MEASUREMENT OF NATURAL RADIOACTIVITY IN SOME SAND AND BRICK IN VIETIANE PROVINCE, LAO PDR

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Abstract

The results of the fist investigation of the activity concentration of some sand samples collected at various locations in Vientiane Capital and Thoulakhom district of Lao People's Democratic Republic (PDR) and bricks produced by a most famous Lao Mai company are presented in this work. The activity concentration of naturally occurring radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the samples were determined by gamma spectrometer using a semiconductor detector HPGe. The activity concentration of naturally occurring radionuclides are in the range from 9.47±0.08 to 19.88±0.13 with the mean of 14.22± 0.30 for ^{226}Ra, from 9.54±0.13 to 32.05±0.33 with the mean of 20.05±0.66 $Bq.kg^{-1}$ for ^{232}Th and from 229.57±2.96 to 545.40±5.65 with the mean of 447.37±13.85 $Bq.kg^{-1}$ for ^{40}K. These mean values of the activity concentration are lower than the average worldwide ones, which are 33, 45 and 420 $Bq.kg^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K. For the brick samples, the mean values for ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$ are 41.59±5.43, 54.79±7.62 and 614.60±34.90, respectively. The obtained activity concentrations of naturally occurring radionuclides were used for estimation of all radiation hazard indices including the absorbed gamma dose rate in air at 1m above the ground surface, the radium equivalent activity, the external hazard index and internal hazard index and the representative level index. Our results show that the measure sand and brick samples do not pose any significant source of radiation hazard from naturally occurring radionuclides ^{226}Ra, ^{232}Th and ^{40}K and they are safe for use in dwelling construction.

Keywords: Gamma ray spectrometry, Naturally occurring radionuclide, Activity concentration, Sand, Brick, Radiation Hazard indices, Lao PDR

1. Introduction

Naturally occurring radionuclides are present everywhere with different concentrations. They were created together with the creation of the Earth. Among naturally occurring radionuclides, ^{238}U, ^{232}Th and ^{40}K are most significant. The isotopes ^{238}U and ^{232}Th are radioactive and they undergo radioactive decay into many other radioactive isotopes until they are stable. As radium and its daughter products produce 98.5 % of the radiological effects of the uranium series, the contribution from the ^{238}U is used to be replaced with the decay product ^{226}Ra.

Naturally occurring radionuclides emit gamma radiation which continuously affect human health. Therefore, investigation of their concentrations in the living environments of human beings is an important task in order to be able to estimate the radiation hazard from these radionuclides to human.

Sand and brick are the main dwelling materials and naturally occurring radionuclides always exit in these materials. Bricks are the largest component of dwelling materials used for construction of dwellings in Lao PDR. Almost all the houses are constructed from the baked bricks. The presence of natural radioactivity in these dwelling materials results in internal and

external exposure to the occupants. In order to limit the risks, it is necessary to measure the activity concentration of naturally occurring radionuclides in these materials before their use for construction. Due to the importance of this issue, the survey of the activity concentration of naturally occurring radionuclides in these materials has been attracted the interest of many researchers in the world [1,2,3,4]. In Lao PDR, this issue so far has not been interested.

This study is a part of continuing work in which various dwelling materials have been investigated [5]. In this work, we will present the first results of measuring the activity concentration of naturally occurring radionuclides of sand and brick samples which are mostly used for dwelling construction in the capital Vientiane of Lao PDR by using high-resolution gamma-ray spectroscopy. It is necessary to stress that this is the first investigation of the natural radioactivity in the sand of Lao PDR. Such kind of investigation will be carried out continuously in the future in different provinces of Lao PDR in order to provide the data on natural radioactivity of sand in different areas of Lao PDR. These data will help the authorities for better planning to use these materials for construction of dwellings in Lao PDR as well as to reduce the level of influence of natural radioactivity to people health of Lao PDR.

