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NATURAL RADIOACTIVITY OF SOME MONGOLIAN BUILDING MATERIALS

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INTRODUCTION

The assessment of the radiation dose in humans due to natural sources is particular importance because the natural radiation is main contributor to the collective dose of the world's population. The determination of the radioactivity of granite and building materials containing granite is important for the estimation of the enhanced radiation hazard due to the use of granite. Knowledge of the natural level of radioactivity is important to evaluate the gamma ray exposure contribution from building materials. The main contributors to indoor dose are the members of ^{238}U,^{232}Th decay series and ^{40}K. These radionuclides are widely dispersed in the environment and their concentrations have a broad range from one place to another. Radon (^{222}Rn and ^{220}Rn) is produced in ^{238}U and ^{232}Th decay series and is the product of radium. Radon is a colourless, odourless and chemicaly inert gas. Radon has produced in terrestrial and building materials and the production rate depends on the activity concentrations of the radium content. Usually, granites have high, basalt have low radium content and sedimentary and metamorphosed rocks have intermediate values. They are the main source of radiation in soils and rocks from which traditional building materials are derived. During recent years, surveys on the radionuclides concentration in building materials have been carried out in many countries [1-10].

EXPERIMENTAL PROCEDURE

In this work, samples were randomly obtained from the local building material suppliers in Ulaanbaatar, Darkhan and Erdenet cities samples were analyzed by Gamma spectrometry in order to determine their natural and man made radioactivity content. Experiments were carried out in the Department of Nuclear Analytical Techniques of Nuclear Research Center, Mongolia.

To evaluate the contribution of the radioactivity of the building materials to the natural exposure, simple formule of the exposure rate and dose limitation were used. Soil samples were collected in order to gain some information about the environment. The natural radioactivity and man made radioisotopes were measured with a HPGe Coaxil (GC3020-7500SL) detector coupled to an amplifier Mod.2020 and PC Board card S-100 (Canberra) analyzer. Each sample was crushed into powder with a grain size <0.5 mm and then dried at 105°C for 10-15 hours. Each sample was weighed and sealed in a container box O 70 mm, H12 mm for about 28 days to give the sample sufficient time to reach equilibrium. Sample masses varied from 30 g to 70 g in containers.

The gamma spectra were obtained in the 60 keV to 2700 keV energy range for a period of 3600 - 6000s. The background correction was accounted for by obtain a gamma spectrum after replacing the samples with an identical water filled container. The activity of ^{40}K was determined by measuring its 1461 keV gamma rays. The content of ^{226}Ra was determined using the gamma rays of 295.2; 351.9 keV (^{214}Pb) and 609.3, 1764.5 keV (^{214}Bi). The content of ^{228}Ra was determined using the gamma rays 238.6 keV (^{212}Pb); 583.1, 2614.7 keV (^{208}Tl) and 338.7, 911.2 keV (^{228}Ac). The content of U also was measured using the gamma rays 63.3, 92.6 keV (^{234}Th), 143.8, 163.4 keV (^{235}U) and 1001.0 keV (^{234m}Pa). As Certified Reference Materials for the Gamma-Ray Spectrometry Analysis we used uranium ores DH-1, DL-1 (NBL, USA); minerals SARM 3 NIM-L Lujavrite, SARM 1 NIM-G Granite (South African) and Soil-375 (IAEA) samples.

RESULTS AND DISCUSSION

Table 1 shows the natural activity concentration of the samples collected near Darkhan city's sites. The activity of the soil samples varies from 24 $Bq.kg^{-1}$, to 40 $Bq.kg^{-1}$ for ^{226}Ra; from 42 $Bq.kg^{-1}$ to 56 $Bq.kg^{-1}$ for ^{228}Ra and from 190 $Bq.kg^{-1}$ to 230 $Bq.kg^{-1}$ for ^{40}K. For the building materials the corresponding ranges are: from 12 $Bq.kg^{-1}$ to 68 $Bq.kg^{-1}$ for ^{226}Ra; from 17 $Bq.kg^{-1}$ to 81 $Bq.kg^{-1}$ for ^{228}Ra and from 150 $Bq.kg^{-1}$ to 575 $Bq.kg^{-1}$ for ^{40}K. This indicates that no other materials with more elevated radiation content (such as industrial wastes) were added during manufacturing.

Table 2 shows the range of the activity concentration measured in building materials from Mongolia and other countries. These values are arithmetic mean of the content measured in different materials. The building materials from North of Mongolia showed background and intermediate contents of ^{226}Ra and ^{228}Ra lower than, those of other places. Some materials from Brazilian ES State [7] showed a high natural radioactivity content and high ^{232}Th concentration in samples of granite from RN State [6]. The higher content of ^{226}Ra in Bangladesh was measured in sand samples [4]. Finnish building materials showed higher ^{226}Ra content in by-product gypsum [5].

