MEASUREMENTS OF RADON ACTIVITY CONCENTRATIONS IN THE ENVIRONS OF AIZAWL CITY, MIZORAM

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Abstract: In this paper, we report our findings on the measurement of indoor radon activity and soil radium content in Aizawl city of Mizoram, India. The measurements were carried out using Solid State Nuclear Track Detectors viz. LR-115 Type2 films. The indoor radon activity concentration has been found to vary from 20 to 75.4 $Bq.m^{-3}$, with an arithmetic mean value of 42.33 ±15.42 $Bq.m^{-3}$ and geometric mean value of 39.59 ±1.45 $Bq.m^{-3}$. The radium content value was found to range between 9.1 to 33.1 $Bq.kg^{-1}$ with an arithmetic mean of 20.35 ± 5.5 $Bq.kg^{-1}$ and a geometric mean of 19.59 ±1.33 $Bq.kg^{-1}$.

Keywords: SSNTD; radon; radium; alpha index; working level month; annual effective dose

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1. Introduction:

Radon is a decay product of naturally occurring radionuclide radium, unevenly distributed in trace amounts in soils and rocks around us. As radon decays from radium in mineral grains, some of it emanates into interstitial space between soil grains, diffuses through soil layers and then exhales into the atmosphere or to indoor structures [1]. The presence of radon itself is of no consequence to humans but that it is radioactive and emits the potentially harmful alpha particles is the main cause of concern, and the danger mounts as most elements in its chain of decay products also emit alpha particles. Although a plethora of ailments have been associated with elevated exposures from alpha-radiation associated with radon and its progeny, the main concern however is the from lung cancer. While no environment is radon-free and the debate is still open on whether there actually exists a safe lower limit for exposure, nevertheless, there are mounting evidences of the association of significant lung cancer risks with high indoor radon concentrations; in recognition of which many countries and radiation safety associations (both national and international) have proposed permissible limits of radon concentration in the living environment. The outdoor radon concentration is far below any of these limits, primarily because the radon gas exhaled from the ground is rapidly diffused over the vast atmosphere, but buildings and structures may prevent this dilution and so accumulate radon to levels beyond the permissible limits, even for areas with low exhalation rates from the ground. The enhancement in indoor radon concentration may also be aided by other factors such as exhalation from the walls of the building, from indoor water usage etc.

The first step in tackling the radon problem is the assessment of radon levels and appraisal of the radon potential (i.e. the geologic and anthropogenic factors that may give rise to potentially hazardous radon concentration) of a given area, so that depending on the outcome of the assessment, decision on mitigation measures may be instituted. To this end, the present study on the measurement of indoor radon concentrations and the radium content in soils is carried out in the capital city of Mizoram state, India; the soil radium content will provide an indication of the radon potential of the area and the indoor radon values an insight into the actual status of the radon problem.

2. About the study area:

Aizawl is the state capital of Mizoram situated in the northeastern part of Indian subcontinent. It is located at about 3715 feet from the sea level with the tropic of cancer passing below. 20 different locations from 10 sites in

Aizawl city have been chosen as our study, shown in figure 1. Mizoram occupies an important strategic position sharing the international boundary of about 722 km with Bangladesh on the west and Myanmar on the east and south. The temperature varies from 11°C to 21°C in winter and 20°C to 29°C in summer. The state experience monsoon influences and rainy months are generally from May to September with the annual average rainfall of 208 cm.