2. Experimental methods

2.1 Sample collection and preparation

The sampling locations of sand in the sand mines on the bank of Mekong river of Vientiane Capital and Nam Ngeum river in Thoulakhom district of Lao PDR are presented in figure 1. A total number of the locations are 8 and they are indicated by the circles with the dots inside in the map. Six samples were collected in the sand mines on the bank of Mekong river which were marked NK1,... NK6 and two samples were collected in the sand mines on the bank of Nam Ngeum river of Thoulakhom district which were marked by SG1 and SG2. The sand sampling procedure described in [6] was followed: At each sampling location, samples were collected at a depth of about 0.3 meter from the surface layer of four corners and the center of a square area corresponding to $1m^2$. The fife sub-samples were mixed together in situ and this sand mixture, weighing approximately to 1.25 kg, was considered representative of the sampling site.

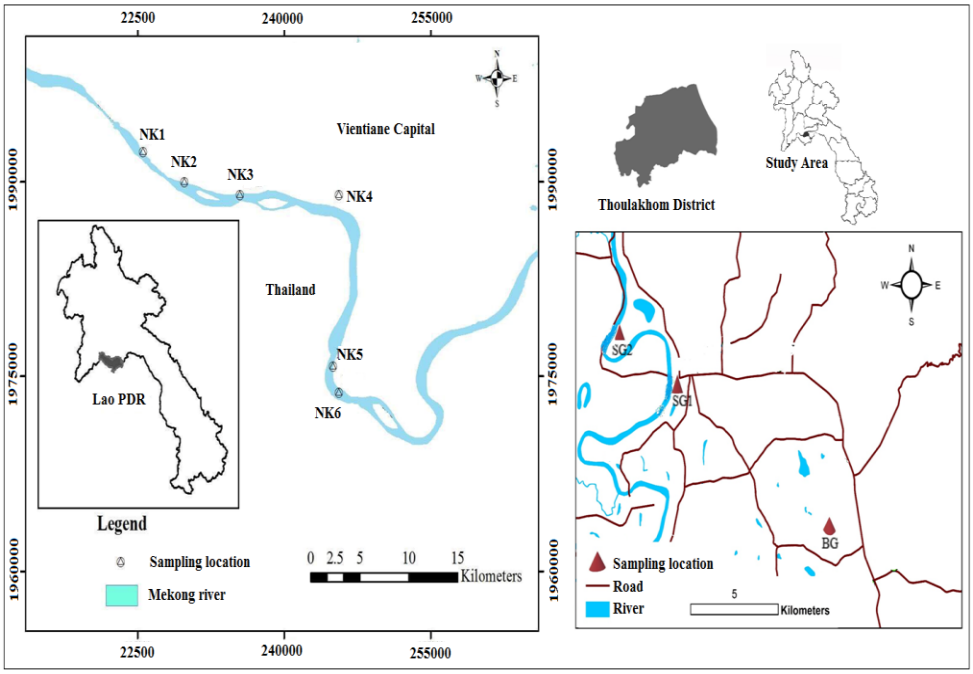

Fig.1. The map of the sampling locations of sand in Vientiane Capital (left side) and Thoulakhom district (right side). The location of the brick company is named as BG on the right map.

The brick samples produced by Lao Mai brick company were collected. This is a most famous brick company in Lao PDR. Almost all houses in Vientiane Capital of Lao PDR have been constructed using the bricks made by this company. The number of brick samples collected was 6. All collected sand and brick samples were placed in plastic bags, labeled and carried to the laboratory of radiation measurement of the Institute of Physics, Vietnam Academy of Science and Technology for radiation measurement.

For the sand samples, all measurements were done with 1 mm sieved sand. For the brick samples, they firstly were crushed down, powdered and then sieved by using 1 mm size sieve. The sand and brick samples were dried in an oven at about 100°c until sample weight became constant. The homogenised samples were filled into the cylindrical plastic beakers with the diameter of 10 cm, which were then hermetically sealed with the aid of PVC tape to prevent the escape of airborne ^{222}Rn and ^{220} Rn from the samples. The samples were weighted and stored for more than 30 days for reaching secular equilibrium between ^{226}Ra and its short lived daughters.

