MEASUREMENT OF NATURAL RADIOACTIVITY OF BUILDING MATERIALS USED IN THE THOUBAL DISTRICT OF MANIPUR, INDIA

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Abstract
A study of natural radionuclides of different types of houses was conducted at 222 houses in the Thoubal district of Manipur, India. The average annual effective doses of radiation (gamma) in indoor and outdoor were obtained from the measurements using Micro R-survey meter as 1.23 ± 0.10 (range: 1.02 – 1.35) $mSvy^{-1}$ and 0.76 ± 0.08 (range: 0.60 – 0.89) $mSvy^{-1}$ for reinforced cement concrete (RCC) houses, followed by 1.09 ± 0.10 (range: 0.95 – 1.19)$mSvy^{-1}$ and 0.75 ± 0.08 (range: 0.67 – 0.95) $mSvy^{-1}$ for Adobe laid (AL) earthen houses, 1.03 ± 0.09 (range: 0.78 – 1.24) $mSvy^{-1}$ and 0.74 ± 0.08 (range: 0.65 – 0.91) $mSvy^{-1}$ for Assam-type (AT) brick houses, 0.82 ± 0.09 (range: 0.64 – 0.99) $mSvy^{-1}$ and 0.72 ± 0.08 (range: 0.59 – 0.94) $mSvy^{-1}$ for AT mud houses and 0.70 ± 0.08 (range: 0.66 – 0.79) $mSvy^{-1}$ and 0.70 ± 0.07 (range: 0.65 – 0.82) $mSvy^{-1}$ for AT katcha houses. The activity concentration (^{226}Ra, ^{232}Th and ^{40}K) of building materials available in this district were evaluated using gamma ray spectrometry and found average value as 43.0 (range: 24.1 – 70.2) $Bqkg^{-1}$, 108.6 (range: 21.3 – 211.8) $Bqkg^{-1}$ and 1487.2(range: 998.7 – 2298.6) $Bqkg^{-1}$. Moreover, the annual effective dose conceived from building material was found as 0.7 $mSvy^{-1}$ from Portland cement, 1.0 $mSvy^{-1}$ each both for sand and brick.

Key words: Natural radioactivity, building materials, Annual effective dose rate, Thoubal district

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INTRODUCTION

Natural radionuclides are found in our environment and the knowledge of this radionuclides concentration level and their distribution in the environment has become a focus of much attention in assessing the human risk from natural radiation exposure. Most of the general population spends their maximum time (about 80%) in indoors, and there is a high chance of getting both external as well as internal radiation exposure from natural radionuclide present in the building materials [1-3]. Most of building materials used for constructing our houses such as concrete, brick, sand, marble, granite, limestone, gypsum etc mainly contain natural radionuclides such as Uranium (^{238}U) and Thorium (^{232}Th) and their decay radionuclide products and radioactive Potassium (^{40}K) [4]. In ^{238}U series, 98.5% of the radiological effects are produced by radium and its daughter radionuclide products, so radium and its decay chain segment is radiologically very important [4]. Radon, thoron and their progenies contribute maximum radiation dose to the occupational workers and general public [5]. These two radionuclide gases present in the ambient air as well as in the indoor atmosphere [6]. It is also expected that these gases to be more concentrated in indoor than outdoor. Exhalation of radon and thoron are mainly associated with the presence of ^{226}Ra and ^{232}Th. The Natural radioactivity in soil sample or building material are usually determined from ^{226}Ra, ^{232}Th and ^{40}K contaminant in soil or materials. The average annual indoor effective dose rate of *world*wide due to gamma rays from building materials is estimated to be about 0.4 mSvy^{-1}[7]. Studies on building materials such as granite and phosphogypsum enhances indoor absorbed dose rate up to five times than the dose criterion [8], whereas building materials collected from Yan'an, China may be used safely as construction materials [9]. Thus, the assessment of the level of natural radioactivity in building materials is thus become important to evaluate any possible risk to human health and develop any precautionary measures in using different types of building materials.