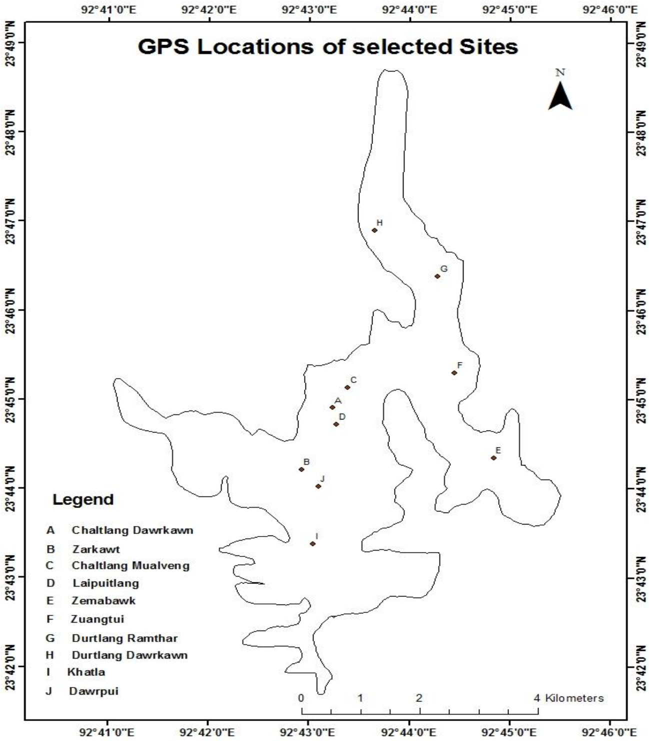

Figure1: Location of 10 study sites in the Aizawl city.

3. Materials and methods:

(a) For indoor radon activity concentration: Solid State Nuclear Track Detectors, namely LR-115 Type2 films are used for our study. The films are cut into small sizes about 2.5 x 2.5 cm^2 sizes and pasted on a cardboard of dimension 6 x 9 cm^2 and hanged in a corner of the rooms. The detectors are placed about 10 cm away from the nearest wall and about 2 meters from the ground. After the detectors are retrieved after 60 days, they are chemically etched in 2.5N NaOH solution at 60ºC for 90 minutes. The perforated holes or tracks which appear as bright spot in reddish background are counted at unit area of the film using an optical microscope at 150x magnification. The track density obtained are then converted into radon activity concentration using the following equation,

$$C_{RN} = \frac{\rho}{kT} \qquad (1)$$

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

(b) 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 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 various 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. The sieved sample is then weighted to 250 grams and filled into a polylab wide mouth plastic 1 liter bottle which 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 sealed for 90 days;

after which time, the films are retrieved and processed in the laboratory i.e. the etched alpha tracks in LR-115 films are counted and the track density is recorded.

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

$$C_{RA} = \frac{\rho h A}{k T_e M} \qquad (2)$$

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) is calculated from equation:

$$E_A = \frac{CV\lambda}{A[T+\frac{1}{\lambda}(e^{-\lambda T}-1)]} \qquad (3)$$

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:

$$E_M = \frac{CV\lambda}{M[T+\frac{1}{\lambda}(e^{-\lambda T}-1)]} \qquad (4)$$

where, M is the mass of soil sample (100 gms). A calibration constant of 0.0245 $tracks.cm^{-2}d^{-1}$ per $Bq.m^{-3}$ [7] has been used to convert the track density (number of $tracks.cm^{-2}$) into radon activity concentration ($Bq.m^{-3}$).

3. Results and discussions:

The measured indoor radon activity concentration values evaluated using equation 1 is shown in table 1. Other measured parameters are annual exposures; annual effective dose calculated using parameters specified in the UNSCEAR report, 2000 [2] and life time fatality risks estimated according to ICRP report 2010 [8]. The indoor radon activity concentration is found to vary from 20 to 75.4 $Bq.m^{-3}$ with the arithmetic mean value of 42.33 ±15.42 $Bq.m^{-3}$ and geometric mean value of 39.59 ±1.45 $Bq.m^{-3}$. Figure 2 shows the measured radon activity concentration at the different sites in Aizawl city; the error bars representing the counting errors in track density estimation. Maximum value of the indoor radon activity concentration is recorded at site in Zemabawk (20.03 $Bq.m^{-3}$) and the minimum in Chaltlang Dawrkawn (75.44 $Bq.m^{-3}$).

Table 1: Sites of the radon survey and the associated values of the measured Indoor Radon Activity Concentration, Annual Radon Activity Concentration, Annual Exposures, Annual Effective Dose and Life Time Fatality Risks.