2.2 Measurement of the activity concentration of the sand and brick samples

A gamma-ray spectrometer has been used for measuring the activity concentration of the sand and brick samples [5]. The gamma-ray spectrometer is connected with a coxial cylinder HPGe detector model GEM20P4-70 made by Ortec company. The relative detection efficiency of the detector is about 20% relative to a 3" x 3" NaI(Tl) scintillation detector. The energy resolution of the detector at 1.332 MeV is 1.8 keV. The electronic system of the spectrometer contains a detector high voltage power supply and signal processing modules. The latter include a main spectroscopy amplifier model 572A made by Ortec company and a computer based PCA-MR 8192 ACCUSPEC multi-channel analyzer. For data acquisition, storage, display and on-line analysis of the acquired gamma-spectra, an advanced multi-channel analyzer emulation software MAESTRO-32 has been used.

In order to reduce the number of background gamma radiation present at the laboratory site, the HPGe detector is placed in a low-level Canberra Model 747 lead shield having a lead thickness of 10 cm. It will prevent high background counts due to external sources, thus reducing counting times and improving the lower limit of detection. The 1 mm tin and 1.6 mm copper graded liner prevents interference by lead x rays. Energy calibration of the detector was carried out by using two different sources ^{60}Co and ^{226}Ra, which emit gamma-rays of energy ranged between 186.21 keV and 2447.86 keV.

The activity concentration of ^{40}K was determined directly by its own gamma-ray at 1460.8 keV (10.7%), while the specific activities of ^{226}Ra and ^{232}Th were calculated based on the weighted mean values of their respective decay products in equilibrium. The specific radioactivity of ^{226}Ra was determined using the 295.22 keV (18.5%), 351.93 keV (35.6%) gamma-rays from ^{214}Pb and 609.31 keV (45.49%), 768.36 keV (4.89%) 1120.14 keV (15.0%), 1764.43 keV (15.28%) from ^{214}Bi. The activity concentration of ^{232}Th was determined using the 583.187 keV (85.0%), the 2614.511 keV (99.79%) from ^{208}Tl and 911.12 keV (25.8%) from ^{228}Ac. The value written inside the parentheses following gamma-ray energy indicates the absolute emission probability of the gamma decay. In order to obtain a good statistics, gamma spectra of the sand samples should be measured in long enough time. In our case, each sample was measured for about 72000 seconds. Measurements with an

empty sample container under the same measuring condition of the sample containers filled with sand were also carried out to determine the ambient background in the laboratory site.

The activity concentrations in each sand sample were determined by relative method using the standard samples made from the IAEA-RGU-1, IAEA-RGTh-1 and IAEA-RGK-1 reference materials [5]. These materials were obtained from the International Atomic Energy Agency (IAEA), for which the activity concentration of the interested radionuclides are known. The densities of the reference and investigated sand samples are similar. Furthermore, the geometry of the containers of the sand samples was identical to that of the reference materials (IAEA-RGU-1, IAEA-RGTh-1 and IAEA-RGK-1). By applying the relative method for the activity concentration determination, many corrections can be avoided.

3. Results and discussion

3.1 Calculation of the activity concentrations

The following equation has been used for calculating the activity concentration of ^{40}K, ^{226}Ra and ^{232}Th radionuclides in the investigated samples:

$$A_m = \frac{C_m}{C_s} \times \frac{M_S}{M_m} \times A_s \times \frac{1-e^{-0.693 t_m / T_{1/2,i}}}{1-e^{-0.693 t_s / T_{1/2i}}} \quad (1)$$

where:

A_m is the activity concentration of radionuclide in the investigated sample given in Bq.kg^{-1};

A_s is the activity concentration of radionuclide in the standard given in Bq.kg^{-1};

C_m is the count rate (counts/second) obtained under the corresponding peak of the sand sample;

C_s is the count rate (counts/second) obtained under the corresponding peak of standard sample;

M_s is mass of the standard sample in kg;

M_m is mass of the investigated sample in kg;

t_m is the measuring live time for the investigated sample in second;

t_s is the measuring live time for the standard sample in second;

$T_{1/2i}$ is the half life of radioactive nuclide in second.