The radioactivity concentration of building materials can be compared using their radium equivalent activities. This index was defined using the assumption that 370 $Bq.kg^{-1}$ ^{226}Ra; 259 $Bq.kg^{-1}$ ^{232}Th and 4810 $Bq.kg^{-1}$ ^{40}K produce the same gamma ray dose rate [1] :

$$C_{Ra.eq} = C_{Ra} + 1.43\ C_{Th} + 0.077\ C_K$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$, respectively.

The radioactivity content can also be used to estimate the external radiation exposure. The gamma ray exposure rate in air, at 1 m above an infinitely extended and thick slab, due to ^{238}U, ^{232}Th series and ^{40}K uniformly distributed in the material, is given by [8] :

$$X = 1.90\ C_U + 2.82\ C_{Th} + 0.179\ C_K \qquad (1)$$

where X is the exposure rate ($\mu R.h^{-1}$), the activity concentration are given in $pCi.g^{-1}$ and C_U is the concentration of ^{238}U. The constants on the right-hand side of Equation 1 are related to the average gamma ray energies for each radionuclide of the series. Using the current units for absorved dose ($8.7\ mGy.R^{-1}$) and for activity (Bq), the estimated absorbed dose rate in air (in $nGy.h^{-1}$) due to gamma radiation is:

$$D = 0.446\ C_U + 0.662\ C_{Th} + 0.048\ C_K$$

where the activity concentration are given in $Bq.kg^{-1}$.

To limit the external radiation dose from building materials to 1.5 $mSv.y^{-1}$ (150 $mrad.y^{-1}$) and to reduce the acceptable maximum concentration of radium to half the normal limit, critierion formule have been proposed [1] (with current units):

$C_{Ra}/370 + C_{Th}/259 + C_K/4810 \leq 1$ for external exposure and

$C_{Ra}/185 + C_{Th}/259 + C_K/4810 \leq 1$ for internal exposure where the concentration are given in $Bq.kg^{-1}$.

The radioactive equilibrium in the uranium and in the thorium series cannot be assured without further measurements, the precursors of ^{226}Ra and ^{228}Ra emit weakly penetrating radiation. The concentrations of ^{238}U and ^{232}Th can, therefore, be replaced by the ^{226}Ra and ^{228}Ra concentrations, respectively, to estimate the exposure rate, radium equivalent and hazard indices. For these samples, $C_{Ra.eq}$ varied from 78.4 $Bq.kg^{-1}$ (sand) to 232.6 $Bq.kg^{-1}$ (aggregate); 702 (granite) and 123.2 $Bq.kg^{-1}$ for soil. Table 3 shows the measured dose rate using Dosimeters on the surface of the building materials' products in Darkhan. The gamma dose rate varied from 0.09 $\mu Sv.h^{-1}$ (metals wire) to 0.27$\mu Sv.h^{-1}$ (lightweight aggregate); 0.36 $\mu Sv.h^{-1}$ (granite) and 0.16 $\mu Sv.h^{-1}$ for soil.

The external hazard index varied from 0.21 (sand) to 0.63 (aggregate) and 0.32 for soil. The internal hazard index varied from 0.26 (sand) to 0.81 (aggregate) and 0.40 for soil. The hazard indices are always lower than unity. The arithmetic mean of the activity concentration and the corresponding radium equivalent activity, absorbed gamma dose rate and hazard indices are shown in Table 3, for each type do the material. It can be seen that, on average, the exposure due to local building materials is greater or approximately equal to those due to local soil samples. These results indicate that such materials are not a major source of exposure. Taking into account that in Mongolia (Darkhan, Erdenet, Ulaanbaatar city) the temperature usually ranges from -35°C (too long winter approximately 6 months) to +35°C (summer) and the building are not ventilated commonly. This means that, one needs to ventilate houses regularly in winter, to reduce the indoor radon concentration.

Table 1. The natural activity in some building materials of Darkhan city, Bq.kg^{-1}.

No	Materials	U (Ra-226)	Th (Ra-228)	K-40,	$C_{Ra.eq}$
1	Sand, coarse	25.0±1.2	20.4±1.5	400±30	85.0
2	Sand, fine	25.0±1.2	20.8±1.5	405±30	85.9
3	Crushed stone	12.3±1.0	28.1±1.2	472±20	88.8
4	River gravel	22.2±1.5	24.0±1.2	462±20	92.1
5	Cement (Darkhan)	18.5±1.3	40.6±1.5	391±30	106.6
6	Lightweight aggregate, coarse	68±2.0	81±2.1	661±18	234.7
7	Lightweight aggregate, fine	64±2.0	77±2.1	575±19	218.4
8	Dolomite powder, white	21±1.2	17±1.2	347±25	72.0
9	Wooden saw-dust	< 12	< 20	150±12	< 52
10	Soil No.1	36±1.8	42±1.5	220±20	113.0
11	Soil No.2	40±2.5	49±1.1	230±20	127.8
12	Soil No.3	24±1.2	56±1.5	190±18	118.7
13	granite	320±10	249±15	337±15	702

Table 2. Range of the mean radionuclide content (Bq.kg^{-1}) in building materials.

