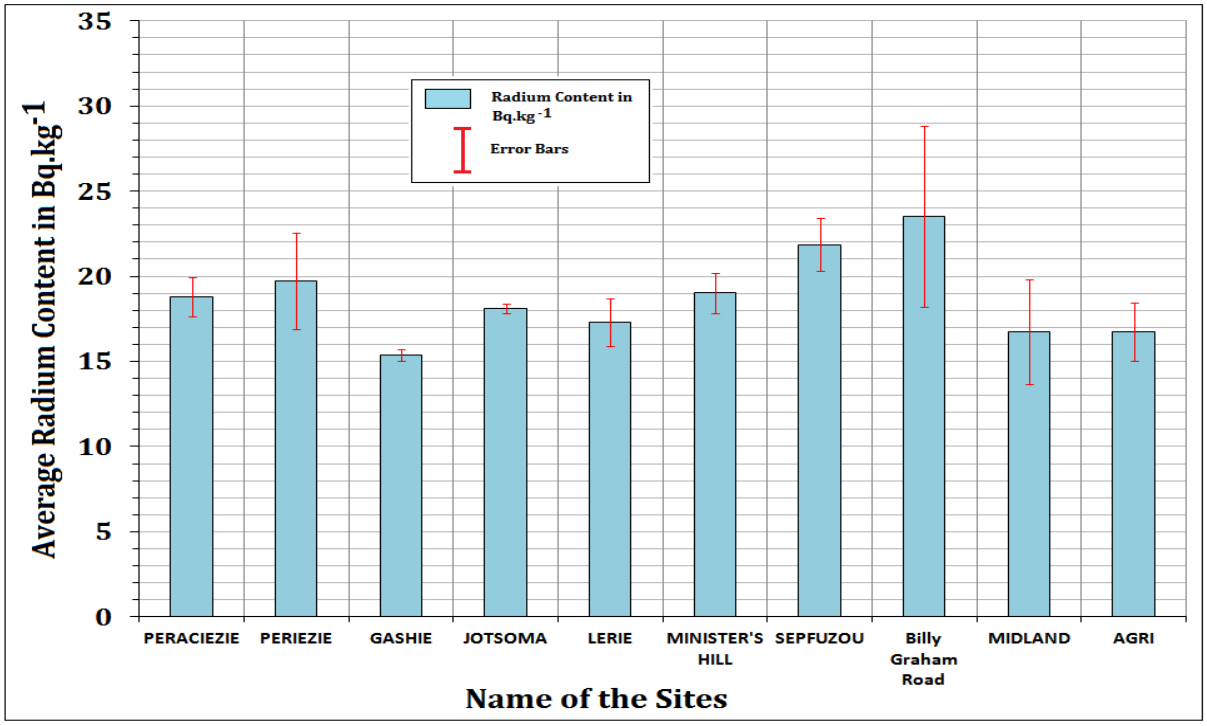

Figure 1: Average radium content measured at 10 studied sites with error bars representing counting errors.