Name of the Site	Radon Activity Conc. ($Bq.m^{-3}$)				Annual Radon Activity Conc. ($Bq.m^{-3}$)	Annual Exposure		AED* ($mSv.y^{-1}$)	Life Time Fatality Risk x 10^{-4}
	AM*	SD*	GM*	GSD*		WLM*	$mJhm^{-3}$		
Chaltlang Dawrkawn	26.5	9.1	25.7	1.2	16.16	0.08	0.28	0.43	0.23
Zarkawt	52.4	4.5	52.3	1.1	31.98	0.15	0.55	0.84	0.46
Chaltlang Mualveng	39.3	22.3	36.0	1.5	23.95	0.12	0.41	0.63	0.35
Laipuitlang	52.1	1.2	52.0	1.0	31.75	0.15	0.54	0.84	0.46
Zemabawk	56.6	26.7	53.3	1.4	34.50	0.17	0.59	0.91	0.50
Zuangtui	48.0	19.2	46.1	1.3	29.31	0.14	0.50	0.77	0.42
Durtlang Ramthar	47.0	17.3	45.4	1.3	28.67	0.14	0.49	0.76	0.41
Durtlang Dawrkawn	38.8	13.6	37.6	1.3	23.66	0.11	0.40	0.62	0.34
Khatla	25.3	3.4	25.2	1.1	15.44	0.07	0.26	0.41	0.22
Dawrpui	37.3	16.0	35.6	1.4	22.77	0.11	0.39	0.60	0.33

*AM=arithmetic mean; SD = standard deviation; GM = geometric mean; GSD = geometric standard deviation; WLM = working level month; AED = annual effective dose.

The estimated radium content and radon flux of the soil samples using equations 2, 3 and 4 are shown in table 2. Alpha index value, which quantifies excess alpha radiation due to radon inhalation originating from building material [9] has also been calculated and values are tabulated in table 2. The radium content values are found to vary from 9.1 to 33.1 $Bq.kg^{-1}$ with an arithmetic mean value of 20.35 ± 5.5 $Bq.kg^{-1}$ and a geometric mean value of 19.59 ±1.33 $Bq.kg^{-1}$. Figure 3 shows the estimated radium content of the soil samples collected from the respective sites; the error bars representing the counting errors in track density estimation. The maximum radium content value has been observed in Dawrpui (33.1 $Bq.kg^{-1}$) and the minimum in Zarkawt (9.1 $Bq.kg^{-1}$).

The measured indoor radon activity concentration is plotted against the estimated radium content of the soil samples as shown in figure 4 and they are found to be negatively correlated (with the correlation coefficient value of -0.38). This negative correlation observed between the two parameters may be due to many factors out of which mention may be made of the architectural framework of houses in the region.

Table 2: List of the name of the sites with the calculated Radium Content values, Radon Exhalation Rates in terms of Mass and Area and the Alpha Index value from the soil samples at various sites in Aizawl, Mizoram.

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	
Chaltlang Dawrkawn	20.5	5.04	20.2	1.19	0.20	0.05	3.28	0.80	0.10
Zarkawt	13.8	6.64	13.0	1.43	0.13	0.06	2.20	1.02	0.07
Chaltlang Mualveng	20.0	0.51	20.0	1.02	0.19	0.01	3.16	0.09	0.10
Laipuitlang	16.2	2.54	16.1	1.12	0.15	0.02	2.57	0.38	0.08
Zemabawk	15.8	4.38	15.5	1.22	0.15	0.04	2.57	0.72	0.08
Zuangtui	20.6	8.21	19.8	1.34	0.19	0.08	3.28	1.29	0.10
Durtlang Ramthar	25.8	2.52	25.8	1.07	0.25	0.02	4.19	0.31	0.13
Durtlang Dawrkawn	22.6	2.37	22.6	1.08	0.22	0.03	3.70	0.44	0.11
Khatla	21.2	1.76	21.2	1.06	0.20	0.02	3.42	0.33	0.11
Dawrpui	26.8	8.95	26.0	1.27	0.26	0.08	4.29	1.41	0.13