The mean activity concentration in Bq.kg^{-1} of naturally occurring radionuclides of ^{226}Ra, ^{232}Th and ^{40}K measured in the collected sand samples are listed in Table 1. In the last row of the table, the world representative concentration in soil of these naturally occurring radionuclides of ^{226}Ra, ^{232}Th and ^{40}K taken from UNSCEAR report [7] are listed for comparison. These values are 35, 30 and 400 Bq.kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K, respectively. As can be seen in this table, the activity concentrations of naturally occurring radionuclides in Bq.kg^{-1} range from 9.47±0.08 to 19.88±0.13 for ^{226}Ra, from 9.54±0.13 to 32.05±0.33 for ^{232}Th and from 229.57±2.96 to 545.40±5.65 for ^{40}K. The mean activity concentrations are 14.22±0.30 Bq.kg^{-1} for ^{226}Ra, 20.05±0.66 Bq.kg^{-1} for ^{232}Th and 447.37±13.85 Bq.kg^{-1} for ^{40}K. They are the same in comparison with the world representative concentrations of these radionuclides in soil.

Table 1. The activity concentrations of naturally occurring radionuclides of ^{226}Ra, ^{232}Th and ^{40}K of the investigated sand samples taken from the sand mines on the band of Mekong and Nam Ngeum rivers.

Sample	The activity concentration (Bq.kg^{-1})		
	^{226}Ra	^{232}Th	^{40}K
NK1	19.88±0.13	32.05±0.33	535.15±5.59
NK2	16.20±0.11	25.73±0.27	541.55±5.62
NK3	15.32±0.11	21.94±0.24	515.04±5.15
NK4	16.53±0.12	24.01±0.26	545.40±5.65
NK5	12.31±0.10	17.12±0.20	456.27±4.88
NK6	12.51±0.10	18.05±0.21	483.12±5.15
SG1	9.47±0.08	9.54±0.13	229.57±2.96
SG2	11.51±0.09	11.97±0.16	272.89±3.38
Mean	14.22 ± 0.30	20.05 ± 0.66	447.37 ± 13.85
Standard deviation	3.14	6.93	117.26
The world representative concentration in soil [7]	35	30	400

The mean activity concentration in Bq.kg^{-1} of naturally occurring radionuclides of ^{226}Ra, ^{232}Th and ^{40}K measured in the investigated brick samples are listed in Table 2 together with the world average values in soil. The average values of naturally occurring radionuclides in the investigated brick samples are 41.59±5.43, 54.79±7.62 and 614.60±34.90 for 238U, 232Th and 40K, respectively. These values are a bit higher than the world representative concentration of these radionuclides in soil, which were written in the last row of the table 2.

Table 2. The mean values of the activity concentrations of the naturally occurring radionuclides of ^{226}Ra, ^{232}Th and ^{40}K of the investigated brick samples produced by the … company.

Sample	The activity concentration (Bq.kg^{-1})		
	^{226}Ra (Bq.kg^{-1})	^{232}Th (Bq.kg^{-1})	^{40}K (Bq.kg^{-1})
BG1	42.46±2.23	54.03±3.10	589.74±14.08
BG2	43.77±2.25	54.84±3.11	598.94±14.14
BG3	41.17±2.21	54.43±3.11	628.26±14.34
BG4	40.38±2.20	53.92±3.10	610.59±14.22
BG5	37.66±2.16	55.98±3.13	634.82±14.38
BG6	44.08±2.26	55.53±3.12	625.25±14.32
Mean	41.59±5.43	54.79±7.62	614.60±34.90
The world representative concentration in soil [7]	35	30	400

3.2 Estimation of radiation hazard indices

By using the obtained activity concentrations of ^{226}Ra and ^{232}Th and ^{40}K radionuclides of the investigated sand and brick samples, the radiological hazard indices of all samples were also calculated including absorbed dose rates (D), radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}) and representative level index (I_γ). Table 3 presents the average values of absorbed dose rate, radium equivalent activity, external hazard index, internal hazard index and gamma-index of all investigated sand and brick samples. In the last row, the recommended safe values taken from [7] were listed for comparison.