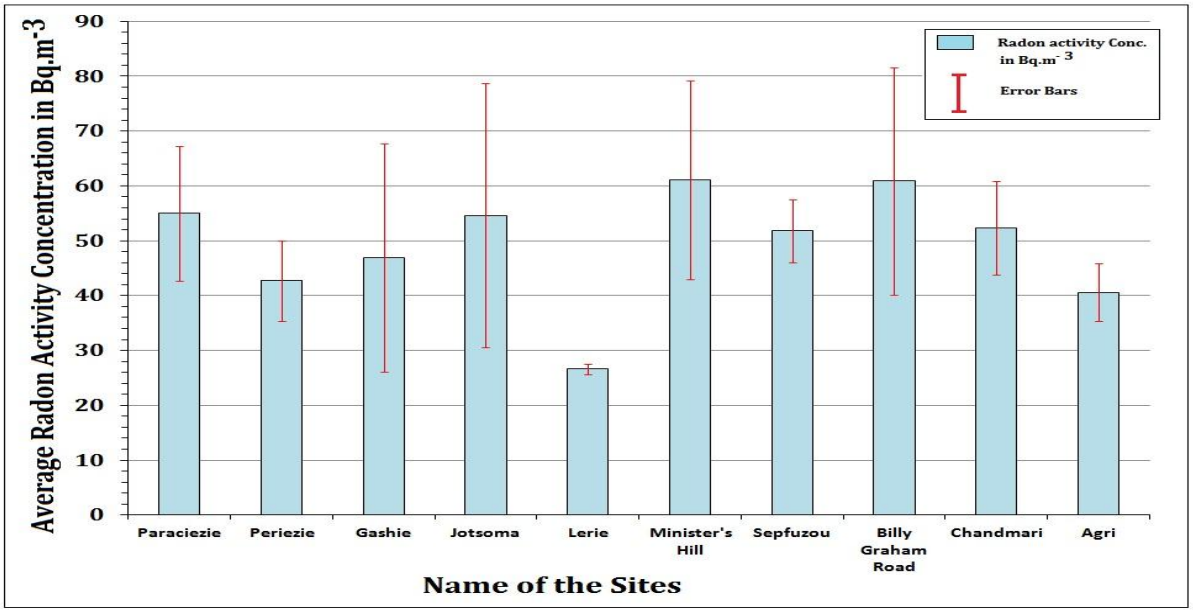

Figure 2: Average indoor radon activity concentration measured at 10 studied sites with the error bars representing the counting errors.

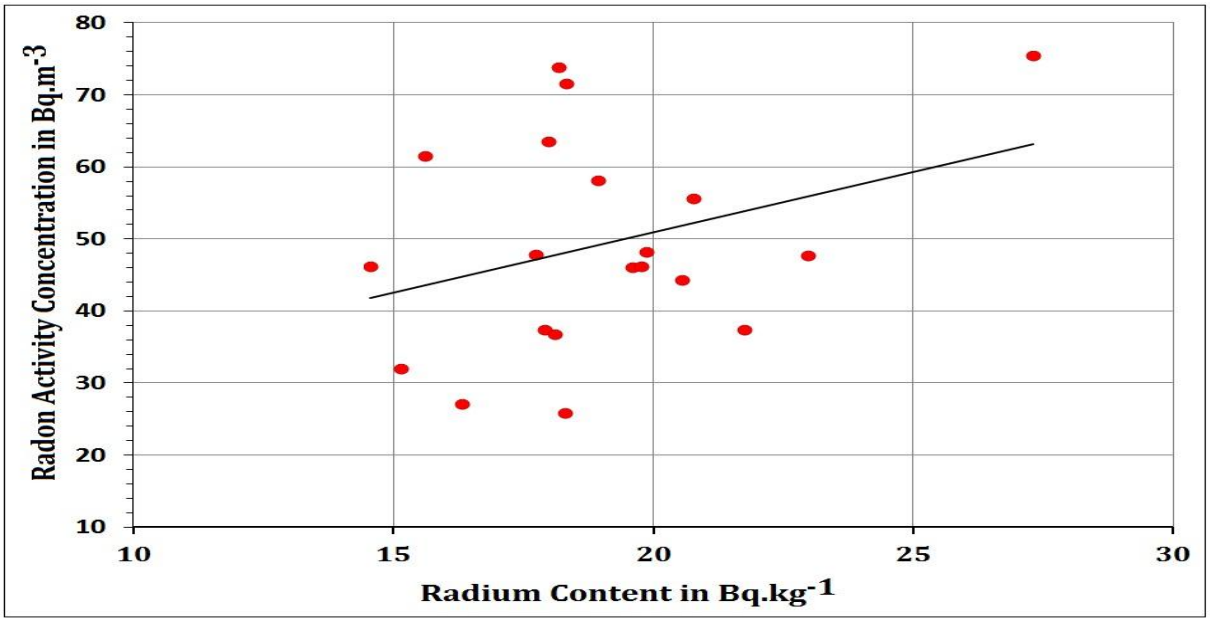

Figure3: Variation of the measured radon activity concentration with estimated radium content of soil samples.

The plot of estimated radium content value at various sites of Kohima town is shown in Figure 1; the maximum average value observed in Billy Graham Road (23.53 ± 5.33 $Bq.kg^{-1}$) and minimum average value observed in Gashie (15.37 ± 0.32 $Bq.kg^{-1}$).