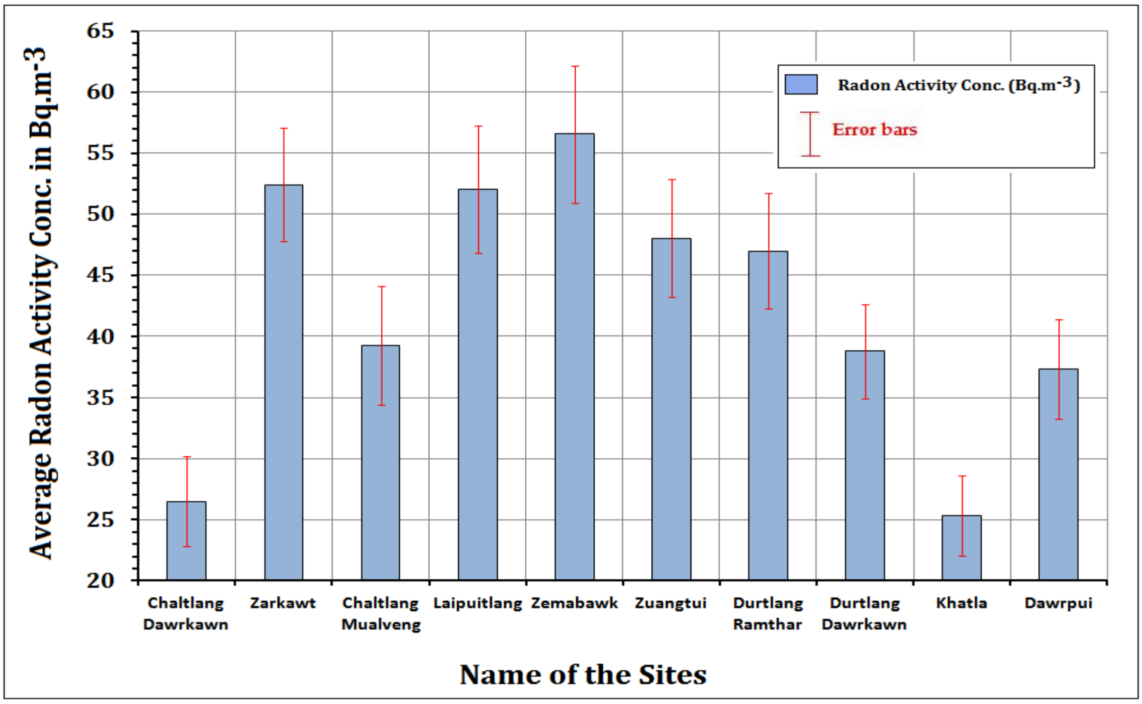

Figure2: Average indoor radon activity concentration measured at the 10 study sites in Aizawl, Mizoram; the error bars represent the counting errors.