The study area namely Thoubal district is in the southern side of the state, Manipur and it is in the North Eastern part of India. Thoubal district is having an area of 514 sqkm with total population of 4,20,517 (2011 census).

MATERIALS AND METHODS

Measurement of radiation dose rate (survey meter):

Indoor and outdoor terrestrial gamma radiation of different types of houses in Thoubal district were measured by using NaI(Tl) scintillator based micro-Roentgen Survey Meter (SM), manufactured by Nucleonix Systems Pvt. Ltd., Hyderabad, India, having a sensitivity of 1µR / hr. It is measured by maintaining the SM at a height of about 1m distance from the ground surface and wall. Repeated measurements were taken, not less than ten times for each spot. The average value for all these ten measurements is assumed to be the natural gamma radiation dose rate for that particular area [10]. Two hundred twenty-two (222) houses from this district were randomly selected for the evaluation of natural gamma radiation dose rates.

Radiological Analysis of building materials

A total of 10 (ten) samples of building materials from study area were collected and crushed into small sizes. The samples were allowed to dry, in a hot air oven at 110°C for 24 hours. It is then, ground into fine powder, homogenized and sieved through a mesh size of 0.45mm [11], approximately 250 g of this homogeneous fine mesh of each sample material was then packed inside a plastic container with predefined geometry (dimension of cylindrical plastic container: 3" diameter X 5" height), weighted, and properly sealed to restrict the escape of radon or thoron gas from the packed. The processed samples were then stored, carefully for a period of about one month to achieve the equilibrium condition of ^{226}Ra and ^{232}Th along with their respective daughter nuclides [10].

A 3"X3" NaI(Tl) scintillation detector based Gamma spectrometer was used with adequate shielding (about 10 cm lead). The efficiency calibration of the gamma spectrometer was made using different energy peaks covering the range up to ≈ 2000 keV. Measurements were performed using calibrated standard source samples, having known activity of gamma ray emitters radionuclides namely ^{133}Ba (356.1 keV), ^{137}Cs (661.6 keV), ^{60}Co (1173 KeV and 1332 KeV) and ^{226}Ra (1764.5 keV) [12]. All prepared samples were subjected to gamma spectral analysis with a counting time of about 36,000 seconds [13]. The concentration of ^{226}Ra was determined from the average activity concentration obtained from the prominent gamma lines of ^{214}Bi (1.76MeV) and ^{214}Pb (0.35MeV) and that of ^{232}Th was evaluated from the average concentration obtained from the gamma lines of ^{212}Bi (0.73MeV), ^{228}Ac (0.91MeV) and ^{208}Tl (2.61MeV) respectively; however, ^{40}K was evaluated from its own gamma photo-peak (1.46MeV) [11, 14-15].

The activity of ^{226}Ra, ^{232}Th series, and ^{40}K were calculated using the following equation [16];

$$A(\text{Bqkg}^{-1}) = N/_{\varepsilon\beta M} \quad (1)$$

Where, N = the net gamma counting rate (counts per second), ε = the detector efficiency of the specific gamma-ray, β = the absolute transition probability of gamma decay and M = the mass of the sample (kg).

The concentration and distribution of ^{226}Ra, ^{232}Th and ^{40}K is not uniform in the environment as well as in building materials. Radium Equivalent (Ra_{eq}) is a single quantity, most commonly used to represent natural radioactivity associated to those materials containing ^{226}Ra, ^{232}Th and ^{40}K. The activity Estimation was made on the assumption that 370.0 $BqKg^{-1}$ of ^{226}Ra, 259.0 $BqKg^{-1}$of ^{232}Th and 4810.0 $BqKg^{-1}$of ^{40}K produce similar gamma dose rate as mentioned by the following equation [17]

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \quad (2)$$

Where, A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$, respectively.

Activity concentration index, or gamma index 'I', is defined, to examine the applicability of using building materials in construction. It is defined by the following expression [18] as

$$I = A_{Ra}/300 + A_{Th}/200 + A_K/3000 \le 1 \quad (3)$$

This is a simple criterion used for the applicability of a building material.