Place	^{238}U*	^{232}Th*	^{40}K
Mongolia (Darkhan)	12-68	17-81	150-661
Mongolian granite	120-350	150-250	200-350

Note: * -Assuming ^{238}U-^{226}Ra and ^{232}Th-^{228}Ra are equilibrium.

Table 3. Dose rate range of building materials and products of Darkhan.

Materials	Mean activit.concentration, Bq.kg^{-1}			$C_{Ra.eq}$ Bq/kg	D μSv/h	Hazard indices	
	^{238}U	^{232}Th	^{40}K			Ext.	Int.
Roof tile	40.0	56.0	430	153.2	0.11-0.16	0.41	0.52
Concrete block	38.0	64.0	412	161.2	0.13-0.20	0.43	0.54
Concrete products	44.6	54.0	395	152.2	0.10-0.24	0.41	0.53
Aggregate	66.0	81.0	660	232.6	0.16-0.27	0.63	0.81
Sand	18 - 20	20	400	78.4	0.16	0.21	0.26
Cement	15 –22	40	391	105.8	0.15	0.28	0.33
Granite	120-350	200-250	340	702	0.28-0.36	0.47	0.80
Soil	24 – 40	42 – 56	210	123.2	0.16	0.32	0.40

REFERENCES

1. Beretka, J. and Mathew, P.J. *Natural Radioactivity of Australian Building Materials. Industrial Wastes and By-products.* Health Phys. **48**, 87-95 (1985).
2. Zikovsky, L. and Kennedy, G. *Radioactivity of Building Materials Available in Canada.* Health Phys. **63**, 449-452 (1992).
3. Schuler, Ch.,Crameri, R. and Burkart, W. *Assessment of the Indoor Rn Contribution of Swiss Building Materials.* Health Phys. **60**, 447-451 (1991).
4. Mollah, A. S., Uhamed, G. U., Husain, S. R. and Rahman, M. M. *The Natural Radioactivity of Some Building Materials used in Bangladesh.* Health Phys. **50**, 849-851 (1986).
5. Mustonen, R. *Natural Radioactivity and Radon Exhalation from Finnish Building Materials.* Health Phys. **46**, 1195-1203 (1984).
6. Malanca, A., Pessina, V. and Dallara, G. *Radionuclide Content of Building Materials and Gamma Ray Dose Rate in Dwellings of Rio Grande do Norte, Brazil.* Radiat. Prot. Dosim. **48**, 199-203 (1991).
7. Malanca, A., Pessina, V., Dallara, G., Luce, C. N. and Gaidolfi, L. *Natural Radioactivity in Building Materials from the Brazilian State of Espirito Santo.* Appl. Radiat. Isot. **46**, 1387-1392 (1995).
8. Kahn, B., Eichholz, G. and Clarke, F. J. *Search for Building Materials as Sources of Elevated Radiation Doses.* Health Phys. **45**, 349-362 (1983).
9. Venturini, L. and Nisti, M. B. *Natural Radioactivity of Some Brazilian Building Materials*. Radiat. Prot. Dosim. **71**, 227-229 (1997).
10. Man, C. K. and Yeung, H. S. *Radioactivity Contents in Building Materials used in Hong Kong*. J. Radioanal. And Nucl. Chem. **232**, 219-222 (1998).
11. Hallenbeck, William H. *Radiation Protection.* ISBN 0-87371-996-4, 1994 by CRC Press, Inc.

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Естественная радиоактивность некоторых строительных материалов в Монголии

Естественная радиоактивность некоторых строительных материалов, используемых в городах Дархан, Эрдэнэт и Улаанбаатар в Монголии, измерена с помощью гамма-спектрометра сверхчистым германиевым детектором. Радиевый эквивалент концентрации и поглощенная доза излучения в воздухе были оценены как внешний и внутренний показатели опасности. Результаты измерения показывают, что эти материалы не являются дополнительным источником облучения.

Работа выполнена в Отделении радиационных и радиобиологических исследований ОИЯИ.

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Natural Radioactivity of Some Mongolian Building Materials

The natural radioactivity of some building materials used in cities of Darkhan, Ulaanbaatar and Erdenet in Mongolia was measured by gamma-ray spectrometry with HP-Ge-detector. The radium equivalent concentration and the gamma absorbed dose rate in air, were estimated as the external and internal hazard indices. The results indicate that these materials are not a major source of exposure.

The investigation has been performed at the Division of Radiation and Radiobiological Research, JINR.

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