Table 3. The values of absorbed dose rate, radium equivalent activity, external hazard index, internal hazard index and gamma-index of the investigated sand and brick samples taken in Vientiane province of Lao PDR.

Sample	D ($nGy.h^{-1}$)	Req ($Bq.kg^{-1}$)	I_γ	H_{ex}	H_{in}
Sand samples					
NK1	51.02±0.31	477.78±18.77	0.405±0.03	0.289±0.02	0.342±0.02
NK2	45.77±0.29	469.99±18.89	0.363±0.02	0.256±0.02	0.299±0.02
NK3	41.96±0.27	443.27±15.86	0.332±0.02	0.233±0.01	0.275±0.02
NK4	45.05±0.29	470.82±19.08	0.357±0.02	0.251±0.02	0.295±0.02
NK5	35.19±0.24	388.12±14.21	0.279±0.02	0.194±0.01	0.227±0.01
NK6	36.97±0.25	410.32±15.83	0.293±0.02	0.204±0.01	0.238±0.01
SG1	19.78±0.15	199.88±5.24	0.156±0.01	0.110±0.01	0.136±0.01
SG2	24.01±0.18	238.75±6.83	0.189±0.01	0.134±0.01	0.165±0.01
Mean	37.47±0.72	387.37±10.71	0.297±0.04	0.209±0.04	0.247±0.04
Brick samples					
BG1	77.02±2.22	573.82±11.92	0.608 ±0.03	0.446±0.02	0.561±0.02
BG2	78.50±2.23	583.38±11.97	0.620±0.03	0.455±0.02	0.573±0.02
BG3	78.28±2.22	602.77±12.11	0.619±0.03	0.452±0.02	0.563±0.02
BG4	76.87±2.21	587.64±12.02	0.608±0.03	0.444±0.02	0.553±0.02
BG5	77.87±2.22	606.52±12.14	0.617±0.03	0.450±0.02	0.552±0.02
BG6	80.17±2.24	604.93±12.11	0.633±0.03	0.464±0.02	0.583±0.02
Mean	78.12±5.45	593.18±29.54	0.617±0.05	0.452±0.02	0.564±0.04
Safe value [7]	55	370	1	1	1

The absorbed dose rate D in air at 1m above the ground surface due to the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K can be calculated using the formula given below [5]:

$$D(nGy.h^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.042A_K \quad (2)$$

where D is the absorbed dose rate in $nGy.h^{-1}$ and A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$ of the sand samples. It should be mentioned

that for calculating the absorbed dose rate D by using above equation, the conversion factor recommended by UNSCEAR was adopted [7]. From Table 3, the average values of calculated absorbed dose rates in the investigated sand samples are ranged between 19.78±0.15 to 51.02±0.31 with the mean of 37.47±0.72 nGy.h^{-1}. They are smaller than the world average of 55 nGy.h^{-1}. The average value of calculated absorbed dose rates in the investigated brick samples is 78.12±5.45 nGy.h^{-1}, which is a bit higher than the world average value.