The absorbed Dose Rate (D) due to natural gamma radiation in air for a standard room dimensions and for common building materials with naturally occurring radionuclides ^{226}Ra, ^{232}Th and ^{40}K was calculated using the guidelines given in EC report 112[18] as

$$D\ (nGyh^{-1}) = (0.92 X A_{Ra}) + (1.1 X A_{Th}) + (0.08 X A_K) \quad (4)$$

The annual effective dose rate (D_{eff}) is calculated by applying the dose conversion factor of 0.7 $SvGy^{-1}$ from the absorbed dose in air received by an adult and a value of 0.8 as an indoor occupancy factor [7]. The annual effective dose rate (D_{eff}) due to gamma radiation from building materials was evaluated as

$$D_{eff}\ (mSv/y) = D\ (nGyh^{-1})\ X\ 8760h\ X\ 0.8\ X\ 0.7SvGy^{-1}\ X\ 10^{-6} \quad (5)$$

RESULTS AND DISCUSSION:

The natural background gamma radiation levels of 222 different houses
of this Thoubal district were measured using SM. These houses may be classified into 5 different types, based on building materials utilized, which are derived from soils and rocks available in and around the valley region of Manipur state. The classified houses are i) Reinforced Cement Concrete (RCC) House, ii) Assam Type (AT) Katcha House, iii) AT Mud House, iv) AT Brick House and v) Adobe Laid (AL)Earthen House (an indigenous – traditional house of Manipur) so called as Meitei Yumjao and are illustrated in Figure 1. The variation of D_{eff} due to natural gamma radiation level in outdoor as well as indoor of these various types of houses are shown in Figure 2 and detail measured data with error are given in Table 1. It shows that average annual effective dose in indoor of RCC house is 1.2 mSv, followed by AL Earthen houses with a value of 1.1 mSv, AT Brick with a value of 1.0 mSv and least with AT Katcha and AT Mud houses, with values less than unity. Indoor D_{eff} of RCC house is slightly higher than the world average exposure of 0.48 $mSvy^{-1}$ [19-20]. Whereas, average D_{eff} of outdoor of these houses are almost similar with average value of 0.73 ± 0.02 $mSvy^{-1}$.

i) Typical picture of RCC House

ii) Typical picture of Katcha house

iii) Typical picture of AT mud house

iv) Typical picture of AT brick house

v) Typical picture of AL earthen house (Meitei Yumjao)

The radioactivity concentration values of ^{226}Ra, ^{232}Th and ^{40}K measured in the building materials are shown in Table 2. All the Portland cements (3 numbers) and sand-3 (1 number) are imported from neighbouring states. The highest values for specific activity of ^{226}Ra, ^{232}Th and ^{40}K are 70.2 Bqkg^{-1}(sand-2 & Soil [21]), 211.8 Bqkg^{-1}(Sand-3) and 2298.6 Bqkg^{-1} (Cement-3) respectively. The average specific activity of ^{226}Ra, ^{232}Th and ^{40}K are 43.0 Bqkg^{-1} (range: 24.1 – 70.2), 108.6 Bqkg^{-1} (range: 21.3 – 211.8) and 1487.2 Bqkg^{-1}(range: 998.7 – 2298.6). The average specific activity of ^{226}Ra is slightly higher than world average value 35 Bqkg^{-1} whereas average value of ^{232}Th and ^{40}K are moderate higher than corresponding world-wide average values of 30 Bqkg^{-1}and 400 Bqkg^{-1} respectively [7]. Radium equivalent (Ra_{eqv}), Gamma index (I), Adsorbed dose rate (D) and Annual effective dose rate (D_{eff}) are given in Table 2. Ra_{eqv} of the building material samples ranged from 216.3 Bqkg^{-1} (Cement-1) to 465.9 Bqkg^{-1}(Sand-3). Ra_{eqv} of two samples namely Sand-3 (465.9 Bqkg^{-1}), and Brick-2 (433.9 Bqkg^{-1}) are found to be higher than the criterion limit of 370 Bqkg^{-1} [22]. However, the average value of Ra_{eqv} obtained from samples of building materials is 312.8 Bqkg^{-1}, which is less than the critical value (370 Bqkg^{-1}) and as such, does not pose a radiological hazard when used for construction of buildings. Figure 3 shows the Ra_{eqv} with different kinds of building materials of Thoubal district, Manipur.