The values for indoor radon activity concentration, Annual Exposures, Annual Effective Doses and Lifetime fatality risk have been tabulated in table 3. The indoor radon activity concentration is found to vary from 25.9 $Bq.m^{-3}$ (at a site in Lerie) to 75.5 $Bq.m^{-3}$ (at a site in Billy Graham Road) with arithmetic mean value of 49.2 ± 14.7 $Bq.m^{-3}$ and geometric mean value of 47.1 ± 1.35 $Bq.m^{-3}$. Figure 2 shows the plot of measured radon activity concentration at different sites studied with the maximum average value observed in Minister's Hill (61.1 ± 18.1 $Bq.m^{-3}$) and minimum average value observed in Lerie (26.6 ± 0.9 $Bq.m^{-3}$). Lifetime fatality risk

estimates suggest that out of 1 lakh people exposed to this amount of radiation level (47.1 $Bq.m^{-3}$) in their lifetime (~30 years), about 4 people may die of lung cancer.

The plot of the variation of estimated radium content and the measured radon activity concentration of houses near the study sites are shown in figure 3. A positive but weak linear correlation is observed between the two quantities with correlation coefficient value of 0.33.

Table 3: List of the name of sites where the detectors were exposed with the measured indoor radon activity concentration, Annual Radon Activity Concentration, Annual Exposures, Annual Effective Dose and Life time fatality risks.

Name of the sites	**Radon Activity Conc. ($Bq.m^{-3}$)**	**Radon Activity Concentration ($Bq.m^{-3}$)**				**Annual Radon Activity Conc. ($Bq.m^{-3}$)**	**Annual Exposure**		**AED ($mSv.y^{-1}$)**	**Lifetime Fatality Risk x10^{-4}**
		AM	**SD**	**GM**	**GSD**		**WLM**	**$mJhm^{-3}$**		
Paraciezie	63.7	55	12.3	54.3	1.2	38.9	0.115	0.41	1.03	0.35
	46.2					28.2	0.084	0.30	0.74	0.25
Periezie	47.9	42.7	7.3	42.4	1.1	29.2	0.087	0.31	0.77	0.26
	37.5					22.9	0.068	0.24	0.60	0.20
Gashie	61.6	46.9	20.8	44.5	1.4	37.6	0.112	0.40	0.99	0.34
	32.2					19.6	0.058	0.21	0.52	0.18
Jotsoma	71.7	54.6	24.1	51.9	1.4	43.7	0.13	0.46	1.15	0.39
	37.6					22.9	0.068	0.24	0.61	0.20
Lerie	25.9	26.6	0.9	26.6	1	15.8	0.047	0.17	0.42	0.14
	27.2					16.6	0.049	0.17	0.44	0.15
Minister's Hill	48.3	61.1	18.1	59.8	1.2	29.5	0.087	0.31	0.78	0.26
	74.0					45.1	0.134	0.47	1.19	0.40
Sepfuzou	55.8	51.8	5.7	51.6	1.1	34	0.101	0.36	0.90	0.30
	47.8					29.1	0.086	0.31	0.77	0.26
Billy Graham Road	75.5	60.9	20.7	59.1	1.3	46.1	0.137	0.48	1.22	0.41
	46.3					28.2	0.084	0.30	0.75	0.25
Chandmari	58.3	52.3	8.5	51.9	1.1	35.5	0.1	0.35	0.94	0.30
	46.3					28.2	0.079	0.28	0.75	0.24
Agri	36.9	40.6	5.3	40.5	1.1	22.5	0.063	0.22	0.59	0.19
	44.4					27.1	0.076	0.27	0.72	0.23

*(WLM=working level month: AED= annual effective dose)

4. Conclusions:

The estimated radium content of the soil samples of Kohima region is well below the world average value of 30 $Bq.kg^{-1}$ given by UNSCEAR, 2008 and is also significantly lower than the permissible value of 370 $Bq.kg^{-1}$, acceptable for safe use **[10]**, which suggests that the soil from the region is safe to use as building material. About 70% of the measured average indoor radon activity concentration is found to be more than the world average value of 40 $Bq.m^{-3}$ given by UNSCEAR, 2000. However, effective annual effective dose received by the residents is found to be 0.79 $mSv.y^{-1}$, which is lesser than the lower limit of the ICRP, 1993, recommended action level 3-10 mSv per year. Hence, the study shows no significant radiological risk arising out of radon in the study area.

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