The radium equivalent activity Ra_{eq}

Radium equivalent activity is an index that has been introduced to compare the activity concentration of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K radionuclides and to represent their activity concentrations by a single quantity, which takes into account the radiation hazards associated with them. It is calculated as the weighted sum of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations, based on the assumption that 10 Bq.kg^{-1} of ^{226}Ra, 7 Bq.kg^{-1} of ^{232}Th and 130 Bq.kg^{-1} of ^{40}K produce the same gamma dose rate. The formula to calculate it is as follows:

$$Ra_{eq}(Bq.kg^{-1}) = A_{Ra} + 1.43A_{Th} + 0.77A_K \quad (3)$$

where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq.kg^{-1}, respectively. The values of the radium equivalent activity of all sand samples as listed in Table 3 show that it ranges from 199.88±5.24 to 477.78±18.77 with the mean of 387.37±10.71 Bq.kg^{-1}, which is about the recommended safety limit of this quantity is 370 Bq·kg^{-1}. For the investigated brick samples, the corresponding average value is 593.18±29.54 Bq.kg^{-1} and is higher than the recommended safety limit of this quantity is 370 Bq·kg^{-1}.

External hazard index H_{ex} and internal hazard index H_{in}

External and internal radiation hazards due to natural radionuclides of ^{226}Ra, ^{232}Th and ^{40}K are defined in terms of internal and external radiation hazard indexes denoted by H_{ex} and H_{in}. They are calculated by the following expressions [5]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

where, A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq.kg^{-1}, respectively. The value of these hazard indexes must be less than unity for safe use in dwelling construction. According to our calculated values of these indexes listed in Table 3, the values of the external hazard index for the investigated sand samples range from 0.110±0.010 to 0.289±0.02 with the mean of 0.209±0.04 while the values of internal hazard index ranged from 0.165±0.01 to 0.342±0.02 with the mean of 0.247. For the brick samples, the average values of the external and internal indexes are 0.452±0.02 and 0.564, respectively. All of these values were lower than the recommended value, which is 1.

Gamma index I_γ

The gamma index I_γ was proposed for identifying whether the European Commision guidelines for dwelling material usage are met. It is defined as follows [9]:

$$I_\gamma = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad (6)$$

The case of $I_\gamma \leq 1$ corresponds to an absorbed gamma dose rate less or equal to 1 $mSv.y^{-1}$, while $I_\gamma \leq 0.5$ corresponds to a dose rate criterion of 0.3 $mSv.y^{-1}$ [7]. The values of the gamma index for the sand samples presented in Table 3 are between 0.156±0.01 and 0.405±0.03 with the mean of 0.297±0.040. The average value of this quantity for the brick samples is 0.617±0.05. All of them were less than 1.

4. Conclusions

This is the first investigation of natural radioactivity of sand in Lao PDR. In this study, the activity concentrations of natural radionuclides of ^{226}Ra, ^{232}Th and ^{40}K in sand samples taken from 8 lacations in Vientiane Capital and Thoulakhom District of Lao PDR were investigated by the help of the high resolution gamma-ray spectrometer using HPGe detector. The activity concentration of naturally occurring radionuclides are in the range from 9.47±0.08 to 19.88±0.13 with the mean of 14.22± 0.30 for ^{226}Ra, from 9.54±0.13 to 32.05±0.33 with the mean of 20.05±0.66 $Bq.kg^{-1}$ for ^{232}Th and from 229.57±2.96 to 545.40±5.65 with the mean of 447.37±13.85 $Bq.kg^{-1}$ for ^{40}K. These mean values of the activity concentration are lower than the average worldwide ones, which are 33, 45 and 420 $Bq.kg^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K. For the brick samples, the mean values for ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$ are 41.59±5.43, 54.79±7.62 and 614.60±34.90, respectively.

The obtained activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were then used to deduce the values of different radiation hazard quantities such as absorbed dose rates (D), radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}) and representative level index (I_γ). The values of these quantities were found to be less than the worldwide mean values. Therefore, the materials do not represent a significant radiological health risk and can be used for dwelling construction.

Acknowledgments

The work was carried out with collaboration between the Institute of Physics, Vietnam Academy of Science and Technology and Institute of Physics, National Academy of Sciences of Belarus, with project number of Vietnamese side VAST.HTQT.Belarus.06/13-14. We acknowledge the financial support of the International Centre of Physics at the Institute of Physics, Vietnam Academy of Science and Technology.

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