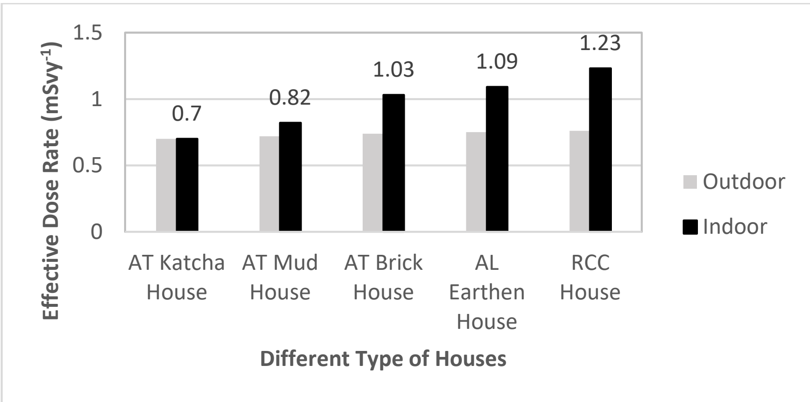

Figure 2: Effective Dose Rate of Outdoor and Indoor for different types of Houses

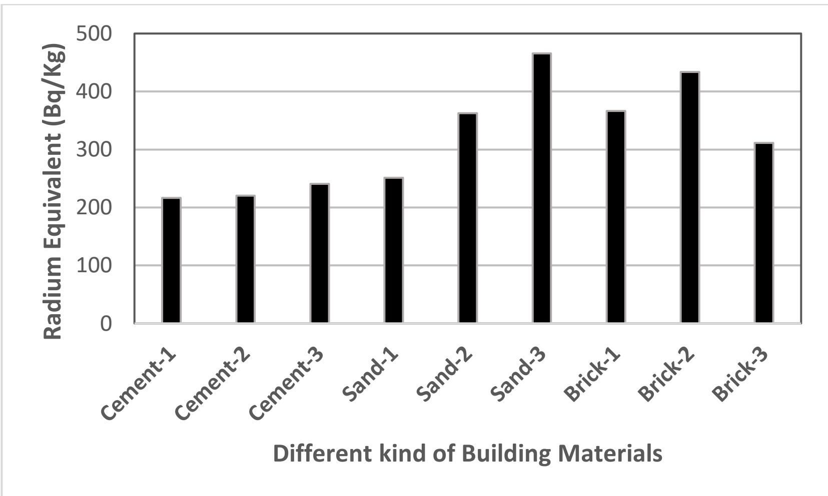

Figure 3: Absorbed Dose Rate for various building materials

Gamma index dealing with the assessment of excess gamma radiation arising from building materials ranged from 0.8 (Cement-1) to 1.7 (Sand-3) with an average value of 1.2, which is marginally higher than the recommended value < 1. [18].

The absorbed Dose Rate due to gamma radiations in air for a standard room dimensions and for common building materials with naturally occurring radio nuclides ^{226}Ra, ^{232}Th and ^{40}K ranged from 104.4 nGyh^{-1} (Cement-1) to 212.1 nGyh^{-1} (Sand-3) with average value of 147.5 nGyh^{-1}, which is higher than world average (populated weighted) indoor absorbed gamma dose rate of 84 nGyh^{-1} [7].

The annual effective dose rate conceived from building materials were found as 0.7 mSvy^{-1} from Portland cement, 1.0 mSvy^{-1} each from sand and brick. Moreover, D_{eff} due to gamma radiation from building materials ranged from 0.6 mSvy^{-1} (Cement-1) to 1.3 mSvy^{-1} (Sand-3) with average value of 0.9 mSvy^{-1}.