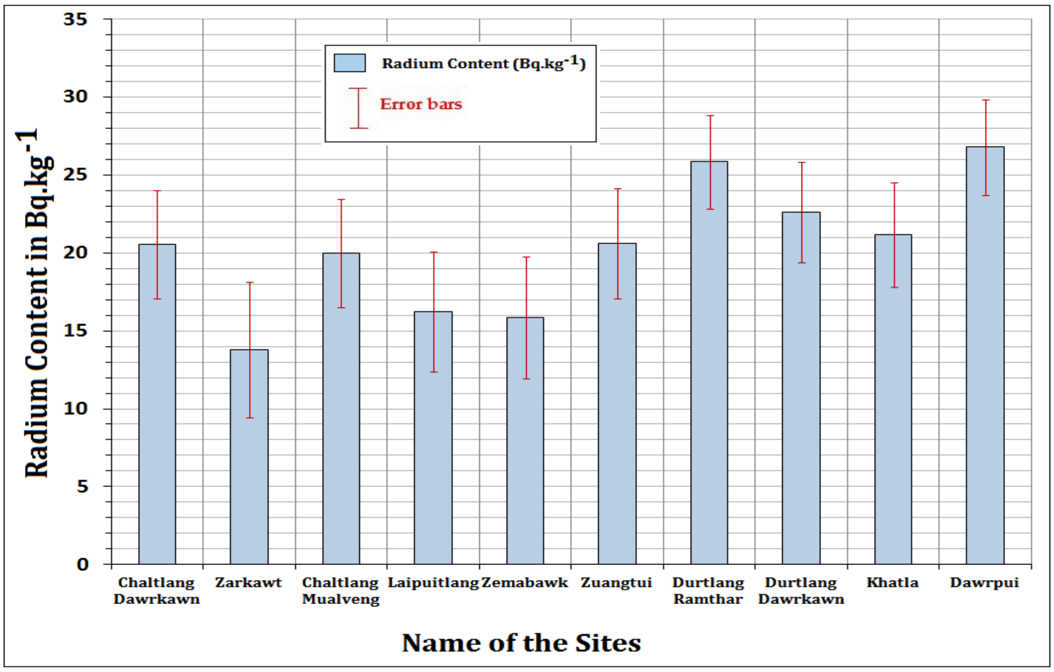

Figure 3: Average radium content measured at the 10 study sites in Aizawl, Mizoram; the error bars represent the counting errors.

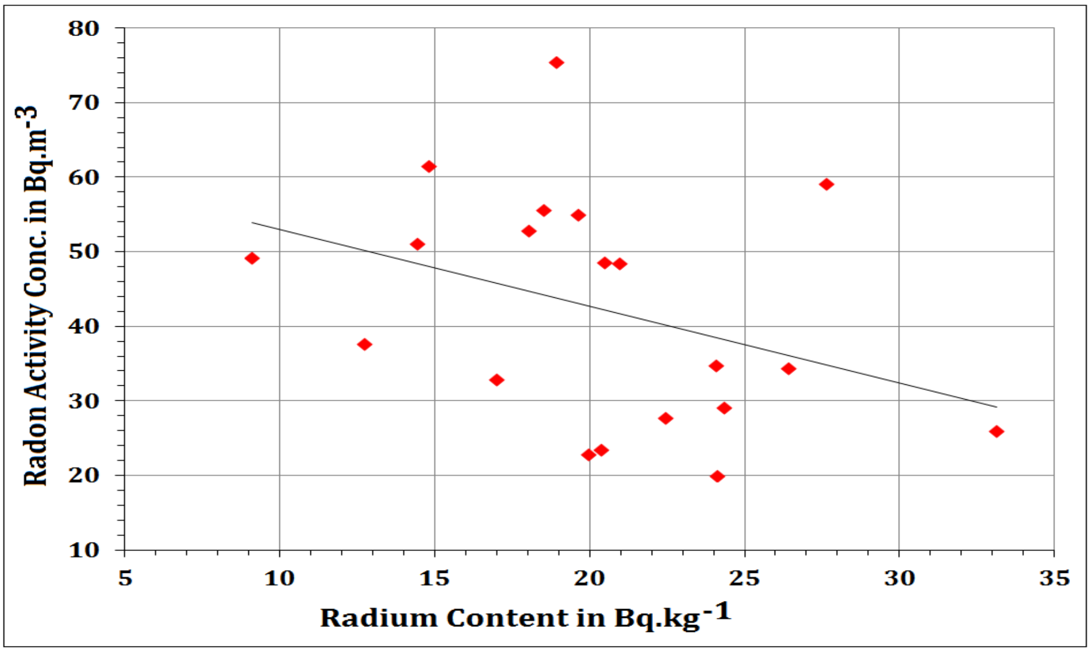

Figure 4: A scatter plot showing the relationship between the measured indoor radon activity concentration and the estimated radium content in soil samples from surrounding area.

4. Conclusions:

The annual average indoor radon activity concentration measured at the study sites are found to have value less than the world average value 40 Bq.m^{-3} given by UNSCEAR, 2000. The annual effective dose received by the residents is also lesser than the lower limit of the ICRP, 1993 recommended action level of 3 to 10 mSv per year. The lifetime fatality risk of the residents is also lesser than 2.83x10^{-4} the annual estimate given by ICRP, 1993. The measured radium content in soil is lesser than average global value of 35 Bq.kg^{-1} and below the recommended action level of 370 Bq.kg^{-1}. The measured alpha index value is found well below 1. The results reveal that the study sites are safe from a health perspective from any hazardous effects from radon.

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