CONCLUSIONS

A study of natural radioactivity of different types of houses available in Thoubal district of Manipur was conducted. Indoor effective dose rate of RCC houses (1.2 mSvy^{-1}) is observed slightly higher than the Adobe laid Earthen houses with a value of 1.1 mSvy^{-1} and Assam type (AT) Brick of 1.0 mSvy^{-1}, and least for AT Katcha and AT Mud houses. The activity concentration of common building materials in this region were found as 43.0 Bqkg^{-1} (range: 24.1 – 70.2) for ^{226}Ra, 108.6 Bqkg^{-1} (range: 21.3 – 211.8) for ^{232}Th and 1487.2 Bqkg^{-1}(range: 998.7 – 2298.6) for ^{40}K. However, the average value of Ra_{eqv} obtained from samples of building materials of Thoubal district (312.8 Bqkg^{-1}) is observed less than the critical value (370 Bqkg^{-1}) and as such, does not pose any radiological hazard when used for construction of buildings.

Table 1: Annual Effective Dose of Different types of house in Thoubal District of Manipur.

Types of House (number)	Indoor (mSvy^{-1})			Outdoor (mSvy^{-1})		
	Minimum	Maximum	Average	Minimum	Maximum	Average
RCC House (73)	1.02±0.07	1.35±0.14	1.23±0.10	0.60±0.07	0.89±0.09	0.76±0.08
Assam Typed Brick House (35)	0.78±0.06	1.24±0.11	1.03±0.09	0.65±0.10	0.91±0.13	0.74±0.08
Assam Typed Mud House (96)	0.64±0.07	0.99±0.11	0.82±0.09	0.59±0.07	0.94±0.09	0.72±0.08
Assam Typed Katcha House (6)	0.66±0.09	0.79±0.09	0.70±0.08	0.65±0.06	0.82±0.08	0.70±0.07
Adobe Laid Earthen House (12)	0.95±0.08	1.19±0.11	1.09±0.10	0.67±0.06	0.95±0.07	0.75±0.08

Table 2: Radiological parameters of Building materials used in Thoubal District of Manipur.

Sample	Activity Concentration (Bqkg^{-1})			Ra_{eqv} (Bqkg^{-1})	I	D (nGyh^{-1})	D_{eff} (mSvy^{-1})
	^{226}Ra	^{232}Th	^{40}K				
	Cement Sample						
Cement - 1	29.1±2.7	61.2±5.6	1294.2±81.3	216.3	0.8	104.4	0.6
Cement - 2	51.8±6.3	23.7±1.7	1749.4±134.5	220.4	0.9	111.2	0.7
Cement - 3	33.5±5.8	21.3±1.7	2298.6±154.6	241.0	1.0	124.2	0.8
Average value	38.1±12.0	35.4±22.4	1780.7±502.9	225.9	0.9	113.3	0.7
	Sand Sample						
Sand - 1	34.1±2.7	56.9±5.8	1764.8±89.6	251.4	1.0	123.7	0.8
Sand - 2	70.2±11.5	122.6±7.4	1521.6±84.3	362.7	1.4	169.9	1.0
Sand - 3	51.4±8.1	211.8±14.3	1449.4±69.5	465.9	1.7	212.1	1.3
Average value	51.9±18.1	130.4±77.8	1578.6±165.3	360.0	1.4	168.6	1.0
	Brick Sample						
Brick – 1	29.7±3.6	177.1±9.6	1084.9±76.1	366.5	1.4	165.9	1.0
Brick – 2	24.1±2.7	196.0±9.8	1682.4±99.6	433.9	1.6	199.7	1.2
Brick – 3	35.8±7.6	139.1±10.4	998.7±54.9	311.6	1.2	142.2	0.9
Average value	29.9±5.9	170.7±29.0	1255.3±372.4	370.7	1.4	169.3	1.0
	Soil Sample						
Average value[21]	69.8±32.3	76.6±48.3	1028.0±551.0	258.5	0.9*	121.4*	0.7*

*Recalculated using equations (3), (4) & (5)

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